Cloud Top Altitudes using GOME on ERS-2

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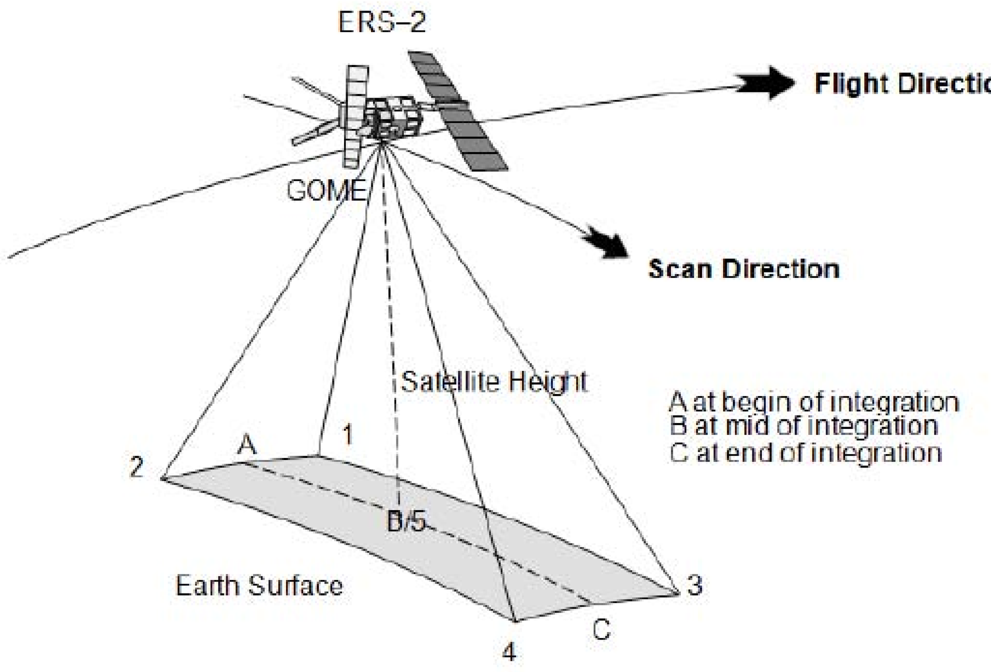
Abstract

Cloud top heights as derived using measurements of GOME instrument onboard the ESA ERS-2 space platform are compared with two different algorithms. It was found that cloud altitudes obtained using thermal IR measurements of ATSR-2 highly correlate with those obtained from top-of-atmosphere (TOA) backscattered solar light measurements of GOME in O_2 A-band using the semi-analytical cloud retrieval algorithm SACURA. The average cloud top heights as obtained by these diverse techniques for the whole data set analyzed (931 GOME pixels) differ by 0.6 km on average, with larger values given by SACURA as applied to GOME data. We found that the standard deviation of SACURA-derived results for cloud top heights from those of ATSR-2 is equal to 1.8 km.

Instrument

GOME is a double monochromator with predisperser prima and 4 holographic gratings. Detectors: 4 Si diode arrays (4×1024 pixels).

- **Spectral resolution** 0.2 / 0.4 nm [240 – 400 / 400 – 790 nm]
- **Spatial resolution** 3 ground pixels with 40×320 km^2 (along×across track, integration time = 1.5 sec). Nadir ≈ 100 × 960 km^2 (integration time = 12 sec)
- **Orbit** retrograde near-polar, sun-synchronous, descending node, altitude 795 km, equator crossing time 10:30 LST
- **Viewing modes** nadir (scan angle $\pm 32°$), polar summer (scan angle $47°$), solar (once a day), lunar (~ times per year)



Methodology

GOME measures the reflected solar light in the NIR including the molecular oxygen A-band centered at 760 nm. The oxygen absorption bands are more pronounced (in the top-of-atmosphere reflected light) for low clouds as compared to high clouds. This is due to the fact that high clouds screen oxygen molecules present in the lower atmosphere.

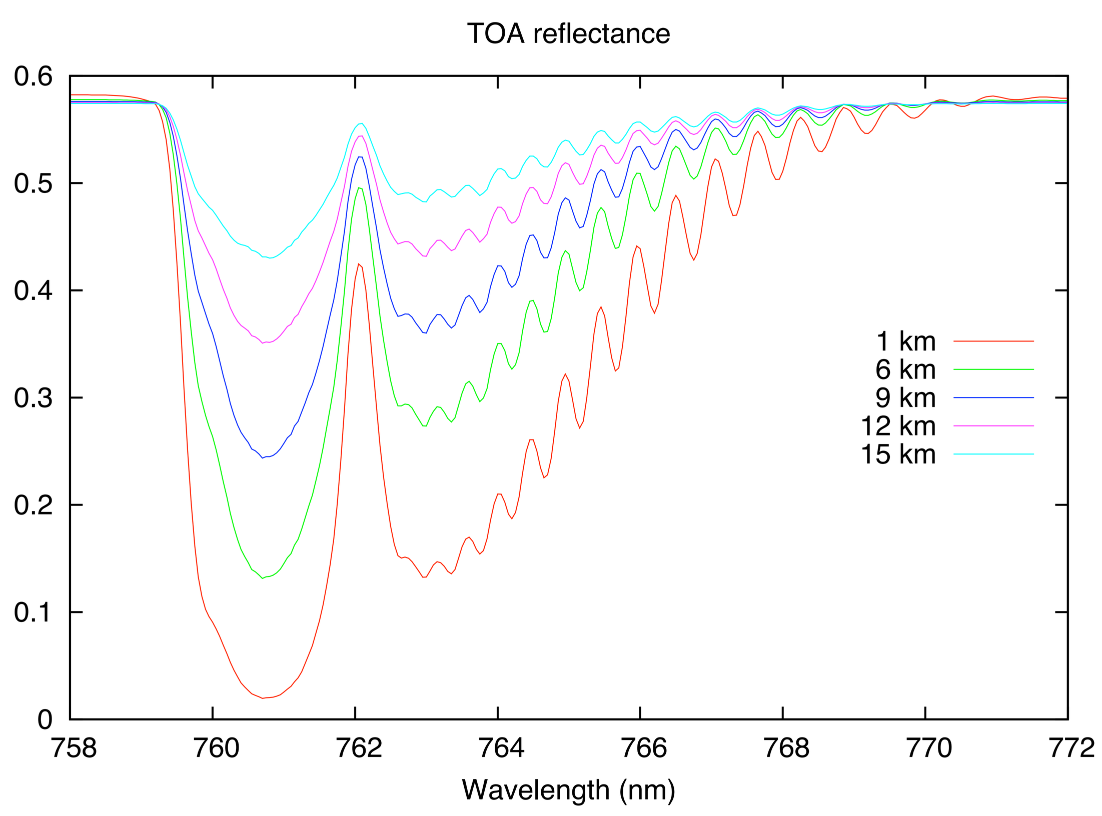


Figure 1 : Synthetic top-of-atmosphere reflectances for different heights of a single layered cloud for optical thickness τ = 20, solar zenith angle θ = 60°, nadir view, effective particle radius a_{eff} = 6 µm, cloud geometrical optical thickness 1 km.

In order to retrieve cloud altitudes, the minimization procedure of SACURA [1], based on the asymptotic radiative transfer theory, is applied to broken cloud fields. Using the indipendent pixel approximation, the measured TOA reflection R_{mes} can be represented as a linear combination of the reflection fraction of the clear part of the pixel R_s and that of the sought cloudy part R_{cl}:

$$R_{mes} = \frac{\pi \ I_{mes}}{cos\ (\theta)\ E_0} \qquad\qquad R_{mes} = c_f R_{cl} + (1 - c_f) R_s.$$

Here E_0 and I_{mes} are the solar irradiance and the terrestrial radiance, as measured by GOME. The R_s part accounts for as a Rayleigh atmosphere as well the ozone absorption, bounded below by a Lambertian surface. The TEMIS database [2] of minimum Lambert-equivalent reflectivities (LERs), as derived from GOME data, has been regridded and matched with processed pixels. As cloud fraction c_f, the value delivered by the neural network algorithm ROCINN from DLR (German Space Agency) has been employed.

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Results

Selected pixels satisfy the following conditions:

- reflectance outside oxygen A-band is larger than 0.2. Therefore the case of thin cirrus clouds is excluded
- cloud optical thickness as retrieved by SACURA is larger than 5
- solar zenith angle is smaller than $75°$
- cloud fraction is larger than 0.2

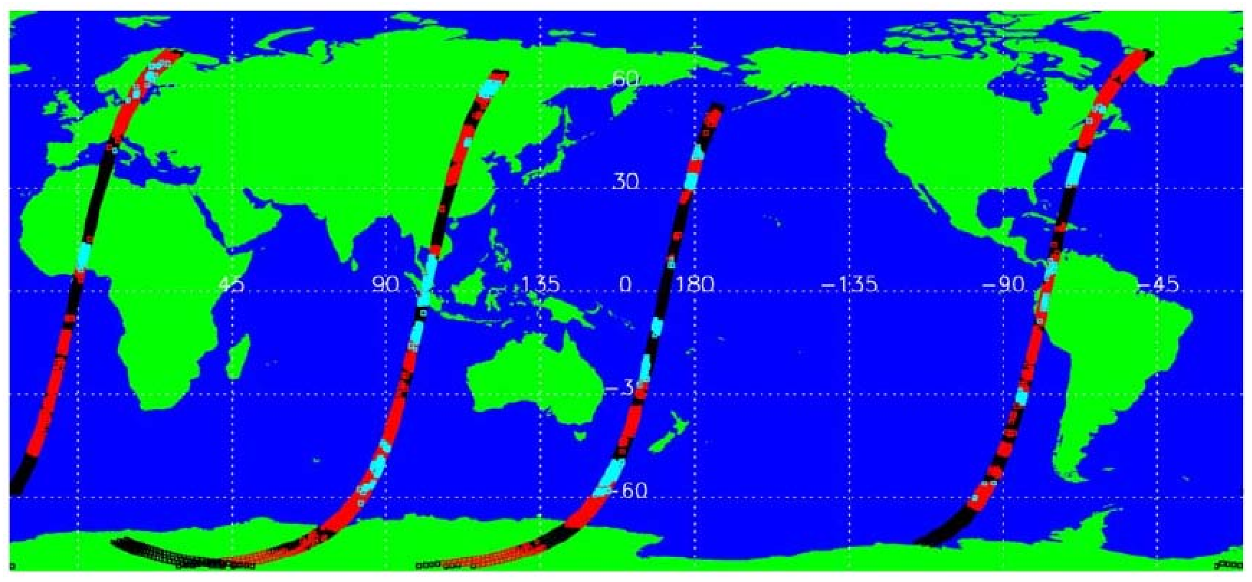

Figure 2: Selected ERS-2 orbits 16910, 18366, 19537, and 15453 (from left to right). Areas with cloud top heights below 7km are marked in red and those with cloud top heights above 7km are marked in blue. Black areas correspond to cloud free scenes.

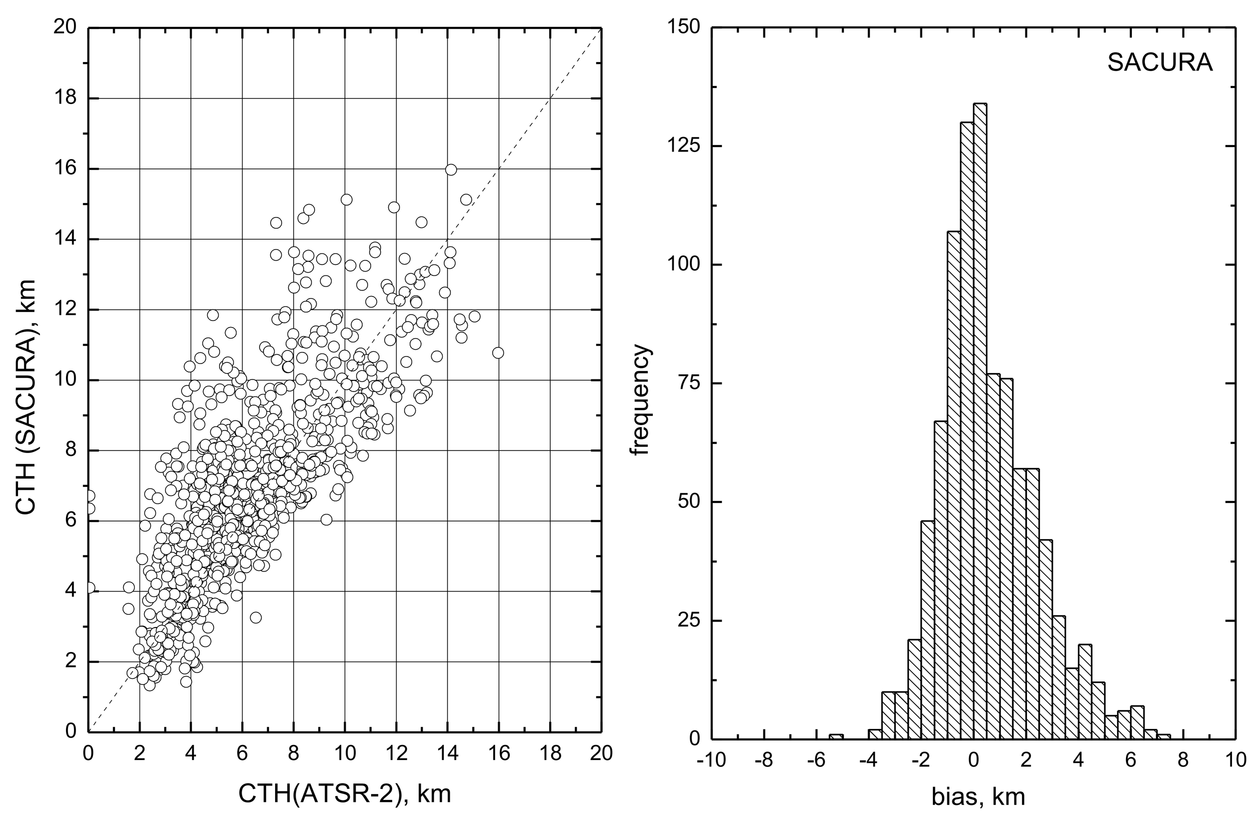

Figure 3: Correlation plot between CTHs obtained with SACURA and thermal IR channel of ATSR-2 (left). Histogram of biases of SACURA GOME-derived CTHs as compared to those derived from ATSR-2 (right).

- Note that the ATSR-2 CTHs (1.1 × 1.1 km^2 resolution) were averaged over the GOME ground scene
- Assuming that the ATSR-2 CTHs are correct then SACURA-derived values, positive biased towards larger values, can be explained as the result of multi-layered cloud systems. SACURA assumes a single layered cloud system

Conclusions

- The average difference between CTH derived from GOME data using SACURA is 0.6 ± 0.6 km as compared to thermal IR ATSR-2 retrievals. The standard deviation is equal to 1.8 km.
- SACURA algorithm can be improved using cloud fractions as derived from ATSR-2 for GOME data and with the emlpoyment of Look-Up-Tables for optical thickness $\tau < 5$.
- Further validations are planned with ground-based radar and (if collocated) with CALIPSO lidar platform as part of the "A-train" NASA satellites' constellation.
- ATSR-2 retrievals of cloud top height, effective radius, and optical depth based on the GRAPE scheme are available from the BADC (www.badc.rl.ac.uk).

Bibliography

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[3] John Burrows et al. (1999). The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, *J. Atmos. Sc., 1999, Vol. 56, 151–175*