THEORETICAL INVESTIGATIONS AND MEASUREMENTS OF THERMALS

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Presented at the XX OSTIV Congress, Benalla, Australia (1987)

Summary

The measurements of some meteorological parameters and comparison with the 1-D thermal model are presented. The meteorological parameters (temperature, relative humidity and liquid water content) and the flight data (vertical acceleration, flight altitude and speed, pressure rate) were recorded during the PUCHACZ SZD-50, SIAT and CESSNA-207 flights. The experiments were carried out in thermals, shallow cumulus clouds and within vicinity of them at Central Anatolia. In order to predict the spatial variation of parameters radiosonde data were applied for 1-D thermal model. The model results were compared with the observation results and the deviation between the two is less than 10%. In order to predict the temporal variation of meteorological parameters, some modifications are necessary in the model. This has been postponed to the next study.

1. Introduction

Thermals are convective elements that rise over ground which is heated by radiation. If they reach the condensation level they become cumulus clouds. Cumulus clouds generally hold the main moisture content in the atmosphere MASON (1971). Thermals and cumulus clouds have positive vertical velocity segments useful for glider flights SCORER (1978).

The purpose of this investigation is to understand the convective structure of dry thermals and cumulus clouds, and to improve the measuring techniques. Our primary measurements were made in central Anatolia in 1983. They were made during flights of gliders and aircraft which were equipped with the meteorological sensors. Last two measurements were carried out in September 1985 and May 1986. During the flights, air temperature, relative humidity, liquid water content and flight data were recorded in thermals and shallow cumulus clouds (cumulus humilis-cumulus mediocris).

2. Procedure

2.1 Measuring techniques

The meteorological parameters and flight data which were recorded are listed in Table I, which also shows technical properties of the data records.

Sensors were mounted near the pitot static tube on a Cessna 207. During the Siat, Glider (Puchacz SZD 50) flights, they were mounted over the side window. In order to measure the vertical acceleration of the air, the accelerometer was mounted at the inertial center of the aircraft or glider. Values of the parameters were recorded for one minute intervals. The measuring period ranged between 20 and 40 minutes. The resolution was between 1.3 km and 1.5 km during the measuring period. In order to prevent measurement errors, the flight velocity and altitude were kept constant.

During the observation convective activities were dominant at Inonu. Especially cumulus clouds were observed in 17-18 of May 1986. The thermal diameters were approximately 600 meters at the altitude of 500 meters above mean ground level. In addition, liquid water content of cumulus clouds was measured at three different levels (top, middle and base). Also, their diameters were not more than 1000 km.

2.2 Analysis of data

The temperature, relative humidity, total water content and total moist static energy variation were analyzed in the thermals and in the vicinity. The analysis show that the thermal segments coincide with the peak values of these variables.

This kind of analysis were also carried out over the lake (Washington Lake) to investigate the convective elements in the surface layer KATSAROS (1986). The fluctuations of dry and wet temperature were recorded in, and in the vicinity of, convective cells.

The nearest radiasonde data (Ankara) were used to apply to the 1-D thermal model. And the model results were compared with the observations BAKER (1985) and TELFORD (1976). The following assumptions were made in the theoretical calculations:

i) Thermals or cumulus clouds rise in a cone,

ii) The entrainment is also taken into account.

Parameter	Instrument	Measurement Range	Resolution
Temperature	Thermocouple	0-45 degrees C	0.1 degrees
Relative humidity	HM-14 Vaisala	0-100%	0.1% RH
Vertical acceleration	DC-9/971-4193	+/- 3g	0.01
Liquid water content	Heated pt-wire	0.5-1.3 g/kg	0.1
Flight speed	(PUCHACZ-)		
Flight altitude	(SIAT-)		
Pressure rate	(CESSNA-207)		
Recorder	CR-21	9 channels	+/- 5 micro V +/- 1 mili V

TABLE 1
THE PARAMETERS RECORDED DURING FLIGHT

The equations of the model are given below:

a) Conservation of mass:

$$\frac{dM}{dz} = 4\pi\alpha\rho_e r^2$$

α : Entrainment coefficient ($\alpha = 0.25$)
M : Mass (kg)
z : Height (m)
r : Radius of the thermal or cumulus cloud (m)
ρ_e : Air density of environment (kg/m^3)

b) Total humidity equation:

$$\frac{d(MQ_c)}{dz} = 4\pi\alpha\rho_e r^2 Q_e$$

Q_c : Total humidity content of thermal or cumulus cloud (kg/kg)
Q_e : Total humidity content of environment (kg/kg)

c) Total moist static energy equation:

$$\frac{d(MH_c)}{dz} = 4\pi\alpha\rho_e r^2 H_e$$

H_c : Total energy of thermal or cloud (J/kg)
H_e : Total energy of environment (J/kg)

d) Momentum equation:

$$\frac{d(Mw_c)}{dz} = \frac{4\pi}{3} r^3 \frac{g}{w_c} (\rho_e - \rho_c)$$

w_c : Vertical velocity in thermals or cumulus clouds (m/s)
g : Gravitation acceleration (m/sn^2)
ρ_c : Density of thermal or cumulus cloud

The following assumptions were made for the boundary of thermals or cumulus clouds:

The initial conditions for space variable z:

$$Q_e = Q_c$$
$$H_e = H_c$$
$$w_e = w_c$$

The initial conditions for time variable t:

w_c = 1 m/s
q = 0.01 kg/kg
α = 0.25
r = 100 m, 200 m, 500 m, 1000 m, 2000 m

The model was applied up to 700 millibar and the height variation of parameters are given at the Figure 1.

3. Results

In Figure 1 we can see the similar profiles for total static moist energy, total water content and vertical velocity profiles in thermals and cumulus clouds.

In Table II the comparison between observation and model results is presented. Except for liquid water content value, the model calculation errors are less than 10%. According to the model results, liquid water content value is lower than the observation values. This was attributed to the fact that the droplet spectrum of the clouds is omitted. The other sources of discrepancy can be listed as follows. Because of space and time variations between the observation point and the data values used in model calculations and measurement errors:

i) The radiosonde data applied for the model are for Ankara observation station. However, the flight center is 250 km away from Ankara.

ii) The measurements made in the afternoon were taken at the same time as the radiosonde data. But, morning measurements were made two or three hours earlier than the radiosonde observations.

Parameter	Observation	Model Result	Error
Liquid water (kg/kg)	(0.0-0.7) X 10^{-3}	(0.0-0.5) X 10^{-3}	0.28
Vertical velocity (m/s)	0.0-1.8	0.5-1.5	0.11
Total moist static energy (J/kg)	(32.5-32.7) X 10^{4}	(31.6-31.9) X 10^{4}	0.03
Radius (m)	100-600	100-2000	-
Total water content (kg/kg)	(0.8-0.9) X 10^{-2}	(0.6-0.8) X 10^{-2}	0.18
Pressure (mb)	875-860	865	0.002
Temperature (degrees K)	287-293	288-293	0.006
Relative humidity	(46-55) %	(45-65) %	0.08

TABLE -II
THE COMPARISON BETWEEN OBSERVATIONS AND MODEL RESULTS

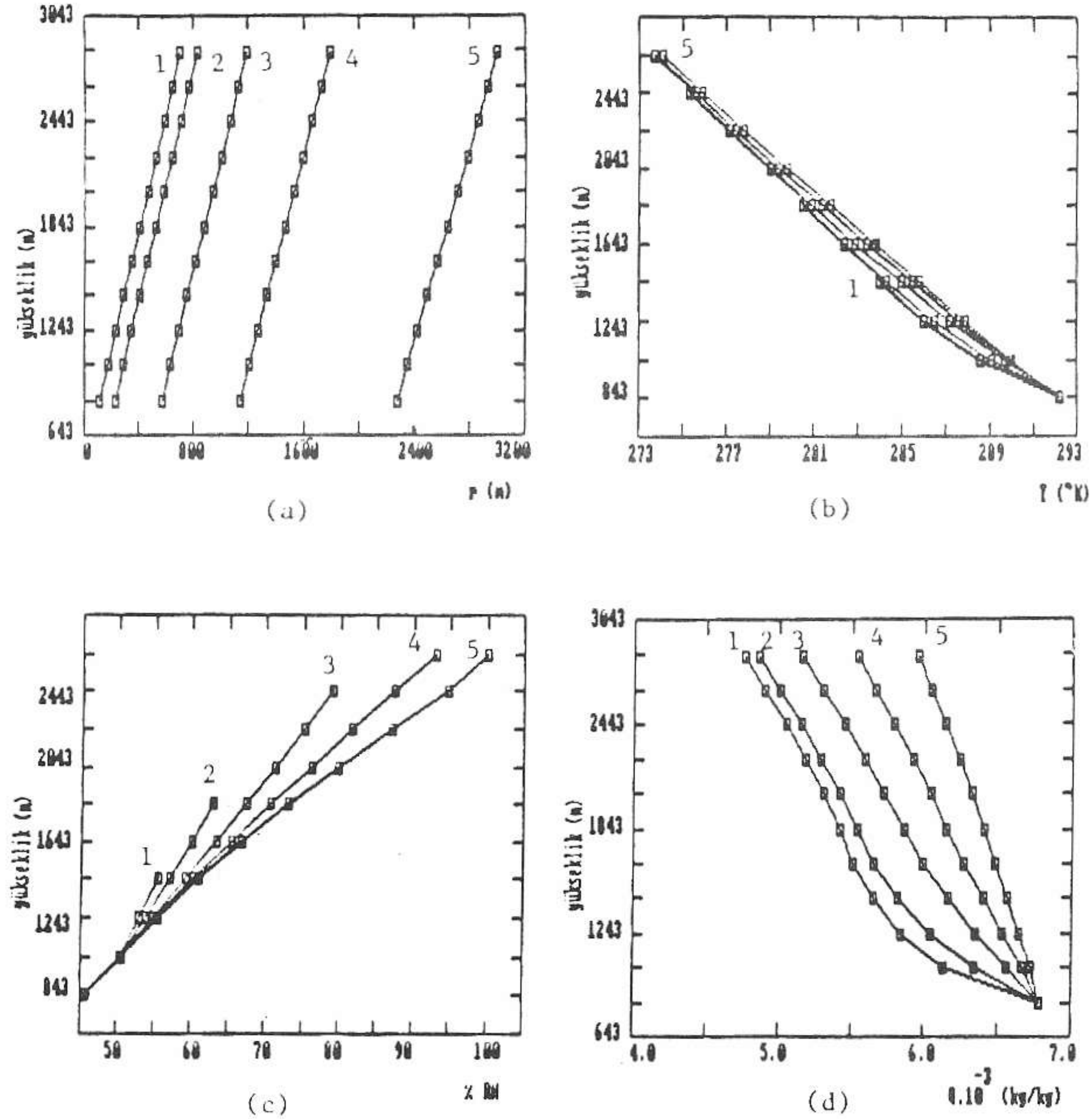


Figure 1

1 — Dimensional Thermal Model Results. (17.05.1986; 12^{00} GMT).

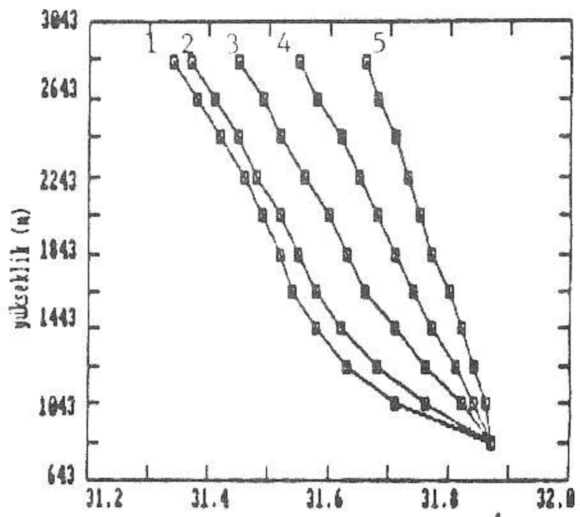
a) The variation of the radius of thermal or cloud as a function of height.

b) The variation of the temperature in thermal or cloud as a function of height.

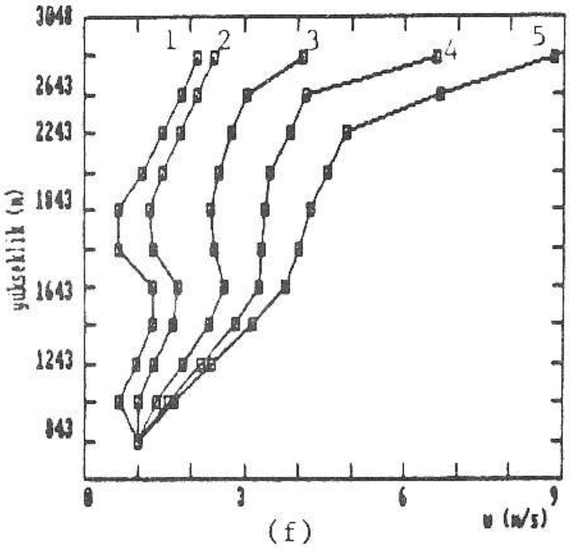
c) The variation of the relative humidity in thermal or cloud as a function of height.

d) The variation of the total humidity content in thermal or cloud as a function of height.

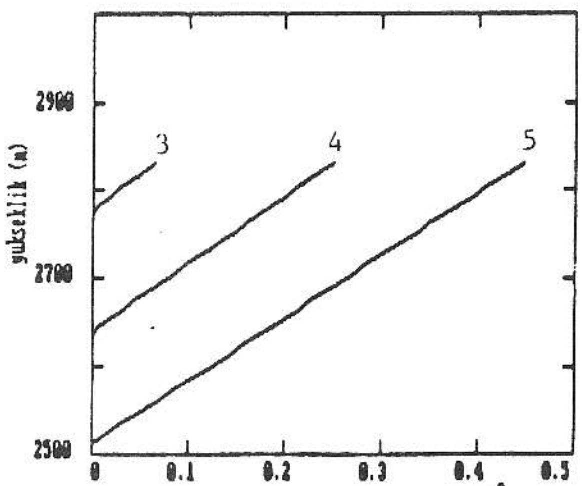
(1) r = 100 m, (2) r = 200 m, (3) r = 500 m, (4) r = 1000 m, (5) r = 2000 m.



(e)



(f)



(g)

Figure 1 (continued)

1 — Dimensional Thermal Model Results 17.05.1986; 12[00] GMT).

e) The variation of the total static energy in thermal or cloud as a function of height.

f) The variation of the vertical velocity in thermal or cloud as a function of height.

g) The variation of liquid water content in cloud as a function of height.

iii) The output voltage values of devices were arranged for the data logger. The error caused by resistants are 5%.

4. Conclusion

1-D thermal model can be used for predicting the meteorological parameters in the thermals and shallow cumulus clouds. This model also gives some information about strength of thermals and humidity potential of cumulus clouds.

In the second part of this research, we plan to calculate the time variation of the meteorological parameters and compare them with the theoretical results.

5. Acknowledgements

This research has been supported by the Turkish Research Council (TOBITAK), Governmental Meteorology Organization (DMI), Turkish Air League (THK) and ITO Faculty of Aeronautics and Astronautics (Project No-MAG 649/A). Also we thank Dr. Jorgen B. Jensen (University of Washington) for help with the model studies.

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