C³IEL Mission

Cluster for Cloud Evolution, ClimatE and Lightning

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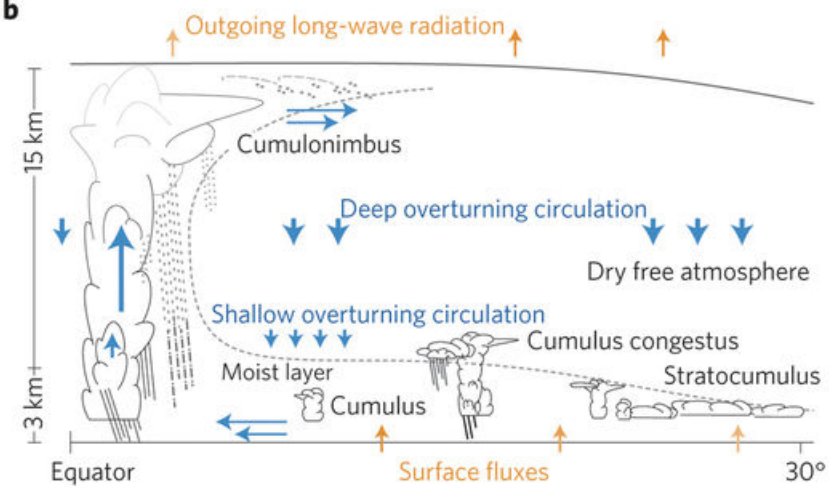
C³IEL : Scientific objectives
1 - Dynamic of the clouds

a

b



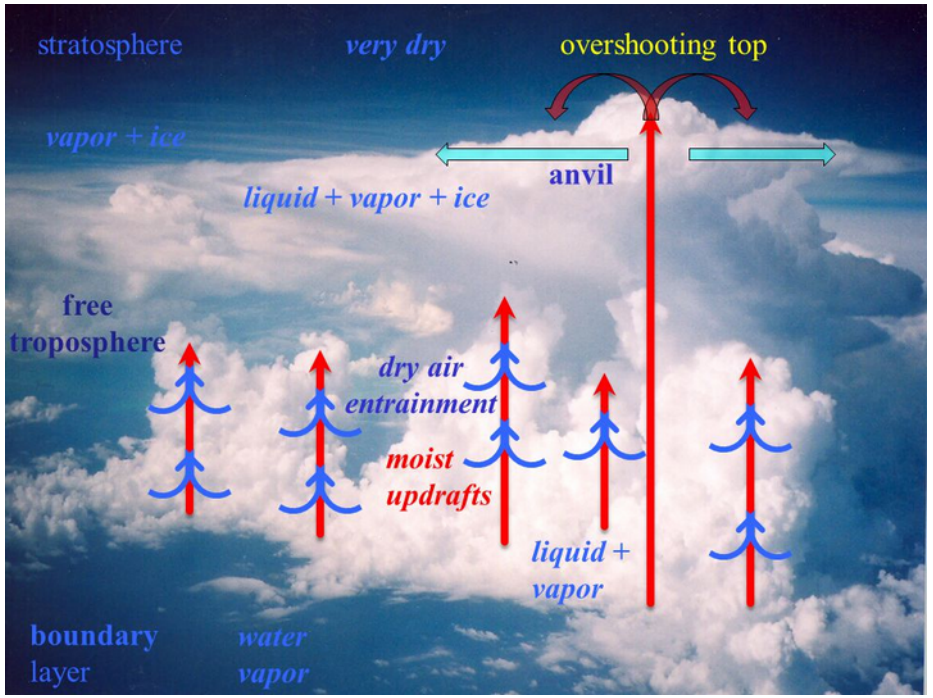
Bony et al. , 2015

According to the latitude, **convective clouds** are diverse with different sizes but all are growing by successive cascade of eddies :

⇒ **Dynamic of small cloud structures** are related to updrafts and downdrafts in the clouds

⇒ **Cloud horizontal and vertical growth** are essential variables for understanding the development and organization of convective clouds

C³IEL : Scientific objectives
2- Cloud and water vapor interactions



Science benefits :

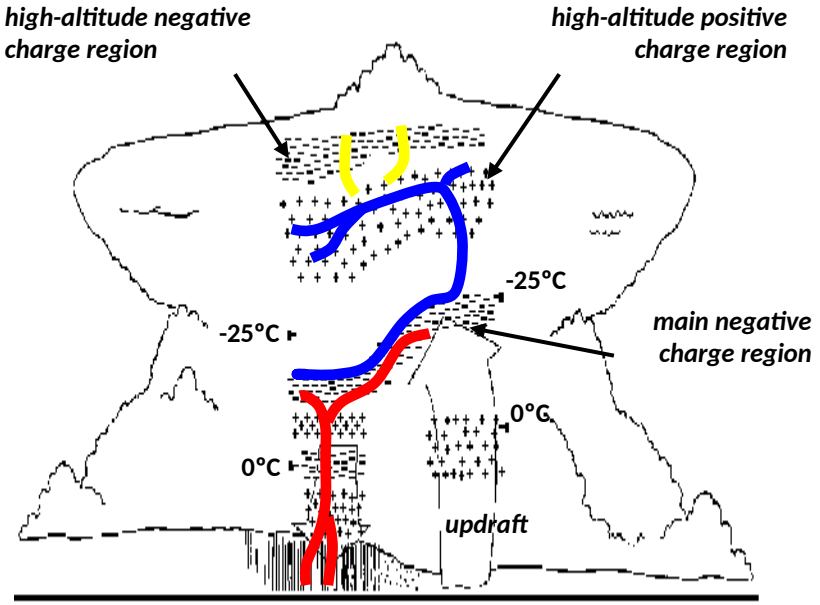
- ***Water vapor and cloud interactions***
- ***Water vapor redistribution in the atmosphere***
- ***Entrainment/detrainment processes between clouds and their environment***
- ***Statistical relationships between spatial organization and amount of water vapor***

C³IEL : Scientific objectives
3- Lightning Activity in relation with cloud dynamics

Science objectives :

- **Links between dynamics, microphysics, precipitation and lightning occurrence**
- **Scattering of the optical lightning signal by ice and liquid hydrometeors => lightning physics**
- **Links between lightning activity and upper tropospheric water vapor (UTWV)**

- ***Lightning census at high latitudes***
- ***Lightning as a proxy of the convective processes***
- ***Lightning to constrain radiative transfer codes***

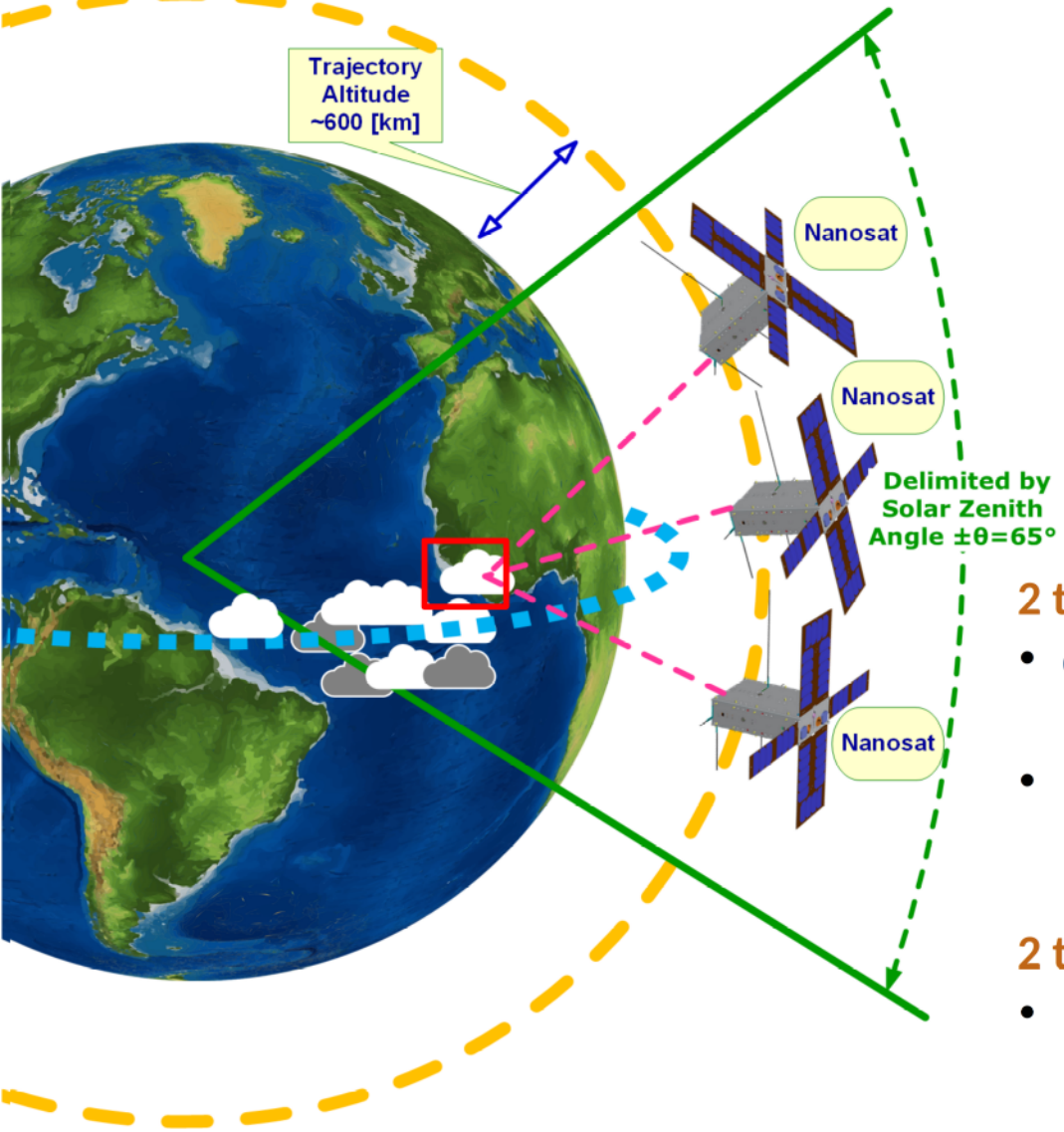


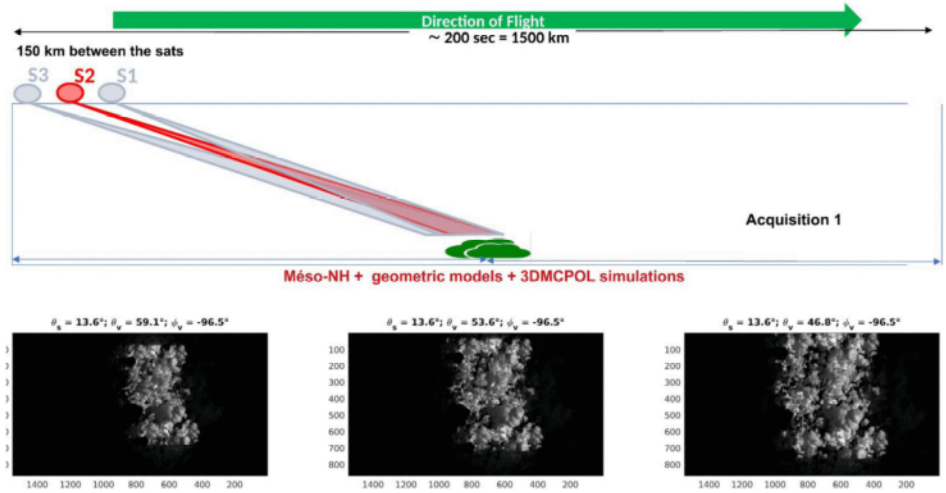
(adapted from Stolzenburg et al., 1998)

Unique scientific novelty of C³IEL

<u>Simultaneous measurements</u> of lightning activity, development rate of the parent cloud towers and surrounding water vapor context from the same platforms and along the same observational strategy to investigate the complex processes of convection

C³IEL :
Cluster for Cloud evolution, ClimatE and Lightning





2 to 3 simultaneous <u>daytime</u> observations with :

- CLOUD (20m) and WV (water vapor) imagers measuring every 20s during 200s
- Lightning Optical Imagers and photometers measuring continuously during 200s

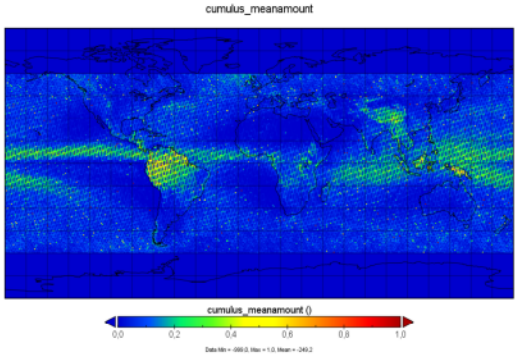
2 to 3 simultaneous <u>nighttimes</u> observations with :

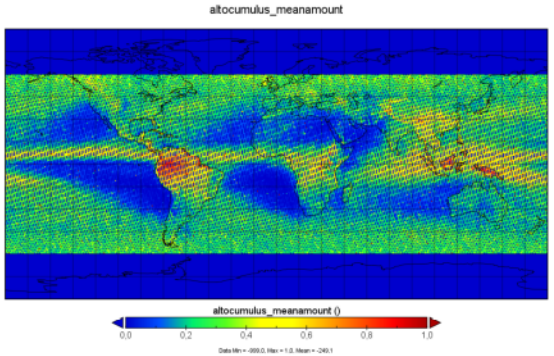
- Lightning Optical Imagers and photometers measuring continuously

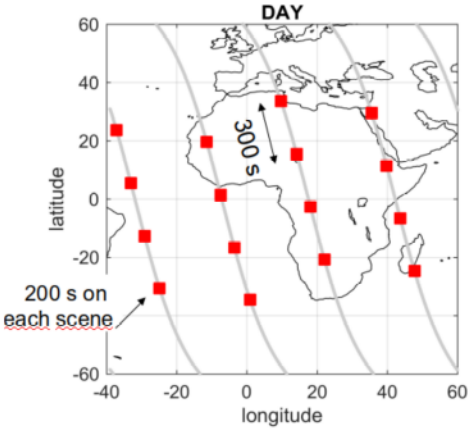
C³IEL : Daytime Observational Strategy

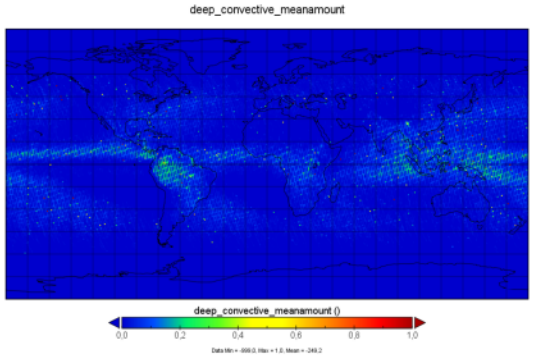
Multi-view images of 45 km x 80 km every 300s

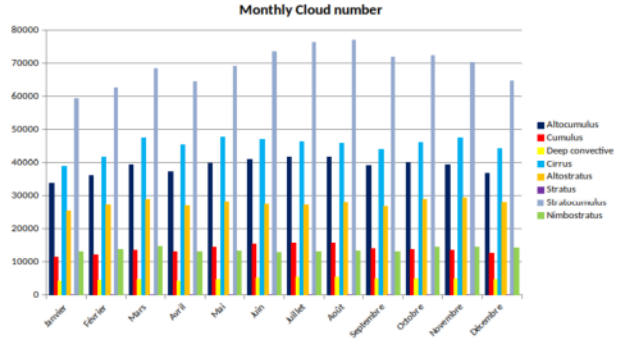
Assessment from 2B-CLDCLASS (CLOUDSAT)











=> about 42000 convective cloud scenes for 4 acquisitions per orbit and a two years missions

Acknowledgments ICARE-AERIS datacenter :
https://en.aeris-data.fr/?noredirect=en_GB

To be improved with the 2B-CLDCLASS-LIDAR products and multi-layer clouds flags

CLOUD Scientific Observations

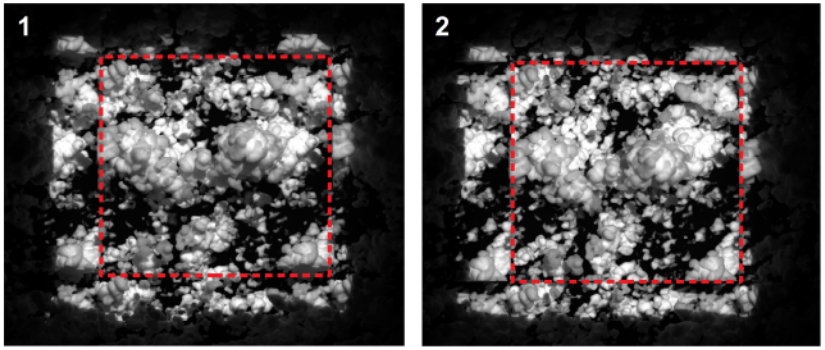
CLOUD imagers (λ=670nm) at 20m resolution for Nadir camera to derive cloud envelop every 20s during 200s

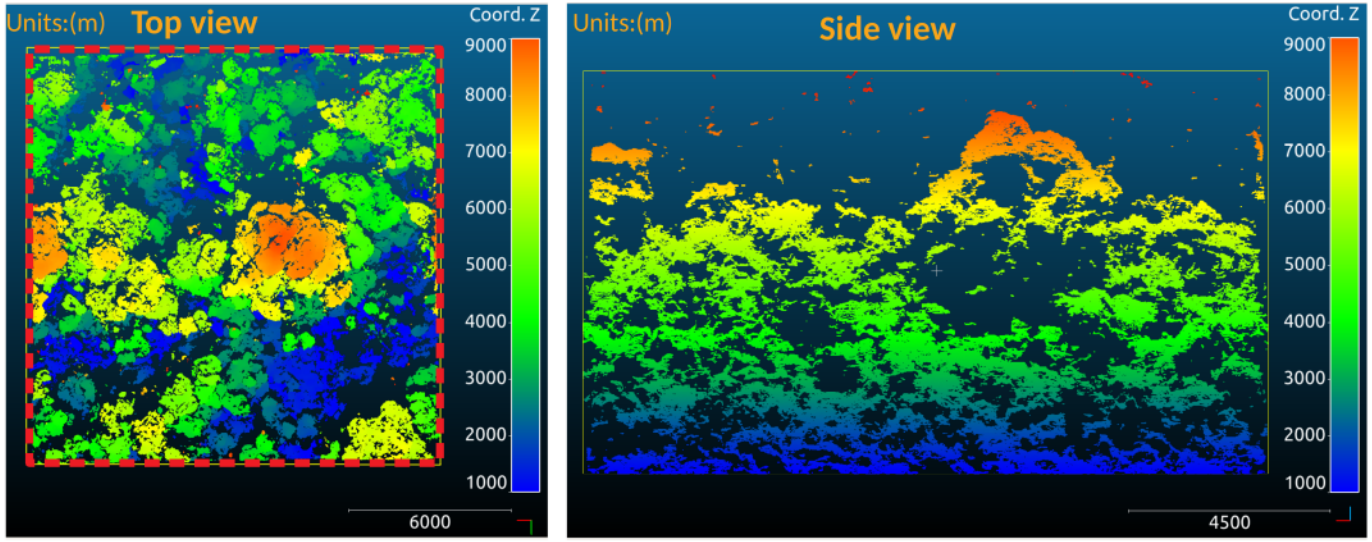
2 or 3 images + Geom. Cam. models

3D retrieval
Satellite Stereo pipeline
(S2P or CARS)

3D point cloud (every 20s)

MESO-NH model => 3DMCPOL simulations.

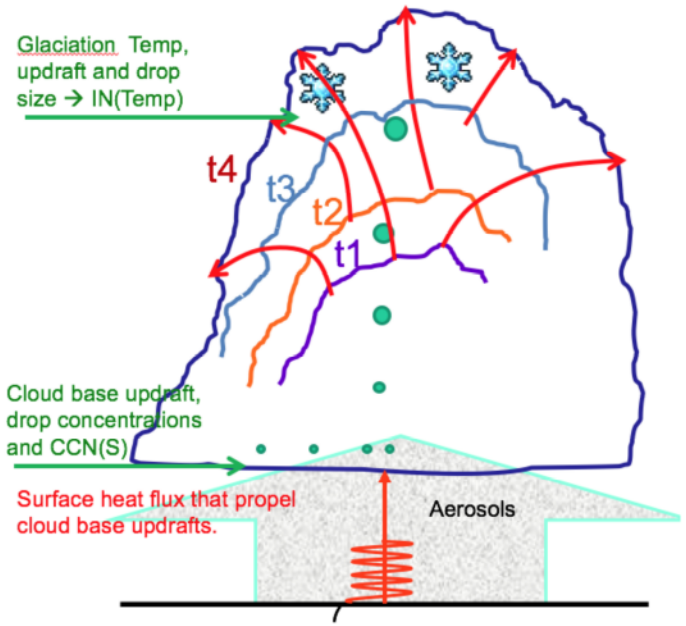




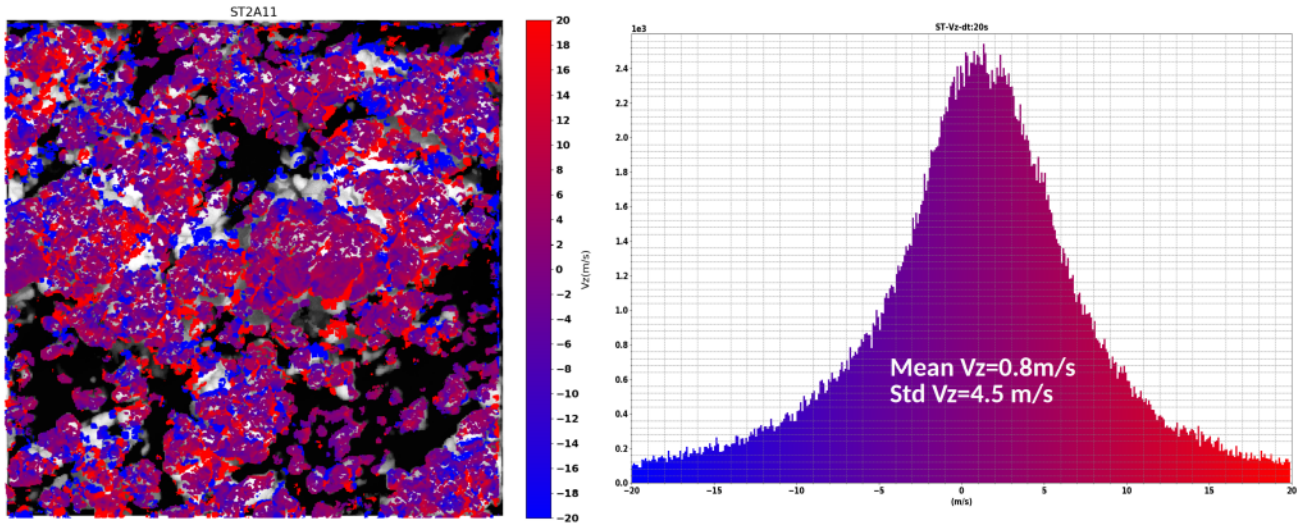
CLOUD Scientific Observations

CLOUD imagers (λ=670nm) at 20m resolution for Nadir camera to derive cloud envelop every 20s during 200s and 3D cloud development velocities

- **Cloud development = velocity along x, y, z of the envelop**

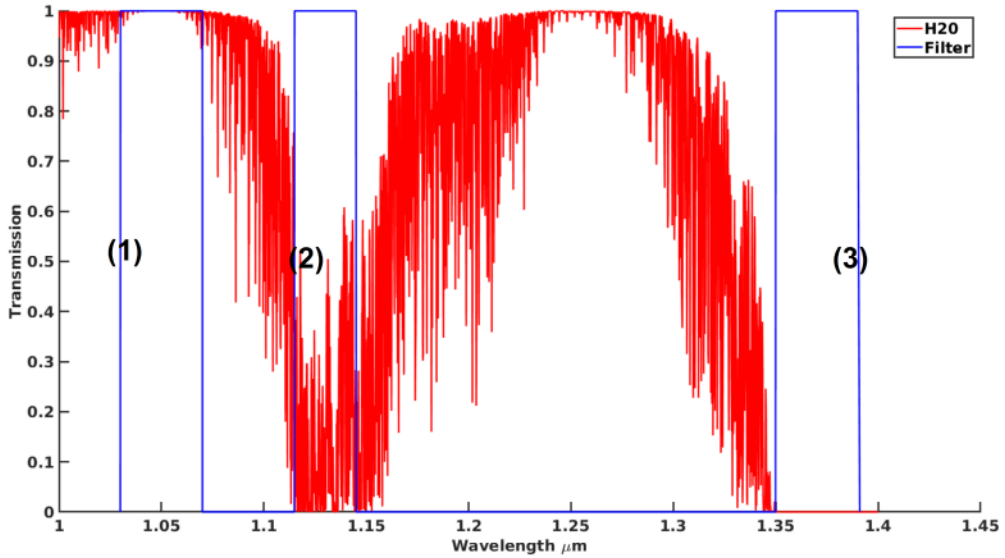


Example : vertical velocity along z



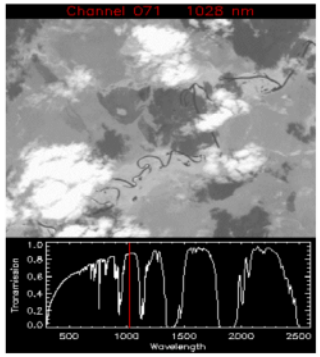
Water Vapor Scientific Observations
Imagers at 3 wavelengths with 125 m resolution

Atmospheric water vapor transmission spectra :



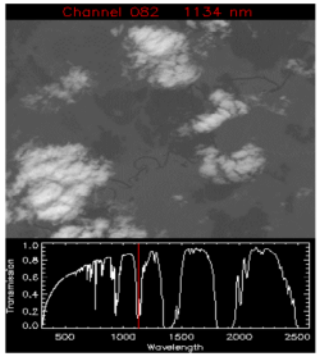
Examples of Aviris data for the three C³IEL channels

1050±20 nm



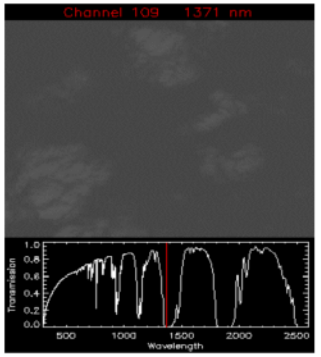
(1) Non absorbing channel => Background

1130 ±15 nm



(2) Moderate absorbing channel => WV Lower Atmosphere

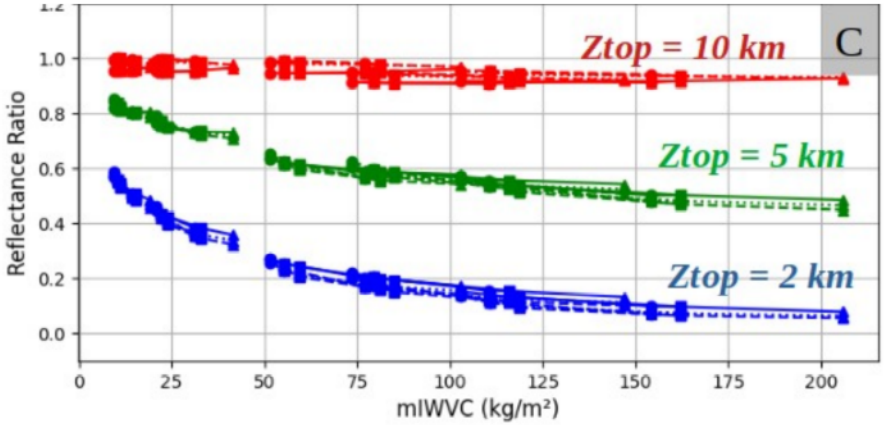
1370 ± 20nm



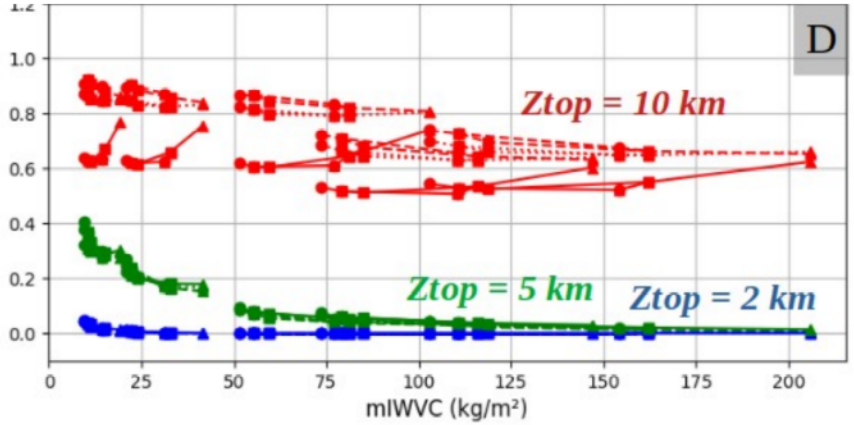
(3) Highly absorbing channel => WV Upper trosposphere

Water Vapor Scientific Observations
Imagers at 3 wavelengths with 125 m resolution

Radiances ratio are function of (air mass factor * vertically integrated water vapor)



Ratio R1130/R1040
(Moderate aborbing)



Ratio R1370/R1040
(Highly aborbing)

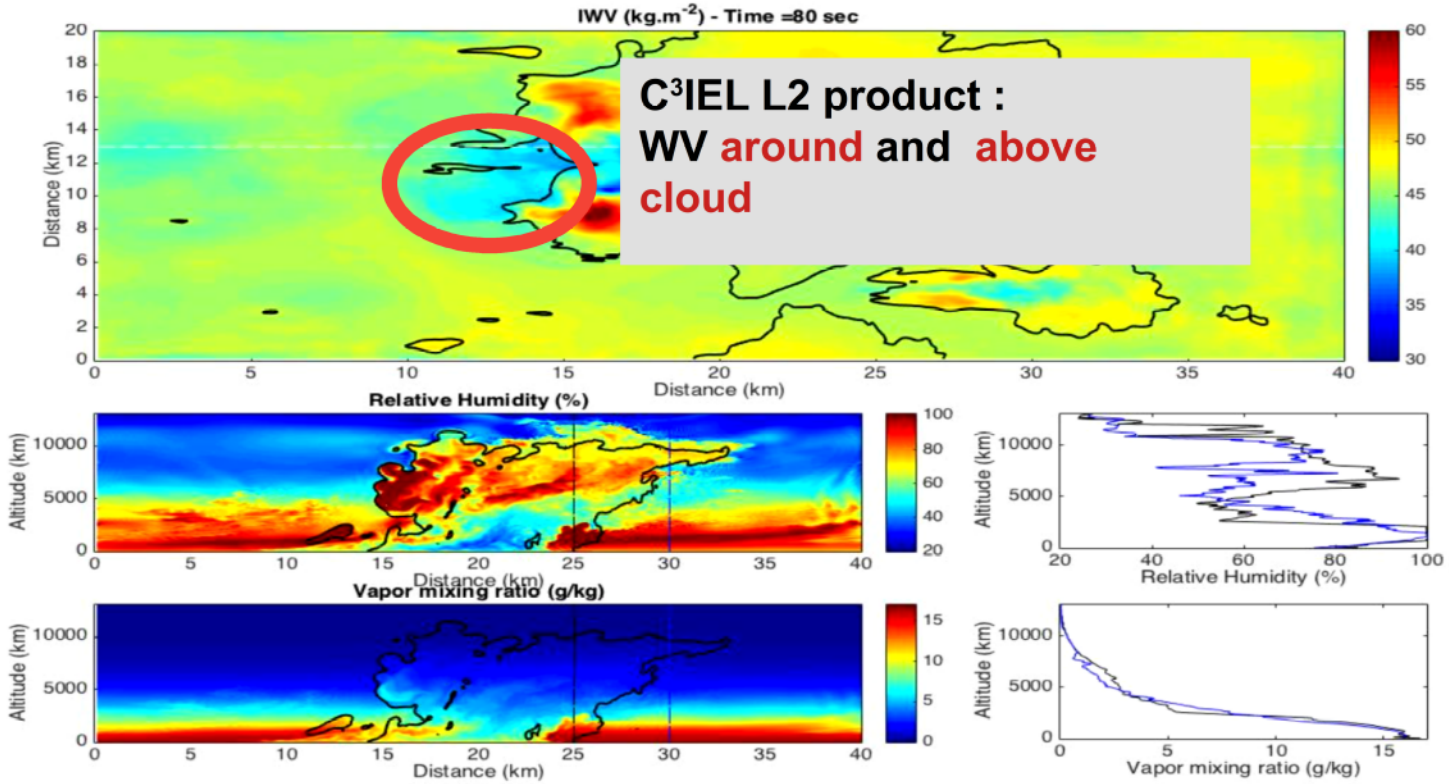
Water Vapor Scientific Observations
Integrated Water Vapor in cloudy atmosphere

- LES (RAMS) simulations (G. Penide) with an horizontal resolution of 100m for Δt=20s

Integrated water vapor in the whole atmosphere

Relative humidity in the atmosphere

Water vapor mixing ratio



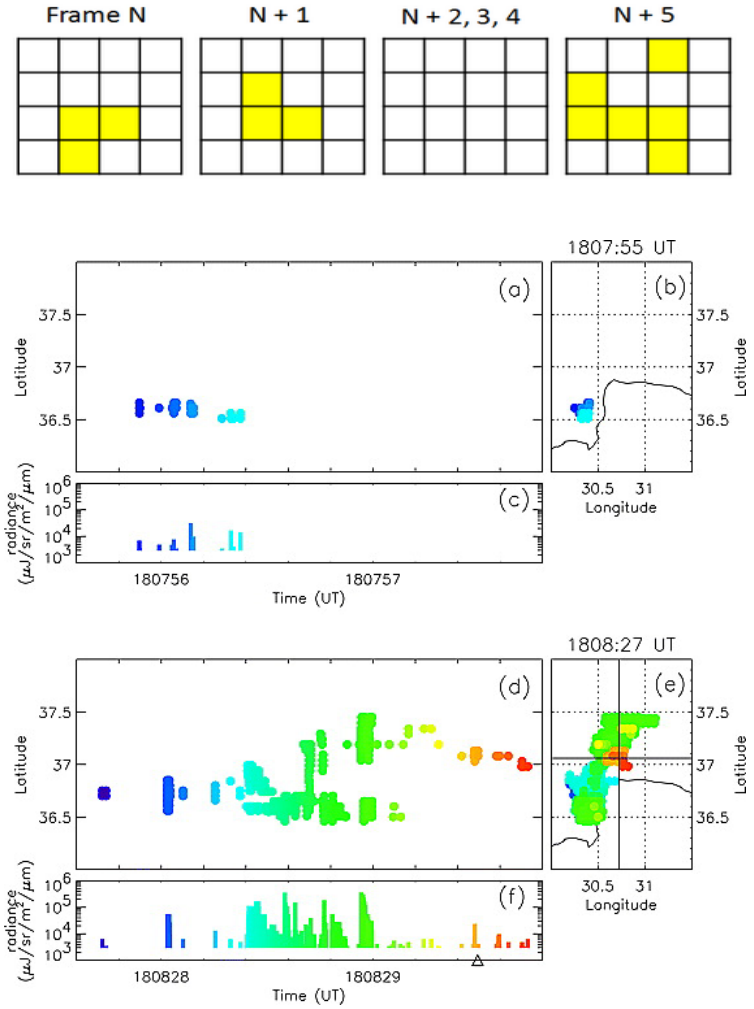
LOIP Lightning Imager Principle

(E. Defer et al.)

- **Detection at 777.4 nm (O2) of transient optical radiation with narrow filter (few nm)**
- **A flash is seen as a succession of illuminated pixels not necessary adjacent in time and space**

- **Comparison between a given frame with the background (integrated over many frames) to identify pixels with signal exceeding a given threshold**
  - On board data processing required to send to ground ***only illuminated pixels***
  - **Background images** to be sent as well to the ground for verification and post-processing (L1 → L2)

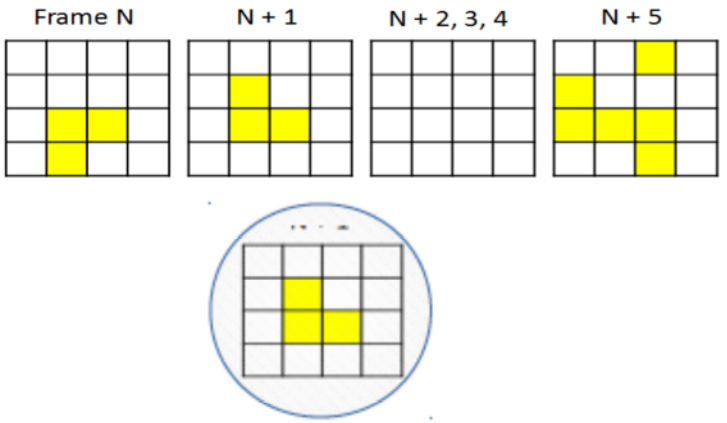
- **Time and space criteria used to merge illuminated pixels (« *events* ») in flash components (« *groups* »), and groups in flashes (« *flashes* ») [*parent-children structure*]**



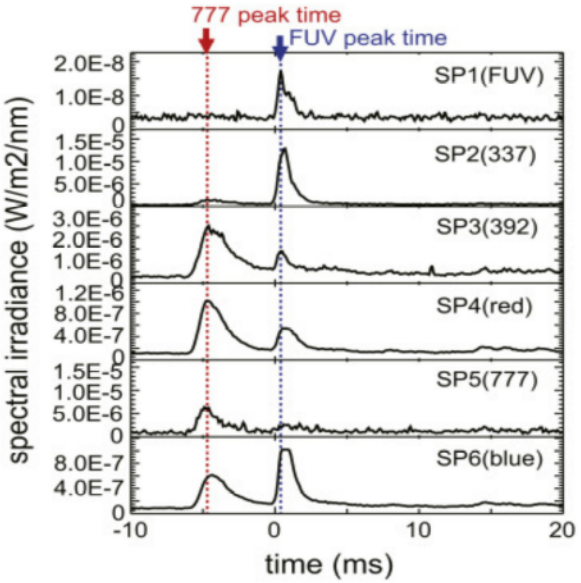
Case of two flashes during one TRMM-LIS overpass over Antalya region (Turkey) on 5 Dec 2002 (Defer et al., 2005)

LOIP Photometer Principle

(E. Defer et al.)



- **Record of the waveform of the optical signal radiated by a lightning flash at different wavelengths (near-UV and visible)**
- **The field of view of the photometers will cover the entire domain observed by the optical imager (sort of « single pixel »but of large scale)**
- **Photometer signal consists in a time series of the calibrated irradiance (one for each observed spectral domain)**
- **Photometer response recorded at temporal resolution (~10 kHz)**



(Adachi et al., 2016)

To summarize

C³IEL is a train of 2 to 3 satellites :

- **New space mission (launch planned in 2024) dedicated to convective clouds**
- **New measurements of clouds and their environment with**

- **CLOUD (high resolution imagers) to derive cloud envelops and cloud development velocity**
- **WVI (Water Vapor Imagers) at 3 wavelengths to derive water vapor content around clouds**
- **LOIP (Lightning Imagers and Photometers) to obtain flash properties and 3D time-dependent lightning activities**

In progress :

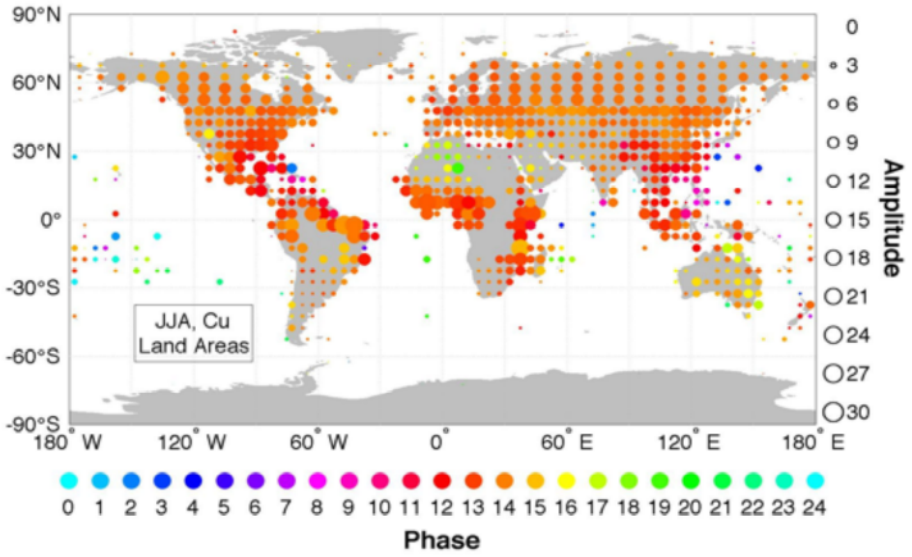
- **Retrieval algorithm under progress => definition of retrieved product will be adjusted (e.g.: velocity every 20s or for the 200s; IWVC for the all atmosphere or only above cloud ?)**

Thank you for your attention !

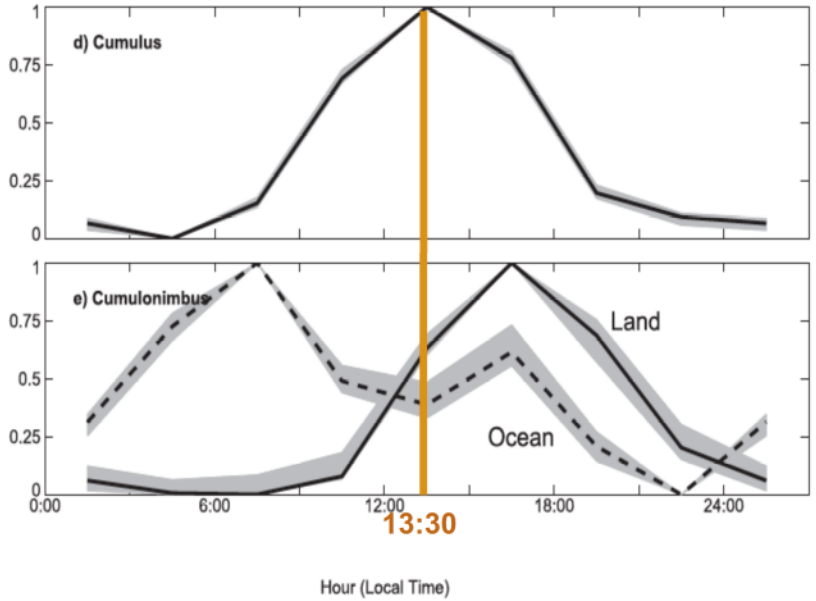
C³IEL : Observational Strategy : 13:30 LT

Statistical cloud occurrence from ground observation (Eastman et Warren, 2014)

Phase = Maximal occurrence hour



Average diurnal cycle



Eastman et Warren, 2014

=> 13: 30 : Numerous developing convective clouds

Additionally, 13:30 gives possibility to use Joint Polar Satellite System (JPSS) coincidence