Cloud fraction retrieved from ceilometer and camera observations: a comparison

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1. Introduction

Clouds intervene in the energy and water balances in the atmosphere through multiple, intricate processes, affecting in turn the climate balance and its change. Therefore, reliable descriptions of cloud climatology and trends are crucial to understand climate change, and to test climate models. In the past, observations of cloud amount and typology have been performed by human observers at selected stations, giving place to many long-term cloud climatologies. Besides, other modern methodologies to monitoring cloudiness from earth surface, as those based on ceilometer measurements and on digital cameras, are receiving increasing interest. In this work we present a comparison among these methodologies, taken out from a year of observations at Girona (NE of Iberian Peninsula). Diurnal periods from 10:00 to 16:00 UTC have been included in the analyses; these periods are centered at 13:00 UTC, a mandatory time for human observations of cloudiness at official meteorological stations. Also human observations at a nearby site have been included in the comparison.

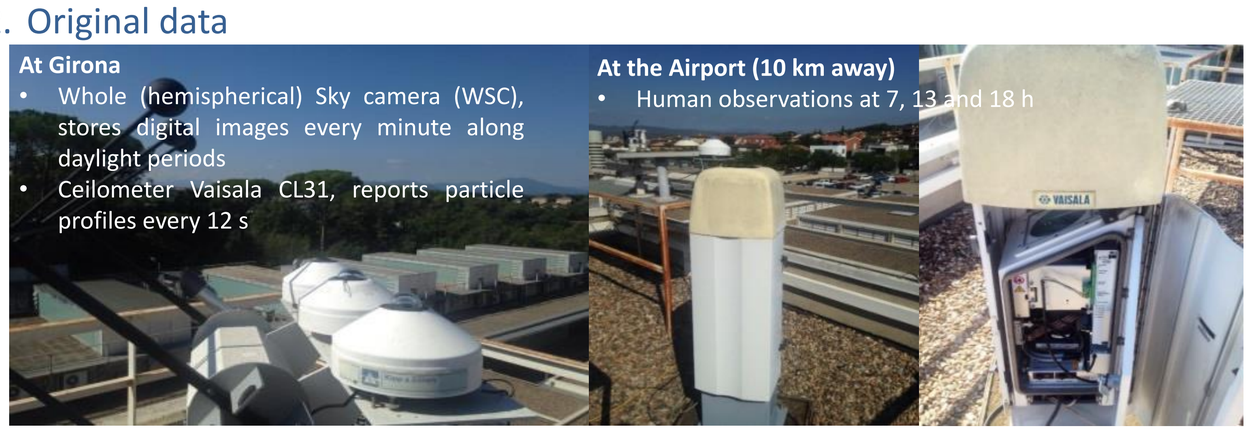
2. Original data

At Girona

- Whole (hemispherical) Sky camera (WSC), stores digital images every minute along daylight periods
- Ceilometer Vaisala CL31, reports particle profiles every 12 s

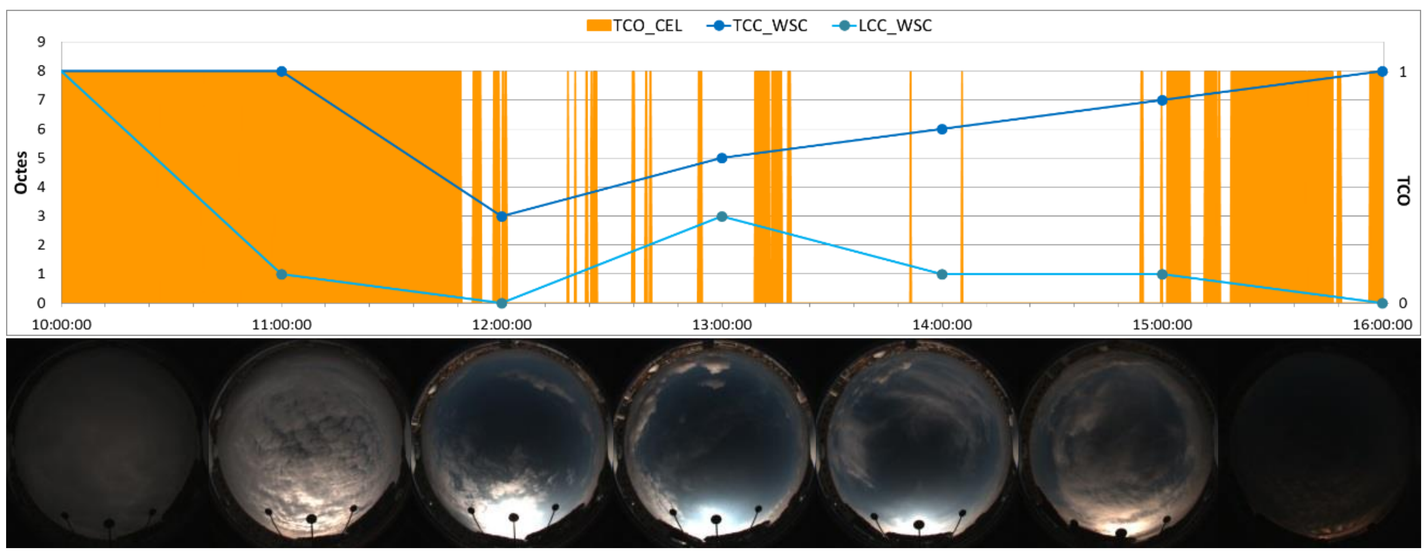
At the Airport (10 km away)

- Human observations at 7, 13 and 18 h



3. Building the daily series

Variable	Cover	Location	Source	Time/Period	Agregation
TCC_OBS_13	Total	Airport	Observer	13 h	Instantaneous
LCC_OBS_13	Low	Airport	Observer	13 h	Instantaneous
TCC_WSC_13	Total	GFA station	WSC	13 h	Instantaneous
LCC_WSC_13	Low	GFA station	WSC	13 h	Instantaneous
TCC_WSC_av	Total	GFA station	WSC	10-16 h	Average
LCC_WSC_av	Low	GFA station	WSC	10-16 h	Average
TCO_CEL_av	Occurrence	GFA station	CL31	10-16 h	Average



Top: Total cloud occurrence detected by the ceilometer, and TCC and LCC estimated by visual inspection of WSC images,. Bottom: images inspected for TCC and LCC estimations (10 to 16 h, 4/01/2011).

We have built seven data series (daily values) for year 2011 (349 days). **TCC_WSC_av** and **LCC_WSC_av** have been used as references for the comparison.

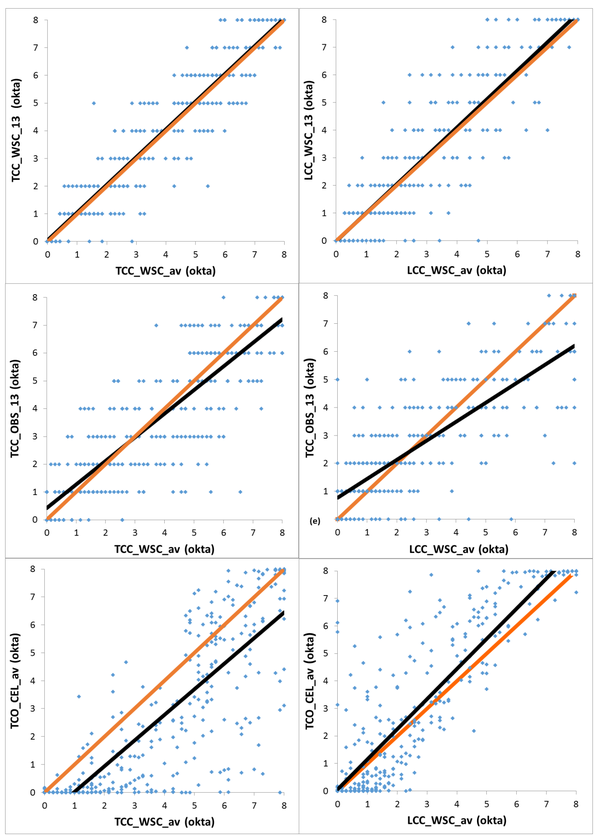
Human observations (Airport)
→ at 13 h
→ **TCC_OBS_13** and **LCC_OBS_13**

Ceilometer data
→ Total Cloud Occurrence (TCO)
→ Conversion to okta
→ average 10-16 h
→ **TCO_CEL_av**

WSC images
→ Visual inspection
→ Estimation of Total Cloud Cover (TCC) and Low Cloud Cover (LCC) every hour in the 10-16 h interval
→ at 13h
→ **TCC_WSC_13** and **LCC_WSC_13**
→ averages 10-16 h (7 images)
→ **TCC_WSC_av** and **LCC_WSC_av**

Frequency distributions of the daily datasets , at 13 h (left), and along the 10-16h period (top)

4.1 Results: daily comparison

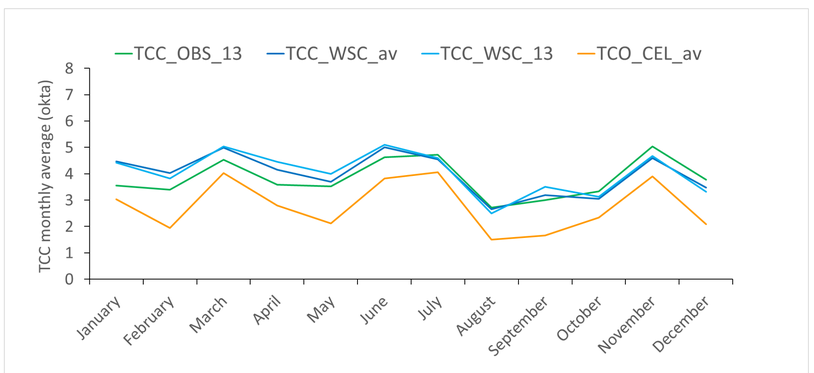


TCC and TCO	TCC_WSC_av (reference)	TCC_WSC_13	TCC_OBS_13	TCO_CEL_av
Mean	4.0	4.0	3.8	2.8
MD		0.1	–0.2	–1.2
RMSD		0.9	1.1	2.1
a		1.00	0.85	0.92
b		0.1	0.4	–0.9
R^2		0.90	0.76	0.67
LCC and TCO	**LCC_WSC_av (reference)**	**LCC_WSC_13**	**LCC_OBS_13**	**TCO_CEL_av**
Mean	2,5	2.5	2.5	2.8
MD		0.1	–0.0	0.3
RMSD		1.1	1.4	1.4
a		1.03	0.68	1.09
b		–0.0	0.8	0.1
R^2		0.83	0.62	0.77

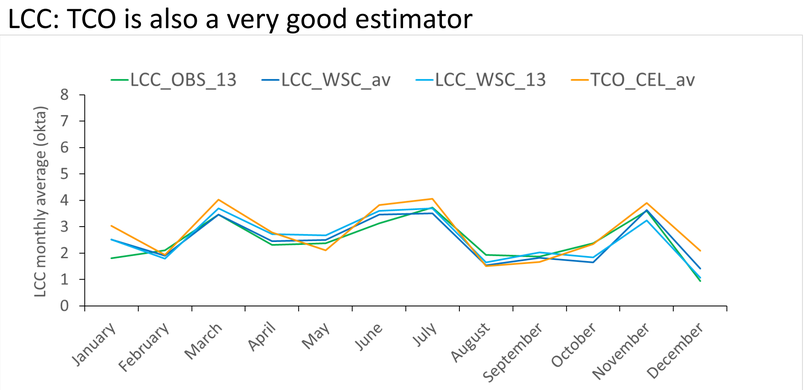
When assessing the total cloud cover fraction (TCC) and low cloud cover fraction (LCC) on daily scale the mean deviation between the methods are quite small, only tenths of okta, with the exception of the method based on the ceilometer TCO, which underestimates the TCC used as a reference by more than one okta.

However, in general important dispersion is found in the differences between daily values, as none of the tested techniques presents RMSD of these values below 1 okta with respect the reference.

4.2 Results: monthly comparison



TCC: evaluation at 13 h is very representative of the 10-16h period. Observations 10 km away gives slight (<1 okta) differences. TCO clearly underestimates (>1 okta).
LCC: TCO is also a very good estimator



5. Summary and conclusions

We have presented a comparison between TCC and LCC evaluated at Girona with different techniques: human observations at a nearby site, analysis of camera images and cloud occurrence in ceilometer measurements. The average TCC and LCC obtained by inspection of images in the period from 10 to 16 h have been taken as the references.

The TCC and LCC obtained from the single image taken at 13h are very representative of the average TCC and LCC along the period from 10 to 16 h. Also the human observations at the Airport give a good mean estimation of both TCC and LCC estimated at Girona from the camera images. Relatively high dispersion is found when comparing series day by day.

TCO clearly underestimates the mean TCC (as expected from the ceilometer limitations in field of view and detection altitude range). Contrarily, TCO constitutes a reasonably good estimator of mean LCC, at least for monthly averages.

Results show that despite their limitations, ceilometers allow describing some sky conditions more satisfactorily than by performing only single visual observations. TCO estimation of daily LCC is (when compared to the reference) better than the estimation with the image inspection at 13 h in 31% of cases. It is also better than the human observations at the Airport at 13h in 43% of cases.

Future work: compare against co-located human observations, extend analysis to nigh-time periods (with a camera system with tuneable exposition), analyze accurately the cases of remarkable disagreement between methods.

References

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Acknowledgements

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