THE AEROSOL MEASUREMENTS DURING THE BEXUS18 KIRUNA FLIGHT

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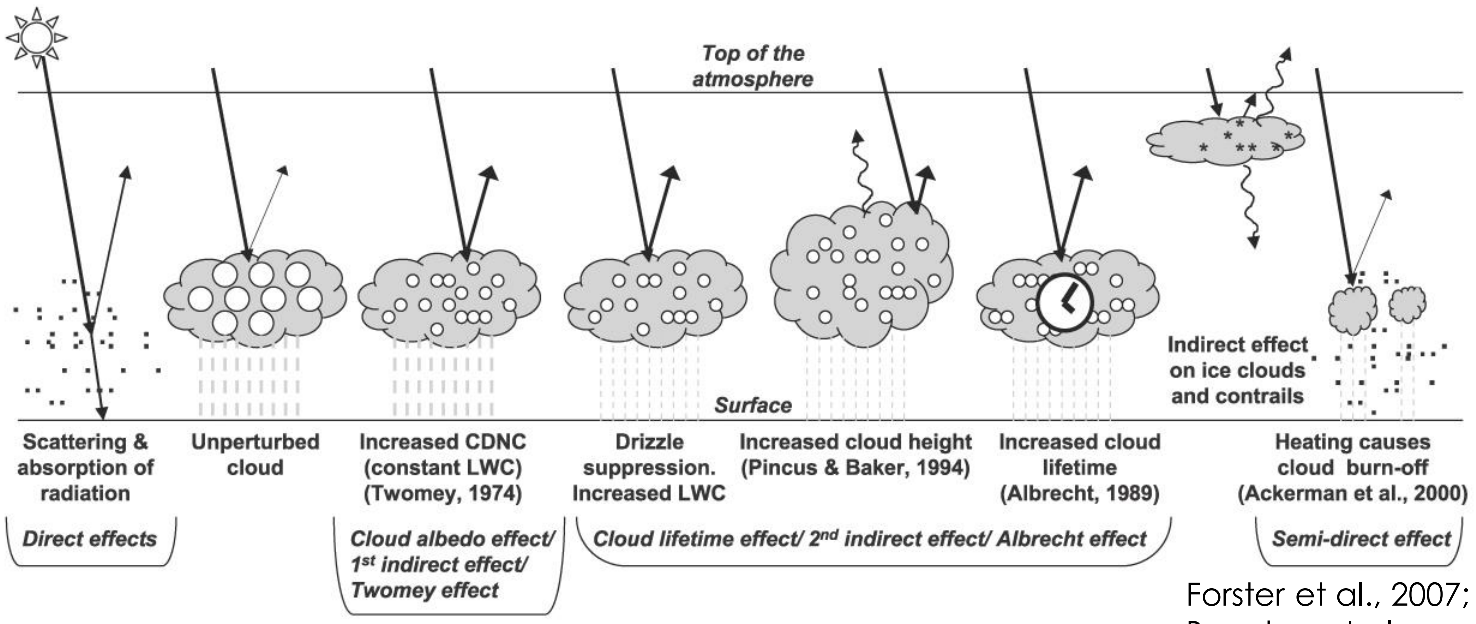
OUTLINE

- Introduction: the A5-UNIBO experiment and its general aims
- Instrumentation
- Main results
- Conclusions

AEROSOL EFFECT ON CLIMATE

- Direct effect: effect exerted by aerosols themselves on the radiative balance of the Earth through a combination of scattering and absorption of radiation
- Indirect and semi-direct effects: suite of possible impacts of aerosols on cloud properties (reflectivity, lifetime,…), due to the action as CCN (Cloud Condensation Nuclei)

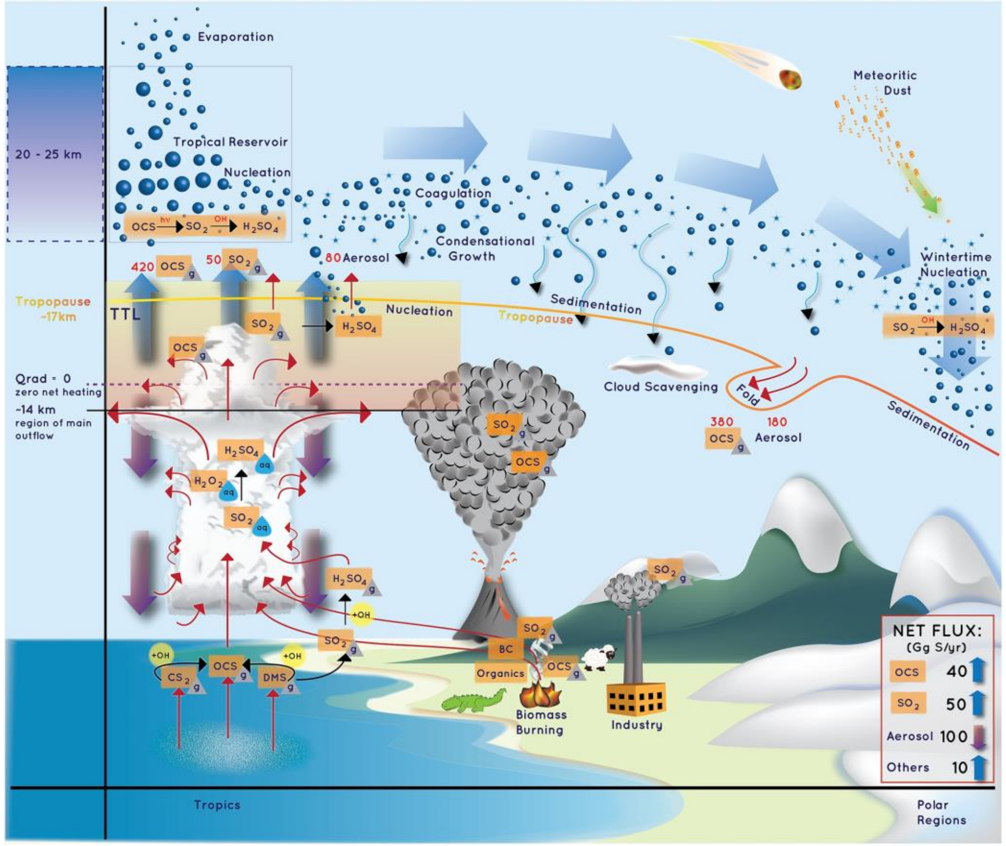


Forster et al., 2007; Boucher et al., 2013

Aerosols and clouds still continue to contribute the largest uncertainties to estimates of Earth's changing energy budget (IPCC, 2021)

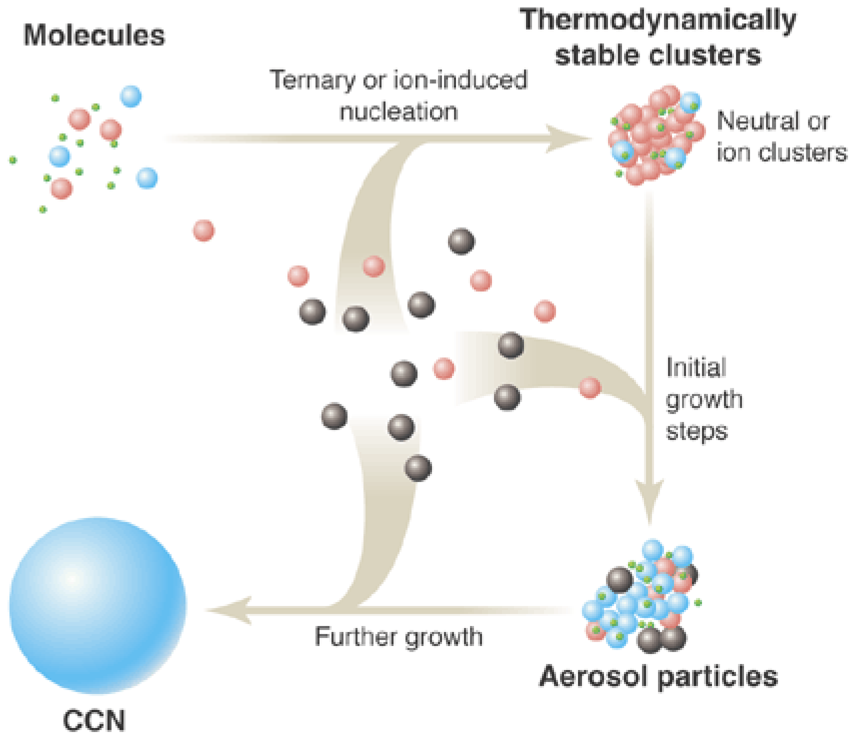
STRATOSPHERIC AEROSOLS

- Increased interest in stratospheric aerosol and its role on climate
- Previous focus on volcanic aerosols, which tend to mask the non-volcanic driven changes
- Availability of new measurement systems and techniques for measuring physical aerosol properties with greater accuracy and for characterizing aerosol composition



Kremser et al., 2016

ION-INDUCED NUCLEATION (IIN)



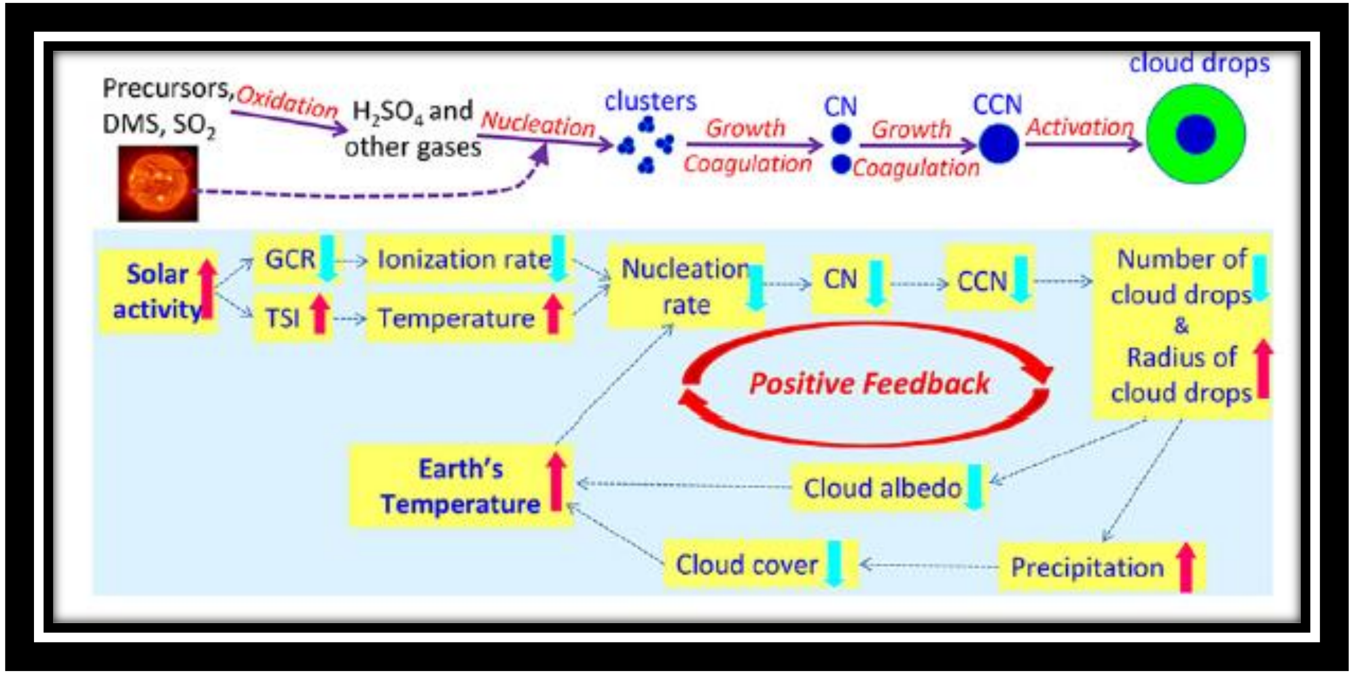
Raes and Janssens, 1985

- New particle formation much more stable in presence of an ion
- 3 main sources of ions in the atmosphere:
  - radon isotopes
  - terrestrial γ-radiation
  - galactic cosmic rays (GCR)

- atmospheric ion concentrations largely determined by the intensity of GCR

  → <u>ion-induced nucleation</u> could explain the observed cosmic ray-climate correlation
- especially true in a clean, pre-industrial atmosphere

ION-AEROSOL CLEAR-AIR MECHANISM



- Enhancement of particle formation and growth due to the presence of ions
- Increase in GCR causes an increase in CCN abundance
- Increase in cloud reflectivity and lifetime
- Observations to study and quantify these effects incomplete and not conclusive

A5-UNIBO ONBOARD BEXUS18

- **A5-Unibo: Advanced Atmospheric Aerosol Acquisition and Analysis**

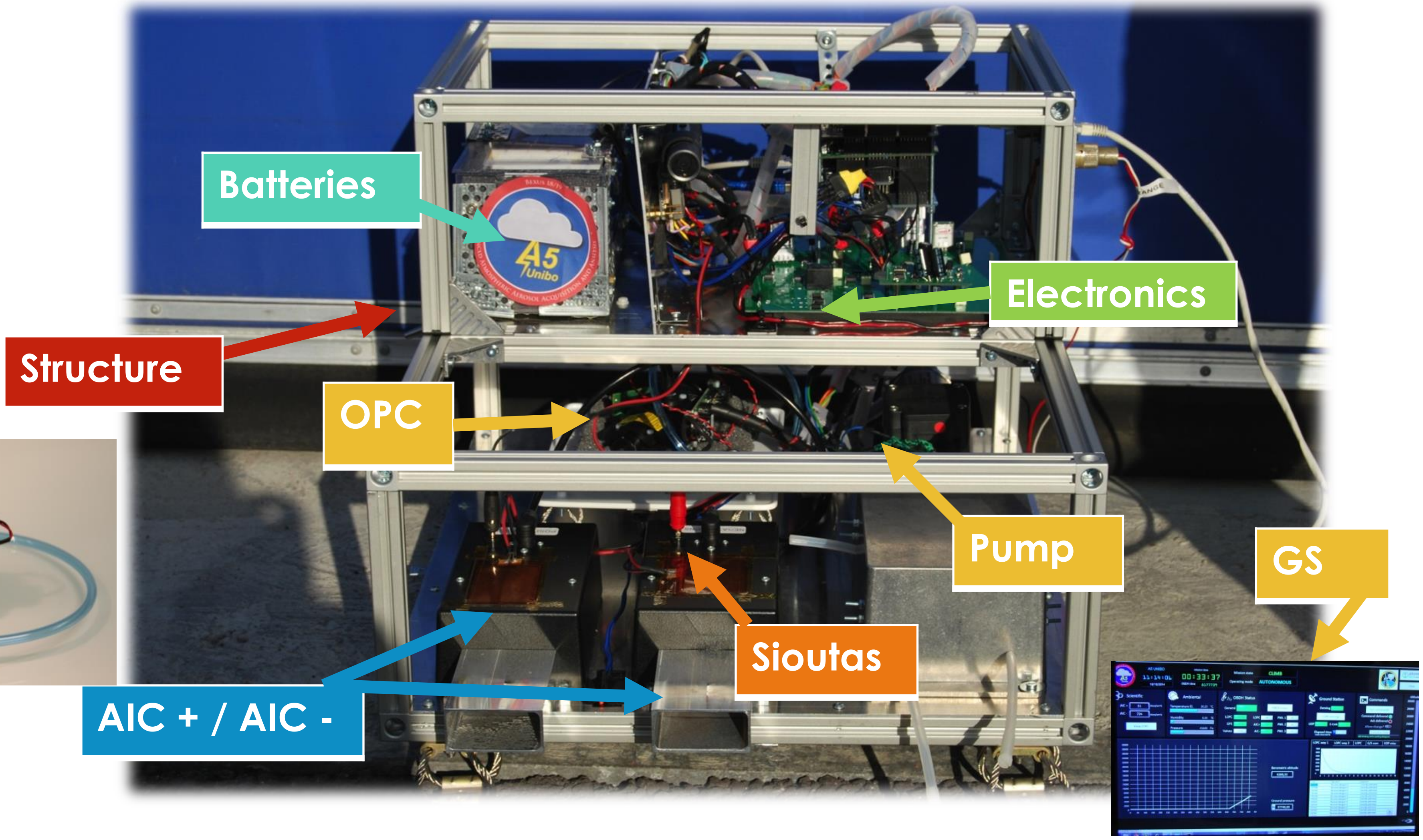
- Experiment flown from Kiruna (Sweden) onboard BEXUS18 stratospheric balloon within the REXUS/BEXUS programme = opportunities for student experiments to be flown on sounding rockets and stratospheric balloons
- Realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board Center (DLR)
- Swedish share of the payload available through a collaboration with the European Space Agency (ESA)

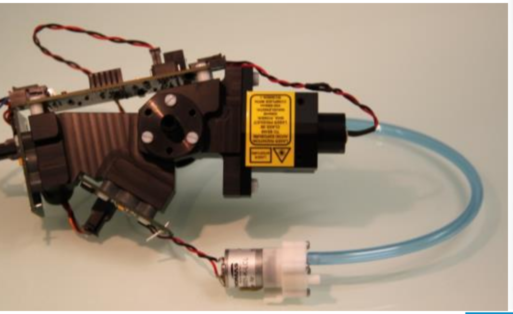
A5-UNIBO OBJECTIVES

- Analysis of vertical profiles of:
  - key atmospheric parameters (temperature, humidity, pressure)
  - particles size distribution (LOAC, Light Optical Aerosol Counter, MeteoModem Inc.)
  - positive and negative ion densities (Air Ion Counter, AlphaLab Inc.)

- Goal: better understanding of atmospheric processes through a rather simple low-cost and light-weight (compared to the conventional instrumentation onboard stratospheric balloons) multi-instrument approach

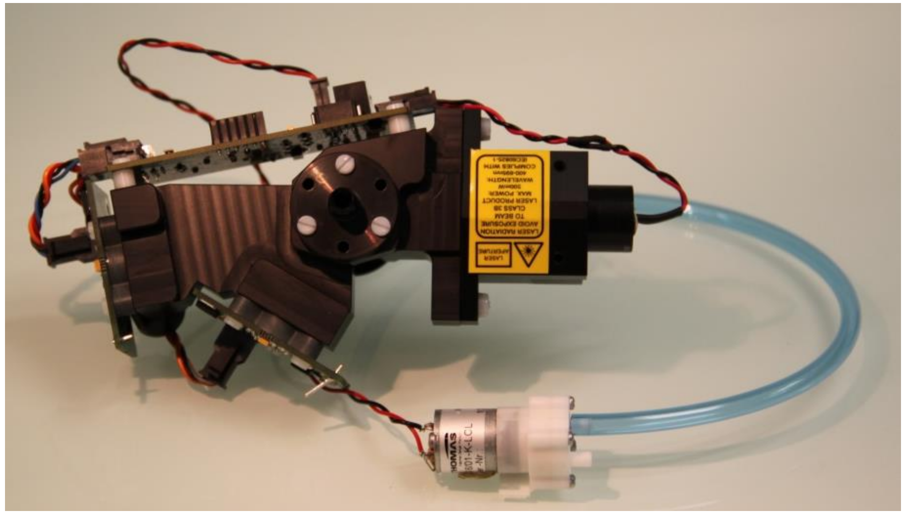
A5-UNIBO MAIN COMPONENTS





LOAC aerosol counter

KEY INSTRUMENTATION



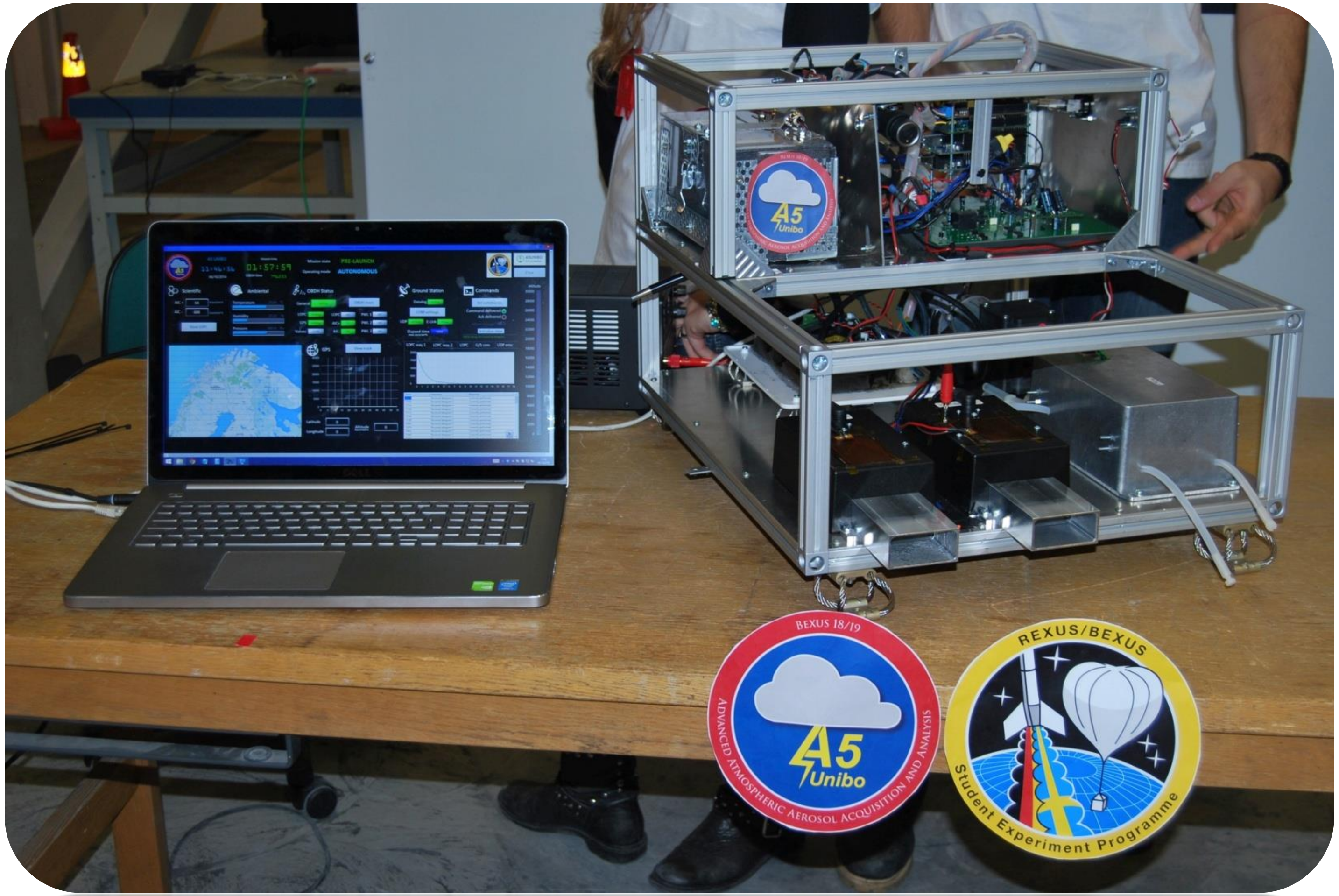
LOAC aerosol counter
(Renard et al., 2016)

Balloon-borne aerosol measurements in the troposphere and in the stratosphere

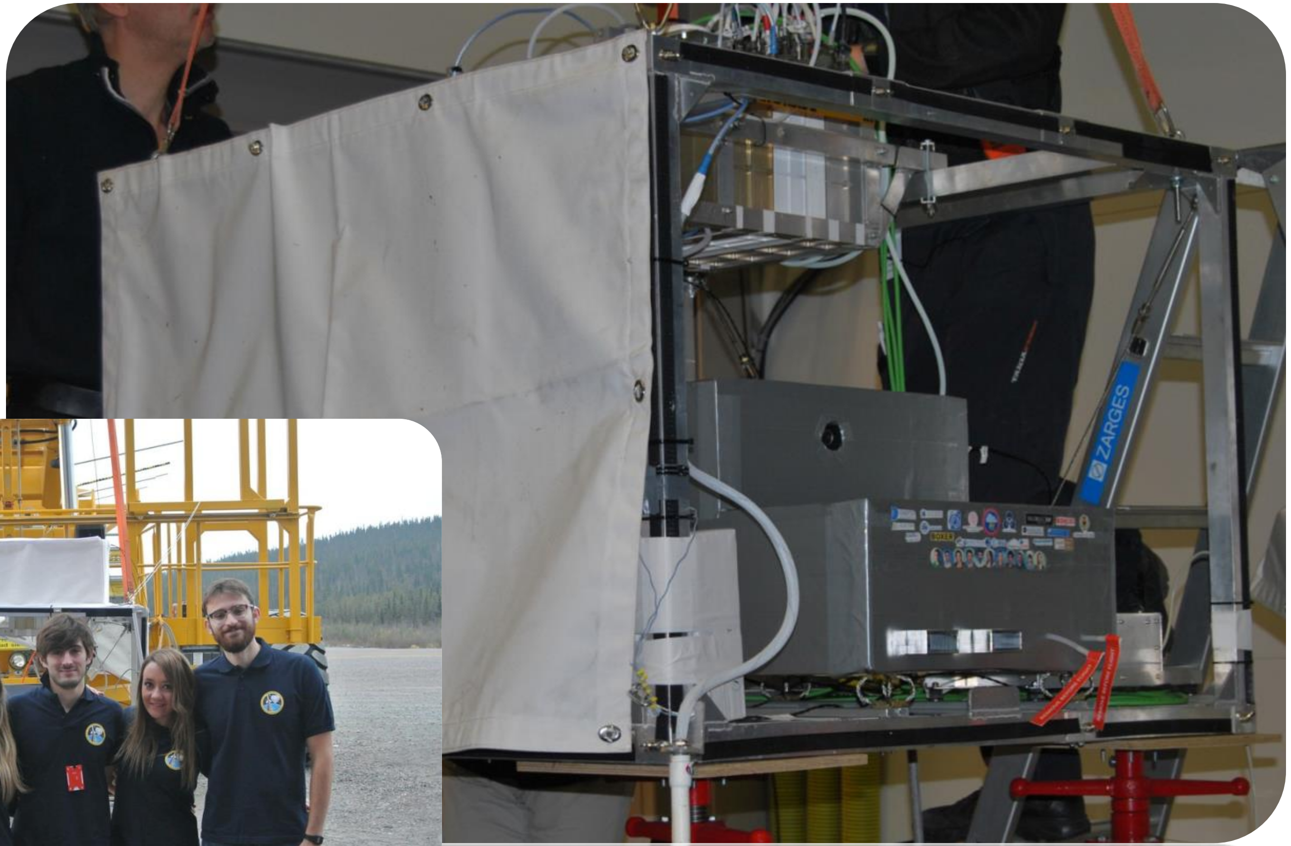
Alphalab air ion counters

Ion density meter; light and small, resolution up to 200 000 ions cm^{-3}

FINAL CONFIGURATION A5-UNIBO



READY FOR FLIGHT

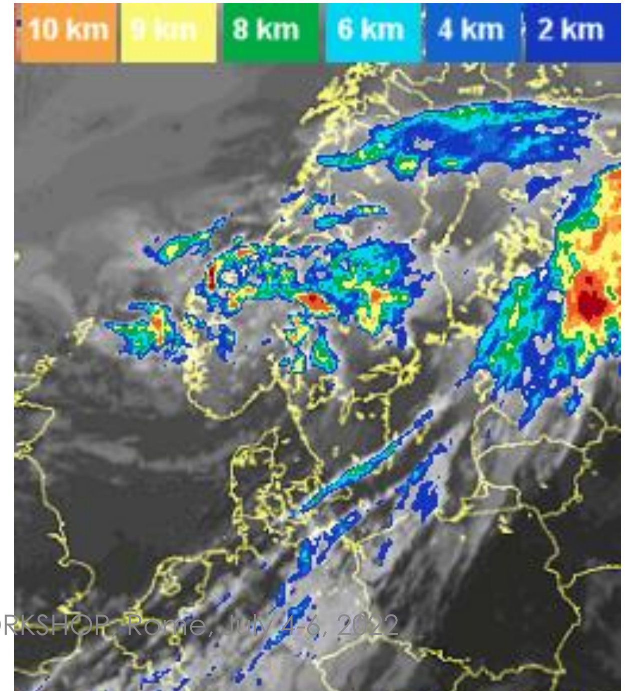


THE FLIGHT

Max Altitude: 27,2 km

Floating time: 1h 8 min

Departure:Esrange Space Center in northern Sweden (Kiruna)
Landing: Finland



FLIGHT EVENTS

Following table describes the Bexus 18 flight from the pilot point of view:

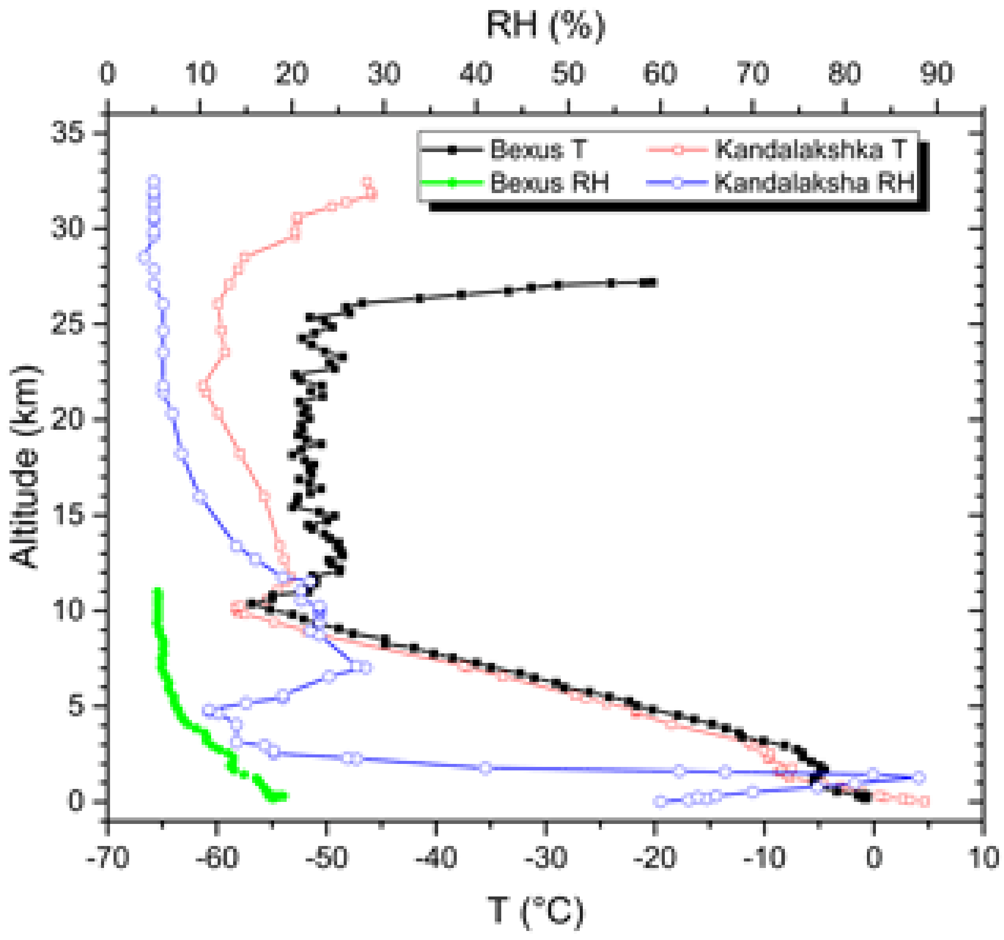
Time (UTC)	Event	Altitude (m)	Notes
08:48:30	Release of balloon	335	Released from Hercules launch vehicle.
08:51:51	Armed the load sensor	1123	Stabile reading on load sensor: 157 kg
10:51:31	Balloon stops ascending Avg. float level ~27200 m	27248	Average ascending velocity during climb: 3.5 m/s
11:58:06	Arming of flight termination device	27112	Preparations for flight termination
12:00:00	Cut-down	27091	Flight terminated on pilot command
12:28:30	Loss of signal	2322	Latitude: 68° 03,508 ′ Longitude: 26° 05.468′

VERTICAL PROFILES: ATMOSPHERIC PARAMETERS

- Comparison with radiosounding at Kandalashka (Russia; 67.15° N, 32.35° E; 25 m a.s.l.)

- **Temperature**:
  - Good agreement in the troposphere: small inversion layer close to ground and tropopause starting at 11km
  - Major differences in the stratosphere, possibly due to solar heating and reflection from other instruments/structures

- **Relative humidity**: major differences due to slow response of instruments onboard BEXUS and to low temperatures in the stratosphere



Brattich et al., 2019

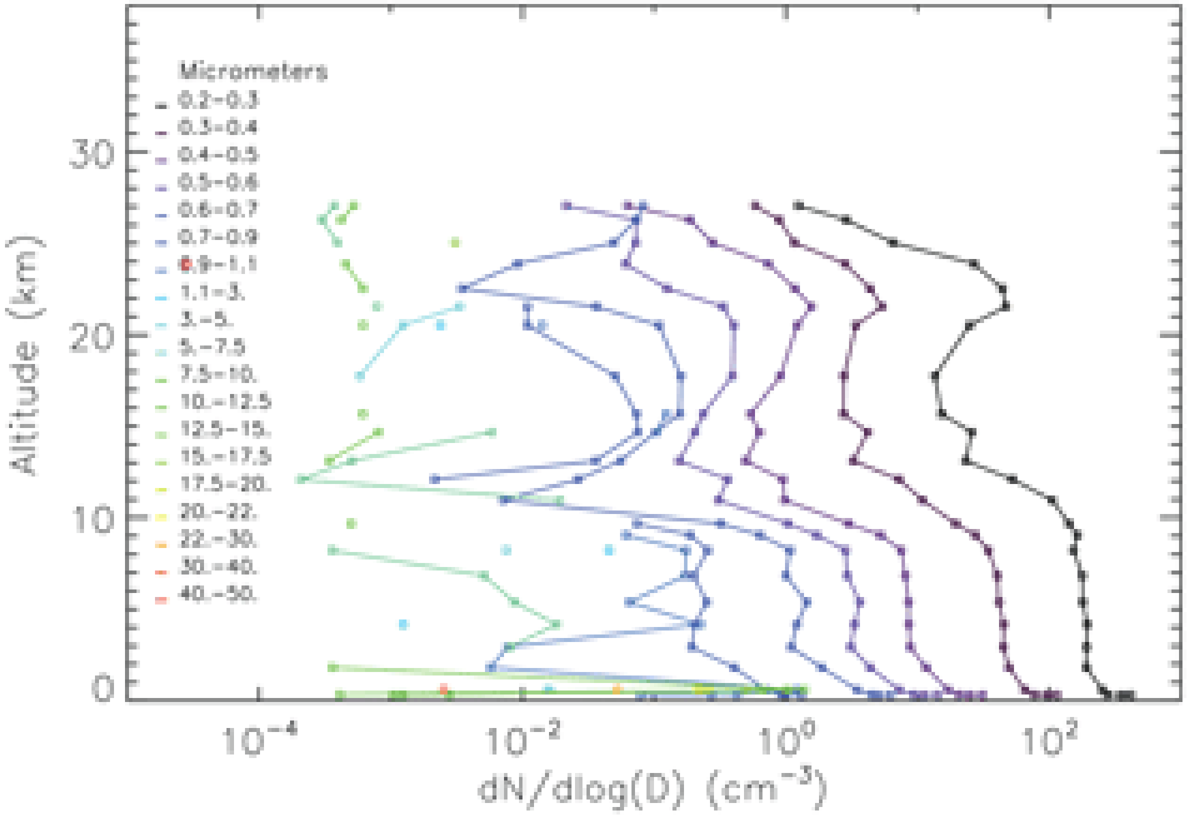
VERTICAL PROFILES OF PARTICLES SIZE DISTRIBUTIONS

- Most of the particles have size < 1µm, as expected in clean free troposphere and in the stratosphere

- Few particles > 1µm and < 15 µm

- All fine particles present same vertical variation, with decreasing concentrations above the tropopauase

- Different variation for larger particles, with abrupt increase in the PBL and then at 10 km



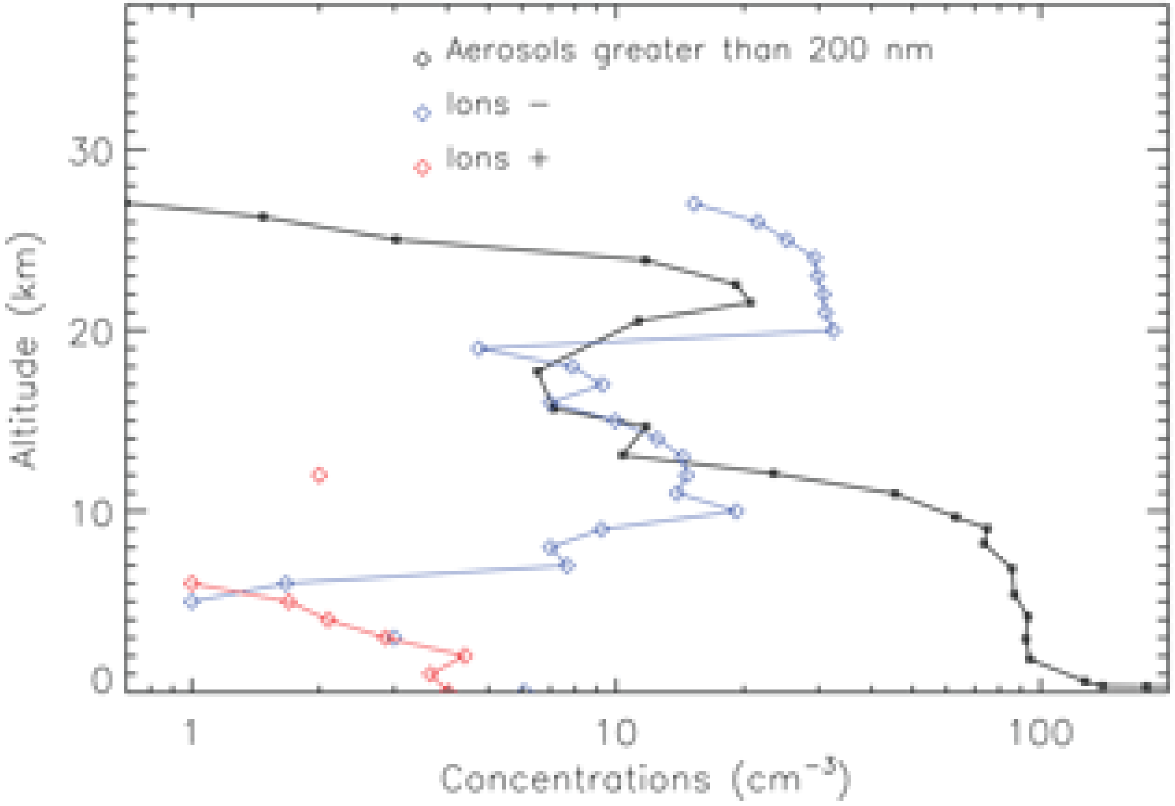
Brattich et al., 2019

VERTICAL PROFILES: AEROSOLS AND IONS

- Cumulative aerosol particle number density together with the negative and positive ions during the ascent

- **Positive charges close to ground and negative charges at upper levels**, agreement with flight in Australia on 8 April 2017

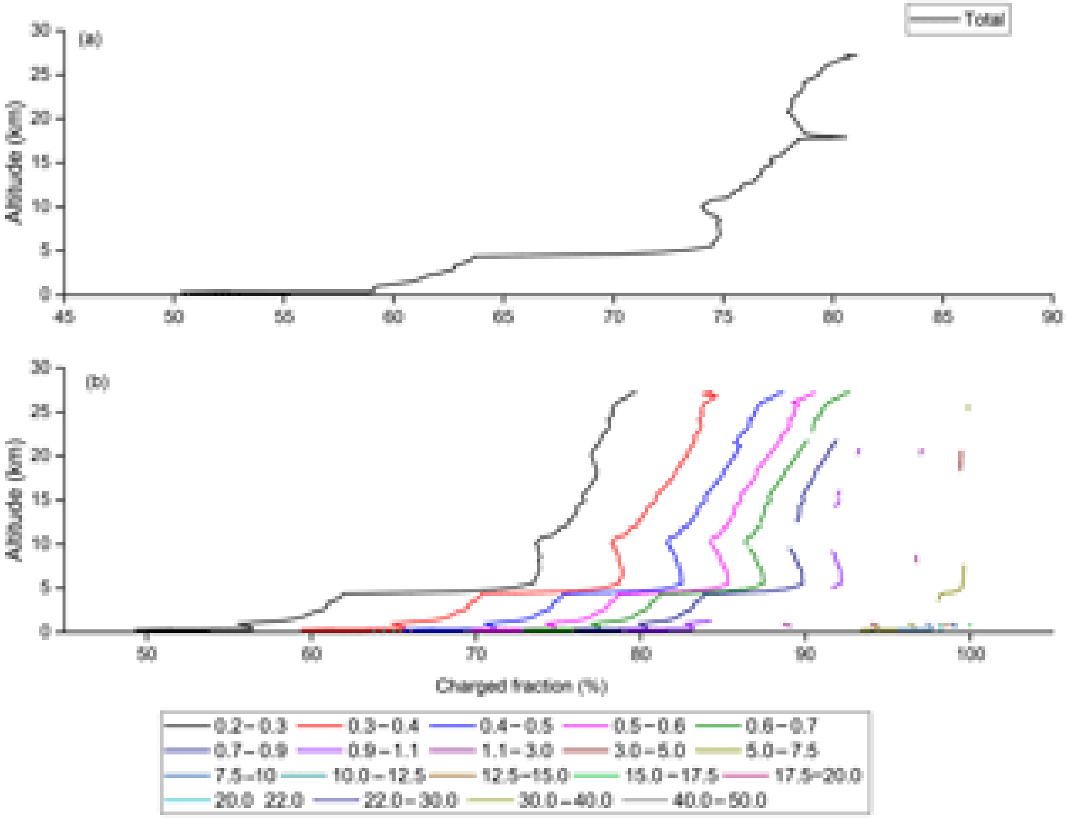
- Same general structure for particles and ions, including enhancement in the 20-25 km altitude range
- Typology:
  - 1km: thin layer of transparent particles (droplets?)
  - Other altitudes: optically absorbing and semi-absorbing particles (dust)
  - >tropopause: stratospheric liquid droplets +optically absorbing material



Brattich et al., 2019

VERTICAL PROFILES OF CHARGED PARTICLES FROM SIMULATIONS

- > 75 % of aerosols charged above 5 km, in agreement with detection from the ion counters
- **Maximum value around 20 km** corresponds to the region of **maximum ionization** (Regener–Pfotzer maximum; Regener and Pfotzer, 1935)
- "**Depletion layer**" of poorly charged aerosols from the tropopause to about 20 km, where the charged fraction drops at about 1 %, similar to Renard et al. (2013)
- Fine particles are the ones contributing to the largest variations in the fraction of the charged fraction, confirming the calculations by Renard et al. (2013)



Brattich et al., 2019

CONCLUSIONS

- A5-Unibo experiment was **successful**: effectiveness of the adopted instrumental setup in measuring vertical profiles of particles' size distributions and particles' typology together with ions
- Detection of **charged aerosols in the stratosphere** and insights onto their possible vertical variability
- **Coherent vertical profiles for particles and ions**, with a particularly strong correlation between negative ions and fine particles, possibly resulting from proposed associations between cosmic rays and ions
- Need for further stratospheric balloon-borne measurements of charged particles also with Geiger counters and small condensation particle counters

ACKNOWLEDGEMENTS

esa

SSC

DLR

ZARM

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

FLIGHT MECHANICS LAB

AlphaLab Inc.
Gauss meters, magnetometers and other laboratory instruments. Manufactured in USA

BOXER

EuroLaunch
A DLR and SSC cooperation

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da oltre 100 anni forniamo soluzioni

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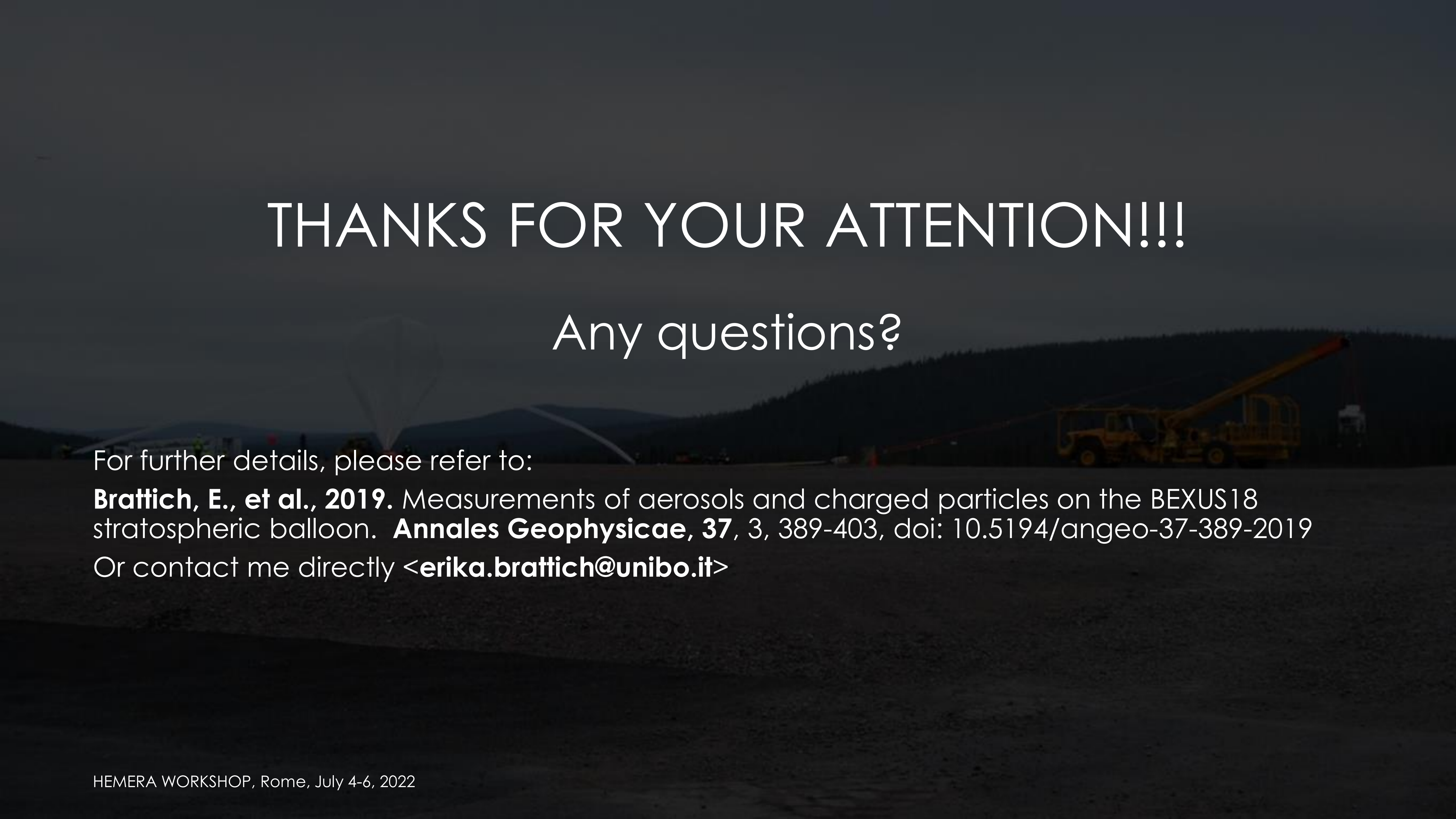
flexible packaging



THANKS FOR YOUR ATTENTION!!!

Any questions?

For further details, please refer to:

Brattich, E., et al., 2019. Measurements of aerosols and charged particles on the BEXUS18 stratospheric balloon. **Annales Geophysicae, 37**, 3, 389-403, doi: 10.5194/angeo-37-389-2019

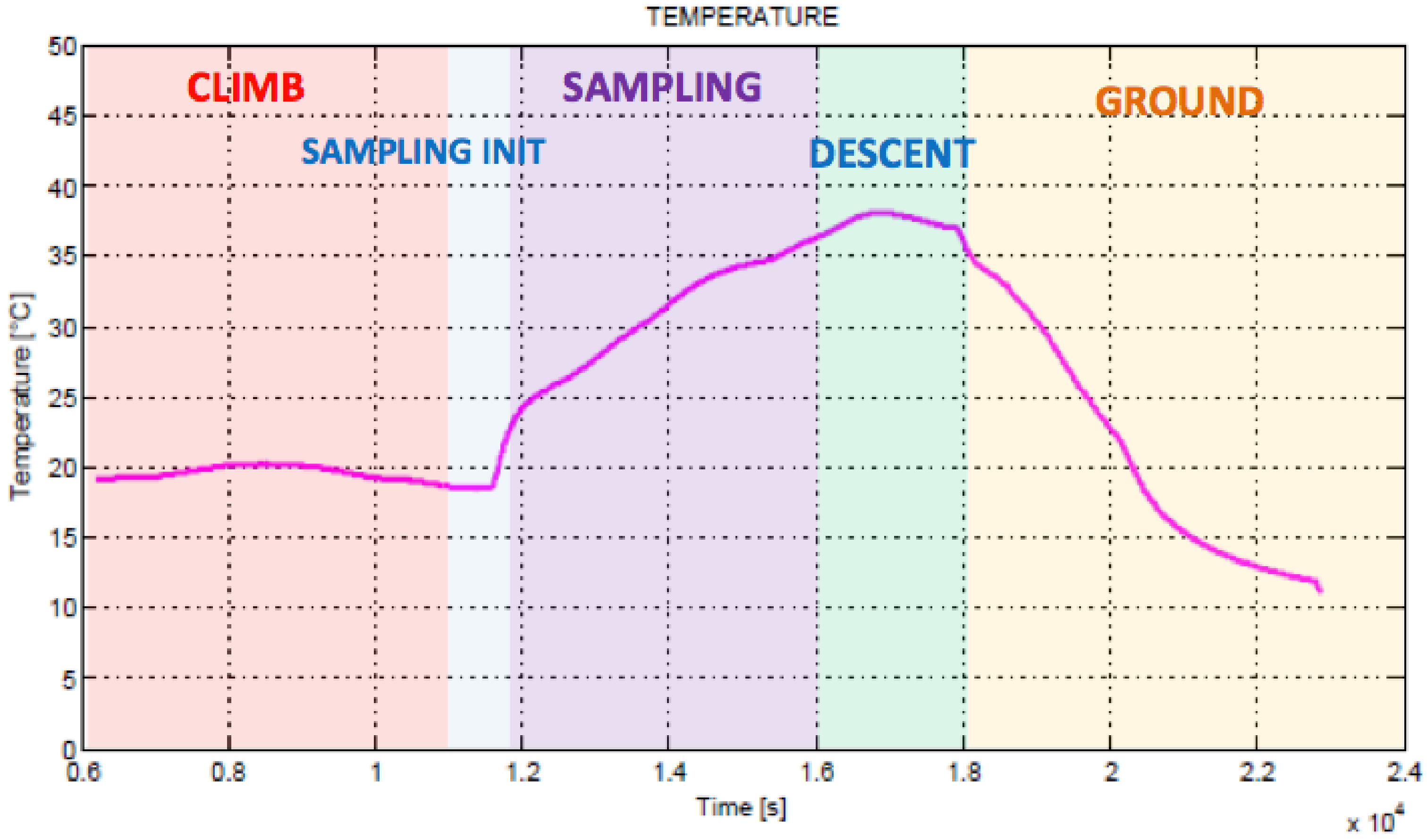
Or contact me directly <**erika.brattich@unibo.it**>

CORRELATIONS IONS - PARTICLES

- strong negative correlation of negative ions with fine particles, possibly from ion-induced nucleation and in particular from the proposed association between cosmic rays and ions (“ion–aerosol clear-air” mechanism)
- agreement with previous observations showing that, in general, negative ions more efficiently promote nucleation than positive ions (Svensmark and Friis-Christensen, 1997; Eisele et al., 2006; Suni et al., 2008).

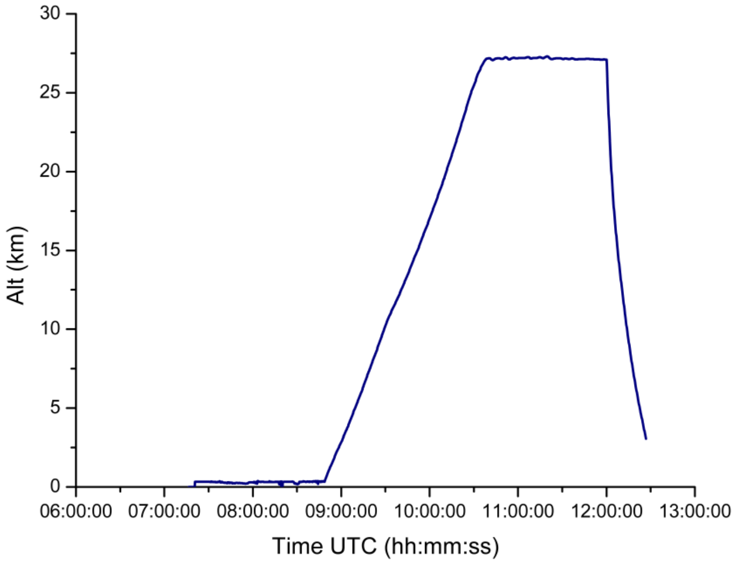
	Positive ions (no. cm^{-3})	Negative ions (no. cm^{-3})
Positive ions (no. cm^{-3})	1.00	
Negative ions (no. cm^{-3})	−0.28	1.00
0.2–0.3 (no. cm^{-3})	0.44*	−0.67*
0.3–0.4 (no. cm^{-3})	0.45*	−0.75*
0.4-0.5 (no. cm^{-3})	0.40*	−0.71*
0.5–0.6 (no. cm^{-3})	0.33*	−0.80*
0.6–0.7 (no. cm^{-3})	0.34*	−0.62*
0.7–0.9 (no. cm^{-3})	0.28	−0.76*
0.9–1.1 (no. cm^{-3})	0.01	−0.62*
1.1–3.0 (no. cm^{-3})	0.31*	−0.22
3.0–5.0 (no. cm^{-3})	0.15	−0.07
5.0–7.5 (no. cm^{-3})	0.12	−0.28*
7.5–10.0 (no. cm^{-3})	0.33*	0.23
10.0–12.5 (no. cm^{-3})	0.17	−0.10
12.5—15.0 (no. cm^{-3})	0.36*	
15.0–17.5 (no. cm^{-3})	0.36*	0.27*
17.5-20.0 (no. cm^{-3})	0.36*	
20.0–22.0 (no. cm^{-3})	0.36*	
22.0–30.0 (no. cm^{-3})	0.32*	−0.18
30.0–40.0 (no. cm^{-3})	0.24	
40.0–50.0 (no. cm^{-3})		0.18
Aerosols > 200 nm (no. cm^{-3})	0.45*	-0.59*

ELECTRONICS TEMPERATURE PROFILE



LAUNCH DAY – 10/10/14

Flight



LANDING AND RECOVERY