IDEAS-QA4EO Service
Cal/Val Workshop #4
1st March 2023, Potsdam

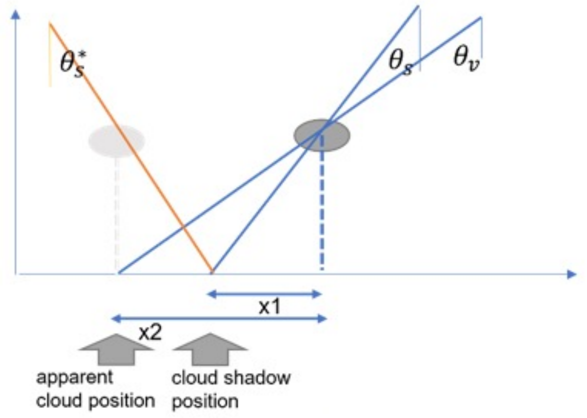
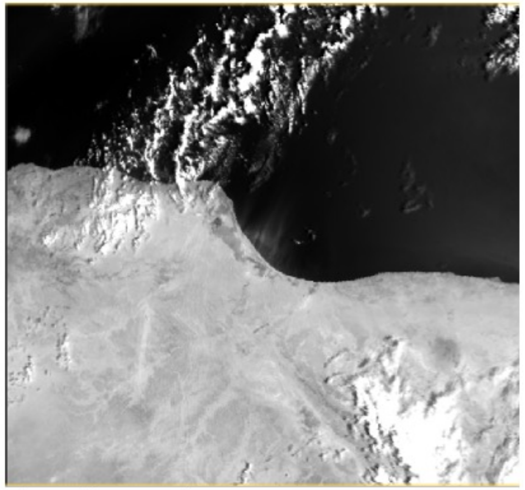
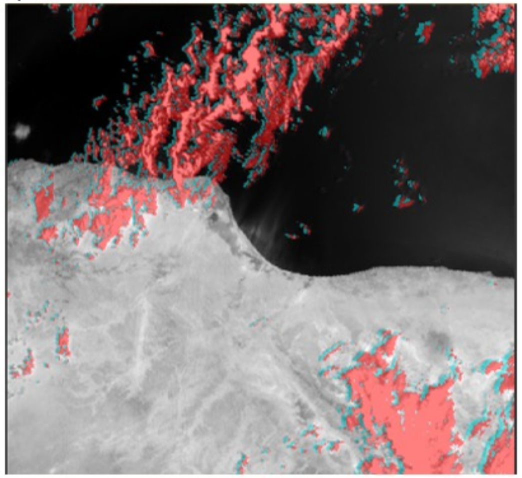


Figure 7 Geometrical correction for apparent sun zenith angle (VAA>180°, SAA>180° or VAA<180°, SAA<180°))

Cloud shadow mask for AATSR

to fulfil CARD4L requirements





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Objective

- The AATSR level 2 product was already largely conform with the CARD4L specification. However, the critical requirement for a cloud shadow mask was not fulfilled. Beside some meta data adaptations this is the remaining requirement which needs to be addressed for CARD4L compliancy.

Approach

- A cloud shadow mask algorithm exists for MERIS and OLCI. This has been implemented in the SNAP IdePix open source tool, and it has been largely tested, e.g. in the framework of the OLCI Mission Performance Centre.
- The algorithm, in brief, uses geometrical calculations to project a cloud to the Earth surface. The cloud properties, in particular the cloud top height, and the precise sun and viewing geometry are carefully taken into account. Surface slopes are not (yet) considered.
- This algorithm is basically transferable to AATSR. However, there are some instrument as well as algorithm specific issues which need to be properly treated, in particular the viewing geometry of AATSR, and the method to retrieve the cloud top height

Methodology

Defining north

- As all calculations of the shadow are translated to the geometry of the pixel grid, it is necessary to calculate the North direction (also called orientation or bearing) for each pixel individually.
- The orientation for a pixel (i,j) is derived from the neighbouring pixel (i, j-1) and (i, j+1) from pixel-geocoded location:

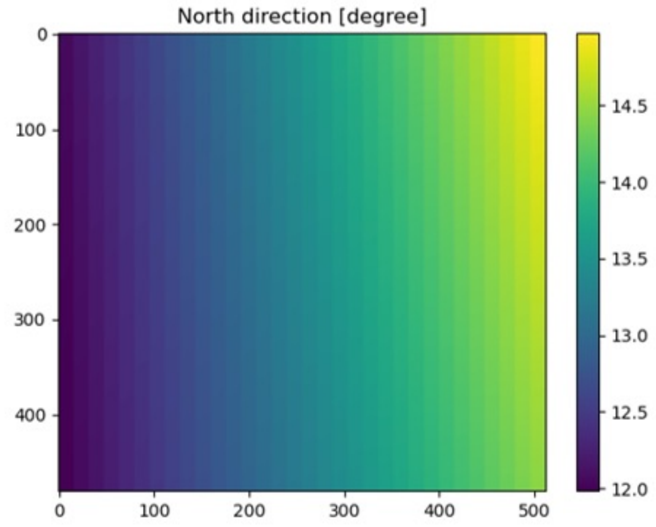


Figure 4 North direction in degree for the example scene at the Mediterranean Sea.

$$orientation(i,j) = \arctan(-(lat_{i,j+1} - lat_{i,j-1}),\ (lon_{i,j+1} - lon_{i,j-1}) * \cos lat_{i,j-1})$$

Methodology

Defining a cloud

The following cloud flags have been combined in a cloud mask:

- cloud_in.visible (bit value 0),
- cloud_in.gross_cloud (bit value 7),
- cloud_in.thin_cirrus (bit value 8), and the
- cloud_in.medium_high (bit value 9).

Defining the cloud height

By default it is fixed at 6km, but CTH can be provided in the processor.

- *How this was handled during processing of AATSR is not known to us (Brockmann Consult)*

Methodology

Adjustment of sun zenith angle for elevated objects (parallax correction)

- Under tilted view (view zenith angle > 0°) elevated objects of unknown height like clouds are projected along the line of view on the surface, so that their apparent location differs from the actual position over ground (nadir view).

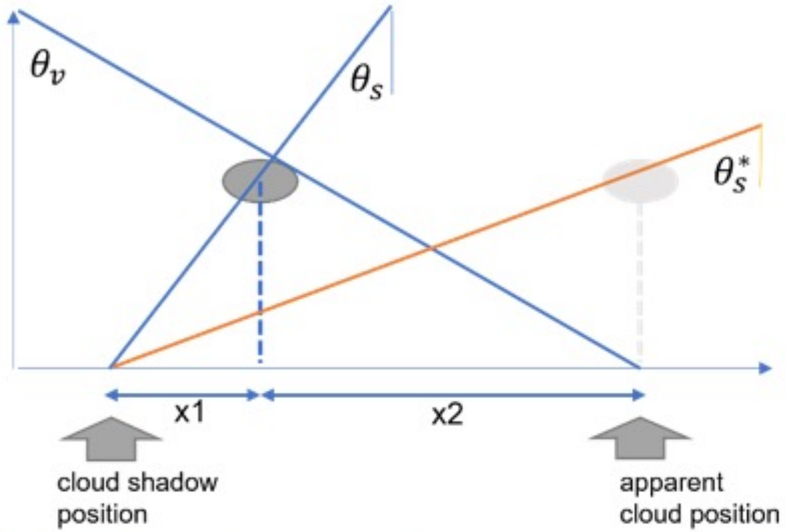


Figure 6 Geometrical correction for apparent sun zenith angle (VAA>180°, SAA<180° or VAA<180°, SAA>180°).

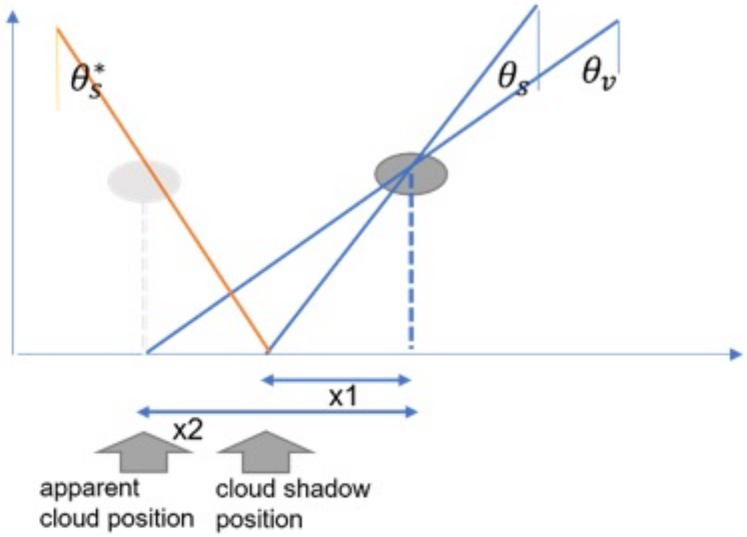


Figure 7 Geometrical correction for apparent sun zenith angle (VAA>180°, SAA>180° or VAA<180°, SAA<180°))

Methodology

Determining the search path in illumination direction

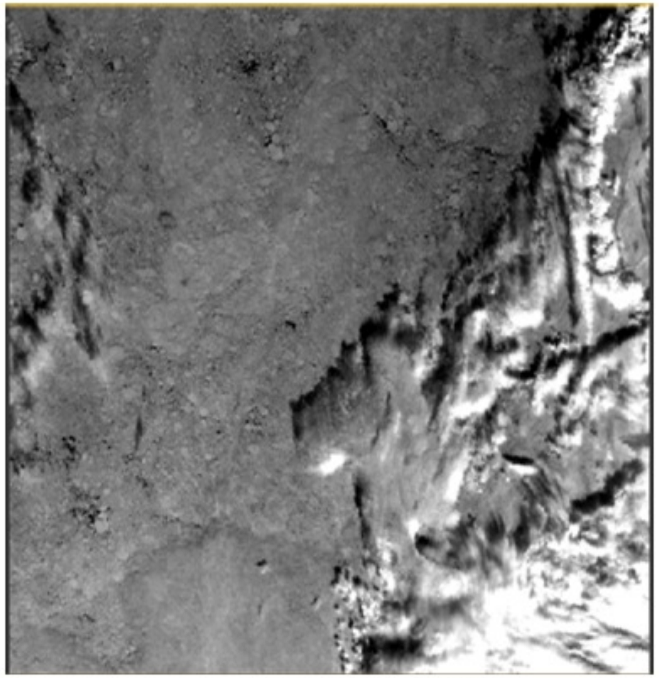
- Starting from a cloud pixel, which is defined by the cloud flag expression, the illumination path is projected on the grid and all pixels up to a maximum distance are identified which are intersected by this path.
- With the adjusted sun zenith angle θ_S^* and the azimuth angles adjusted for North direction, so that they represent the azimuth on the grid against the Y-direction, the geometry of the illumination path on the projection grid can be fully described.

Examples

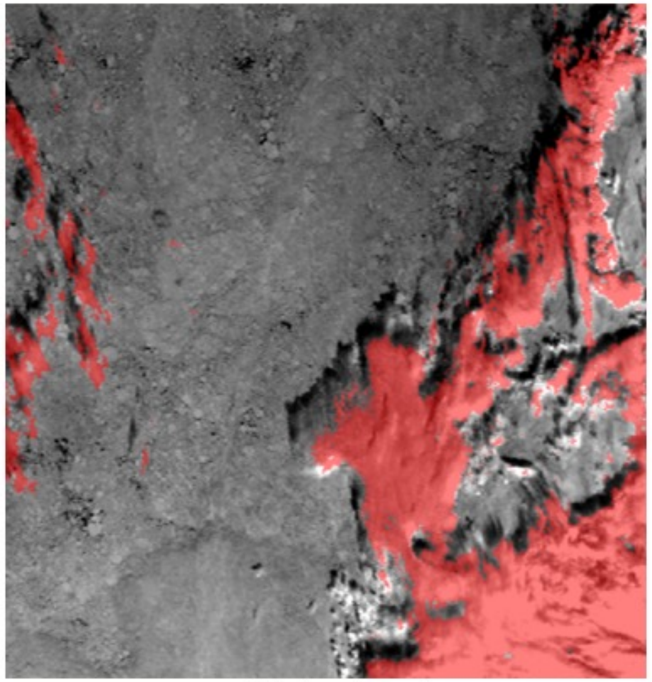
Far North (81°N, 122°E) – 20020810T083508

The solar zenith angle is about 71° at this subset of the orbit (approx. 81°N, 122°E).

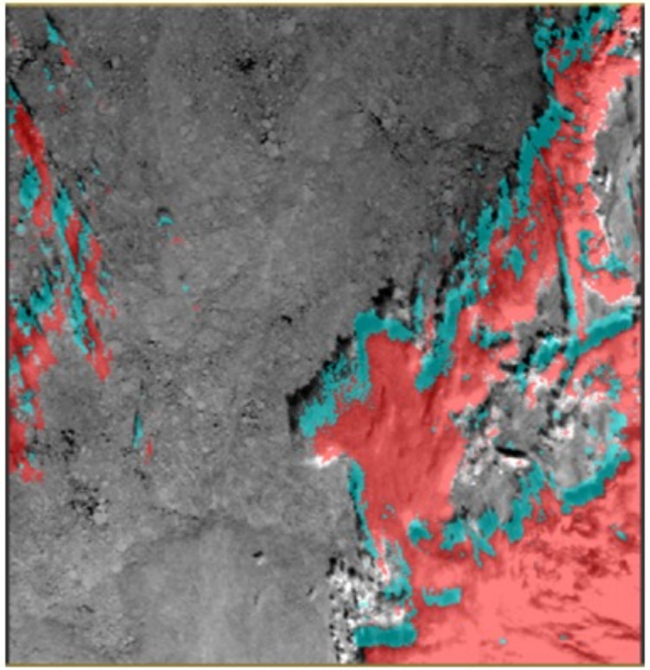
The cloud top height seems to be lower than 6km in some cases, where the cloud shadow flag overextends the actual shadow. Some semitransparent clouds and smaller clouds are not identified correctly, so that the cloud shadow flag in turn does not cover all aeras, visual inspection declares as shadow. Still, direction of shadows is correct.



(a) S2 radiance nadir



(b) cloud mask



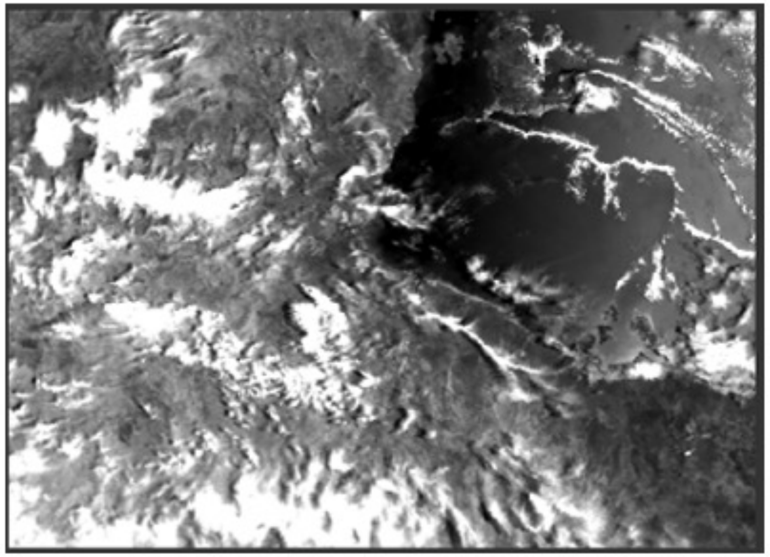
(c) cloud mask and cloud shadow mask

Examples

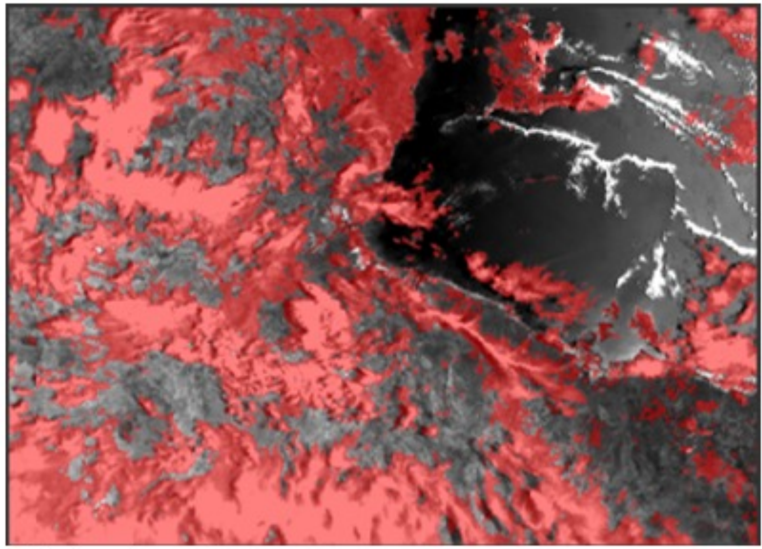
Southern Hemisphere (15°S, 135°E) – 20021129T235200

The cloud mask is raised at some rather dark land areas as cloud, where there is no shadow casting cloud visible.

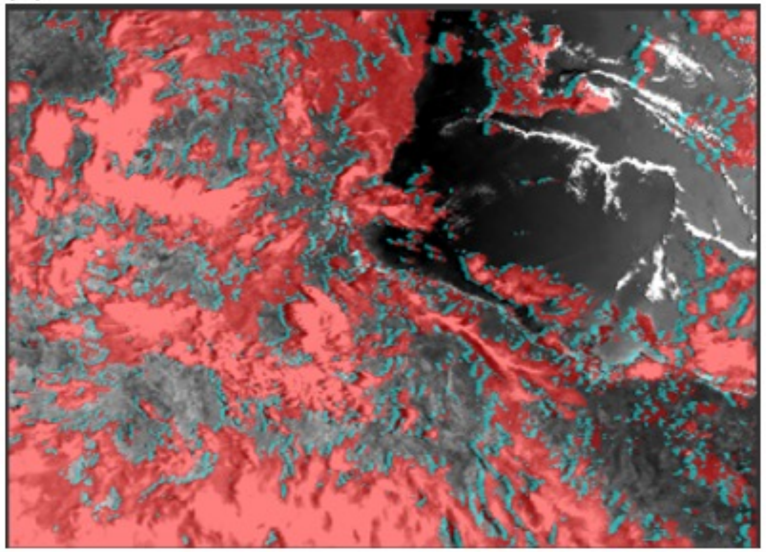
The solar zenith angle is approx. 30°, the direction and extend of cloud shadows seem correct, albeit errors from CTH substantially higher or lower than 6km.



(a) S2 radiance nadir



(b) cloud mask



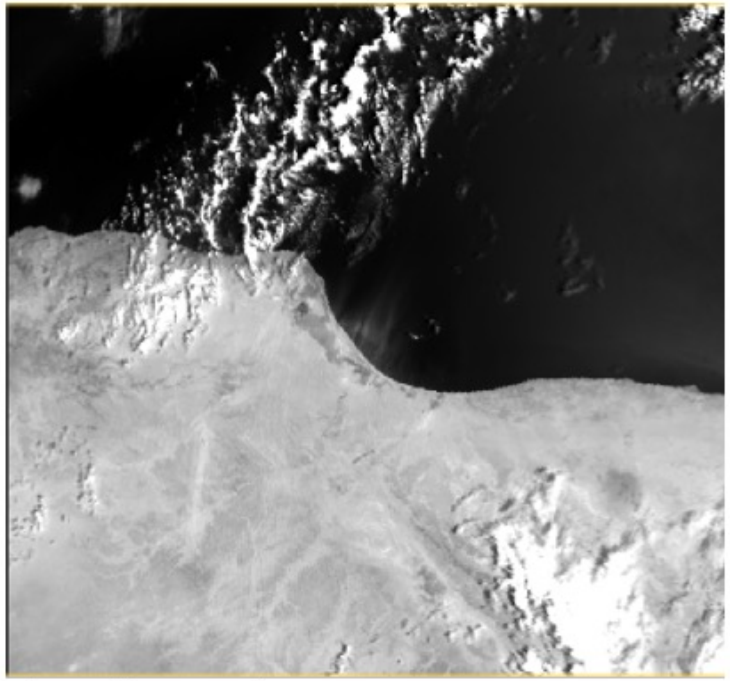
(c) cloud mask and cloud shadow mask

Examples

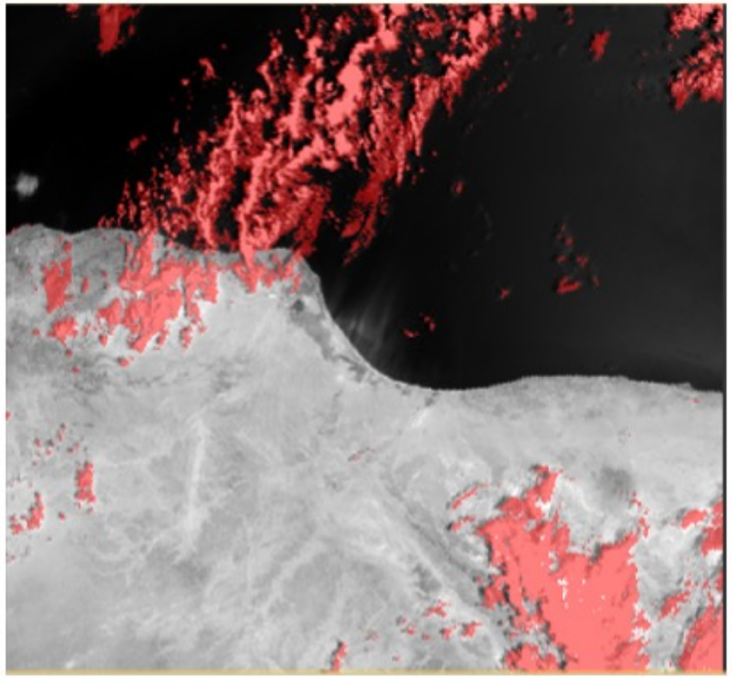
Mediterranean Sea (31°N, 15°E) – 20020810T083508

The solar zenith angle is approx. 28.5°.

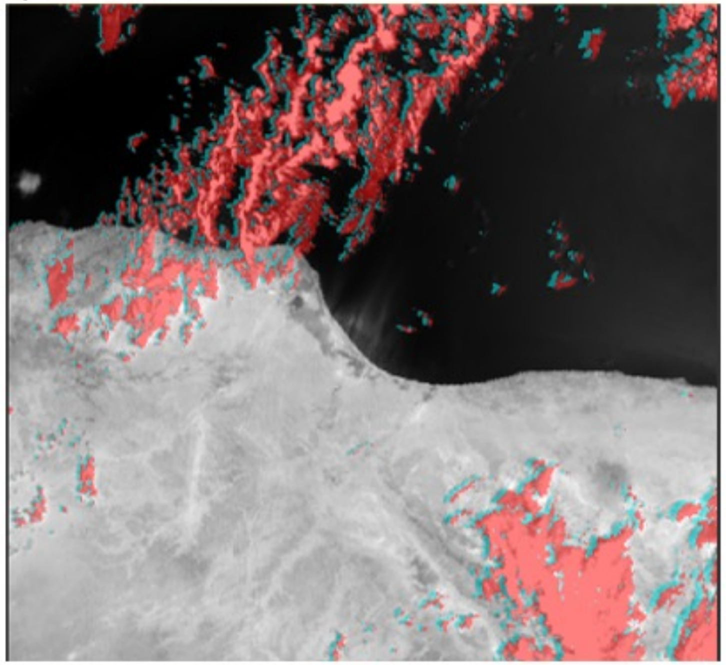
The fixed cloud top height of 6km works fine in this case. Cloud shadows are very well covered by the dedicated mask.



a) S2 radiance nadir



b) cloud mask



c) cloud mask and cloud shadow mask

Open questions

Retrieving cloud top height

- The conversion of brightness temperature into cloud top height is a complex task.
- The Level 1 product (4^{th} reprocessing) holds temperature/pressure profiles from reanalysed data, which could be used to convert CTT into CTP albeit the conversion can yield ambiguous results if inversion zones are part of the profile. The CTP can be converted into CTH, e.g. by the formula used in MERIS cloud shadow algorithm:

$$CTH[m] = -8000 * \log(CTP/1013.0)$$

- The retrieval of cloud top height is not solved yet.
- Currently, the CTH is fixed at 6km. Because the spatial resolution of the grid is coarse (1km), it will not be necessary to derive the CTH with great precision. A CTH within 1km precision is sufficient, if the SZA is below 45°. For larger SZA (lower sun elevation) the projected shadow lengths become larger and the errors in derivation of CTH more obvious.

Limitations

Cloud mask accuracy

- A cloud shadow flag is limited by the accuracy of the cloud mask
  - Cloud shadow algorithm is solely geometrical
  - Under- or over-detection of clouds lead to false cloud shadows

THANK YOU FOR THE ATTENTION