Development of a constant-temperature box for variometers

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The temperature stabilization required for reliable variometer measurements is difficult to achieve in the field. Possible solutions include instrument burial, or the use of containers with active or passive temperature regulation. We have chosen the latter and developed a transportable, thermally insulated box (1×1×0.7 m). The heating power required by active temperature regulation is inversely proportional to the thermal conductivity λ of the insulating layers. On the other hand, passive regulation is best achieved by minimizing the thermal diffusivity. These needs have been fulfilled with a composite 3-layer insulation, whereby each layer fills the ~10 cm space between 4 concentric boxes. The external and internal layers are filled with rigid foam blocks, while the middle layer is filled on-site with ~300 l water, which provides the thermal capacity required by passive insulation. The empty system can be hand-lifted.

The box has 3 cable connections for instrument operation, heating, and temperature monitoring with sensors (colour disks, Fig. 1) outside, inside the three insulating layers, and inside the variometer-hosting inner box, respectively.

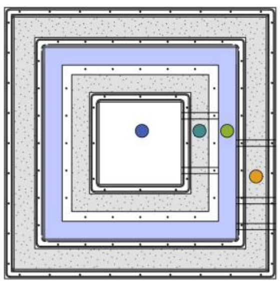

Figure 1: Top view of the insulated container (water in blue) and position of the 5 temperature sensors.

A first performance test has been performed between April and June, with the box directly exposed to the sun. The external sensor recorded daily temperature variations of >16°C, while the maximum daily variation of the inner box did not exceed 0.3°C (Fig. 2).

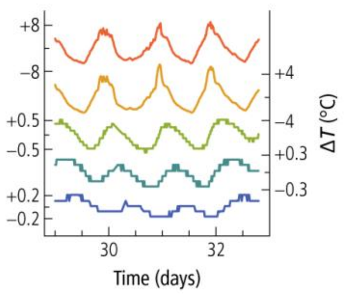

Figure 2: Temperature variations measured by the 5 sensors (same color code as in Fig. 1) during 5 days.

The insulation performance has been modelled by solving the 1-D heat equation with following unknown parameters: the heat transfer coefficient ha to the surrounding air, the effective thermal conductivity λ of the foam blocks, and the heat transfer coefficient h_w between water and the surrounding layers, including heat transmission across the box walls (water is assumed to mix, as deduced from the difference between cooling and warming rates in Fig. 2).

Realistic model parameters (λ = 0.28 W/m·K, h_a = 9 W/m^{2}K, h_w = 4 W/m^{2}K) have been obtained by minimizing the relative difference between predicted sinusoidal daily variations and the mean daily variations recorded by the sensors. The modelled attenuation of periodic temperature variations matches the damping coefficients estimated from a Fourier analysis of the actual temperature records, for periods ranging from 1 day to 1 month (Fig. 3). The passive ≈100-fold attenuation of daily variations enables a satisfactory variometer operation with absolute measurements taken weekly to correct the drift produced by residual temperature variations. The estimated inner box heating power needed to compensate a 20°C temperature variation is <3 W for a 1-day period, and 30W for a 5-day period.

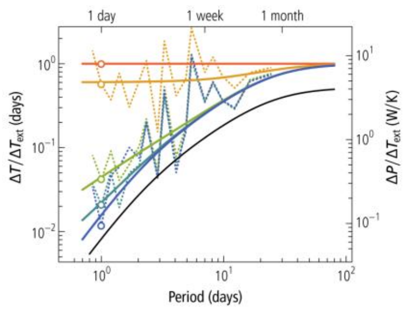

Figure 3: Attenuation of sinusoidal temperature variations recorded by the 5 sensors as a function of their period (dashed lines obtained with Fourier analysis), compared with the corresponding model curves (solid lines). The expected heating power required to fully compensate a 1 K-external temperature variation is shown by the black curve.

These preliminary tests represent a worst-case scenario, since several foam blocks were missing, and the black box was directly exposed to the sunlight.

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