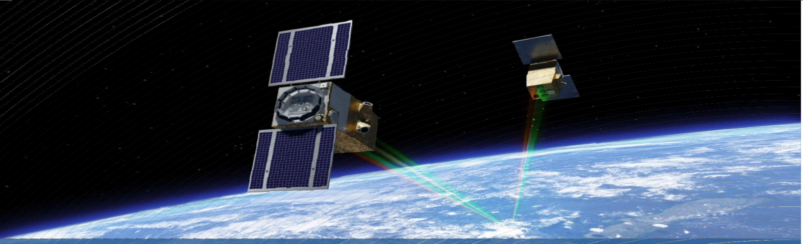

Water vapor content retrieval above and around convective clouds from space

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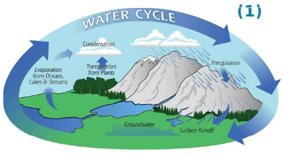
The role of water vapor in the atmosphere

(1)



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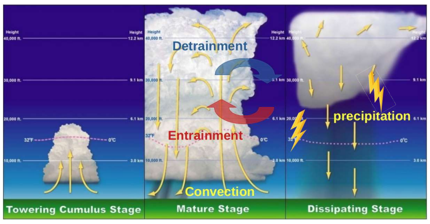
(3)



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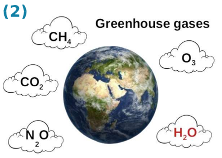
(2)



(1)→ Plays a key role in the water cycle
(2)→ Earth's most abundant greenhouse gas, responsible for about half of Earth's greenhouse effect
(3)→ Essential in the process of clouds formation such as convective clouds which contributes to the water vapor redistribution in the atmosphere

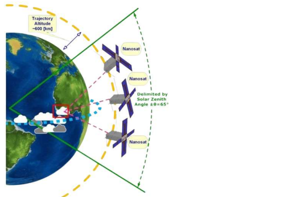
Total mass of water vapor in the atmosphere ~ 1.6×10^{16} kg (Trenberth *et al.*, 2005), it represents about 1 billion of Olympic swimming pools if all that water vapor were condensed in liquid form

C³IEL space mission project

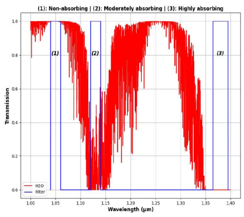
Cluster for Cloud evolution, ClImatE and Lightning

Collaboration between the French (CNES) and Israeli (ISA) space agency in order to study convective clouds at a high spatial (20 m – 100 m) and temporal (200 s) resolution (Rosenfeld *et al.*, 2022). This mission is currently suspended.

→ 3D convective cloud envelope + vertical velocity of the convective cloud development
→ **Integrated water vapor content above and around convective clouds**
→ Electrical activities generated by these convective clouds



2 to 3 nano-satellites flying in train and observing the same scene **:** 11 acquisitions of 2 to 3 simultaneous image every 20 s over 200 s



Water vapor
→ **SWIR** : 3 water vapor bands (1.04 µm, 1.13 µm and 1.37 µm)

Objective / Retrieval algorithm

Objective

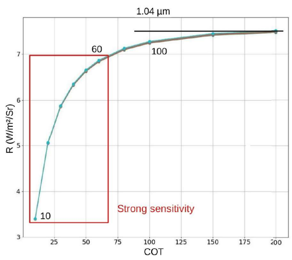
→ Retrieve the Cloud Optical Thickness (COT) and the Integrated Water Vapor Content Above Cloud (IWVC AC) using radiances measured in the SWIR water vapor bands
→ COT retrieval at 1.04 µm band
→ IWVC AC retrieval at 1.13 µm and 1.37 µm bands

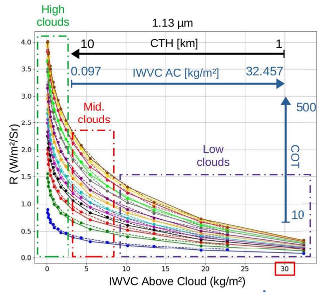
Optimal Estimation Method (OEM) : $y = F(x, b) + \epsilon$

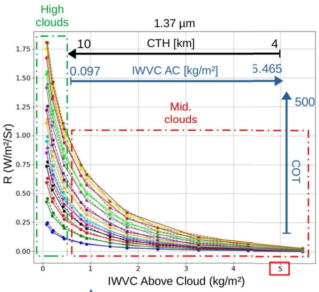
→ y : measurements vector ($R_{1.04}$, $R_{1.13}$, $R_{1.37}$)
→ F : forward model - radiative transfer model (ARTDECO, https://www.icare.univ-lille.fr/artdeco/)
→ x : state vector (IWVC AC, COT)
→ b : fixed parameters in the forward model
→ ε : error vector (for y and b)

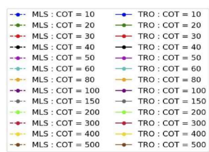
→ To find the best estimate of the state vector in order to minimize the difference between F and y (Rodgers, 2000)

Sensitivity tests of the water vapor bands to the parameters to be retrieved

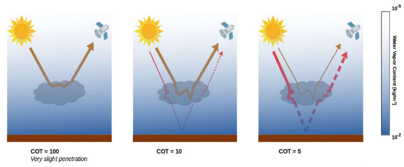








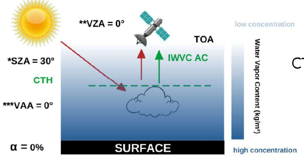
→ Radiance increases as COT increases
→ COT sensitivity decreases as COT increases
→ 1.04 µm band is strongly sensitive to COT from 0 to 60



→ Radiance decreases as IWVC AC increases
→ Radiance decreases as Cloud Top Height (CTH) decreases
→ 1.13 µm band is sensitive to low, mid and high clouds
→ 1.37 µm is sensitive to mid and high clouds

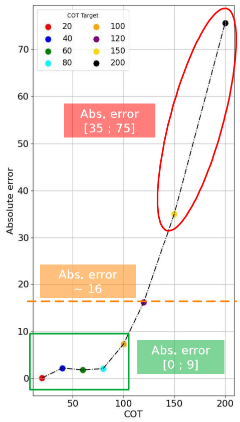
Sensitivity of the retrieval algorithm

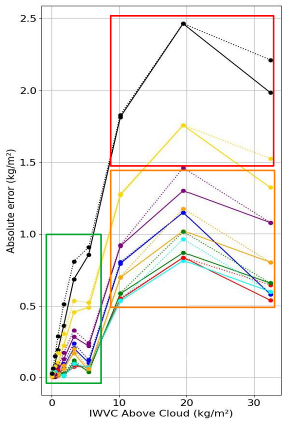
Simulation configurations



CTH from 1 km to 10 km
COT from 10 to 500

* Solar Zenith Angle (SZA)
** View Zenith Angle (VZA)
*** View Azimuth Angle (VAA)





Conclusions

→ COT retrieval is feasible with a good accuracy : absolute error from 0 to 16 for COT ≤ 120.

→ IWVC AC retrieval is feasible in cloudy sky conditions, over ocean surface, for different atmospheric water vapor contents, CTH and COT with low absolute error (≤ 1.2 kg/m²)

Perspectives

→ Deepen the tests in real cloudy sky conditions
→ Add the multi-angular aspect
→ The algorithm can be adapted to the 3MI mission

A paper is also in preparation to present this PhD works

Acknowledgments

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