Cloud detection in Hyperspectral Images With Atmospheric column WAter vapor : the CHIWAWA method

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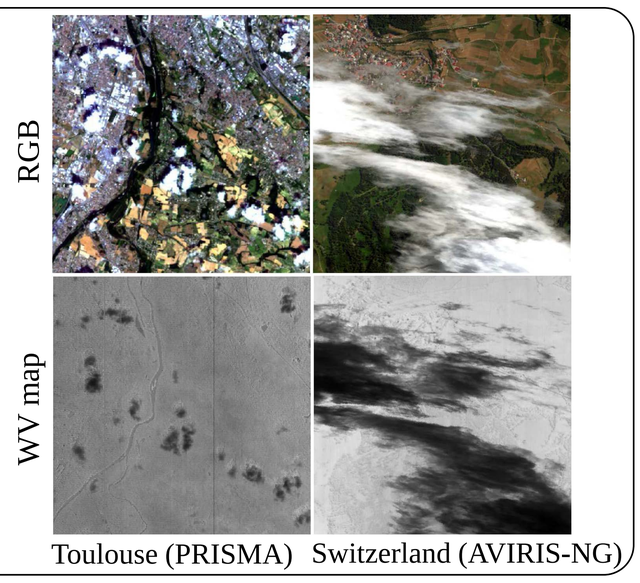
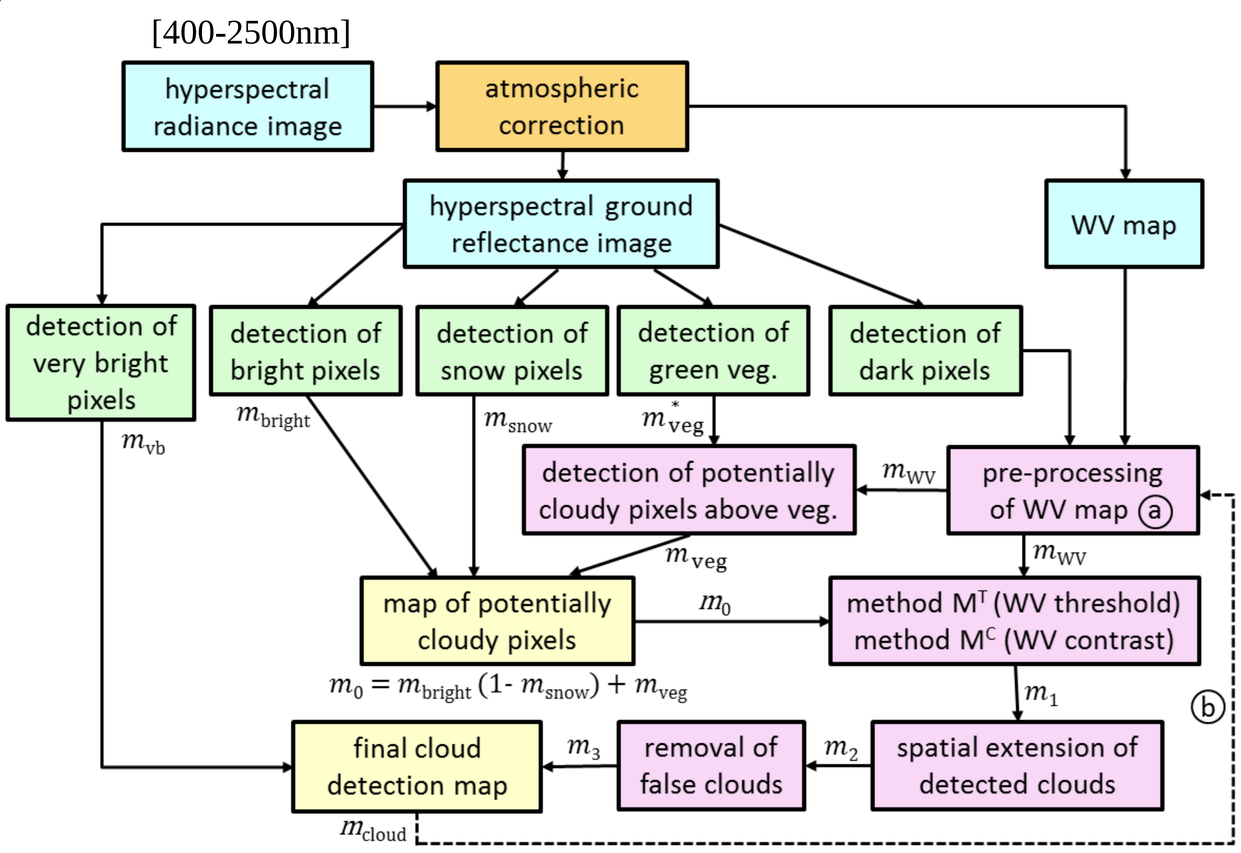
Overview

During atmospheric correction of a hyperspectral radiance image, the atmospheric water vapor column (WV) is estimated for each pixel, leading to the production of a WV map. For a given pixel, in the presence of a cloud, a variable proportion of the photons emitted by the sun are reflected by the cloud and cannot interact with the water vapour beneath the cloud (i.e. be absorbed), leading to an underestimation of the WV value for that pixel. As a result, pixels containing clouds have lower WV values than their surroundings. The CHIWAWA method (Cloud detection in Hyperspectral Images With Atmospheric column WAter vapor) proposes to detect thick and thin clouds by exploiting the complementarity of the information available in the reflectance image and the WV map. It is divided into two main phases:

- Phase 1: detection of potentially cloudy pixels (ground reflectance image is mainly used).
- Phase 2: refinement using WV map. Two complementary methods: M^T (threshold) and M^C (contrast)



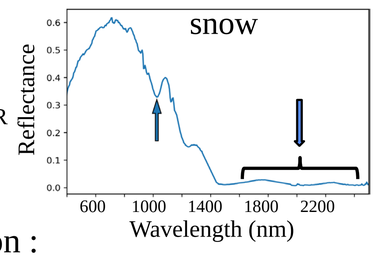


Phase 1

Detection of bright pixels $\min_{\lambda \in VNIR} \rho(\lambda) \geq T_{VNIR}$ $\min_{\lambda \in SWIR} \rho(\lambda) \geq T_{SWIR}$

(T_{VNIR}, T_{SWIR}) = (0.10, 0.03) for AVIRIS-NG
(0.07, 0.07) for PRISMA

Detection of snow : absorption (1025 nm) + low ρ_{SWIR}

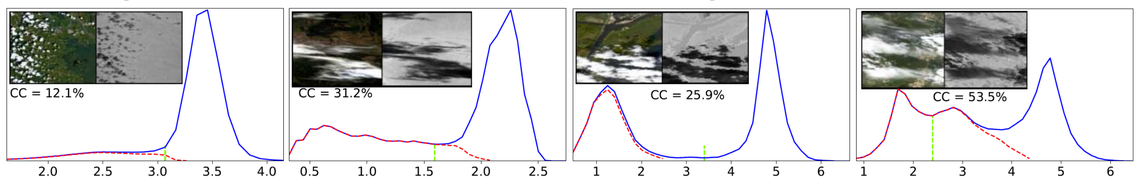


Detection of dark pixels $\max_{\lambda \geq 900} \rho(\lambda) \leq 0.07$

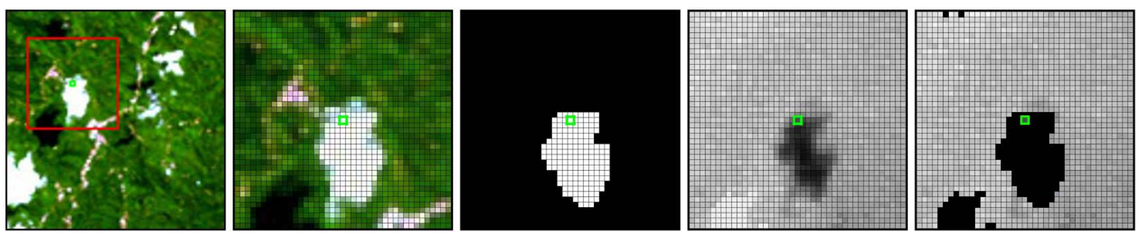
Detection of potentially cloudy pixels above vegetation : detection of green vegetation (CHRIPS) and retain pixels with low WV values

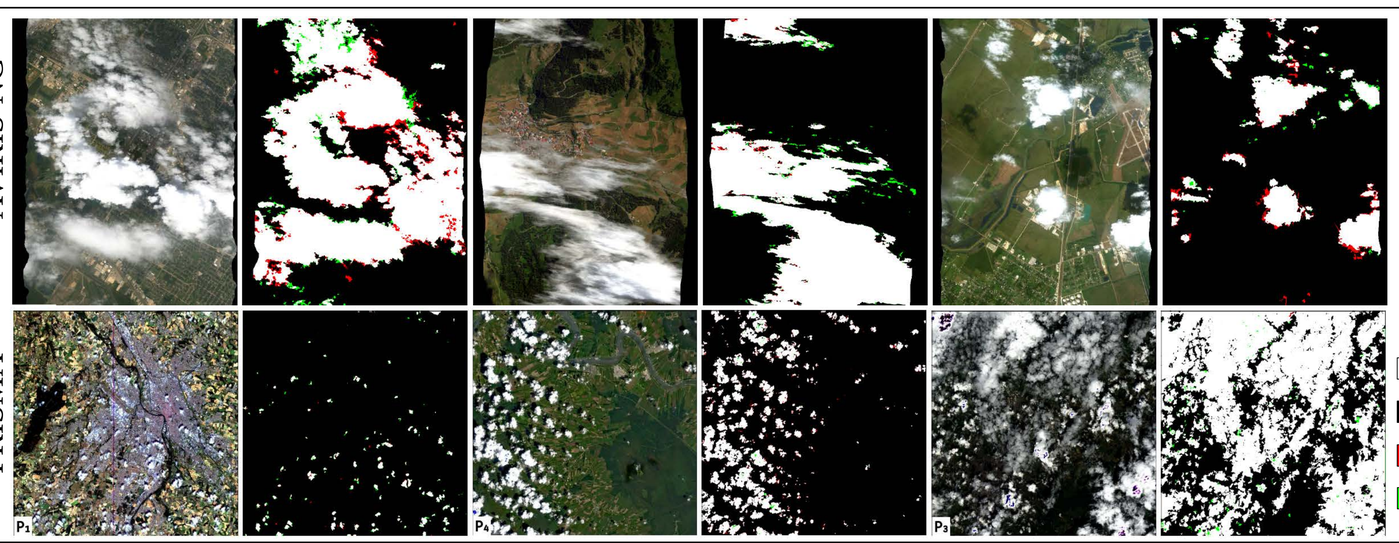
Phase 2

M^T : cloudy pixels have the lowest WV values → threshold the WV map
Different approaches are used to estimate the threshold according to the shape of the histogram (monomodal, monomodal with a long left tail, bimodal, multimodal).



M^C : a pixel is considered as cloudy if its WV value is significantly below the mean WV value of its environment → threshold = 0,1 × histogram range



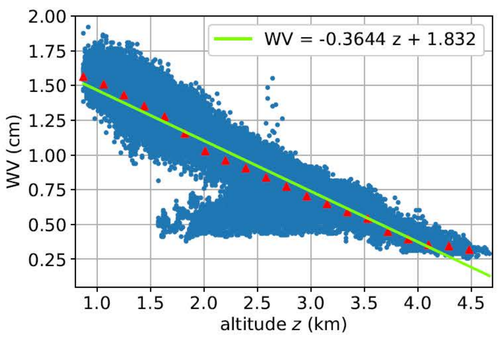


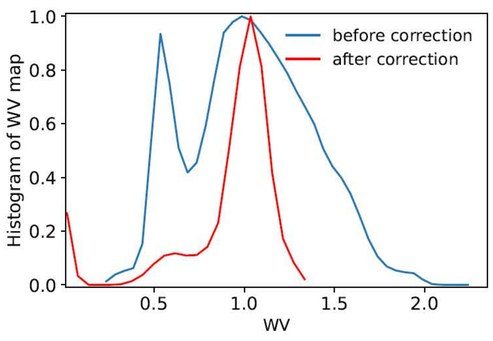
Performances: Precision = TP / (TP + FP)
Recall = TP / (TP + FN)
F_1 score = 2 (Precision^{-1} + Recall^{-1})$^{-1}$

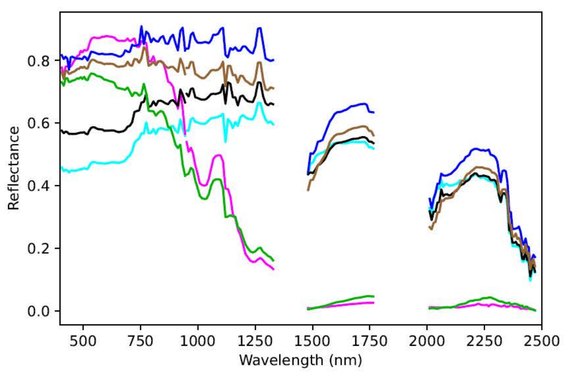
Cloud Cover (CC)

	PRISMA (16 images)	AVIRIS-NG (9 images)
CC >10%	F_1 = 0.94 - 1	F_1 = 0.94 - 0.95
CC ≤10%	F_1 = 0.86 - 0.96	F_1 = 0.79 - 0,91
Single full image	F_1 = 0.98	F_1 = 0.92
Precision on CC estimation	0,5% ± 0,5%	1.0% ± 0.9%

Reduction of dependency between WV value *w* and altitude *z* : $w = a\,z + b$ → $w^{corr} = w_0 \,.\, w / (a\,z + b)$
a and *b* are estimated with least squares → pixels with unreliable WV values and potentially cloudy pixels are not taken into account.

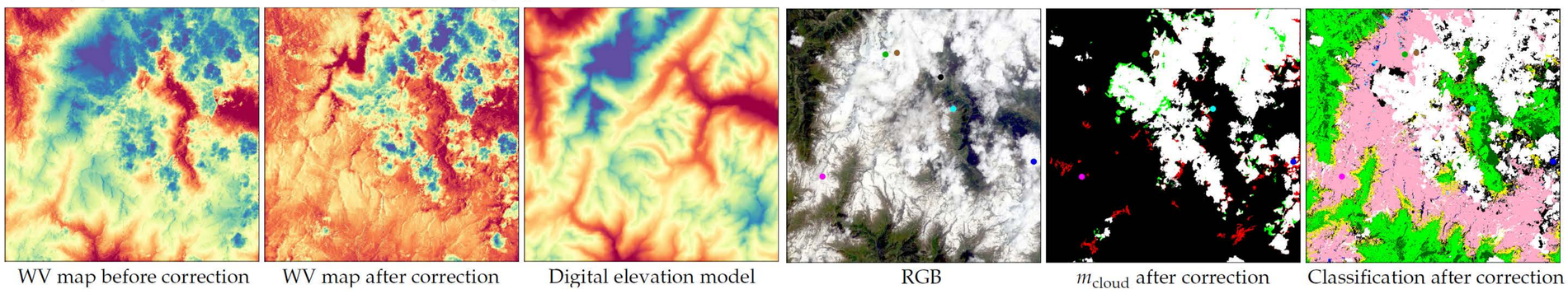






snow
cloud
dark green vegetation
dense green vegetation
sparse vegetation

WV (cm): 0.40 — 1.65 altitude (km): 1.0 — 3.6+



Future work

- Improve performances in urban areas: prior detection of roads and buildings
- Spatial characterization of clouds (texture)
- Creation of indices combining WV map and reflectance
- Adaptation of CHIWAWA for multispectral images in reflective spectral range (WordView, Sentinel2, etc.)