C^2OMODO/AOS : vertical motion within convective cells

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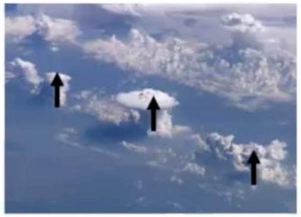
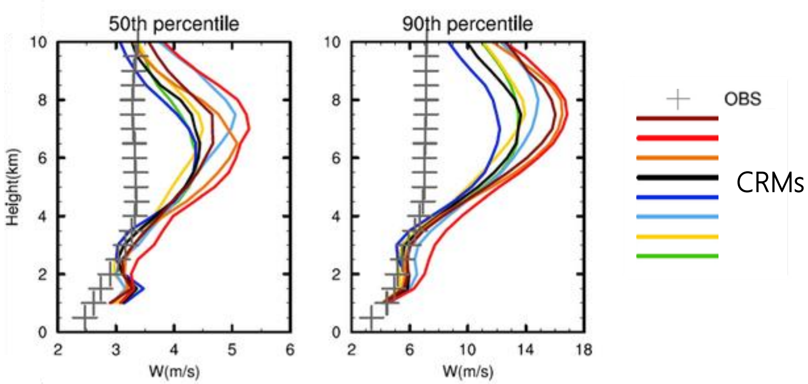
GEWEX UTCC-PROES meeting – IPSL – 19-21 May 2025

Some locks on deep convection

✓ One important parameter is the convective mass flux, related to the strength of the updraft, which influences the intensity of convection as well as precipitation rates



✓ Numerical models fail at producing the vertical velocity observed within convective updrafts which is related to lacks of understanding of its properties *(horizontal size, strength, duration, growth of anvil…)* and their relationship to environmental factors *(role of aerosols, role of moisture, …)*



Vertical profiles of updraft vertical velocity at the 50th and 90th percentiles, with observed estimated retrieved from multi-Doppler retrievals for a squall line observed in the US Great Plains, represented by "+". The sampled convective updrafts are defined by w > 2m/s

[Fan et al, 2017]

⇒ Observing/Measuring the convective mass flux (area & intensity) at a global scale will help to improve the representation of deep convection, linked to extreme events, in weather prediction models as well as in climate models

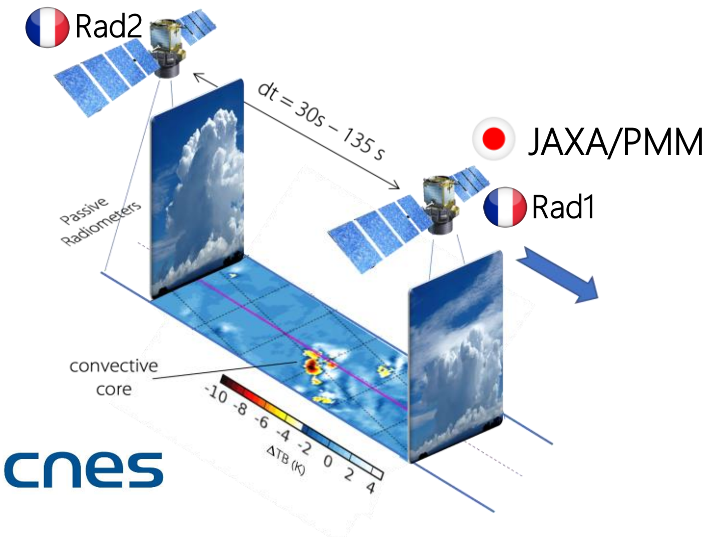
Past, current and future satellite missions for cloud dynamics (not exhaustive)

Target	Method	Refs
Cloud top vertical velocity	Rapid scan mode of IR imagers from geostationnary satellites	Adler & Fenn (1979) … → Hamada & Takayabu (2016)
	Vertical velocity of convective tops within A-Train (Aqua + Cloudsat CPR)	Luo et al (2014), Masunaga & Luo (2016)
	3D-envelop of cloud tops with stereocameras C3IEL mission (CNES-ISA) *scheduled 2028*	Rosenfeld et al (2022)
	Height-resolved cloud top motions with stereo IR instruments Harmony (ESA Earth Explorer 10) *scheduled 2029*	Lopez-Dekker et al (2021)
In-cloud vertical velocity	<u>Active sensors</u> : radars - W-band (94 GHz) with <u>Doppler</u> mode EarthCARE (NASA) *launched in 2024* WIVERN (ESA) Earth Explorer 11 candidate (selection summer 2025) - short delays (30-120s) Ka-band (35 GHz) INCUS mission (NASA) *scheduled in 2026*	Illingworth et al (2015), Kollias et (2022).. Illingworth et al (2018).. Sy et al (2017), Prasanth et al (2023), Haddad & Sy (2024)…
	<u>Passive sensors</u> : MW radiometers C^2OMODO (CNES) *scheduled 2029-2030*	Brogniez et al (2022), Lefebvre et al (2025)…

mission

"Convective Core Observations through MicrOwave Derivatives in the trOpics"

NASA/C²OMODO-Sat



Phase B since July 2024

Scientific overarching goals :

Understanding the evolution of updrafts during the life cycle of convective cells

> Water cycle : rainfall and extreme events
> Energy cycle: development of anvil clouds

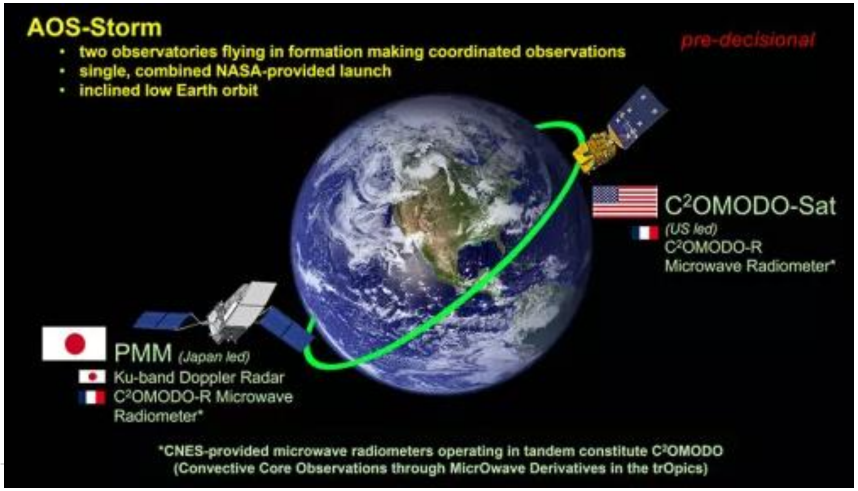
Objectives of the mission :

Document and map the intensity of updrafts associated to deep convection

Design :

Two twin multispectral passive microwave radiometers in absorption bands (183GHz and 325GHz) on two satellites

French labs involved



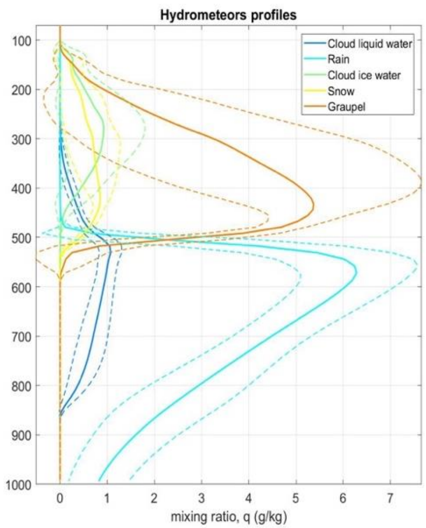
Some technical details

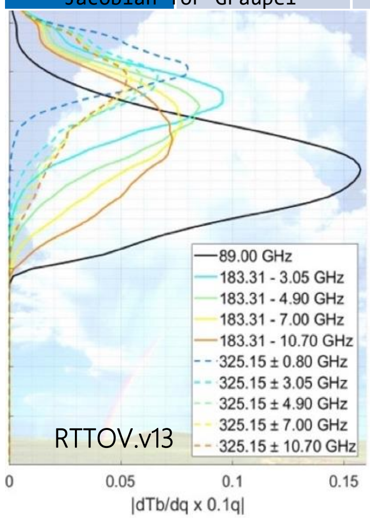
The C²OMODO-Radiometer

Central frequencies f_0 (GHz)	Frequencies (GHz)			Bandwidth (MHz) [min-max]	NEDT (K)	Target IFOV
89	(C0)			3333 - 4000	< 0,5	≤ 20 km, 10km at nadir
183,31	Single Side Band cf AWS/Sterna	f_0 - 3,05 f_0 - 4,90 f_0 - 7,00 f_0 - 10,7	(C1) (C2) (C3) (C4)	1250 - 1500 1500 - 1800 1667 - 2000 2500 - 3000	< 1,1 < 1 < 1 < 0,8	≤ 10 km 5 km at nadir
325,15	Double Side Band	f_0 ± 0,80 f_0 ± 3,05 f_0 ± 4,90 f_0 ± 7,00 f_0 ± 10,7	(C5) (C6) (C7) (C8) (C9)	667 - 800 1250 - 1500 1500 - 1800 1667 - 2000 2500 - 3000	< 3,7 < 2,7 < 2,5 < 2,5 < 2	≤ 10 km 3 km at nadir

3km & 5km footprint resolutions
⇒ will allows to detect regions of intense vertical transport [Dolan et al, 2023]

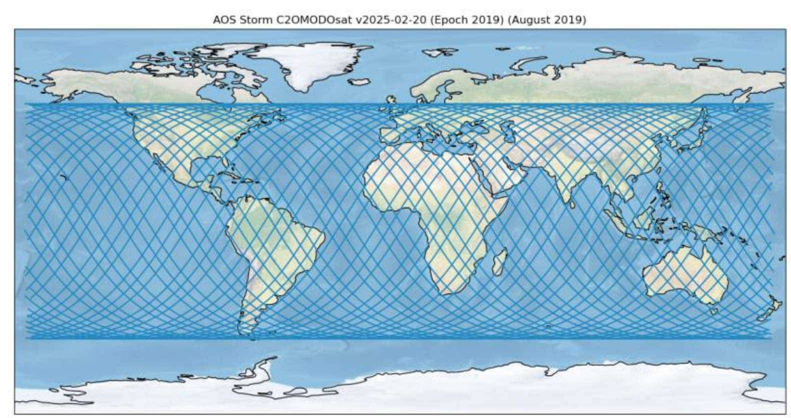
+ swath of 700km (altitude of satellite ~ 430km)
⇒ horizontal mapping of convective cells and for not-to-wide organized convection



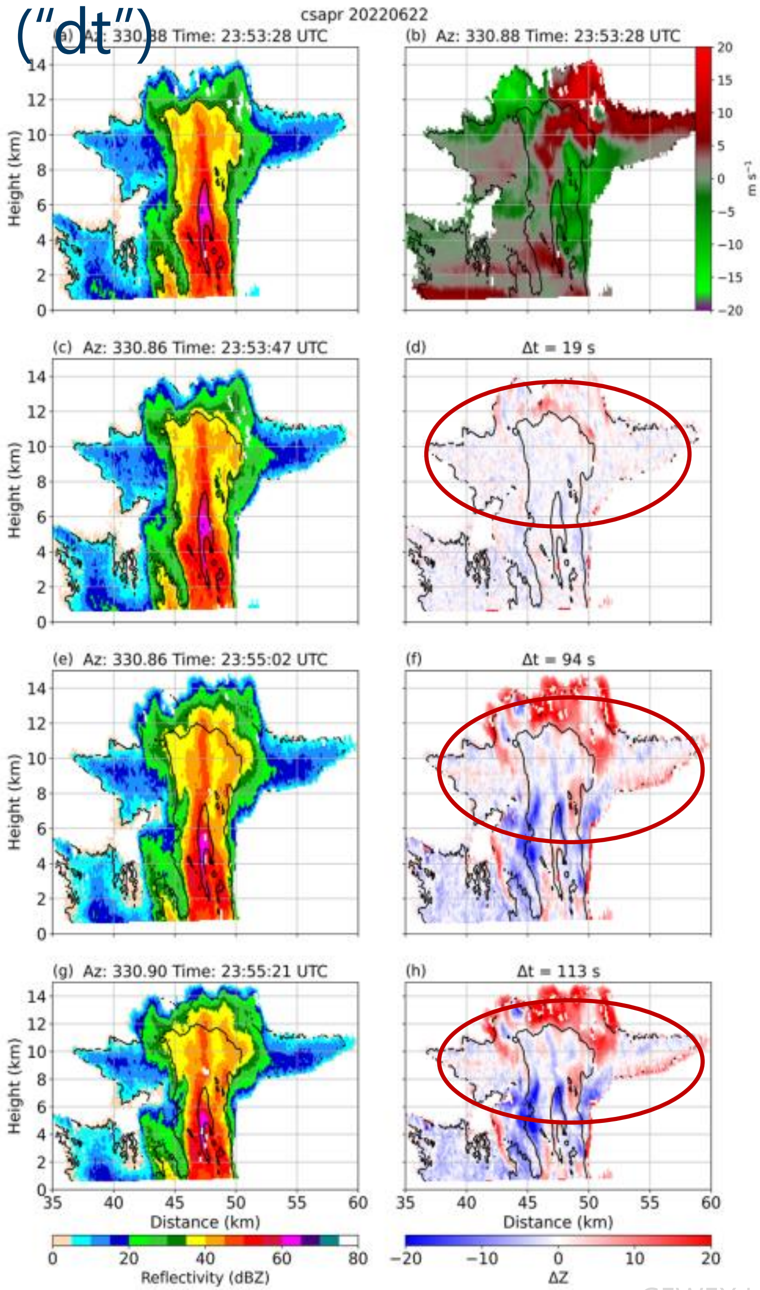


Selection of different channels that complement one another for vertical profiling of ice

+/- 55° around equator
⇒ diurnal evolution of the convective cells.



About the time delay ("dt")



1. Significant dZ changes throughout the storm development underlying the rapid change in the vertical distribution of ice

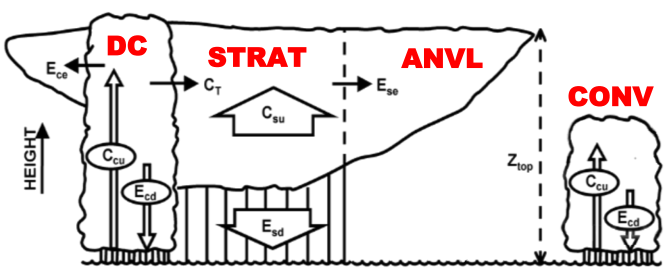
2. A short dt will minimize the contribution of horizontal advection to changes in the vertical mass flux and then to the signal in the measured ΔTB

⇒ dt ∈ [30s; 135s]
⇒ There will be a test phase after launch to adjust the dt

Sequences of vertical cross sections reflectivities from a C-band radar (4-8 GHz) at an azimuth of ~330° on 22 June 2022 at t0=23:53:28 UTC and dt=19, 94 and 113s. Black contours represent the 5-, 35- and 55-dBZ contours. (b) Radial velocity at t0. (d)-(f)-(h) Variations of reflectivities dZ (in dBZ) with respect to t0. [Dolan et al, 2023]

Planned Geophysical Variables – level 2

Level 2	Name	Description	
Mono-instrument GVs	RH(z) (%)	relative humidity profile – range : 0-100%	non convective scenes
	IWP (kg/m^2)	ice water path - range : 0-100 kg/m^2.	convective scenes
Tandem GVs	flag	classification of convective parts – 5 classes & probabilities	all scenes – focus on convection
	dIWP/dt ($kg/m^2/s$)	tendency of IWP – range : -0.2 – 0.5 ($kg/m^2/s$)	convective scenes
	$V_{ice}(z)$ (m/s)	$V_{ice}(z) = V_t^{ice}(z) + w_{air}(z)$ + shape parameters : w_{max} (m/s) and $z_{max}(w_{max})$ (km)	convective scenes
	$\overline{w_{ice}}$ (m/s)	integrated velocity of ice particles – range : 0 – 50 m/s)	convective scenes
	$V_{env}(z)$ (m/s)	clear air vertical motion at several pressure levels to adapt from Poujol & Bony (2024) for IR WV channels	non-convective environment



a convective system from House (2014)

All GVs (except RH) related to convective cells are defined by their id. flag

Variable	IWP ($kg.m^{-2}$)		dIWP/dt ($kg.m^{-2}.s^{-1}$)		$\overline{w_{ice}}$ ($m.s^{-1}$)	
Model	Global	Specific	Global	Specific	Global	Specific
ANVL	0.99	0.99	0.92	0.93	0.05	0.17
STRAT	0.99	0.99	0.93	0.94	0.06	0.21
CONV	0.97	0.98	0.92	0.94	0.67	0.80
DC	0.97	0.98	0.89	0.90	0.56	0.60

R^2 for regression models for the 3 variables across the 4 cloudy classes for global model (trained for all point) or specific model (trained for each class).
MESO-NH simulations for "HECTOR" convection – Δx=1km

[Lefebvre et al, 2025, IEEE TGRS, paper currently under review]

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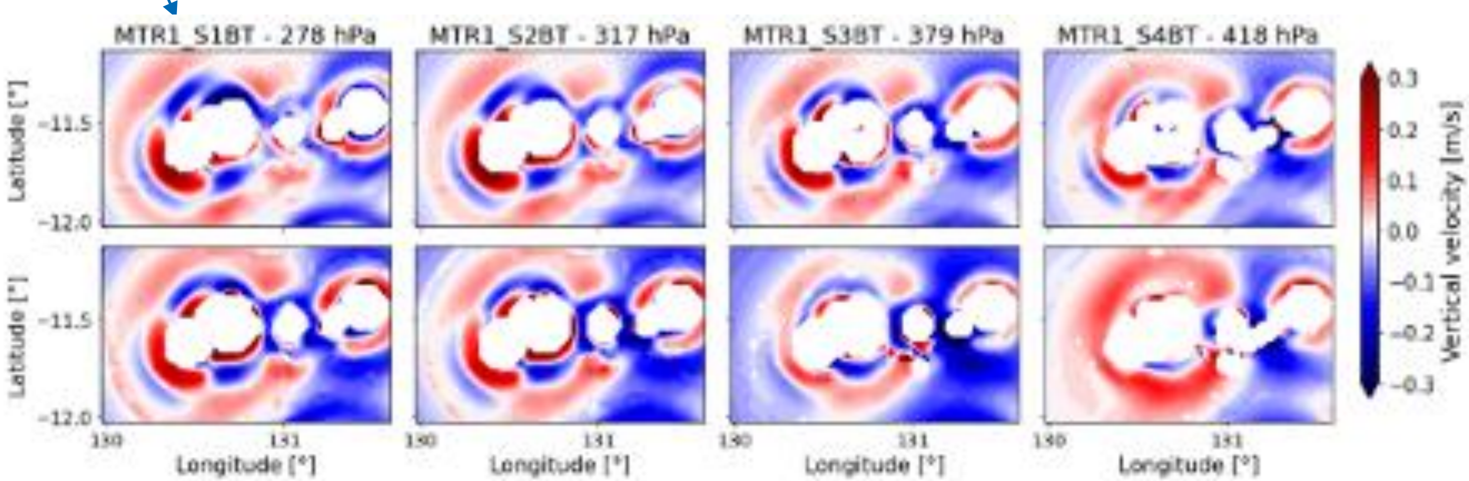
MESO-NH

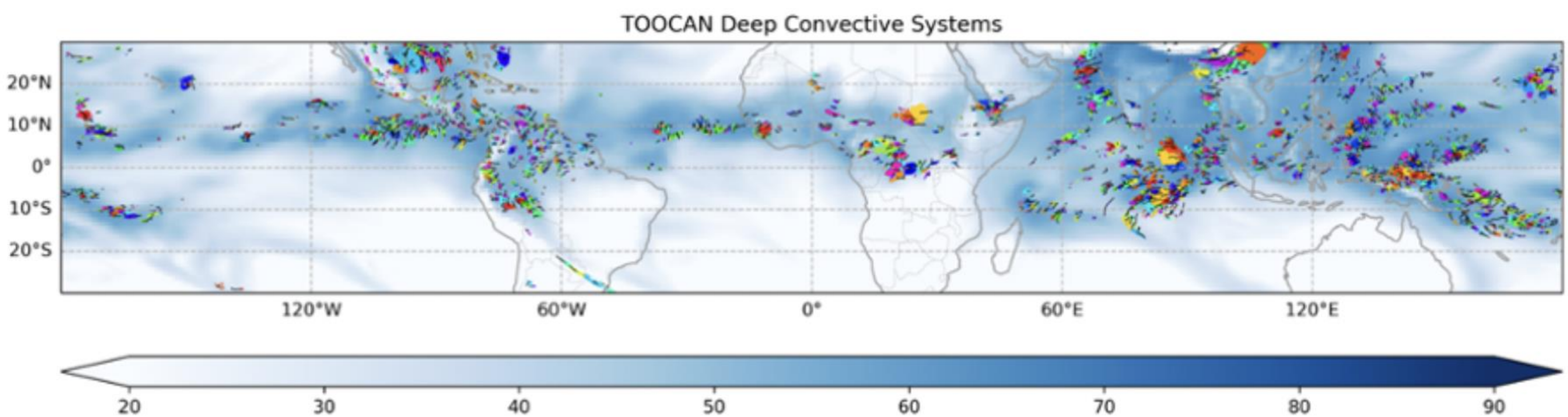
retrieved



⇒ Need to see how to adapt the approach to C^{2}OMODO with CNES support (question of the radiometric noise wrt to the dTB$_{WV}$ signal)

Planned Geophysical Variables – level 4

Level 4	Name		Description
TOOCAN tracking	coloc		co-location of GVs from Level 2 C^{2}OMODO products with auxiliary data linked to the cold cloud shields of convective systems
	org		characterization of organization and spatial arrangement of deep convective cores within the cloud shields of convective systems > derived from L4-coloc
	carto	classic	1° / 1-month : cloud type grid fraction
		object	1° / 1-month : spatial density of convective cores



Snapshot of the Deep Convective Systems tracked by TOOCAN from the Infrared channel of the ISCCP-NG L1g data in July 25, 2020, at 20:00 UTC, overlaid on the precipitable water field derived from the ERA5 reanalysis data. T. Fiolleau/LEGOS

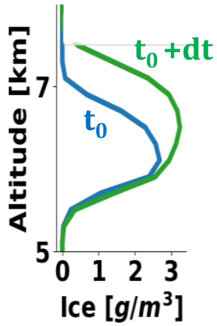
Insights on the vertical velocity

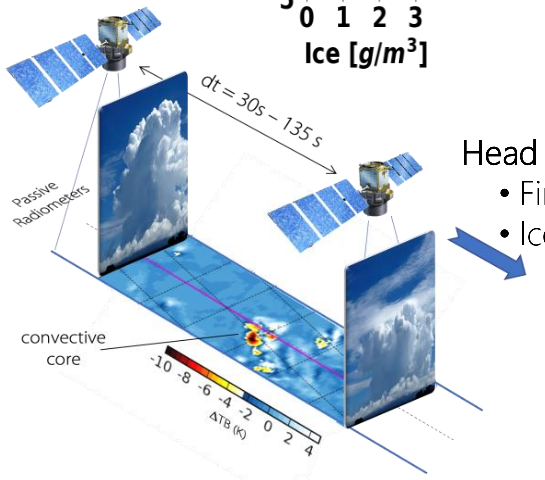
How to go from t_0 to t_0+dt ?

$$V_{ice}(z) = V_t^{ice}(z) + w_{air}(z)$$

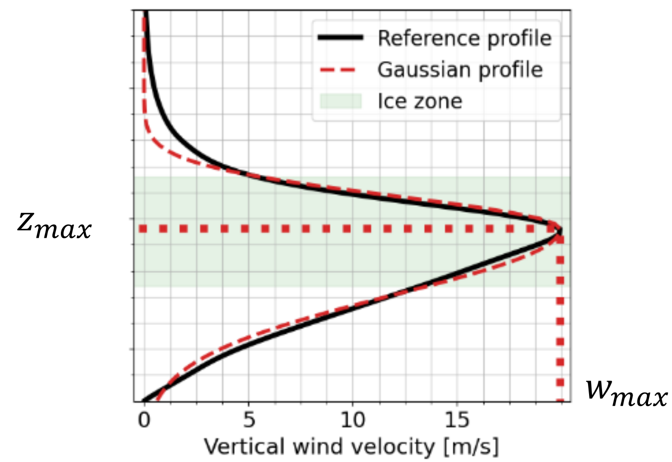
$\Rightarrow$ Assumptions: - quasi-gaussian profile for $w_{air}(z)$
- ice profile only modified by updraft
(no microphysics, no lateral inputs…)

Tail radiometer
- Second set of TBs
- Ice profile at t_0+dt

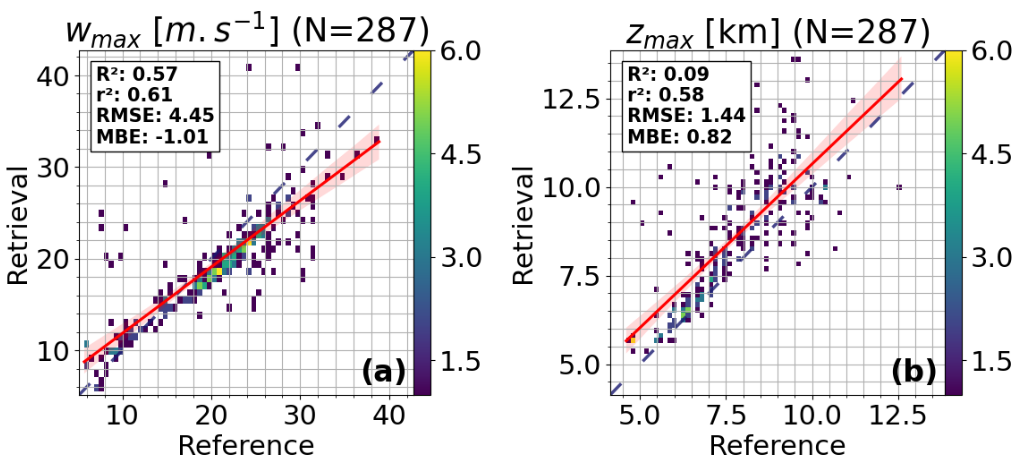


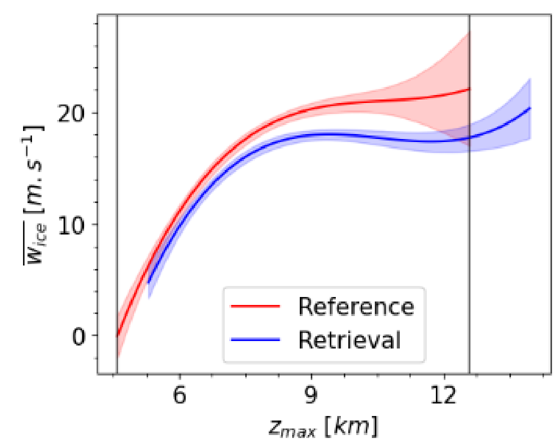


Head radiometer
- First set of TBs
- Ice profile at t_0



Evaluation on a subset of growing convective cells [Lefebvre et al, 2025, in prep]





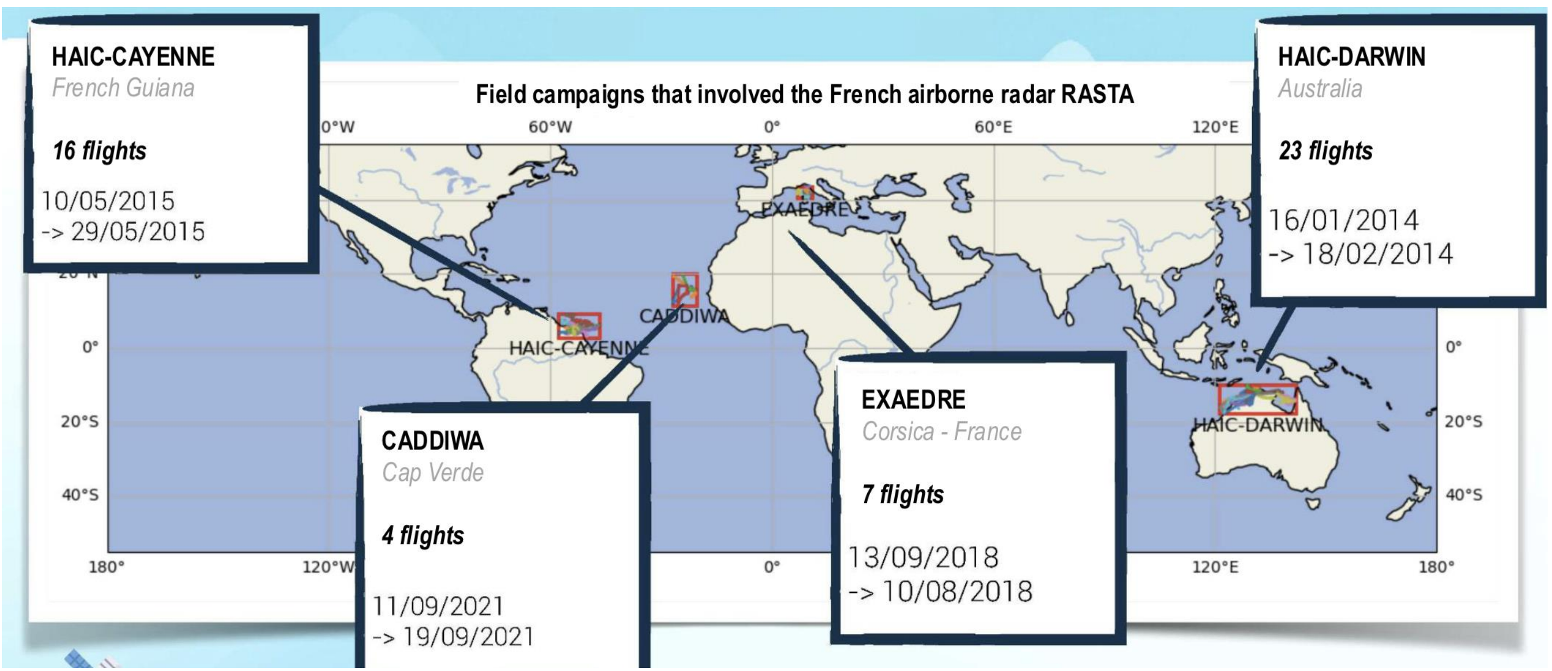
On-going studies and next developments

- Complementarity with JAXA Ku Doppler Precip Radar (PMM) & C^{2}OMODO

- Cal/Val strategies :
    - Development & tests of a balloon-borne radar/lidar system.

    - Other km-scale simulations of field campaigns with measurements linked to the properties of convection (eg: recent 2024 MAESTRO/ORCESTRA campaign)

(MESO-NH @ 200m, J-P Chaboureau / LAERO)



Thank you !

Questions ?