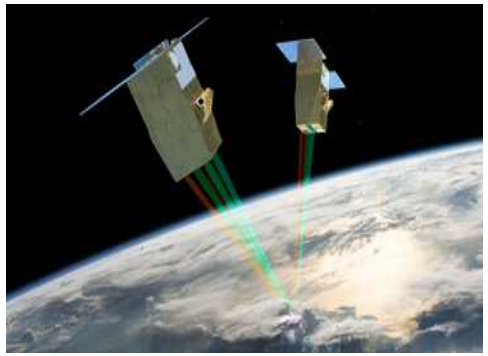


La mission C³IEL

Cluster for Cloud evolution ClImatE and Lightning

C. Cornet[1], D. Rosenfeld[2], E. Defer[3], V. Holodovsky[4], G. Penide[1], C. Price[5], D. Ricard[6], A. Rimboud[1], Y. Schechner[4], Y. Yair[7], C. Cheymol[8], A. Deschamps[8], A. Frid[9], L. Gillot[8], A. Kaidar[9], and S. Aviad[10]

[1] LOA, France | [2] The Hebrew University of Jerusalem, Israel | [3] Laero, France
[4] Viterbi Faculty of Electrical Engineering Technion, Israel | [5] Tel Aviv University, Israel
[6] CNRM, France | [7] Reichman University, Israel | [8] CNES. France
[9] Asher Space Research Institute, Israel | [10] ISA, Israel

Convective clouds are complex systems

Adapté de Villalba-Pradas 2022

Ice hydrometeor frictions => electrification
=> lightning flashes

Cooling with altitude => water vapor condensation
=> cloud droplets and/or crystal ice formation

condensation
= heating release

Precipitation formation

Subsidence

Entrainment

Detrainment

water vapour redistribution +
cloud development

Closure (cloud base mass flux)

Precipitation and
evaporation

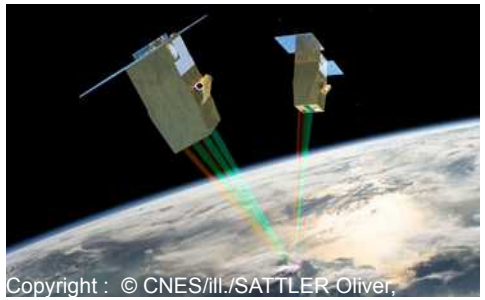
Downdraft

Updraft

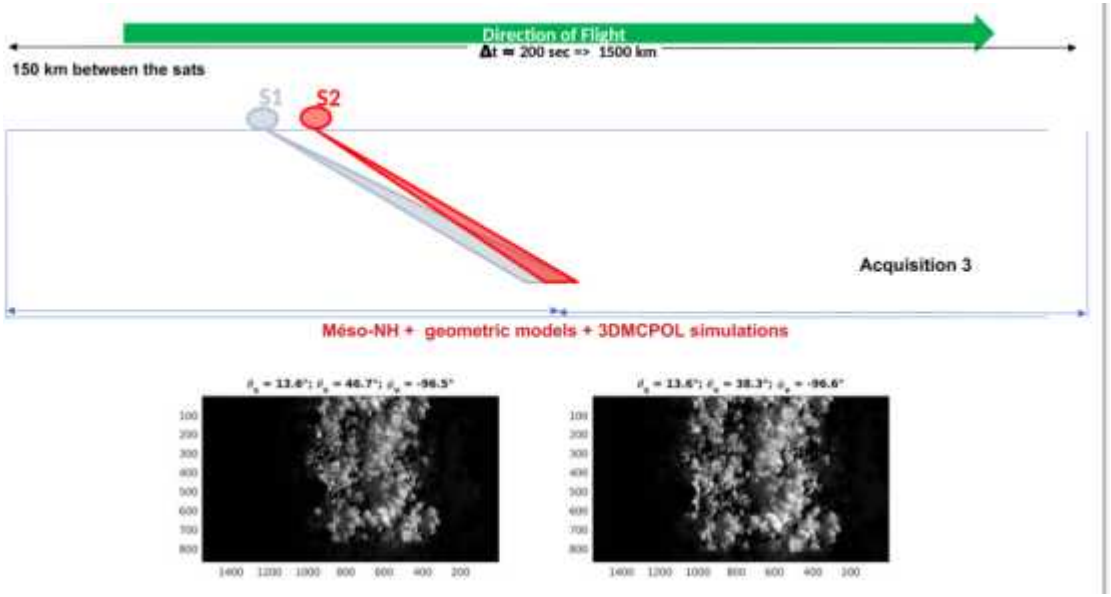
warm updrafts

Trigger

Caractéristiques des instrument



https://videotheque.cnes.fr/index.php?urlaction=doc&id_doc=37976&rang=1&id_panier=



2 synchronized satellites with :

Instrument	Characteristics	Variable	Targeted uncertainties
CLOUD *(Day)*	**Visible imager** at 647.5nm Δx_{nadir} = 17 m Δt = 20s during 200s FOV = 80 km x 45km	Cloud envelop developmment velocity	1-2 m.s^{-1} over 200s
WV *(Day)*	**SWIR** imagers at 1.04, 1.13 and 1.37 µm Δx_{nadir} = 125 m Δt = 20s during 200s FOV = 80 km x 64km	Integrated water vapor content around clouds + water vapor vertical profile	few kg.m^{-2}
LOIP *(Day and night)*	**Visible imager** at 777.4 nm Δx_{nadir} = 140 m ; Δt = 15 ms FOV = 360 km x 302 km **Photometer** at 777.4, 337 and 391 nm FOV = ~360 km diameter sampling at 20 kHz	Spatial and temporal lightning activity	70 to 90% of detection efficenciy

Orbit : ascending node orbit at 1:30

Day orbit : 4 sequences of 11 acquisitions of 2 cloudy scenes (images)

Night orbit (LOIP) : continuous measurement during 1200s (20 min)

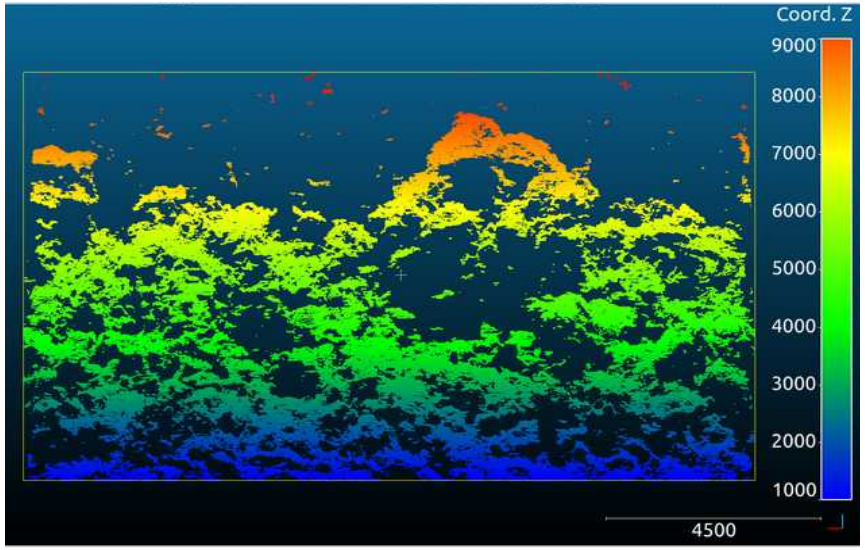
Sun-synchroneous orbit with local time at the tropics between 12:00 and 14:00 PM with a preferred time at 13:30 pm and a maximum drift of one hour, only toward a later local time (+1h)

Launch scheduled for 2028

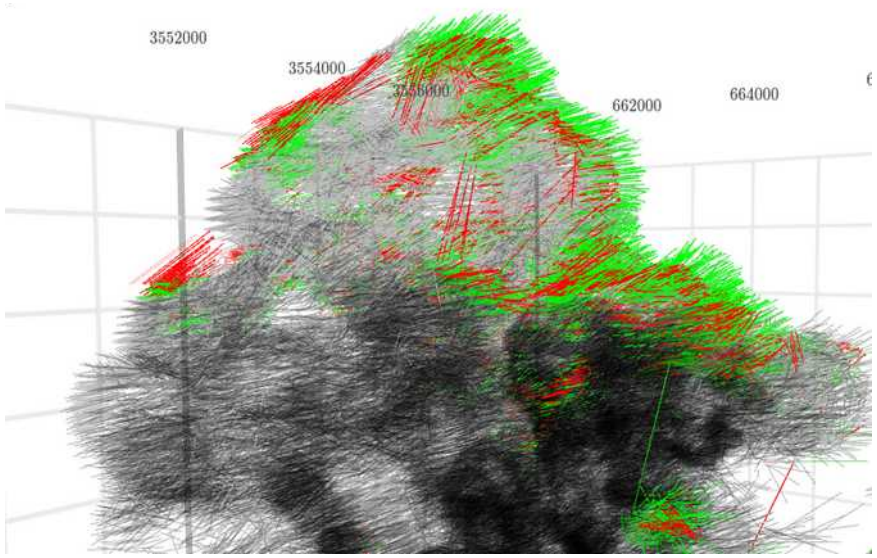
CLOUD : Enveloppe et vitesse de développement du nuage par stéréo-restitution

Instrument	Characteristics	Variable	Targeted uncertainties
CLOUD *(Day)*	**Visible imager** at 647.5nm Δx_{nadir} = 17 m Δt = 20s during 200s FOV = 80 km x 45km	Cloud envelop developmment velocity	1-2 $m.s^{-1}$ over 200s

L2A : 3D points de l'enveloppe du nuage



L2B : vitesse de développement de l'enveloppe



Black vectors: Ground estimation velocity vectors.
Red vectors: Velocity vectors from stereo-restitution
Green vectors: Ground estimation vectors (originally plotted in black), close to the red stereo-restituted vectors.

+

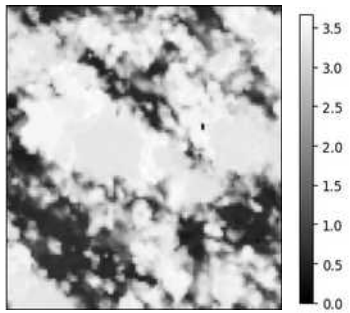
L3 : vitesse moyenne de sommets nuageux sur 200s

Dandini, et al., 2022, AMT

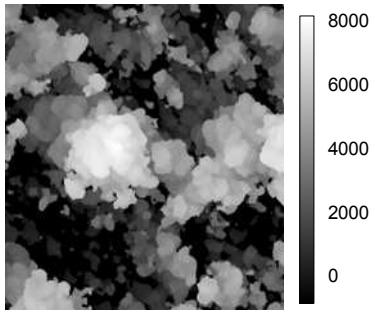
WV : restitution de la vapeur d'eau autour des nuages

Instrument	Characteristics	Variable	Targeted uncertainties
WV *(Day)*	**SWIR** imagers at 1.04, 1.13 and 1.37 µm Δx_{nadir} = 125 m Δt = 20s during 200s FOV = 80 km x 64km	Integrated water vapor content around clouds + water vapor vertical profile	few $kg.m^{-2}$

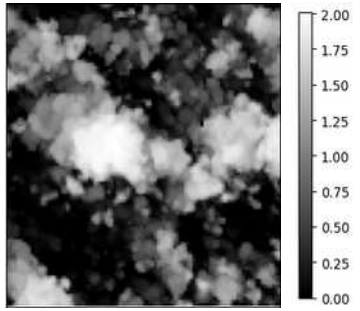
L2 : contenu intégré au-dessus des nuages



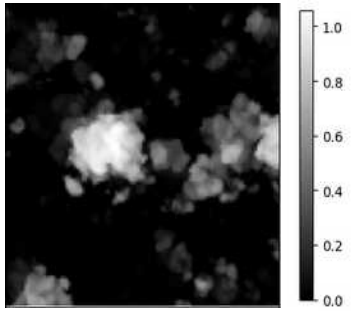
1040 nm (ARTDECO)



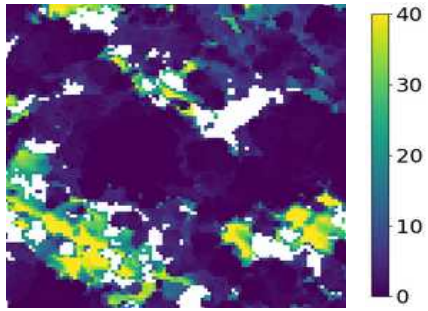
CTH (m) = CLOUD



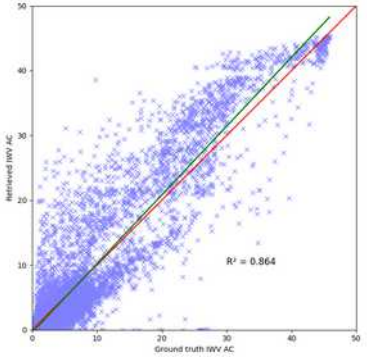
1130 nm (ARTDECO)

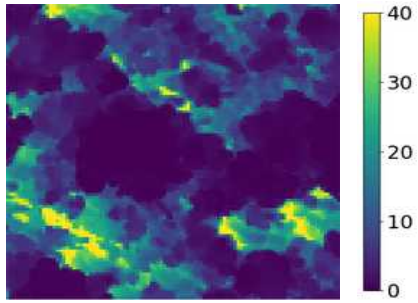


1040 nm (ARTDECO)

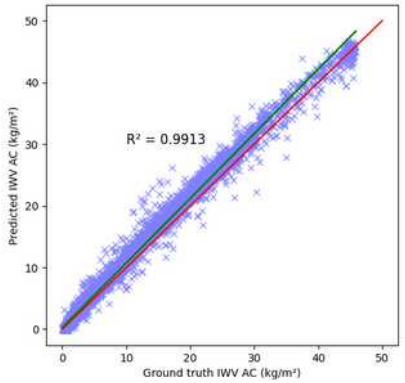


IWV AC (OEM) (kg/m²)

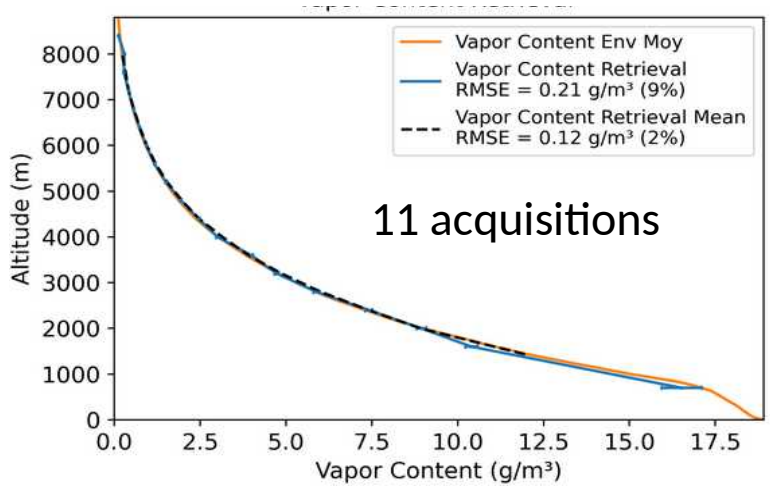




IWV AC (Auto-encoder) (kg/m²)

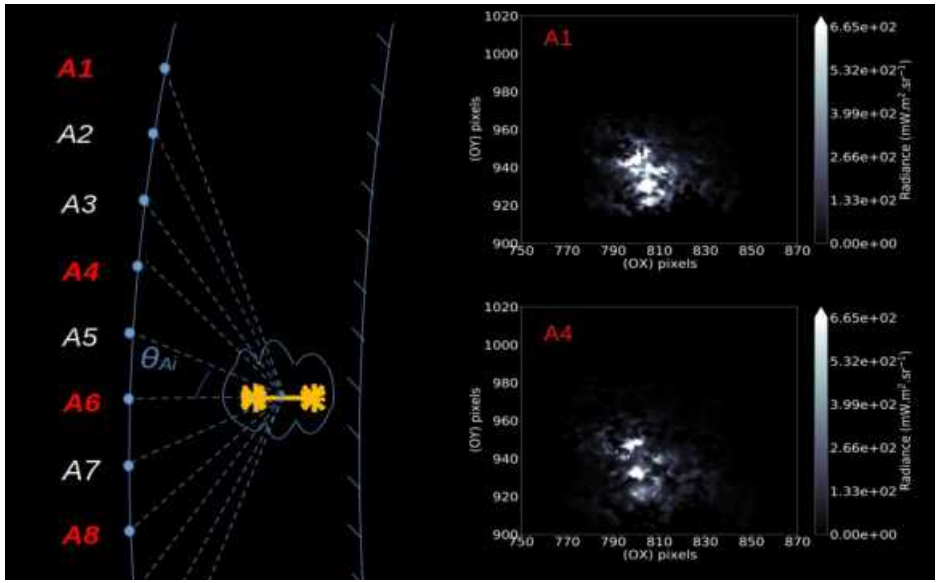


L3 : Profil moyen de la scène nuageuse



Thèse Alexis Zemb
Peroni et al., 2025, AMTD

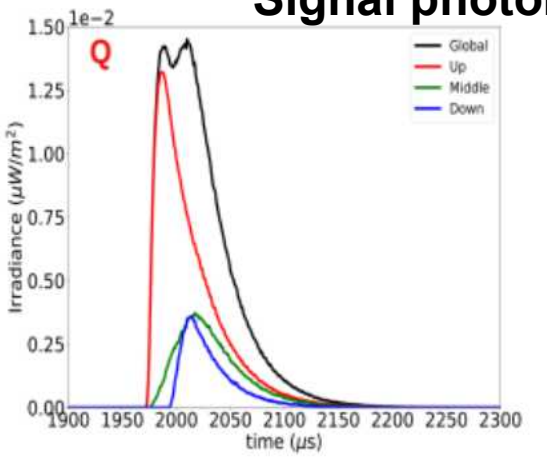
LOIP : Observation de l'activité électrique



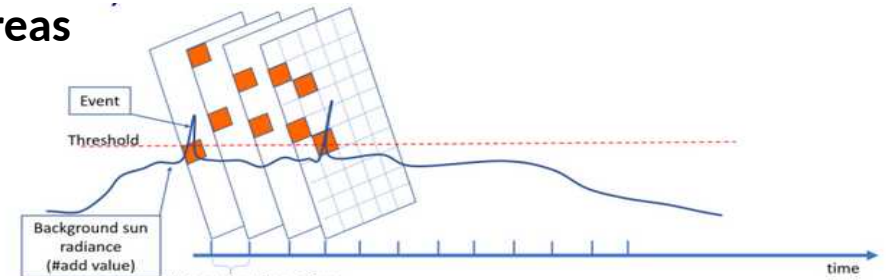
Realistic numerical simulation of the optical lightning signal
(Rimboud et al., in preparation

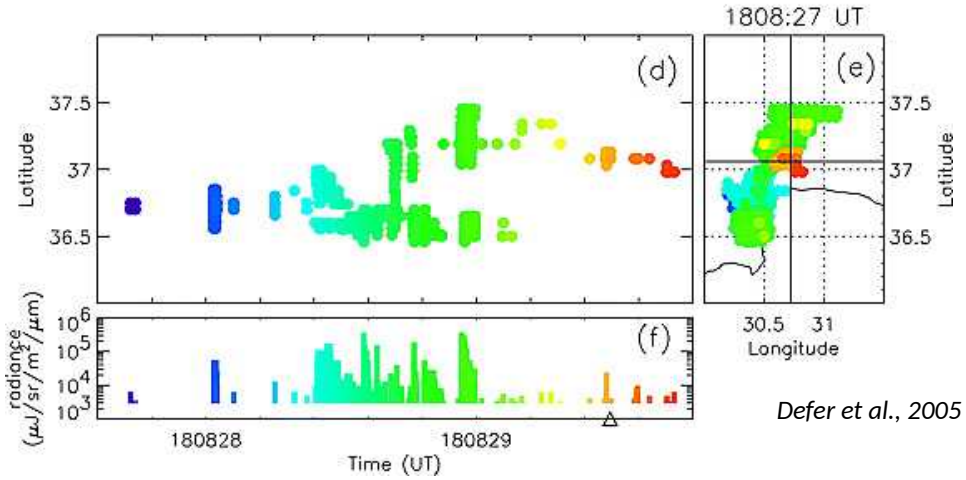
Instrument	Characteristics	Variable	Targeted uncertainties
LOIP *(Day and night)*	**Visible imager** at 777.4 nm Δx_{nadir} = 140 m ; Δt = 15 ms FOV = 360 km x 302 km **Photometer** at 777.4, 337 and 391 nm FOV = ~360 km diameter sampling at 20 kHz	Spatial and temporal lightning activity	70 to 90% of detection efficenciy

Signal photométrique



L2A : Illuminated pixels are merged together to form a group, and groups in flashes, and flashes in areas





Defer et al., 2005

C3IeL
CLUSTER FOR CLOUD EVOLUTION CLIMATE AND LIGHTNING

=

New observations of convective clouds, their environments and the associated lightning activity

Launch in 2028 !