SCIDAR-MASS comparison

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1 Data overview

MASS and SCIDAR worked jointly at Mauna Kea on October 20-23 2002 (the dates refer to the beginning of night throughout this document). The sky was not always clear during those 4 nights.

SCIDAR was developed at the Nice University and operated by J. Vernin and A. Ziad. It was installed at the 88-inch telescope of the University of Hawaii. It uses a suitable bright binary star as light source and works in generalized mode, measuring all turbulence. A profile is determined with 20-s integration time. The vertical sampling of the profile is on a 300-m grid extending from some altitude below the mountain (to take the ground layer correctly) to ∼20 km above.

MASS was built by a team of V. Kornilov under a contract with AURA. It was installed at the 24-inch telescope and operated by A. Tokovinin. It uses bright single stars selected near zenith. Low-resolution profile is obtained every minute. MASS restores turbulent profile by two methods: 6 fixed layers at pre-defined altitudes of 0.5, 1, 2,..., 16km and 3 "floating" layers with arbitrary altitudes. In the following, only the results of fixed-layer restorations are used. However, "floating layers" were used to generate Fig. 1.

No normalization or other "adjustment" was applied to the data sets in question.

2 Detailed comparisons

A first qualitative comparison is given in Fig. 1. Here, a half-tone representation of the profiles (with square-root stretch to accentuate weak turbulence) is given. Both data sets were re-binned on a regular time grid, starting at 5h UT and ending at 15h UT, with 1-min. step. The altitude scale is linear, starting at the mountaintop. The MASS "fixed-layer" data were convolved with artificial response functions.

We see that MASS is capable to localize correctly the altitudes of the strongest turbulent layers. The atmospheric conditions were not "favorable" for MASS: the turbulence was weak and distributed over the whole atmosphere. Still, the appearance of strong layers at 2-4km around 6:00UT and 15:50UT on October 21 was well detected, as well as an appearance of a strong 1km layer after 14:00UT on October 23.

More quantitative comparison is done by integrating the SCIDAR data with triangular weighting functions of MASS. The resulting intensities of turbulent layers J (in $\mathrm{m}^{1/3}$) are transformed into seeing (at 500 nm at zenith) $\beta = (J/6.8 \cdot 10^{-13})^{3/5}$. The results are plotted in Figs. 2-5 as a function of time. No time re-binning or averaging was done.

Note a good match of MASS and SCIDAR "seeings" for 4-km and 2-km layers on October 21 when those layers briefly became strong. On the other hand, there is a strong mis-match of the two highest layers on October 23 before 6:30UT. We suspect that there was some problem with SCIDAR because the agreement with MASS for those layers is otherwise excellent.

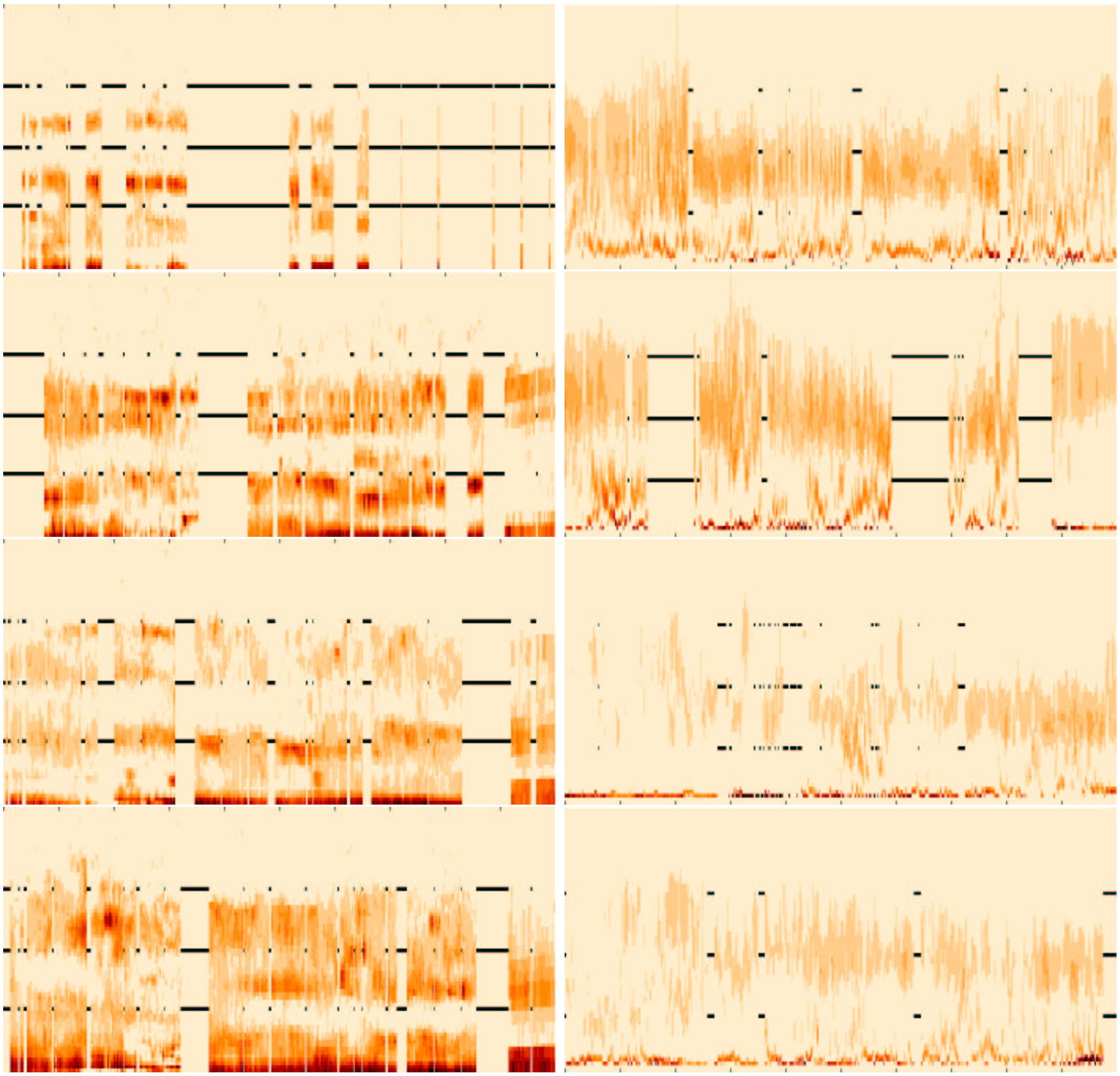

Figure 1: Turbulence profiles on October 20-23 (top to bottom) as measured by SCIDAR (left) and MASS (right). A square-root stretch with arbitrary normalization is used in both plots. Black horizontal lines mark the altitudes of 5, 10, 15 km above site, vertical ticks - UT hours. The period from 5h UT to 15h UT is plotted. The results of MASS "floating-layer" restoration are plotted, the layers are smoothed to 1.5*altitude.

Summing up all intensities and transforming them into seeing, we compare the overall response of the two instruments (Fig. 6). The agreement is very good.

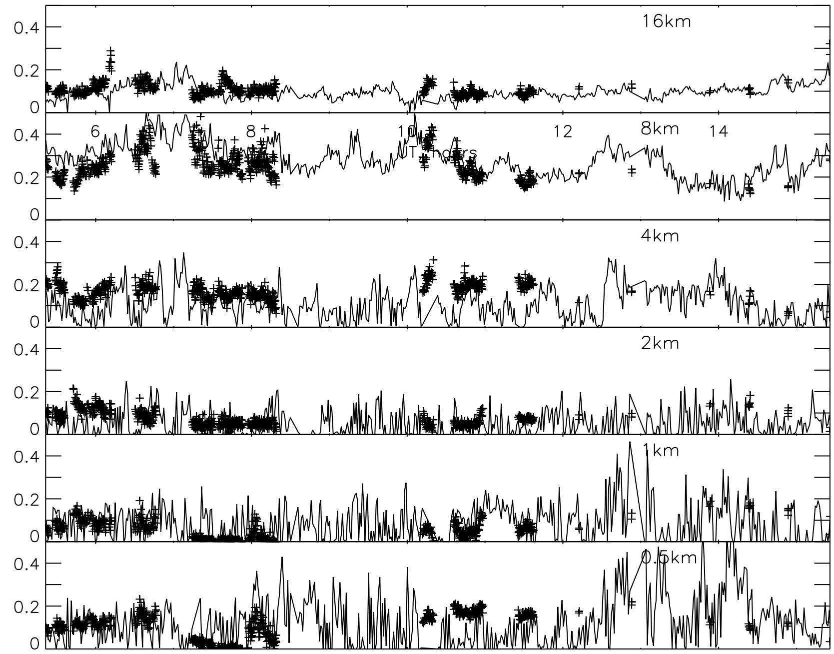

Figure 2: Seeing produced by each of the 6 “slabs” (vertical axis, arc-seconds) as a function of UT time according to MASS (lines) and SCIDAR (crosses) on October 20, 2002.

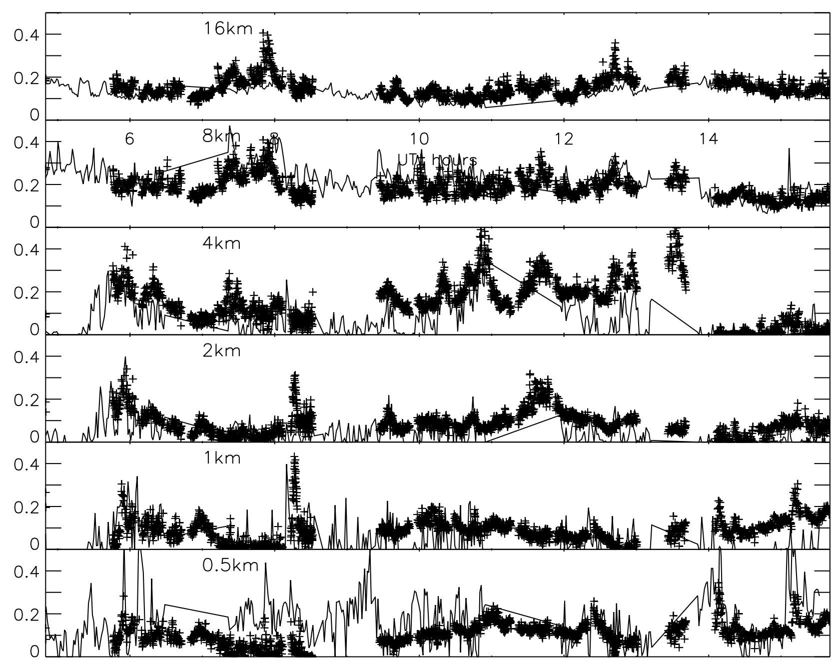

Figure 3: Same as Fig. 2 for October 21, 2002.

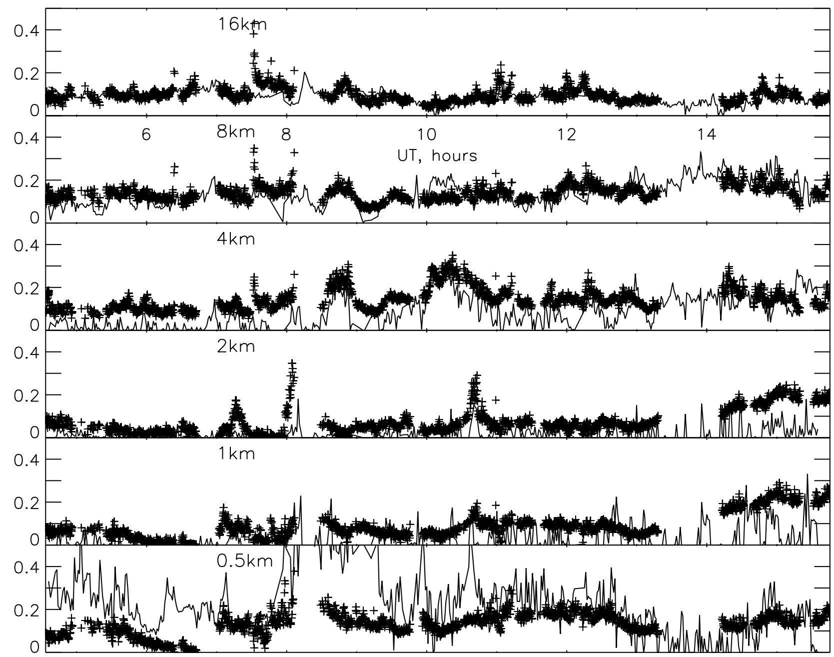

Figure 4: Same as Fig. 2 for October 22, 2002.

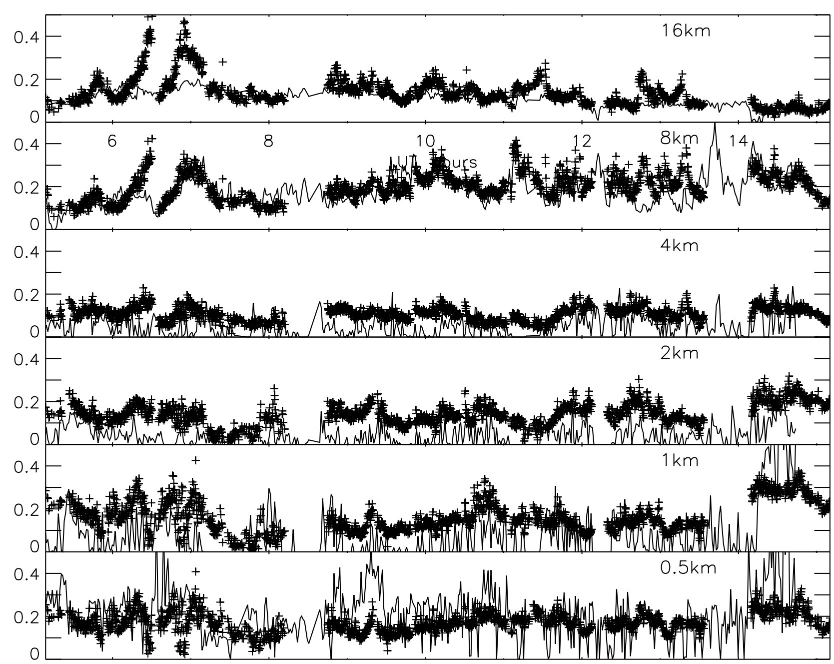

Figure 5: Same as Fig. 2 for October 23, 2002.

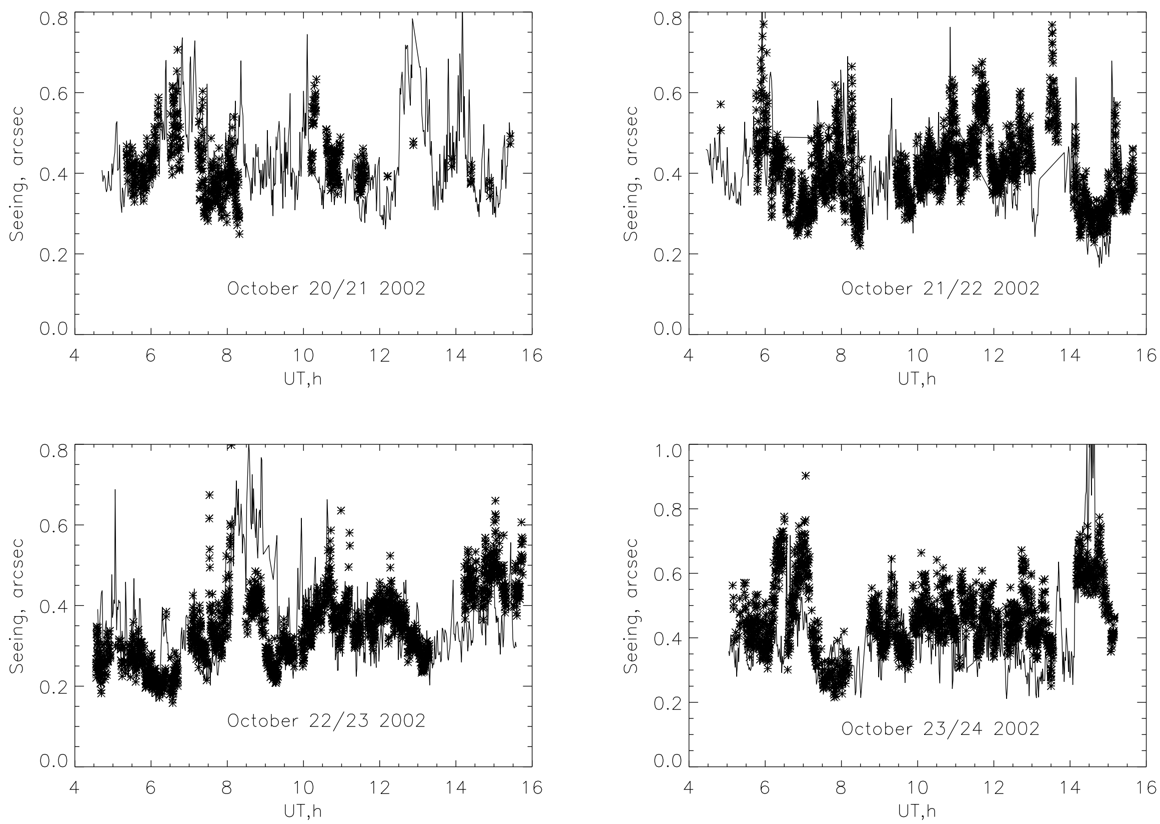

Figure 6: Comparison of free-atmosphere seeing measured by MASS (lines) and SCIDAR (asterisks).

3 Comparison of time-averaged values

Given the high noise in the data (especially MASS), the natural "noise" of turbulence (intermittency) and different viewing directions, it makes sense to compare averaged quantities. To this end, we averaged the intensities of turbulent layers J over time intervals of 1 hour for both instruments. Only data where both instruments are synchronous within 1 min. are taken into consideration, and a minimum number of averaged profiles during any hour is set at 20. Hence, not all hours produce useful comparisons.

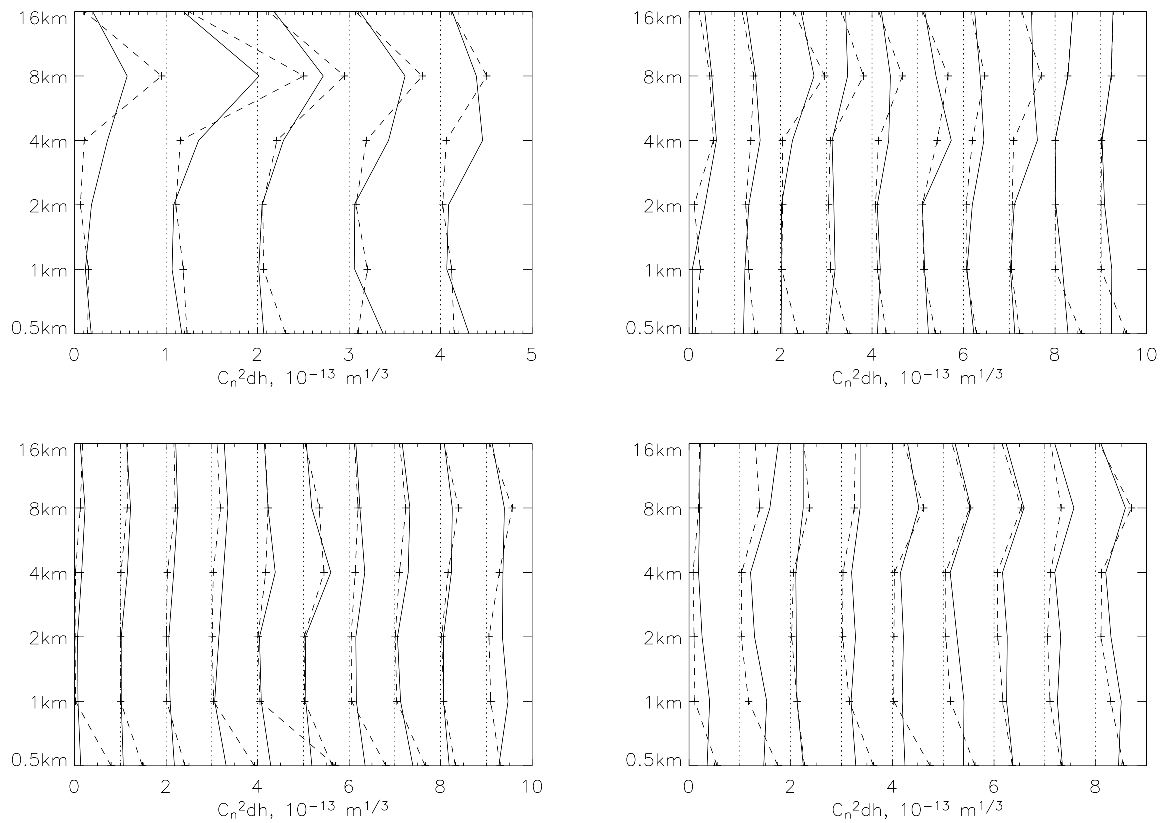

Figure 7: Hourly-averaged turbulence profiles with low vertical resolution from SCIDAR (lines) and MASS (dash with crosses) on October 20-23 (left to right and top to bottom).

In Fig. 7 the time-averaged data are represented as profiles, comparing directly MASS with SCIDAR. An x-y plot for all layers and all average points (total 34) is given in Fig. 8.

In Table 1 the statistical comparison of average turbulent intensities measured on each night and in each layer is given. The ratios M/S (MASS divided by SCIDAR) are computed point-by-point and then averaged, hence the result is different from the ratio of the average values. The last column of Table 1 compares the sum of all layers. The agreement of average values is very good, despite completely independent calibrations of MASS and SCIDAR.

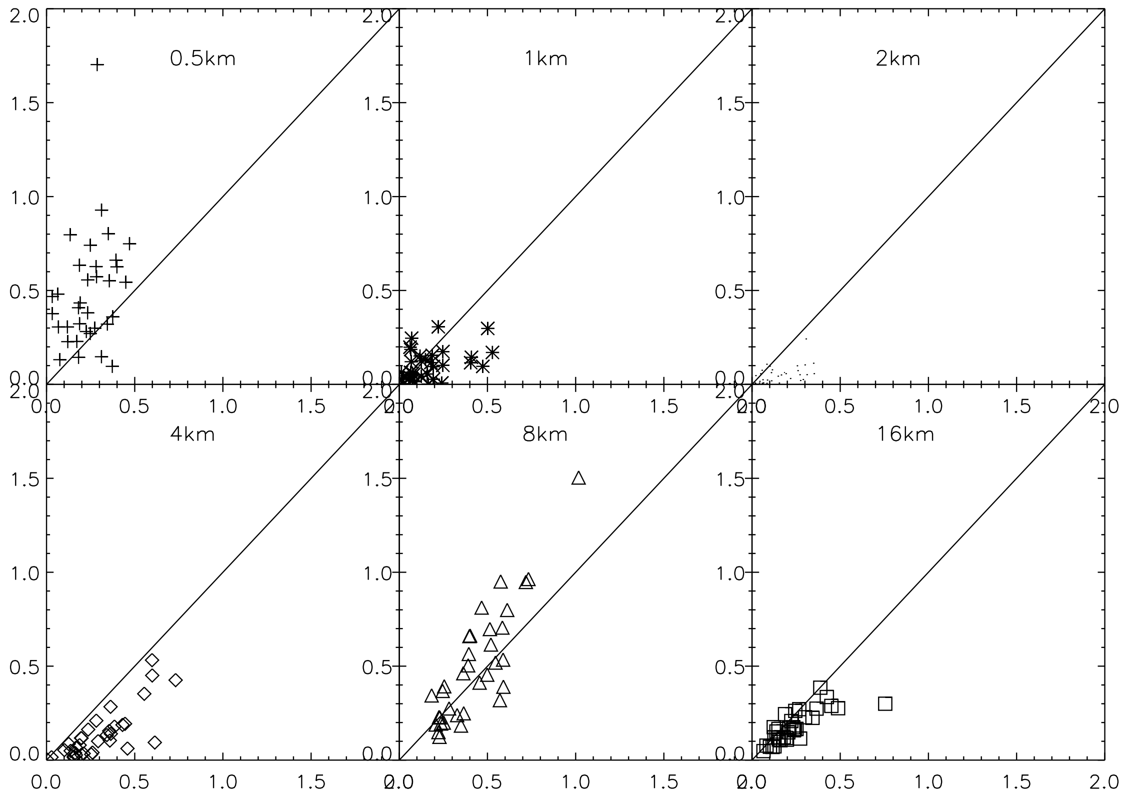

Figure 8: Hourly-averaged turbulence intensities (in units of 10^{-13} m$^{1/3}$) are compared for the whole data set, with SCIDAR on the horizontal axis and MASS on the vertical axis.

Table 1: Statistical comparison of hourly-averaged turbulence intensities in units of 10^{-13} m$^{1/3}$

Parameter	0.5m	1km	2km	4km	8km	16km	Total
October 20, 5 points							
SCIDAR	0.22	0.06	0.09	0.38	0.66	0.16	1.58
MASS	0.18	0.14	0.06	0.14	0.94	0.13	1.61
M/S	1.47	2.88	0.89	0.41	1.41	0.82	1.02
October 21, 10 points							
SCIDAR	0.15	0.13	0.15	0.37	0.43	0.32	1.56
MASS	0.37	0.10	0.08	0.19	0.56	0.24	1.54
M/S	4.2	1.15	0.67	0.65	1.28	0.74	1.00
October 22, 10 points							
SCIDAR	0.24	0.12	0.10	0.29	0.27 7	0.15	1.17
MASS	0.70	0.04	0.02	0.14	0.26	0.12	1.29
M/S	3.47	0.42	0.20	0.39	0.99	0.86	1.16
October 23, 9 points							
SCIDAR	0.35	0.32	0.25	0.17	0.47	0.30	1.86
MASS	0.53	0.15	0.05	0.07	0.43	0.20	1.43
M/S	1.56	0.52	0.21	0.38	0.95	0.73	0.79

4 Conclusions

- Two independently calibrated instruments, MASS and SCIDAR, show a very good (better than 20%) agreement on the turbulence integral in the free atmosphere.

- The intensities of the highest layers (8km and 16km) also agree very well.
- Intermediate layers (2km and 4km) are systematically under-estimated by MASS when those layers are weak compared to higher turbulence, by a factor of 2 to 5 typically. When a strong turbulence is present at those altitudes, it is measured by MASS correctly.
- The intensity of the lowest layer (0.5km) measured by MASS is frequently higher that indicated by SCIDAR. Part of this difference may be attributed to the weighting function used to convolve the SCIDAR data into a 0.5-km layer: that function drops to zero at 250m altitude, whereas real MASS weight drops to zero only at the surface, and thus integrates a larger fraction of the strong ground layer. Another reason of insecure data at 0.5km is the crudeness of the MASS single-layer model: this model works well at high altitudes when the weighting functions are smooth, but fails at low altitudes where the weights change rapidly. This has been established previously in simulations: a “hump” in MASS sensitivity at 0.5km was seen amounting to some 20%.