

Electrical charge measurements in clear and cloudy conditions from fixed wing UAVs

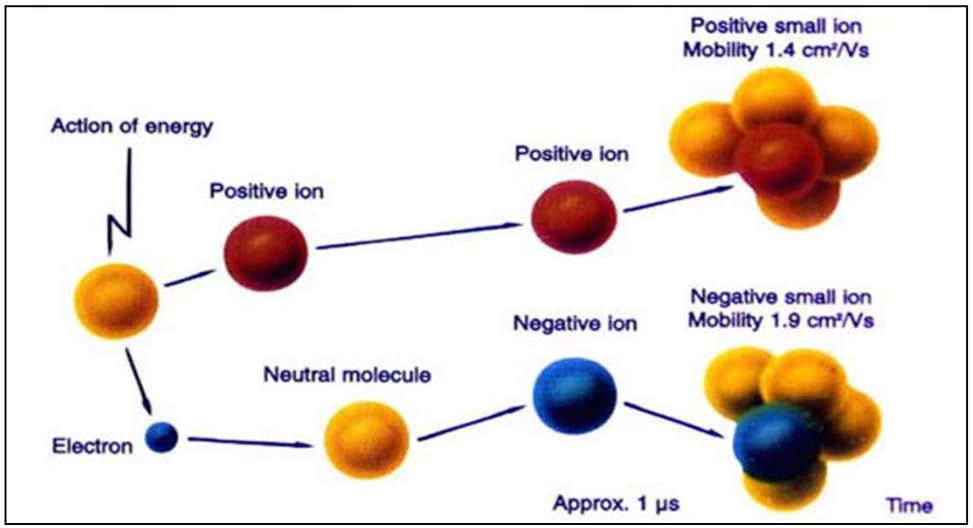
Keri Nicoll[1]

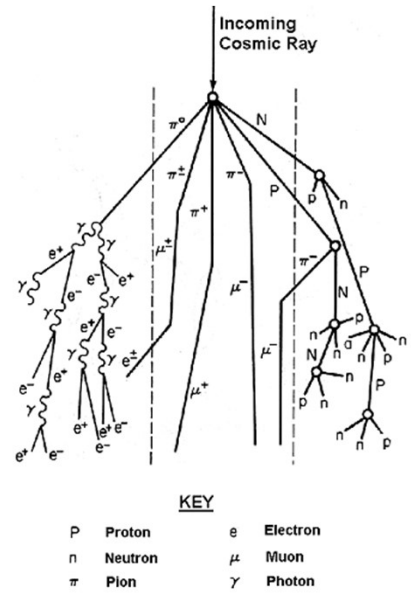
Giles Harrison[1], Greg Roberts[2]

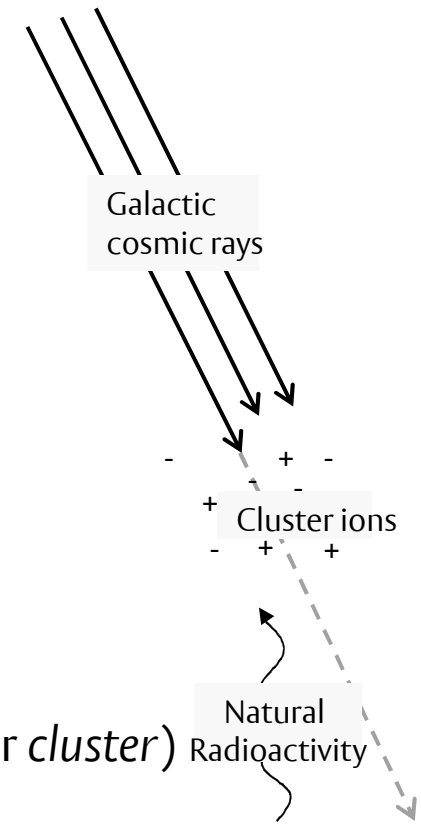
1 Department of Meteorology
University of Reading
2 MeteoFrance, Toulouse

Charge generation in air

- Charge is ubiquitous in the atmosphere – not just in thunderstorms
- Charge created by radioactivity from Earth's surface, and cosmic rays from outside solar system







- Air ions formed cluster with water molecules, to generate *small* (or *cluster*) ions
- Ion concentrations in surface atmospheric air depends on aerosol concentrations, but concentrations are typically 100 to 500 cm^{-3}

Ion-aerosol attachment

- Ions collides with aerosol particles and droplets => charging
- Charging has potentially important implications for:

- Long range transport of dust/volcanic ash

- Cloud microphysical processes (=>production of rain, lifetime of clouds)

- Processes affected by charge:

- particle-particle collisions (coagulation)

- particle collection by droplets (scavenging)

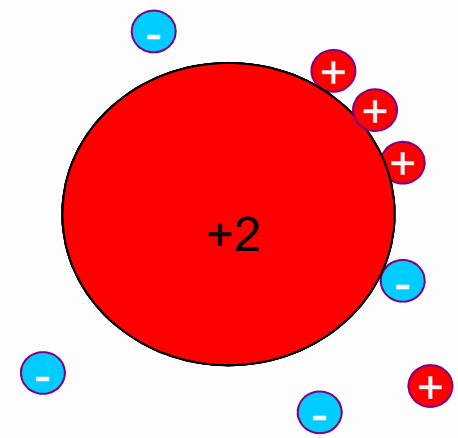
- droplet evaporation

- freezing of droplets

- droplet-droplet interactions (collision and collection)

Typical ion diameter = 1nm (10^{-9}m)
Typical aerosol diameter = 1µm (10^{-6}m)

Ion-particle attachment



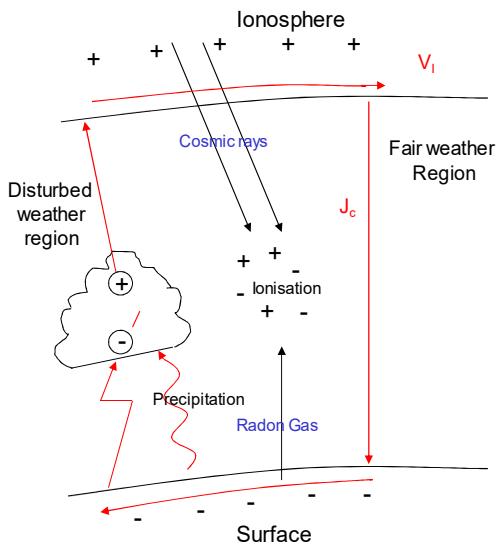
aerosol particle carries net charge of +2

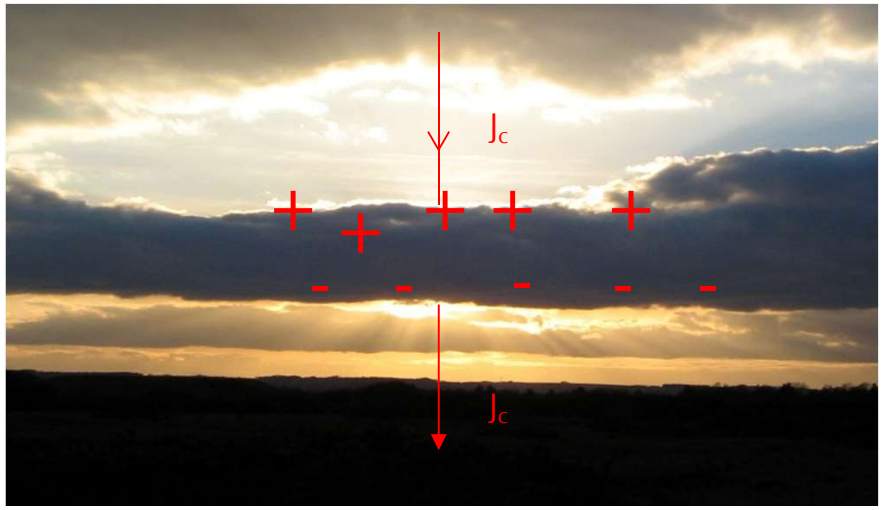
Charging of layer clouds

University of Reading

•Global electric circuit current flows through layer clouds

K.A. Nicoll and R.G. Harrison, Vertical current flow through extensive layer clouds *J. Atmos Solar-Terr Physics* **71**, 12, 1219-1221 (2009)





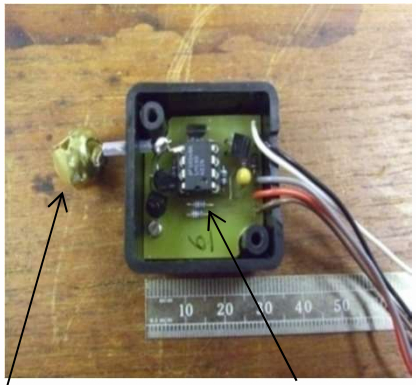
- Horizontal cloud (and aerosol) layers cause charge separation from the sharp conductivity transition at cloud edges
- Local space charge density depends on vertical conduction current (of ions) and the sharpness of the cloud edge

→ Cloud edge charge

Charged cloud instrumentation

University of Reading

Charge sensor



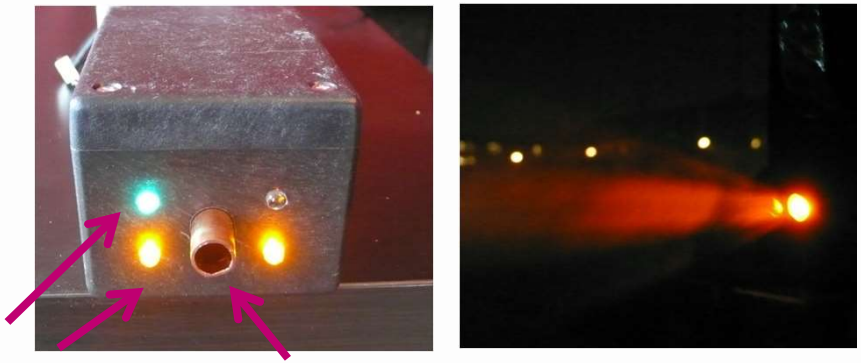
Electrode

Electrometer circuit

- Spherical electrode and electrometer
- measures current induced by changing electric field (i.e. displacement current

Nicoll K.A. and R.G. Harrison, A lightweight balloon-carried cloud charge sensor, *Rev. Sci. Instrum.*, DOI:10.1063/1.3065090, 2009

Cloud droplet sensor



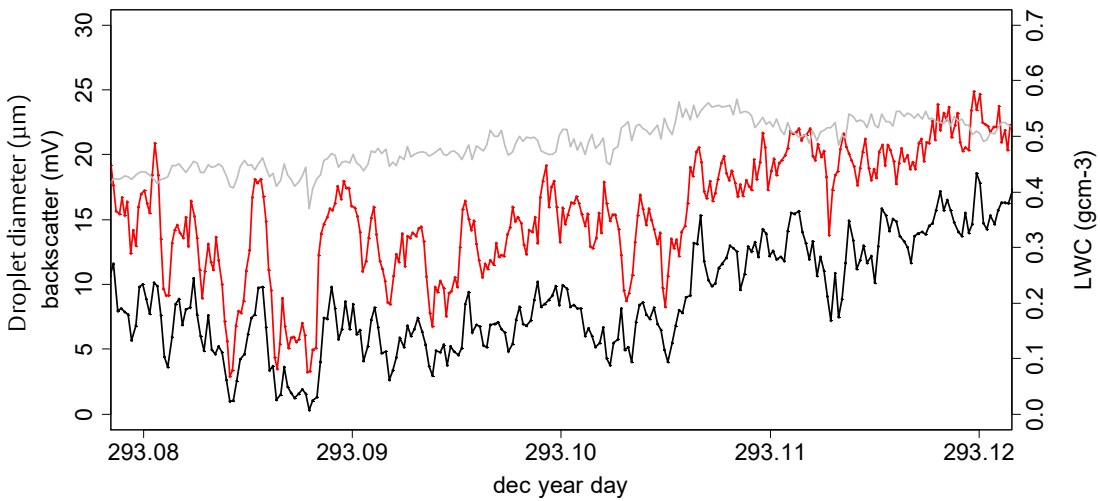
LED sources **detector**

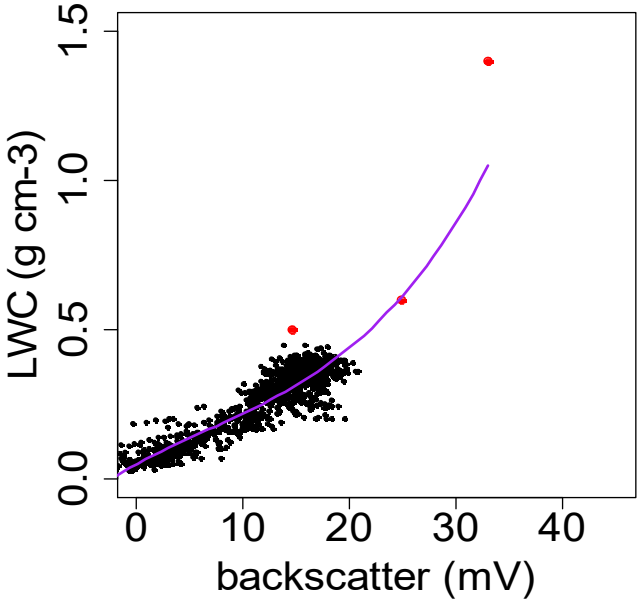
- Backscatter device
- uses ultrabright LEDs as source and photodiode as receiver in an open path device
- Light source is modulated to allow signal recovery despite background light variations
- multiple channels to allow size discrimination

Harrison, R.G. and K.A. Nicoll, Active optical detection of cloud from a balloon platform, *Rev. Sci. Instrum.*, **85**, 066104, 2014

Cloud droplet sensor characterisation

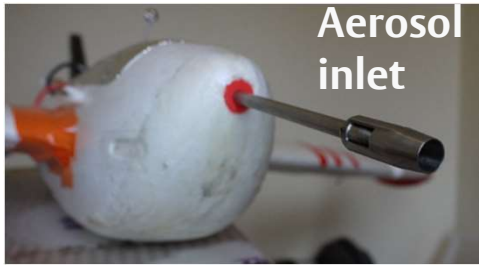
- Comparison with DMT Cloud Droplet Probe (CDP) number concentration shows very good agreement for droplets > 5µm diameter
- Relationship between backscatter and CDP Liquid water content (LWC) found for 20µm droplets
- Current work underway to derive droplet size information from backscatter

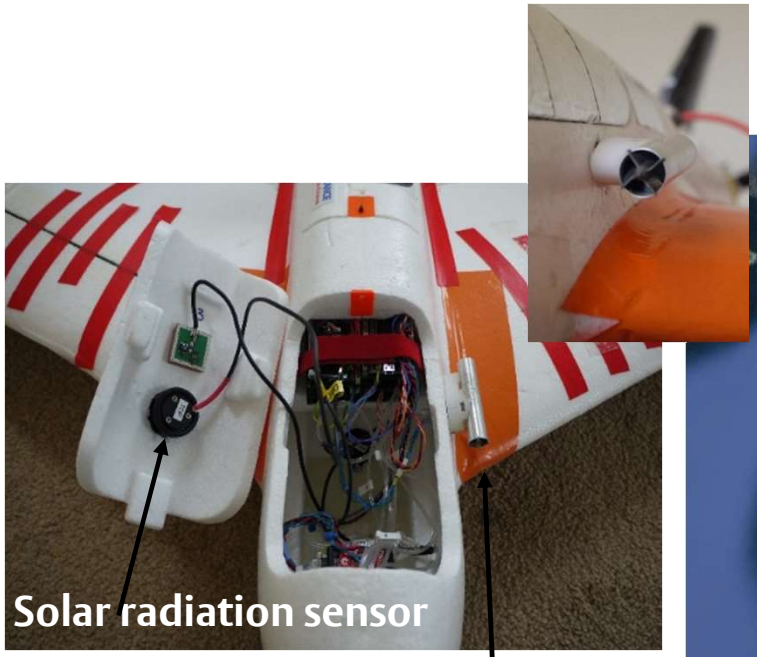


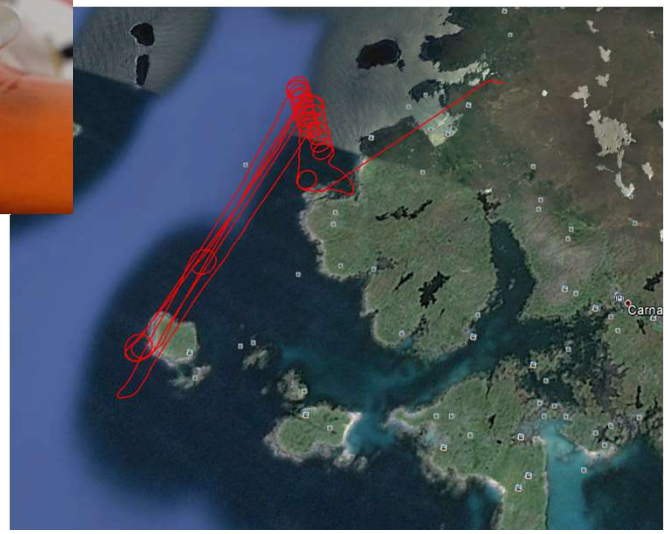


Cloud and aerosol campaign

- 2 week campaign in August 2015
- Mace Head, Ireland
- Skywalker X6 UAV (1.5m wingspan, 1kg payload)
- 4 different aircraft with various payloads including aerosol, turbulence, cloud + charge



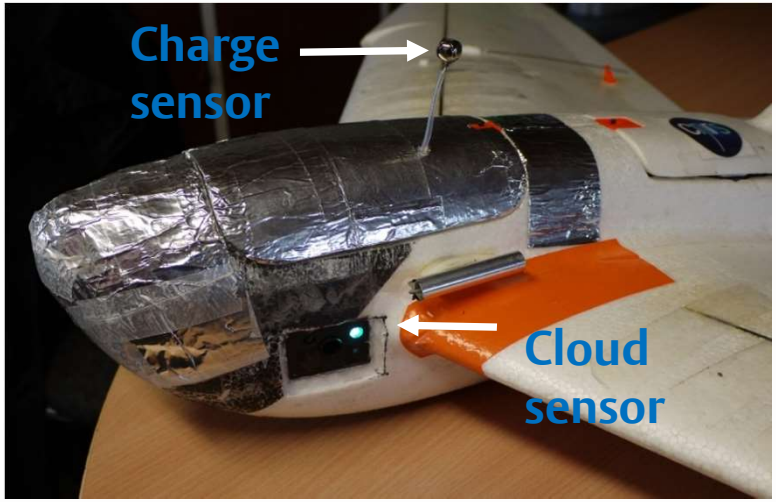




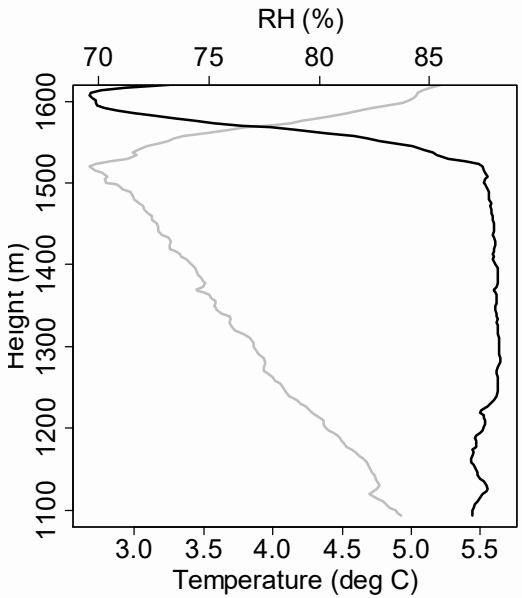
Temperature and RH

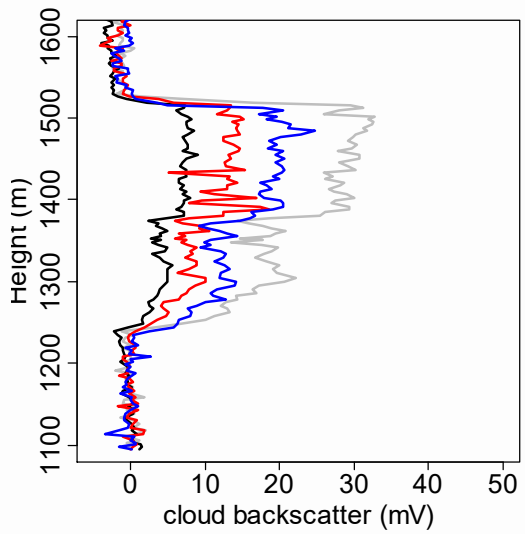
Charged cloud measurements

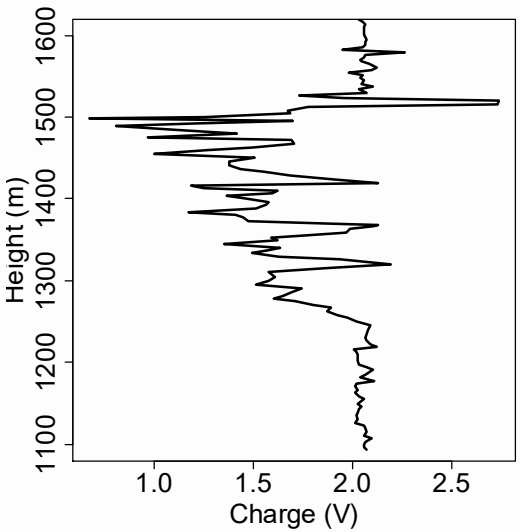
- 20 flights through different cloud layers (often multiple ascents and descents and temporal sampling)
- Clear identification of cloud from cloud and charge sensors
- All clouds sampled were charged



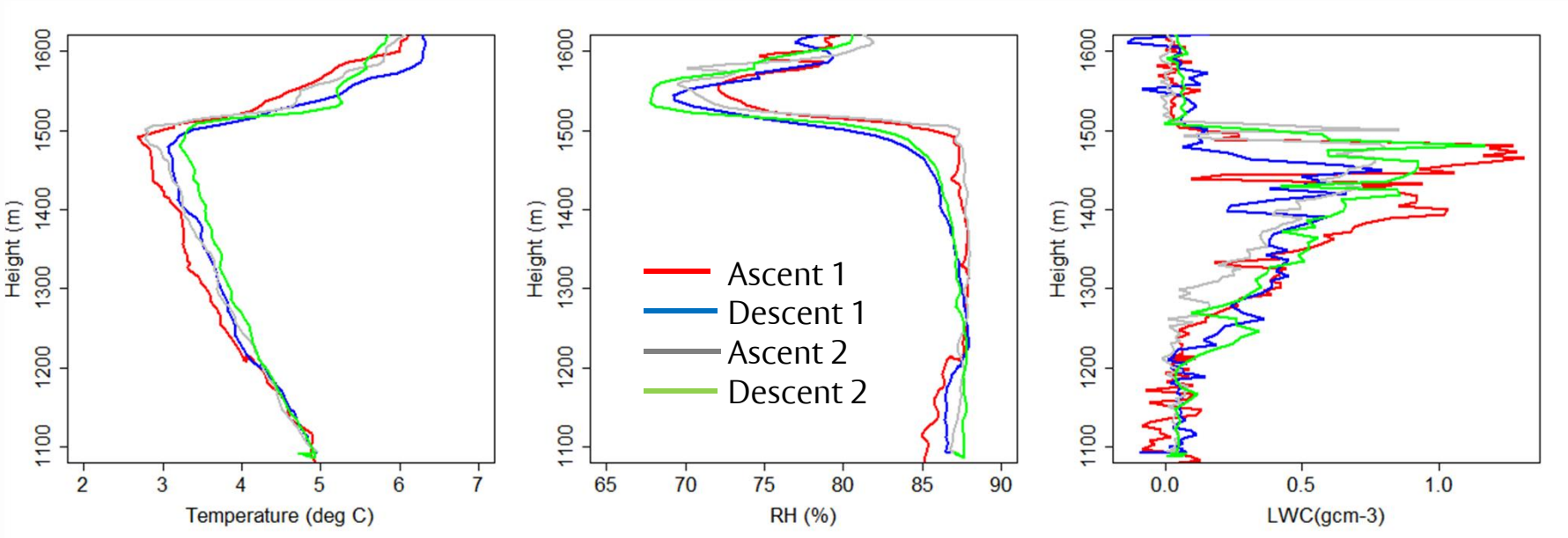
11th August, flight 23







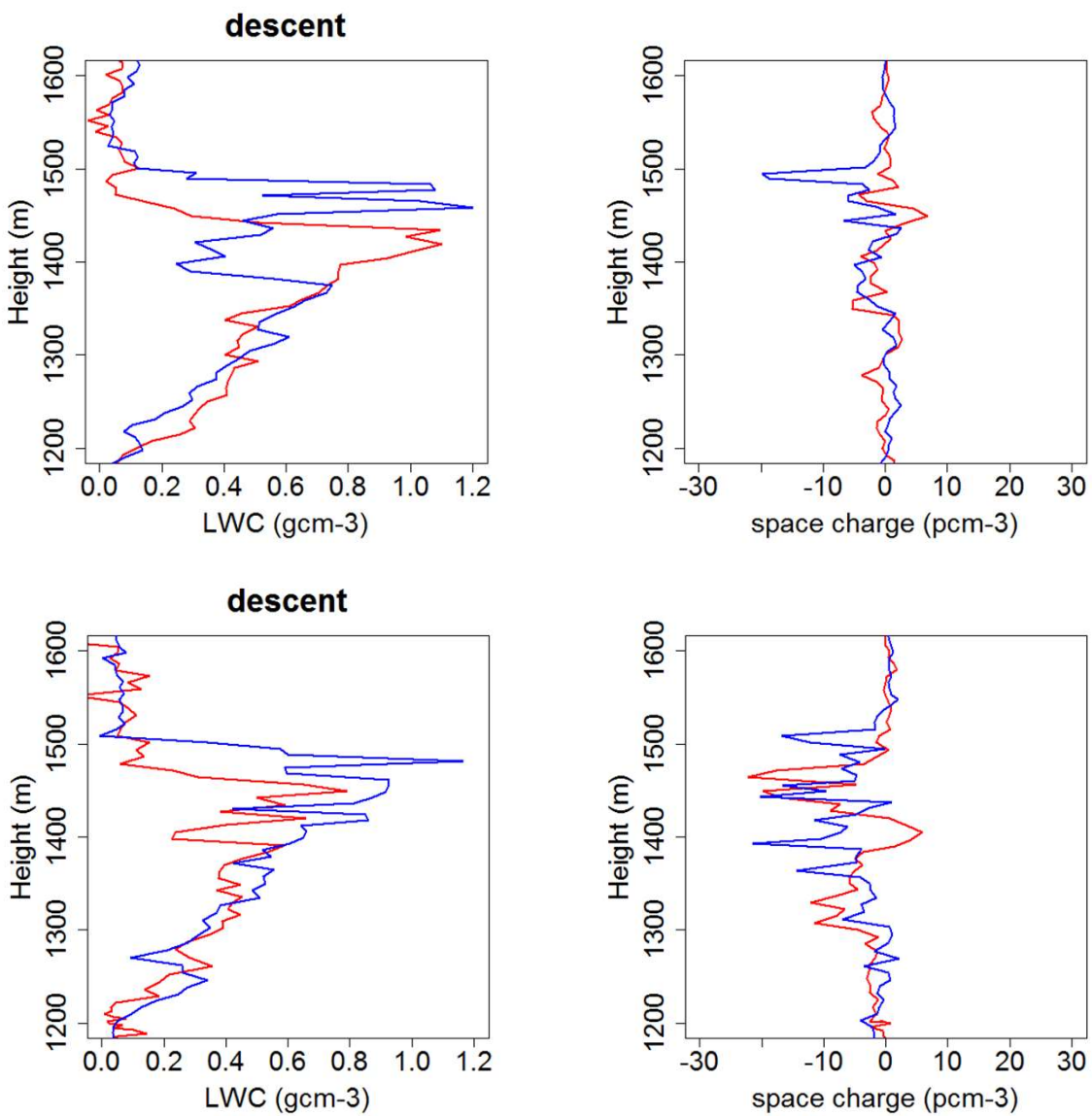
Multiple ascents through cloud



Multiple profiles through long lived stratocumulus cloud layer

Cloud backscatter to liquid water content (LWC) (IR channel)

Mace head charged cloud measurements



11/08/16
13:00
Flight 23

Descent 1
Descent 2

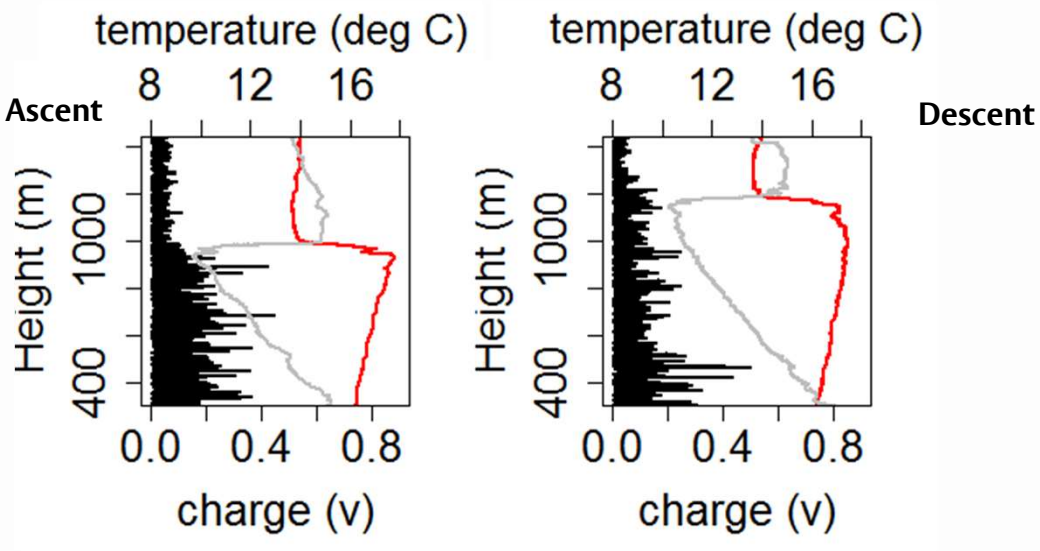
- Comparison of two different flights 3 hours apart
- Very little change in cloud droplet profile or cloud charge

11/08/16
15:54
Flight 25

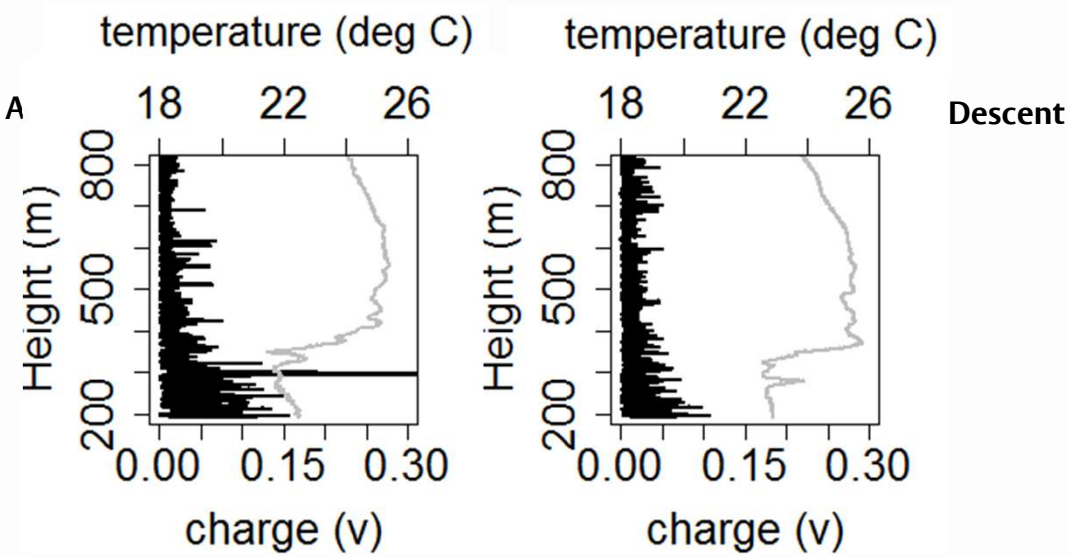
Fair weather charge measurements

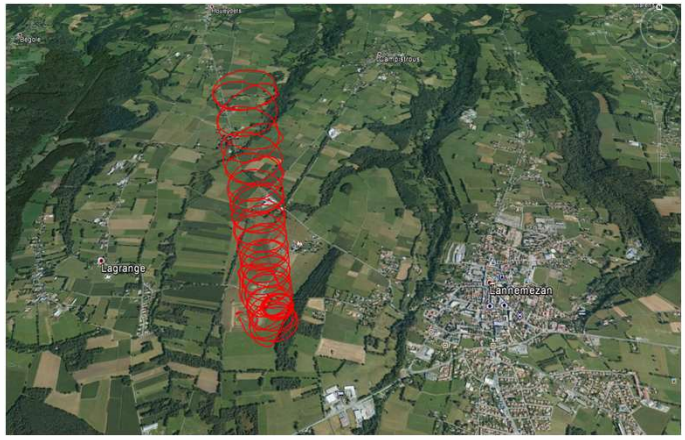
Lannemezan, France

09/07/15 13:20 LT



10/07/15 11:38 LT



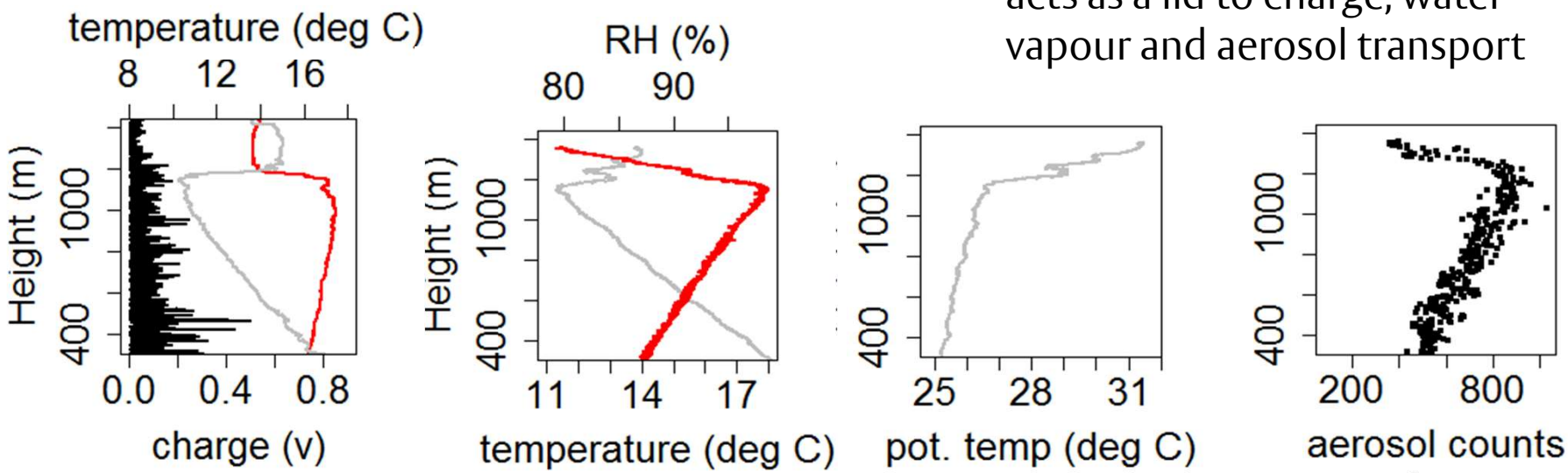


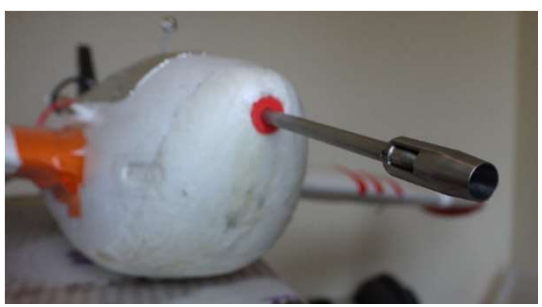
Charge and aerosol profile

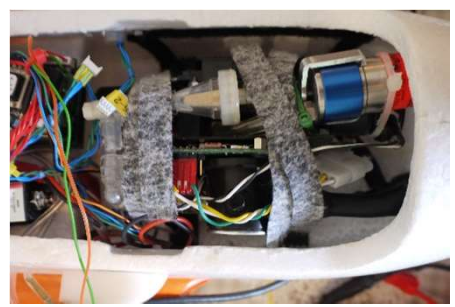
Lannemezan, France

09/07/15 13:20 LT **09/07/15 15:54 LT**

Strong temperature inversion acts as a lid to charge, water vapour and aerosol transport





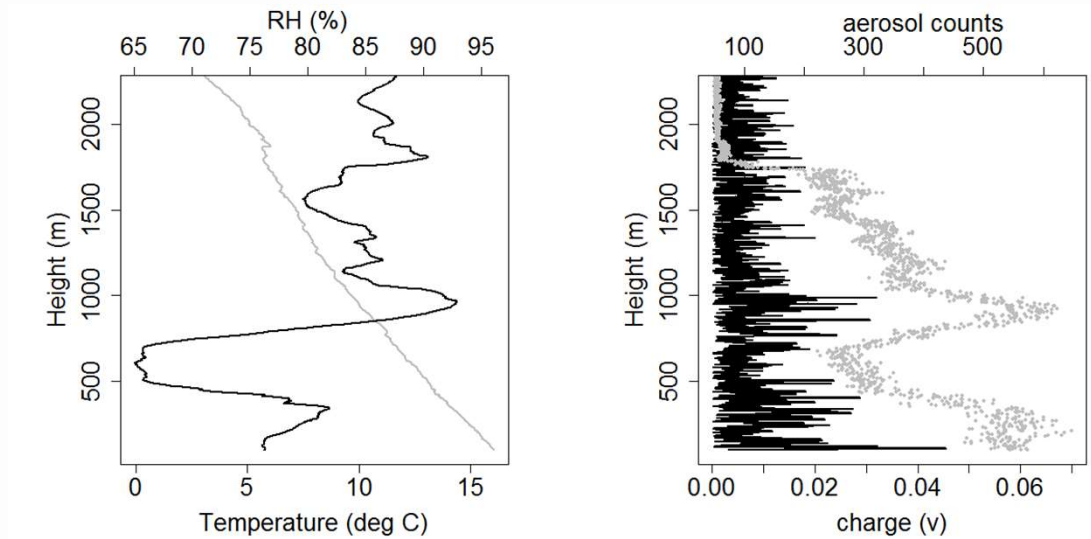


Total aerosol number counts across all size bins from Optical Particle Counter (0.3-3µm)

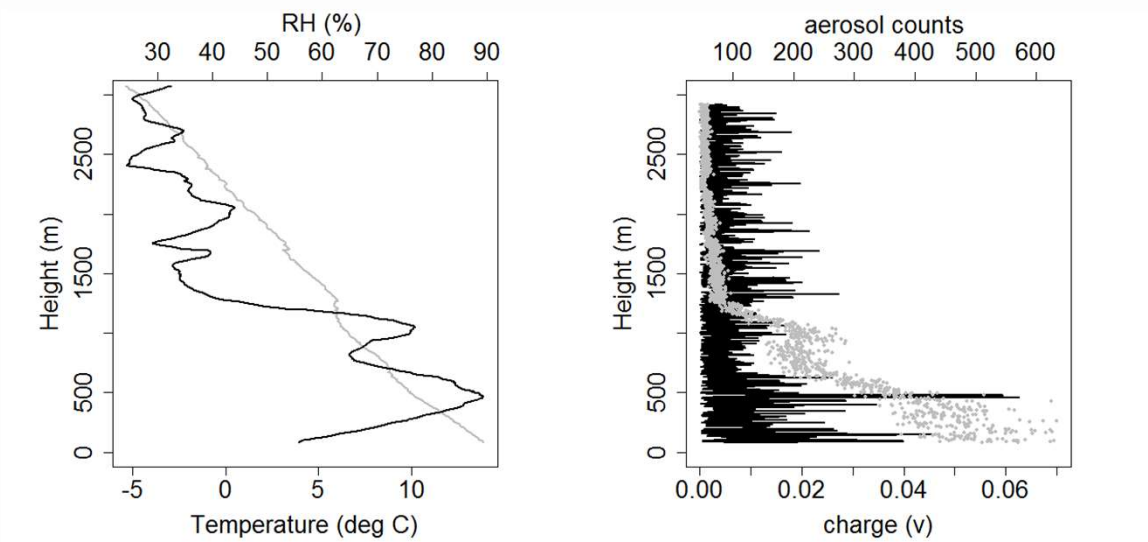
Charge is affected by same turbulent processes that transport aerosol and water vapour, therefore expect profiles to be similar

Charge and aerosol profile

Mace Head, Ireland 17/08/15



Mace Head, Ireland 22/08/15



- Cases where no significant inversion exists show close relationship between charge and aerosol profiles
- Turbulence data from nose mounted probe also available

Summary

- Charge can serve as a useful tracer for both cloud and aerosol layers as well as boundary layer top location

- Ongoing measurements are characterising the typical charge values within cloud and aerosol layers in order to inform modelling studies of charge effects on microphysical processes

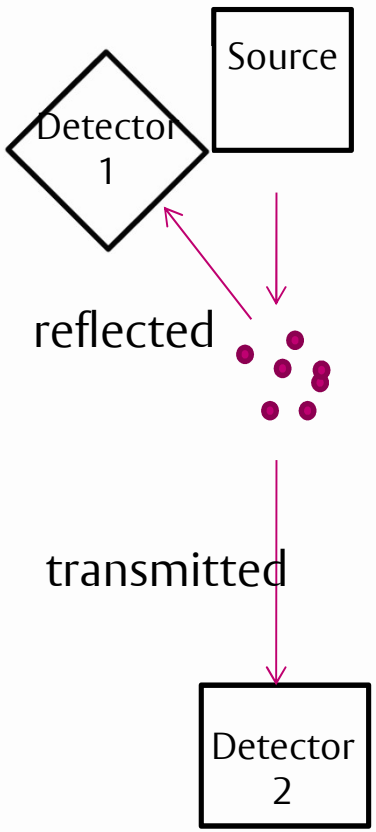
- Further analysis of charge data in clear air will look at relationships between:
- Boundary layer stability
- Turbulence and surface heat flux

Thanks to Greg Roberts, Radiance Calmer, Kevin Sanchez and the team from MeteoFrance

…… and thank you for listening

Calibration of optical droplet detector

- Transmission and backscatter experiments performed simultaneously



•Transmission signal ($I(t)$) related to optical extinction (ξ)

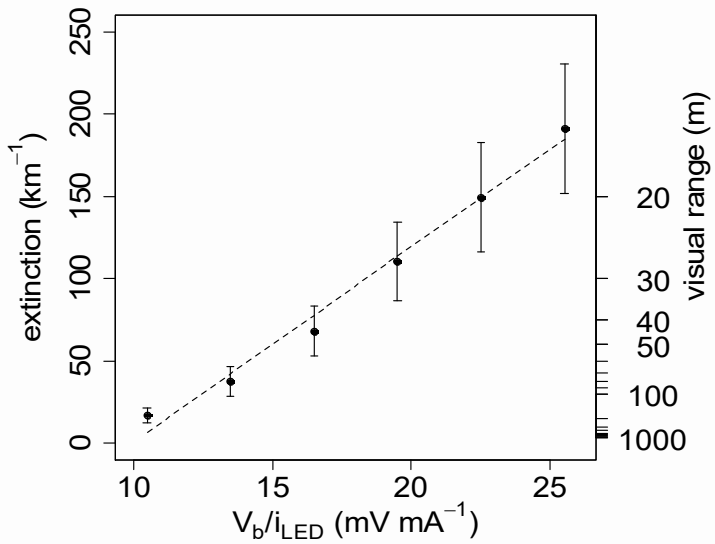
$$I(t) = I_0 \exp[-\xi(t)d]$$

d = path length

•Visual range calculated from extinction :

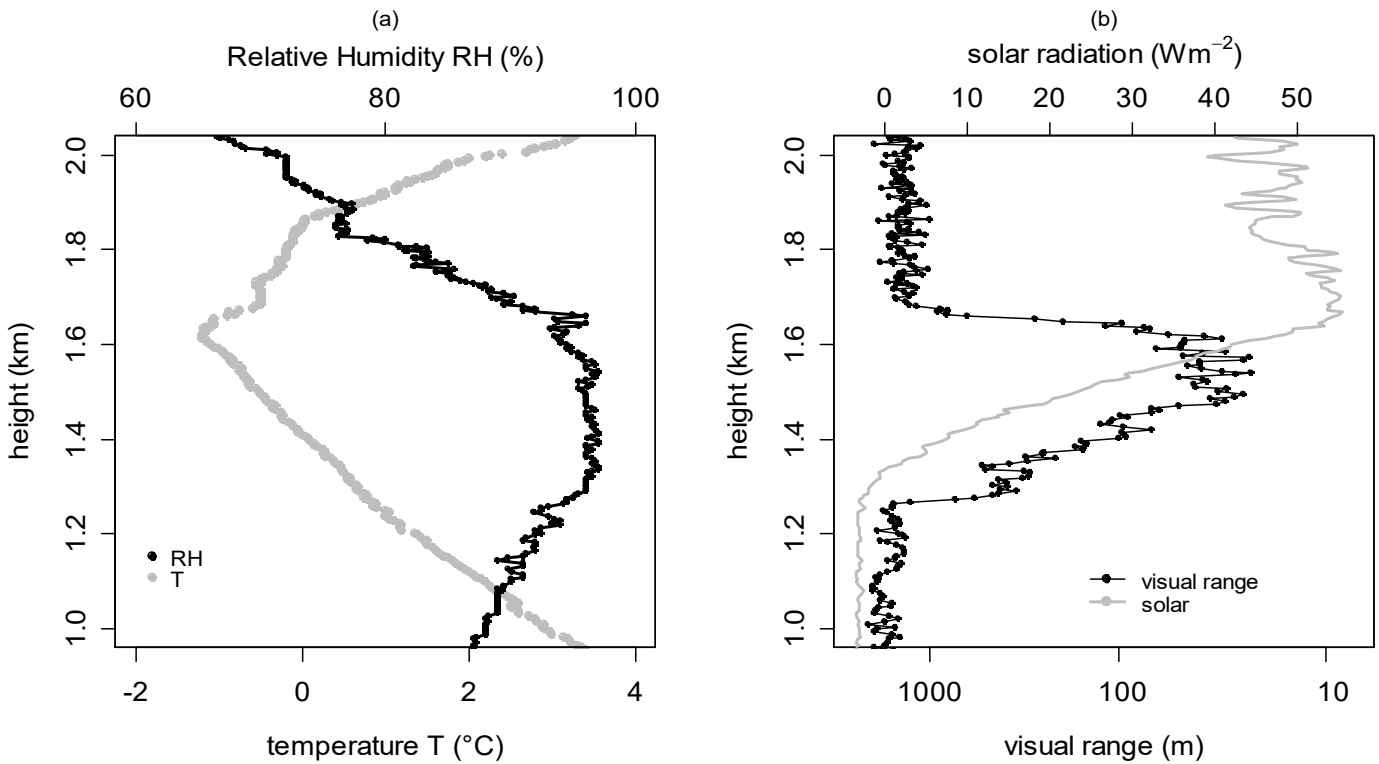
$$X = -\frac{\ln \varepsilon}{\xi}$$

ε = visual contrast factor = 0.05
ξ = extinction
X = visual range



Atmospheric flights of optical droplet detector

- Measurements made during a daylight sounding through a stratocumulus layer of stratocumulus about 400 m thick, with cloud base at 1200 m.



Standard thermodynamic detection (coarse indication of cloud position and poor threshold RH value)

Active cloud detector using ultra-bright LED light source shows sharp cloud boundaries