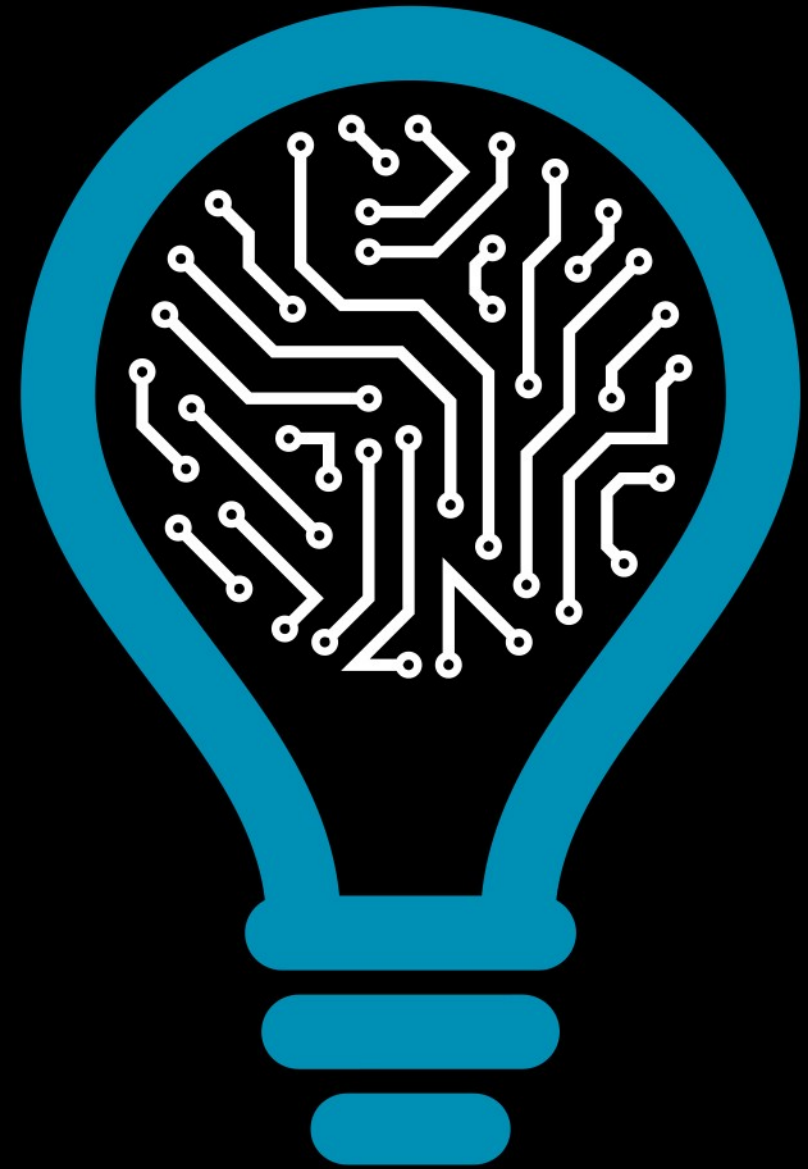


# Atmospheric ionization and space-earth interactions

Susana Barbosa

INESC TEC (CSIG / CRAS)



# Outline

## Scientific motivation

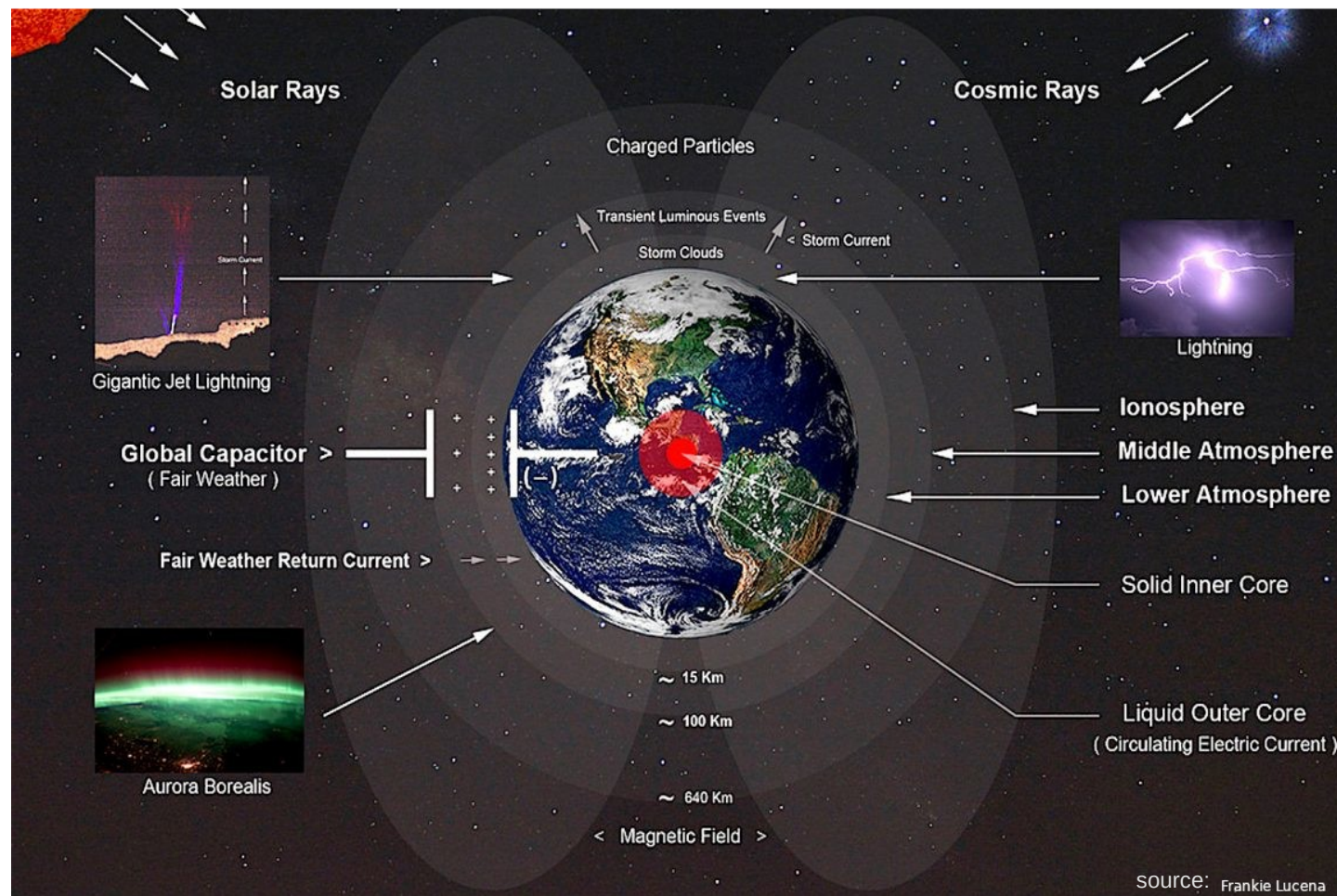
- Earth's electric circuit
- Atmospheric ionisation

## Field campaigns

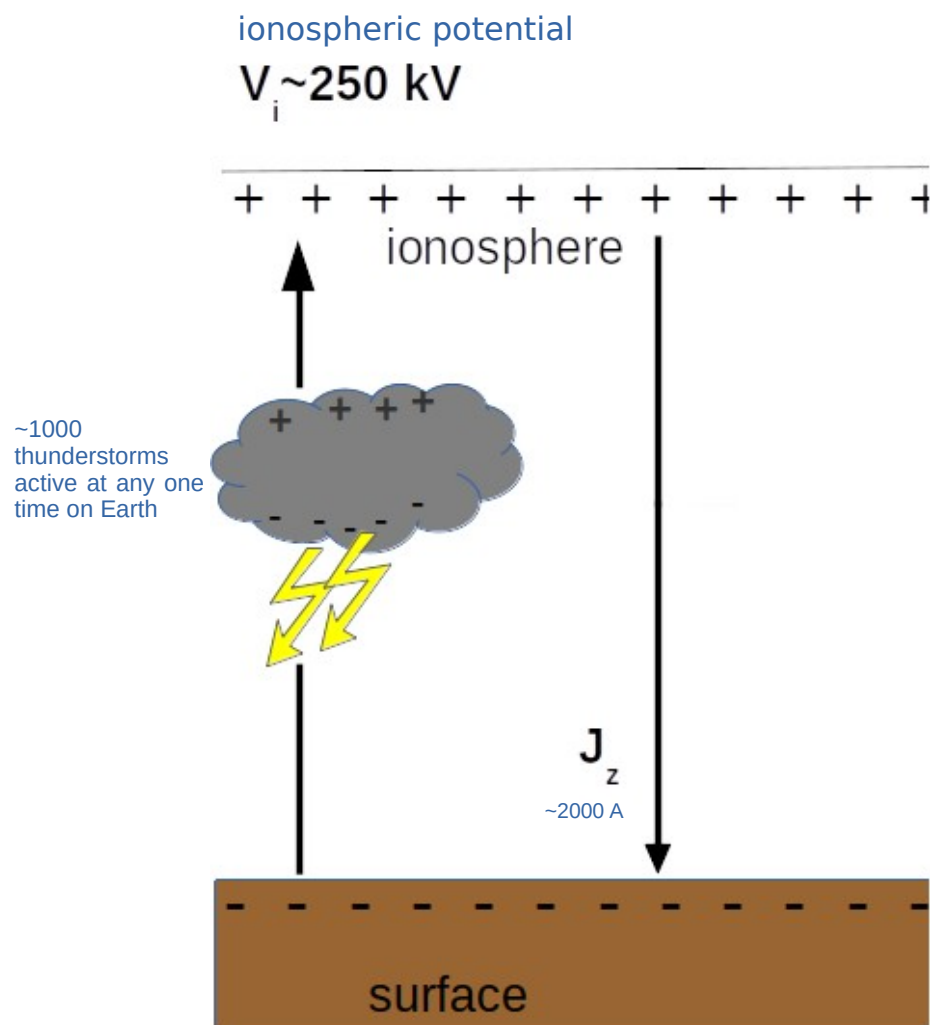
- GRM – Gamma radiation monitoring – ENA (Graciosa island, Azores)
- RELECT campaign – Hyytiälä station (Finland)
- SAIL campaign (NRP Sagres, Atlantic ocean)

# Earth-space interactions

Systems science / holistic perspective



# Earth's electric field

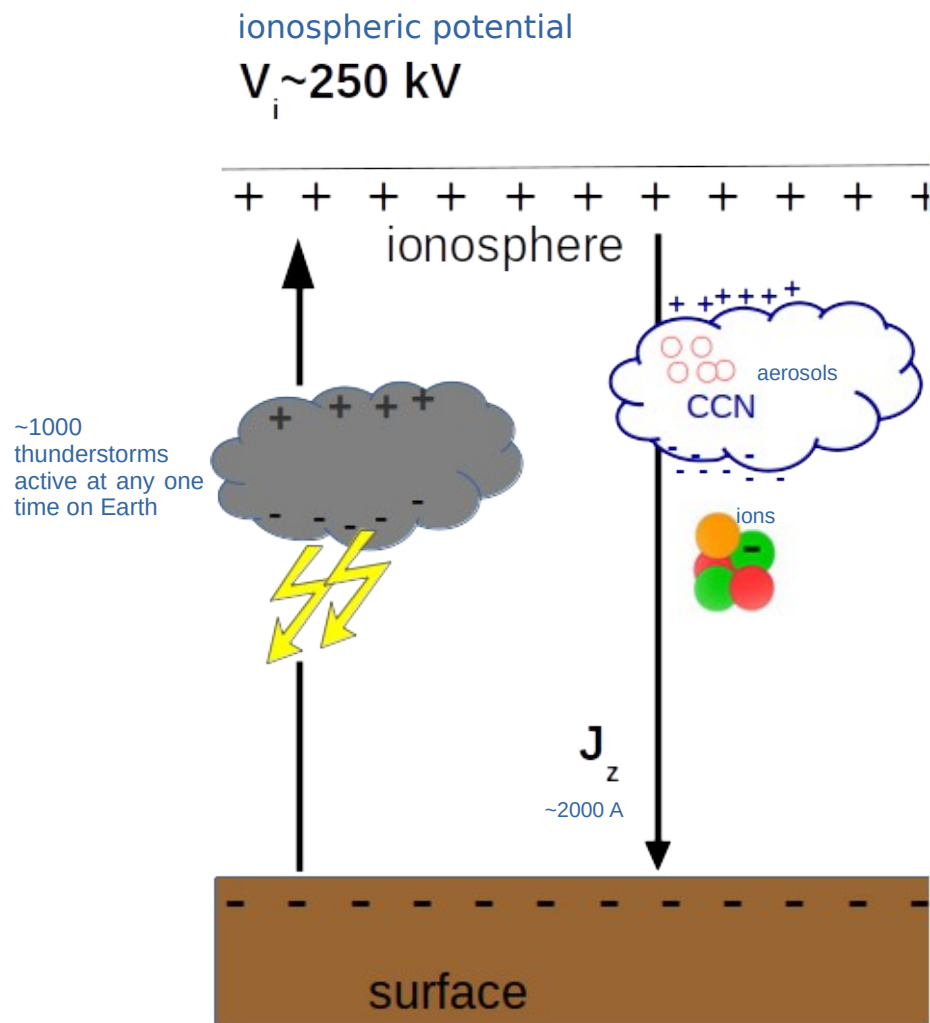


Solar activity

Geomagnetic field

Global thunderstorm activity

# Earth's electric field



Solar activity

Geomagnetic field

Global thunderstorm activity

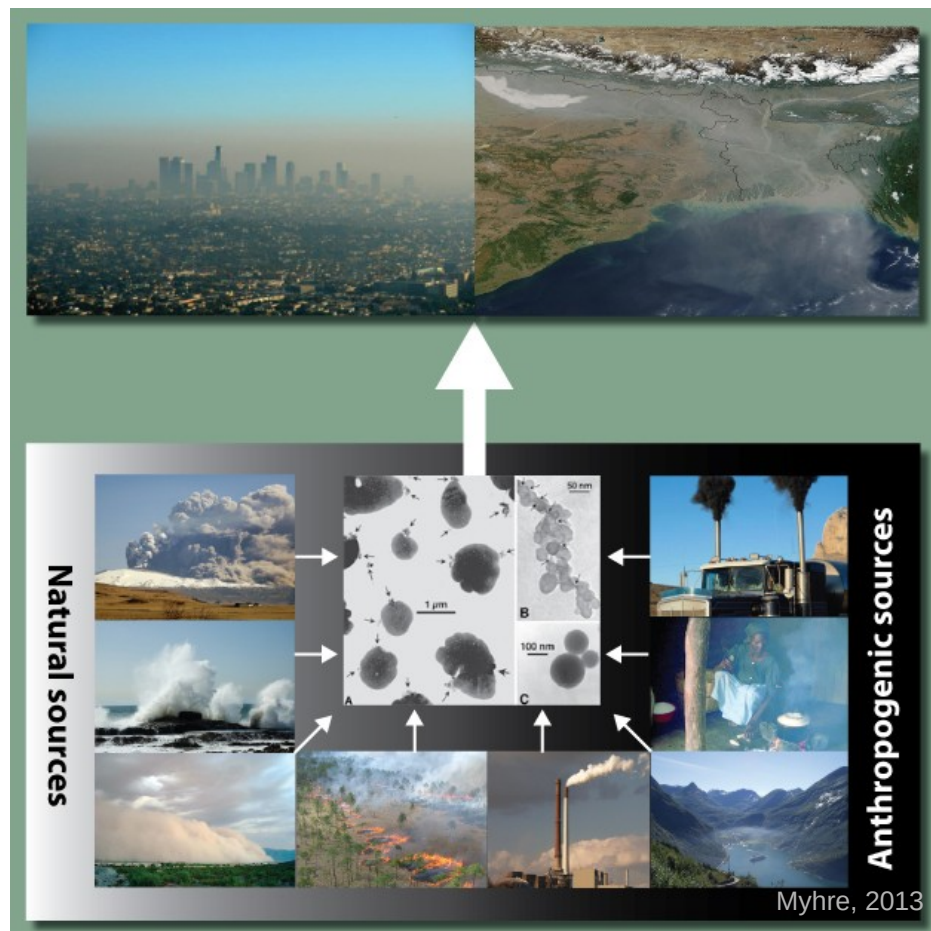
Atmospheric conductivity

\* aerosols

\* ionisation

# Aerosols

Primary (emitted particulate matter)

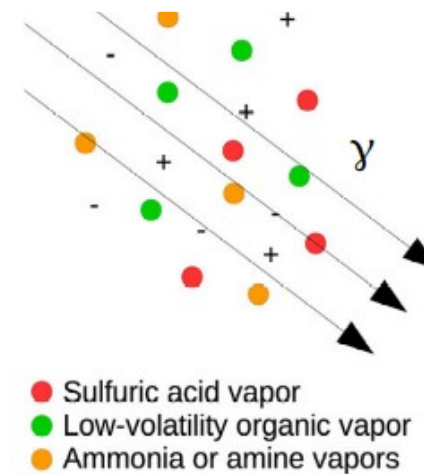
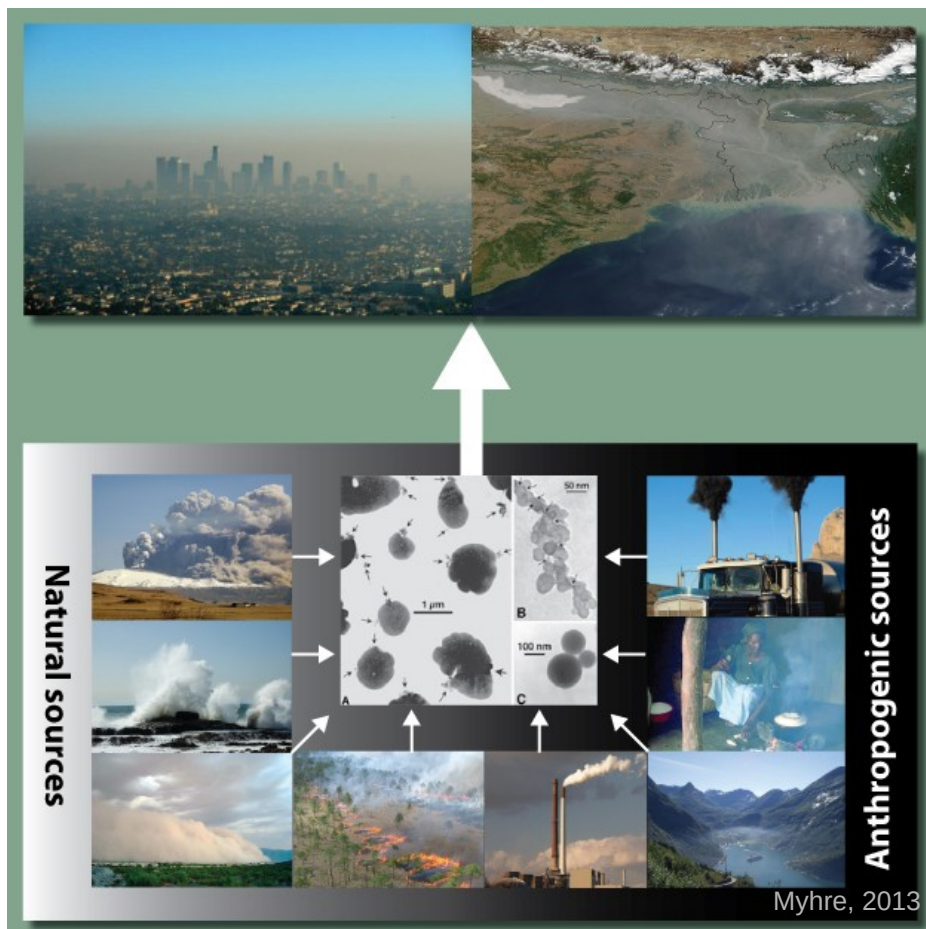




# Aerosols

Primary (emitted particulate matter)

Secondary (formation from precursor vapors)

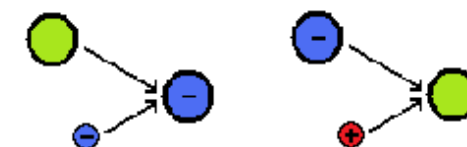


aerosol nucleation  
- gas-particle conversion  
- ion-induced nucleation

**aerosols**

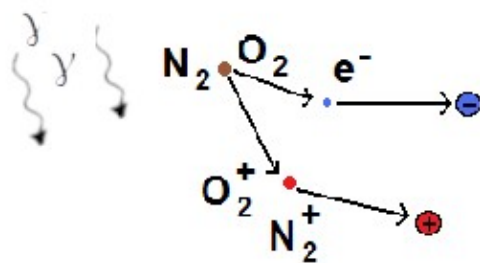
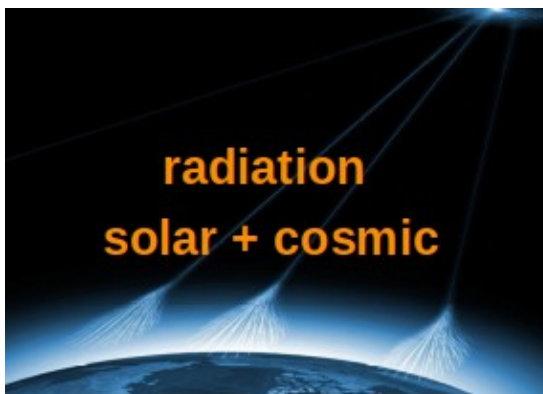
Ion-Aerosols attachment

- ion removal
- ions size / mobility



# Atmospheric ionisation

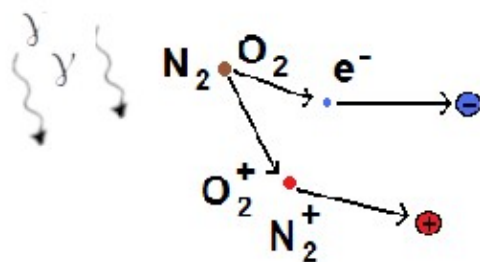
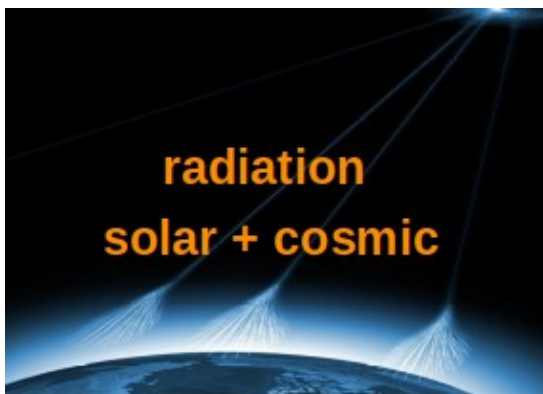
> 10 km – cosmic radiation





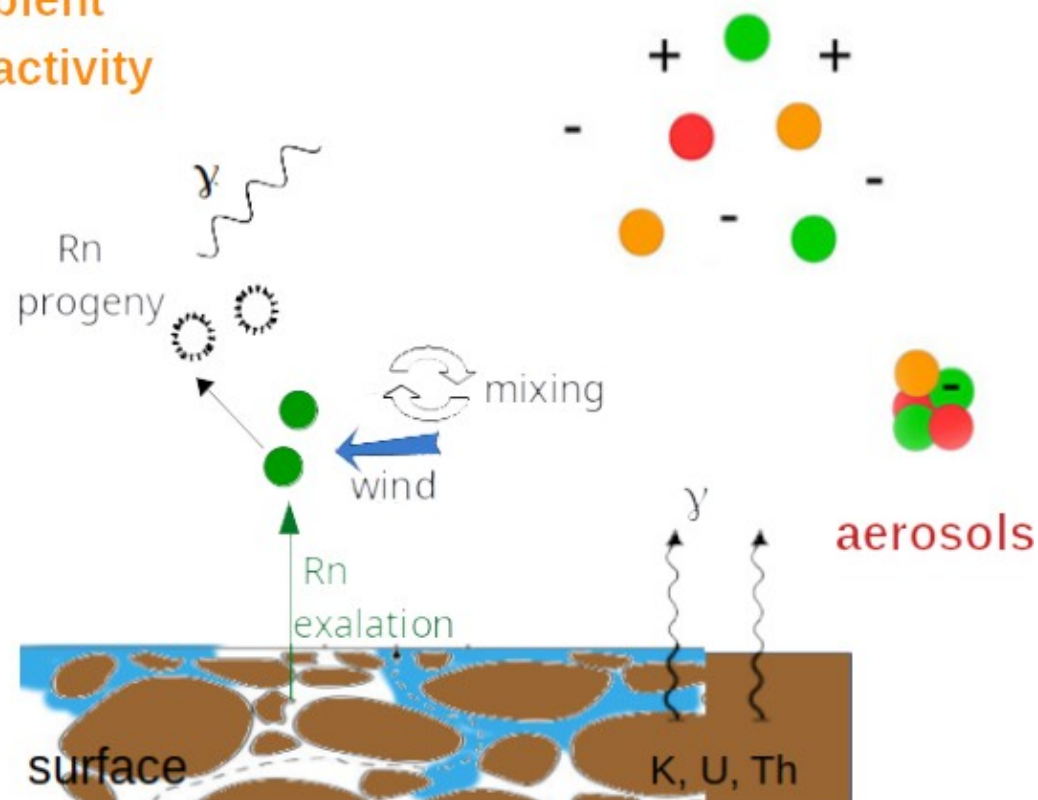
# Atmospheric ionisation

> 10 km – cosmic radiation

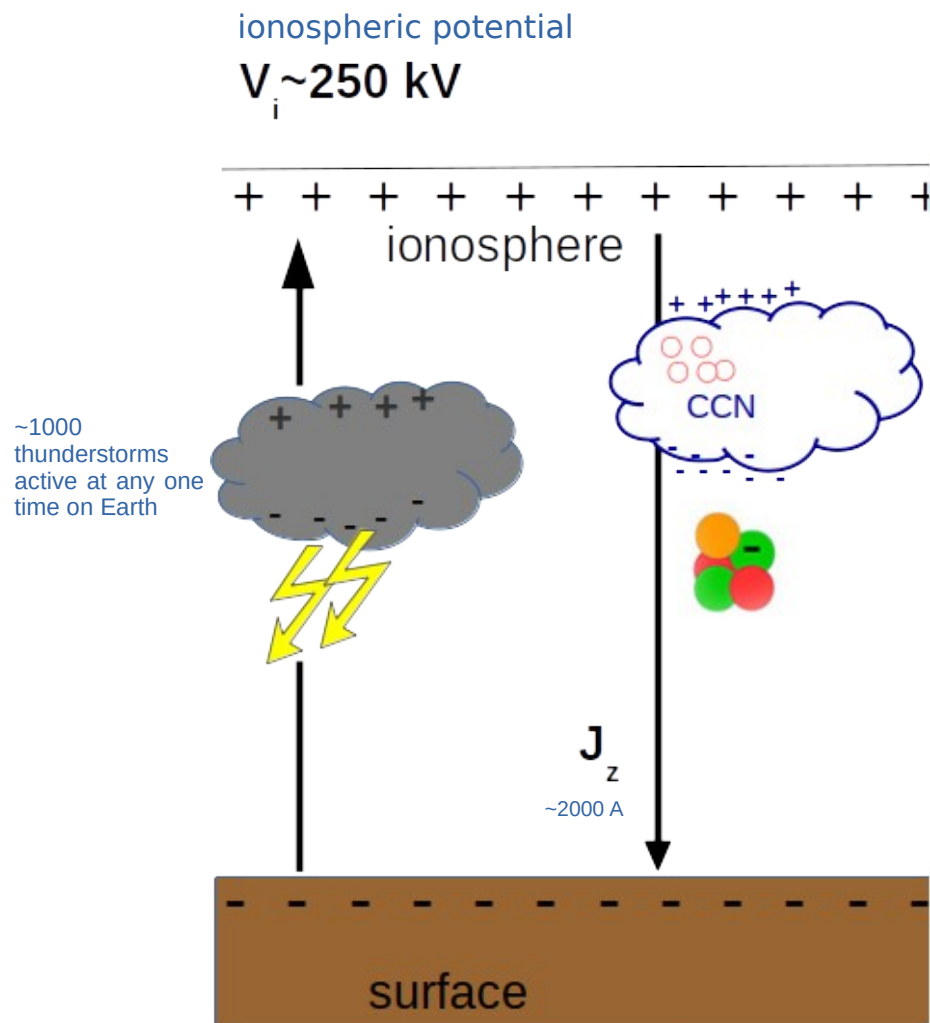


< 2km – ambient radioactivity

ambient  
radioactivity



# Earth's electric field



Solar activity

Geomagnetic field

Global thunderstorm activity

Atmospheric conductivity

\* aerosols

\* ionisation

Space / earth processes

Global / Local processes

Climate-driven / Climate-drivers

# Field campaigns

Systems science / holistic perspective

Ambient radioactivity

+

Atmospheric conditions

+

Surface conditions

+

Electric field



# Field campaigns

Systems science / holistic perspective

Ambient radioactivity

+

Atmospheric conditions

+

Surface conditions

+

Electric field

Azores – gamma radiation + atmosphere + surface - island

Hyytiälä – “ “ + soil Radon + electric field – high-latitude

SAIL – gamma + electric field + meteo - over ocean

# GRM campaign - Azores

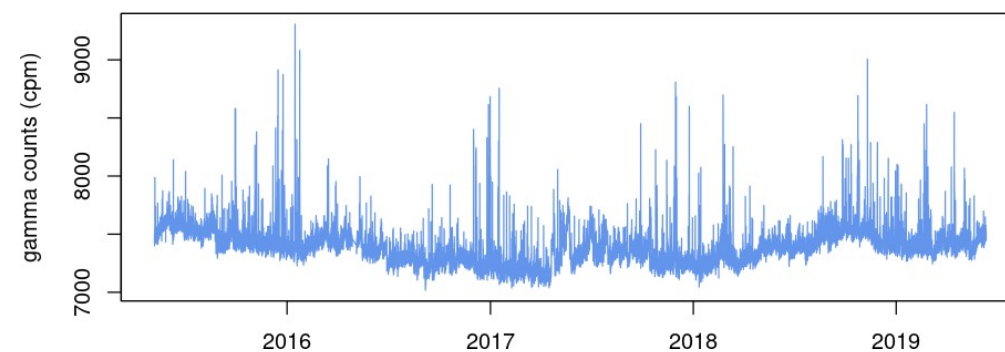
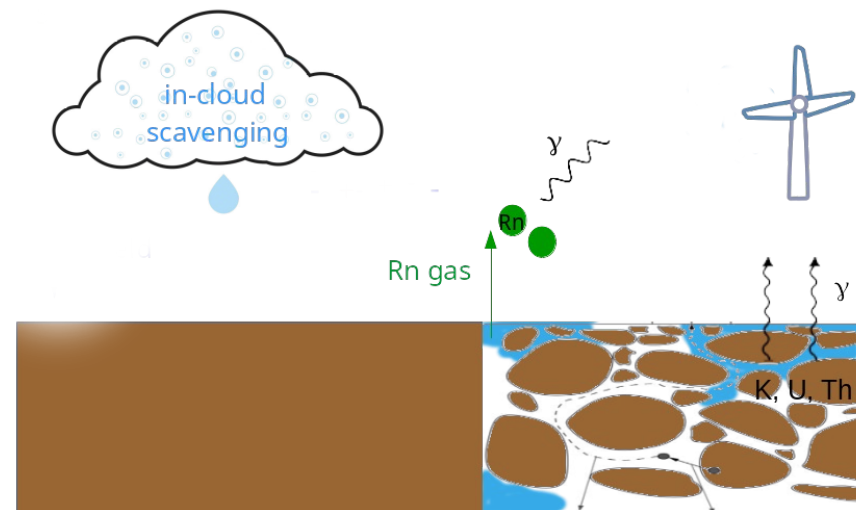
Gamma Radiation Monitoring [2015 - current]



U.S. Department of Energy  
**Eastern North Atlantic**

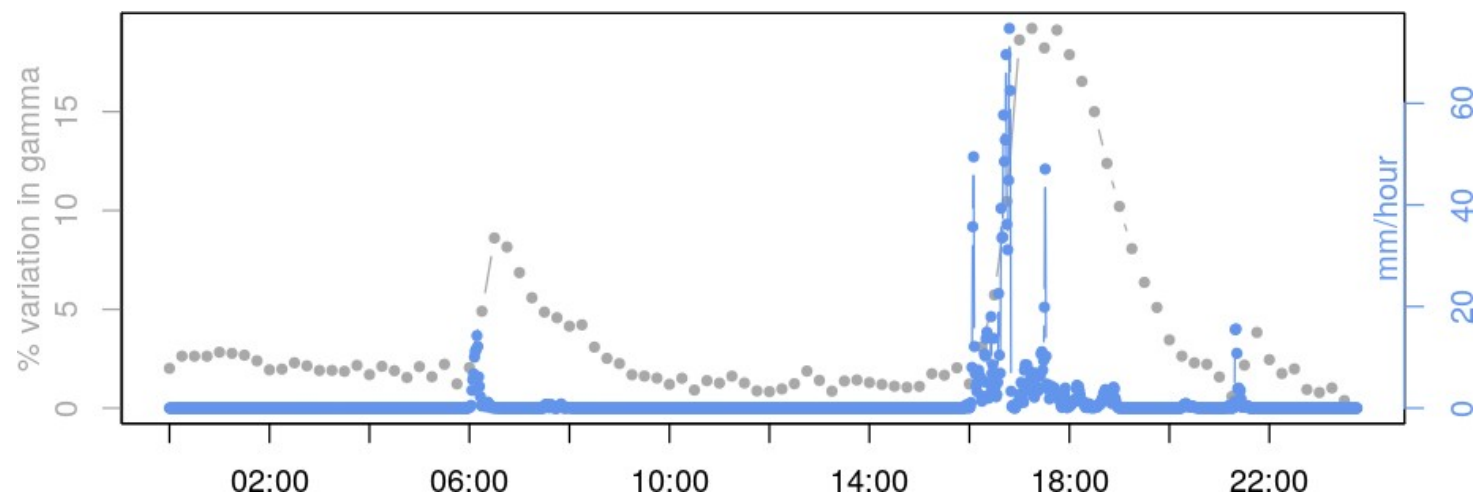


surface-atmosphere interactions



# GRM campaign - Azores

## Gamma radiation & precipitation



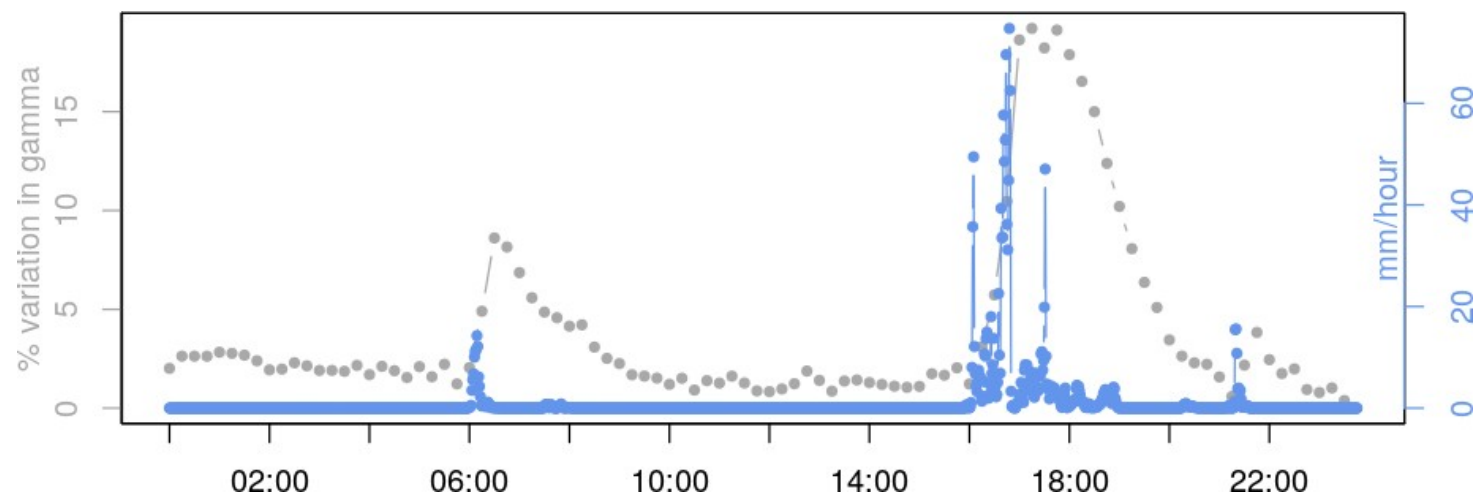
Drop formation mechanism:  
slow condensation



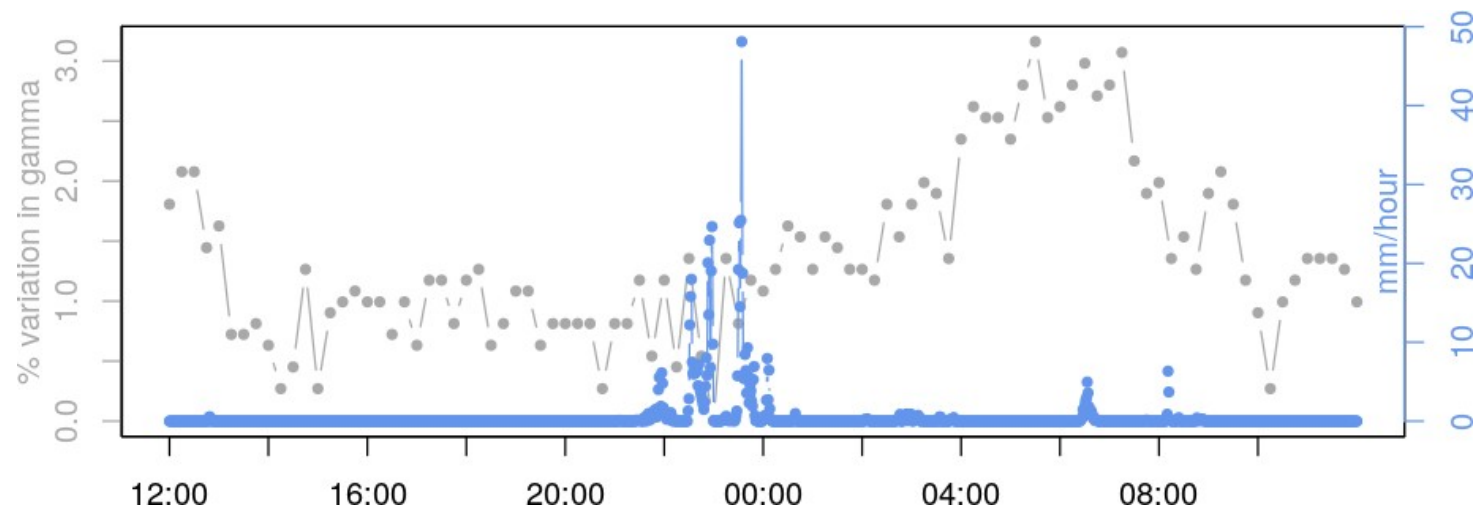
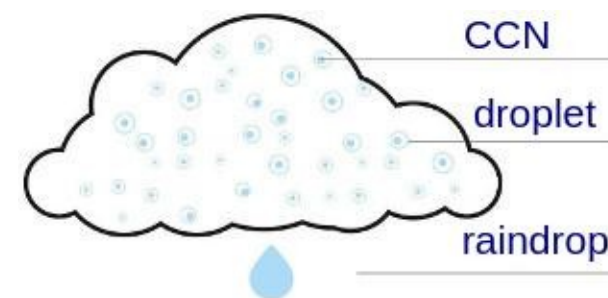


# GRM campaign - Azores

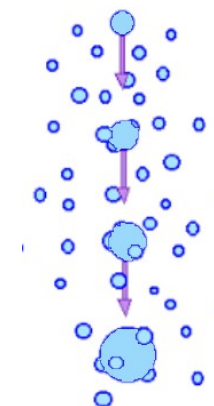
## Gamma radiation & precipitation



Drop formation mechanism:  
slow condensation



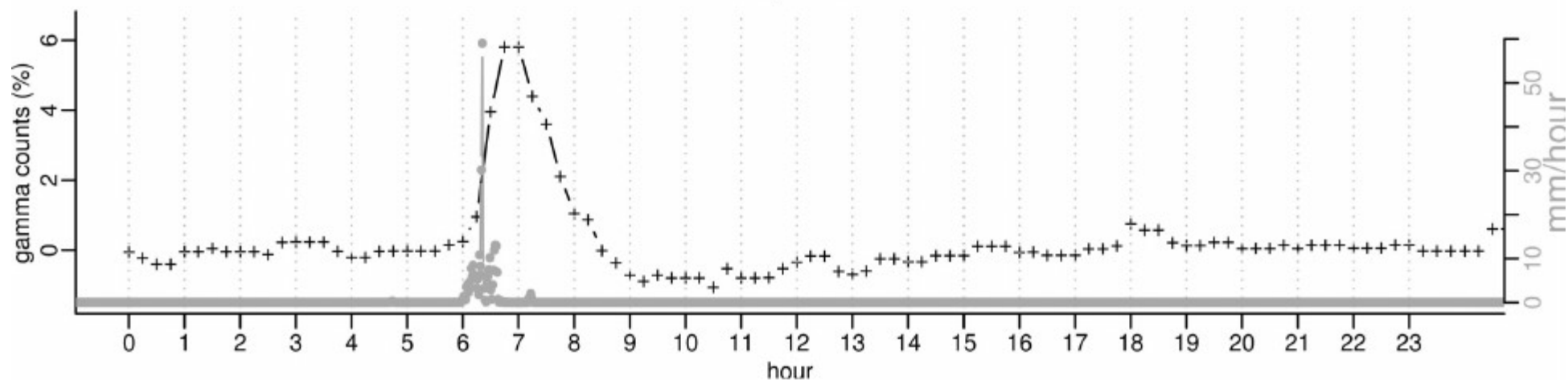
Drop formation mechanism:  
fast collision-coalescence



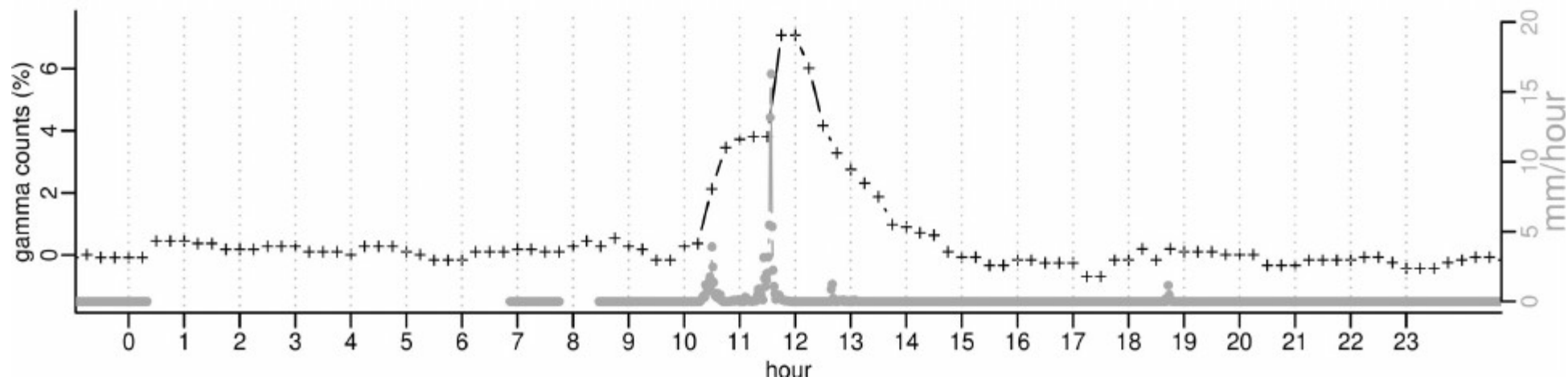
# GRM campaign - Azores

## Gamma radiation & precipitation

Day 128



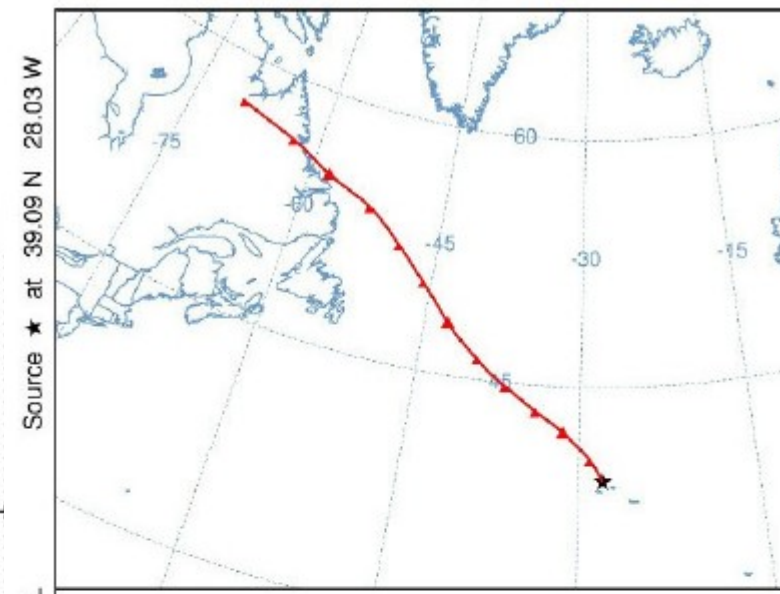
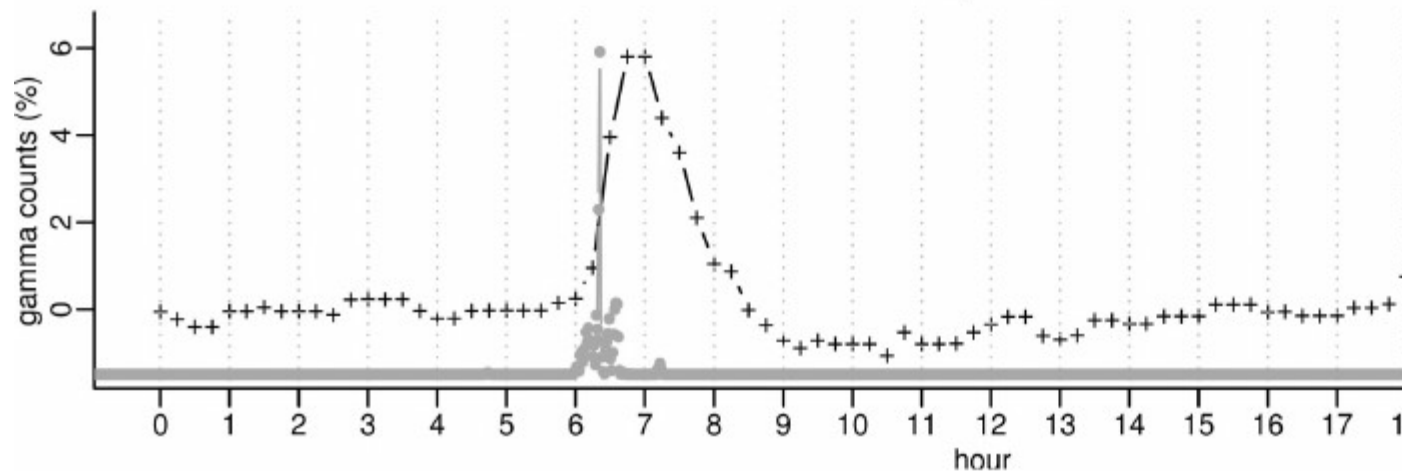
Day 161



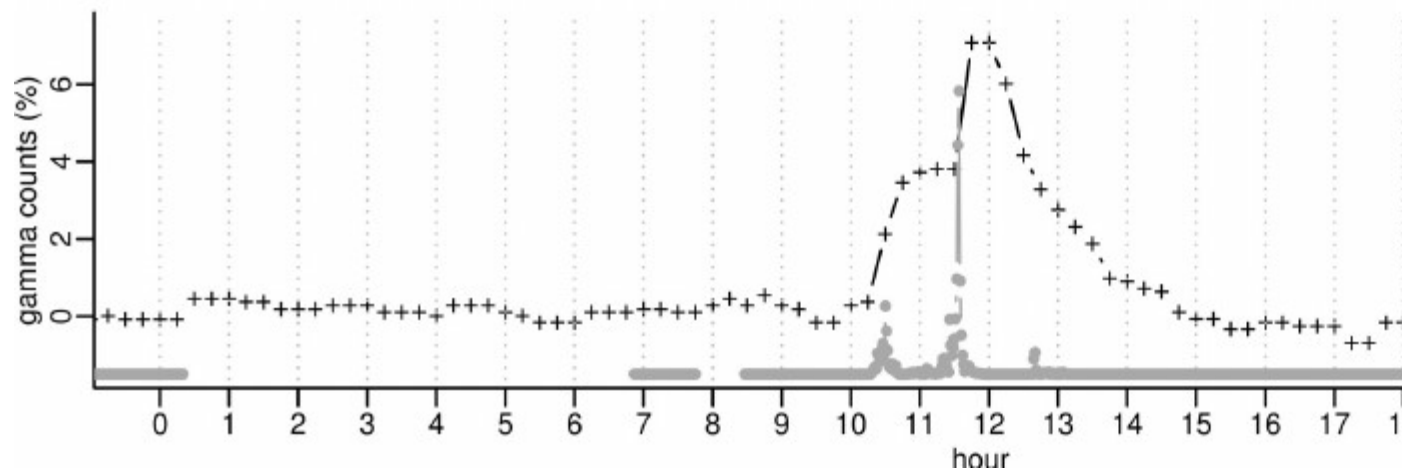
# GRM campaign - Azores

## Gamma radiation & precipitation

Day 128



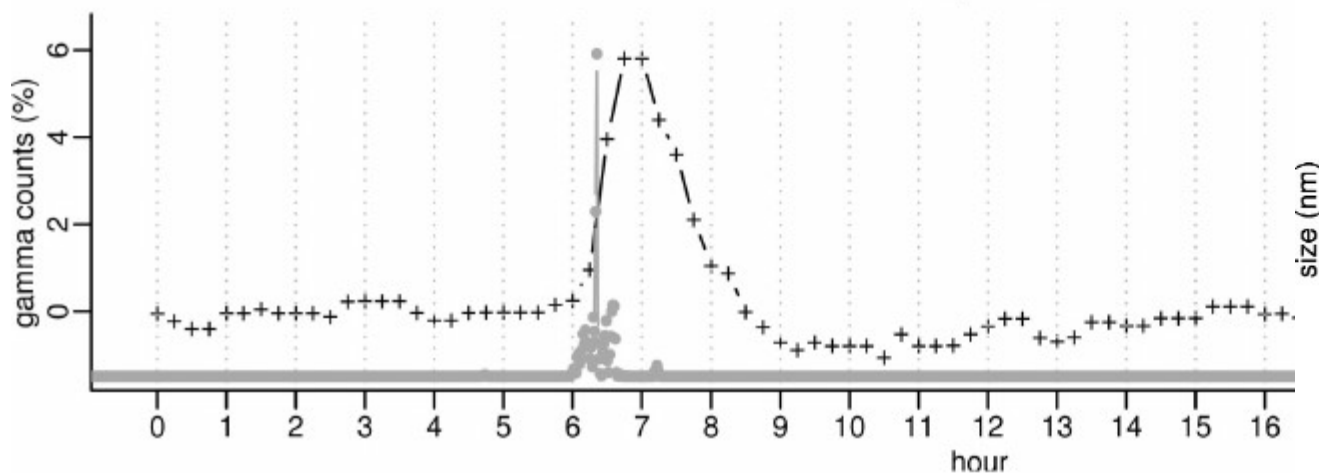
Day 161



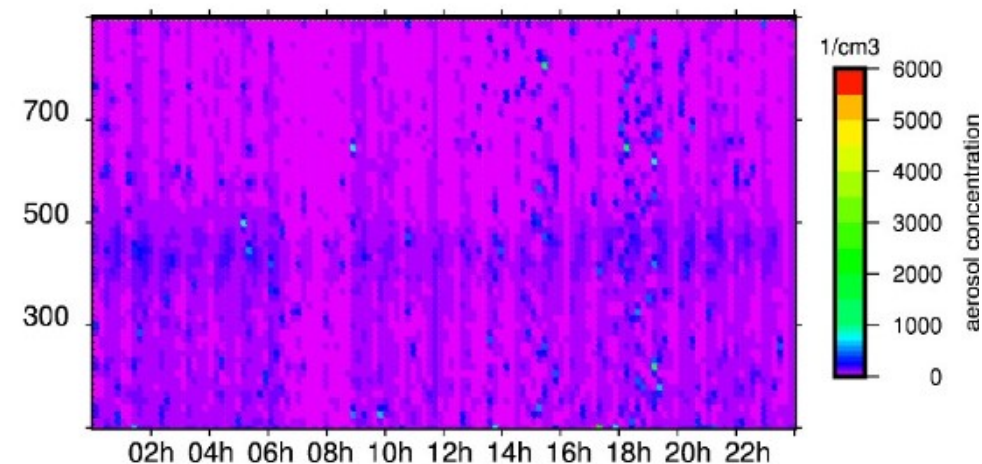
# GRM campaign - Azores

## Gamma radiation & precipitation

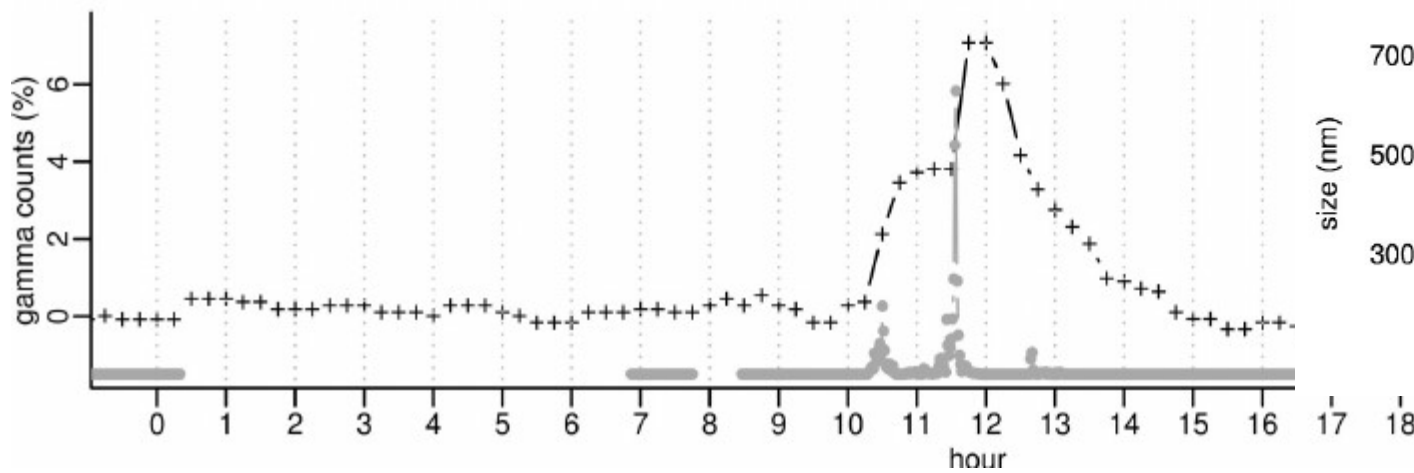
Day 128



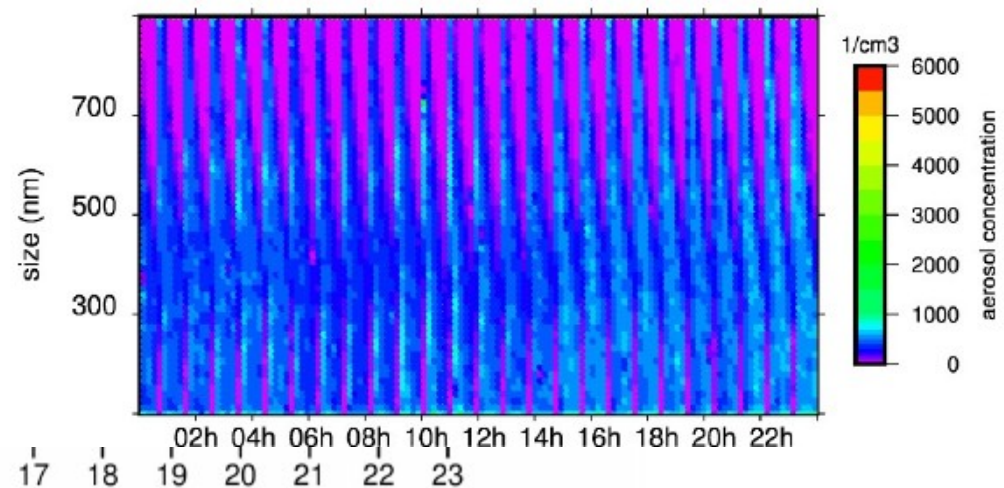
day 128



Day 161



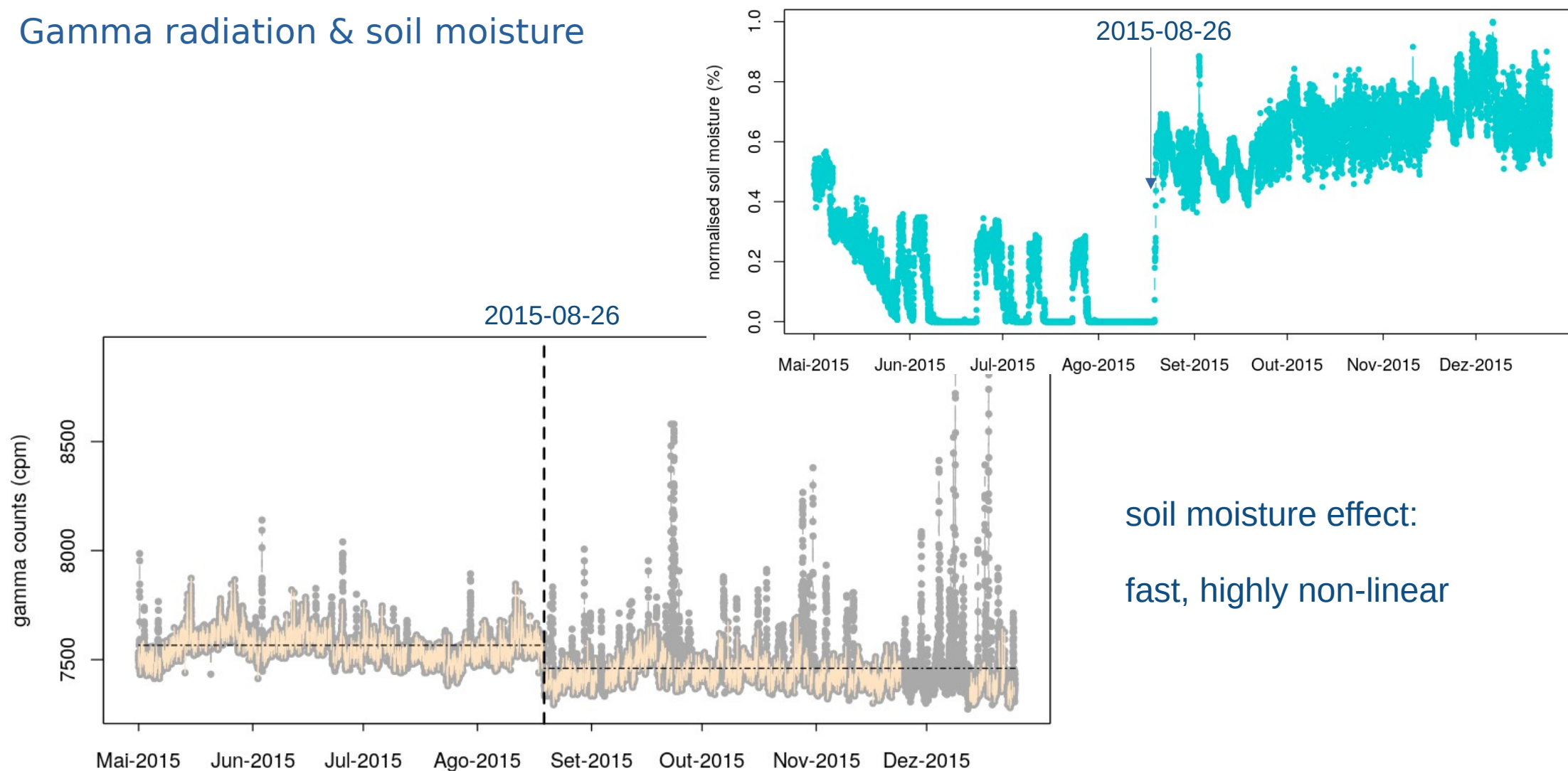
day 161





# GRM campaign - Azores

Gamma radiation & soil moisture



soil moisture effect:  
fast, highly non-linear

# RELECT campaign - Hyytiälä

Gamma in air + Rn in soil + Electric field [ Jun-Dec 2017 – including X-class flare 9.3 on 09-06]





# SAIL campaign

## How it began

Celebration of the 500 years of the 1st circumnavigation  
by the Portuguese Fernão de Magalhães (1519-1522)

NRP Sagres circumnavigation in 2020/21





# SAIL campaign

## Motivation

The Carnegie under full sail, 1909



source: the Carnegie Institute of Washington

# SAIL campaign

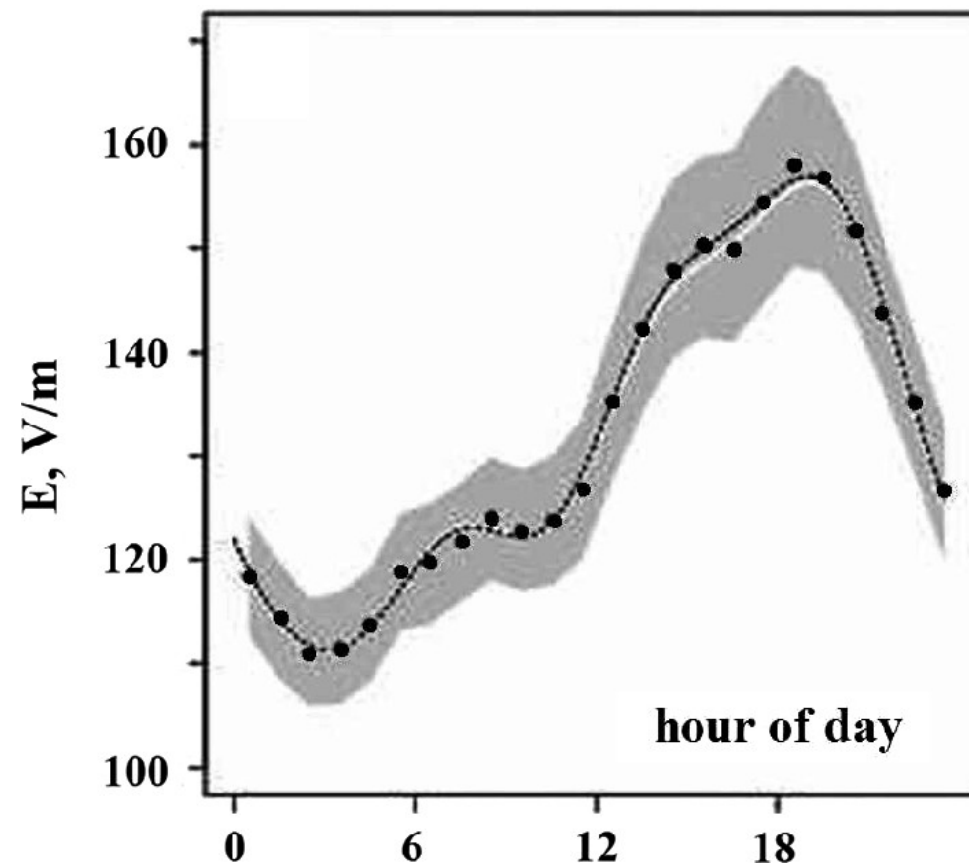
## Motivation

The Carnegie under full sail, 1909



source: the Carnegie Institute of Washington

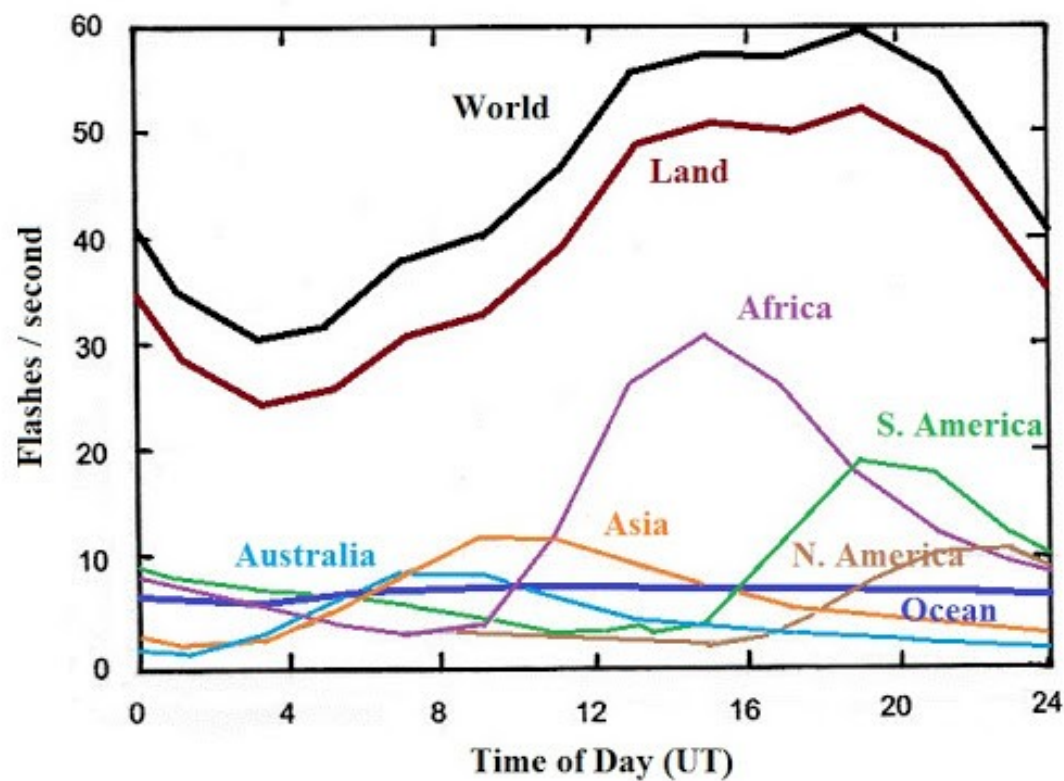
Atmospheric electric field – Carnegie curve



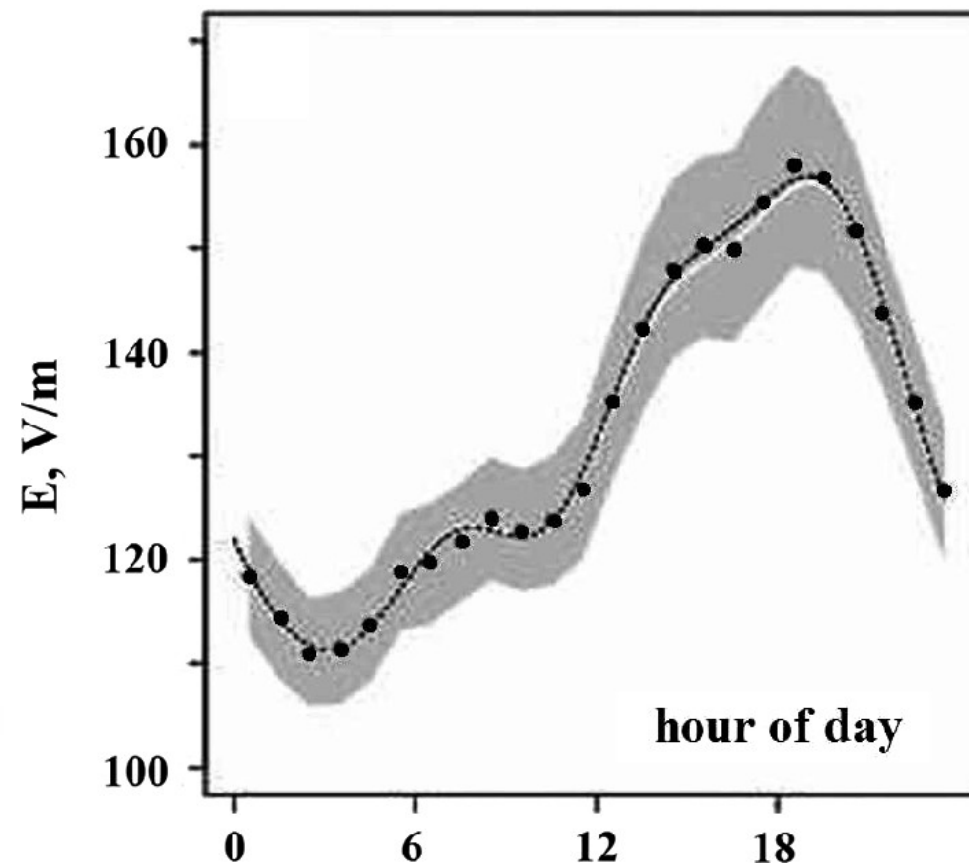
source: Harrison, 2013

# SAIL campaign

## Motivation



Atmospheric electric field – Carnegie curve



source: Harrison, 2013



# SAIL campaign

## Motivation

1909-1921



2020



Global measurements over the ocean still used today as the reference (the Carnegie curve)

Compelling motivation for XXI measurements:

- \* Climate change → + convection → + lightning
- \* Pollution → + aerosols → conductivity

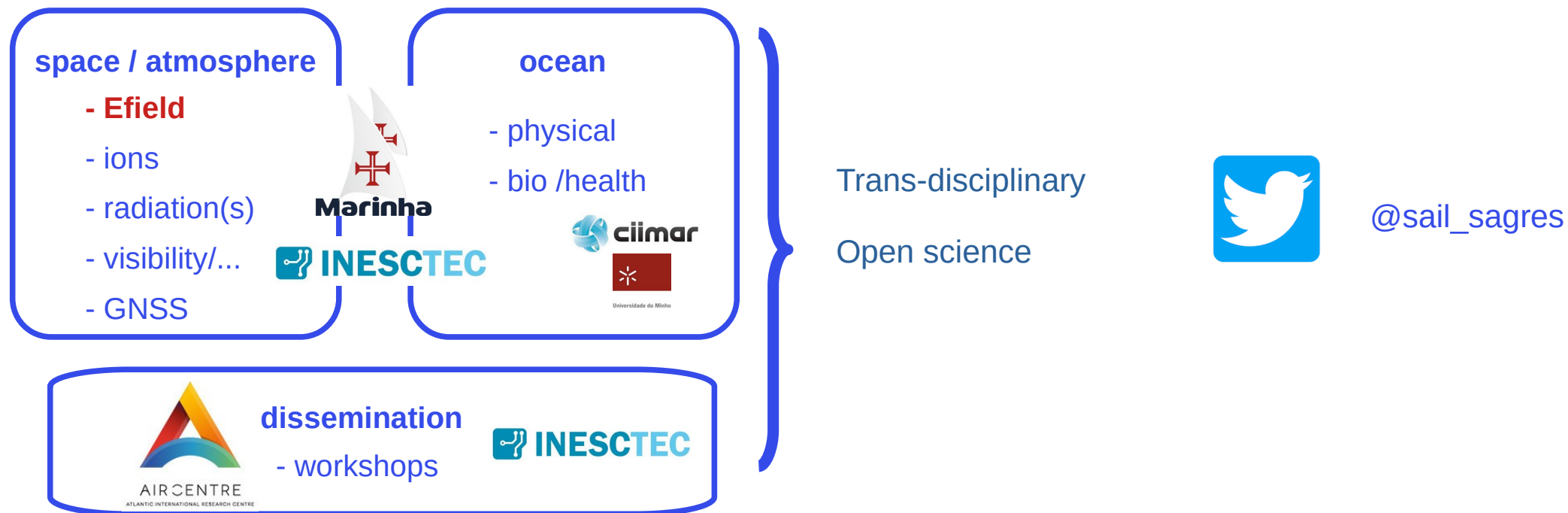


Credit: Tommy Eliassen/Science Photo Library

# SAIL campaign



Space-Atmosphere-Ocean Interactions in the marine boundary Layer





# SAIL campaign

Set-up

Oct-Dec 2020





# SAIL campaign

## Earth-space interactions



### 1-sec measurements

- Atmospheric electric field (2 sensors,  $\neq$  heights)
- Gamma radiation (+ cosmic radiation)
- Ion counter (concentration + mobility)
- Visibility sensor
- Solar radiation + meteo (navy)
- Kinematic GNSS

SAIL TOOL			
<b>SYSTEM</b> Time: 11:41:32 UTC Date: Wednesday, 04 March 2020 DISK (GiB): Total: 438.28 Free: 405.53	<b>NETWORK-ATTACHED STORAGE</b> NAS SYSTEM: <span>OK</span> Total memory: 17.889 TiB Available memory: 17.555 TiB	<b>TOW FISH</b> STATUS: <span>OFFLINE</span> Description: Towfish is disconnected. Last RX: 2020-02-24 21:31:00	<b>NMEA</b> STATUS: <span>OK</span> Description: NMEA is logging. Last RX: 2020-03-04 11:41:31 Time: 11:41:31 Latitude: 3506.066852 Longitude: 5532.135510 Altitude: 6.644700 m Speed: 8.131000 knots Course: 95.300000 Quality: 1 Satellites: 27 Hdop: 0.500000 Clients: 1
<b>GNSS 1</b> STATUS: <span>OK</span> Description: ANTENNA 1 is logging (3). Last RX: 2020-03-04 11:41:32 Description: ANTENNA 2 is logging (3). Last RX: 2020-03-04 11:41:32	<b>GNSS 2</b> STATUS: <span>OK</span> Description: ANTENNA 1 is logging (3). Last RX: 2020-03-04 11:41:31 Description: ANTENNA 2 is logging (3). Last RX: 2020-03-04 11:41:32	<b>GNSS 3</b> STATUS: <span>DISABLED</span>	
<b>GNSS 4</b> STATUS: <span>DISABLED</span>	<b>ELECTRIC FIELD CS110 1</b> STATUS: <span>OK</span> Description: Sensor is logging. Last RX: 2020-03-04 11:41:31 State: Healthy (01)	<b>ELECTRIC FIELD CS110 2</b> STATUS: <span>OK</span> Description: Sensor is logging. Last RX: 2020-03-04 11:41:31 State: Healthy (01)	<b>GAMMA NaI(Tl)</b> STATUS: <span>OK</span> Description: Sensor is logging. Last RX: 2020-03-04 11:41:31
<b>VISIBILITY SWS050</b> STATUS: <span>OK</span> Description: Sensor is logging. Last RX: 2020-03-04 11:40:32 No significant weather. 20.695 NM	<b>SOLAR IRRADIANCE SP510/610</b> STATUS: <span>OK</span> Description: Sensor is logging. Last RX: 2020-03-04 11:41:31	<b>CLUSTER ION COUNTER</b> STATUS: <span>OK</span> Description: Logging data.	<b>MICROSCINTILLATOR</b> STATUS: <span>ERROR</span> Description: No serial device. Last RX: n/a

source: Nuno Dias



# SAIL campaign

## Data collection



1-sec data from all sensors

~10 GB / day

5 January – 9 May 2020 (navigation)

15 May – 20 September - Lisboa (port)

21 – 27 September – South coast of Portugal

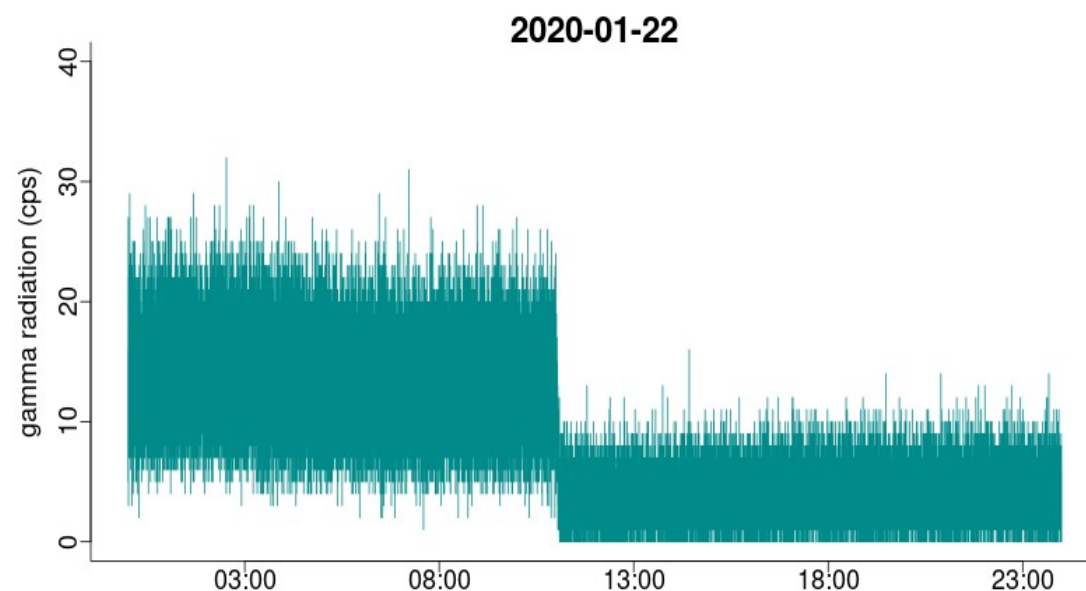
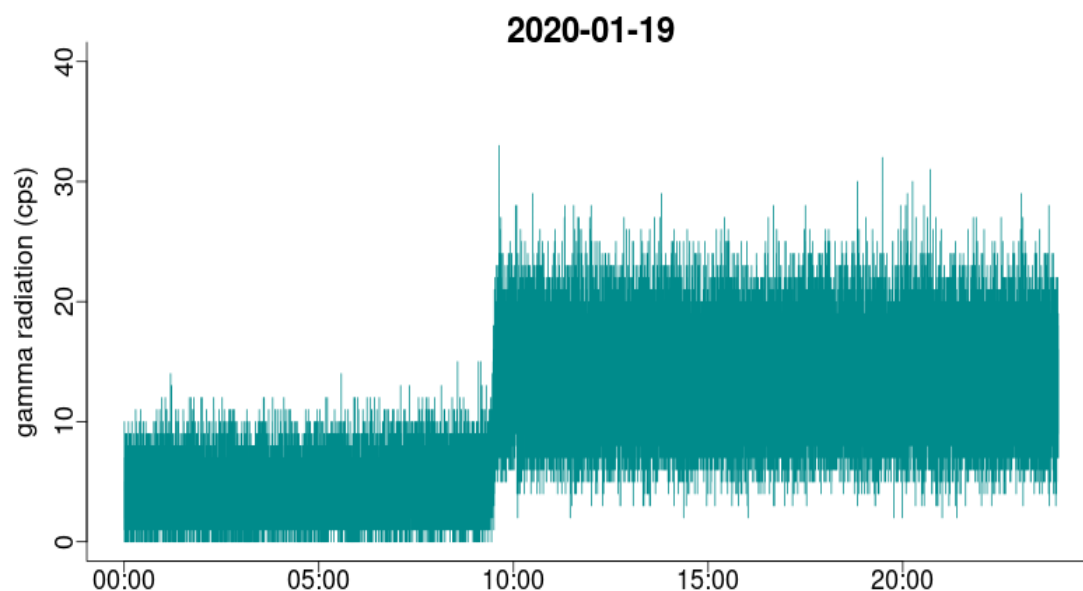
since 27 September - Lisboa (port)



# SAIL campaign

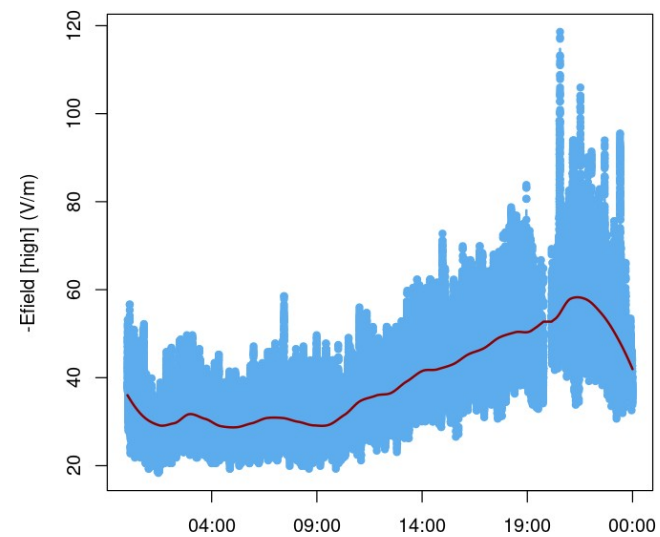
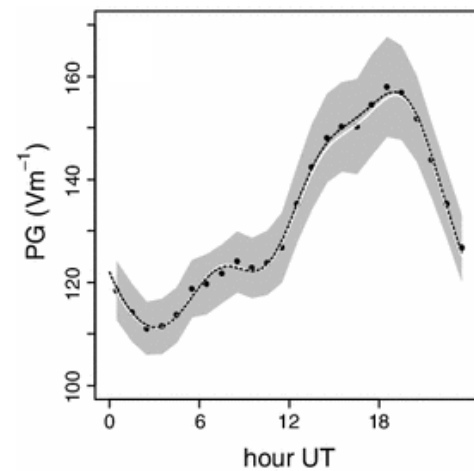
## Preliminary results

gamma radiation – land /ocean contrast



# SAIL campaign

## Preliminary results





# SAIL campaign

[Open Science](#)

## Project SAIL community

### Recent uploads



February 8, 2021 (v1)

Technical note

Open Access

#### SAIL campaign - Technical report on Sensor Data correction

Amaral, Guilherme; Dias, Nuno;

Technical report on the correction of sensor data from the SAIL campaign

Uploaded on February 8, 2021

View

January 18, 2021 (v1)

Technical note

Open Access

#### SAIL campaign - Technical report on GNSS Post-processing

Ferreira, António;

Technical report on the post-processing of GNSS data from the SAIL campaign

Uploaded on January 18, 2021

View

New upload

Community



Space-Atmosphere-  
Ocean Interactions  
in the Marine  
Boundary Layer

### Project SAIL community

Project SAIL (**S**pace-**A**tmosphere-**O**cean **I**nteractions in the marine boundary **L**ayer) Zenodo community. SAIL aims to improve the scientific understanding of the marine boundary layer by means of an unique monitoring campaign on board the ship-rigged sailing ship NRP Sagres during its 2020 circumnavigation expedition.







# SAIL campaign

## Outreach



## VOLTA AO MUNDO EM ELETRICIDADE

O Sagres zarpa em janeiro para comemorar a mais venturosa das expedições marítimas e recolher dados que não são recolhidos há quase um século, mas que poderão revelar-se determinantes no estudo das alterações climáticas

«A viagem de Magalhães foi feita devido ao conhecimento científico e, por sua vez, deu um grande impulso à ciência. O que nos deu a ideia: por que não meter projetos científicos nesta missão?», recorda Maurício Camilo.

O mote estava dado: quando iniciar a rota de Magalhães, a Sagres levará consigo três cientistas de âmbito multidisciplinar...



Chama-se *Towfish*, vai a reboque na água e tem sensores para medir o som, a salinidade, a temperatura e também o oxigénio no mar

Nos mastros, vão sensores de raios gama (a radiação dos fenómenos espaciais) e um contador de iões (átomos ou moléculas que têm carga elétrica)



## Viagem da Sagres ajuda a prever mudanças climáticas

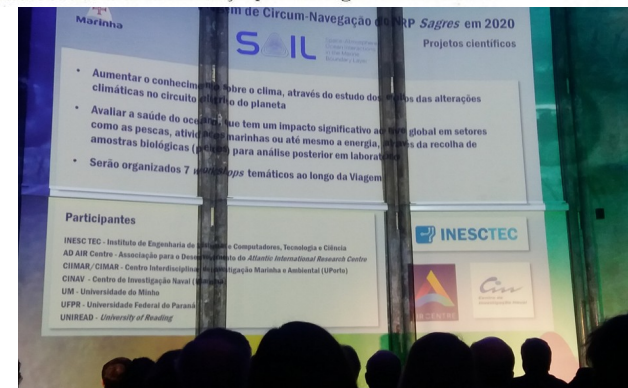
Objetivo do projeto SAIL, do INESC TEC, é melhorar os modelos de estudo do clima e da saúde dos oceanos. Recolhidos todos os dias 13 GB de informação para investigar durante três anos

### OUTROS DADOS

**Há cem anos**  
A última medição do campo elétrico da atmosfera numa expedição global a bordo de um navio aconteceu entre 1907 e 1920, com o norte-americano Carnegie. Depois, os russos tentaram uma expedição no Atlântico, e os japoneses no Pacífico.

**Microplásticos**  
Há outro projeto de investigação a bordo do navio que vai monitorizar o lixo marinho e medir a quantidade de microplásticos no oceano, realizado, com o Instituto Hidrográfico. Os dados vão contribuir para mapear zonas de acumulação e avaliar a saúde dos peixes.

**Apoio do Governo**  
O Ministério da Defesa Nacional e o do Ambiente e da Ação Climática garantiram um financiamento de 200 mil euros aos trabalhos de investigação a bordo da Sagres, através do Fundo Ambiental. Metade é para o SAIL, no qual o INESC TEC prevê investir 300 mil no total.



# Concluding remarks

Earth-space interactions – holistic, trans-disciplinary perspective

Relevance of field measurements (+ models + lab )

“Low-cost” campaigns

- Available infrastructure
- Specific environments

Open science (data, technical documentation,...)

Climate scientific basis

**Susana Barbosa**

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