TEMPERATURE LAPSE RATE ESTIMATION BY DOPPLER SODAR

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ABSTRACT

A statistical approach of turbulence in the lower atmosphere by Blackadar permits to anticipate the estimation of the temperature lapse rate in the stable cases by Sodar if the first two moments (intensity and doppler shift) of the backscattered echo are accuratly measured. The validity of this estimation was first tested using data provided by the Kernforschungszentrum (Nuclear Research Center) in Karlsruhe (West Germany), where a REMTECH Doppler Sodar had been operating for years, one hundred meters away from a 200-meter-high meteorological tower. We had shown that this method can be extended to unstable cases and that the Sodar's lapse rate is well correlated with the tower data, provided that weak turbulent cases are conveniently treated. Over the past years we have improved the method by allowing an adaptive estimation of the first moment, which accounts for the antenna efficiency variations (for instance because of ambient temperature changes). Recent data using a PA0 (very small Sodar) and a PA5 (long-range Sodar) will be presented. Very recently we have also applied this method to the RASS temperature vertical profile range extension.

1. THE THEORETICAL APPROACH

The following approach corresponds to the so-called "Level 2" of Mellor & Yamda <2> where advection and diffusion terms are neglected in the Fluid Mechanics equations, which leads to (in the PBL aproximation):

$$q^3/\lambda_1 = -uw\ (\partial U/\partial z) - vw\ (\partial V/\partial z) + \beta g\, w\theta'$$

$$q\, \sigma_\theta^2/\lambda_2 = -w\theta'\ (\partial\theta/\partial z)$$

where:

- λ_1, λ_2 characteristics lengths
- u, w horizontal and vertical speed fluctuations
- θ' potential temperature fluctuation
- q kinetic energy
- σ_θ sigma of the potential temperature fluctuations

Blackadar <1> uses it with:

$$\lambda_2 = q/\sigma_w\ l^{-1}\, C_\theta$$

which lead to:

$$C_\theta\, l^{-1}\, \sigma_w\, \sigma_\theta^2 = -w\theta'\ (\partial\theta/\partial z) \qquad (1)$$

where:

- C_θ coefficient (0.19 according to Blackadar)
- l turbulence scale
- σ_w sigma of vertical windspeed
- $w\theta'$ vertical heat flux
- $\partial\theta/\partial z$ temperature lapse rate

For monostatic Sodars the backscattered echo E can be shown to be proportional to the temperature structure fonction CT

$$(C_T^2 = [\theta(r'+r) - \theta(r')]^2\ r^{2/3}$$

where the distance r is within the inertial range):

$$E \sim C_T$$

Through dimensionnal analysis, one has:

$$C_T^2 = \sigma_\theta^2 / l^{2/3}$$

On the other hand, the vertical heat flux is rewritten:

$$w\theta' = \mathrm{corr}[w, \theta']\ \sigma_w\ \sigma_\theta$$

where the correlation [w, θ'] is considered constant (typically –0.25 -0.50).

Replacing thus in equation (1):

$$C_T^2\, l^{-1/3} \sim (\partial\theta/\partial z)$$

In stable cases the characteristic turbulence length can be written:

$$l = \sigma_w / N$$

where:

- N Brunt Vaisala "frequency"

Since:

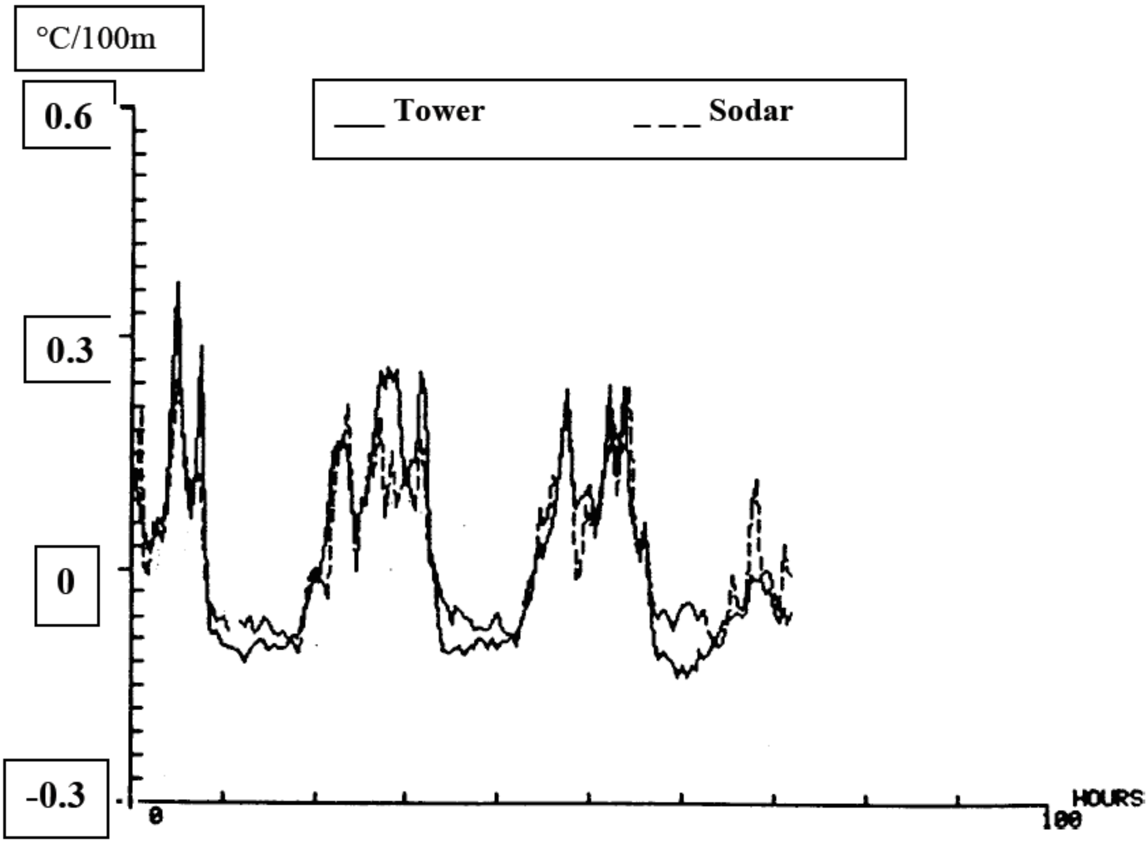
$$N^2 \sim g/\theta\ (\partial\theta/\partial z)$$

We thus have:

$$\sigma_w^{-2/3}\, C_T \sim (g/\theta)^{-1/3}\ (\partial\theta/\partial z)^{2/3}$$

If the variations of θ are considered small compared to θ, we then have:

$$\partial\theta/\partial z \sim C_T^{3/2}\ \sigma_w^{-1}$$



2. EXAMPLE OF INTERCOMPARISON

The figure shows the Sodar temperature lapse rate estimation versus tower data at Karlsruhe. The empirical formula, which is applied to the Sodar data reads:

$$\partial \theta / \partial z = A + B E 3/2 \sigma w\text{-}1$$

in which A and B are empirical coefficients which have been estimated using previous data.

3. IMPROVING THE METHOD

Long-term intercomparison have shown that A and B exhibit seasonal variations. One way to come up with an adaptive estimation of A and B is to infer an adiabatic lapse rate during midday hours.

REFERENCES

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