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Fast simulation of downwards UV doses, indices and irradiance at the earth's surface

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1 Abstract

Many radiative transfer models are currently capable of simulating ultraviolet (UV) radiation levels with high accuracy, e.g., libRadtran. However, for applications requiring repetitive computations, such as computations of UV doses, model pseudo-inversions, sensitivity studies, operational quality assurance of measured UV spectra, and production of UV maps, such models are generally too computationally demanding.

Fastrt is a fast and user-friendly, yet accurate simulation tool which remedies the above shortcomings. The first version computed downward surface irradiances in the spectral range 290-400nm as a function of bandwidth, solar zenith angle and ozone content. We have now enhanced and expanded the program to account for typical aerosol, cloud and surface conditions.

We have also made a QA program to check incoming UV spectra for an EU-funded European UV database. The algorithm is based on distance metrics between measured UV spectra and simulations by Fastrt.

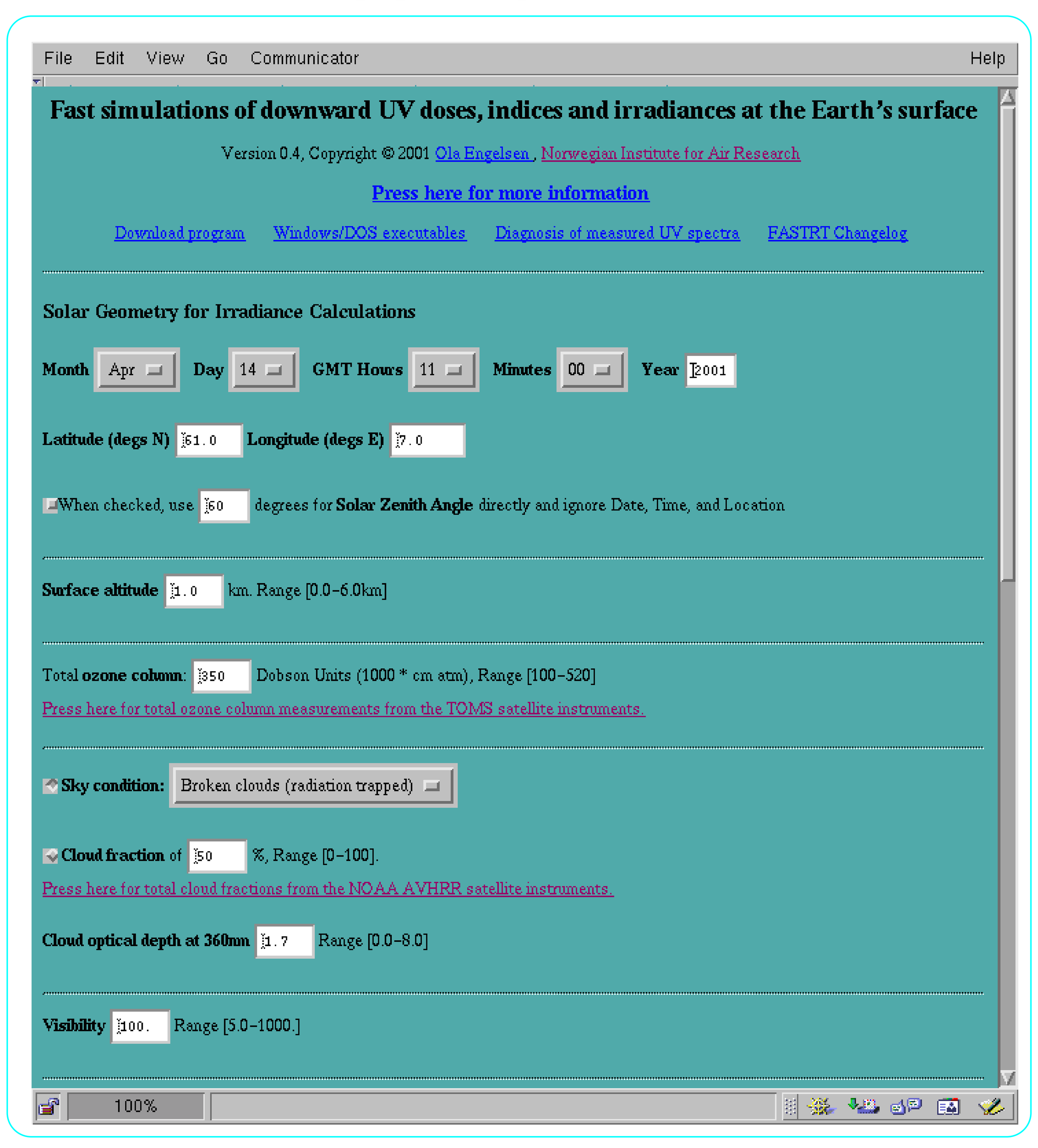
2 Interactive WWW site and downloads:

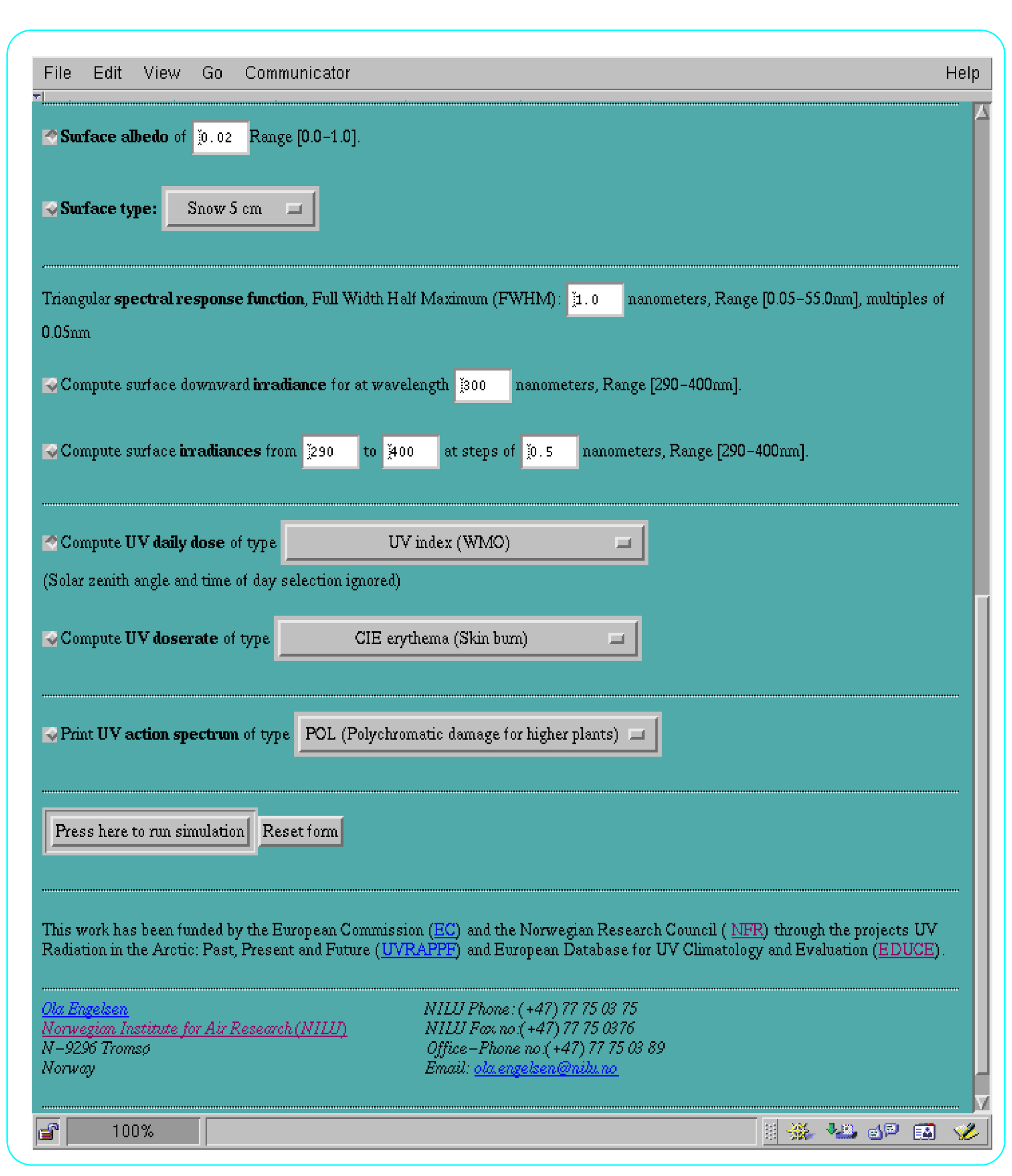
http://zardoz.nilu.no/~olaeng/fastrt/fastrt.html

This site allows the public to run the Fastrt program with most input options. This page also contains updated information about the Fastrt and QA programs and links to an anonymous ftp site for free download of all source code.

The site also contains a pointer to libRadtran, the accurate radiative transfer model used to compute the lookup tables which fastrt is based on. Libradtran is currently found on the internet at **www.libradtran.org**

FASTRT WWW home page example:





3 Basic principles

The Fastrt program computes downward surface irradiances and UV doses in the spectral range 290-400nm in terms of solar zenith angle, ozone content, cloud type and thickness, aerosol loading, surface type and altitude and instrumental characteristics. The software may be run through a WWW interface (see example) or on a command-line prompt.

The surface irradiances are obtained by functional interpolation of effective transmittances stored in Look-Up Tables (LUTs). The LUTs were computed using the freely available, yet rigorous and accurate, libRadtran atmospheric radiative transfer software package [www.libradtran.org]. LibRadtran is based on the multi-stream discrete ordinates radiative transfer equation solver DISORT by Stamnes et al. (1988). The computations were here done using the pseudospherical approximation (SDISORT) by Dahlback and Stamnes (1991) in order to ensure high levels of accuracy even for low solar elevations.

4 UV action spectra, doses and doserates

The following biologically effective doses are readily available to the user:

- UV-A
- UV-B
- Erythema (skin burn) action spectrum
- DNA (skin cancer) action spectrum
- ACGIH action spectrum
- SCUP / SCUP-M / SCUP-H action spectra
- PRT (DNA to protein crosslinks) action spectrum
- SSB (DNA breaks) action spectrum
- POL (polychromatic actions spectrum for higher plants)
- PTP (phytoplankton photoinhibition) action spectrum
- TYP (typhimurium killing) action spectrum
- Plant Damage action spectrum
- Mammalian Non-melanoma Skin Cancer Action Spectrum
- DNA Damage action spectrum

5 Quality assurance of measured spectra

A quality assurance tool is developed for measured UV spectra to flag atmospheric and instrumental anomalies. The method is based on comparisons of measured and simulated irradiances under clear sky, high albedo (snow), high aerosol loading, broken clouds, and optically thick clouds.

6 Limitations

In principle any atmospheric and surface scenario may be simulated provided the look-up tables (LUTs) are made large enough. However, for practical reasons it is desirable to limit the number of represented scenarios. Not only will a compact LUT speed up the software, and save disk storage. Input information is generally incomplete, and the user must concentrate on simulation of representative scenarios.

The following atmospheric and surface conditions are currently assumed.

- US standard atmosphere (Anderson et al, 1986)
- Visibility formula with rural aerosols (Shettle, 1989)
- Spring summer aerosol profile
- Stratospheric aerosol: background conditions
- 11 surface types, otherwise arbitrary constant surface albedo
- Alto-stratus clouds (Shettle, 1989)
- Broken clouds: trap all surface-reflected radiation, otherwise independent pixel approximation is applied

7 References

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- Shettle E P, "Models of aerosols, clouds and precipitation for atmospheric propagation studies, In Atmospheric propagation in the UV, visible, IR and MM-region and related system aspects, AGARD Conf. Proc. pp. 15-1-15-13,1989
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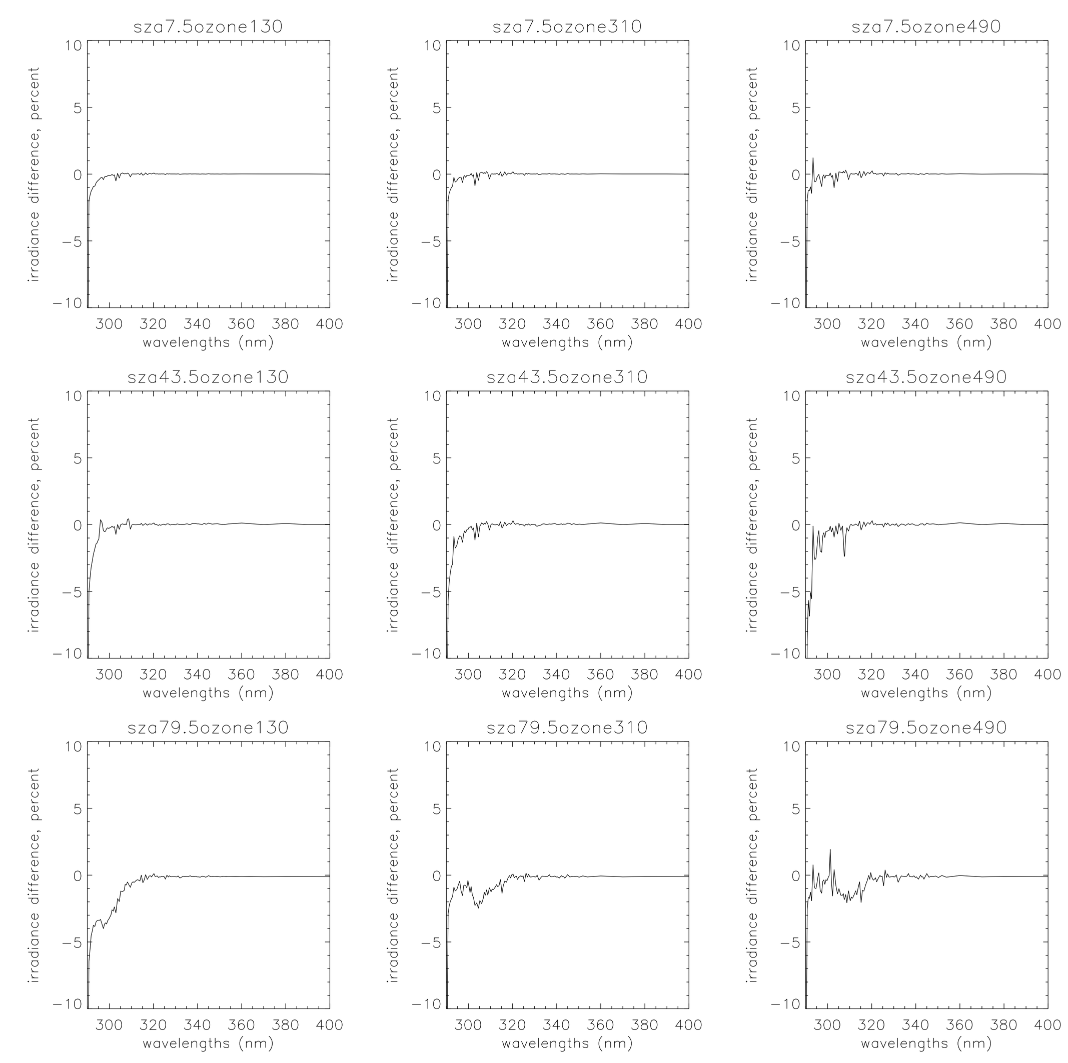
- Dahlback A and Stamnes K, "A new spherical model for computing the radiation field available for photolysis and heating at twilight", Planet. Space Sci., 39, 671-683, 1991

8 Error Analysis



The figures above show the percent difference of the surface irradiance spectra generated by the FASTRT model and the libRadtran model with respect to the latter. The titles indicate solar zenith angles (sza) in degrees and total ozone columns (ozone) in Dobson units.

Table 1: Erythema doserates obtained by FASTRT and libRadtran models and difference with respect to libRadtran.

Solar Zenith Angle (deg)	Total Ozone Column (DU)	FASTRT	RADTRAN (exact)	**Percent error**
7.5	130.0	7.683e+02	7.860e+02	**2.253**
7.5	310.0	2.793e+02	2.836e+02	**1.502**
7.5	490.0	1.624e+02	1.635e+02	**0.667**
43.5	130.0	3.492e+02	3.573e+02	**2.258**
43.5	310.0	1.252e+02	1.264e+02	**0.957**
43.5	490.0	7.473e+01	7.505e+01	**0.420**
79.5	130.0	1.439e+01	1.458e+01	**1.303**
79.5	310.0	6.124e+00	6.152e+00	**0.445**
79.5	490.0	4.433e+00	4.457e+00	**0.550**

The overall accuracy for clear sky is better than UV instruments (5%). Larger uncertainties in input parameters exist for cloudy, aerosol and snow scenarios, and consequently somewhat larger deviations are acceptable (<20%)

9 Acknowledgments

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