P1.4 INTERCOMPARISON OF ULTRASONIC ANEMOMETERS DURING THE MAP RIVIERA PROJECT

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1. INTRODUCTION

As part of the MAP-Riviera Project (Rotach et al., 2000) a field intercomparison of ultrasonic anemometer-thermometers (sonics) was carried out from July 12 to July 16 1999 at San Vittore Airfield, Southern Switzerland. The motivation for this study was the intercomparison of different sensor types and calibration methods under ideal field conditions. This information will be used for interpretation and data verification of turbulence measurements under complex conditions at steep slopes (Calanca et al., 2000; van Gorsel et al., 2000; Vogt et al.,2000).

2. SITE AND INSTRUMENTATION

The intercomparison site is located in the lower part of the 35 km long alpine Mesolcina Valley in the Piano di San Vittore (270 m a.s.l., 46°14'25" N, 9°06'00"E WGS-84). The flat valley ground at the airfield is 1 km wide, surrounded by mountains with an average height of 2000 m a.s.l. This site allowed to compare sonics under the influence of a large thermally driven valley wind system.

A total of 18 sonics with 5 different designs were compared (Tab. 1). All sonics were mounted at a height of 1.8 m in two arrays. The arrays were 10 m apart and spacing between single instruments was 1 m. Fetch in downvalley direction consisted of homogeneous 35 cm high grassland which extended up to 800 m.

The intercomparison period was dominated by nearly cloudless radiation days with shortwave irradiance up to 1000 Wm^{-2}. Air temperature patterns show a nighttime minimum of 12°C and a maximum around 28°C at 15:00 CET. Strong upvalley winds (WSW) started daily at 13:00 CET. Wind speeds were up to 5 ms^{-1} and persisted until 18:00 CET. During nighttime cold air drainage flows with wind speeds around 1 ms^{-1} were observed. Daytime *TKE/m* values were up to 3 m^2s^{-2}.

3. DATA PROCESSING

From all sonics raw data were collected. Block averages over 30 min from 120 hours of data were calculated. For mean and covariance data no detrending was applied. The coordinate system was rotated into mean wind ($\overline{v}$ = 0 and $\overline{w}$ = 0) (Kaimal et al., 1994).

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Manufacturer Sonic Type	No of Sensors	Sampling Rate [Hz] (Internal / Output)	Path Length [mm]	Uncalibrated	Manufacturer calibration	Matrix calibration
Gill Instruments R2A (asymmetric)	8	168 20.8	3 x 147	yes	yes	part.
Gill Instruments R2	5	168 20.8	3 x 147	yes	yes	part.
Gill Instruments HS	1	100 20	3 x 153	no	yes	yes
Campbell Scientific CSAT3	3	60 20	3 x 116	yes	no	yes
METEK USA-1	1	10 10	3 x 180	yes	no	yes

Tab. 1. San Vittore field intercomparison: Involved ultrasonic anemometer types, sampling rates and applied calibrations.

Standard output data ("uncalibrated") is compared to a two dimensional matrix calibration (Vogt, 1995) obtained from sensor-specific wind tunnel measurements. Windtunnel measurements were carried out with 8 sonics just before the field experiment. Transit counts or uncalibrated data were collected from R2 to see improvements between pure data and manufacturer calibration applied afterwards ("Gill calibration").

4. RESULTS

The Campbell CSAT3 #199 was chosen as reference instrument. Data within the undisturbed W-sector were compared by terms of linear regression $m_{sen}= am_{ref}+b$. If not mentioned then b is insignificant.

The intercomparison of mean wind speed points out, that CSAT3, Gill HS and METEK USA-1 correlate best with the reference, followed by Gill R2 with matrix or Gill-calibration. The martix-calibration applied to the CSAT3 and USA-1 improves slopes to values between 0.98 and 1.00 ($|b|<0.04$ ms^{-1}, $r^2>0.998$). For HS and R2 the improvement of matrix calibration is in the same order as the manufacturer calibration ($0.97<a<1.01$, $|b|<0.05$ ms^{-1}, $r^2>0.997$). Mean wind speed from R2, especially from asymmetric ones, show higher scatter (down to $r^2=0.92$). 3 of 14 R2 with manufacturer calibration are out of the accuracy range given by the manufacturer.

σ_u- and σ_v-regressions show slope values for matrix calibration of CSAT3 and USA-1 around a=0.97 ($r^2>0.989$), of HS 0.97 ($r^2>0.993$) and of R2 between 0.96 to 1.00 ($r^2=0.964$). Slopes up to 0.86 and r^2 to 0.87 were observed for some R2 with Gill calibration.

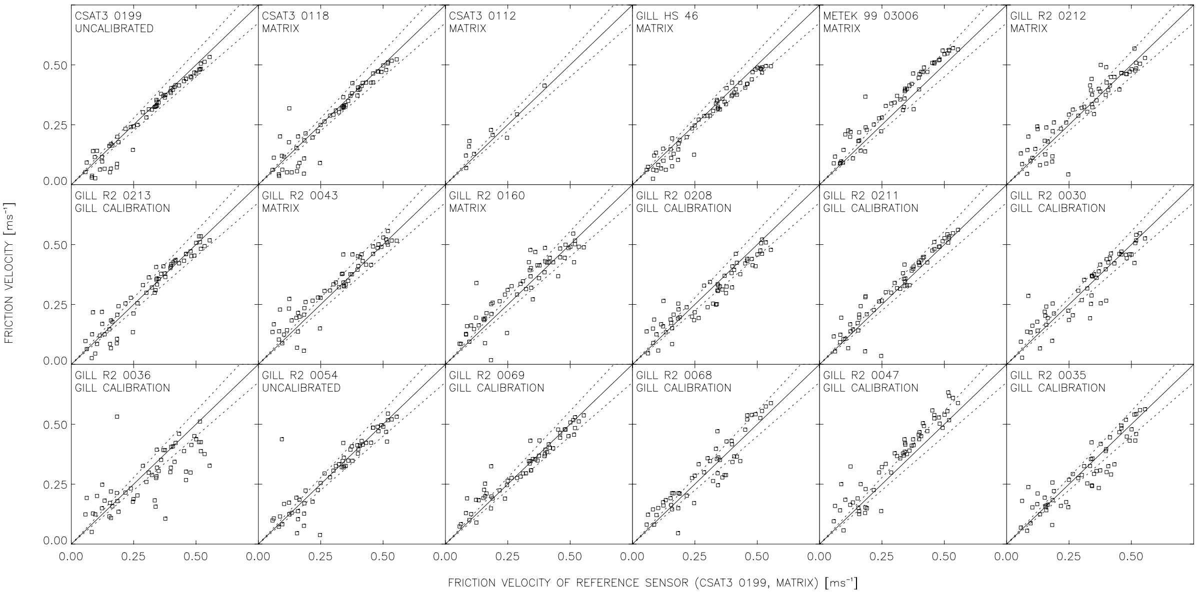

Fig. 1. Intercomparison of friction velocity u_*. Best calibration for each sensor is compared to friction velocity of reference sensor (CSAT3 #0199, matrix calibrated). Each point represents a 30min mean value. Dashed lines border the area with less than 10% deviation. Only data within a mean winddirection of 170° and 350° are plotted. CSAT #0112 was operated only one day.

σ_w has slightly better agreement between sensors and less scatter than σ_u and σ_v. Systematic underestimation of σ_w is observed with uncalibrated CSAT3 (a=0.95), uncalibrated USA-1 (a=0.90) and all R2 with uncalibrated data (a around 0.86). Gill suggests a correction of vertical windspeed for R2 by factors between 1.08 and 1.18 dependent on azimuth. Results show, that this “Gill correction” works well.

Mean absolute virtual acoustic temperature $\overline{\theta}$ without path correction has offsets up to +12K between sensors. 16 of 17 Sonics overestimated $\overline{\theta}$. CSAT3 and USA-1 are within the manufacturer specified offset. HS and some R2 show significant temperature dependence of absolute θ error. Three different pathlength sets (manufacturer, recalculated pathlength from windtunnel and field data) were applied to improve measurements of absolute θ of R2. σ_θ shows more scatter than σ_u, σ_v and σ_w. While non-reference CSAT3 agree well (0.96<a<1.04), USA-1 underestimates σ_θ by a=0.90 (r^2=0.978), HS overestimates it by a=1.13 (r^2=0.964) and all R2 lie in the range 0.72<a< 1.22 with high scatter (0.68>r^2 >0.96).

Precision of the mean covariance $\overline{u'w'}$ is improved by matrix calibration for CSAT3, HS and most R2 to a satisfactory level. Uncalibrated USA-1 underestimates absolute values of $\overline{u'w'}$ systematically, matrix calibrated USA-1 shows an overestimation. Because of small absolute values, $\overline{v'w'}$ shows little agreement between different sensors. Friction velocities u_* calculated with $[(\overline{u'w'})^2+(\overline{v'w'})^2]^{0.25}$ have values up to 0.6 ms^{-1}. u_* shows high inter-instrument uncertainty below 0.2 ms^{-1}, especially for R2 (see Fig. 1).

Surprisingly, scatter of $\overline{w'\theta'}$ is higher than for $\overline{u'w'}$. Matrix calibrated CSAT3 and HS show slopes between 1.03 and 1.08 (|b|<-4.6 Wm^{-2}, r^2>0.913), For the USA-1 $\overline{w'\theta'}$ improves from a=0.88 to a=0.95 by applying the matrix calibration (r^2>0.89). R2 have deviations up to ±25% (0.83<a<1.18, r^2>0.58 for 20<H<150 Wm^{-2}).

CONCLUSIONS

CSAT3 and HS show highest inter-instrument agreement. USA-1 is improved substantially by applying matrix calibration. Effects of different calibrations methods are higher on first moments than on second order moments. Flux measurements are in most cases not improved significantly by matrix calibration.

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