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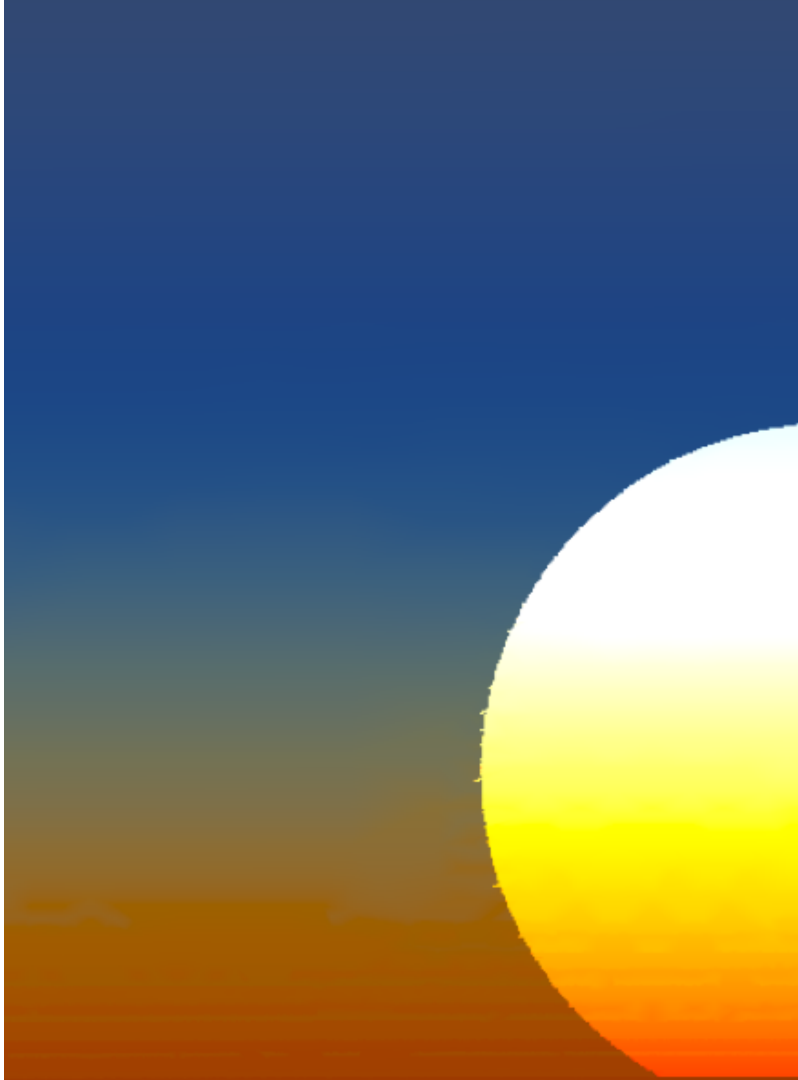
FAKULTÄT
FÜR MATHEMATIK, INFORMATIK
UND NATURWISSENSCHAFTEN

Extending ARTS to shortwave radiation

Manfred Brath

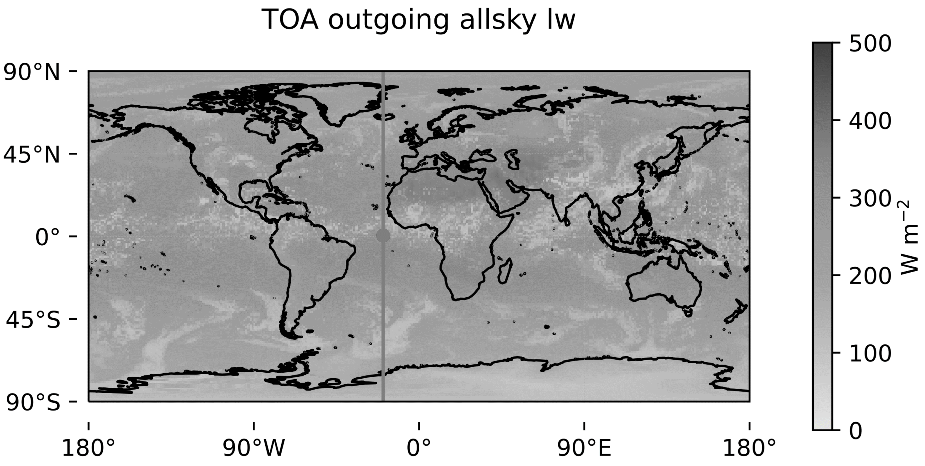
Meteorological Institute

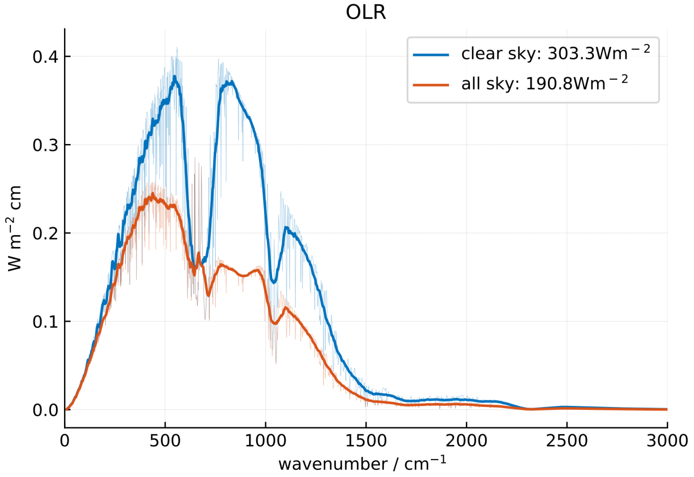


What's new?

Good old ARTS: "dark and grey"

Confined to thermal radiation





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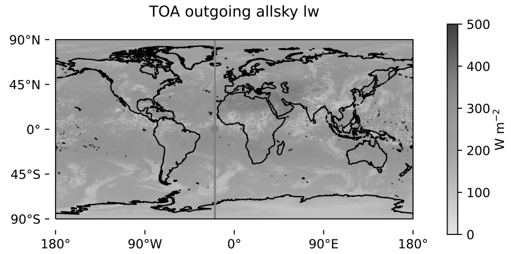
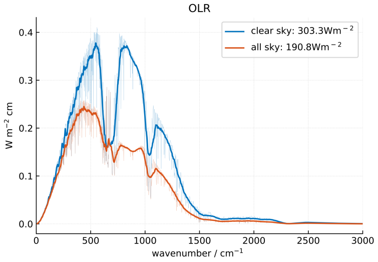
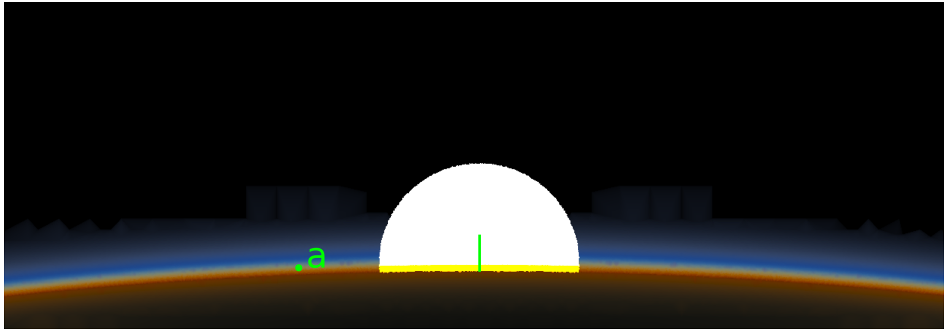
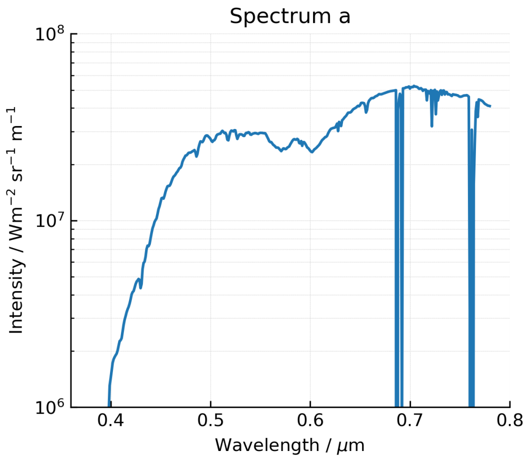




Now: “bright and colorful”
The sun is rising in ARTS.





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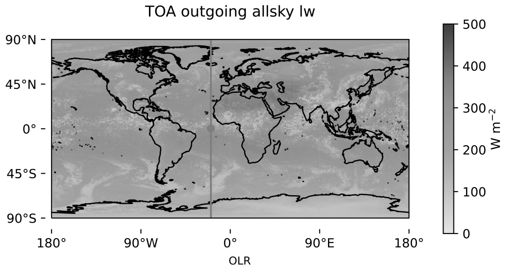

Paper about the new SW features in preparation

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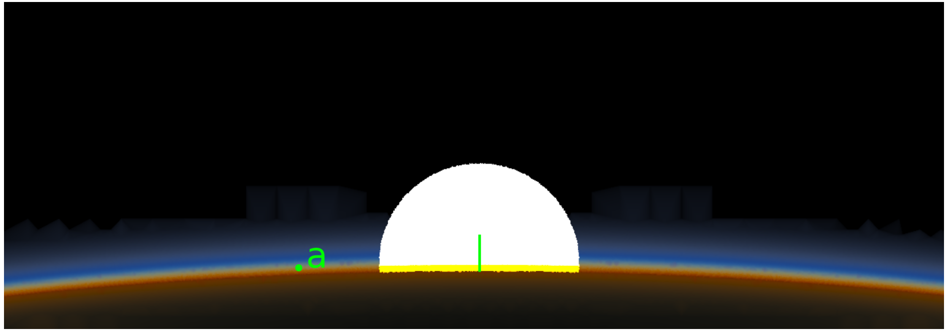

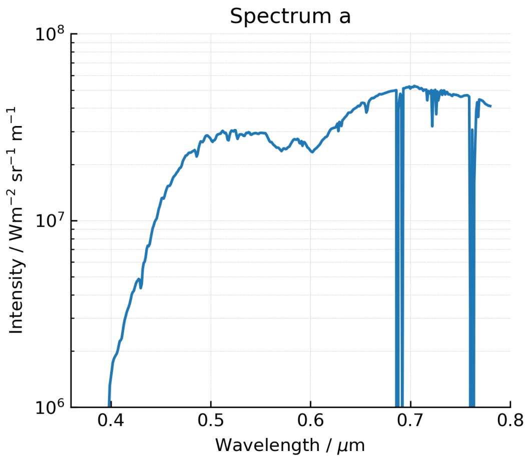

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What was missing?

- The absorption part of ARTS were used for SW (Gasteiger et al., 2014, JQSRT; Emde et al., GMD, 2016)
- ARTS could not simulate highly directed sources like the sun.

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The Solution

- Add collimated beam source (CBS) to simulate the incoming solar radiation

Collimated Beam Source

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

Additional Needs: Molecular scattering

- Rayleigh scattering cross section parametrization from M. Callan (Stamnes et. al, Book, 2017)
- $$\sigma(\lambda) = \lambda^{-4} \sum_{i=0}^{3} a_i \lambda^{-2i} \times 10^{-28} \left[cm^2\right]$$
- Accurate to 0.3% between 0.205 µm and 1.05 µm
- Phase matrix including depolarization (Hansen and Travis, *Space Science Reviews*, 1974)

Additional Needs: Surface Updates

Two surface types can be used for SW simulation:

- Lambertian
- Specular
  - With fixed reflectivity
  - Fresnel reflectivity

SW simulations

Simulate SW Radiation

Two ways to conduct SW simulations:

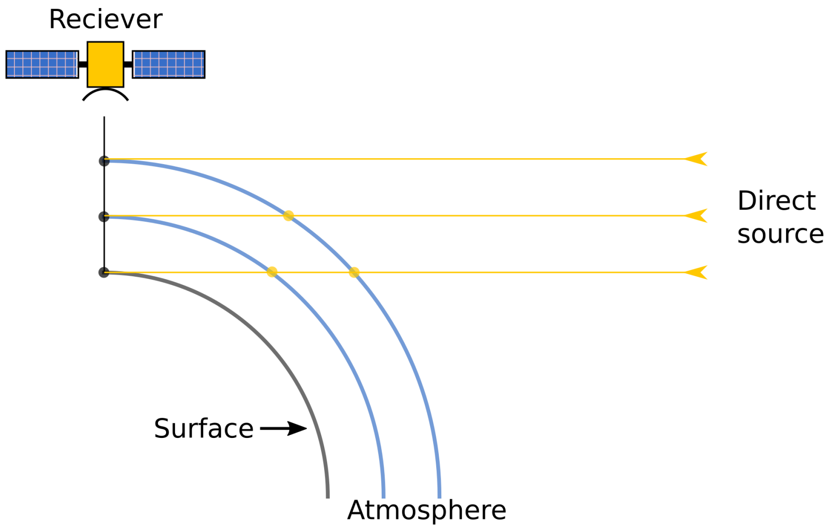
1. **iyClearsky**
   ARTS' internal clear sky solver

2. **CDISORT** (Buras et. al, JQSRT, 2011)
   3rd party solver. C version of DISORT 2.1 (Stamnes et al., Report, 2011)

iyClearsky

$$\frac{dI}{ds} = -kI + aB(T) + \sum_{n=1}^{N_{suns}} F^{*}{}_{s,n} P(\Omega_i, \Omega_s)$$

- 3D clear sky solver for spherical geometry
- Fully polarized
- Multiple suns
- 1st order molecular scattering and surface scattering



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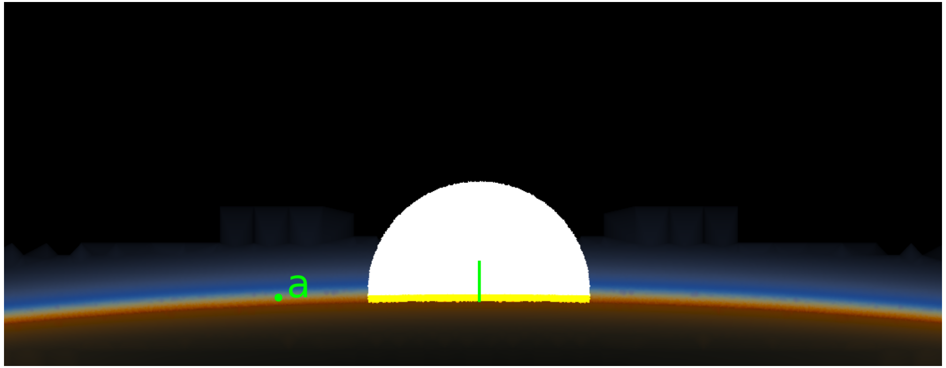
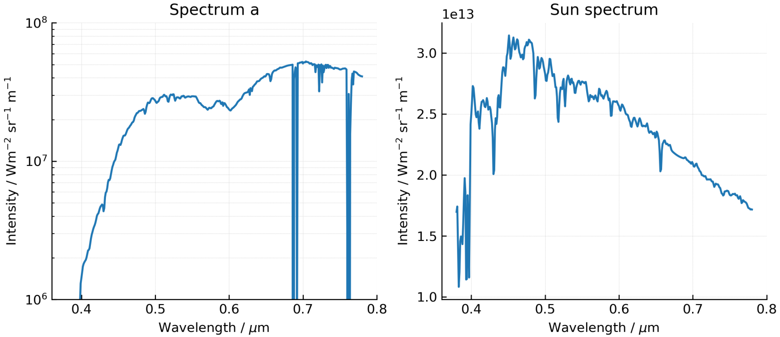
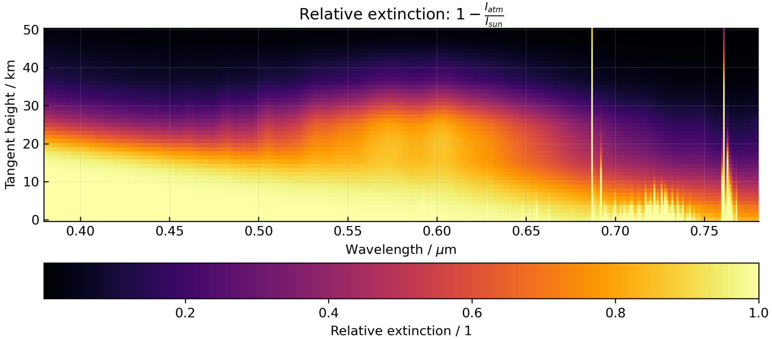
What can we simulate with iyClearsky?

A sunrise from space



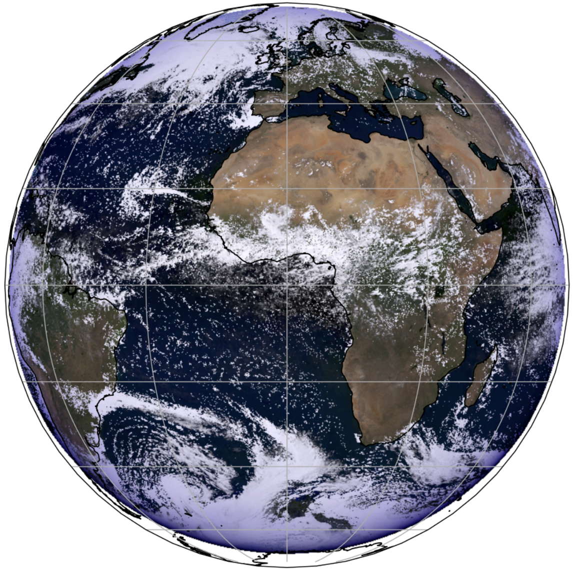




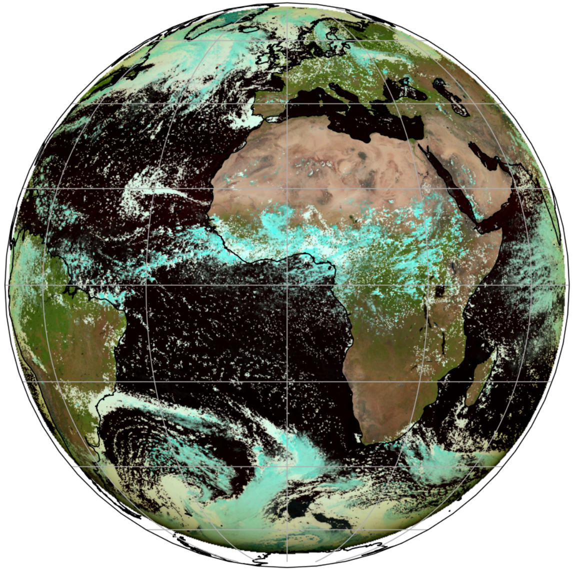
(C)DISORT

- 1D all sky solver for plane parallel atmospheres
- Hybrid geometry
  - Sun geometry 3D → needs to be run for specific location
  - Radiative transfer 1D
- Multiple scattering
  - Molecular scattering and particulate scattering
  - Particulate scattering (so far) realized only for hydrometeors
- No polarization
- One sun only
- Radiance and irradiance mode
- Only Lambertian surface

What can we simulate with DISORT?



MODIS



SEVIRI

- Simulation of geostationary satellite with spectral channels like MODIS and SEVIRI.
- Corrected reflectances mapped to RGB
- Snapshot of ICON Monsoon run by L. Kluft @ 5km

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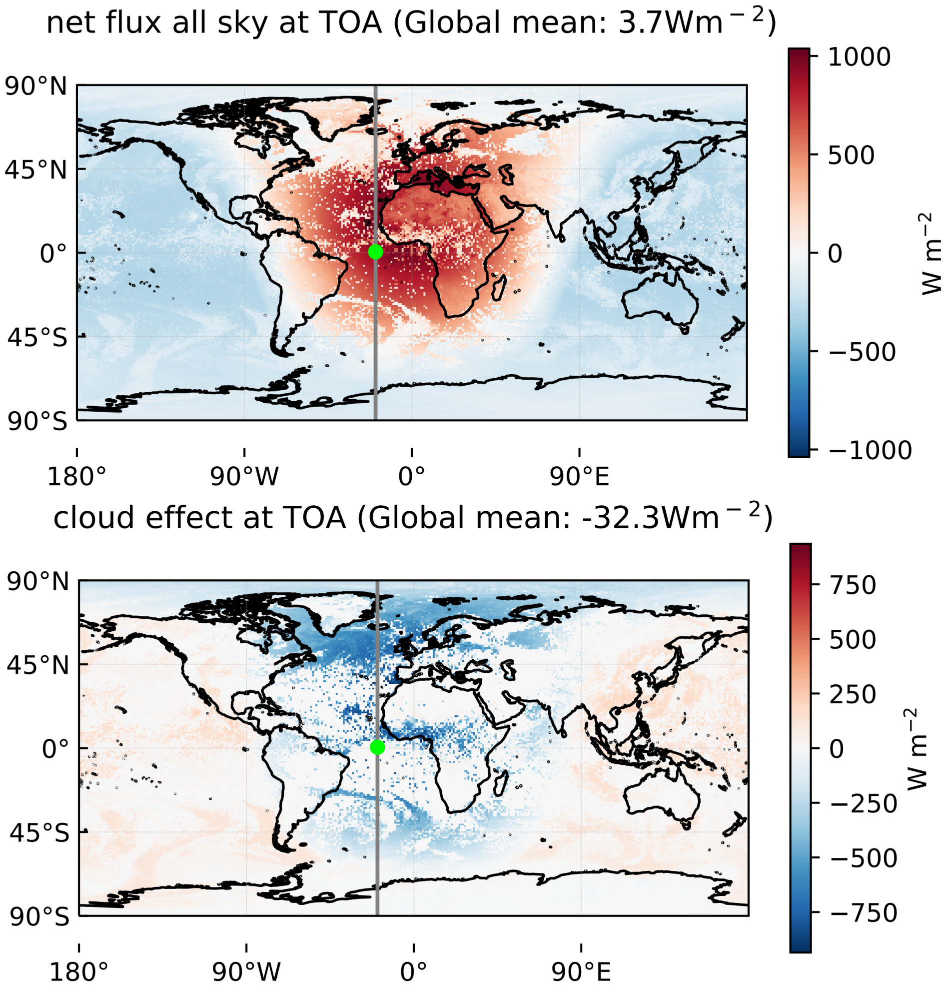
What else can we simulate with DISORT?

- Cloud radiative effect (CRE)
- Line-by-line simulation with 4000 frequencies from the far infrared (FIR) to the ultraviolet (UV)
- Snapshot of ICON Monsoon run by L. Kluft
- For flux simulation sampled @ 1°



Summary

What do we have achieved?

- Added collimated beam source
- Added new clearsky solver and updated DISORT interface
- Able to simulate
  - Sunsets
  - Skylight
  - Limb geometry
  - SW Satellite images
  - All sky full spectrum radiation fluxes

What is missing?

- Wind roughened ocean surface model like Cox and Munk [1954] or Lin et al. [2016]
- Sophisticated Rayleigh scattering cross-section model like Bodhaine et al. [1999] or Tomasi et al. [2005]
- Scattering data and parametrizations for aerosols as they are important scatterers within the short wave range

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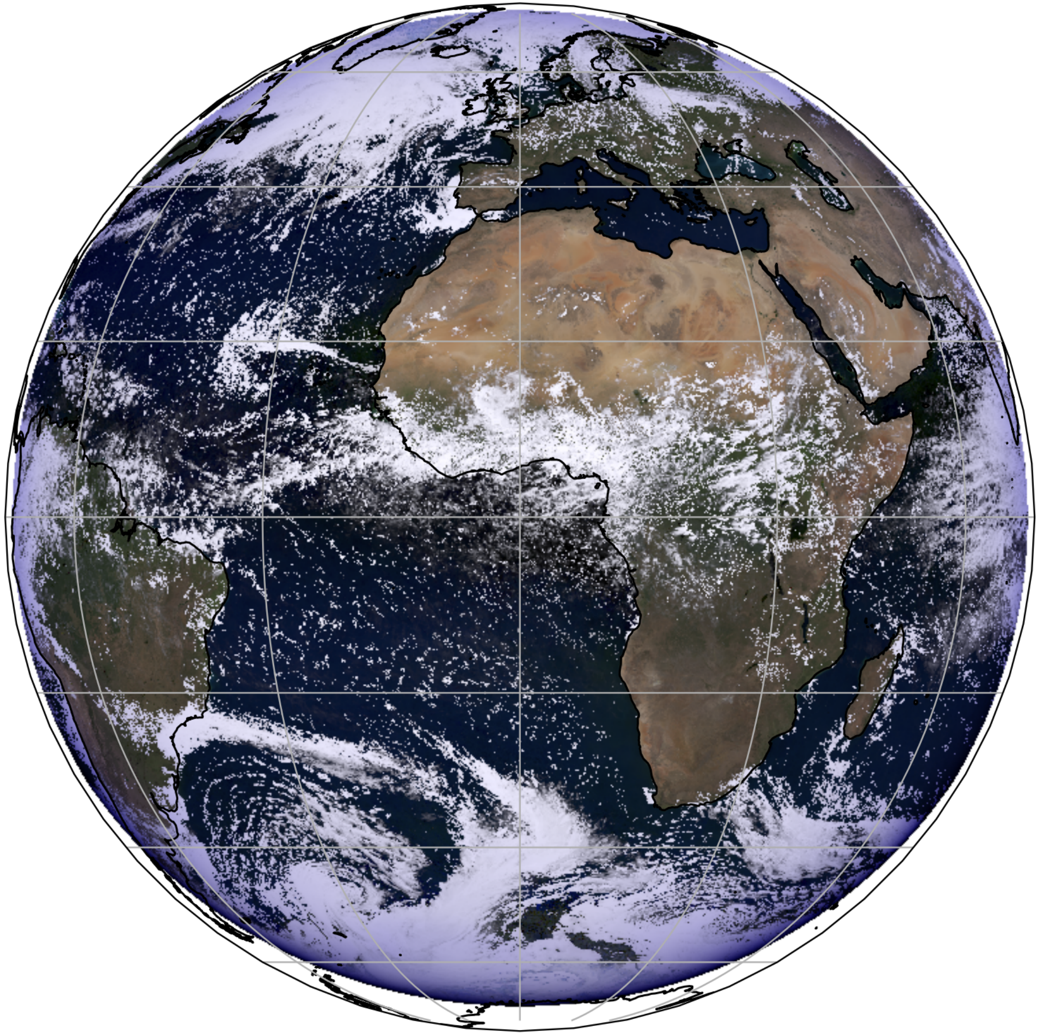
Despite these issues, ARTS is already a powerful and versatile tool for the short wave range especially by its line-by-line capability.



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