



# Image: Market state sta

**Stefan Buehler** ARTS Workshop at Kristineberg, 2024-06-04



#### News

#### 2024-03-14: ARTS 2.6.0 Release

A new version of ARTS is now available. Many changes have gone into ARTS since the 2.4.0 release. Below you find some key features and improvements in ARTS 2.6.0:

- extension to shortwave radiation
- support of measured cross-section data (e.g. HITRAN absorption cross sections)
- new clear-sky solver with support for shortwave radiation (iyClearsky)
- molecular scattering (clear-sky Rayleigh scattering)
- improved DISORT interface
- much improved Python integration

We recommend to install ARTS in Miniforge3 with conda install -c rttools pyarts. Further details can be found on the documentation page.

#### radiativetransfer.org

#### The Atmospheric Radiative Transfer Simulator ARTS, Version 2.6 — Deep Python Integration

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#### Abstract

The atmospheric radiative transfer simulator ARTS is a software for computing atmospheric absorption, scattering, the transfer of radiation through an atmosphere, and sensor characteristics. It is written in C++ and can simulate remote sensing observations and radiative energy fluxes. The article describes version 2.6 of the software. There are numerous changes compared to the last ARTS publication, the most striking being that the program is now controlled by Python scripts, which is convenient and allows for great flexibility. The article discusses the ARTS history, the theory behind the computations of absorption and radiative transfer, available solvers for atmospheres with scattering, the computation of energy fluxes and heating rates, and the built-in system for inverting remote observations to atmospheric state variables by optimal estimation. ARTS is publicly available, open source, and free of charge.

*Keywords:* atmospheric radiative transfer simulator, ARTS, infrared, microwave, radiation, absorption, scattering, spectroscopy, polarization, radiative transfer *PACS:* 42.68.Ay, 42.68.Ca, 42.68.Ge, 42.68.Mj

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## History

- Started in 2000, so already >20 years of ARTS!
- Buehler, S. A., P. Eriksson, T. Kuhn, A. von Engeln and C. Verdes (2005), ARTS, the Atmospheric Radiative Transfer Simulator, J. Quant. Spectrosc. Radiat. Transfer, 91(1), 65-93, doi:10.1016/j.jqsrt.2004.05.051.
- Eriksson, P., S. A. Buehler, C. P. Davis, C. Emde, and O. Lemke (2011), ARTS, the atmospheric radiative transfer simulator, Version 2, J. Quant. Spectrosc. Radiat. Transfer, doi:10.1016/j.jqsrt.2011.03.001.
- Buehler, S. A., J. Mendrok, P. Eriksson, A. Perrin, R. Larsson, and O. Lemke (2018), ARTS, the atmospheric radiative transfer simulator — version 2.2, the planetary toolbox edition, Geosci. Model Dev., 11(4), 1537–1556, doi:10.5194/gmd-11-1537-2018.



## Literature analysis on ARTS usage

- Remote sensing / atmospheric energetics
- Clear-sky / all-sky
- Passive / active
- Microwave / sub-millimeter / terraherz / infrared / UV-visible

#### Main new features

- Deep integration with Python
- Redesigned LBL absorption core
- Built-in OEM retrieval framework
- Solar source term enables shortwave simulations
- Integrated support for flux and heating rate calculations

## **Deep integration with Python**

Installation:

conda install -c rttools pyarts

#### Usage:

- 1 import numpy as np
- 2 import pyarts
- 3 from pyarts.workspace import Workspace, arts\_agenda
- 4 ws = Workspace(verbosity=0)
- 5 ws.VectorNLinSpace(ws.f\_grid, 5, 32000000000.0, 32200000000.0)

## **Redesigned LBL absorption core**

- Completely rewritten by Richard
- Much faster, uses spectral binning to efficiently handle line wings
- New philosophy: Use standard ARTS line catalogue for more user-friendliness (catalogue based on HITRAN)
- Can also use polynomial representation of laboratory absorption cross sections for complex molecules (e.g. halocarbons)
- Can include absorption continua (MT\_CKD, ...) and/or HITRAN data of collisioninduced absorption

#### **Built-in OEM retrieval framework**

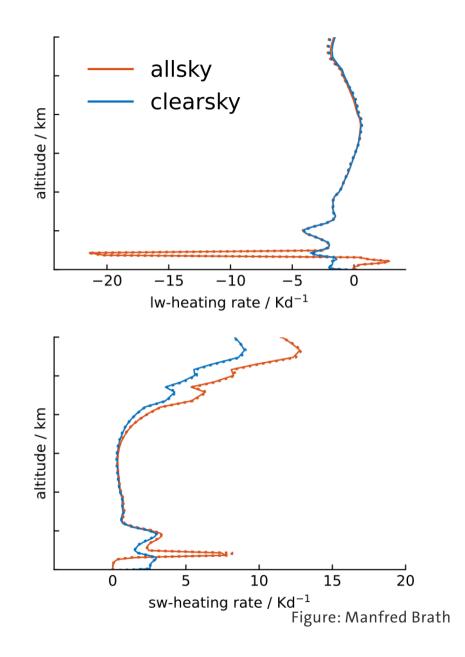
 Roughly similar functionality to old ARTS/Qpack, but more efficient due to C++ implementation

#### Solar source term enables shortwave simulations

Upcoming presentation by Freddy

## Integrated support for flux and heating rate calculations

- Convenient if ARTS is used for atmospheric energetics
- Efficient also for all-sky, thanks to DISORT flux mode



## **Other (traditional) features**

- Fully polarized (Stokes formalism)
- 1D/2D/3D
- Clear-sky RT solver based on vector Schwarzschild formalism, including Jacobian
- Different scattering solvers (ARTS-DOIT, ARTS-MC, DISORT, RT4, Hybrid)
- Support for going from bulk condensate to scattering properties, using size distributions and scattering habits
- Single scattering and multiple scattering (MC) radar simulators
- Extensive support for simulating sensor properties

#### **Documentation**

- https://atmtools.github.io/arts-docs-2.6/
- Examples
- The Workspace (built-in documentation for each method and standard variable)
- Traditional Pdf guide documents (user / theory / developer)
- Mailing lists

	/ The Workspace / Workspace Methods	View page source
<b>ARTS</b> 2.6.2	Workspace Methods	
Search docs	<pre>• abs_cia_dataAddCIARecord()</pre>	• JacobianTargetSet()
	• abs_cia_dataReadFromCIA()	<pre>• lat_gridFromRawField()</pre>
Features	<pre>• abs_cia_dataReadFromXML()</pre>	<pre>• lat_gridFromZRaw()</pre>
Installation	• abs_cia_dataReadSpeciesSplitCatalog()	lbl_checkedCalc()
Examples	<ul> <li>abs_hitran_relmat_dataReadHitranRelmatDataAndLines()</li> </ul>	<ul> <li>line_irradianceCalcForSingleSpeciesNon0</li> </ul>
	<ul> <li>abs_lines_per_speciesAdaptHitranLineMixing()</li> </ul>	<pre>• LocalTimeOffset()</pre>
The Workspace	<ul> <li>abs_lines_per_speciesAdaptOnTheFlyLineMixing()</li> </ul>	Ion_gridFromRawField()
Workspace Groups	<ul> <li>abs_lines_per_speciesBaseParameterMatchingLevel()</li> </ul>	<pre>• lon_gridFromZRaw()</pre>
Workspace Methods	<ul> <li>abs_lines_per_speciesBaseParameterMatchingLevels()</li> </ul>	<ul> <li>losAddLosAndDlos()</li> </ul>
Workspace Variables	<ul> <li>abs_lines_per_speciesChangeBaseParameterForMatchingLevel()</li> </ul>	<ul> <li>MagFieldsCalc()</li> </ul>
Workspace Agendas	<ul> <li>abs_lines_per_speciesChangeBaseParameterForMatchingLevels()</li> </ul>	<ul> <li>MagFieldsCalcExpand1D()</li> </ul>
API Reference	<ul> <li>abs_lines_per_speciesChangeBaseParameterForMatchingLines()</li> </ul>	<ul> <li>MagFieldsCalcIGRF()</li> </ul>
PDF Guide Documents	<ul> <li>abs_lines_per_speciesChangeBaseParameterForSpecies()</li> </ul>	<ul> <li>MagFieldsFromAltitudeRawCalc()</li> </ul>
	<ul> <li>abs_lines_per_speciesCompact()</li> </ul>	MagRawRead()
Indices	<pre>• abs_lines_per_speciesCreateFromLines()</pre>	• main_agendaSet()
Contact	• abs_lines_per_speciesCutoff()	<ul> <li>MapOfErrorCorrectedSuddenDataCreate()</li> </ul>
	• abs lines per speciesCutoffMatch()	ManOfErrorCorrectedSuddenDataSet()



## Summary

- ARTS-2.6 is the current version
- Will not receive new features only bug fixes
- New solar / shortwave part deserves more description → upcoming talk by Freddy
- Development version is ARTS-3 → upcoming talk by Richard



Questions?