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Measuring dynamical properties of atmospheric convection using C²OMODO a tandem of microwave radiometers

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1 Scientific context: Deep Convection

- **Extreme cloud systems, occurs** in Intertropical zone
- air, aerosols & water updrafts up to the tropopause
- Strong impacts on : Water & Energy Cycles
- Issues around deep convection **:**
  - Lack of observations of convective updrafts
  - High spatial and temporal sampling
  - In-situ measurement difficulties over oceans.
  - Limited representation in **meteo/climate models**

2 Space mission : C²OMODO

C²OMODO (**C**onvective **C**ore **O**bservations through **M**icr**O**wave **D**erivatives in the tr**O**pics) :

- Contribution to Atmosphere Observing System (AOS) program (NASA-led with CSA, JAXA, CNES)
- Observation of **clouds and storms dynamics**
- Twin multispectral **passive microwave radiometers**
- Measurement expressed in brightness temperature (Tbs)
- $\boldsymbol{Tbs}$ related to **ice scattering attenuation**
- $\frac{dTbs}{dt}$ related to growth of convection **[1][2]**

General Description	Frequency [GHz]	IFOV [km]
Orbits Inclined ± 55° latitudes	183.31	5
Launch : [2028 – 2030] Mean altitude : 427 km	325.15	3
Swath : > 750 km	89	10

Table.1 : Description of C²OMODO and instrumental configuration used. IFOV at nadir.

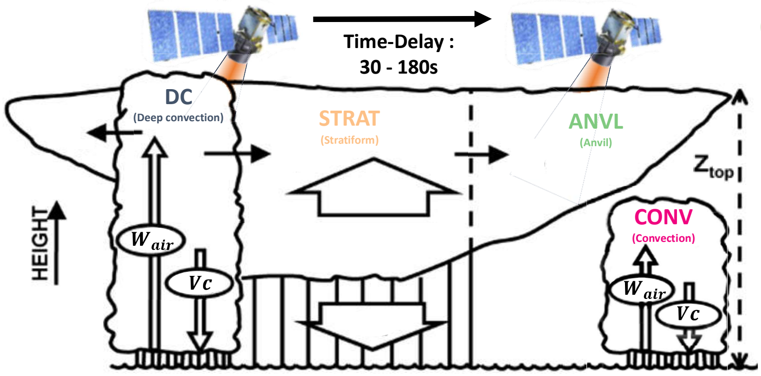

Fig.1: C²OMODO principle. Cumulonimbus (liquid and frozen water) observed with twin radiometers
W_{air} : In-cloud vertical wind velocity ; Vc : Terminal velocities ; In red : Cloud classes

3 Numerical tools

MESO-NH [5] (Cloud Resolving Model) :
- Laboratoire d'Aérologie et Météo-France
- Non-hydrostatic (Resolved convection)
- Hector simulation [6]:
  - 6h ; 256*200 km² ; up to 30km
  - Δx = 1km ; Δz = 200m ; Δt = 30s

RTTOV.13 [7] (Radiative Transfer Model) :
- Simulation of satellite measurements
- No spatial observation geometry yet
- Default particle size/shape distribution [8]
  - ➢ To be explored in another study

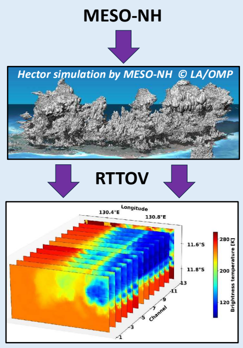

Fig.3 : Tbs samples across channels

4 Machine learning method

Method : GBDT - LightGBM [9] (Article in preparation) :
- Convective cell structure (Based on [4]) :
  - Single-radiometer : Cloud structure (Fig.4)
  - Tandem-based : Ice variation phases
- High performance retrieval of IWP and $\frac{dIWP}{dt}$

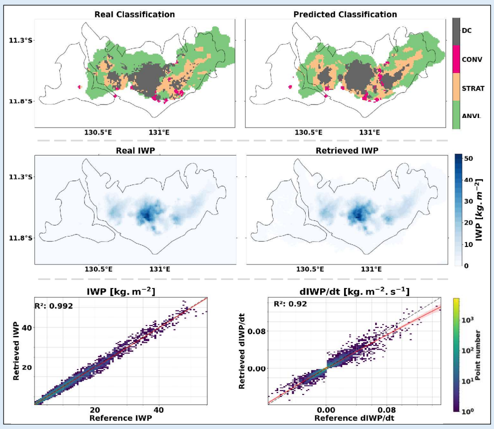

Fig.4: Results of the Machine learning methods.
Top line: map of the real and predicted classes.
Middle line: map of the real and retrieved IWP (Ice Water Path $[kg.m^{-2}]$: total atmospheric ice content).
Bottom line : Diagram of dispersion of IWP (left) and dIWP/dt (right).

5 Variational approach method (1D-VAR)

Method :
- Iterative principle - Based on Bayesian theory [5]
- Retrieval of ice water content
- Retrieval of vertical wind velocities profile, $\boldsymbol{W(z)}$
  - Gaussian model based (Fig.5)
  - Advection scheme similar to MESO-NH (Fig.6)

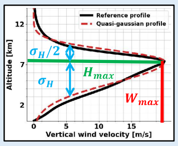

Fig.5: Wind vertical velocity profile based on gaussian model

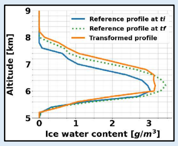

Fig.6: Advection scheme compute vertical motion between initial and final time measurement

First results :
- Fig.7: Spatial coherence of dynamical properties
- Fig.8**:** Consistent ice content and vertical velocity profile
- Fig.9: $\mathbf{W_{max}}$ and $\mathbf{H_{max}}$ well estimated

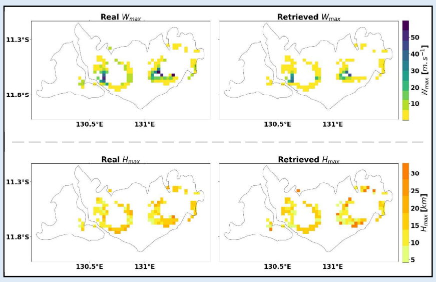

Fig.7: 1D-VAR peformance retrieval map.
Top line : map of the real and retrieved Wmax. Bottom line : map of the real end retrieved Hmax.

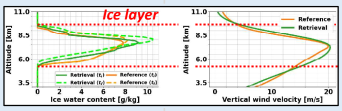

Fig.8: Real and retrieved ice profile and vertical wind velocities

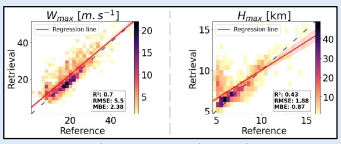

Fig.9: Scatter plot of 1D-VAR retrieval in function of reality-like values.
Red line : regression line.

- **[1] : Brogniez et al, (2022), Front Remote Sens.**
- **[2] : Auguste F and Chaboureau J-P (2022), *Front. Remote Sens.***
- **[3] : *Houze, R. A, Jr (2014), Cloud Dynamics.***
- **[4] : *Marinescu et al (2016), J. Geophys. Res. Atmos.***
- **[5] : *Lac et al (2018), Geosci. Model Dev.***
- **[6] : Dauhut T and Chaboureau J-P (2015), Atmos. Sci. Let.**
- **[7] : *Saunders, R., et al (2018), Geosci. Model Dev.***
- **[8] : *Geer et al (2021), Geosci. Model Dev.***
- **[9] : Ke, G., et al (2017), *Neural Information Processing Systems.***
- **[10] : Rodgers (2000), *World Scientific Publishing.***

5 Conclusions and perspectives

Among other possible products, **C²OMODO enable the retrieval of:**
- Using **Machine Learning** : Cells structure and Integrated geophysical variables
- Using 1D-VAR : Profile of : **Ice Water Content** & **Vertical wind velocities**

PHD perspectives : Investigation of 1D-VAR biases, Application on other cloud structure, Sensitivity analysis to tandem parameters (Tandem simulator), Publication on the 1D-VAR.

C2OMODO

AIRBUS DEFENCE & SPACE