THERMIC POTENTIAL FOR SOARING AT İNÖNÜ

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1. INTRODUCTION

The vertical and regional variations of some meteorological parameters in a convective boundary layer have been experimentally and theoretically analyzed in this study. The convective activities which are observed in the convective boundary layer are of importance for gliding and also for other sportive flights. These convective activities are generally observed in two different kinds, as thermals and plumes. Thermals are individual air masses and continually rise from heated surfaces. Plumes are characterized by continuous sources of heated surfaces. Their initial radius may vary from ten meters to a few hundred meters. Their strength is directly proportional to radius. While ascending thermals experience turbulent lateral entrainment of surrounding air, their moisture content and temperature become modified. In order to describe this convection, vertical profiles of temperature, moisture, and wind are needed. The profiles are changed by synoptic processes such as large scale subsidence or ascent, horizontal advection and convection itself.

Precise measurements of structure and dynamics of thermals are difficult, because of the size of areas and column heights to be scanned through in the relatively short lifetime of a thermal, which may be of the order of 20 or 40 minutes. A statistical description of shape and velocity of thermals can contribute to the general view on their characteristics that have been measured by Lindemann (1978).

Sailplane flights, surface observations and the thermal waves are analyzed by Lindsay (1970). The satellite data could produce worthwhile results useful in forecasting low level turbulence, the waves and their relation to clear air turbulence. Various characteristics of locating the thermals and improved instrumentation technology have been presented by MacCready (1970). Two basic types of thermals are discovered: one with a single core of maximum vertical velocity and one with several cores of Konovalov (1970). The average and extreme soaring conditions for three widely separated soaring areas have been investigated in the USA by Lester (1976). The characteristics of dry thermals under various meteorological conditions have been recorded and analyzed in South Australia by Hancy (1976). Hindman and Young (1983) have investigated a winter time convergence zone with a sailplane in northeast Colorado. A convective plume cloud model which gives the linearly interpolated and calculated cloud parameters such as cloud temperature, vertical velocity and water vapor content has been studied by Baker and Jensen (1987). Using the parcel method a simple lagrangian model has been constructed in order to investigate the relative importance of different parameters, governing the characteristic of dry convection by Olofsson (1987).

This model shows that the initial acceleration of a thermal is entirely due to the temperature difference between the thermal and the surrounding air. Pearson (1991) has presented a graphical method to forecast the thermal characteristics such as convective layer depth and thermal strength.

This paper is an attempt to initiate the cumulus convection studies by means of flight observations in Turkey. The previous study has been carried out in Eskisehir (İnönü) between 1983 and 1987, (Öney, Aslan, Peremeci and Adall, 1987). The main goal of the present study is to investigate the micro physical and dynamical structure of thermals and plumes below cumulus clouds by using different measuring systems and theoretical models, the specific purposes being:

i) To investigate the thermic potential of İnönü, an important center for training and flying activities in

Turkey,

ii) To develop a forecasting model for predicting thermic convection vis-a-vis optimal flight plan.

2. MATERIAL AND METHOD

In order to accomplish the objectives of the study, some meteorological parameters such as dry and wet-bulb temperature and flight data such as flight speed, altitude and vertical velocity of the glider were measured in and around the thermals and cumulus clouds by means of Wilga airplanes or Puchacz-SZD-50 gliders in Eskisehir-Turkish Air League Flight Training Center between the 14th of September and October 2, 1992. Ground measurements at Eskisehir and radiosonde observations of Ankara were also considered.

2.1 SOARING THERMAL FORECASTING METHOD

It is a graphical method which gives the thermal strength (or lift) and convective layer depth by Pearson (1991). The model investigates the meteorological conditions from the point of view of soaring. The input parameters are: early morning soundings of air temperature, at three successive levels viz., 1800, 2700 and 3600 meters above MSL, the expected maximum surface temperature and difference between maximum and minimum air temperature of the previous day. Four different nomographs have been used for different periods of the year. The forecast trigger temperature, trigger time associated with forecast trigger temperature, predicted maximum flight altitude and vertical velocity (lift) are defined by using a nomogram (Pearson, 1991). A case study related with this method is given at the following section. The results are compared with observations.

2.2 ONE DIMENSIONAL PLUME MODEL

The second model presented in this paper is a computer model called "One Dimensional Plume Model." The variations of micro physical and dynamic parameters such as water vapor content, temperature and vertical velocity below convective clouds are discussed.

Simpson and Lilly (1983) presented a cumulus model incorporating the effect of mixing through a steady jet at the cloud base with that of entrainment at the sides of the cloud. The entrainment rate can be computed as,

$$\text{Entrainment rate} = \frac{1}{M} \bullet \frac{dM}{dz} = \frac{2\alpha}{r} \qquad (1)$$

where M is mass of the plume, and α the entrainment parameter with a value of 0.1. For thermal theory, it is around 0.25. The energy released in the plume or a thermal must be related to the mass inflow at the base. The equations for the model are considered in two steps:

i) Equations for environmental air,

ii) Equations inside a plume.

The model assumes a steady similarity plume. Inside the plume:

$$w \frac{d\zeta}{dz} = \text{source } \zeta - \text{sin } k_{\zeta} \qquad (2)$$

$$\text{Source due to entrainment:} = \frac{2\alpha w(z)}{r(z)} \zeta_{env.} \qquad (3)$$

$$\text{Sink due to entrainment:} = \frac{2\alpha w(z)}{r(z)} \zeta \qquad (4)$$

This, the basic equation governing the plume-environment interaction is:

$$w \frac{d\zeta}{dz} = \frac{2\alpha w}{r} (\zeta_{env.} - \zeta) \qquad (5)$$

Temperature gradient is given by:

$$\frac{dT}{dz} = -g\left(\frac{A-B}{C}\right) \qquad (6)$$

Where,

$$A = \left(\left(\frac{Lv}{R_d T_{vc}} - 0.61\right) q_{vc} + 1\right) \frac{Pi}{Pi - es} \qquad (7)$$

$$B = \left[2\alpha (T_c - T_e) + L_v \left(\frac{q_{vc} - q_e}{C_{pd}}\right)\right]. \qquad (8)$$

$$C = (1 + C_{pv} - q_{vc}) / C_{pd} + \frac{Lv^2}{Cpd\ Tc^2 q_{vc}} \qquad (9)$$

Vertical air velocity gradient is:

$$\frac{dw}{dz} = \frac{g(T_{v_{plum}} - T_{v_{env.}})}{T_{v_{env.}}\ w} - \frac{2\alpha}{r} w \qquad (10)$$

Vertical variation of a plume radius is:

$$\frac{dr}{dz} = \frac{6}{5}\alpha = 1.2\alpha \qquad (11)$$

Water vapor content gradient in a plume is:

$$\frac{dQ}{dz} = \frac{2\alpha}{r} (Q_{env.} - Q) \qquad (12)$$

Where,

Tc: plume temperature,

Tvc: virtual temperature of plume,

α: entrainment parameter (α = 0.1),

Te: environmental temperature,

Q=qvc-qv: water vapor content in plume,

qe: total water vapor content of environment,

cpd: specific heat of dry air at constant pressure,

cpv: specific heat of humid air,

r: radius of a plume,

Tve: environmental temperature.

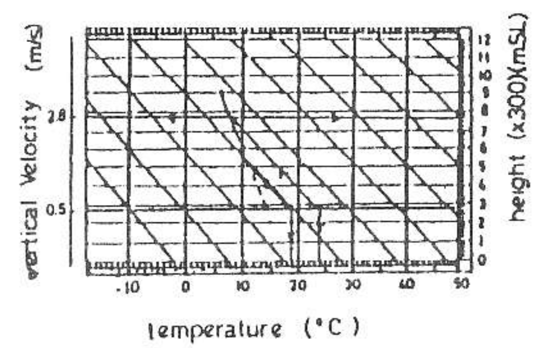
For every Dz=20 meters air layer, all the observations are interpolated.

Vertical variation of the temperature inside a plume is given as:

$$Tc(i+1) = Tc(i) + (dT/dz)Dz \qquad (13)$$

Where Dz is the layer thickness. The total water content (qtc), vertical velocity (w), plume radius (r) and pressure (P) equations are given as below:

$$qtc(i+1) = qtc(i) + (dqtc/dz)Dz \qquad (14)$$



22,9,92	TEMPERATURE GROUND (°C)	TIME	ALTITUDE (m, MSL)	LIFT (m/s)
TRIGGER	19	11.25	840	--
FORECAST	24	15.00	2250	2.3
ACTUAL	23.5	15.00	1800	1.5

FIGURE 1. Measurements and Model Results, September 22, 1992.

$$W(i+1)=W(i)+(dw/dz)Dz \quad (15)$$

$$r(i+1)=r(i)+(dr/dz)Dz \quad (16)$$

$$P(i+1)=P(i)+(dP/dz)Dz \quad (17)$$

As input parameters for the theoretical one-dimensional plume model, the glider measurements at afternoon and Ankara radiosonde data are considered. The initial radius of a plume is assumed as 40, 50, 80, 100 and 200 meters.

For real time calculations, the meteorological parameters under a cumulus congestus cloud, the initial values of water vapor content, vertical velocity and temperature based on the observations at the cloud base are taken into account. For prognostic calculations based on early morning Ankara radiosonde data, the initial values of water vapor content, vertical velocity and temperature are assumed as $9x10^{-4}$ kg/kg, 1m/sec and 1°C respectively.

3. ANALYSIS

The boundary layer soundings are performed between 7:30 and 9:00 a.m. with a tow aircraft. The vertical variation of temperature is measured with a thermocouple mounted on the frontal part of the aircraft. The temperature values and altitudes are recorded on a tape for every 30 meters of height increments. These measurements are considered as input parameters for one of the theoretical models. During the glider flights between 2:00 and 4:00 p.m., vertical air velocities and available maximum flight heights are recorded. These measurements are compared with the model results. To compare the temperature and vertical velocity variations in and in the near vicinity of thermals, the program of constant height flight with the Puchacz-SZD-50 glider was carried out and the data recorded every 30 seconds. The accuracy of the digital temperature measuring system is 5%. All data were recorded on a tape. Some details related with the flight path and other meteorological observations are also recorded on a tape-cassette.

The form of thermic forecasting based on the observations on 22nd, September, 1992, actual data and model results are presented in Figure 1.

In Figure 2 the time variations of air temperature and vertical velocity are presented. The increasing temperature values correspond to the greater vertical velocity values.

Figure 3 and Figure 4 show the height variations of the simultaneous vertical air velocity and temperature beneath a convective cloud.

Observed maximum vertical velocity is 3.5m/s on the 25th of September, 1992 at İnönü.

4. RESULTS

According to this study during a flight program with constant speed and constant altitude, temperature and vertical air velocity variations are almost similar. But in the top of the convective layer, the mixing regions of a plume and the layers below the cumulus clouds, variations of both parameters are not playing an important

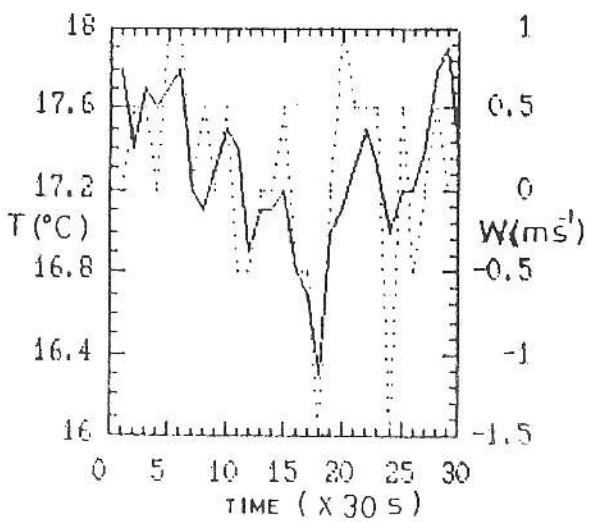


FIGURE 2. Measurements at 320m above mean ground level. ...vertical velocity, _____ temperature, September 28, 1993, 14:30 - 15:00 (local time).

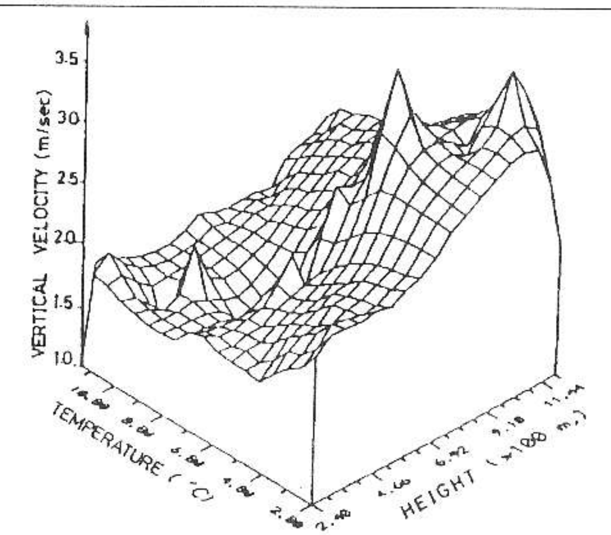


FIGURE 3. The height variations of temperature and vertical air velocity (September 25, 1992, 240 - 1200m above mean ground level).

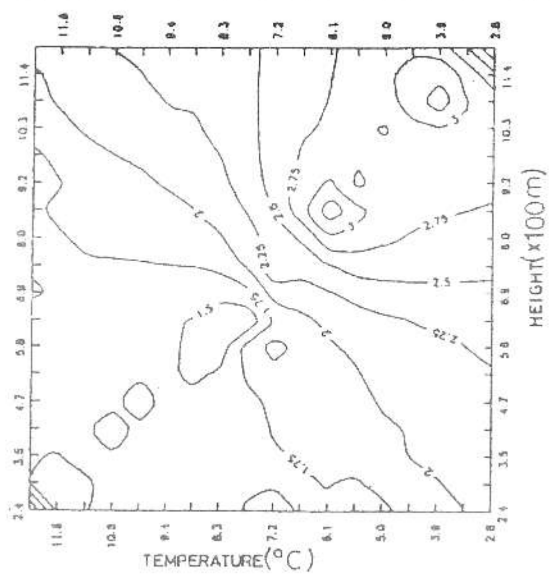


FIGURE 4. The height and temperature variation of vertical air velocity isolines beneath a convective cloud, (September 25, 1992, 240-1200m above mean ground level).

role to define an updraft. As the flight level of a glider is increasing beneath a cumulus cloud, temperature variations do not indicate thermal sectors, but vertical air velocity variations do.

When the easterly winds are not observed, especially under the northerly wind conditions, the first model called "Soaring Thermal Forecasting Method" is applied to predict the thickness of convective boundary layer, and thermal strength (i.e., vertical air velocity) with confidence. The plume model results are the vertical variations of temperature, vertical velocity and total water content within a plume. Real time Ankara radiosonde data (1200GMT) and surface measurements of İnönü are considered as input parameters for the model. This model also requires the initial conditions (initial vertical velocity, temperature and radius) of the plume. The height variations of temperature, vertical air velocity and water vapor content based on the model results are in good agreement with the observations. The mean relative errors of real time comparisons between model results and observations are 0.05 for temperature, 0.05 for water vapor content, 0.558 for vertical velocity. The correlation coefficients between model results and observations are 0.99 for temperature, 0.57 for vertical velocity and 0.98 for water vapor content.

When one-dimensional plume model is used for forecasting the afternoon soaring conditions and plume parameters, 0000GMT Ankara radiosonde data are taken into account as model input parameters. According to the comparisons of forecasting values, the linear correlation coefficient between vertical velocity values is 0.49. The relative errors amongst observed and predicted values of plume temperature, vertical velocity and water vapor content are 1.4%, 34% and 23% respectively. The results of the two models presented in this paper, encourages further investigation of the studies of thermal potential forecasting.

In order to have statistical results on the thickness of the convective boundary layer, size and strength of thermals, and the effects of wind direction and wind shear on thermals, more flight measurements are needed.

5. ACKNOWLEDGMENTS

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