Identifying optically thin cloud areas in in shallow cumulus cloud fields

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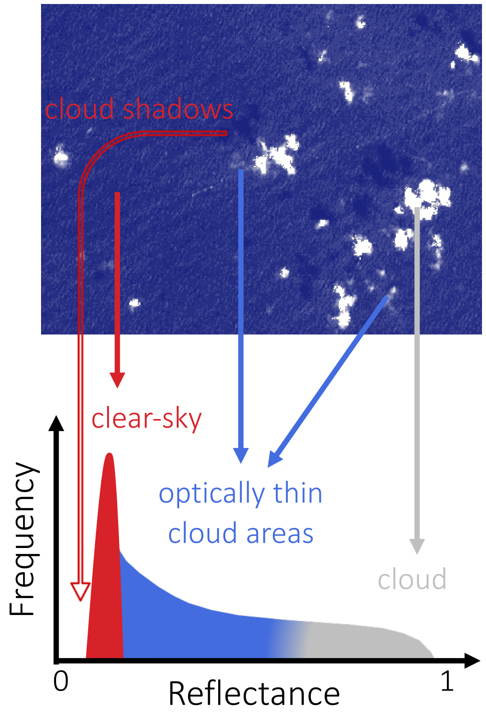
Motivation and Study Design

What? We investigate the contribution of optically thin cloud areas to the total cloud reflectance in high-resolution ASTER images.

Why? Optically thin cloud areas and cloud fragments often fall into the sub-pixel range of typical satellite cloud products. Their contribution to the total cloud reflectance and cloud radiative effect is unknown*.

How? We build a simple clear-sky model to identify clear-sky observations, exclude them and investigate the remaining cloud-related relfectances.



* Koren et al., 2008

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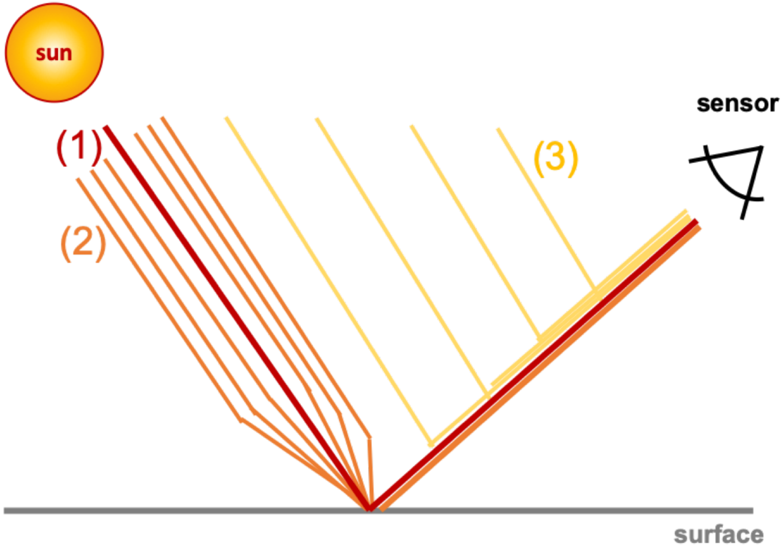
Components of a simple clear-sky model

The direct beam (1) and the hemispheric diffuse radiance (2) reflected at the ocean surface are estimated with the Cox and Munk surface parameterization*.

Additional diffuse radiance (3) is estimated assuming only single-scattering events.



$$R(\mu_o, \mu_v, \Delta\phi, \boldsymbol{ws}, \boldsymbol{\tau}) = \frac{\pi}{\mu_o} \left[\exp\left(\frac{-\tau}{\mu_v}\right) \left[(1)\ \exp\left(\frac{-\tau}{\mu_o}\right) BRDF(\mu_o, \mu_v, \Delta\phi, ws) + (2)\ \int_0^{2\pi} \int_0^1 \mu\, BRDF(\mu, \mu_v, \Delta\phi, ws) \frac{I_{diff}}{E_0}(\tau, \mu, \phi) d\mu\, d\phi\right] + (3)\ \Theta_{HG}\, \omega_o \frac{\mu_o}{\mu_v} \int_0^{\tau} \exp\left(\frac{-\tau'}{\mu_o}\right) \exp\left(\frac{-\tau'}{\mu_v}\right) d\tau'\right]$$

* Cox and Munk, 1954
Lin et al., 2016

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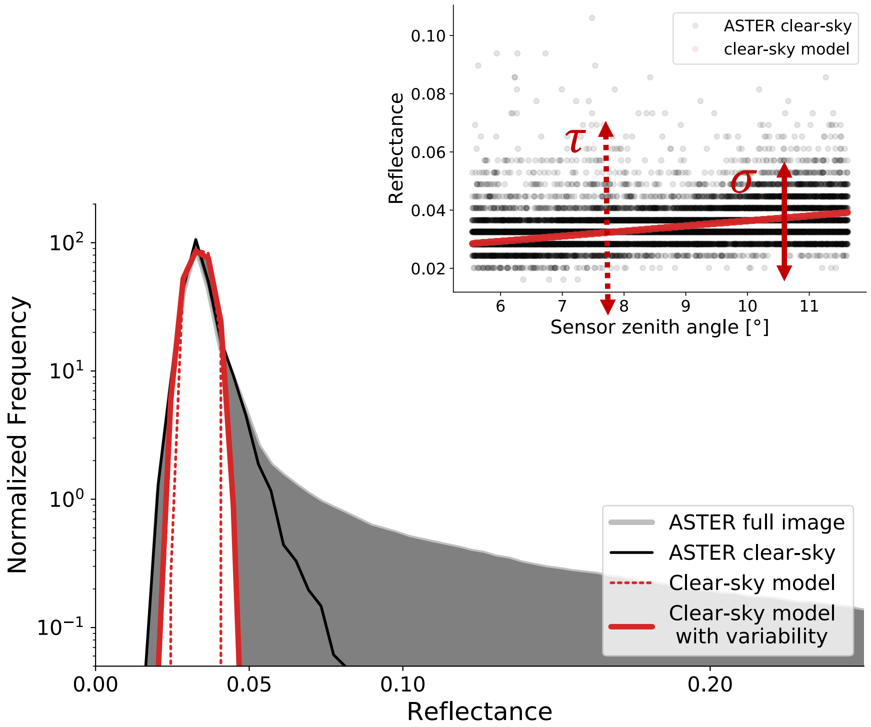
Identifying clear-sky in ASTER imagery

Step 1: estimating the aerosol optical thickness τ. τ is chosen such that the observed and modelled reflectances match best.

Step 2: The clear-sky model provides average reflectances. Therefore, we add a Gaussian variability σ to every clear-sky model reflectance estimate.



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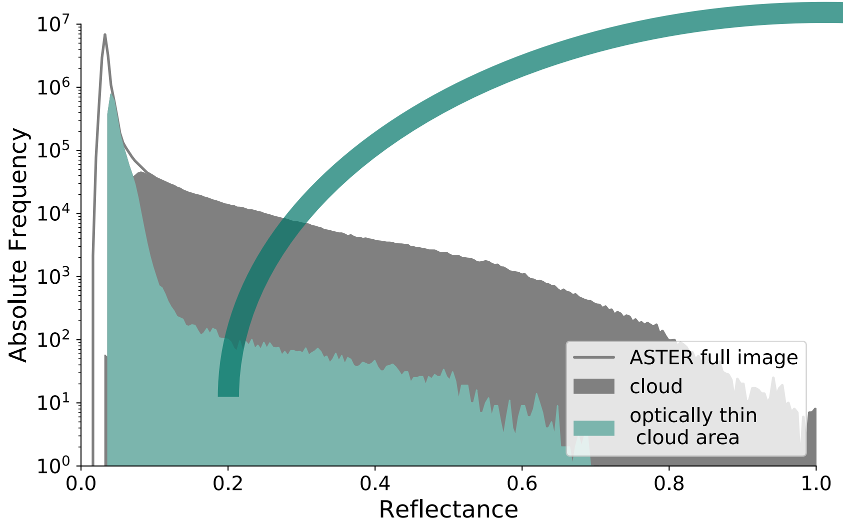
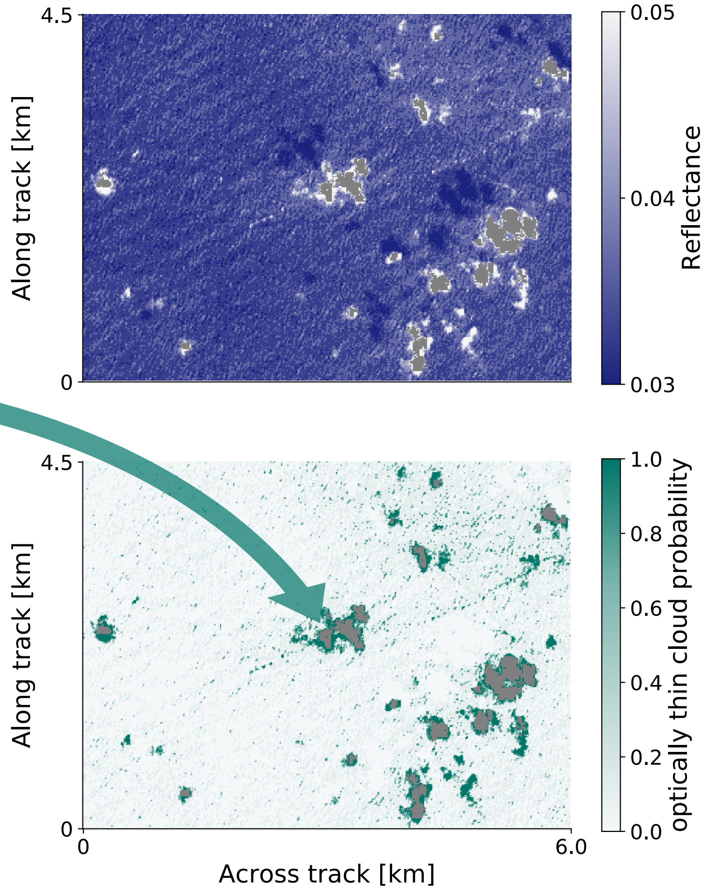
Identifying optically thin cloud areas

Translating reflectance occurence into an „optically thin cloud probability“





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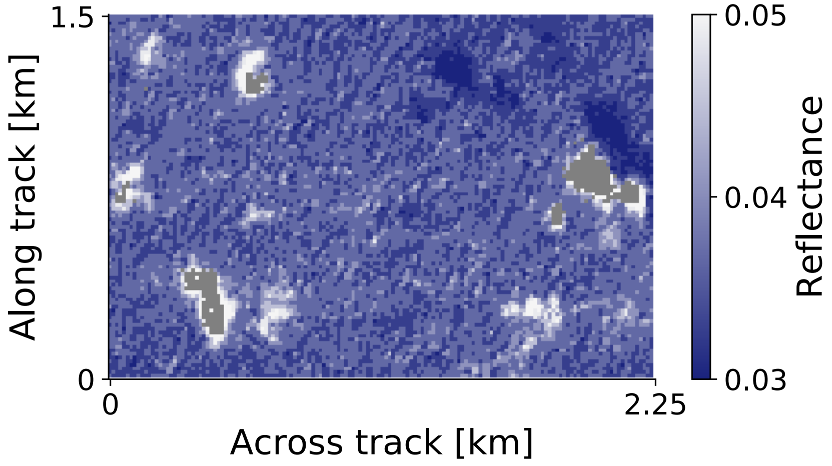
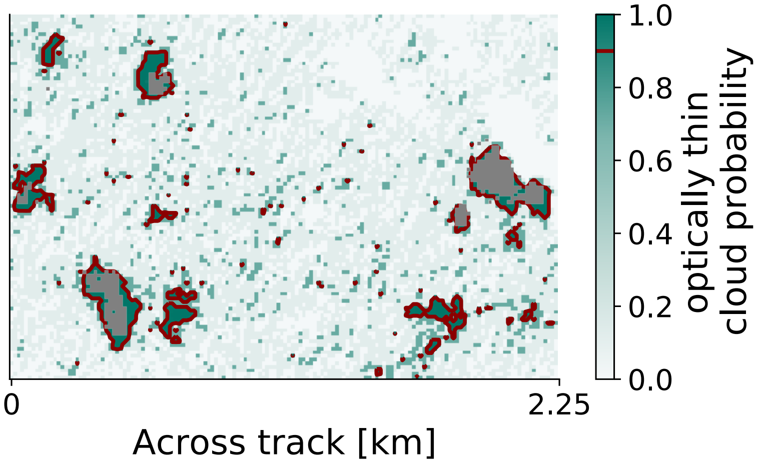
Conclusion and Outlook

We can identify optically thin cloud areas in shallow cumulus cloud fields and continue to investigate their patch sizes versus their reflectance contribution to the total cloud reflectance.





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Supplement:
EUREC4A ASTER dataset

For more information on the ASTER instrument see **NASA webpage**.

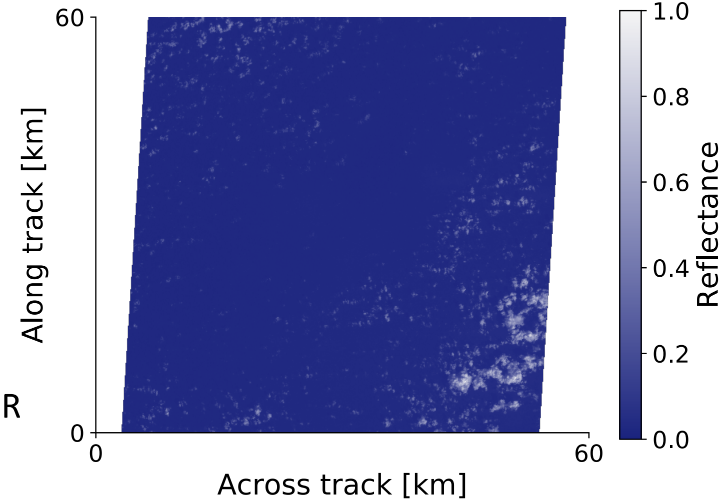

Figure 1
ASTER sample image recorded 2020-02-05 14:25:15 near Barbados. Band 3 (nadir view) at 0.807 micron and 15 m pixel resolution. ASTER has 3 bands in the visual near infrared (15 m) and 5 bands in the thermal infrared range (90 m).

Figure 2
Temporal and spatial coverage during EUREC4A in January / February 2020: ASTER recorded 412 images on 25 days east of Barbados. **Many thanks again to the ASTER science team that planned the data acquisition !!**