Universität Zürich[UZH]

Department of Geography

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UrbaNature

A physically based approach to compensate for shadow effects in imaging spectroscopy data

Introduction & Motivation

- Climate change increases frequency of heatwaves
- Cities are particularly vulnerable due to urban heat island effects
- Green infrastructure mitigates heat via shade and evapotranspiration
- Remote sensing has potential for mapping the mitigation capacity of vegetation city wide but also its health state during heat events

Challenges in urban remote sensing:

- High spatial heterogeneity
- Complex 3D structure
- Cast and gradual shade
- Complex light scattering regimes

Assumptions in common approaches:

- Surfaces are flat and fully illuminated
- Fractional contribution of direct and diffuse irradiance is simplified
- Wavelength dependency is negligible

Research Problem

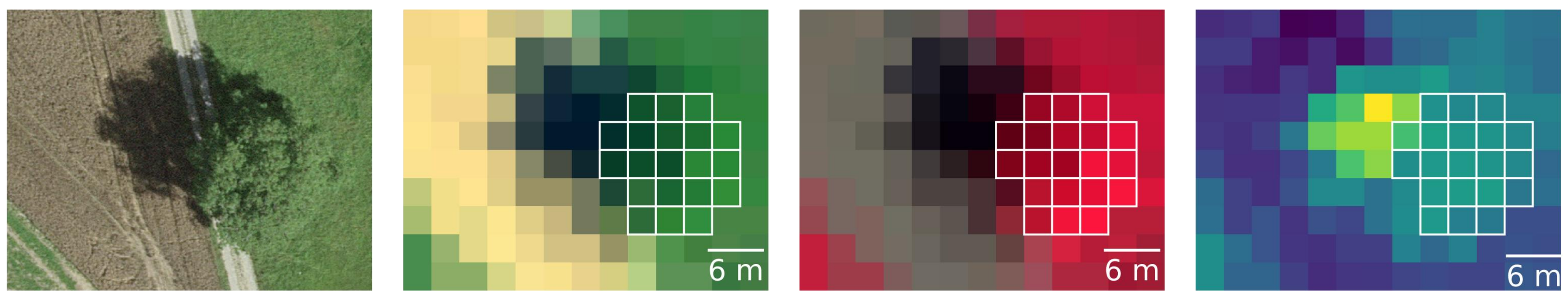

Fig.1 Aerial overview of study area. From left to right: true colour SWISSIMAGE (10cm) image ©swisstopo; HyPlant radiance (3m) image shown in true colour; HyPlant as false colour; HyPlant derived NDWI. Tree crown pixels are highlighted in white.

Research Questions

1) How are direct and diffuse irradiance spatially distributed?
2) Does a physical based approach allow to compensate shade and minimize illumination sensitivity of retrieval approaches?

Methods & Results

Illumination correction was performed on HyPlant [1] airborne imaging spectroscopy data (3m) using a physically based scheme implemented using libRadtran [2]:

Step 1: Semi-Automatic selection of illuminated pixels

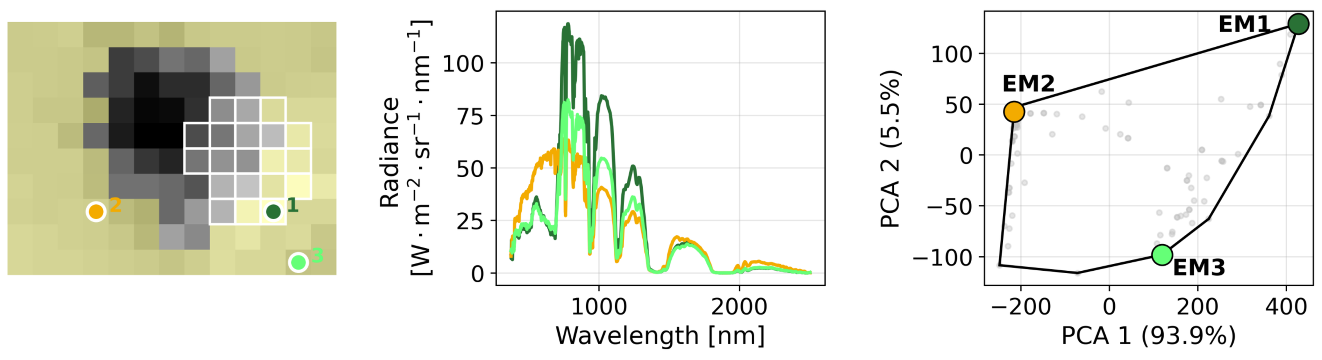

Fig.2 Semi-automatic endmember selection. Left: Manual shadow mask. Middle: Spectral signature of three endmembers identified using the N-FINDR algorithm. Right: PCA feature space with the convex hull and the endmembers as extreme vertices of the data distribution.

Step 2a: Estimate direct and diffuse irradiance

$$L_{ToA}(\rho) = L_p + \frac{T^{up} * (E_{dir}^{ToC} * \mathrm{m} + E_{dif}^{ToC} * \mathrm{n}) * \rho/\pi}{1 - s\rho} \qquad \rho = \sum_{i=1}^{k} x_i * p_i \; where \; x_i \geq 0, \sum x_i = 1$$

L_{ToA}: At sensor radiance
L_p: Path radiance
E_{dir}^{ToC}: Direct downwelling irradiance
E_{dif}^{ToC}: Diffuse downwelling irradiance
n and m: Scaling factors
ρ: Reflectance
s: Spherical albedo
T^{up}: Upward transmittance

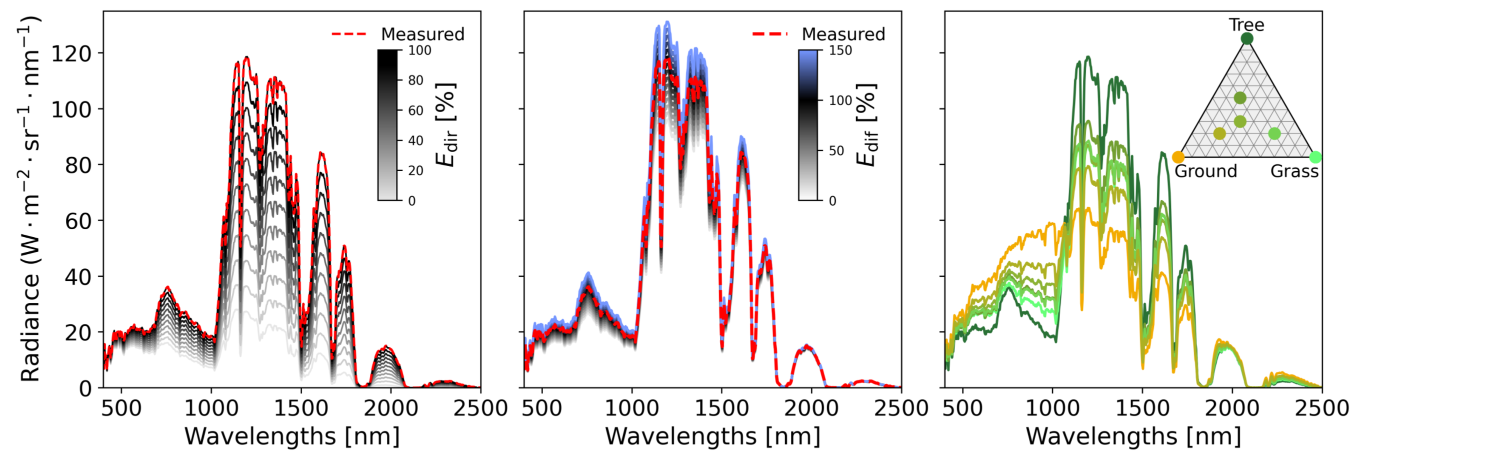

Fig.3 Spectral sensitivity of Ltoa to variations m, n and ρ. Left: scaling E_{dir} from 100% to 0%. Middle: scaling E_{dif} from 0 to 150%. Right: Variations in reflectance (ρ) modeled using three endmembers.

Step 2b: Apply the cost function to each pixel

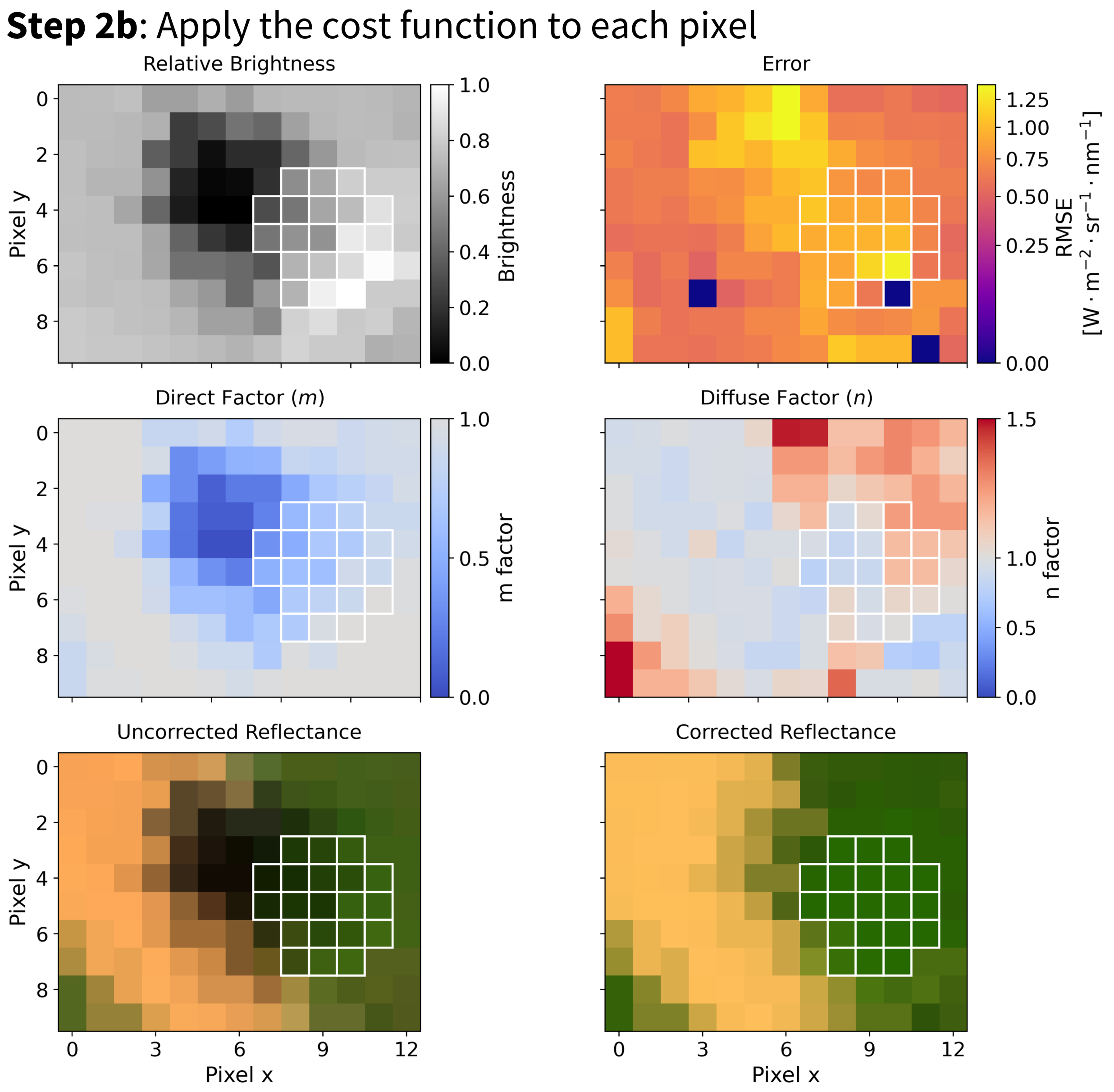

Fig.4 Spatial distribution of estimated irradiance factors and reflectance. Panels show brightness, RMSE between simulated and measured radiance, direct (m) and diffuse (n) factors, and reflectance before and after correction.

Step 3: Retrieved vegetation products

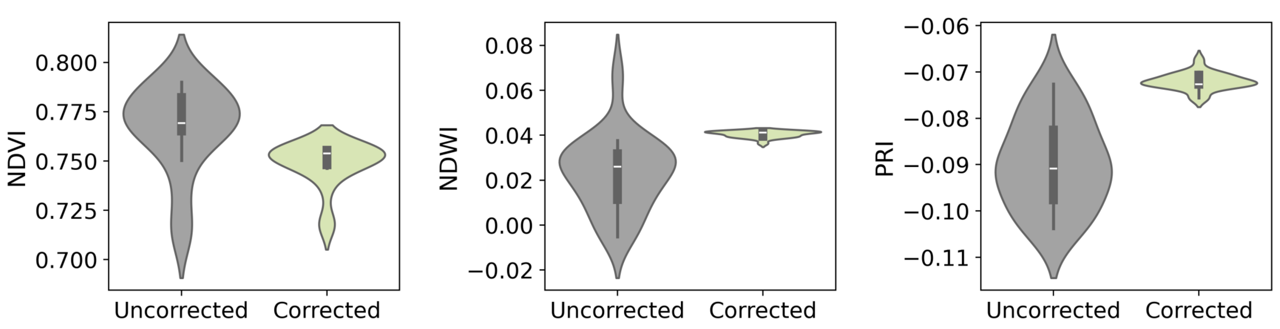

Fig.5 Distribution of vegetation indices within the tree crown before and after the illumination correction

Step 4: Application to larger areas

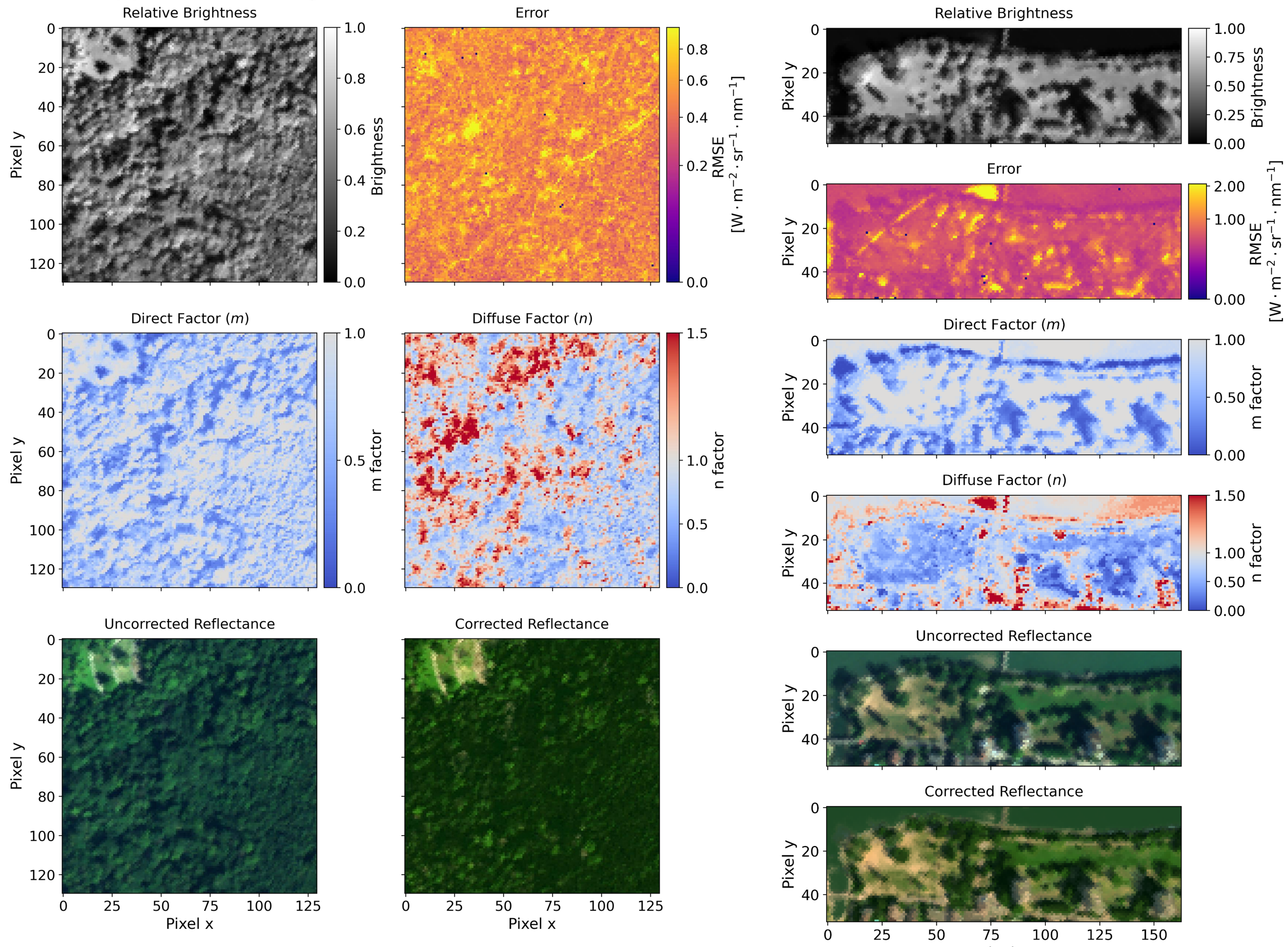

Fig.6 & 7 Spatial distribution of estimated irradiance factors and reflectance for two scenes. Panels show brightness, RMSE between simulated and measured radiance, direct (m) and diffuse (n) factors, and reflectance before and after correction.

Conclusion & Outlook

- Physically-based approach allows estimating direct and diffuse irradiance for multi-surface regions.
- Fully automated endmember selection for dark albedo surfaces so far not possible.
- Consideration of effective irradiance reduces illumination effects in tree crowns of up to 61% in the NDVI.

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Acknowledgement & References

Co-financed by the Federal Office for Meteorology and Climatology MeteoSwiss within the framework of GAW-CH and GCOS-CH

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[2] C. Emde, R. Buras-Schnell, A. Kylling, B. Mayer, J. Gasteiger, U. Hamann, J. Kylling, B. Richter, C. Pause, T. Dowling, and L. Bugliaro. The libradtran software package for radiative transfer calculations (version 2.0.1). Geoscientific Model Development, 9(5):1647-1672, 2016