Total Energy – Part 2: The Unreliability of existing TE Variometers in Turbulent and Vertically Moving Air

François Ragot
St. Auban, France
Avia40p@aol.com

Presented at the XXX OSTIV Congress, Szeged, Hungary, 28 July - 4 August 2010

Abstract

The Total Energy variometer of a glider takes into account the dynamic energy exchanges with the atmosphere. Unfortunately glider pilots take them erroneously as resulting from an effective vertical speed of the air. Furthermore the present day TE variometers measure the speed, and accordingly the kinetic energy of the gliders, in relation to the surrounding air, and not in relation to a constant speed inertial referential as they should do. Consequently, their indications of dynamic energy exchanges are gathered together and delayed. As a result, both effects mislead the accurate information necessary for an optimal location of thermals. Using modern gyrolasers, accelerometers and GPS techniques, it is now affordable to improve our TE variometers.

Nomenclature

$\vec{z}$	Vertical unit, vector positive upwards
ΔH_{dyn}	Equivalent dynamic altitude
$\vec{V}$	Glider inertial speed vector
$\overrightarrow{V_{air}}$	Glider airspeed vector
$\overrightarrow{W}$	Inertial wind vector
W_z	Vertical inertial wind component
v_{zdyn}	Glider's dynamic equivalent vertical speed
$\vec{\gamma}$	Relative acceleration vector of the glider
g	Acceleration of gravity
m	Glider mass

Introduction

This paper is a revision of my 1981 OSTIV Congress lecture, entitled 'Unsuitability of present variometers for dynamic soaring'[1]. It is divided in two parts. The second part is this paper. The first part precedes this paper.

The main information contained in the first part was the determination of the algebraic expression of the dynamic energy exchange as its equivalent climb rate

$$v_{zdyn} = \vec{\gamma}\overrightarrow{W}$$

or the dot product of the relative acceleration vector (acceleration vector of the glider divided by the gravity acceleration) and the inertial wind vector.

In fact, glider pilots are often unaware of dynamic energy exchanges because they confuse them with illusive vertical air speeds. They think that gusts are quite simply unprofitable turbulence and, since they cannot get rid of them, they try to reduce their effects by using pneumatic or electronic filters[2,3]. These, regrettably, also damp the indicated total vertical speed.

But, there is another piece of information that is even more pertinent: present day TE variometers do not give accurate readings in turbulent air and in vertically moving air, this being quite simply due to the way they function. Even if their response times are very short, they do not indicate in real time the value of the total vertical speed. Kinetic energy measurements only are actually accurate in real time when speeds are measured in relation to an inertial referential. This is not the case for speeds measured using pressure sensors (static, total and total energy); these being measured in relation to the surrounding air, the speed of which is variable depending of the inertial wind.

These variometers, thus, are very sensitive to inertial headwind or tailwind gusts that change the air speed of the glider and consequently the kinetic energy erroneously taken into account, whereas the inertial speed remains unchanged. This is the reason why our variometers oscillate permanently in inertial headwind or tailwind gusts. For example, entering almost instantaneously into a headwind gust will result in a fictitious gain in total altitude, hence the peak indicated by a present day TE variometer. The excitability of such a variometer is misleading and can lead the pilot to believe that the glider has entered a strong thermal.

On the other hand, these variometers are not sensitive in real time to accelerations occurring when the glider is in an inertial wind blowing perpendicular to its speed, when in fact the variometers should be.

The corresponding dynamic energy exchanges are indicated when leaving the inertial wind area after a lapse in time and this delay can be significant and disruptive.

It should be noted that present day variometers only are accurate if all the air particles are moving at the same horizontal speed.

For the reasons referred to above, present day variometers tend to mislead pilots in their search for thermals and they are totally unsuitable for achieving voluntary dynamic energy gains. They delete stick thermals but create gust thermals which are less disturbing, it is true, but more so than generally imagined.

Considerable gains in dynamic energy, which alone would be sufficient for soaring during a part of a flight, never can be achieved unless the pilot is aware in advance of how speeds of the air are distributed over the possible trajectories to follow, which would enable the glider to be placed in an inertial wind at optimal attitude and speed. If the pilot does not have this essential information, there is no chance of achieving a substantial gain in dynamic energy. Albatrosses know the distribution of the speed of the wind in relation to the altitude. As for those who fly model aircraft, practising dynamic gliding techniques downwind of steep cliffs, they know that the wind is strong at altitudes higher than the cliff and gentle at lesser altitudes.

Slight dynamic energy exchanges

Gliding requires the permanent readjusting of the glider's attitude, which is constantly being modified by inertial wind changes. The glider is permanently at the mercy of small repetitive accelerations, with the inertial wind constantly changing direction. The result is that the accurate total vertical speed is permanently affected by these slight dynamic effects.

For example, changes in vertical speed of the air and in the headwind or tailwind gust speed lead to a slight dynamic energy gain, which is the result of the pilot's normal reaction:

1) Change in the vertical speed of the air

The longitudinal glider attitude changes due to the glider's longitudinal stability, nose down if the vertical speed increases and vice versa. In both cases, the pilot's manoeuvre made in order to maintain the attitude of the glider produces an acceleration having a component in the direction of the inertial wind, hence achieving a slight gain in dynamic energy. As before, the pilot gains energy without intending to, whereas a great deal more could be gained if the pilot knew how to do so.

2) Headwind or tailwind gust

The glider's air speed varies, with no real dynamic energy exchange, but the pilot manoeuvres to maintain the air speed of the glider – pull/push or push/pull, which causes the glider's lift to tip in the direction of the gust for the entire duration of the manoeuvre, producing an acceleration which results in a slight gain in dynamic energy. Here again, the pilot gains energy without trying, whereas much more could be gained if the pilot knew how to do so.

In both cases 1) and 2), correct piloting will result in a small energy gain. If the pilot does nothing, the glider will start a phugoïd oscillation and the positive or negative exchange of energy will depend on his subsequent position on the phugoïd trajectory when leaving the gust.

3) In a side wind gust, the opposite occurs

The pilot's reaction will oppose a gain in dynamic energy. The gust forces the glider to slip sideways and if the pilot does not react, due to the dihedral effect, the glider will bank, which in the end produces an acceleration in the same direction as the gust and, hence, a gain in dynamic energy. If the pilot maintains zero bank angle, the dynamic energy exchange is nil.

Errors made by present day TE variometers in vertically moving air and horizontal gusts

Let us take, again, the three examples mentioned in the Part 1 of this paper, assuming that the speed of the inertial wind is constant.

1) Entering a rising air mass (Fig. 16)

A glider enters a rising air mass. At first the angle of attack increases for a very short period, as well as the aerodynamic force, until the glider pitches down due to its longitudinal stability in order to recover its previous angle of attack. Then, the pilot manoeuvres in order to obtain a suitable constant airspeed flight in the rising air and the glider climbs at this airspeed as long as the air mass is rising.

The dynamic energy exchange resulting from the manoeuvre depends on the difference of the vertical inertial speeds of the glider between entering the rising air mass and climbing inside.

Theorem of projections

$$v_{zdyn} = (V'_{zair} - V_z)\, W_z / g.$$

If the glider enters with an upward inertial vertical speed equal to that in the rising air, there is no dynamic exchange after entering. If it enters with a downward vertical speed or with an upward one lesser to that in the rising air, it gains dynamic energy. If it enters with an upward vertical speed higher than that in rising air, it loses dynamic energy. It is, then, in the interest of the pilot to enter the rising air mass at the highest downward vertical speed and to fly out of it at the highest upward vertical speed in order to get the opportunity of making a higher or longer acceleration in the rising air and gain more dynamic energy. *Do not pull up before being in the thermal and do not push down before being out of it.*"

An ideal accurate variometer reading will register the resulting dynamic energy exchange, while a present day variometer will ignore it. After the manoeuvre, both types of variometer will indicate the speed of the rising air until the glider leaves it. On leaving it, the pilot will accelerate downwards in order to obtain the suitable speed in quiet air, without dynamic energy exchange.

If the upward acceleration of the glider is 0.4 g in a 3 m/s rising air, an accurate variometer indicates $n_z W_z$= 4.2 m/s, of which 1.2 is a dynamic energy gain. The vertical speed indicated on a present day variometer would still be 3 m/s, because it refers to the glider's air speed which has not changed and it ignores the increase in inertial speed when it occurs, whereas this constitutes a gain in dynamic energy. Present day variometers only take this gain into account with a certain delay when the glider leaves the rising air.

2) Side wind gust (Fig. 17)

A glider flying horizontally enters a horizontal gust coming from its right. Due to its lateral stability, it veers right in order to cancel the slip. The angle created by the bisector of its airspeed and its inertial speed with the direction of the gust may be obtuse or acute, in which case the air speed of the glider will increase or decrease on entering the gust. This has no effect on what is indicated by an ideal accurate variometer, but a positive or negative fictive peak will be indicated on a present day variometer. If the glider does not accelerate when in the gust, on leaving the gust an opposing peak will be indicated by the present day vario, cancelling the first one (Fig. 18). If the angle made by the bisector and the direction of the gust is 90°, the present day variometer will indicate nothing.

If the glider accelerates sideways and left in the gust, the inertial speed will increase, resulting in a dynamic energy gain that will be indicated by an ideal accurate variometer, while a present day variometer will indicate no change, like the air speed (Figs. 19 and 20). On leaving the gust, the air speed will change again. A present day variometer will register a corresponding peak taking into account both effects, the opposing peak and the dynamic energy gain peak.

For a gust of 3 m/s and a lateral acceleration γ_y of 1 g, the acceleration and the gust having the same direction, the total vertical speed indicated by an ideal accurate TE variometer would be $v_{zt} = \gamma_y W$ = 3 m/s in the gust, and zero for a present day variometer.

3) Headwind gust (Fig. 21)

A glider flying horizontally at 40 m/s enters a 3 m/s headwind gust. On entering, the glider's air speed increases to 43 m/s and a present day variometer will indicate an increase in total vertical height of $\Delta V^2 / 2g = 12$ m, whereas an ideal accurate variometer reading will remain unchanged. If the pilot maintains the airspeed of the glider (43 m/s) within the gust, on leaving the gust this airspeed will recover its initial value (40 m/s) and a present day variometer will register the decrease of airspeed, thus cancelling the effect of the previous increase (12 meters height). An ideal accurate variometer reading will remain unchanged.

If the pilot makes a vertical upwards acceleration within the gust, the dynamic energy gain is not significant but will be indicated in real time by an ideal accurate variometer. A present day variometer, however, will indicate nothing during the manoeuvre but on leaving the gust will indicate a peak that is equivalent to the gain in dynamic energy added to the negative peak compensating the illusive gain when entering.

When there are strong headwind gusts, errors made by a present day variometer can be as significant as the equivalent of 12 metres altitude over a very short period, which is huge. This is more than enough to lead pilots to make mistakes when locating thermals.

Conclusions

The compensation of present day TE variometers is only accurate if all the air particles are moving at the same horizontal speed. They react to inertial headwind or tailwind gusts and to vertically moving air components and take into account the dynamic energy exchanges only when leaving them, whereas these take place when the glider is inside. But, an ideal accurate variometer also would hinder the localisation of thermals because it would still be impossible for the pilot to distinguish dynamic energy exchanges from static energy exchanges. The pilot only has access to an indication of the total of the two, whereas each requires different manoeuvres in order to achieve an energy gain. A previous study showed that significant gains in dynamic energy could only be achieved if the pilot knew in advance of the existence and the position of inertial wind gusts and vertical moving air to come, in order to be able to position his glider correctly and make the most of them. Information provided by cumulus is not precise enough to be able to carry out such manoeuvres effectively. Thus, there is not much hope for dynamic energy gains for gliders flying blind. If the pilot only had one indication alone, it would be better to ignore dynamic energy exchanges and make use of a variometer that indicates exclusively the vertical speed of the air at the position the glider is in. Anyway, two indications on the same instrument would be the best.

In order to produce an accurate total energy variometer[3], it is necessary to know the exact position and the inertial speed of the glider. This is possible using a mini-inertial-platform (gyrolaser + accelerometer) combined with a GPS[4]. *Apple* already produces these components for a reasonable price. Then, we can expect a new type of variometer to be available in the near future.

References

[1]François Ragot. Unsuitability of existing TE variometers for dynamic soaring. OSTIV Congress 1981.

[2]Rudolf Brözel. Total energy Kompensation. September 1985.

[3]Taras Kiceniuk. A variometer for dynamic soaring. *Technical Soaring*, volume 25, number 4, October 2001.

[4]François Ragot. Best speed story, page 12, left column, *Technical Soaring*, volume 28, Numbers 1 /2, January/April 2004.

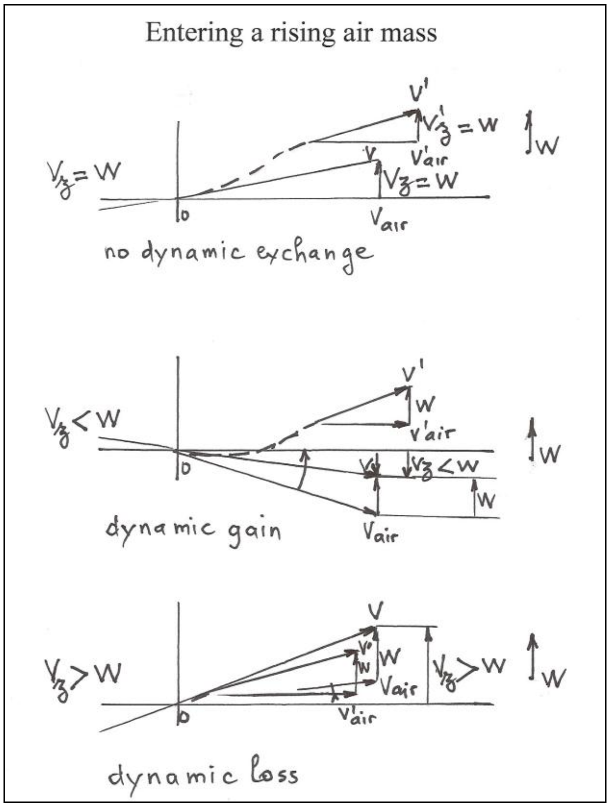

Figure 16 Entering a rising air mass

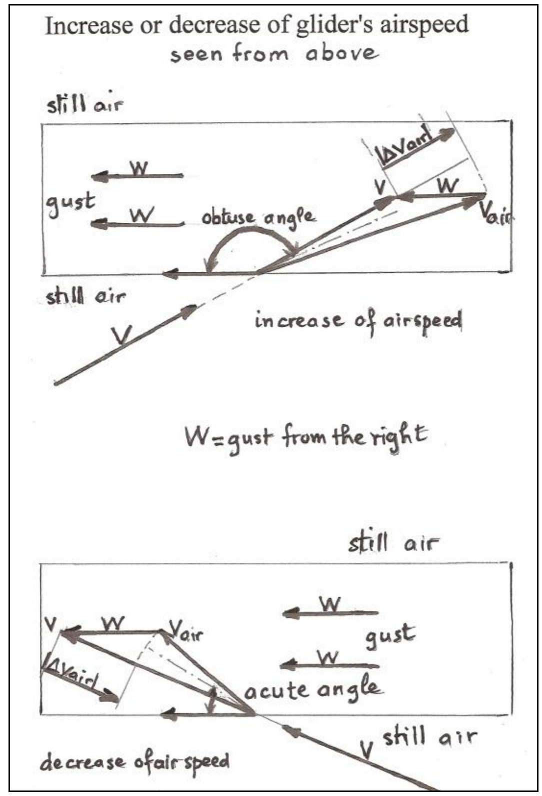

Figure 17 Increase/decrease of glider airspeed (seen from above)

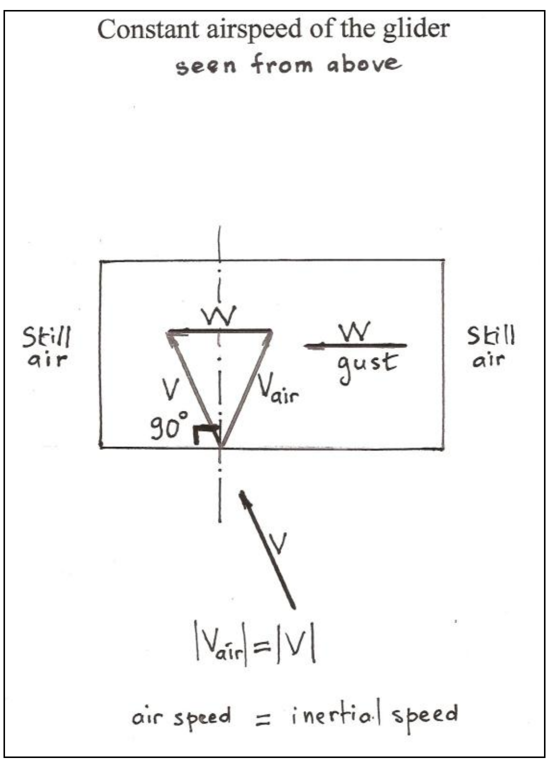

Figure 18 Constant airspeed of a glider (seen from above)

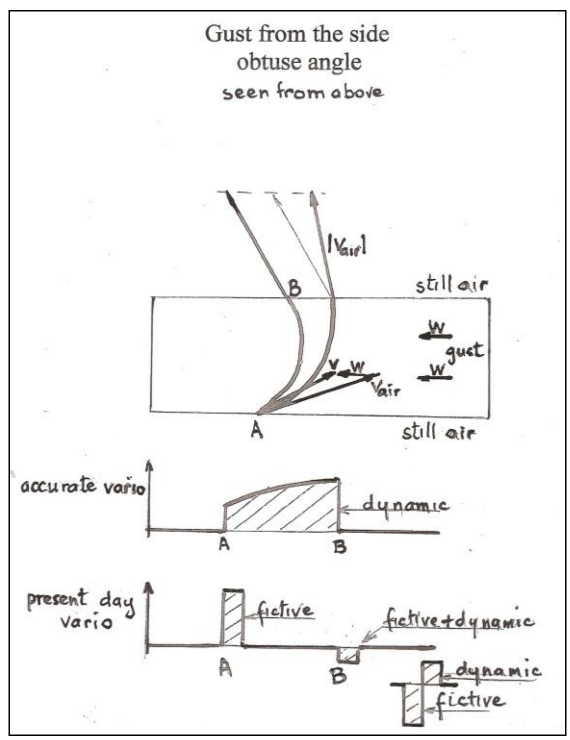

Figure 19 Side gust – obtuse angle (seen from above)

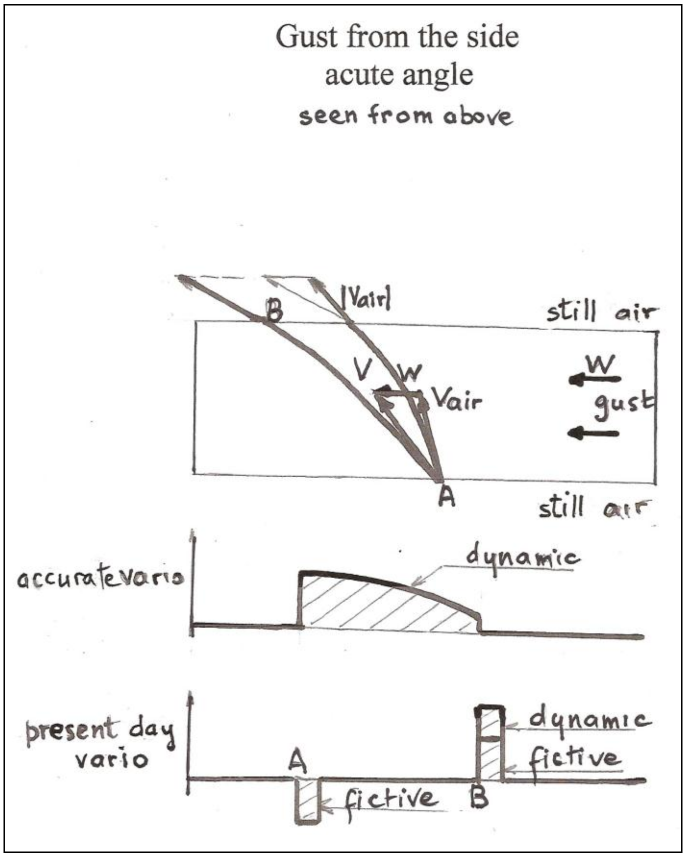

Figure 20 Side gust – acute angle (seen from above)

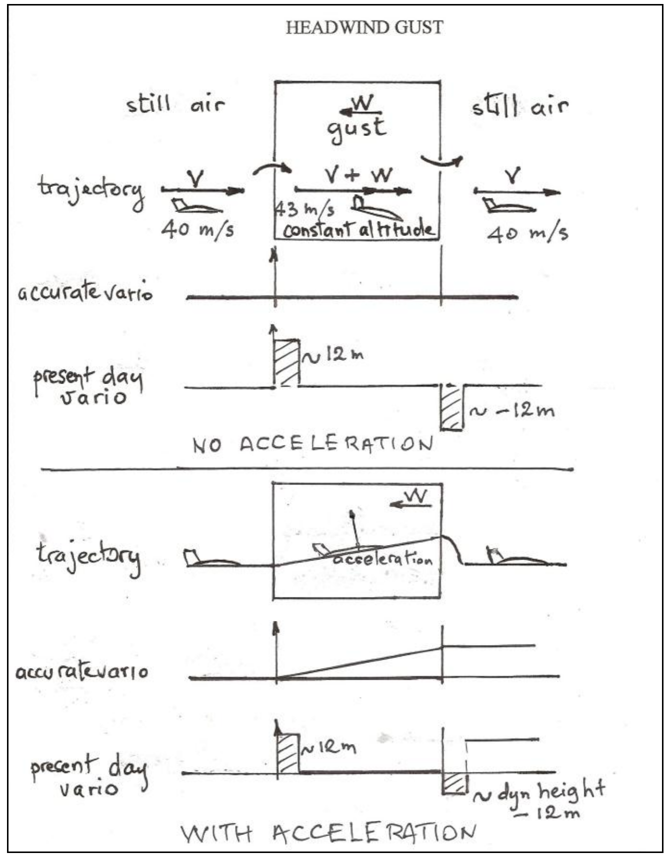

Figure 21 Headwind gust