# Azores stratoCumulus measurements Of Radiation, turbulEnce and aeroSols (ACORES)

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Leibniz Association

Atmospheric Physics Seminar, University of Warsaw, May 21st, 2021

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Leibniz Institute for
Tropospheric Research

# What to expect in the 45 minutes

- A brief overview of motivating scientific questions for the ACORES campaign

- A few aspects of the general sampling strategy

- Why do we prefer the Azores for measuring clouds, radiation, aerosol,...

- A few details about instrumentation
- A few results
- Nice pictures

## Scientific Topics:

- Radiative cloud properties
  - Cloud-top cooling
  - Variability of brightness temperature
- Aerosol conditions
  - Vertical aerosol distribution (cloudy & cloud-free conditions)
  - Aerosol in the cloudy boundary layer & free atmosphere
  - Cloud Condensation Nuclei
- The Cloudy Boundary Layer and Entrainment
  - Role of shear at cloud top
  - Structure of the entrainment layer
  - Coupled and de-coupled BLs (Jakub Nowak et al.)

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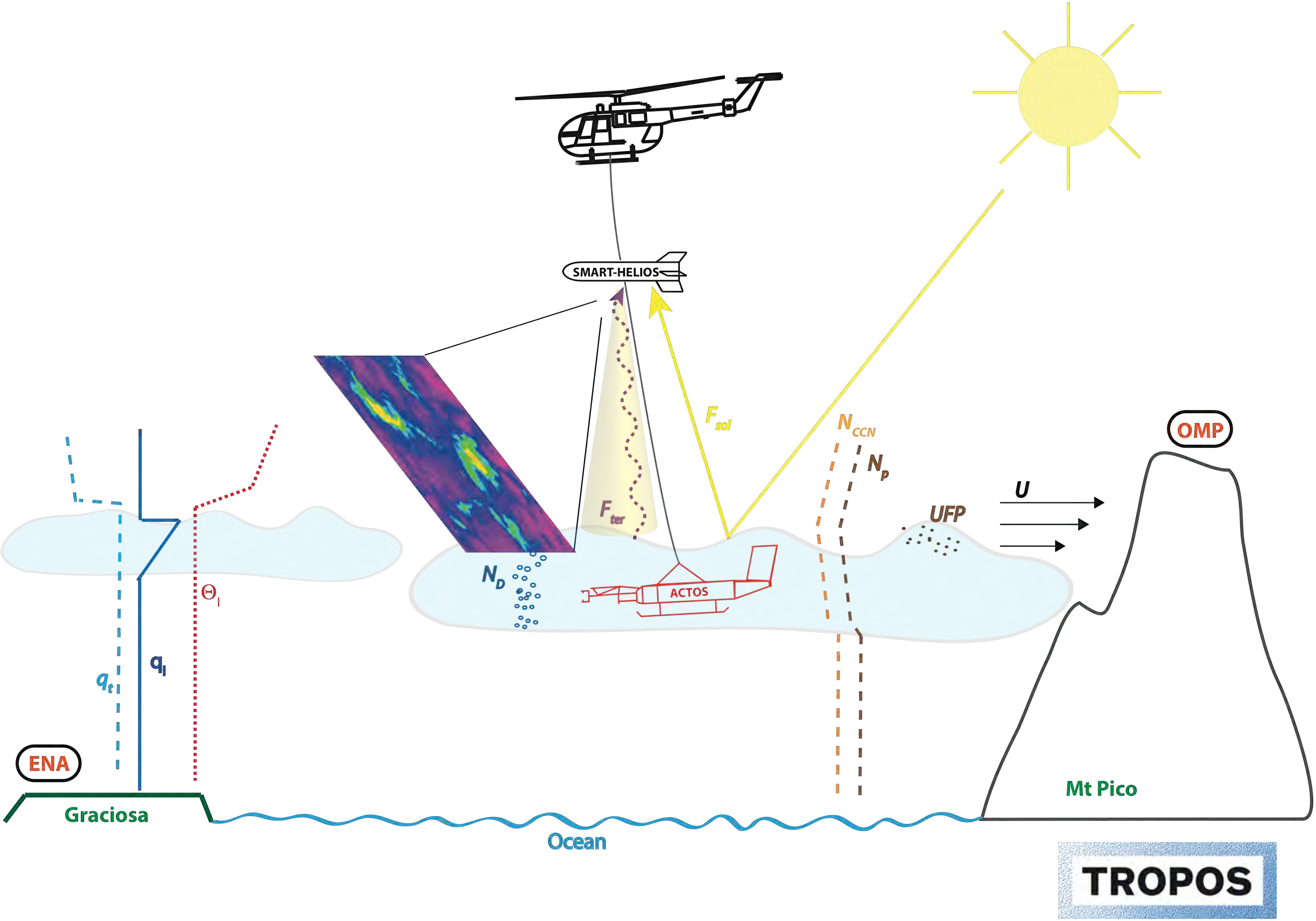
SMART-HELIOS
$F_{sol}$
$F_{ter}$
$N_{CCN}$
$N_p$
UFP
U
OMP
$N_D$
ACTOS
$\Theta_l$
$q_l$
$q_t$
ENA
Graciosa
Ocean
Mt Pico
TROPOS

# Why the Azores?

1. In the transition between mid-latitudes and trade wind regime (Sc vs shallow Cu), about 2000 km off Europe

2. Variable synoptical situations and therefore cloud and aerosol conditions

3. Great logistics and infrastructure without too many restrictions

4. ENA-ARM site with a lot of remote sensing and in-situ obs

5. No measurement tower but Mt Pico (2225 m) !!

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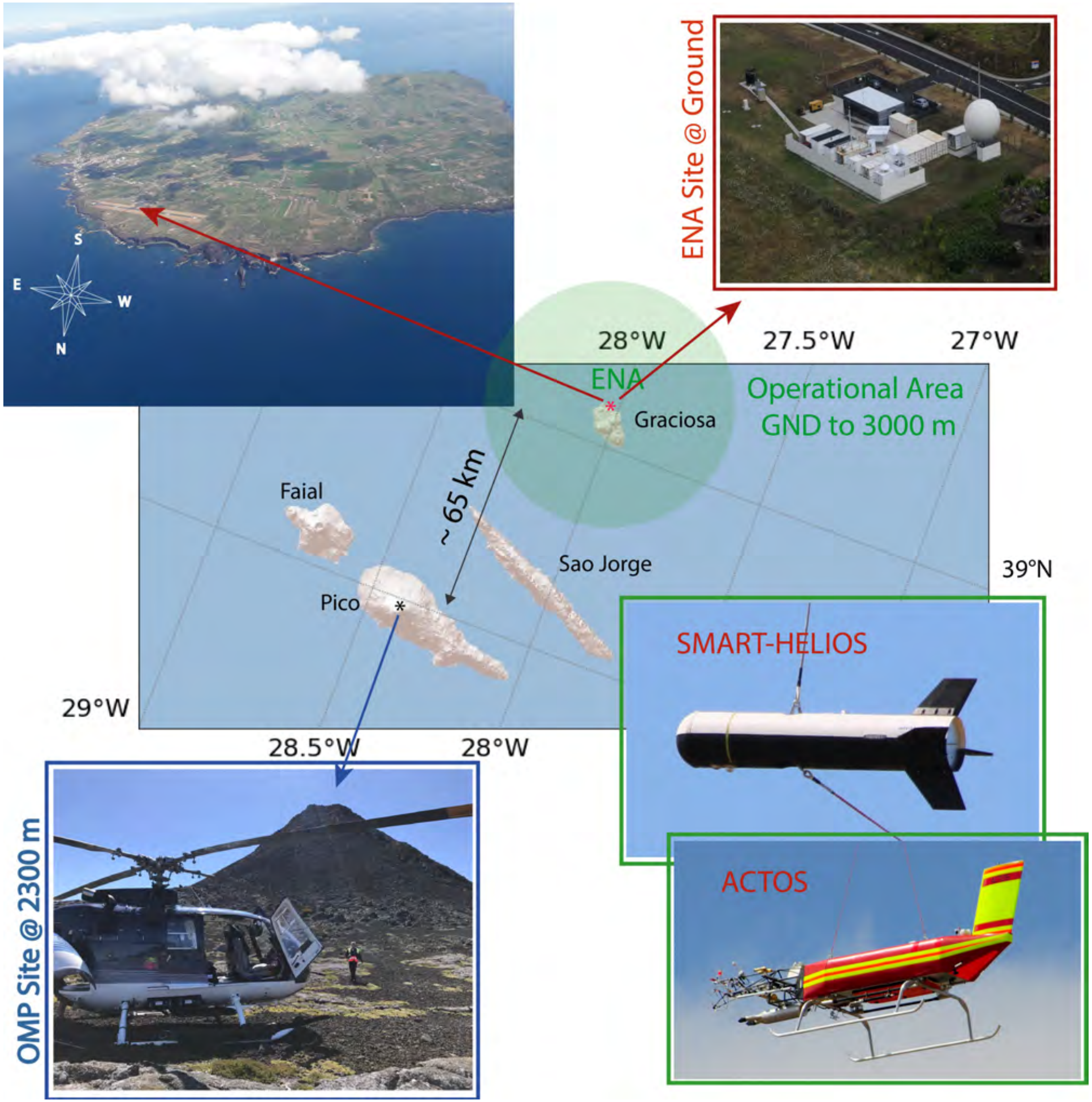
ENA Site @ Ground
S
E
W
N
28°W
27.5°W
27°W
ENA
Graciosa
Operational Area
GND to 3000 m
Faial
~ 65 km
Sao Jorge
39°N
Pico
29°W
28.5°W
28°W
SMART-HELIOS
ACTOS
OMP Site @ 2300 m
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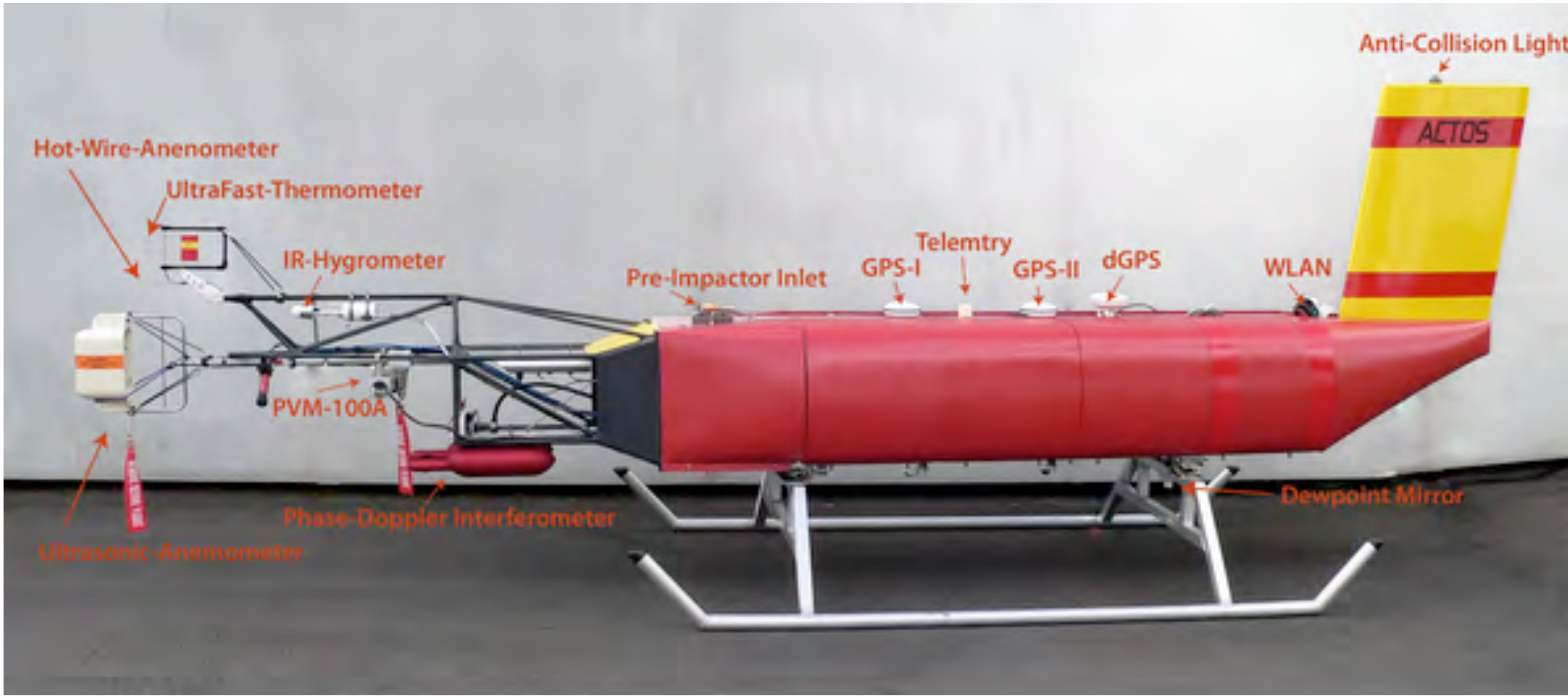
# ACTOS: Airborne Cloud Turbulence Observation System

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| Standard & cloud parameter measured on ACTOS | |
|---|---|
| Wind vector & virtual temperature | 3D ultrasonic anemometer (Solent HS) |
| Small-Scale Turbulence | Hot-Wire Anemometer |
| Attitude & Motion | Inertial Navigation Unit (IMU) |
| Position & Heading | Global Positioning System (2 Antenna GPS) |
| Liquid Water Content & Particle surface Area | Particle Volume Monitor (PVM-100A) |
| Cloud Droplet Sizes | Cloud-Droplet Probe (CDP-2) |
| Water Vapor | Fast Dewpoint Mirror, IR-Absorption Hygrometer (LI7500 |
| In-Cloud Temperature | UltraFast Thermometer (UFT) |

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## Aerosol parameter measured on ACTOS

| | |
|---|---|
| Total Particle Number Concentration (> 8 nm) | Condensation Particle Counter (CPC) |
| Total Particle Number Concentration (> 10 nm) | Fast Mixing-Type CPC (10 Hz) |
| Particle Number Size Distribution (8 – 350 nm) | Scanning Mobility Particle Sizer (SMPS) |
| Particle Number Size Distribution (350 – 2500nm) | Optical Particle Counter (OPC) |
| Particle Absorption Coefficient (450, 525, 624 nm) | Absorption Photometer (STAP) |

## Radiation parameter measured on ACTOS

| | |
|---|---|
| Broadband Irradiance (Solar, 0.2 - 3.6 μm) | Up- & Downlooking Pyranometer (CMP22) |
| Broadband Irradiance (Terrestrial, 4.5 – 42 μm) | Up- & Downlooking Pyrgeometer (CGR4) |

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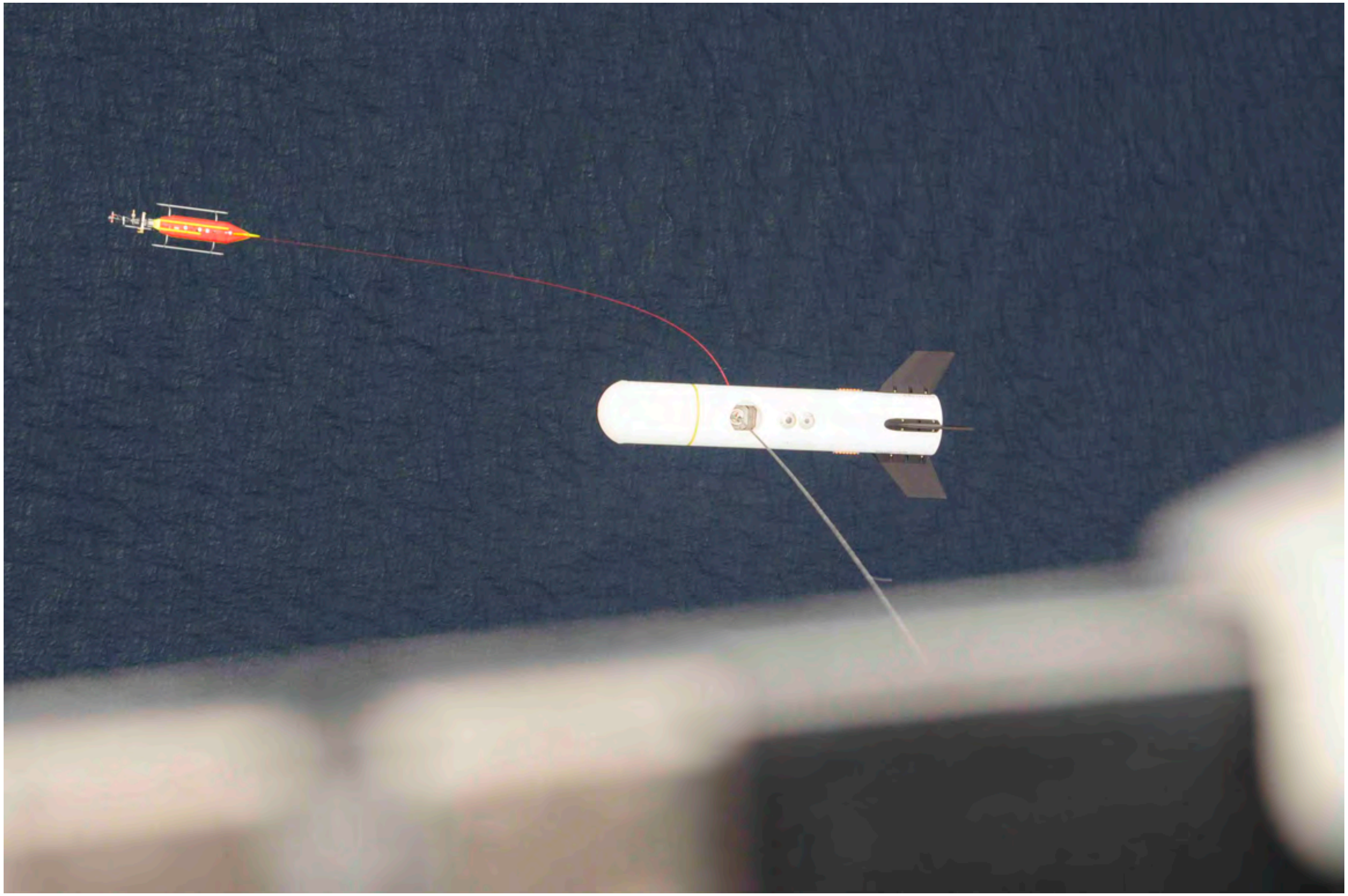
| Parameter measured on SMART-Helios | |
|---|---|
| Broadband Irradiance (Solar, 0.2-3.6 μm) | Up- & Downlooking Pyranometer (CMP22) |
| Broadband Irradiance (Terrestrial, 4.5-42 μm) | Up- & Downlooking Pyrgeometer (CGR4) |
| Spectral radiance (180–1100 nm, 900–2200 nm) | Downlooking 2.1° radiance inlet with Zeiss Spectrometer |
| Infrared temperature (8 – 14 μm) | Downlooking IR-camera (Gobi-640GigE) |
| Distance to cloud top | Downlooking Altimeter (ILM-500-R) |
| Cloud images | Camera (Canon DIGITAL IXUS 80 IS) |
| Attitude | Attitude Heading Reference System |
| Position | Global Positioning System (GPS) |

# ACTOS and SMART-Helios



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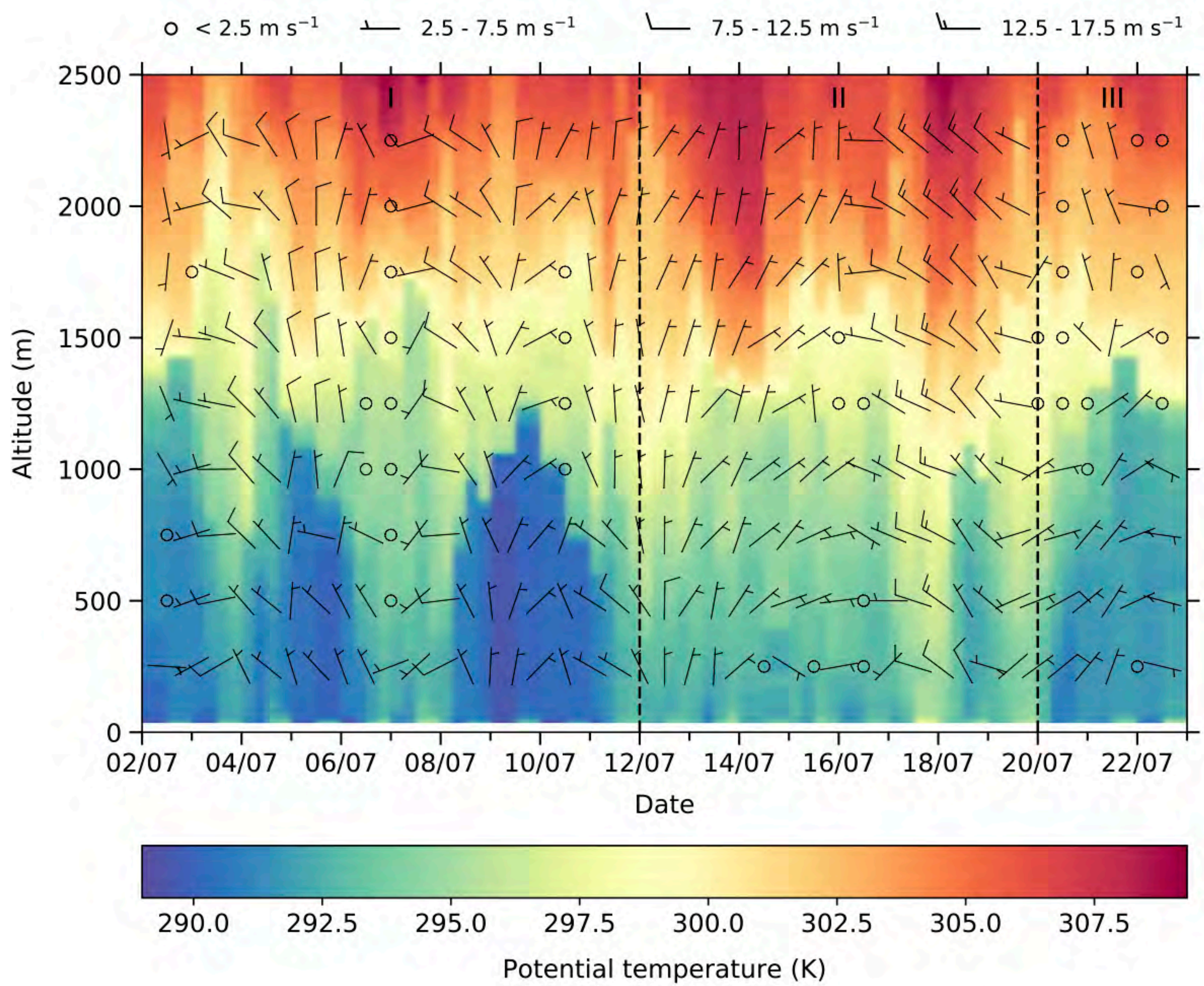
# A few impressions from the field (Graciosa airport)

Helicopter was dismantled and shipped in a 40“ container from Germany  to Terceira


...and then flown from Terceira to Graciosa



< 2.5 m s$^{-1}$
2.5 - 7.5 m s$^{-1}$
7.5 - 12.5 m s$^{-1}$
12.5 - 17.5 m s$^{-1}$
I
II
III
Altitude (m)
2500
2000
1500
1000
500
0
02/07
04/07
06/07
08/07
10/07
12/07
14/07
16/07
18/07
20/07
22/07
Date
290.0
292.5
295.0
297.5
300.0
302.5
305.0
307.5
Potential temperature (K)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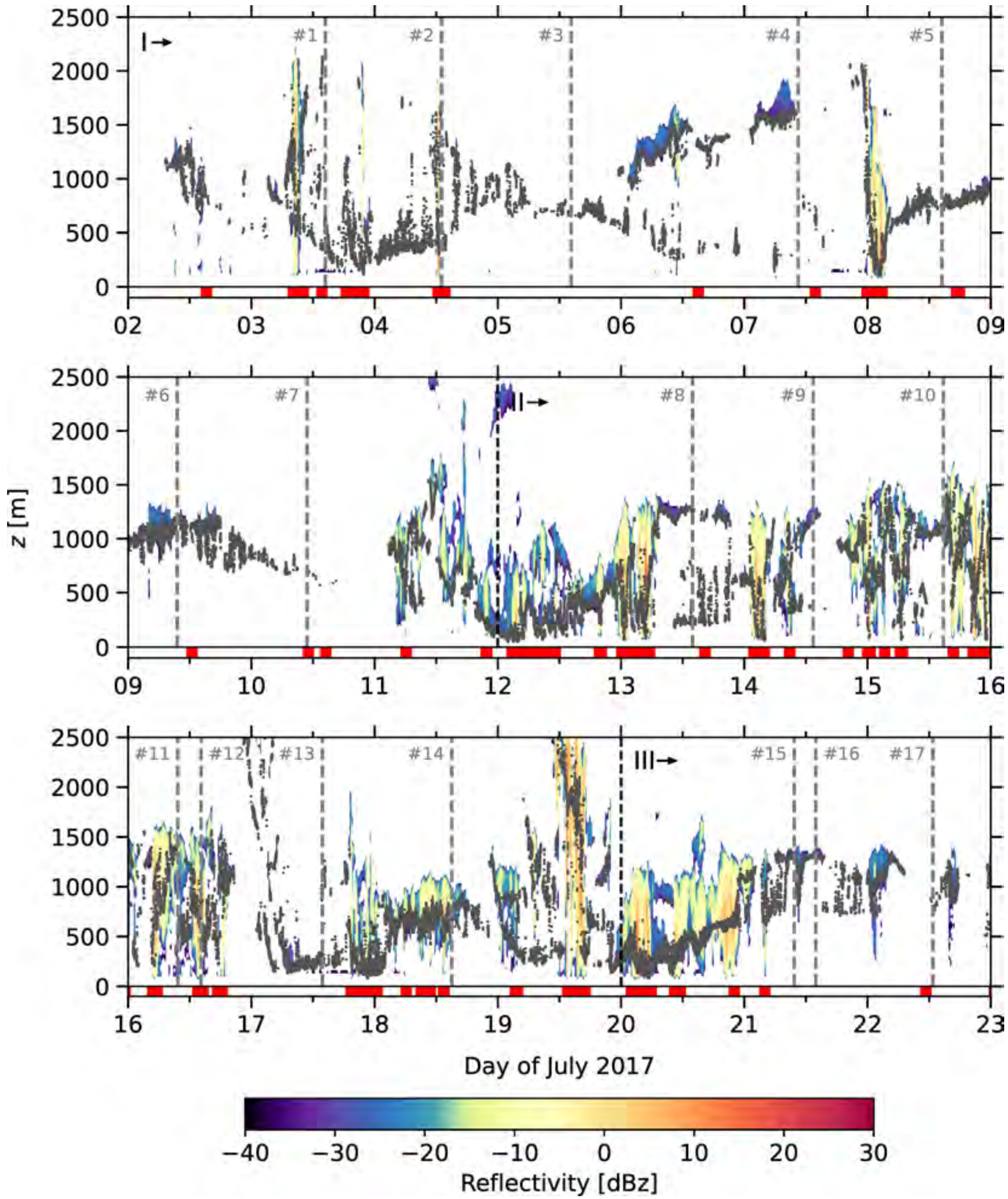
# Three different periods identified during the campaign

I. Azores high located west, northerly flow of dry and cold air, low cloud fraction with thin shallow Cu/Sc

II. Azores high centered above, weak winds, warm and moist air mass, daily cycle of stronger convection with frequent precipitation

III. Azores high located west, stable conditions with changing winds, dry and cold air mass, low cloud fraction with shallow convection

Specific humidity [g kg$^{-1}$]




radar reflectivity measured by the Ka-band ARM zenith radar at ENA

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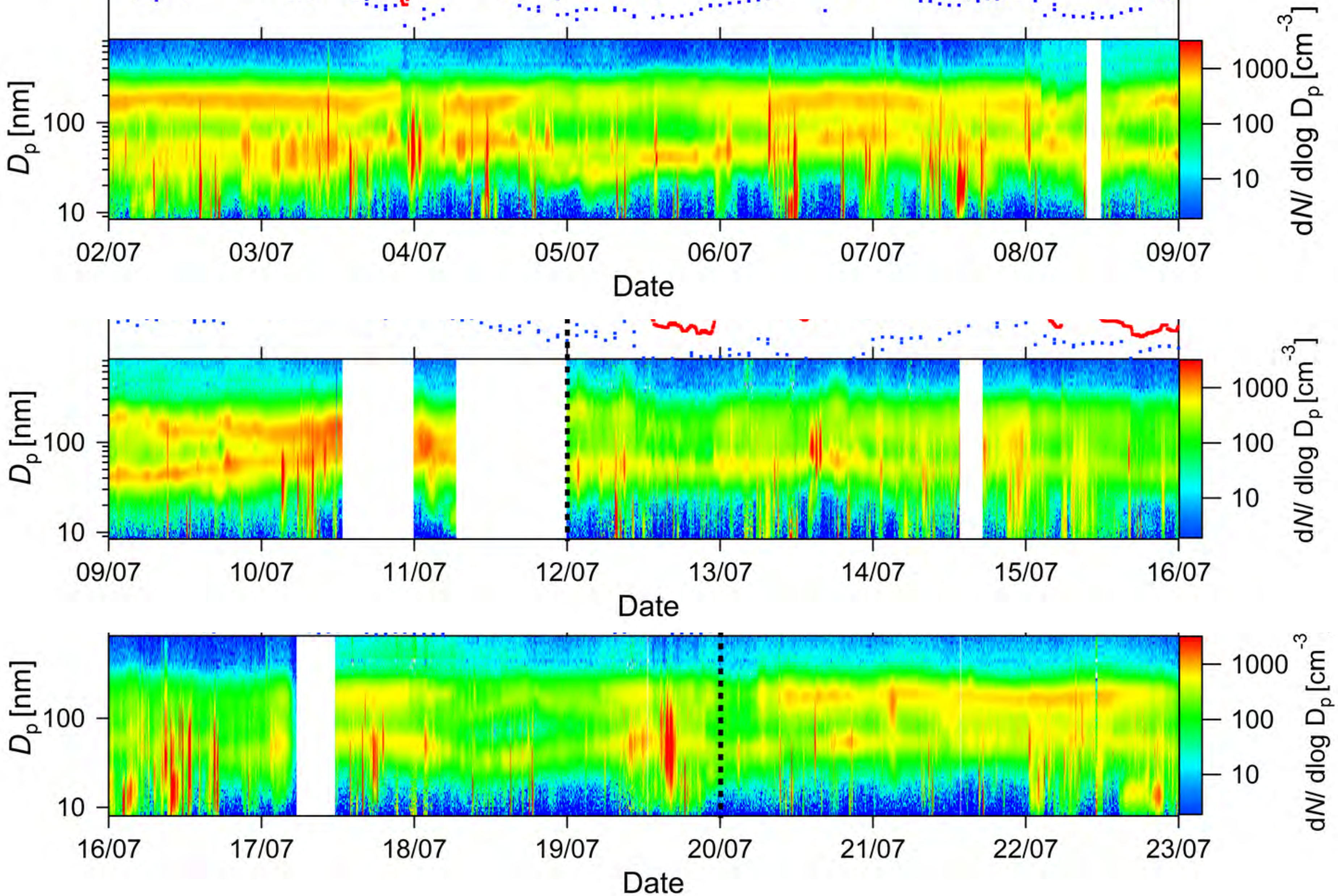


In the warm & humid period (II) accumulation mode is less pronounced at ENA

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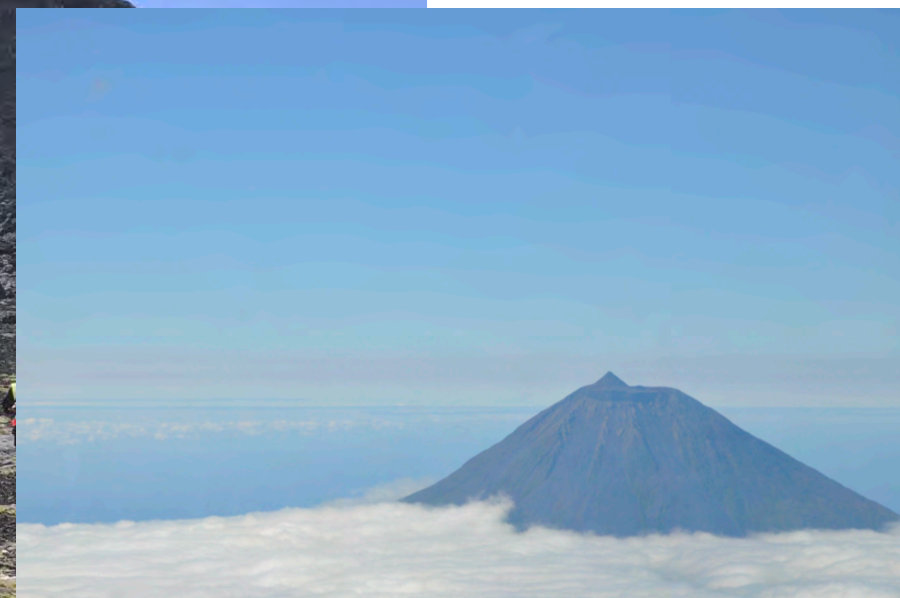
# Transport of additional sensor equipment to the Mt Pico station



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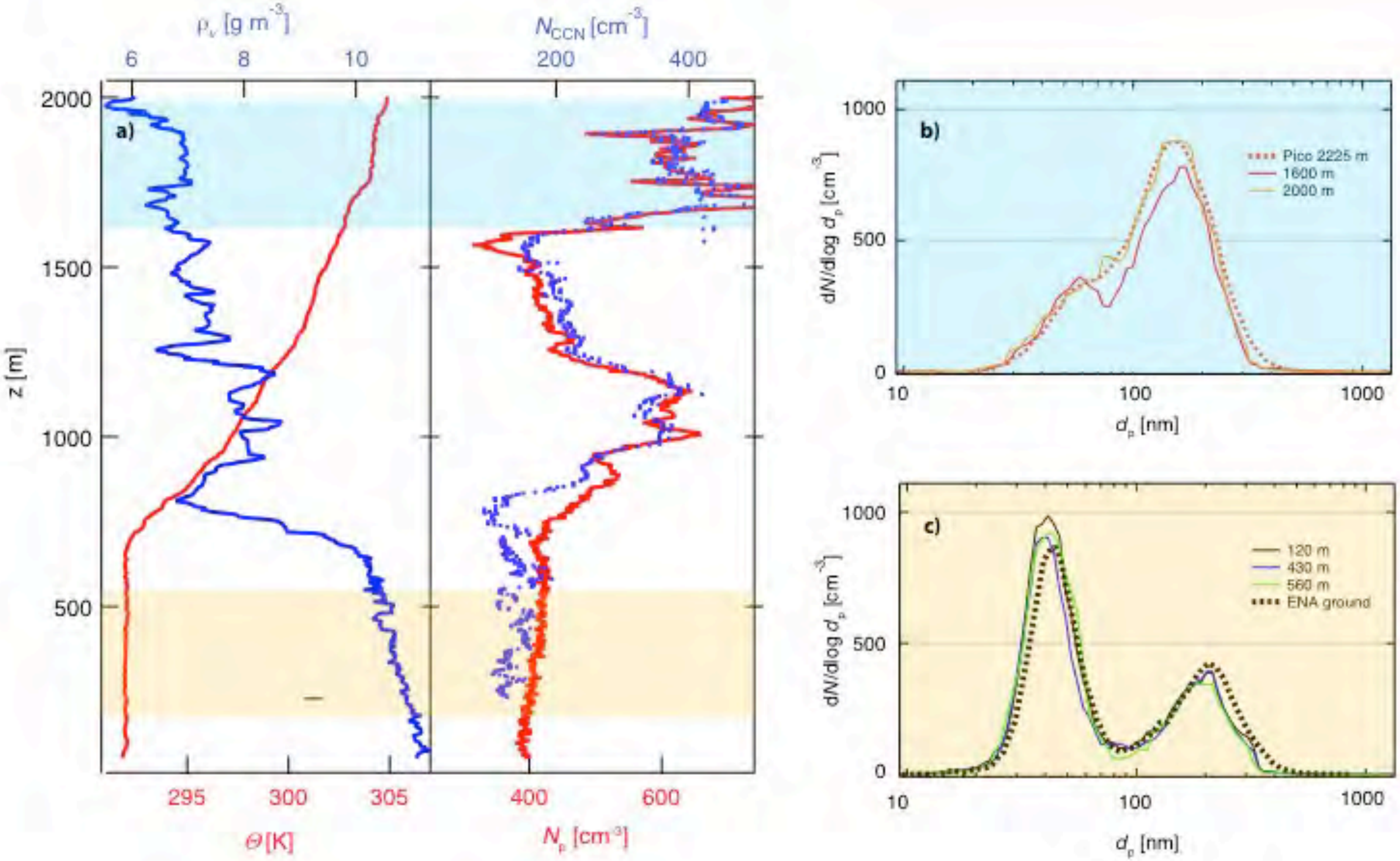
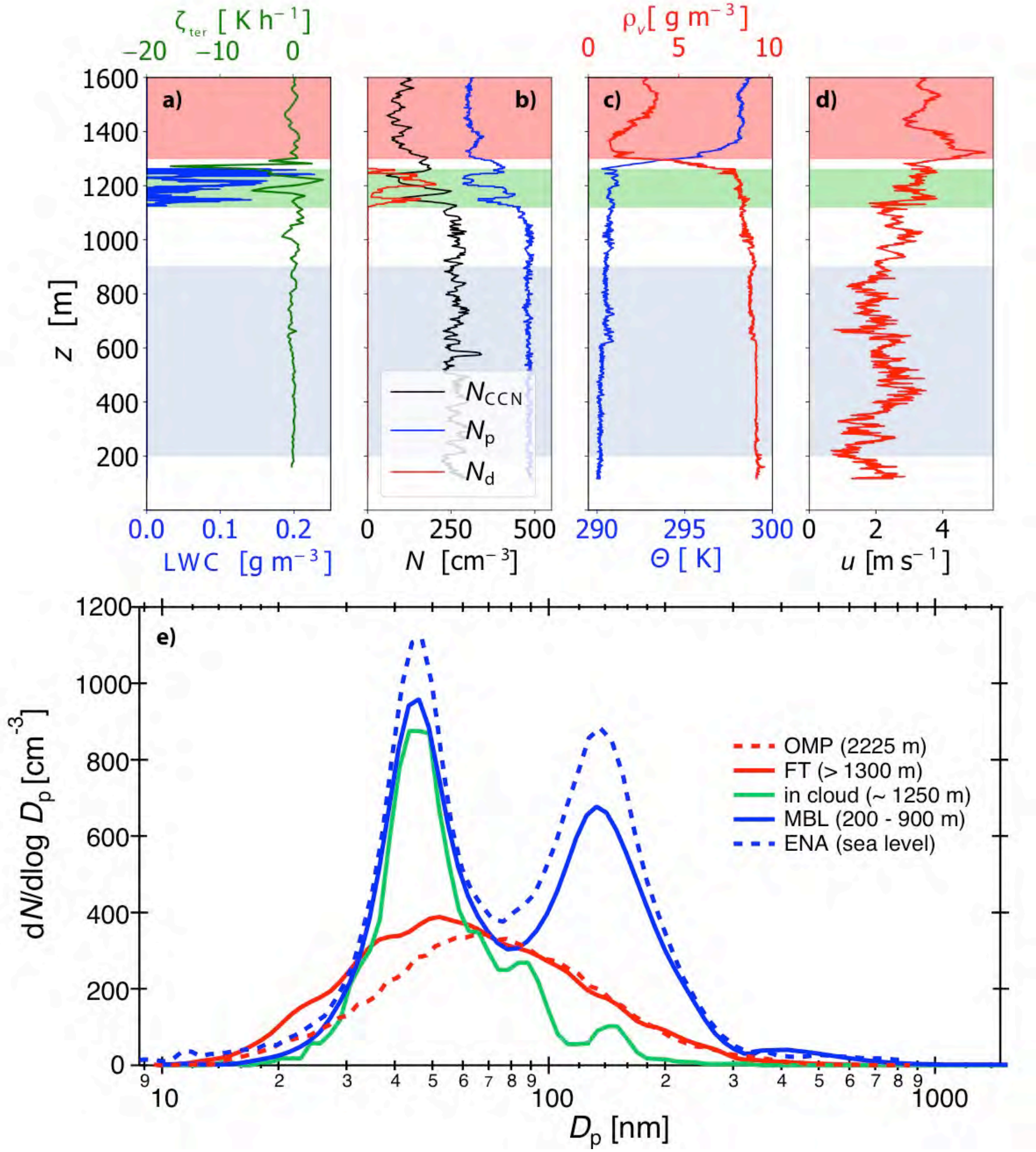
# Cloud-free case: Aerosol load in the ABL versus FT




⇒ Mt Pico exhibits the same type of aerosol as the free troposphere

⇒ ENA exhibits the same type of aerosol as the marine boundary layer

# Cloud case: Aerosol load in the ABL versus FT




Here: less aerosol in FT, almost no accumulation mode in the FT

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# Vertical aerosol particle transport within the boundary layer

## - turbulent particle fluxes -

Several methods to estimate the aerosol particle flux:

- Gradient method (K-Ansatz)
- Co-variance method
- ....

$$F = -K \frac{\partial N_\mathrm{p}}{\partial z}$$

$$F = \langle w' N_\mathrm{p}' \rangle$$

For example (Hanna 1968): $K = 0.3 \sigma_w \mathcal{L}$

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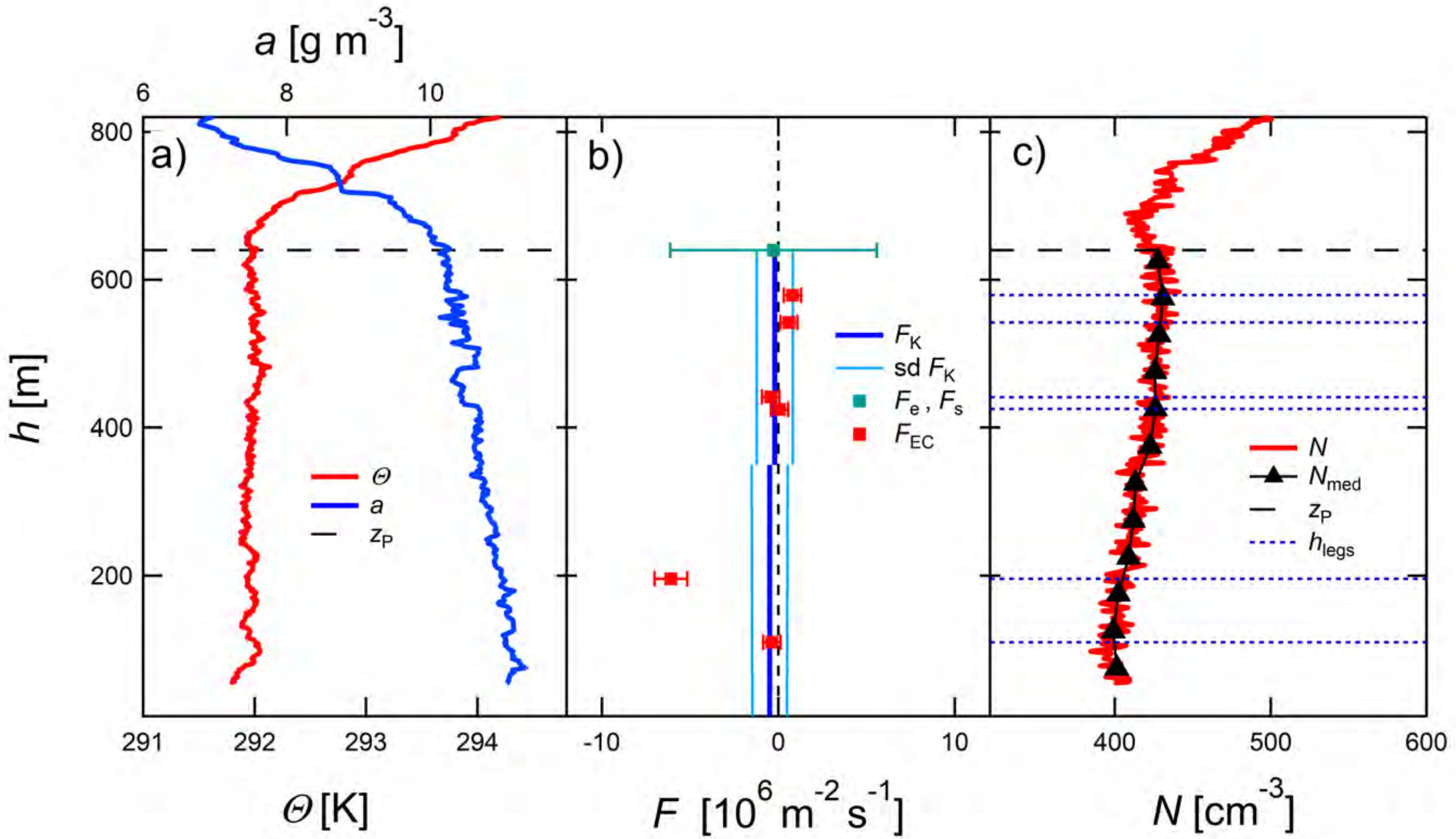
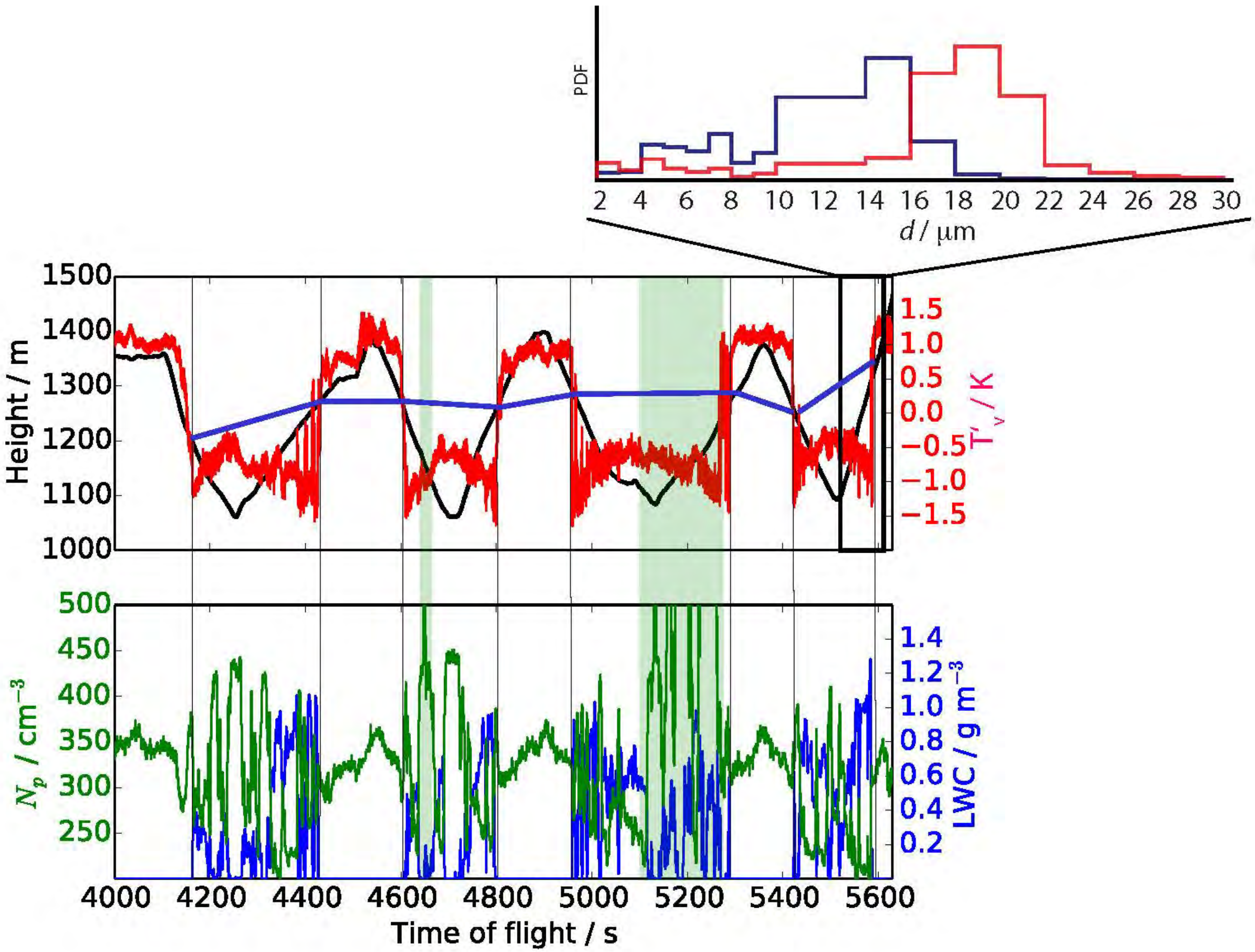

a [g m-3]
6
8
10
800
600
400
200
h [m]
a)
Θ
a
zP
291
292
293
294
Θ [K]
b)
FK
sd FK
Fe , Fs
FEC
-10
0
10
F [10^6 m-2 s-1]
c)
N
Nmed
zP
hlegs
400
500
600
N [cm-3]




=> New particle formation around cloud-top region

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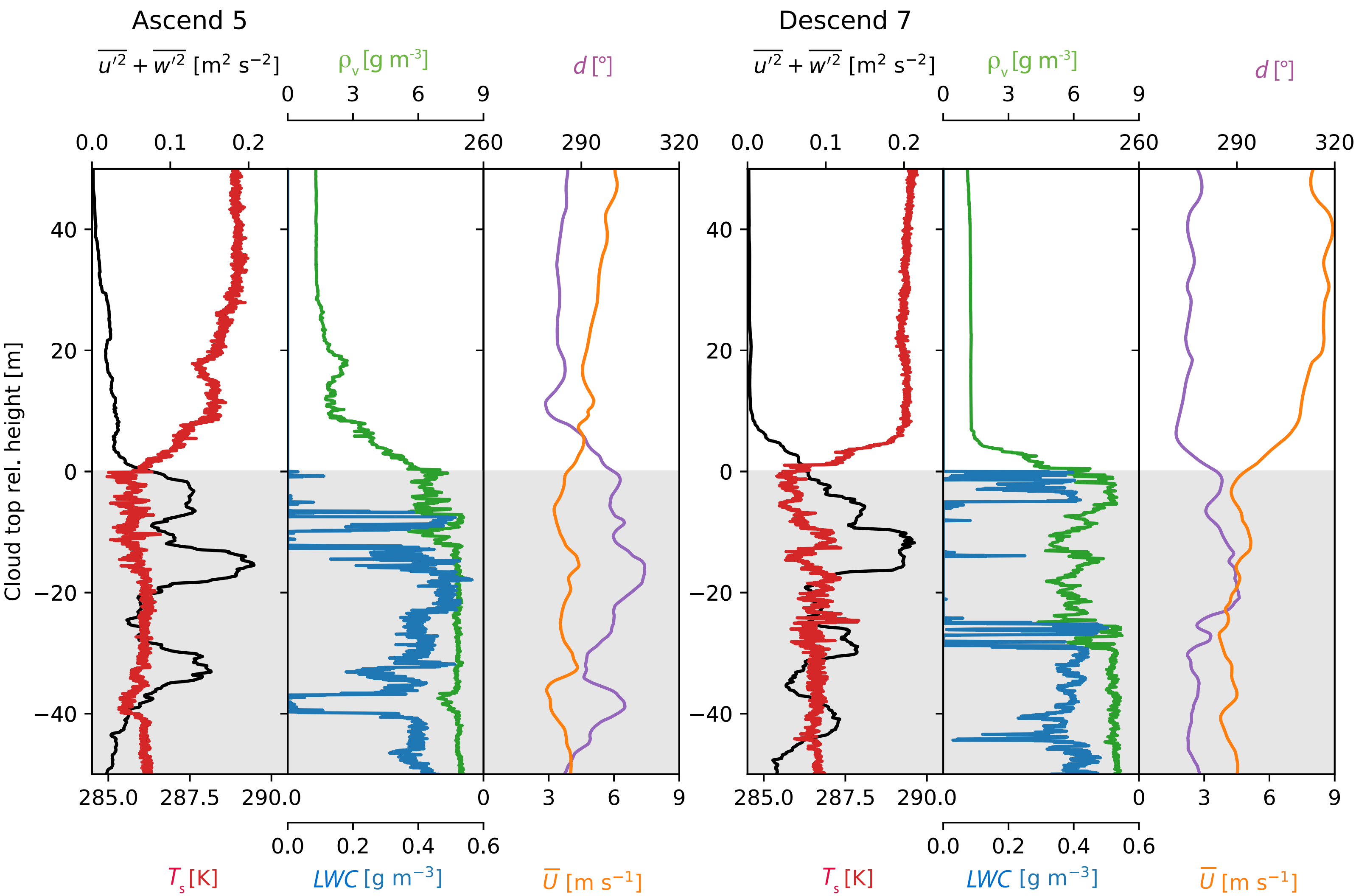
# The role of wind shear for vertical mixing -- 9 July 2017




Weak inversion with less shear

Strong inversion with stronger shear

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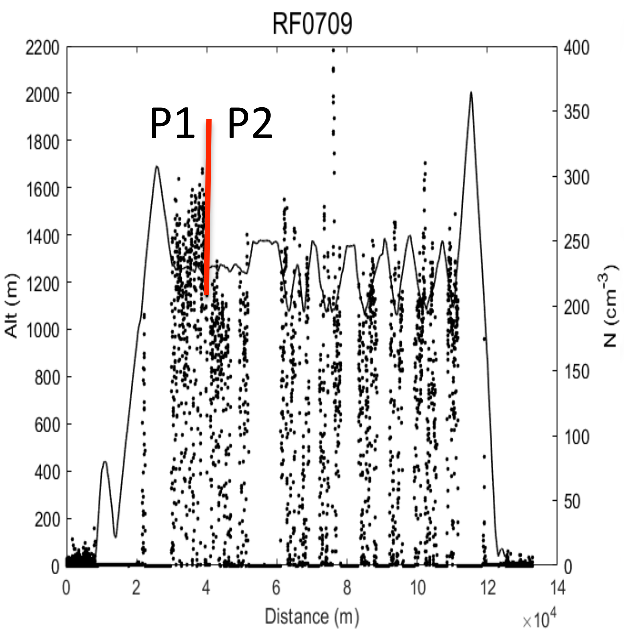
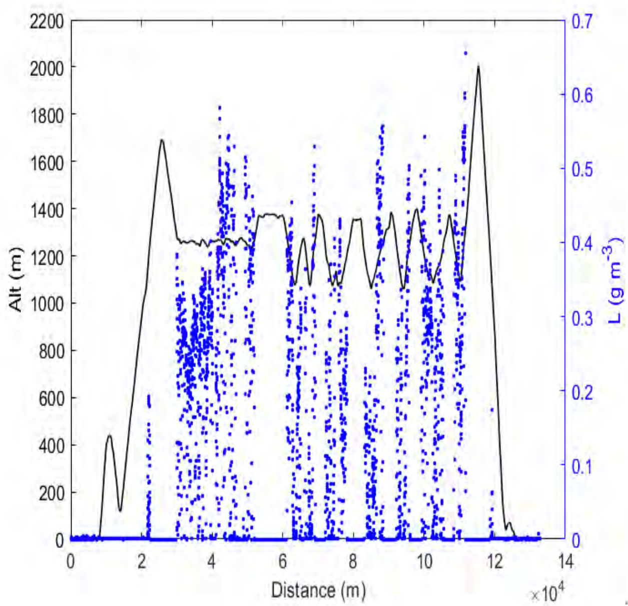
# Interplay of wind shear, aerosol, and entrainment,...

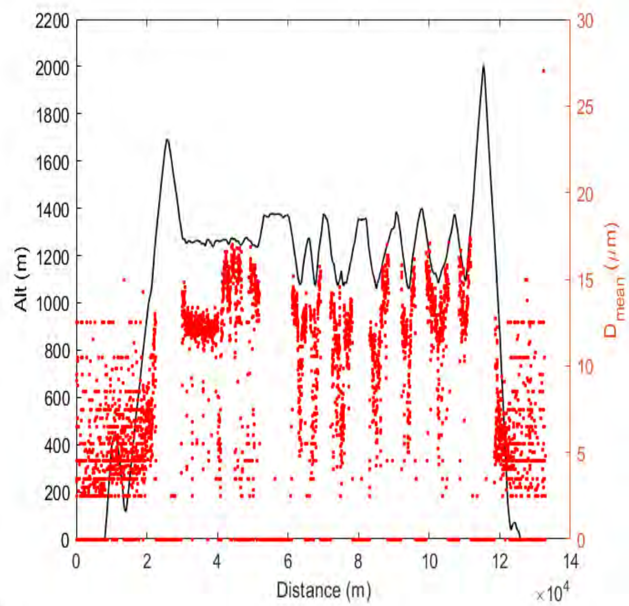
## Case study July 9th




Droplet concentration $N_d$




Liquid water content LWC




Droplet diameter $D_p$

Horizontal leg with two parts (P1 & P2) at constant height:

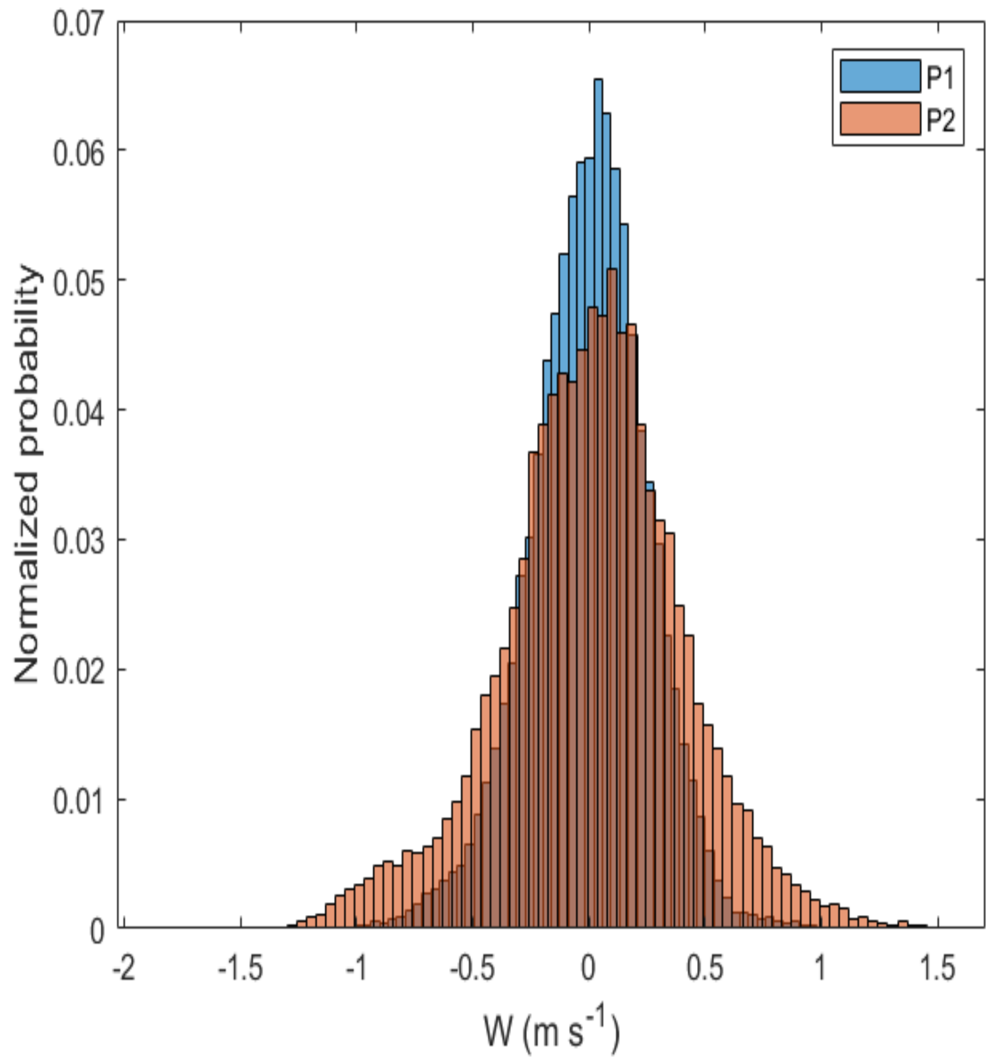
$N_d$ (P1) > $N_d$ (P2)
LWC (P1) < LWC (P2)
$D_p$ (P1) < $D_p$ (P2)

What cause these significant differences in cloud microphysical properties ??

# 1. Observations

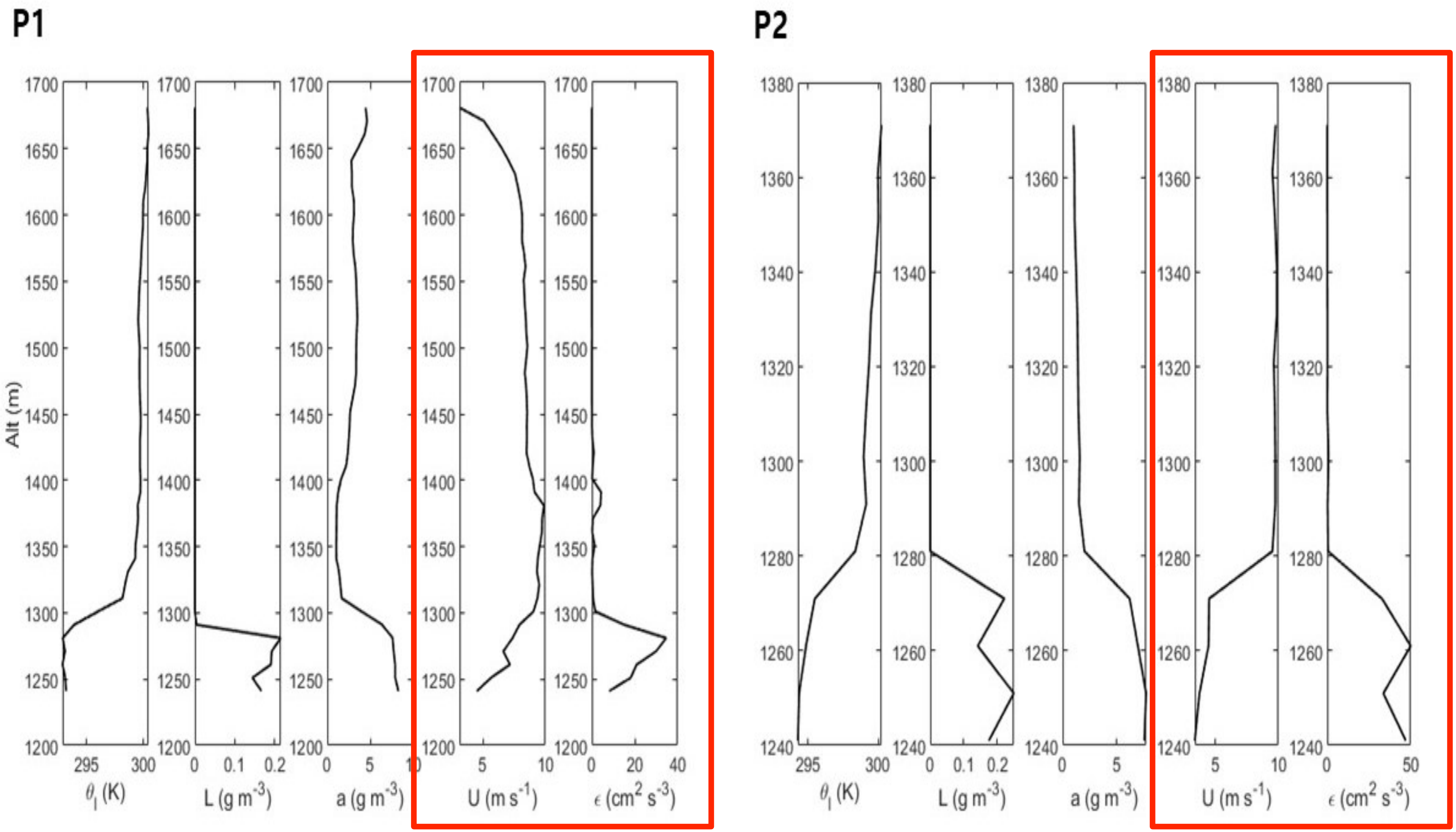
- **In-cloud vertical velocity of P1 and P2 during RF0709**

-The values of in-cloud vertical velocity (W) of P2 show higher fluctuations than those of P1.



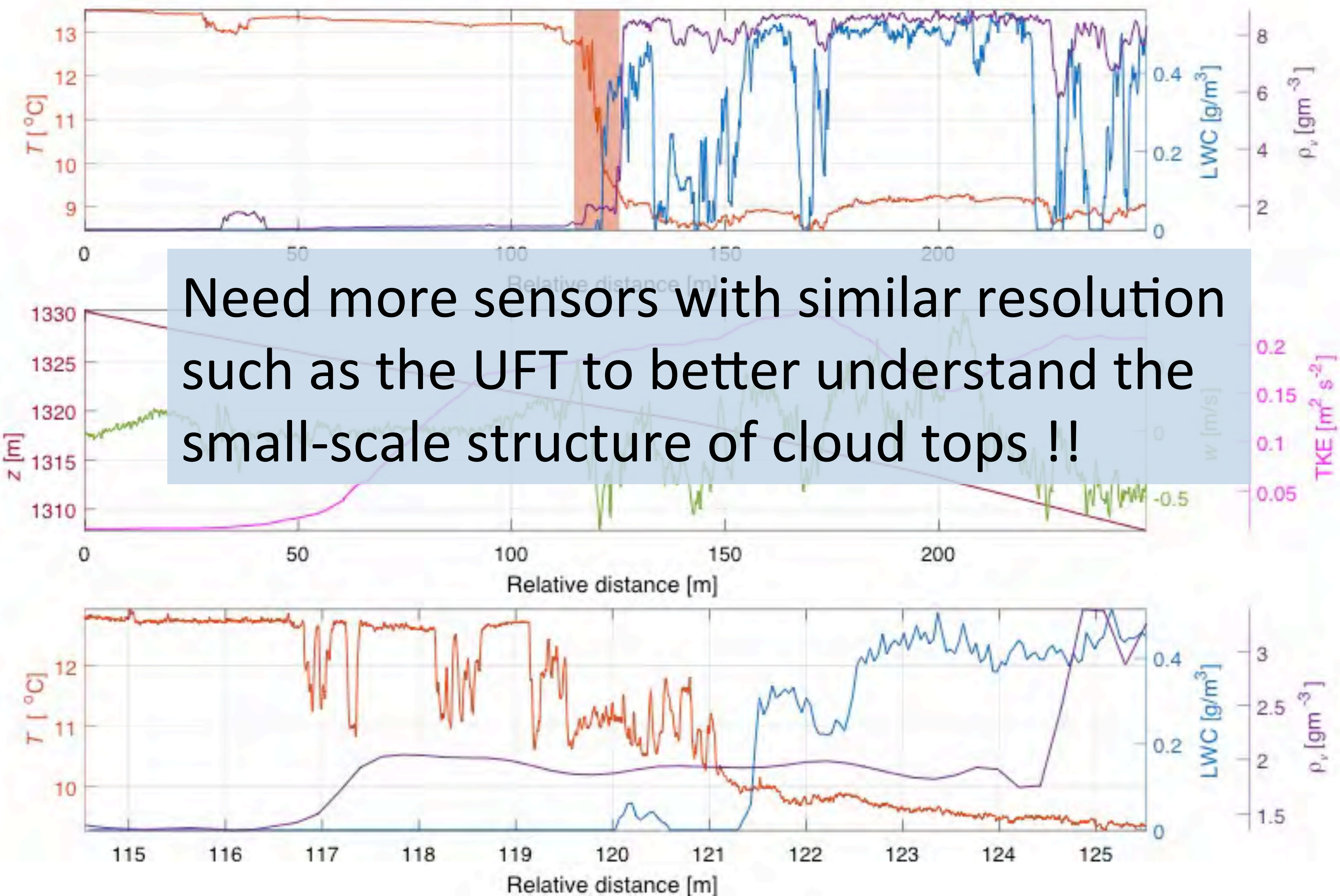
# 1. Observations

- **Vertical profiles of P1 and P2 during RF0709**

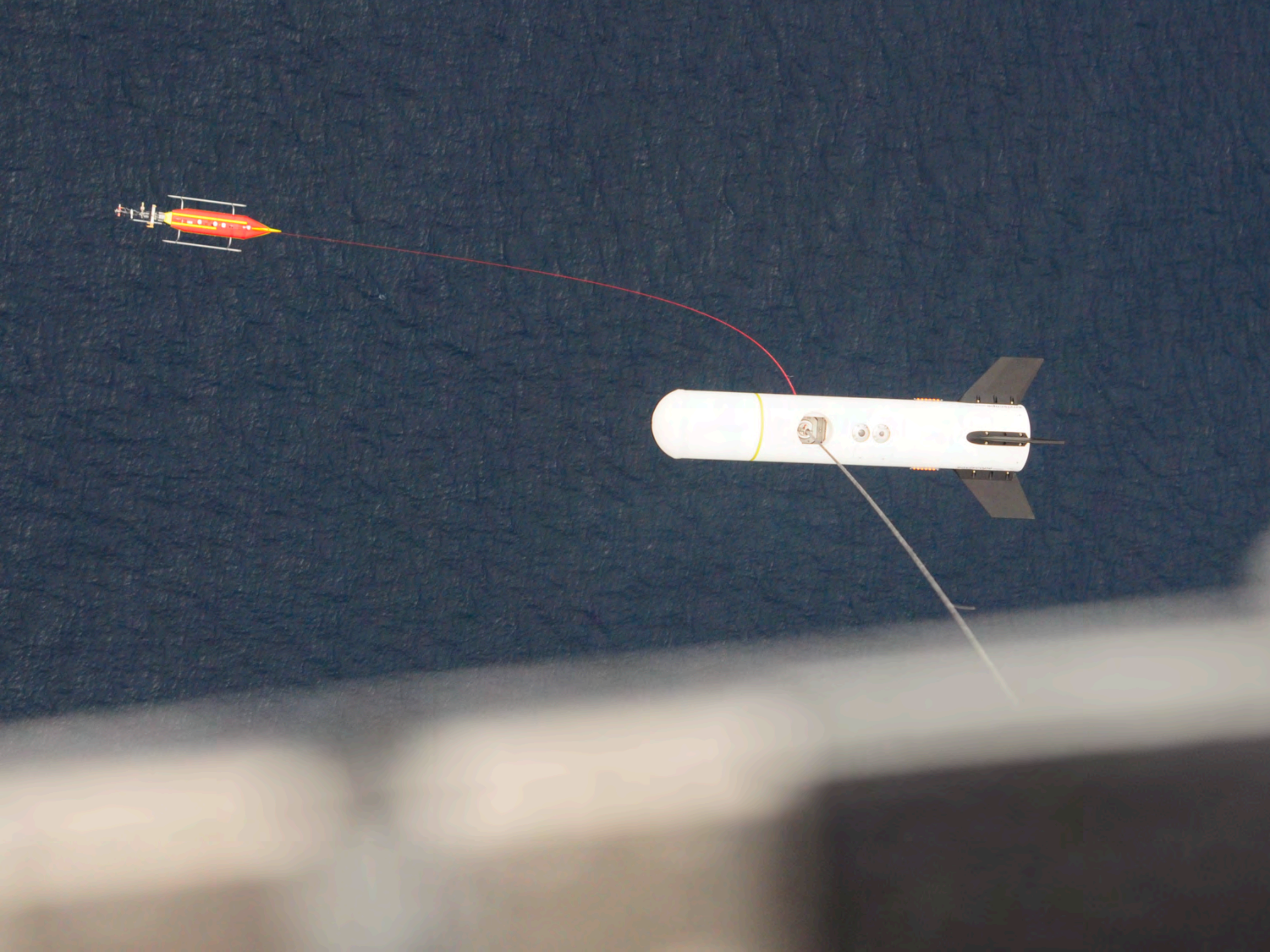



-Wind shear and turbulent dissipation rate are stronger in P2 than in P1.

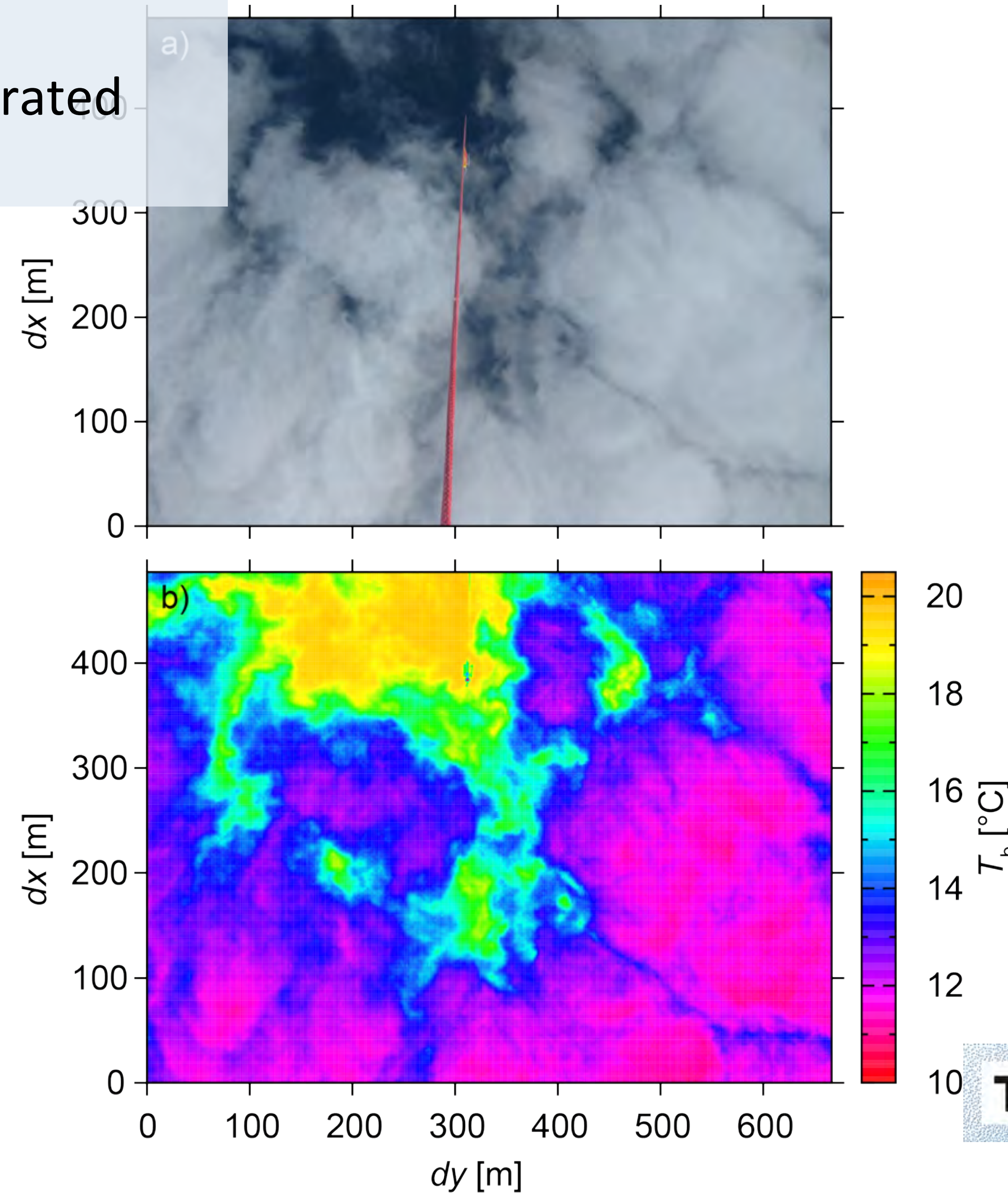
# Small-scale structure of the cloud top region




Need more sensors with similar resolution such as the UFT to better understand the small-scale structure of cloud tops !!



# Benefit of two vertically seperated payloads

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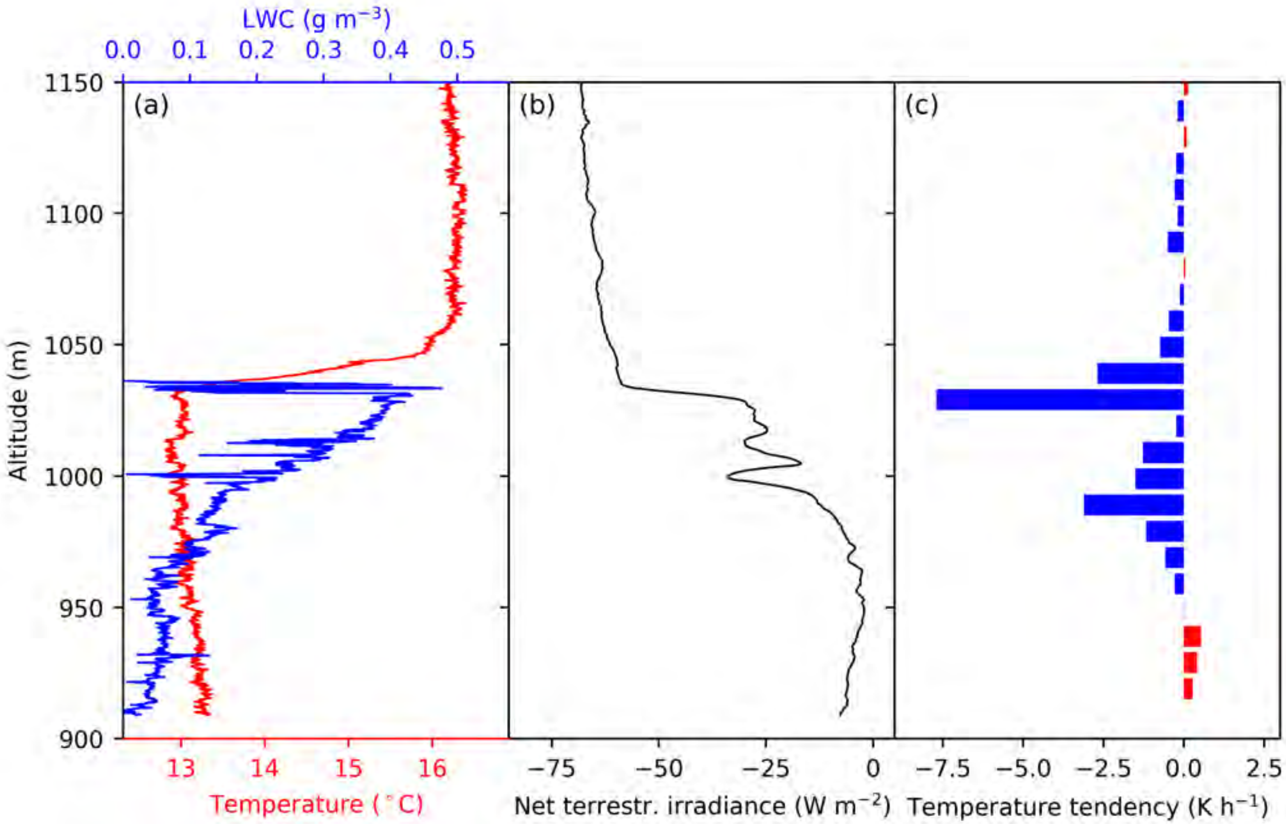
# Vertical profiles of cooling rates




$$\frac{\partial T}{\partial t} = \frac{1}{\rho c_p}\frac{\partial F_{\text{net}}}{\partial z} \text{ with } F_{\text{net}} = F^{\downarrow} - F^{\uparrow}$$

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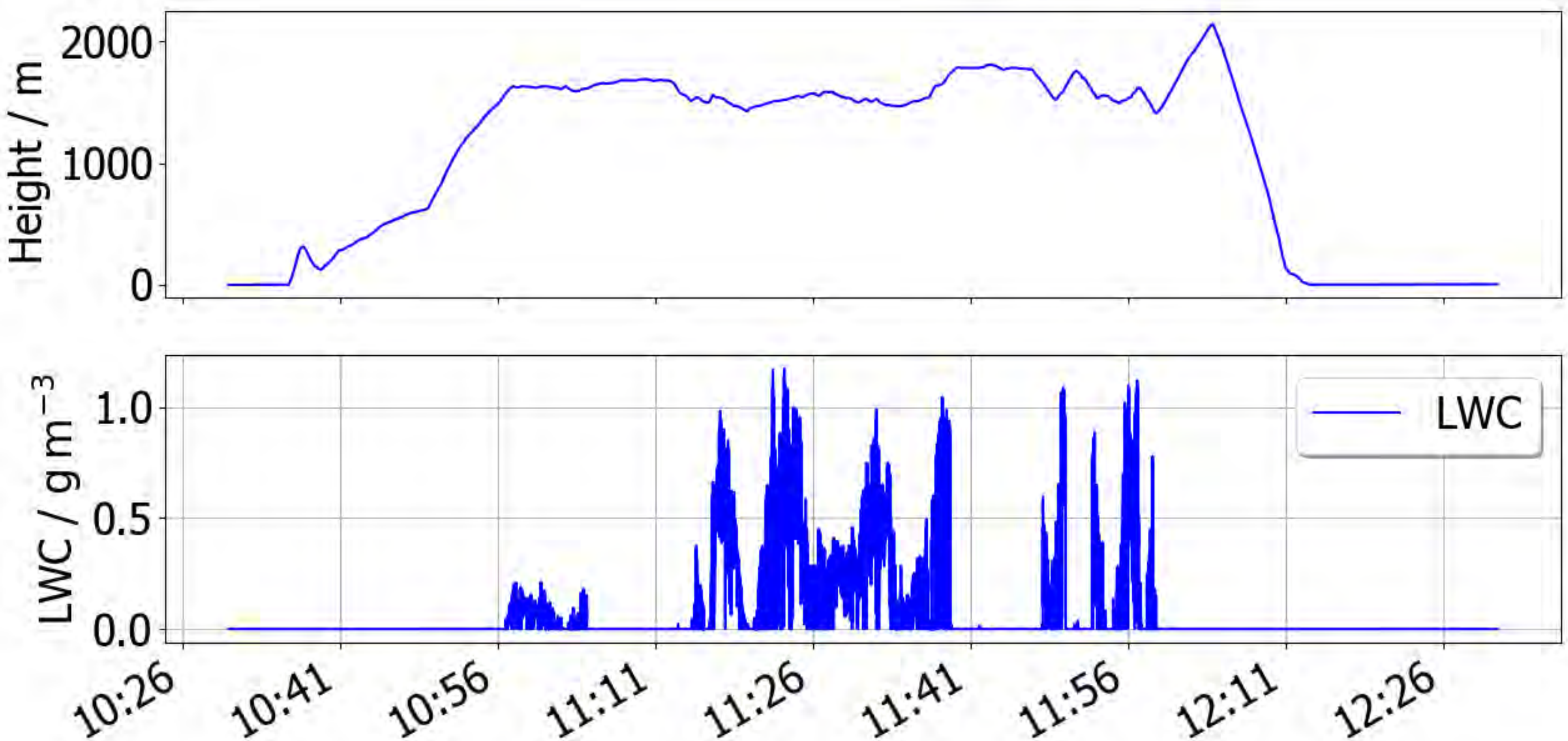
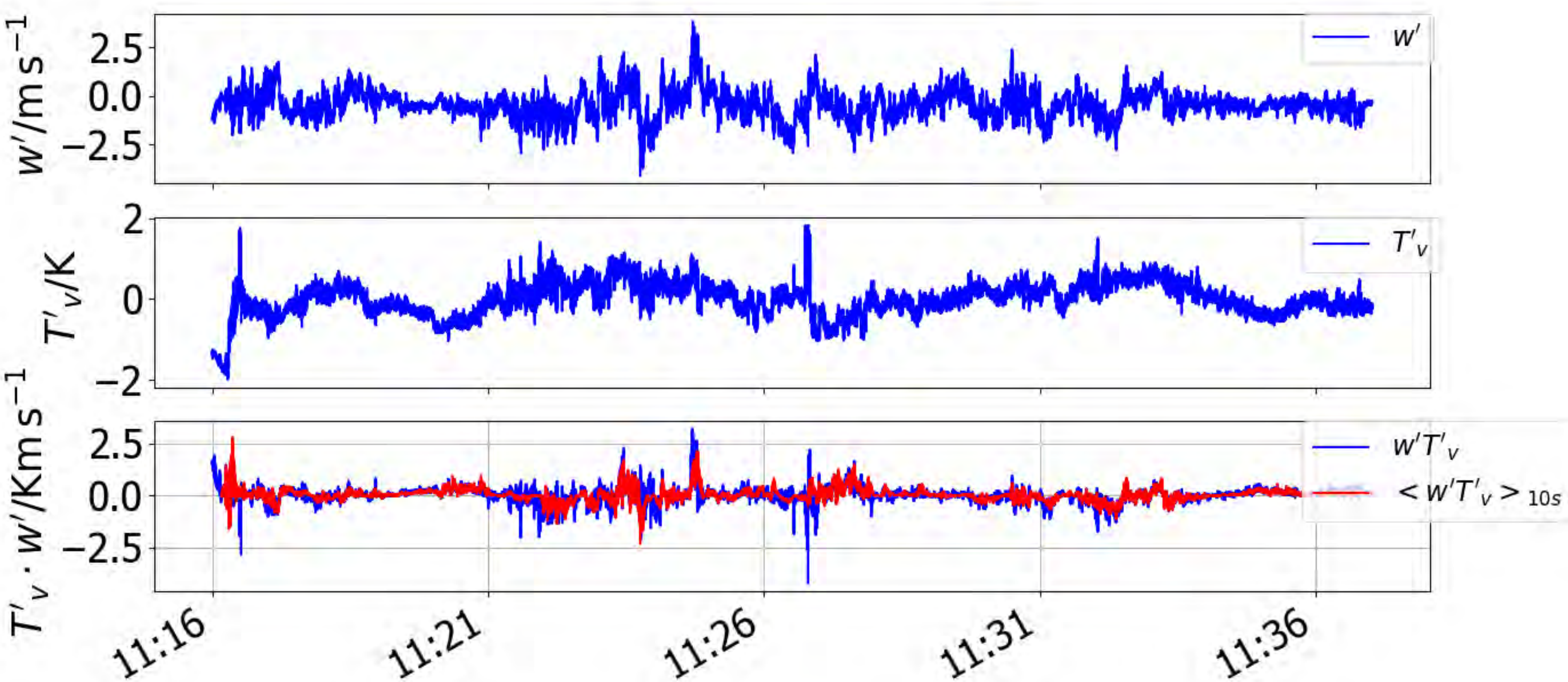
# ACORES July 7th

A comparable persistent cloud deck with high internal variability and mixing – an Island effect?

# ACORES July 7th



# ACORES July 7th




Nice test case for buoyancy flux observations !

**Approach to Graciosa Airport**


Thank four joining the campaign and listening to the talk