GLIDER MEASUREMENTS AND MODELLING OF THERMALS

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Presented at the XIX OSTIV Congress, Rieti, Italy (1985)

Summary

Measurements of some meteorological parameters (temperature, relative humidity and wind speed) and flight data (flight direction and speed, altitude, pressure rate of change) were obtained in clear sky as well as in thermals and near the vicinity of clouds particularly in the atmospheric boundary layer during the flight of a glider (PUCHACZ). The type and mounting design of the instruments used in the experiments are explained. Also our plans for the next measurements and an axisymmetric thermal simulated in a water tank have been discussed.

1. Introduction

The purpose of this research is to improve measuring techniques and to identify thermal segments. Different procedures have been used to investigate structure of thermals. Some of these include direct measurements by means of aircraft, tethered balloons and towers and remote sensing by acoustic sounders, lidars and radars (6). Here we will only discuss the glider measurements of some meteorological parameters and flight data.

2. Simulation of axisymmetric thermals

A thermal is a mass of warm air rising from the ground warmed by sunshine. A thermal made visible in water resembles a cumulus cloud. We also observe that the thermal grows in size as it moves vertically, but retains roughly the same shape. It is reasonable to suppose that all thermals tend to take up the same shape, with the same mean velocity and density distributions. All the velocities, including typical eddy velocities, will be determined by the total buoyancy and overall size of the thermal (8).

p = density of environment
p′ = density of the thermal

$\beta = \frac{p - p'}{p}$ average buoyancy

g = gravity
C = a constant
R = the radius of the thermal
w = vertical velocity of the thermal

$$w = C\,(g\beta R)^{1/2} \qquad (1)$$

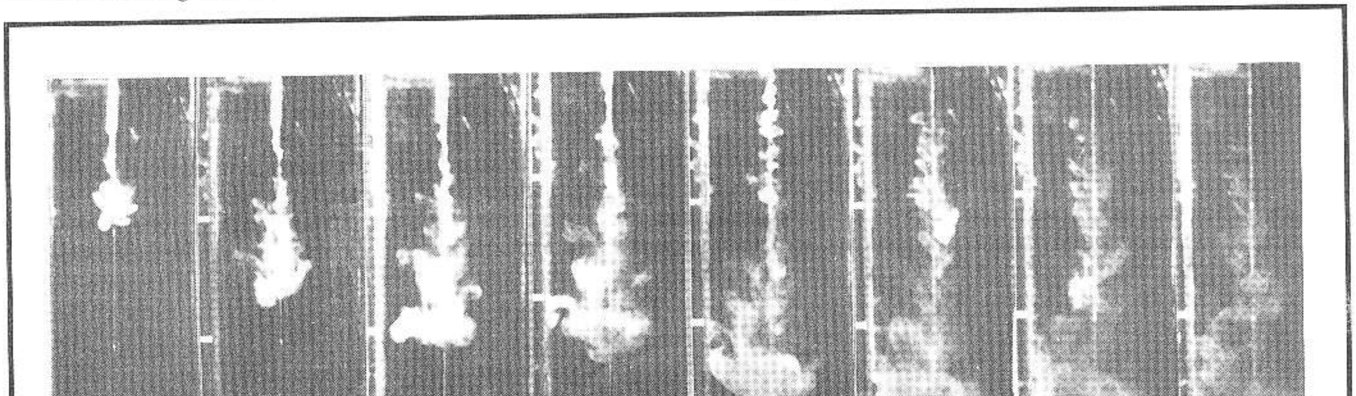

Figure 1. Successive photographs of laboratory thermals.

If R is defined as the radius of the largest horizontal cross section and w is w_c, the vertical velocity of the cap or upper most point of the thermal, then the experimentally determined C is approximately equal to 0,14. This analysis is valid only if the Boussinesq approximation is valid and the accelerations of the fluid are small compared with g(8). Since the fluid accelerations are produced by the buoyancy forces in the first place all we need to ensure is that

$$\beta \ll 1 \qquad (2)$$

The thermals were simulated in a water tank by using milk, and the photographs of its successive positions were taken (**Figures 1 and 2**). The value of z at which R = 0 can be determined. If we plot z^2 against time, we find that the points lie on or very close to a straight line.

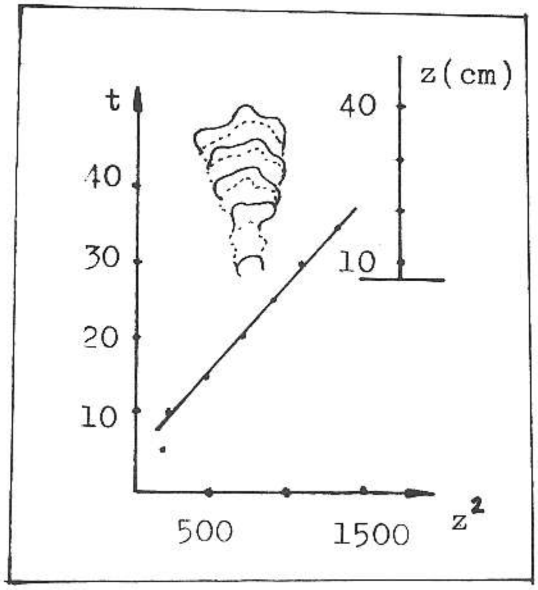

Figure 2. Outlines of successive positions of the thermal drawn from film. Below are plotted graphs of z^2 against time.

3. Measurements in the atmospheric boundary layer

Parameters were measured at the Turkish Air League - Training Center (Eskisehir) on 5 and 25 August 1983. The PUCHACZ SZ D 50-3, which is used in the experiments, is a two-seater glider with normal performance (9,10). The aircraft or gliders which are well equipped with meteorological sensors have been preferred. Thus, the measurements can be taken from a few meters of the surface on up through the top of the convective boundary layer (or mixed layer). The glider provides a low air speed for high resolution measurements, has some advantages in the placement and ease of mounting of equipment, and also is free from the problem of motor effect (4).

3.1 Instruments and mounting design:

Mounting design, type and accuracy of the instruments are given in Table 1 and Figure 3.

3.2 Corrected wind velocities:

The wind velocities measured by a glider have to be corrected. To remove the biases of wind velocities the procedure given below is followed (1, 3, 5, 7).

a) Vertical air velocity:

w_{AP}:	the vertical air velocity relative to the glider (measured by hot-wire anemometry),
w_{PG}:	the vertical glider velocity relative to the ground, (measured by variometer),
w_{AG}:	the vertical air velocity relative to the ground,
$w_{AG} =$	$w_{AP} + w_{PG}$

b) Horizontal wind speed: (see also Fig. 4)

TAS:	the aircraft velocity relative to the air,
TH:	the aircraft orientation angle with respect to true north,
GS:	the aircraft velocity relative to the ground,
TK:	the aircraft orientation angle with respect to true north,
DD/FF:	horizontal wind direction and velocity,
DA:	drift angle.

4. Instruments and measurements planned to be included in the next mission

We planned to investigate the relationship between various meteorological parameters in particular with vertical velocity and liquid water content (in summer 1985). Also the measurements results will be compared with the theoretical vertical wind velocity and liquid water content will be calculated by one dimensional cloud model.

The micro computer will be used to evaluate the data. The data recording system which has 16 channels, is to be used to record the data in one second intervals (11).

4.1 Meteorological parameters

The following meteorological parameters will be recorded:

a) vertical wind velocity:

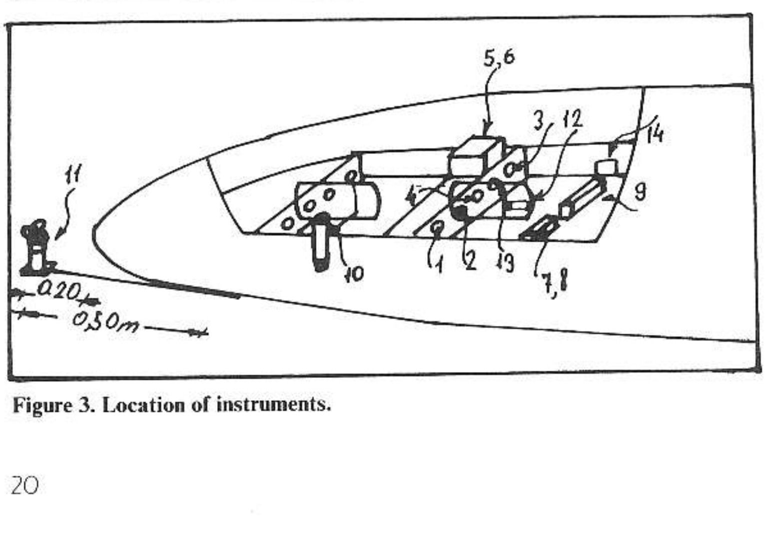

Figure 3. Location of instruments.

1. flight speed indicator
2. variometer
3. compass
4. altimeter
5. temperature indicator
6. humidity indicator
7. horizontal wind indicator (speed)
8. horizontal wind indicator (direction)
9. hot-wire anemometer
10. hot-wire probe
11. horizontal wind probe
12. relative humidity and temperature probe
13. time indicator
14. recorder

Table 1. Basic parameters measured on PUCHACZ SZ D 50-3.

parameter	type of instrument	range	accuracy
temperature	HM 14-Vaisala	-5 to 45°C	± 0,15°C
relative humidity	HM 14-Vaisala	0 to 100% RH	1% RH
vertical wind velocity	Hot wire anemometer (Wilh Lambrecht)	0 to 5m/s	0,1 m/s
horizontal wind velocity (direction)	(AE 400-36T)	0 to 360°	5°
horizontal wind velocity (speed)	(AE 400-36 T)	0-30 m/s 0-60 knots	0,1 m/s
flight speed	PUCHACZ SZ D 50-3	25-140 knots	± 3 km/s
flight direction	PUCHACZ SZ D 50-3	-	-
flight altitude	PUCHACZ SZ D 50-3	-	-
pressure rate of chance	PUCHACZ SZ D 50-3	-	-

- DISA 55 M system with hot-wire probe (for taking measurements in clear sky and thermals)

- DISA 55 M system with hot-film probe (for taking measurements in cumulus and cumulus congestus).

- accelerometer.

b) Relative humidity and temperature:
HM 14, Humicap Humidity Meter (VAISALA)

c) Liquid water content:

We got in touch with Prof. Dr. aufm Kompe (who is a retired professor from Bonn University) to make the Hot Wire Liquid Water Content Meter (2). We added a wheatstone bridge to the circuit of probe and calibrated it in an open wind tunnel. Two Pt-wires (each about 1 m. long) which are wound around an insulating cylinder made of teflon act as electrodes. The space between them is filled with lithium chloride. The teflon cylinder is placed in a tube which has a slot with an area of approximately 1 cm^2.

A brass tube which has a slot of the same size as that of the water content meter is used to calibrate the probe in an open wind tunnel. A piece of blotting paper, which was weighed before and after the exposure, was placed opposite to the slot within the tube. This system was planned particularly for taking some measurements in Cumulus and Cumulus Congestus. Diameter of droplets was examined by using plates, coated Silicon-Oil or MgO, and an optic microscope. The droplet spectrum was convenient with that of Cumulus and Cumulus Congestus. They are between 2 and 180μ.

4.2 Flight Data

One glider (PUCHACZ SZ D 50-3) and two aircraft (Beech-Craft and Wilga) will be used to take the data. We plan to record the following parameters.

- flight velocity (direction and speed),
- altitude,
- vertical displacement velocity of the aircraft,
- angle of attack.

Note: This study is a part of my ongoing Ph.D Thesis research program and it has been also supported by the Turkish Technical Scientific and Research Council (Project Number is MAG-649/A), Governmental Meteorological Organization, Turkish Air League and Istanbul Technical University.

5. References

(1) Grossman, R.L. (1977) A procedure for the correction of biases in winds measured from aircraft. J. Appl. Metero. 16, 654-658.

(2) Kampe, H.J. (1955) A continuously recording water-content meter. J.Met. 13, 64-66.

(3) Larsen, E.S. (1974) Hot-Wire measurements in the atmosphere. DISA Information, 16, 15-33.

(4) Larsen, H.R. (1980) Aircraft measurements of mountain wave cloud. Communication a la VIIeme Conference Internationale sur la Physique des Nuages Vol I, France, 157-160.

(5) Lawson, R.P. (1980) On the airborne measurement of vertical air velocity. J. Appl. Metero, 19, 1416-1419.

(6) Lenschow, D.H. (1980) The role of thermals in the convective boundary layer. Bound. Layer Meteor. 19, 509-533.

(7) Peremeci, O.E. (1983) Sayisal Deney Yontemleri. Istanbul Teknik Universitesi.

(8) Scorer, R.S. (1978) Environmental Aerodynamics. Coll House Press, 488 pp.

(9) Stafiej, W. (1980) Iki Kisilik SZ D 50 3 "PUCHACZ" Planoru ucus el kitabi. Turk Hava Kurumu.

(10) Ural, R. (1983) Planor Okulu Kurs Notlari. Turk Hava Kurumu.

(11) (1973) The boundary layer sub programme. Gate Report, No 5, 126 pp.

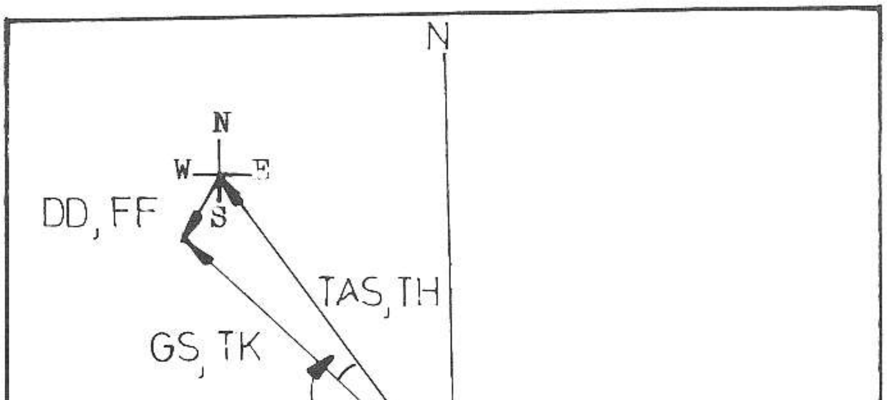

Figure 4. Corrected horizontal wind speed.