Storms and TGFs

Investigating TGF origins with LEO radars

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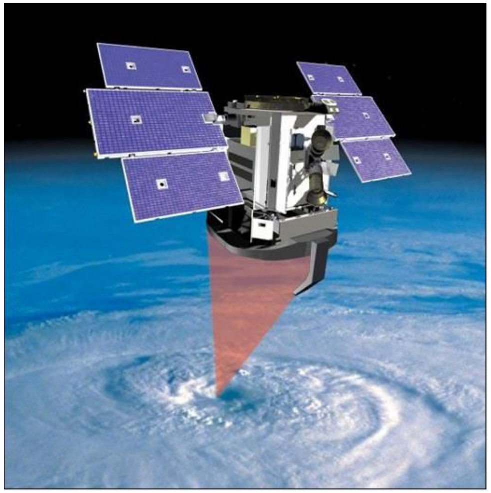
15th AGILE Science Workshop

Summary

- CloudSat
  - The CloudSat Mission
  - One recent ice-lightning study
- GPM
  - The GPM mission
  - Convection and lightning: the Naples hailstorm
- Agile and GPM: looking for coincidences
- Open questions

The CloudSat mission, what it does and how it does it



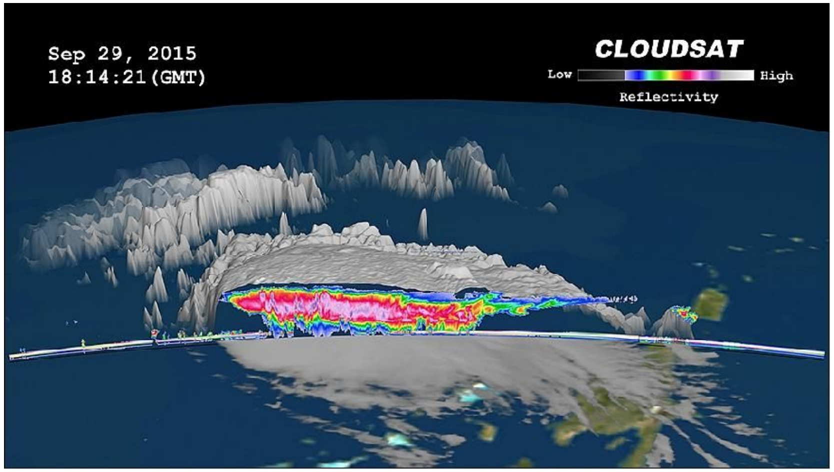
2006

CloudSat Mission Objective:

Provide, from space, the first global survey of cloud profiles (height, thickness) and cloud physical properties (water, ice, precip) needed to evaluate and improve the way clouds, moisture and energy are represented in global models used for weather forecasts and climate prediction.

The time delay of the returned signal tells us where the condensed cloud particles are located. We can create vertical slices of information that reveal the inner working of clouds.

We can see the condensation process directly at work



CloudSat flies a special type of RADAR.
Unlike weather radar, the CloudSat radar provides us with a way of seeing **inside clouds**, revealing their inner structure.

Buiat, M., Porcù, F., and Dietrich, S.: **Observing relationships between lightning and cloud profiles by means of a satellite-borne cloud radar**, *Atmos. Meas. Tech., 10, 221-230, 2017.*

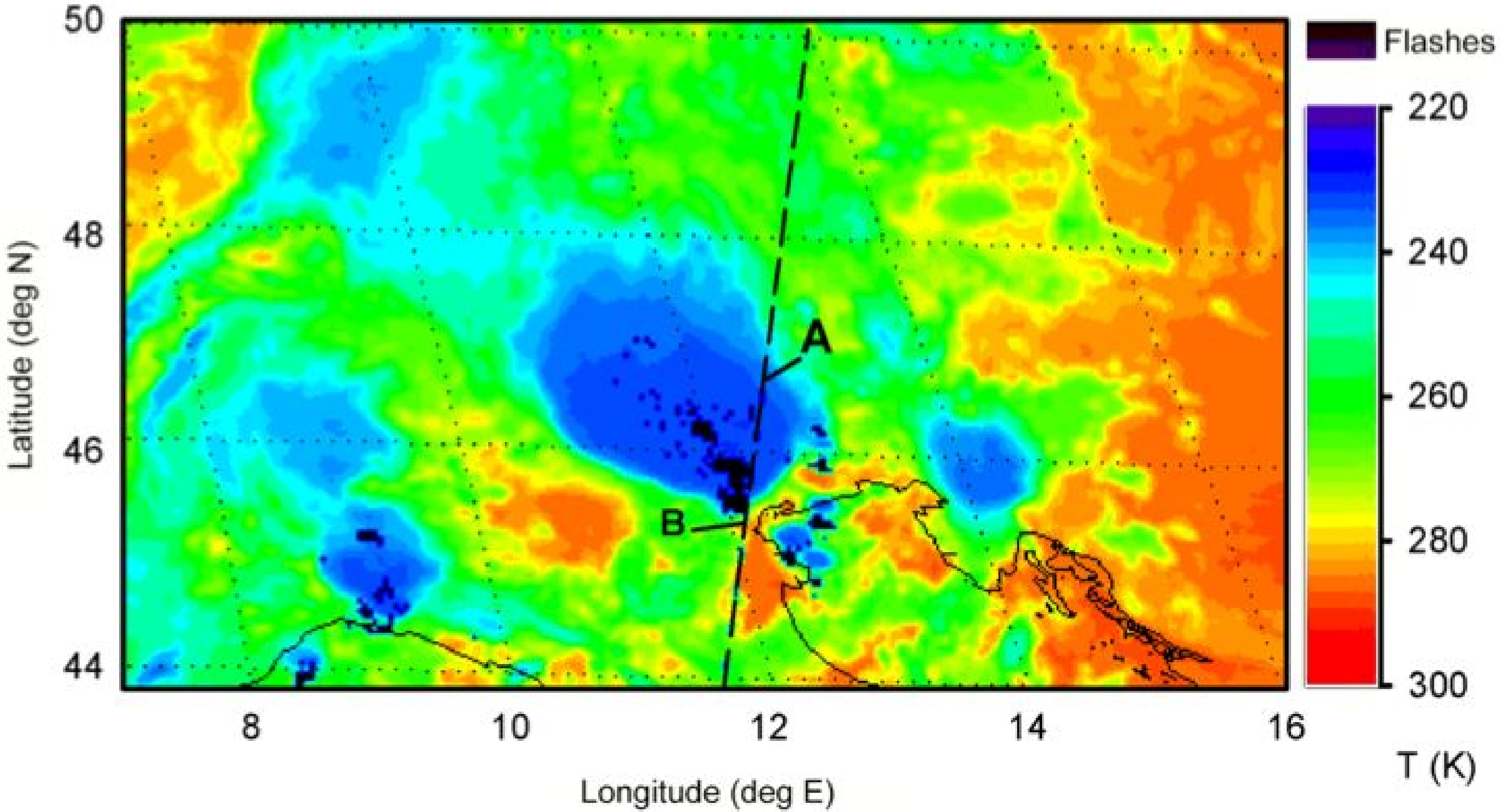


Fig. 1 - The 10.8 µm METEOSAT SEVIRI image at 01:27 UTC on 13 August 2010 centred on the analysed cloud system. Dashed line indicates the track of CloudSat orbit, A and B indicate the beginning and the end of the vertical cross section detailed in Fig. 2.

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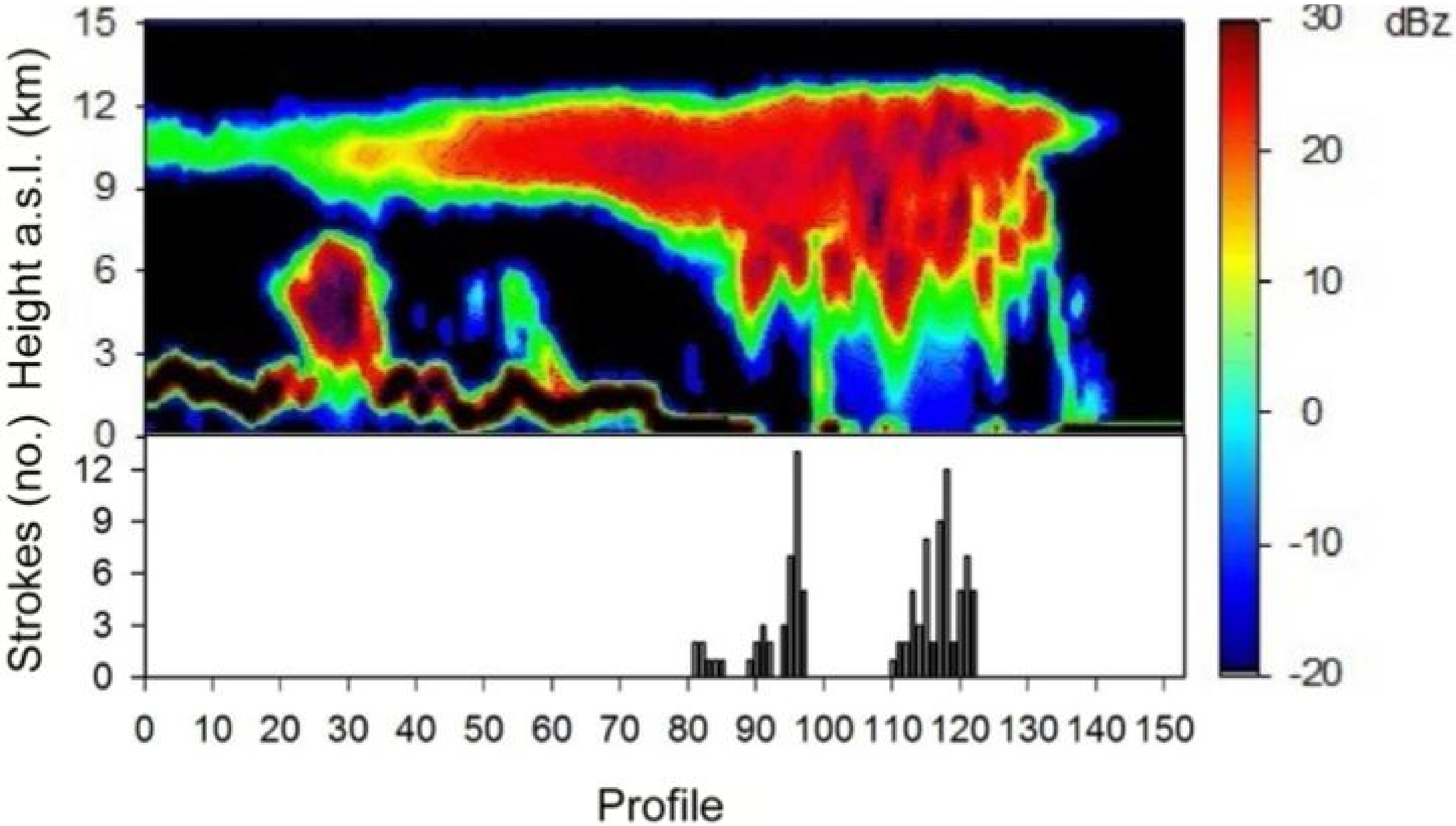

Fig. 2 - Vertical cross section of the CPR reflectivity along the path shown in Fig. 1. In the bottom panel, the number of CG strokes recorded by LINET for each CPR profile are reported.

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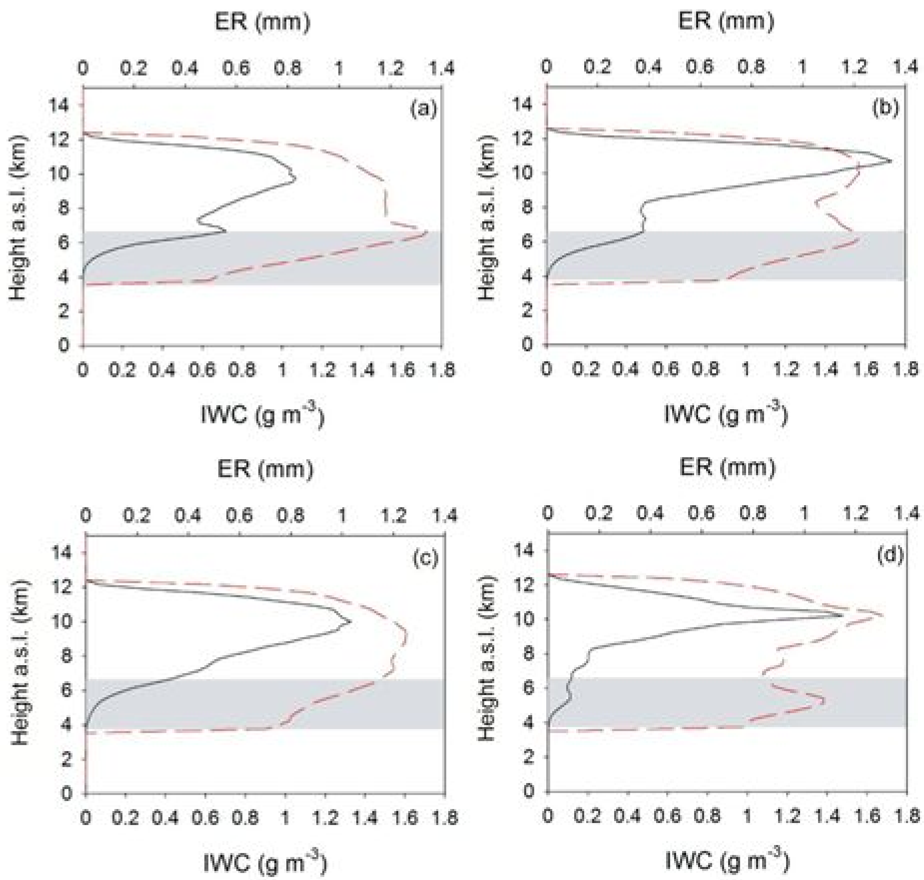

Fig. 3 - Vertical profiles of IWC (black line, bottom axis) and ER (red line, top axis) for four CPR profiles, namely (**a**) no. 96 (13 strokes), (**b**) no. 118 (12 strokes), (**c**) no. 106, and (**d**) no. 124 (zero strokes).

The gray band indicates the mixed-phase layer, where -20° < T < 0°.

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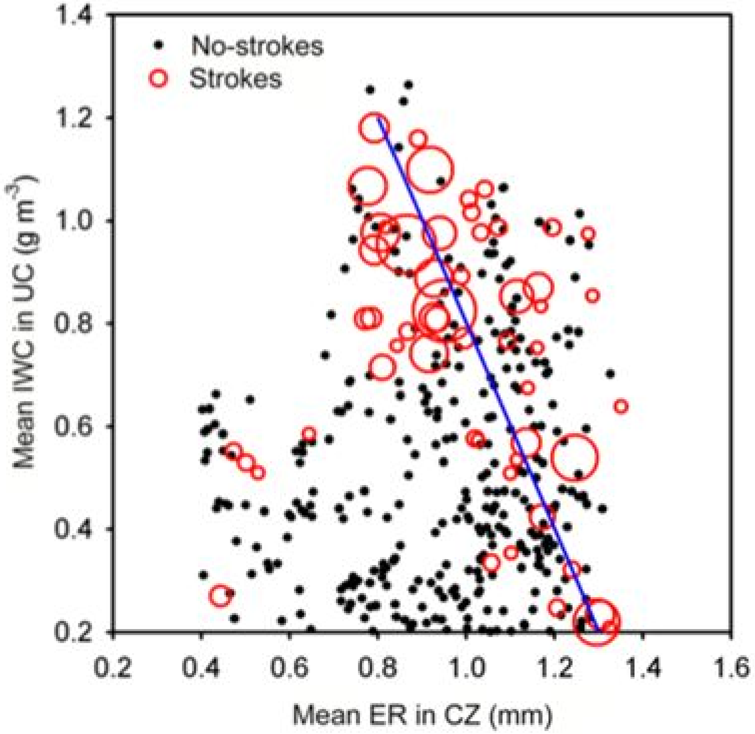
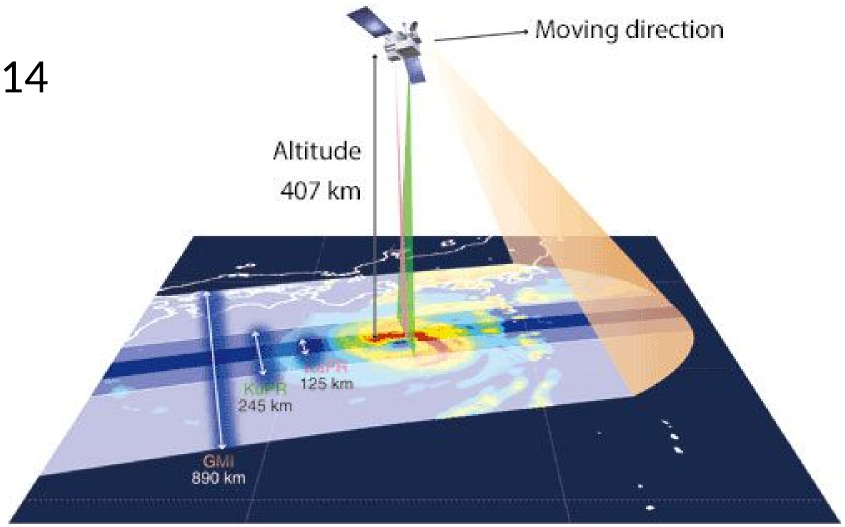


Fig. 8 - Distribution of profiles with strokes (red circles, with radius proportional to the number of strokes) and without strokes (black circles), with respect to mean IWC in the -20-40°C cloud layers (above 9 km) and mean ER in the 0-20°C.
In this case we assume that the profile is entirely composed by ice.
The blue line fits the distribution of profiles with strokes.

The GPM mission, what it does and how it does it

2014

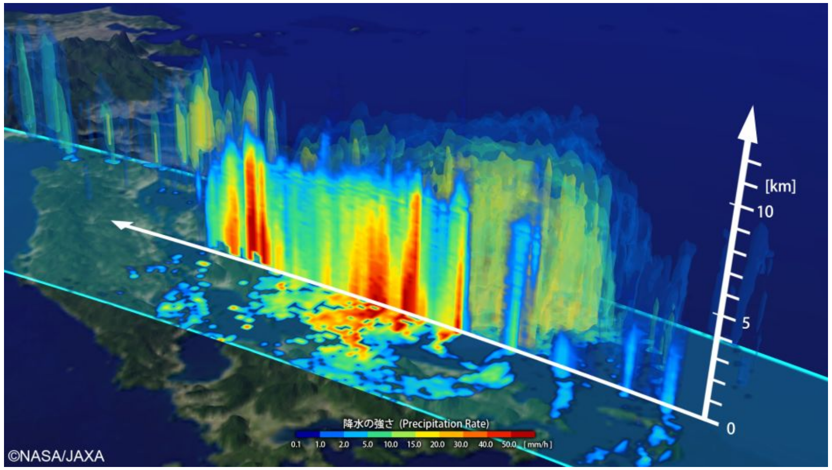


Core Satellite Instruments:

Dual-frequency Precipitation Radar (DPR)
Microwave radiometer (GMI)

- Precipitation with higher accuracy
- Discrimination between rain and snow

OBJECTIVE: understand the Horizontal and Vertical Structure of Rainfall and its Microphysical Element.

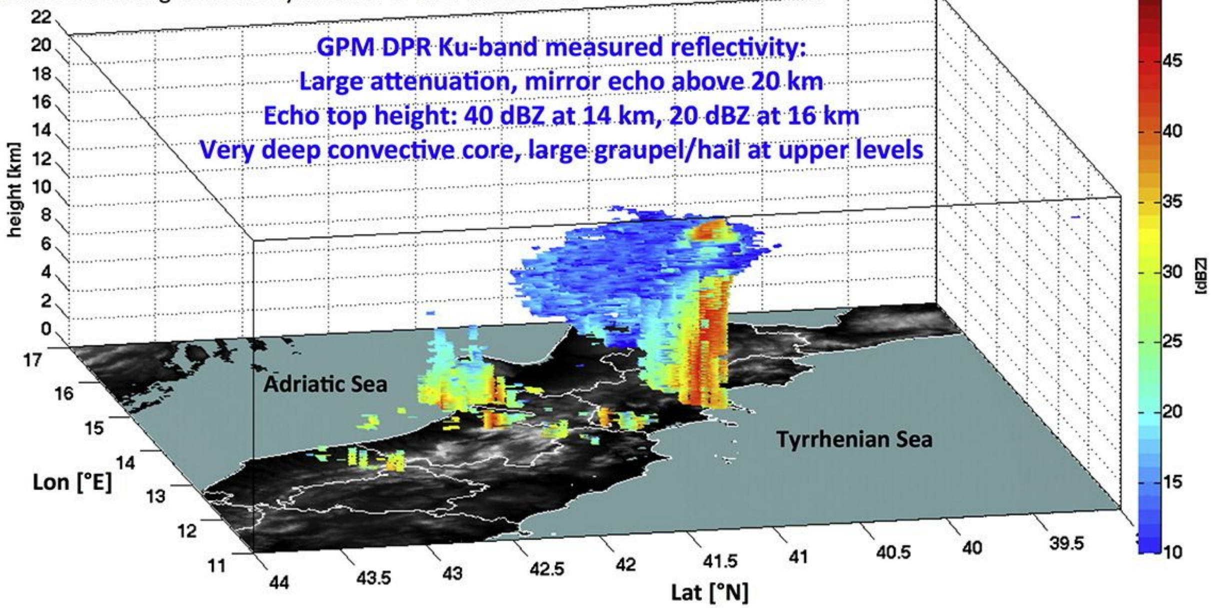


A.C. Marra, F. Porcù, L. Baldini, M. Petracca, D. Casella, S. Dietrich, A. Mugnai, P. Sanò, G. Vulpiani, G. Panegrossi:
Observational analysis of an exceptionally intense hailstorm over the Mediterranean area: Role of the GPM Core Observatory*, Atmospheric Research, Volume 192, 2017, 72- 90*

Naples hailstorm – 5 September 2015

MSG VIS-IR:
Minimum cloud top temperature 198 K
Peak cooling rate 4.5 K min^{-1}
Outflow region with overshooting top, and cloud-top plumes extending from the Tyrrhenian to the Adriatic Sea

C-band polarimetric ground radar:
strong hook-echo
three-body scattering



GPM GMI Brightness Temperatures:
Large convective core with record minimum at 19 GHz (globally) and ≤ 37 GHz (Mediterranean area)
20 K lower at 89 GHz than at 166 GHz
Complex upper level structure revealed by 166 GHz V-H signal

LINET:
21000 strokes in two hours
Peak rate 300 min^{-1}
IC+ fraction and heights correlated to updraft strength

http://dx.doi.org/10.1016/j.atmosres.2017.03.019

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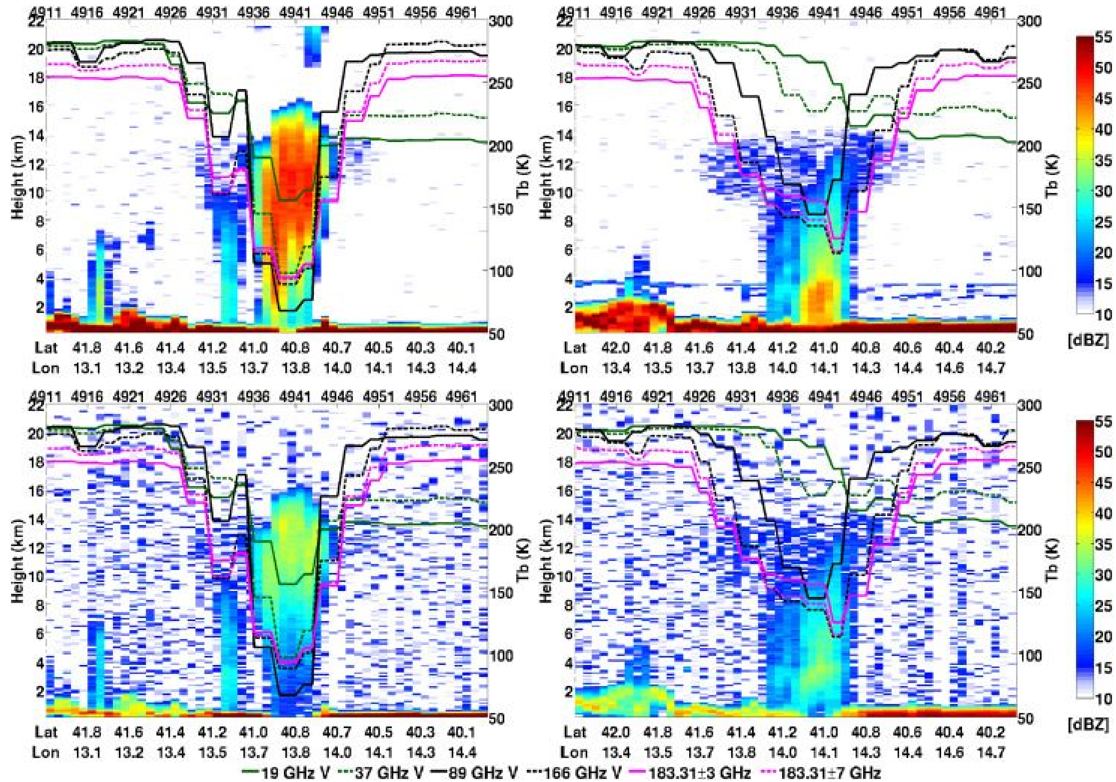

Fig. 12 - DPR along-track sections: section A (left column) and section B (right column) of measured reflectivity (Zm) at Ku (first row) and Ka (matched scan, MS) (second row). Corresponding GMI TBs at six selected window and water vapor channels are also shown...

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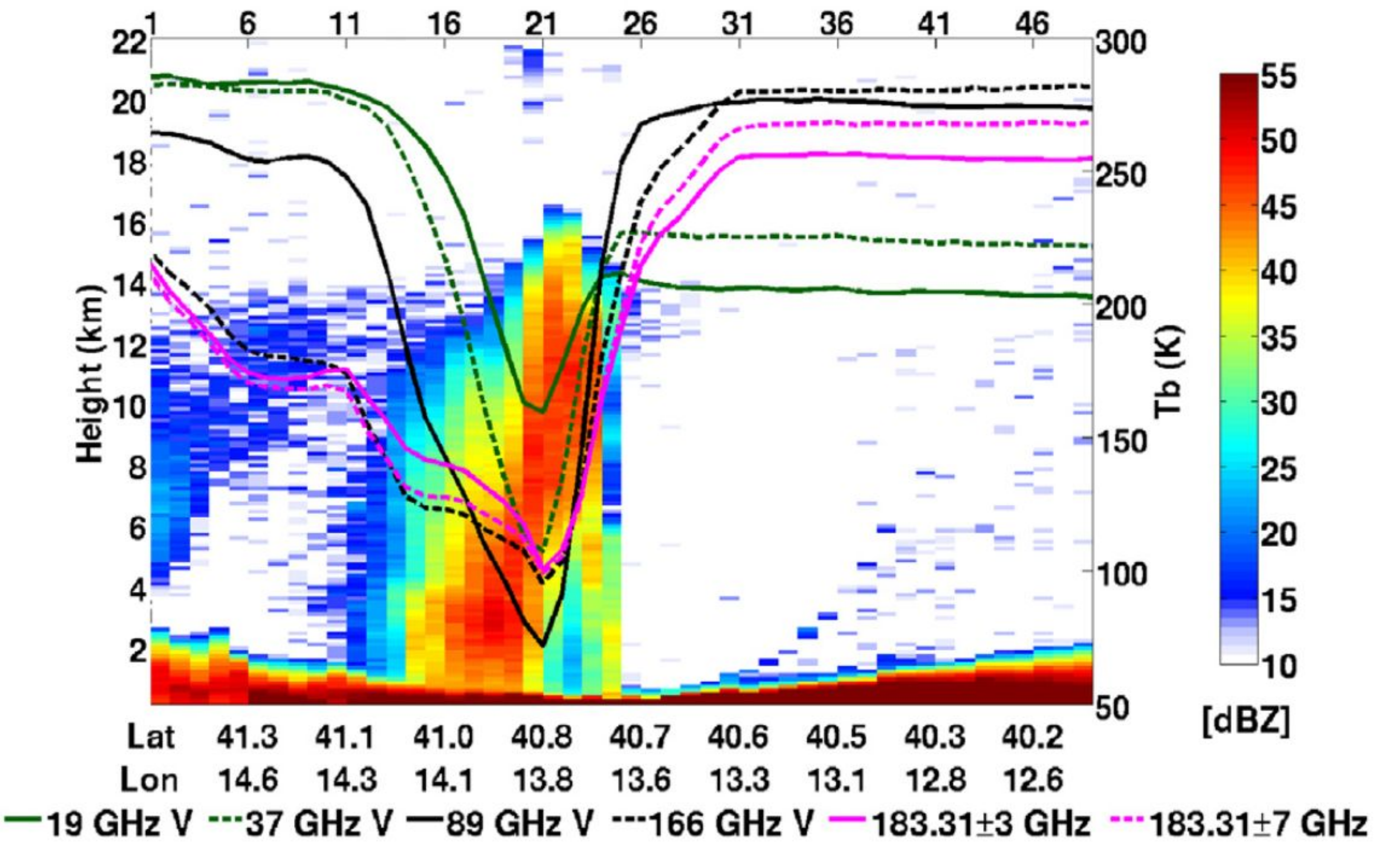

Fig. 13 - DPR cross-track section C of Ku measured reflectivity (Zm), together with corresponding GMI TBs as in Fig. 12. On top the DPR Ku-band ray number along the cross-section is indicated. See Fig. 8 as reference for the position of section C.

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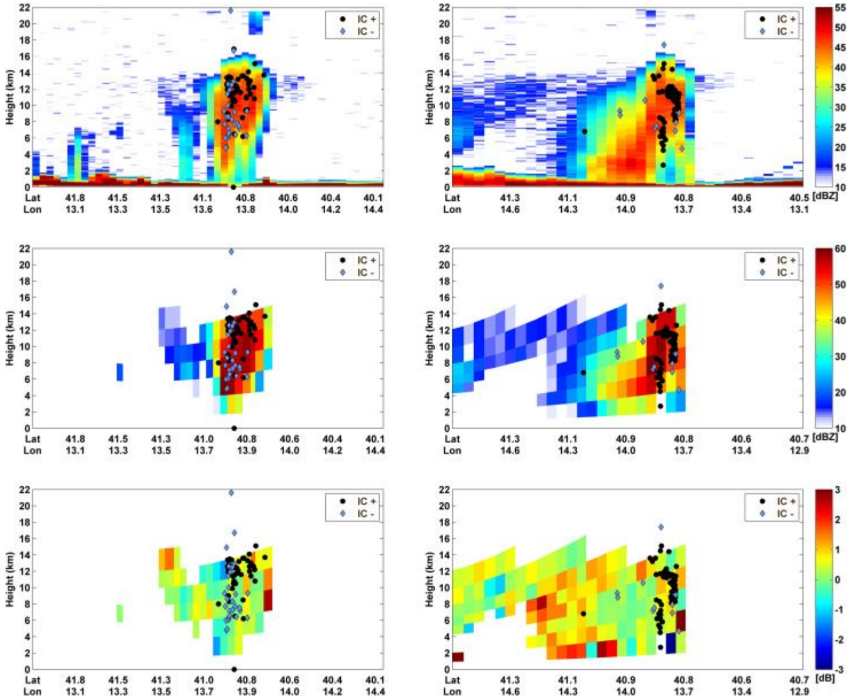

Fig. 15 - DPR and GR cross-section A (left panels) and C (right panels) with LINET strokes (IC+ and IC−) registered in 4 min around 08:47 UTC within a circular area of 2.5 km radius around each radar pixel. Top panels: Ku measured reflectivity Zm (dBZ). Middle …

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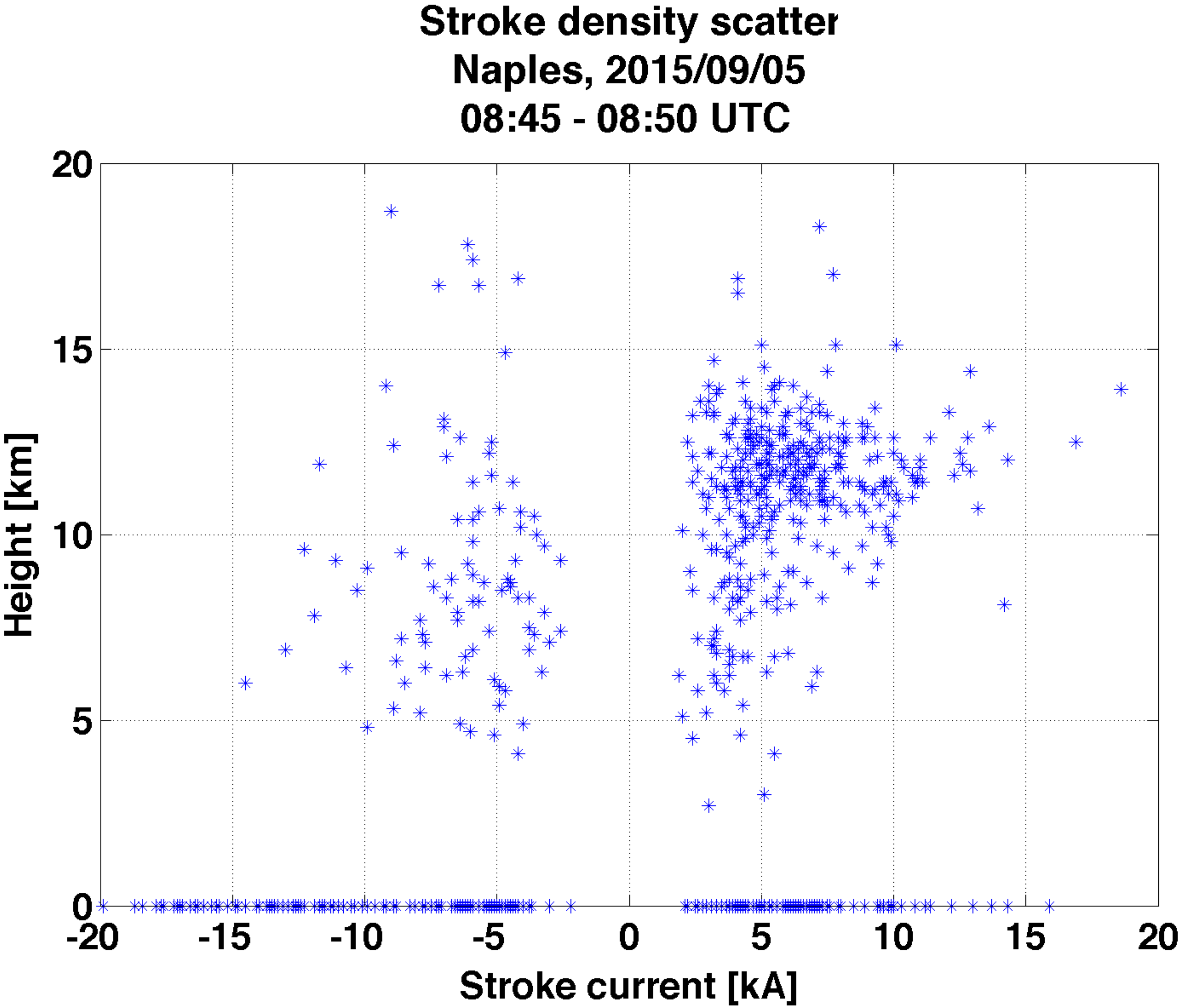
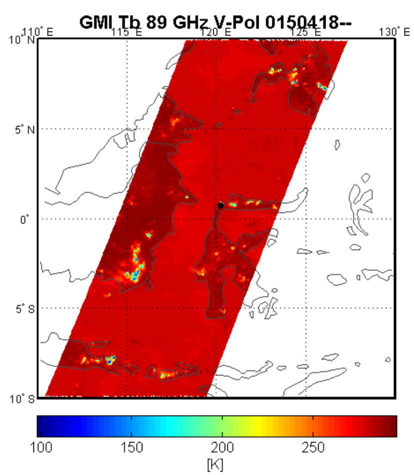

Stroke density scatter
Naples, 2015/09/05
08:45 - 08:50 UTC
Height [km]
20
15
10
5
0
-20
-15
-10
-5
0
5
10
15
20
Stroke current [kA]

GPM on AGILE Observation

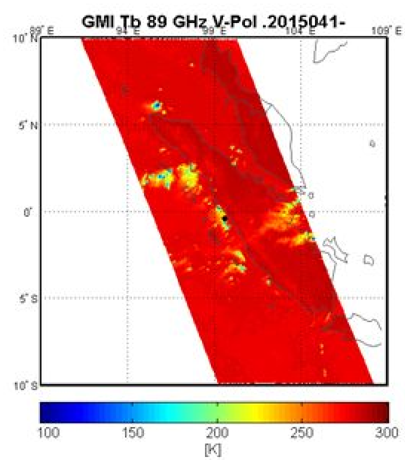
AGILE → TGF
WWLLN → POSITION (accuracy ~ 10 km)
SATELLITE →
1. CLOUD PROFILE (HEIGHT, THICKNESS)
2. CLOUD PHYSICAL PROPERTIES (WATER, ICE, PRECIP)

GPM EXAMPLES CONNECTIONS:

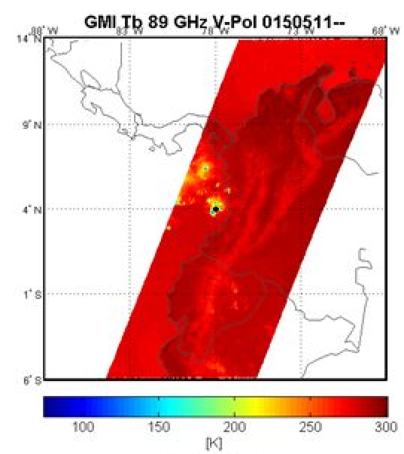
1. 2015/04/18 a Δt = - 31 sec
2. 2015/04/18 b Δt = -17 min
3. 2015/05/11 Δt = + 39 min



18 APRILE 2015 - 31 SEC



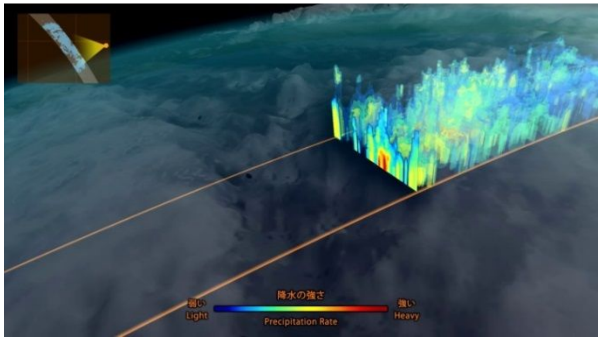
18 APRILE 2015 (2) - 17 MIN

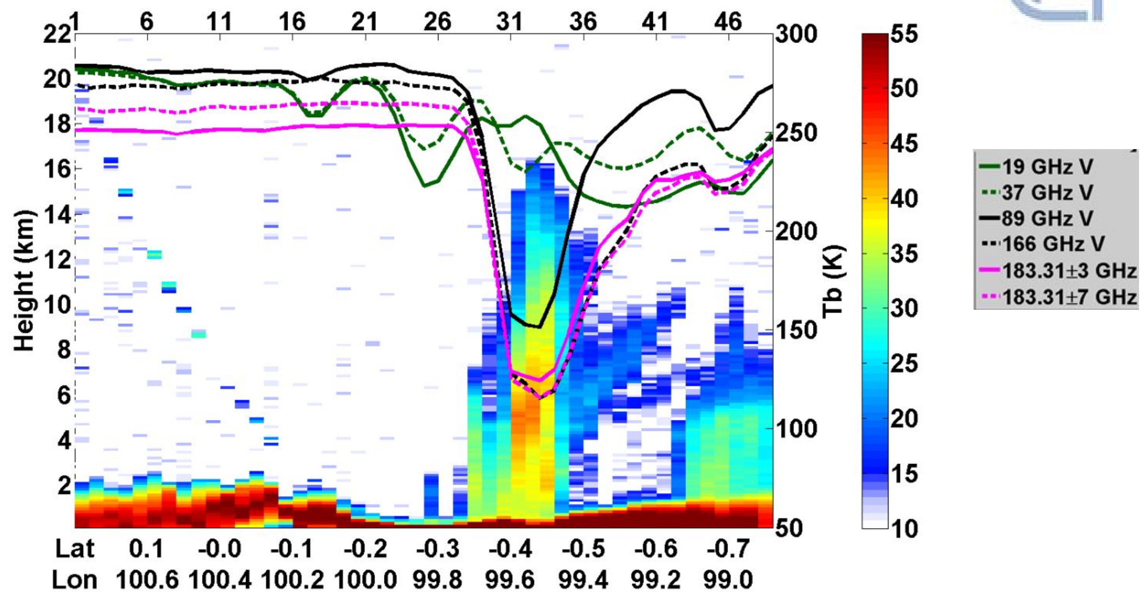


11 MAGGIO 2015 - 39 MIN

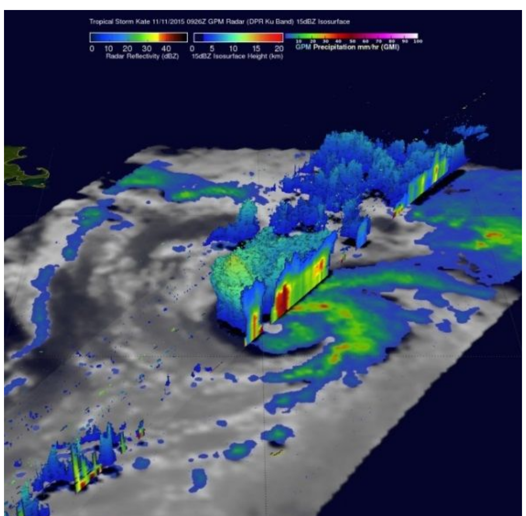
DPR SCAN for: 2015/04/18 TIME 21:41:49 - LAT -0,45 LON 99,6

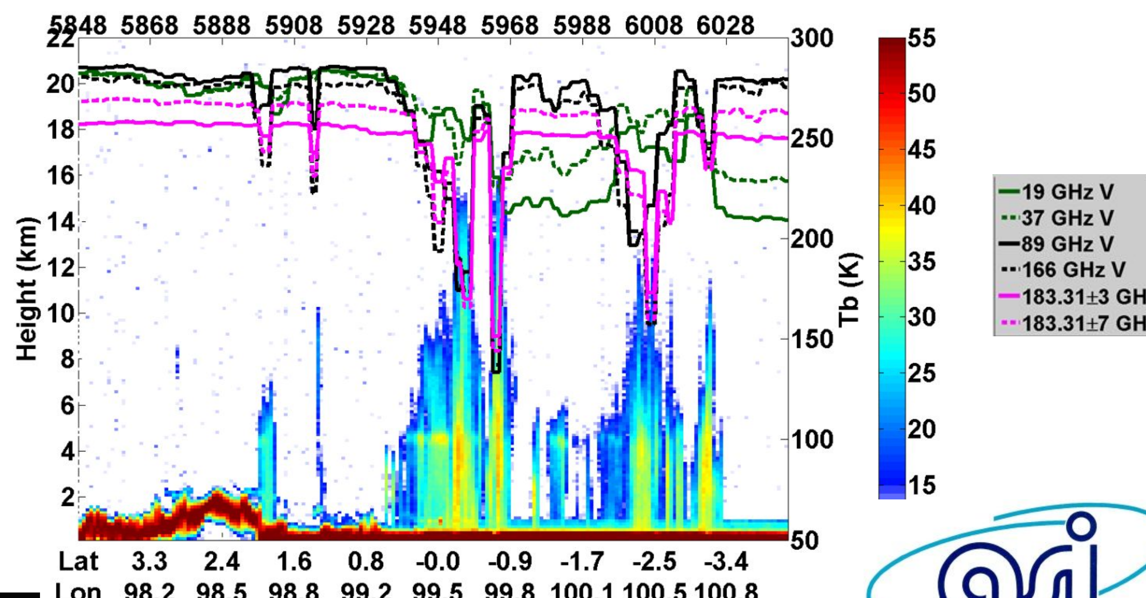
Scan: transversal





Ray: longitudinal





Open questions

- Climatology of TGFs
- Cloud Electrical evolution
- Which lightning type
- Which phase of the storm

What’s next?

ESA Stratospheric High Altitude Pseudo-Satellites (HAPS) programme for Earth Observation, Telecommunications and Navigation:

a stratospheric platform over a fixed point at an altitude of ~ 20 km. It offers new opportunities to extend the capabilities of satellites measurements.