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FAKULTÄT
FÜR MATHEMATIK, INFORMATIK
UND NATURWISSENSCHAFTEN

Shortwave simulations with ARTS

Examples and explanations

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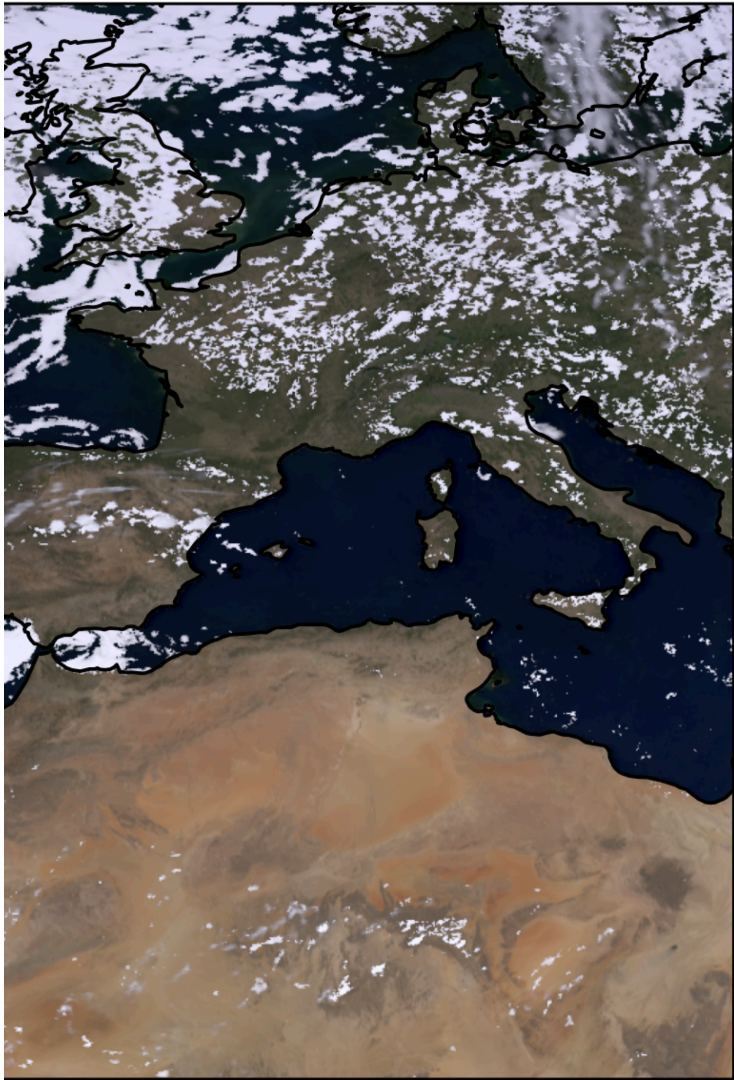


Shortwave simulations

- Some things are different in the SW range than we are used to.
- Planck emission is less important.
- Molecule scattering is important.
- Even for 1D radiative transfer there is zenith and azimuth dependency.

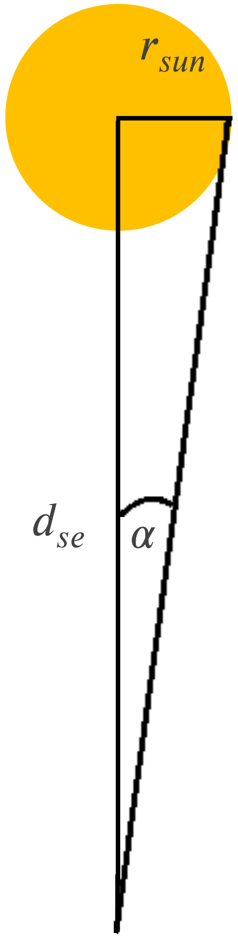
  ⇒ There is no azimuthal symmetry anymore!

Purpose of this talk

- Explain the main steps to simulate SW radiation
- Focus: Difference or additional steps compared to thermal radiation

Collimated Beam Source (recap)

- Assumptions:
  - $r_{sun} \ll d_{se}$, solar radiation is parallel
  - Radiation at surface of the sun is isotropic
- $I_{TOA}(\Omega) = F_{Sun,TOA}\delta(\Omega - \Omega')$
- $$F_{sun,TOA} = F_{sun}\sin^2\alpha = F_{sun}\frac{r_{Sun}^2}{d_{\mathrm{se}}^2 + r_{sun}^2}$$
- F_{sun}: Spectral irradiance at the position of the sun



Set up the source

The sun in ARTS is defined by

- Irradiance spectrum at the position of the sun
- Radius and distance to the planet
- Geographic location where the sun is at zenith

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Example:
Date: March 22
POI: 0°N, 0°E
UTC-time: 9h00
⇒zenith latitude = 0°N
⇒zenith longitude = 45°N

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WSM to define the sun(s):

- **sunsAddSingleBlackbody**
- **sunsAddSingleFromGrid**
- **sunsAddSingleFromGridAtLocation**

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We provide 6 solar spectra from NOAA for different conditions at 1nm resolution in `arts-xml-data/star/Sun`

Set up absorption

- Mostly similar than for longwave
- Use cutoffs (750GHz) and continua
- Ozone:
    - $\lambda >$ 1.4µm: line-by-line
    - $\lambda <$ 1.4µm: absorption cross-section

- Most important absorbers in UV/vis and NIR:
    - O_3, O_2 , H_2O

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Set up molecular scattering

- Defined within **gas_scattering_agenda**
- Possible workspace mathods:
  - **gas_scattering_coefAirSimple**
  - **gas_scattering_coefXsecConst**
  - **gas_scattering_matIsotropic**
  - **gas_scattering_matRayleigh**

- Set the WSV **gas_scattering_do** to 1

Two ways to conduct SW simulations:

1. **iyClearsky**

   ARTS' internal clear sky solver

   - 3D fully polarized clear sky solver with multiple suns
   - 1^{st} order molecular scattering and surface scattering

2. **CDISORT** (Buras et. al, JQSRT, 2011)

   3rd party solver. C version of DISORT 2.1 (Stamnes et al., Report, 2011)

   - 1D non polarized all sky solver for plane parallel atmospheres with one sun
   - Multi scattering

SW clearsky simulation with iyClearsky

- Use **iyClearsky** in **iy_main_agenda**
- Atmosphere must be 3D!
- Setup molecule scattering via **gas_scattering_agenda**
- Define sun(s)
- Define surface via **iy_surface_agenda**, do not use **surface_rtprop_agenda**.
  This will not work!

Surface methods

Lambertian surface

- iySurfaceLambertian()
- iySurfaceLambertianDirect()

Specular surface

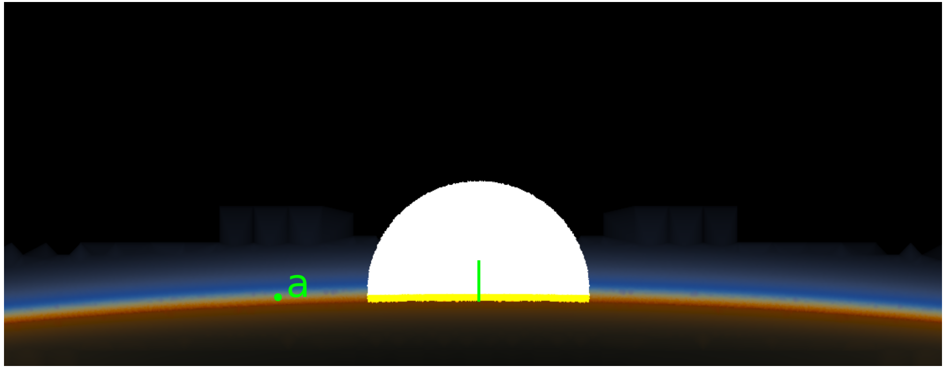
- iySurfaceFlatReflectivity()
- iySurfaceFlatReflectivityDirect()
- iySurfaceFlatRefractiveIndex()
- iySurfaceFlatRefractiveIndexDirect()

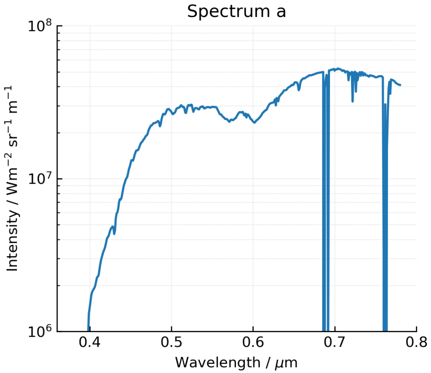
iyClearsky: Example

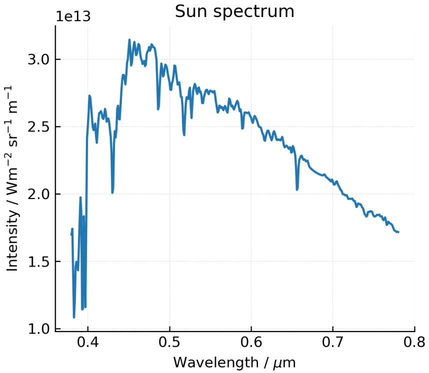
- Sensor position: 25000km, 0°N,0°E
- Looking direction: 168°, 90°
- Sun position: 1.49x10⁸km, 0°N, 168.25°E
- Surface: Specular (Fresnel)
- $\Delta\lambda = 1$ nm

- Virtual camera: 2.5° x 0.94°
- Postprocessing:
  - Transform spectral image to RGB using CIE color matching kernels
    typhon 0.10 : **match_color()**

A sunrise from space







SW all sky simulation with DISORT

- Radiance mode: **cloudbox_fieldDisort()**
- Scattering data is more complex than for MW.
    - Important when doing high spectral simulation, high ram usage.
    - Apart from that everything is the same as before.
    - Scattering database of Yang et al.[2013] and Bi and Yang [2017] in ARTS format is freely available from Zenodo (https://doi.org/10.5281/zenodo.10807525).
    - Only Lambertian surface
- Sun geometry 3D → DISORT needs to be run for specific location.
- Atmosphere must be 1D

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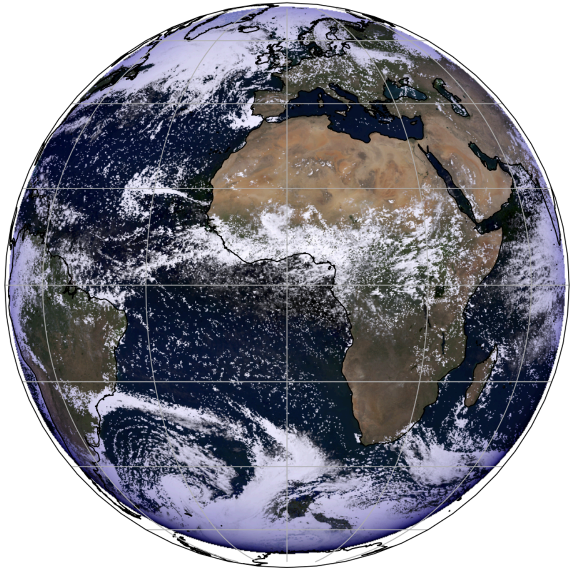
Problem:

If using yCalc-formalism and 1D atmospheres, ARTS expect no azimuth dependency, but cloudbox_field (DISORT output) has an azimuth dependency.

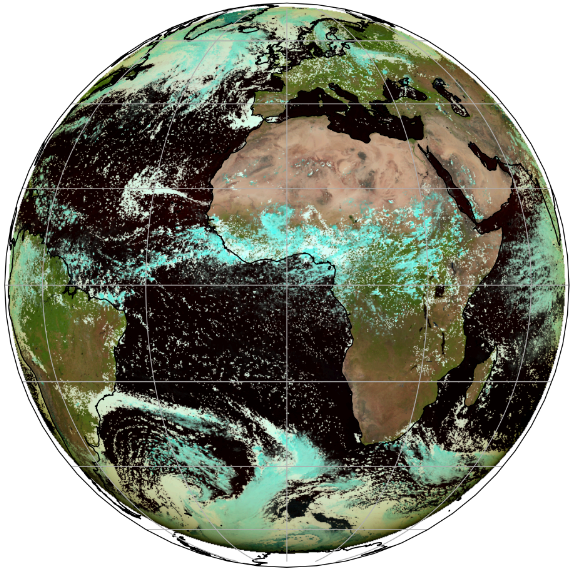
Solution

- Remove azimuth dependency:
  - Calculate for the location of the atmospheric profile the local azimuth angle towards the sensor.
  - Interpolate/select specific azimuth angle from the cloudbox_field using **cloudbox_fieldInterp2Azimuth**
- Expand **cloudbox_field** to actual 3D (not tested)
- Important: This problem will be gone in ARTS 3!

DISORT: Example



MODIS



SEVIRI

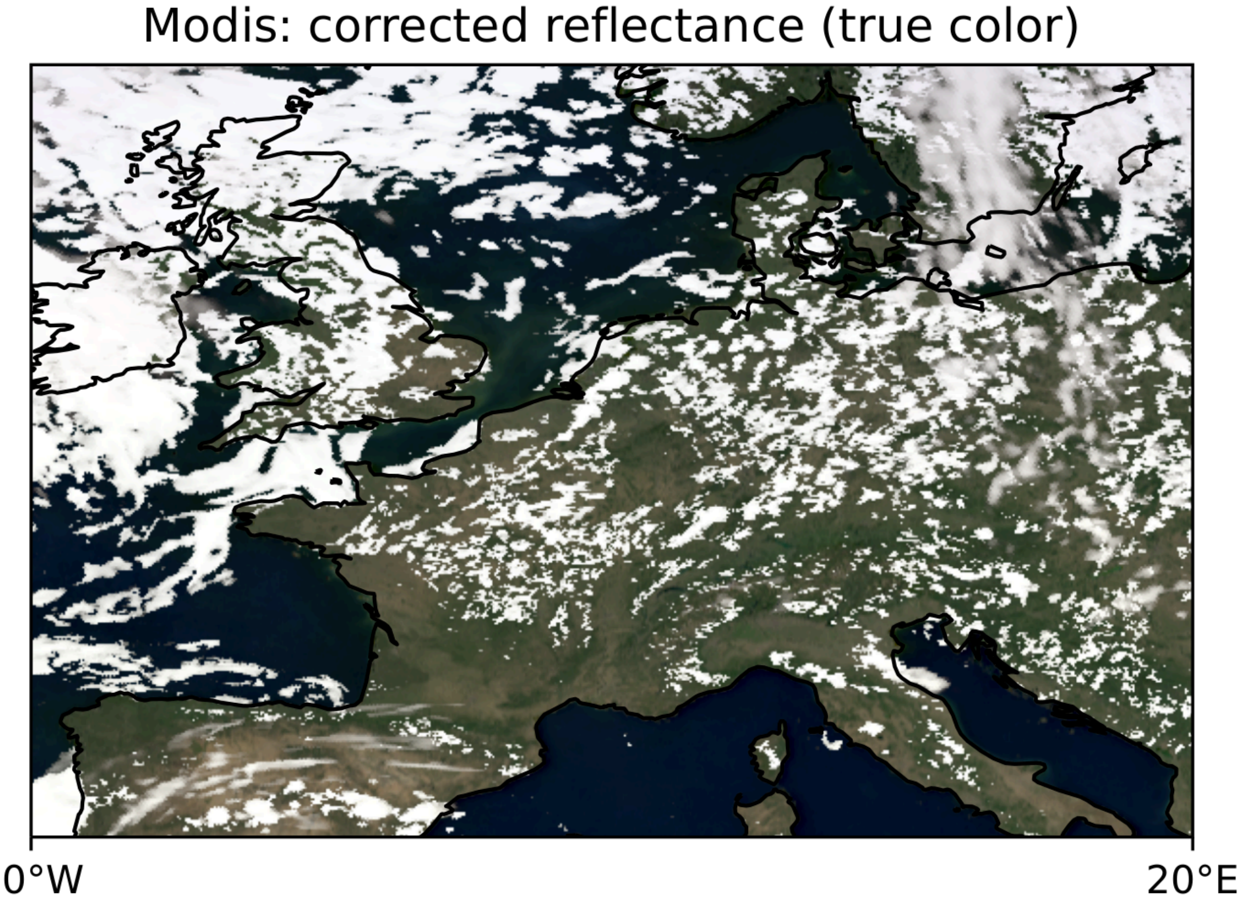
- Simulation of geostationary satellite
- Corrected reflectances

$$R = \frac{\pi I_{TOA}}{F_{sun,TOA}\cos\theta}$$

mapped to RGB

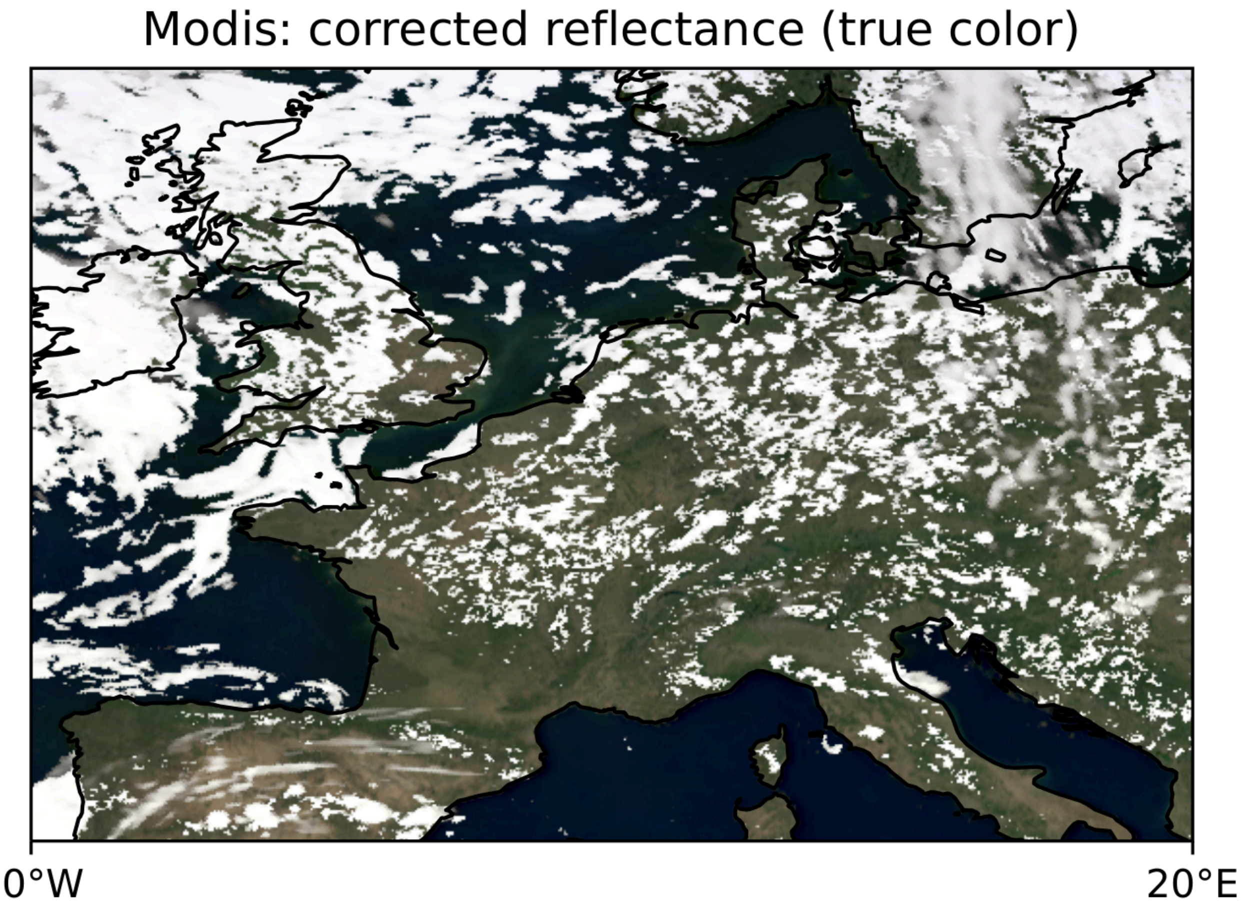
- Snapshot of ICON run by L. Kluft @ 5km (3600X3600 pixels)
- Sun position: 1.49×10^{8}km, 18°N, 0°E
- Sensor position: $\approx$ 36000km, 0°N,0°E

Let‘s take a closer look...



Let‘s take a closer look...

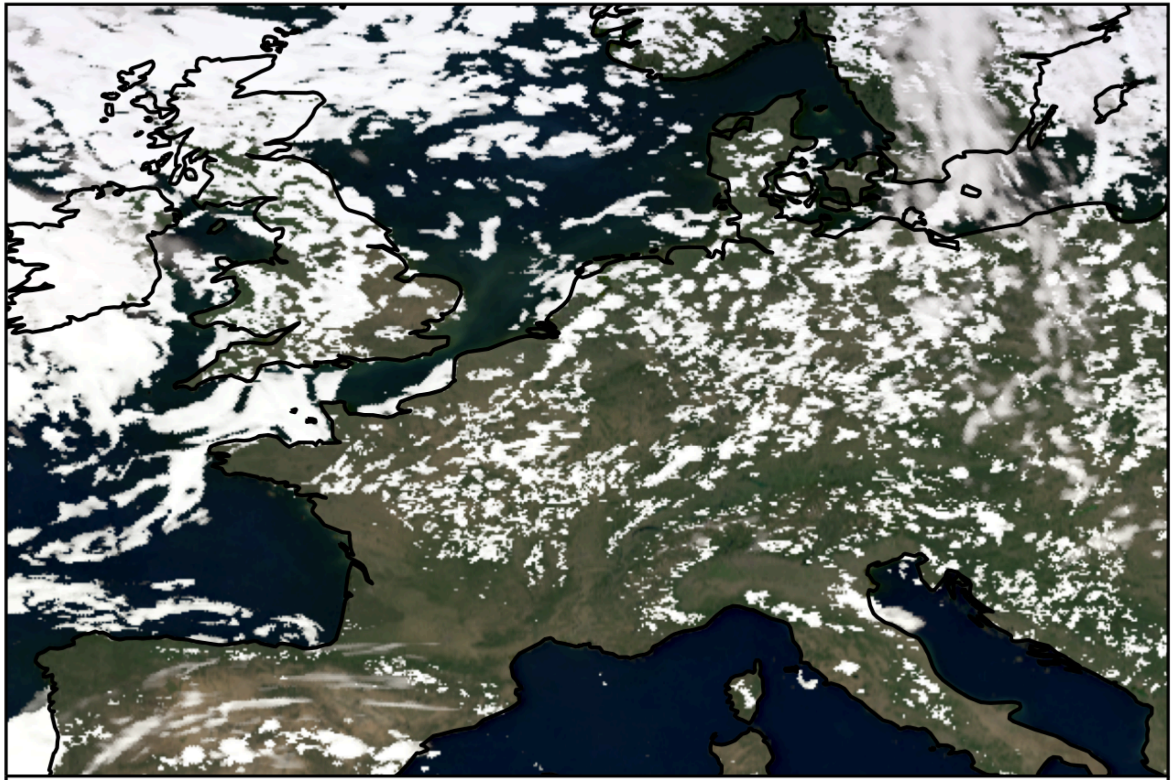
- As radiative transfer is 1D:



Let‘s take a closer look...

- As radiative transfer is 1D:
- No shadows present

Modis: corrected reflectance (true color)



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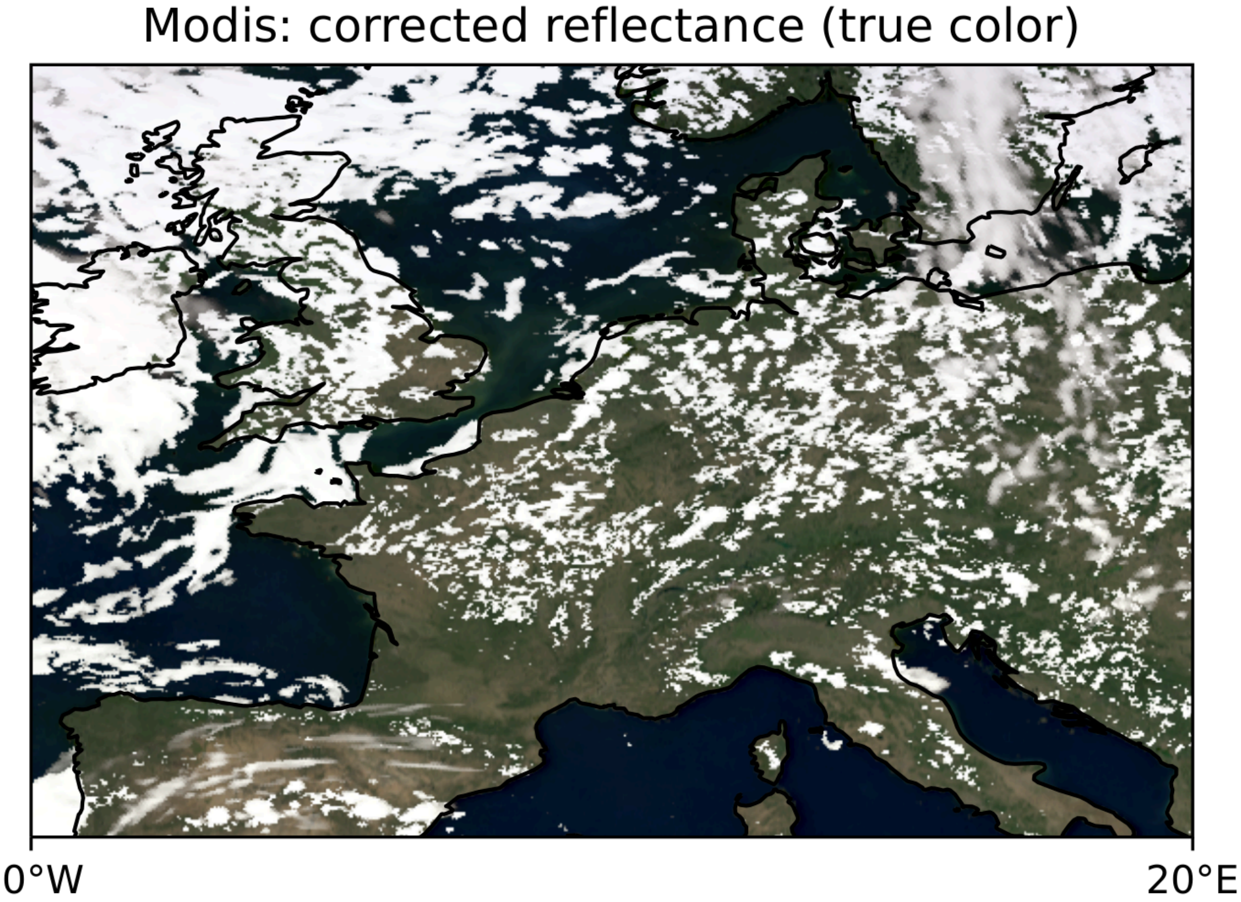
- No shadows present
- Small scales clouds tend to be rougher than in 3D



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- As radiative transfer is 1D:
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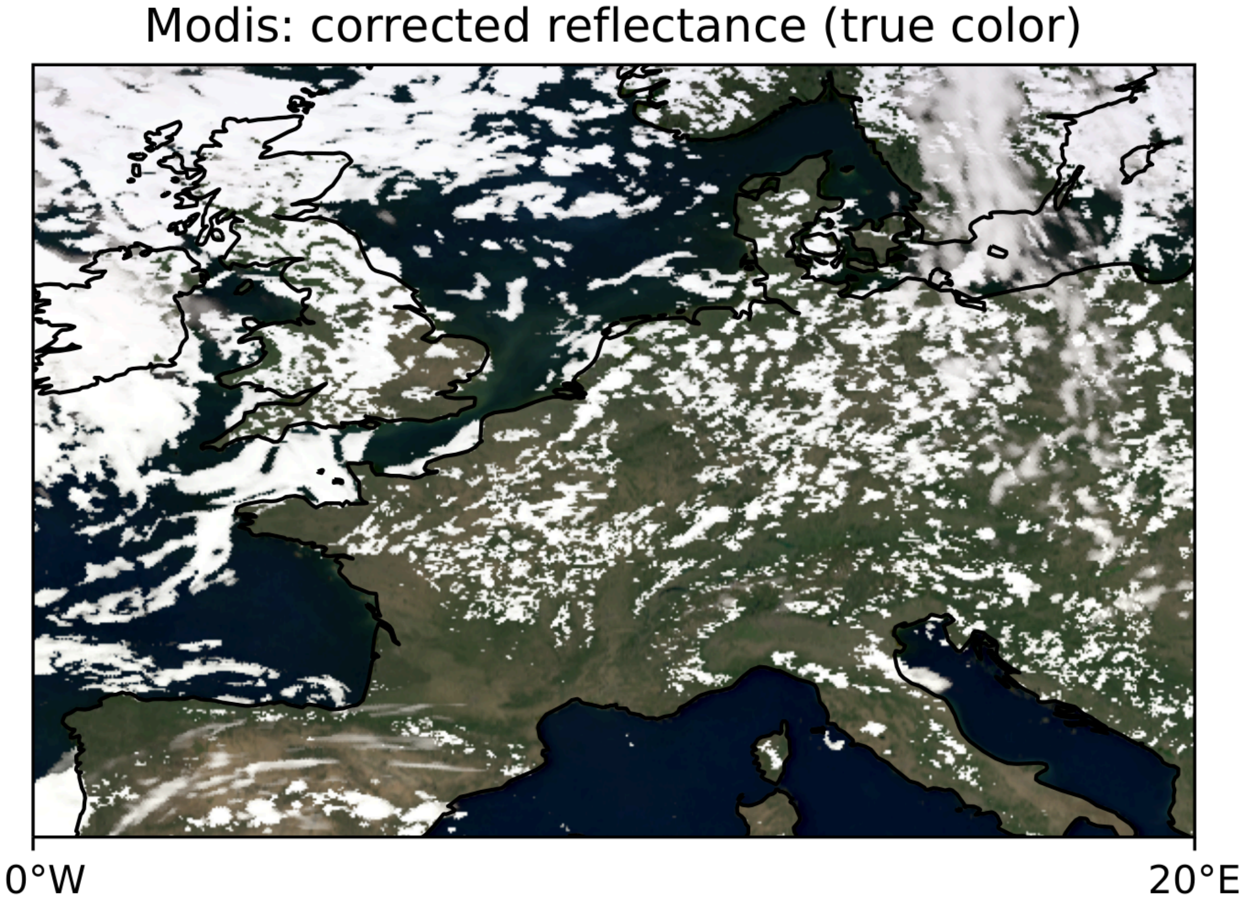
- Small scales clouds tend to be rougher than in 3D
- In general: 3D effects are not included



Summary

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- There is no azimuthal symmetry in SW simulations.
- Molecular scattering is important.
- iyClearsky:
    - 3D clear sky simulations with specular or Lambertian surface
- DISORT:
    - 1D all sky simulations with Lambertian surface
- **ARTS can be used for a wide range of new applications!**