Cloud cover estimation based on ceilometer measurements: a comparison with visual observations

M. Costa-Surós[1], J. Calbó[2], J.A. González[2] and A. Sanchez-Lorenzo[3]
[1] Institute of Geophysics and Meteorology, University of Cologne (Germany),
[2] Department of Physics, University of Girona (Spain), [3] Instituto Pirenaico de Ecología, CSIC (Spain)

1. Introduction

In the present study, we analyze the temporal averaging of ceilometer data as an estimator of **cloud cover** (CC), given that a measured cloud base height (CBH) means that there is a **cloud occurrence** overhead (CO). Although standard ceilometers only see in the zenithal direction, clouds usually move, so a temporal averaging of occurrence measurements must be an approximation of the areal extension of clouds [1].

Eight years (2007-2014) of CO from **ceilometer** measurements at a site in Girona (Spain) are compared with the corresponding human CC **surface observations** at the airport nearby. The comparison of the **total cloud cover** (TCC) and **low clouds cover** (LCC) is performed on one hand in daily mean basis, and then at the time when the instantaneously observations where done (i.e.: 7, 13 and 18 h), for which 15 different time periods have been tested for the temporal averaging.

2. Methodology

Cloud cover observations from the “Agencia Estatal de Meteorologia” (AEMET) made at Girona - Costa Brava **Airport** (41.90°N, 2.77°E) have been compared with **cloud occurrence estimations** from a Vaisala **ceilometer** CL-31 located in the roof of the Polytechnic School of the University of Girona (41.96°N, 2.83°E) [2] (distance: 10 km).

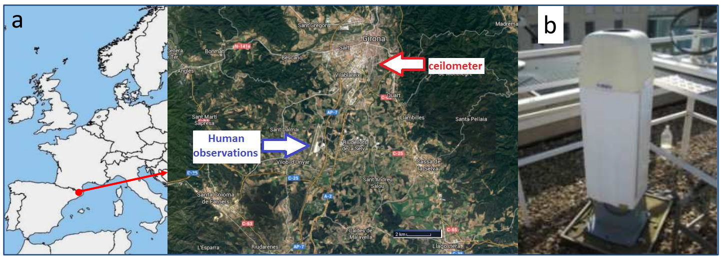

***Fig. 1**: (a) Ceilometer site and airport location maps, (b) ceilometer CL-31 at University of Girona.*

The ceilometer laser emits at a central wavelength of 910 ± 10 nm, and by analyzing the received backscatter signal it can retrieve up to 3 CBH every 12 s. It is able to detect clouds up to ~7500m, and it was configured with a height resolution of 10 m.

3. Results:

Frequency distributions of daily mean **TCC** and **LCC** for the airport observations and the ceilometer estimations for the whole period of 8 years (2007-2014):

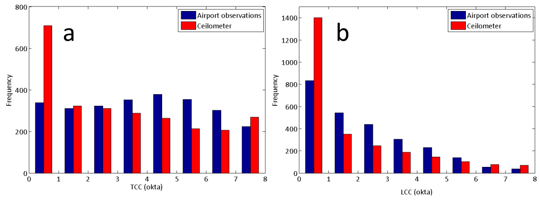

***Fig. 2**: Histograms of daily mean for (a) TCC and (b) LCC.*

Mean **coefficient of determination** between the cloud cover observed in the airport and the cloud occurrence measured with the ceilometer (daily means) for the period 2007-2014 is **0.70** (and 0.61 for low clouds). The mean **bias** is **-0.79** (-0.65 for low clouds).

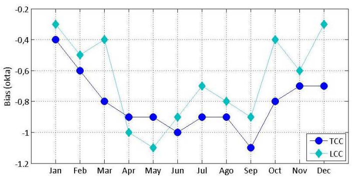

***Fig. 3**: Monthly bias (oktas).*

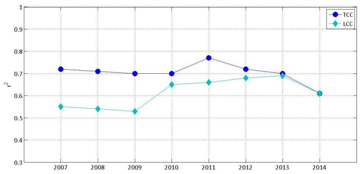

***Fig. 4**: Yearly coefficient of determination.*

Results for instantaneous observations, for each of the 3 obs. times:

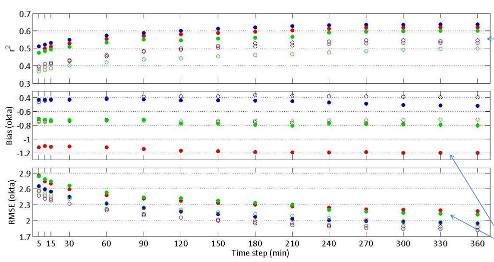

***Fig. 5**: Coefficient of determination (r^2), bias and RMSE for TCC and LCC at the three observational times (7h,13h, and 18h), and for 15 time periods. The whole period 2017-2014 is included.*

Is it because of the BL daily evolution that r^2 for TCC and for LCC became worst as the day draws on? Or we cannot base such affirmation only in the r^2?

Note that LCC bias < TCC bias because LCC=<TCC by definition.

Importance of combining different statistics: e.g. TCC bias at 13h show larger negative values than for the other observational times, but the corresponding RMSE indicate that they are comparable to the other observational times.

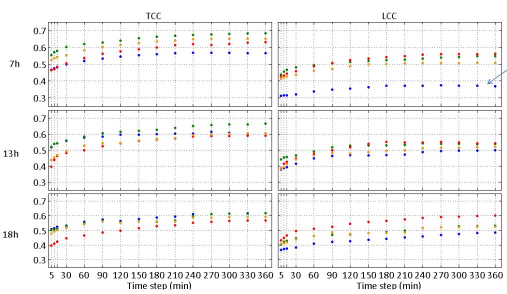

***Fig. 6**: Seasonal r^2 for TCC and LCC at 7h,13h, and 18h, and for 15 time periods.*

It is remarkable the poorer Winter correlations for LCC at 7h. It might be due to the poorer visibility in wintertime linked to the sunrise time and/or the frequent fog situations.

LCC/TCC ratio in Summer is higher than in the other seasons [2]: this fact explains why r^2 behavior in Summer is better for LCC and worst for TCC.

4. Conclusions and future work

- The results are encouraging since the **correlation** (det. coeff) for the period 2007-2014 between the daily mean TCC observed at the airport and the CO measured with the ceilometer is 0.70 and 0.61 for LCC.
- However, there is a clear tendency of the ceilometer to **underestimate** TCC and LCC (negative biases: -0.79 and -0.60 oktas respectively), probably due to its limited range (7.5km) and the consequent missing of high clouds [2]. This behavior has been already found in the past e.g. when ASOS meteorological network was implemented in the US [3]. In particular, the ceilometer detects a larger amount of clear or almost clear cases (≤ 1 okta) than the observations (Fig. 2). The highest **bias** values are found between April and September. In the future, an expression to correct the estimate of CC from CO will be suggested.
- 15 **time periods** (from 5min to 360min) have been analyzed to estimate CO to be compared to instantaneous observations of CC. For short time periods (<60min) the correlations are lower than for the longer ones, whereas the optimum time lapse seems to be usually, but not in all cases, around 300 min. So, the next step will be to look for the optimum time period. It will not only be based on r^2 but on a combination with other statistics (see box in Fig. 5). Future studies will also be done regarding the level of CC. Therefore, eventually stablishing different optimal time lapses for clear sky, broken clouds, and overcast cases.
- In general, **better estimation** of **TCC** than LCC is found despite that the ceilometer should better detect the low clouds (note that its range is up to 7.5 km). Nevertheless, their particular nature (e.g. usually scattered, short lifetime) makes them become difficult to detect, so sometimes low clouds can be missed by the ceilometer [3].
- Despite the differences found and the limitations described, this kind of studies are of interest to **extend long-term traditional measurements** of CC as the number of human observers at meteorological stations tends to decrease, while the number of ceilometers is increasing.

References
1- Kassianov, E., Long, C. and Ovtchinnikov, M., 2005: Cloud sky cover versus cloud fraction: Whole-sky simulations and observations, J. Appl. Meteorol., 44, 86–98pp.
2- Costa-Surós, M., Calbó, J., González, J.A. and Martin-Vide, J., 2013: Behavior of cloud base height from ceilometer measurements, Atmospheric Research, 127, 64–76pp.
3- Sun, B. and P. Y. Groisman, 2004: Variations in low cloud cover over the United States during the second half of the twentieth century, J. Climate, 17, 1883–1888p.

Acknowledgements:
This study has been partly financed by the Spanish Ministry of Science and Innovation (currently Ministry of Economy and Competitiveness) projects NUCLIERSOL (CGL2010-18546) and NUBESOL (CGL2014-55976-R). Cloud cover observations at Girona-Costa Brava Airport were supplied by the “Agencia Estatal de Meteorologia” (AEMET).

XVII International Conference on Clouds and Precipitation (ICCP), Manchester, U.K., 25-29/07/2016 (Ref. 70)