Experimental determination of the effect of clouds on the atmospheric heating rate of black and brown carbon in the Po Valley

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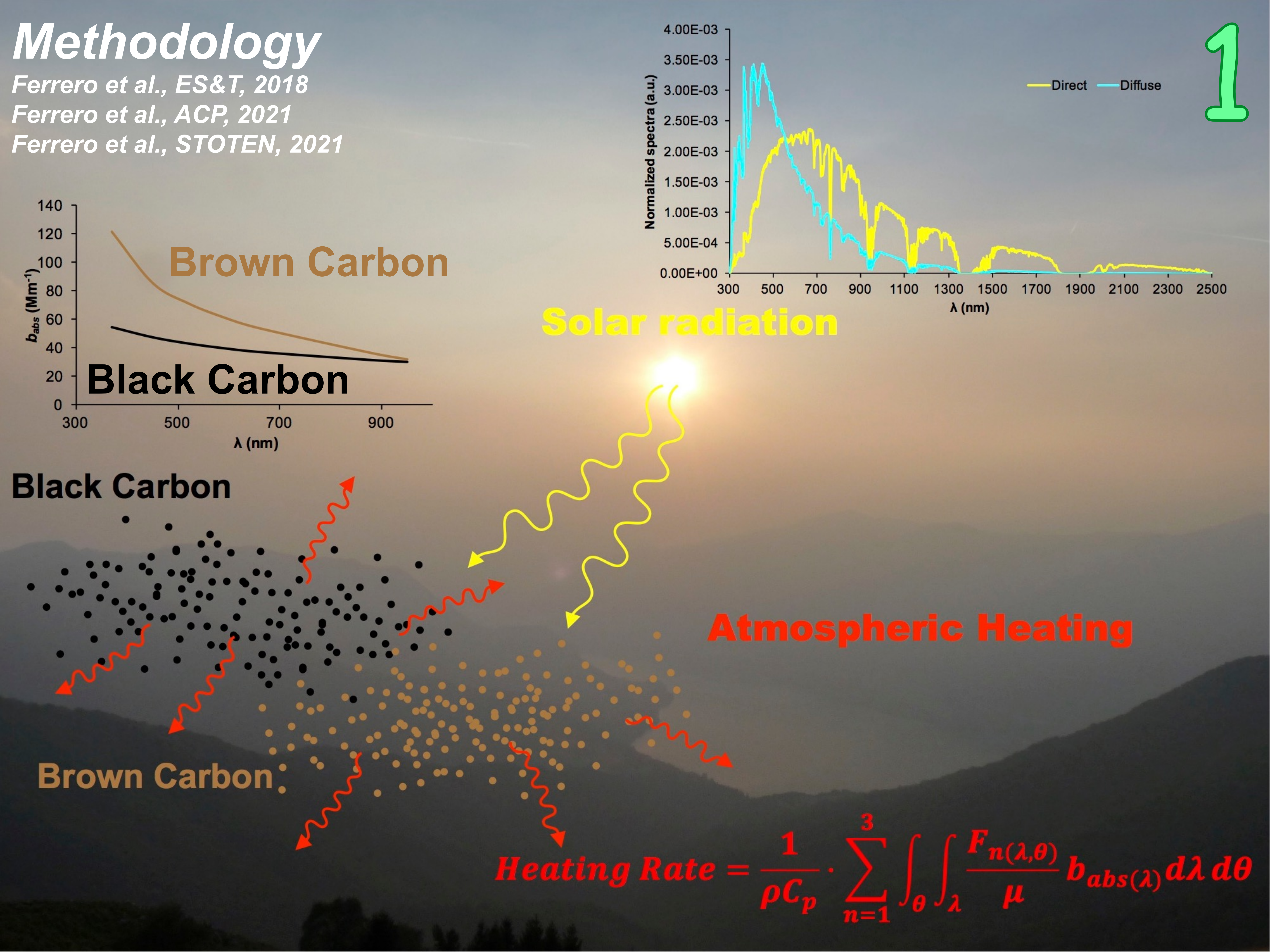
Methodology
Ferrero et al., ES&T, 2018
Ferrero et al., ACP, 2021
Ferrero et al., STOTEN, 2021
1
Direct
Diffuse
Normalized spectra (a.u.)
λ (nm)
Solar radiation
Brown Carbon
Black Carbon
b_{abs} (Mm^{-1})
λ (nm)
Black Carbon
Brown Carbon
Atmospheric Heating
$$Heating\ Rate = \frac{1}{\rho C_p} \cdot \sum_{n=1}^{3} \int_{\theta} \int_{\lambda} \frac{F_{n(\lambda,\theta)}}{\mu} b_{abs(\lambda)} d\lambda\, d\theta$$

Methodology

1

$$\text{Heating Rate} = \frac{1}{\rho C_p} \sum_{n=1}^{3} \int_{\theta} \int_{\lambda} \frac{F_{n(\lambda,\theta)}}{\mu} b_{abs(\lambda)} \, d\lambda \, d\theta$$

(K day^{-1})

Air properties
(ρ: kg m^{-3}; C_p: 1005 J kg^{-1} K^{-1})

Absorptive Direct Radiative Effect
(ADRE: W m^{-3})

ADRE and HR in function of radiation

$$ADRE_{dir} = \int_{\theta} \int_{\lambda} \frac{F_{dir(\lambda,\theta)}}{\mu} b_{abs(\lambda)} \, d\lambda \, d\theta$$

$$ADRE_{dif} = \int_{\theta} \int_{\lambda} \frac{F_{dif(\lambda,\theta)}}{\mu} b_{abs(\lambda)} \, d\lambda \, d\theta$$

$$ADRE_{ref} = \int_{\theta} \int_{\lambda} \frac{F_{ref(\lambda,\theta)}}{\mu} b_{abs(\lambda)} \, d\lambda \, d\theta$$

$$ADRE_{tot} = ADRE_{dir} + ADRE_{diff} + ADRE_{ref}$$

ADRE and HR apportionment

$$\frac{b_{abs}(\lambda_1)_A}{b_{abs}(\lambda_2)_A} = \left(\frac{\lambda_1}{\lambda_2}\right)^{-AAE_A}$$

$$\frac{b_{abs}(\lambda_1)_B}{b_{abs}(\lambda_2)_B} = \left(\frac{\lambda_1}{\lambda_2}\right)^{-AAE_B}$$

$$b_{abs}(\lambda) = b_{abs}(\lambda)_A + b_{abs}(\lambda)_B$$

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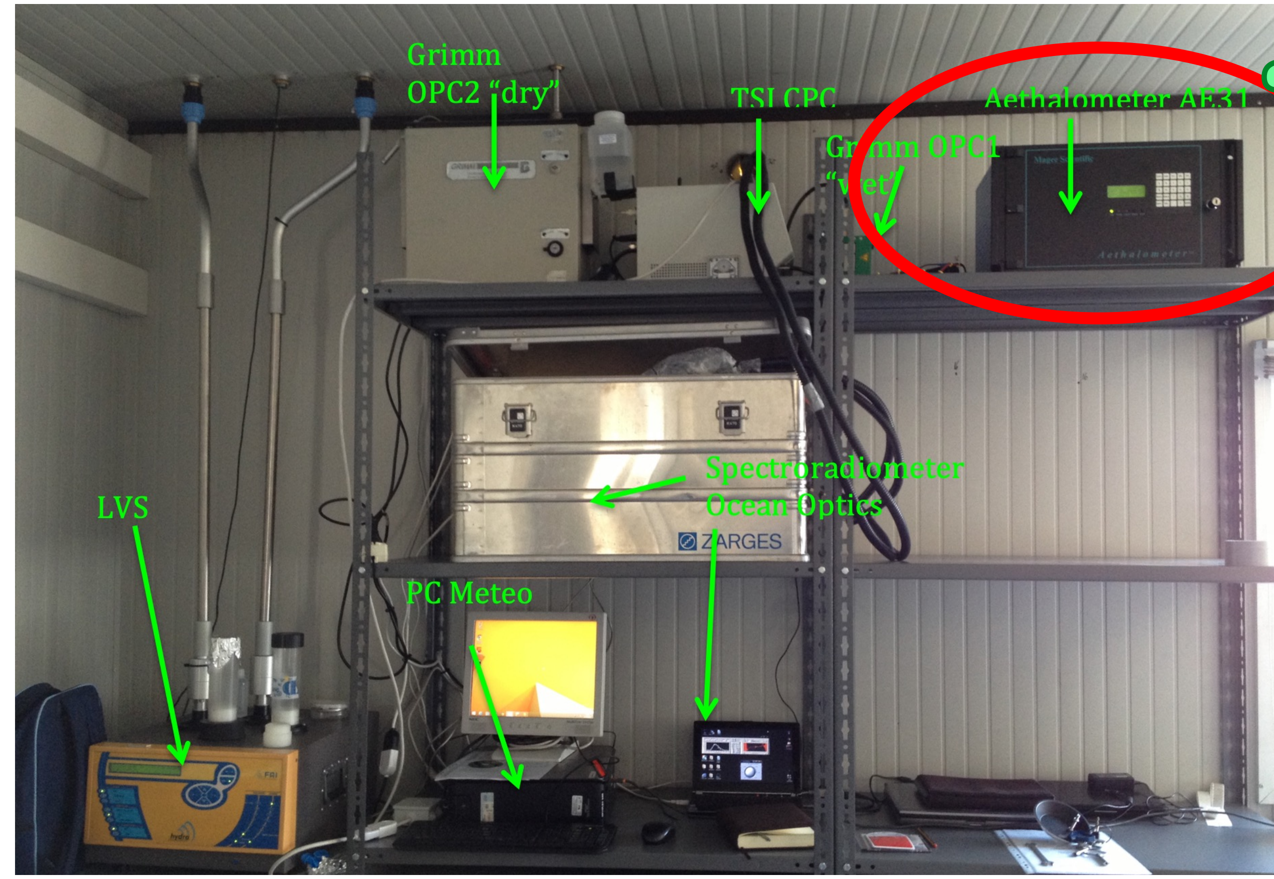
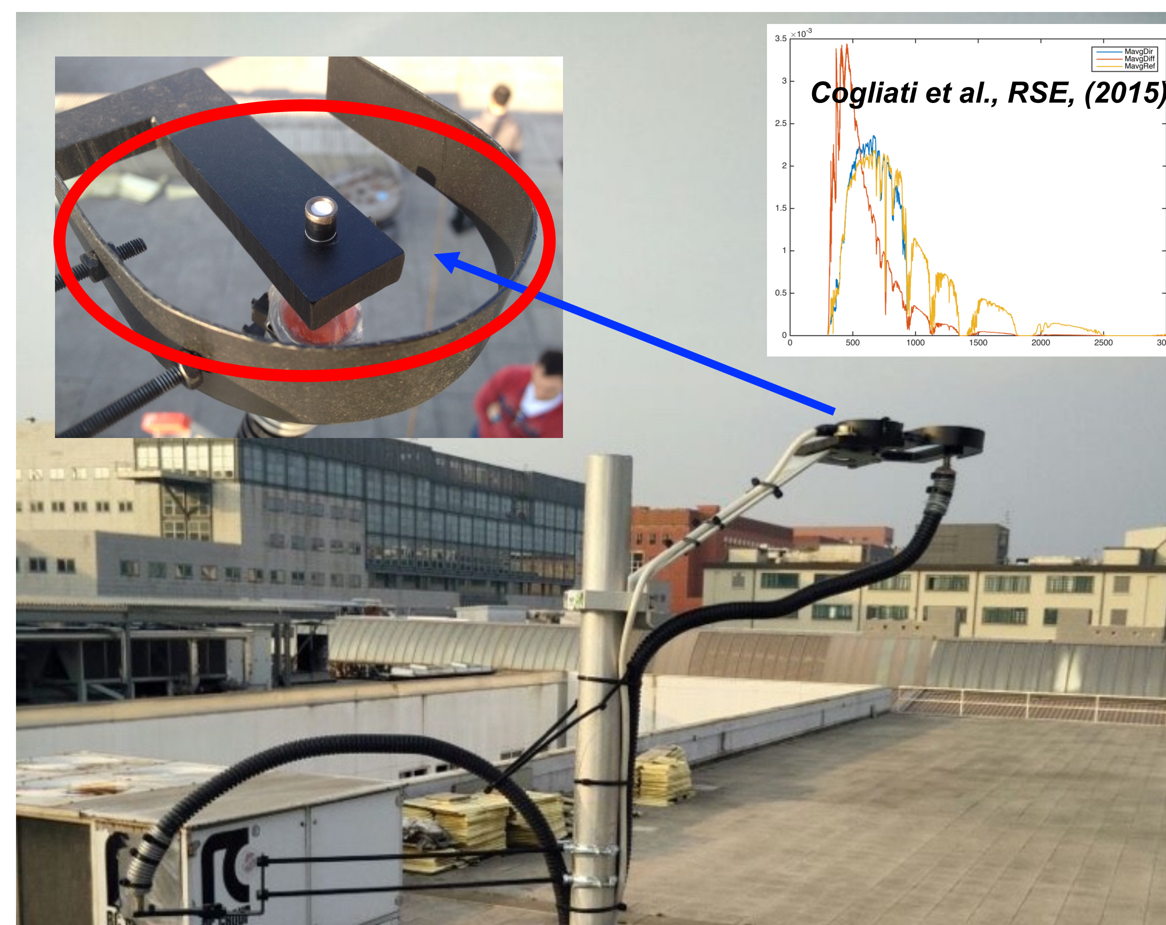
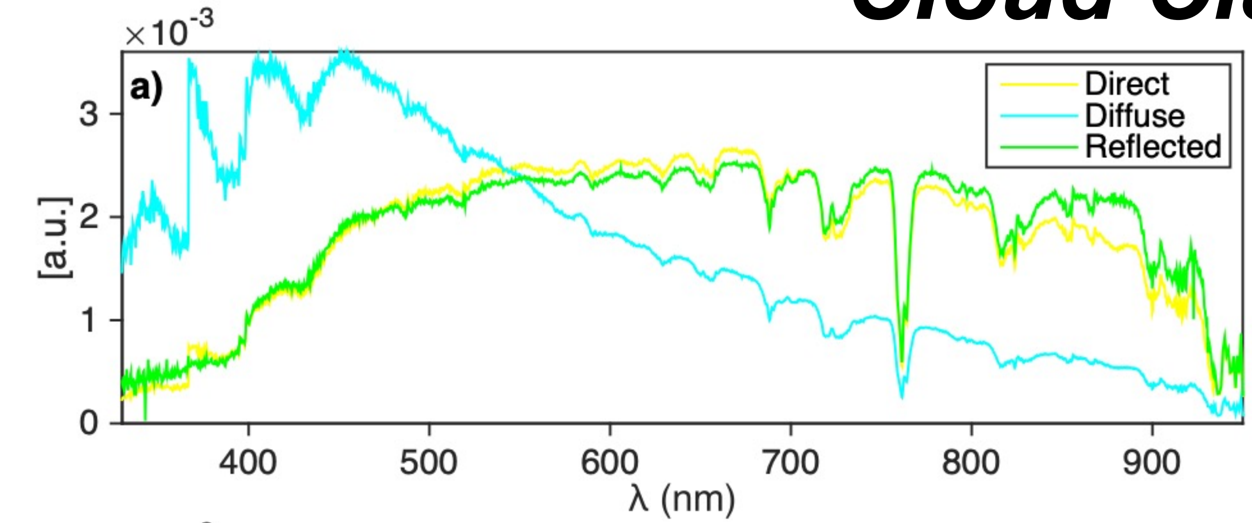
Experimental HR determination

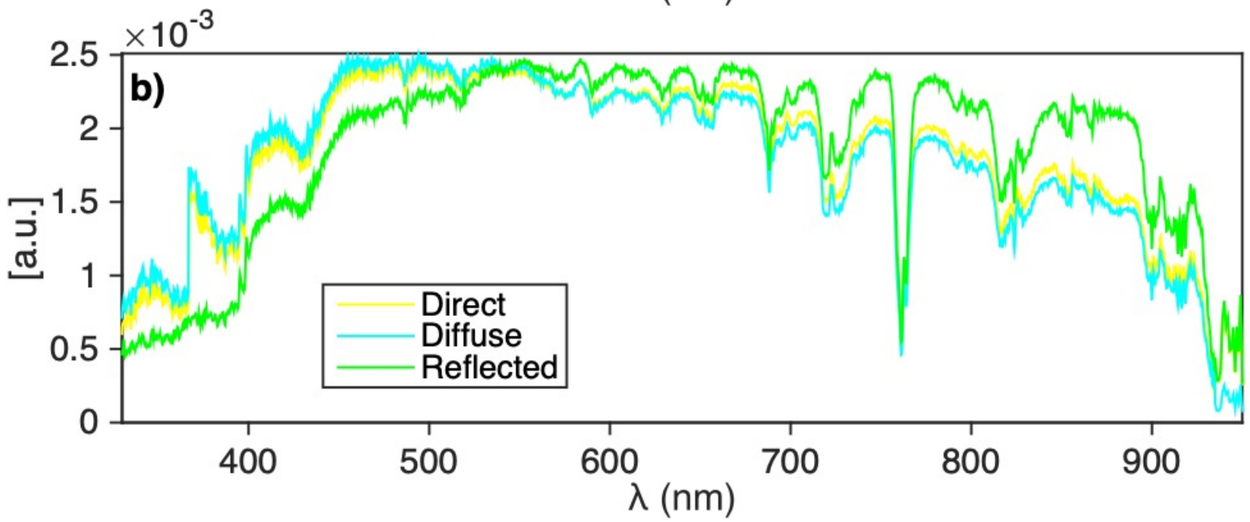
1

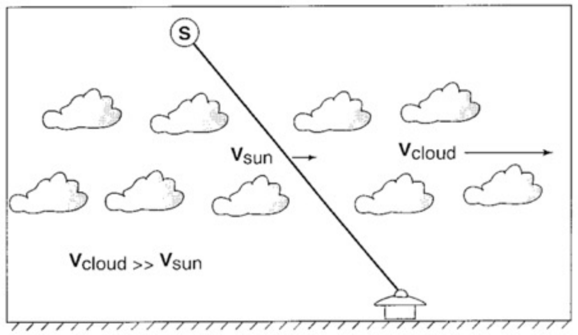




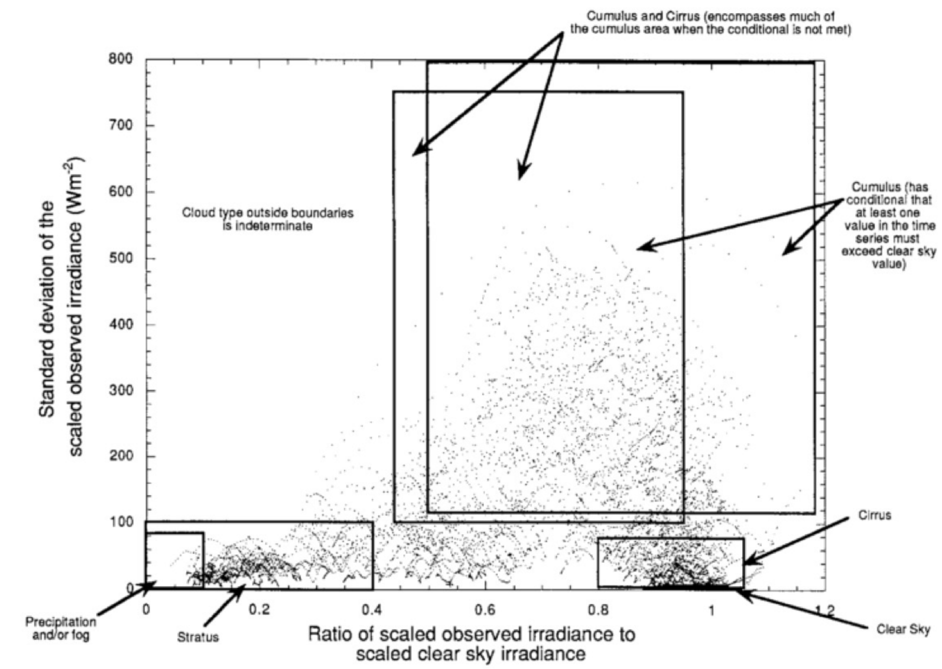
Cloud Classification

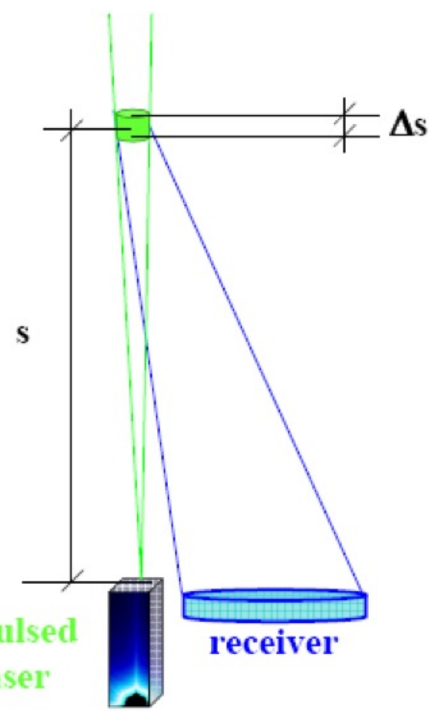


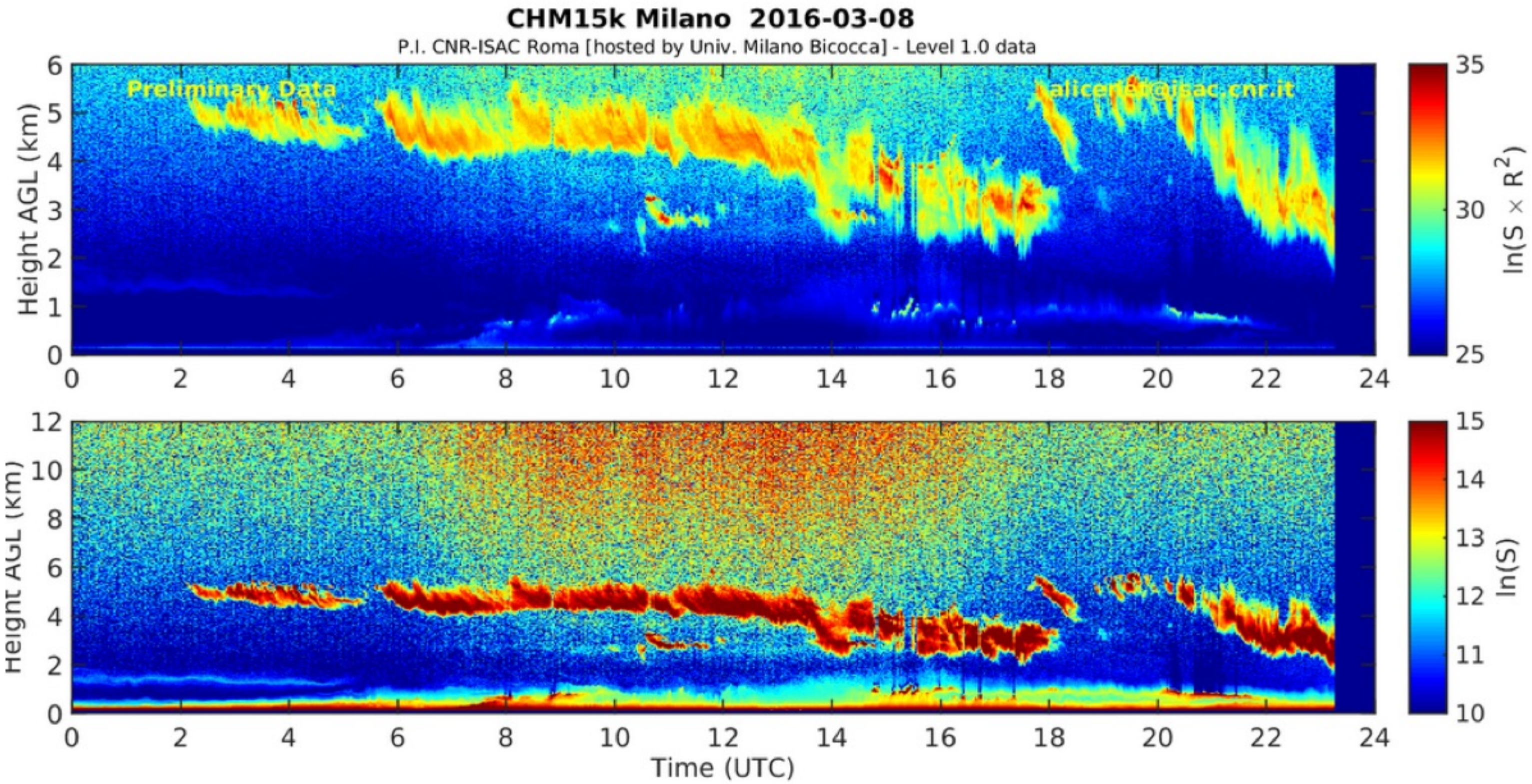




Duchon, C. E., and O'Malley, M., 1999, Estimating Cloud Type from Pyranometer Observations: Journal of Applied Meteorology, v. 38, p. 132-141.

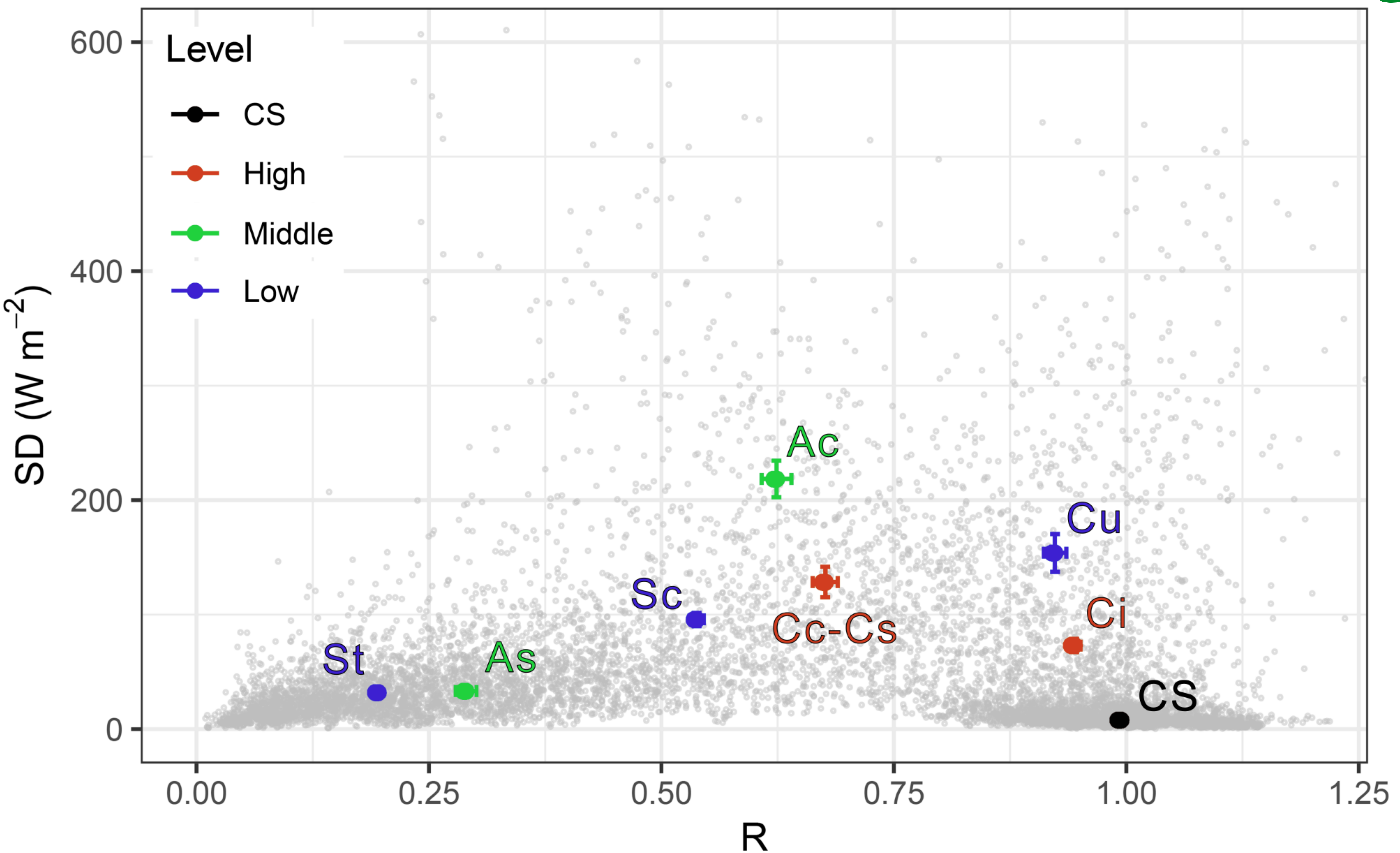






Cloud classification

2



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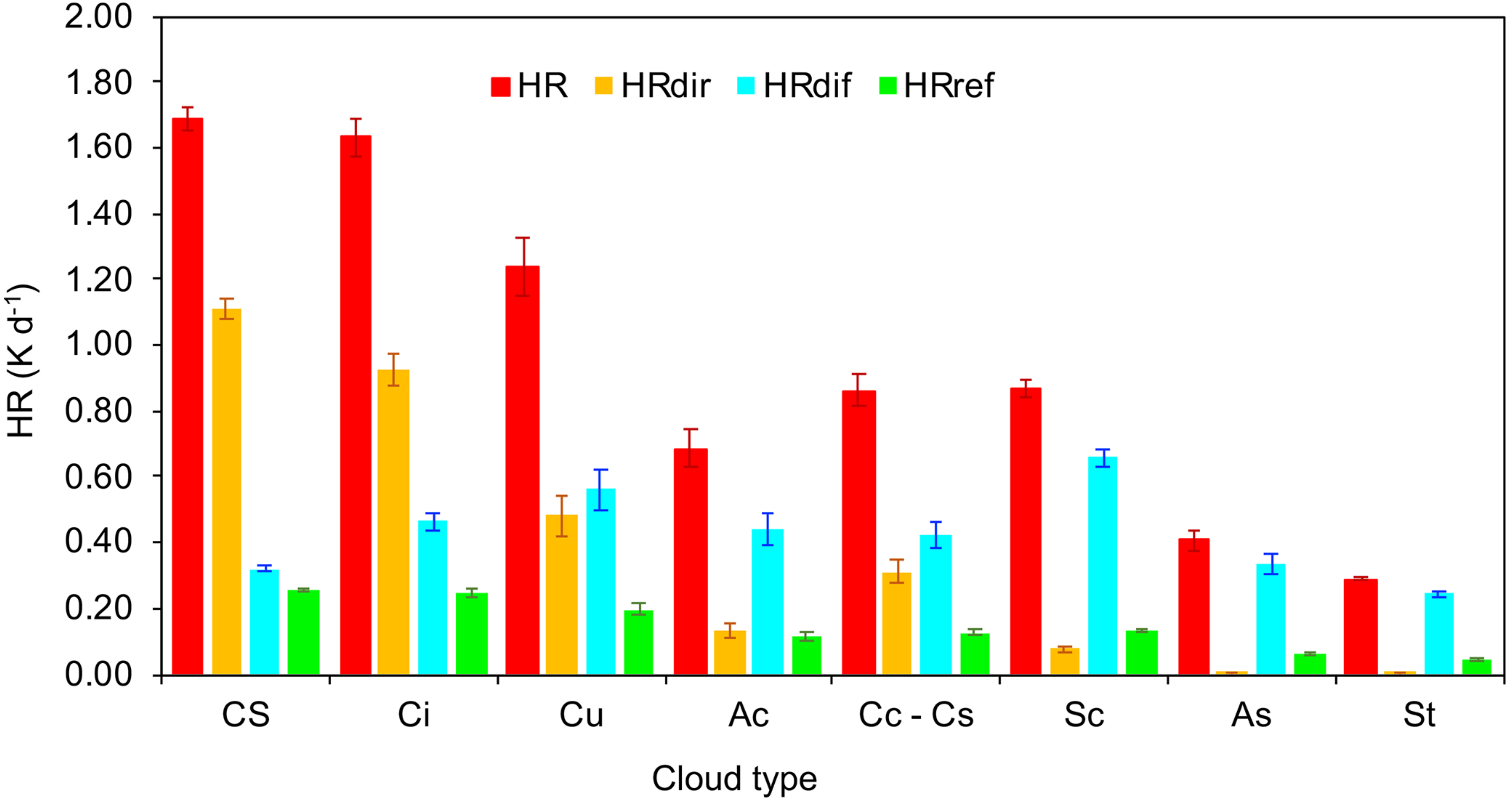
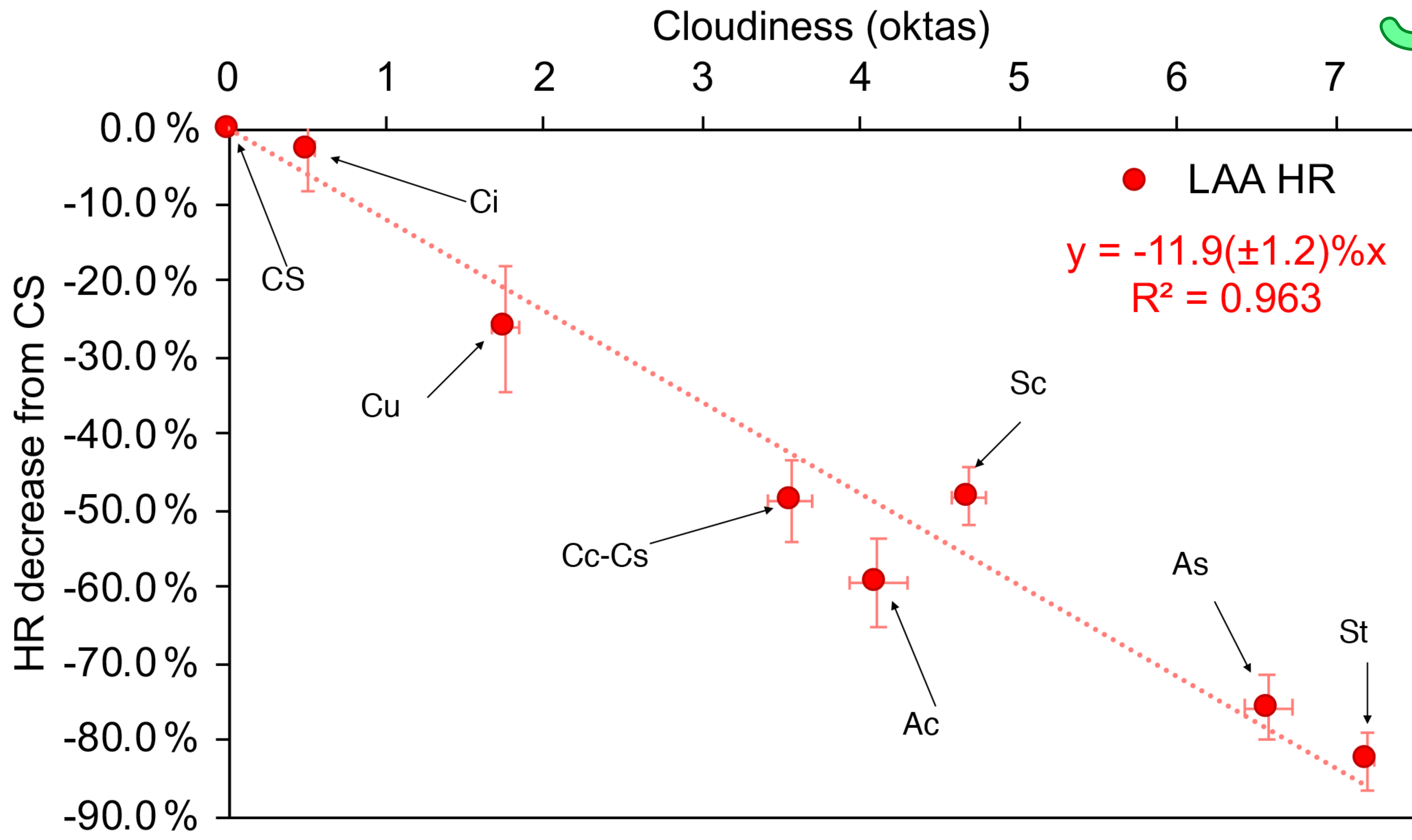
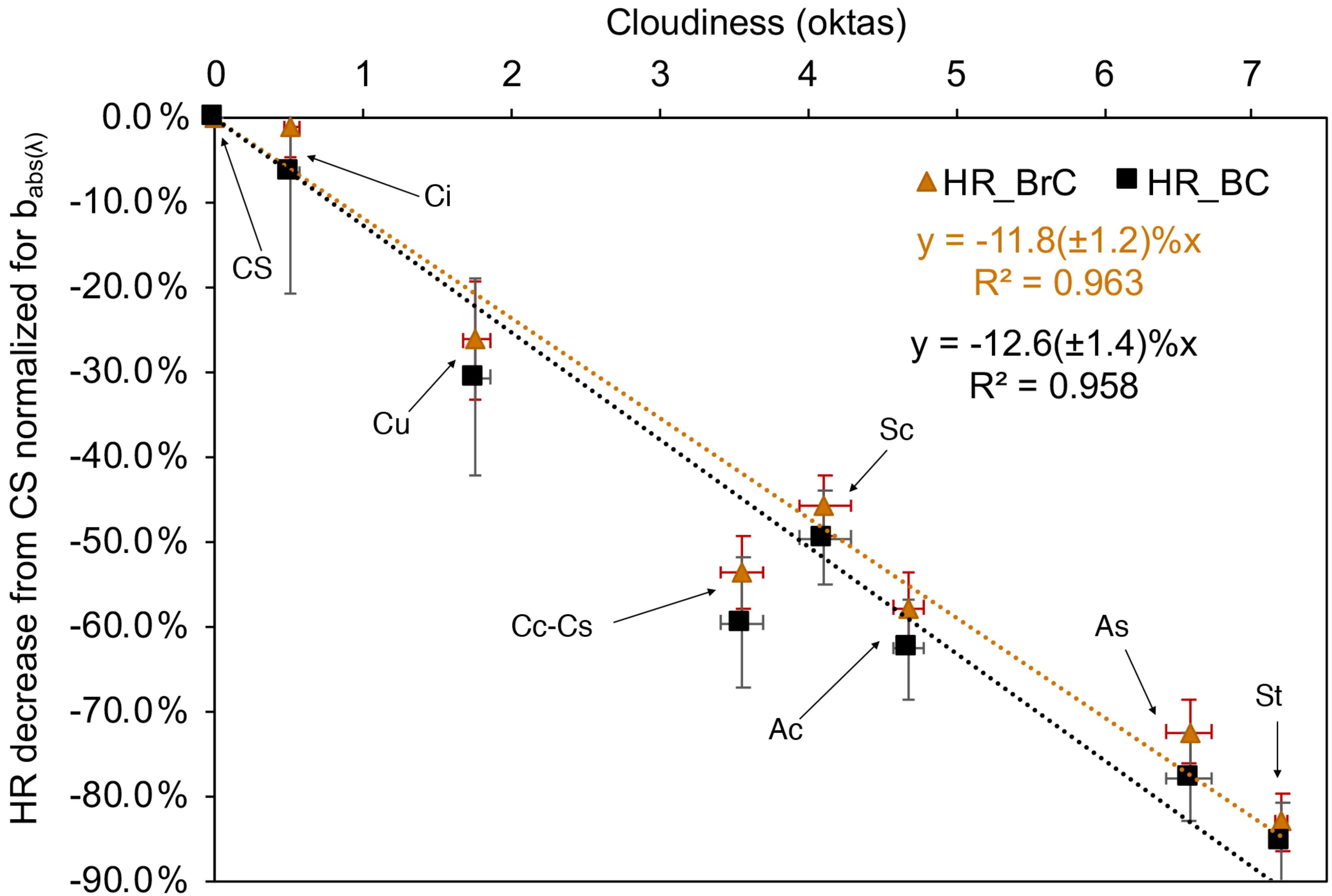


HR_{dir} was only dominant during periods of CS and Ci clouds (HR_{dir}: 1.11±0.04 and 0.92±0.05 K day^{-1}, respectively), explaining 66±3 and 57±4% of the total atmospheric HR. **In the cases of other clouds (St, As and Sc) HR_{dif} dominates, reaching the highest absolute contribution of 84.4±3.8, 83.0±10.7 and 76±4%** (HR_{dif}: 0.25±0.01, 0.34±0.03 and 0.66±0.02 K day^{-1}), respectively.

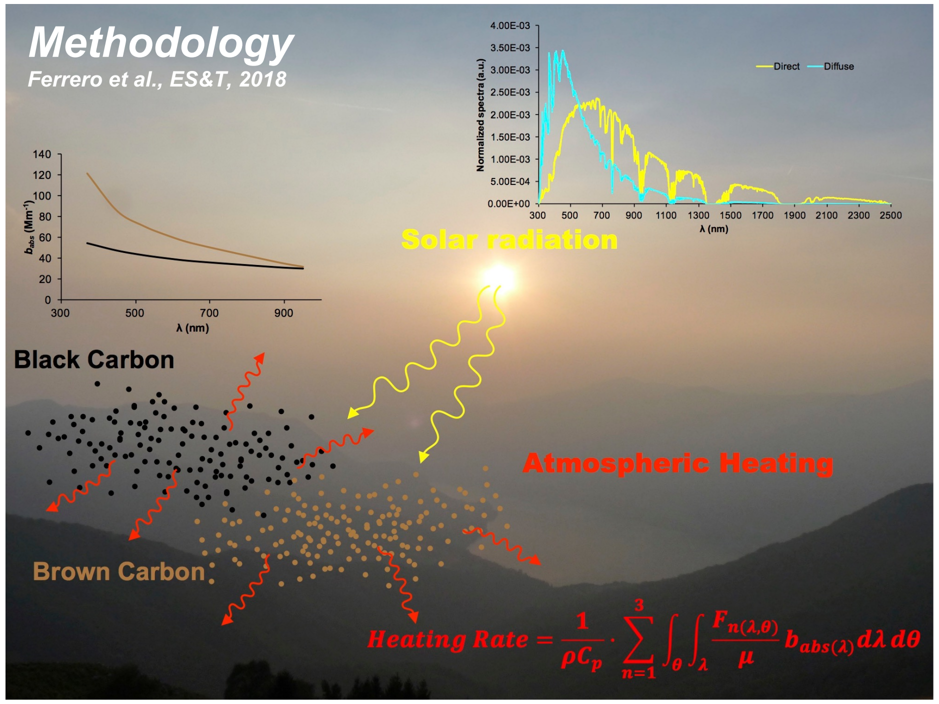
Results: The role of Clouds

3





Ci were found to produce a statistically negligible impact on cloudiness decreasing the HR_{BC} and HR_{BrC} by ~1-6%, respectively. Cu (1.76±0.09 oktas) decreased the HR_{BC} and HR_{BrC} by -31±12% and -26±7%, respectively. Cc-Cc featured oktas of 3.56±0.14, and were responsible for a -60±8% and -54±4% decrease of the HR_{BC} and HR_{BrC}. Their impact was comparable to that of Ac (4.11±0.18 oktas): -60±6% and -46±4% decrease of the HR_{BC} and HR_{BrC}. Sc (4.68±0.10 oktas) had a higher impact, decreasing HR_{BC} and HR_{BrC} of -63±6% and -58±4%. The highest impact was given by As (6.57±0.15 oktas; -78±5% and -73±4% of HR_{BC} and HR_{BrC}) and by St (oktas: 7.19±0.04) suppressing the HR_{BC} and HR_{BrC} by -85±5% and -83±3%, respectively.



Thank you for your attention!!!

Ferrero et al.: The impact of cloudiness and cloud type on the atmospheric heating rate of black and brown carbon, Atmos. Chem. Phys., 21, 4869–4897, 2021. (https://doi.org/10.5194/acp-21-4869-2021)

Contact for any cooperation

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