How different are the dust particle size distributions between Morocco and Iceland? Unveiling insights through field measurements

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Severo Ochoa Research Seminar

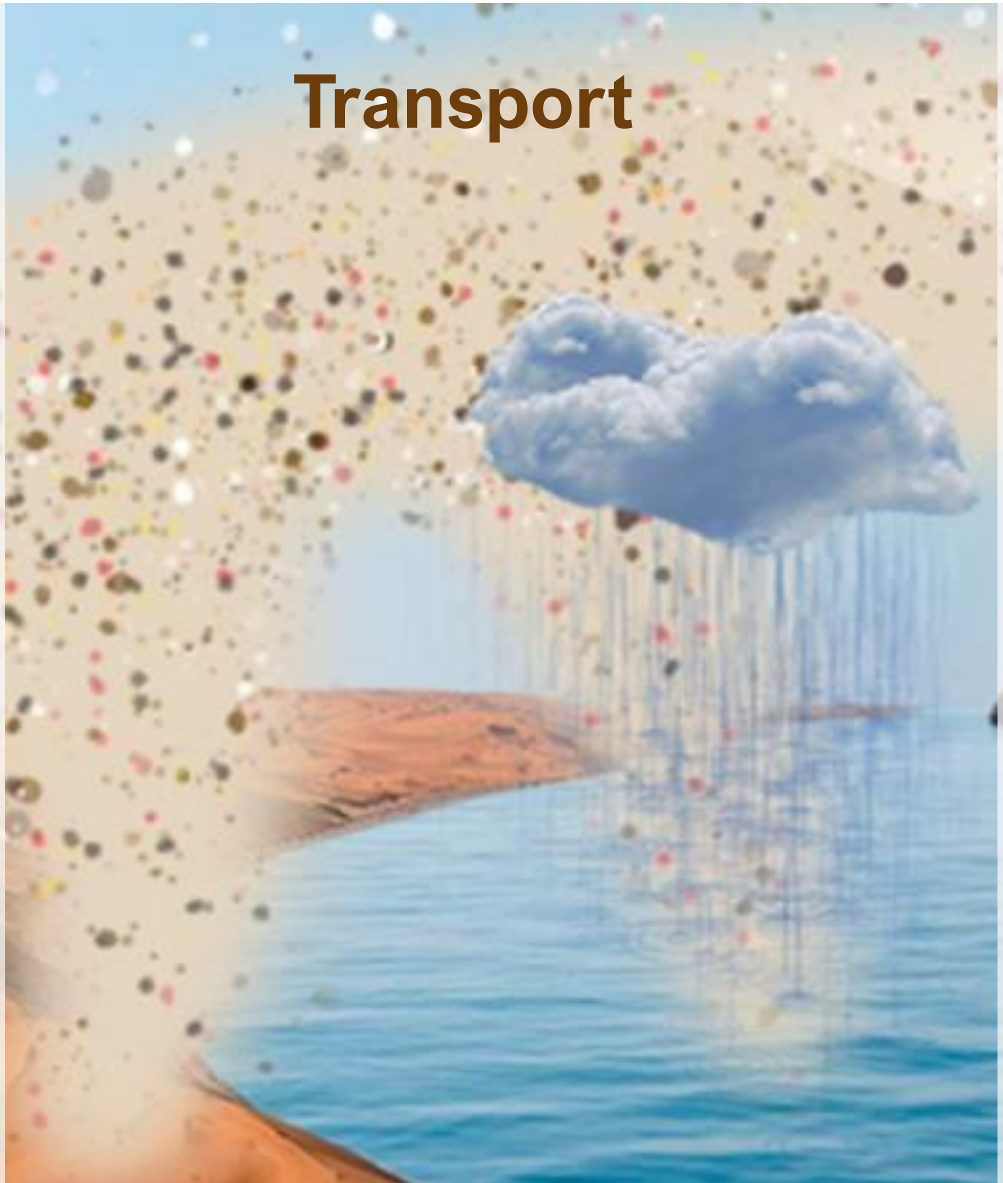
The atmospheric mineral dust cycle

Emission

- Arid and semiarid areas.
- Strong winds.
- Every year between 3400 and 9100 Tg (D≤20μm) are emitted globally.
  (Kok et al., 2021)

The atmospheric mineral dust cycle

- Dust lifetime in the atmosphere depends on:
  - Size
  - Environmental conditions



- There is increasing evidence of the long-range transport of coarser dust.

(Jeong et al., 2014; Van Der Does et al., 2016, 2018; Weinzierl et al., 2017)

Climate models are likely missing ≈75% of particles with D>5μm!

(Adebiyi and Kok, 2020)

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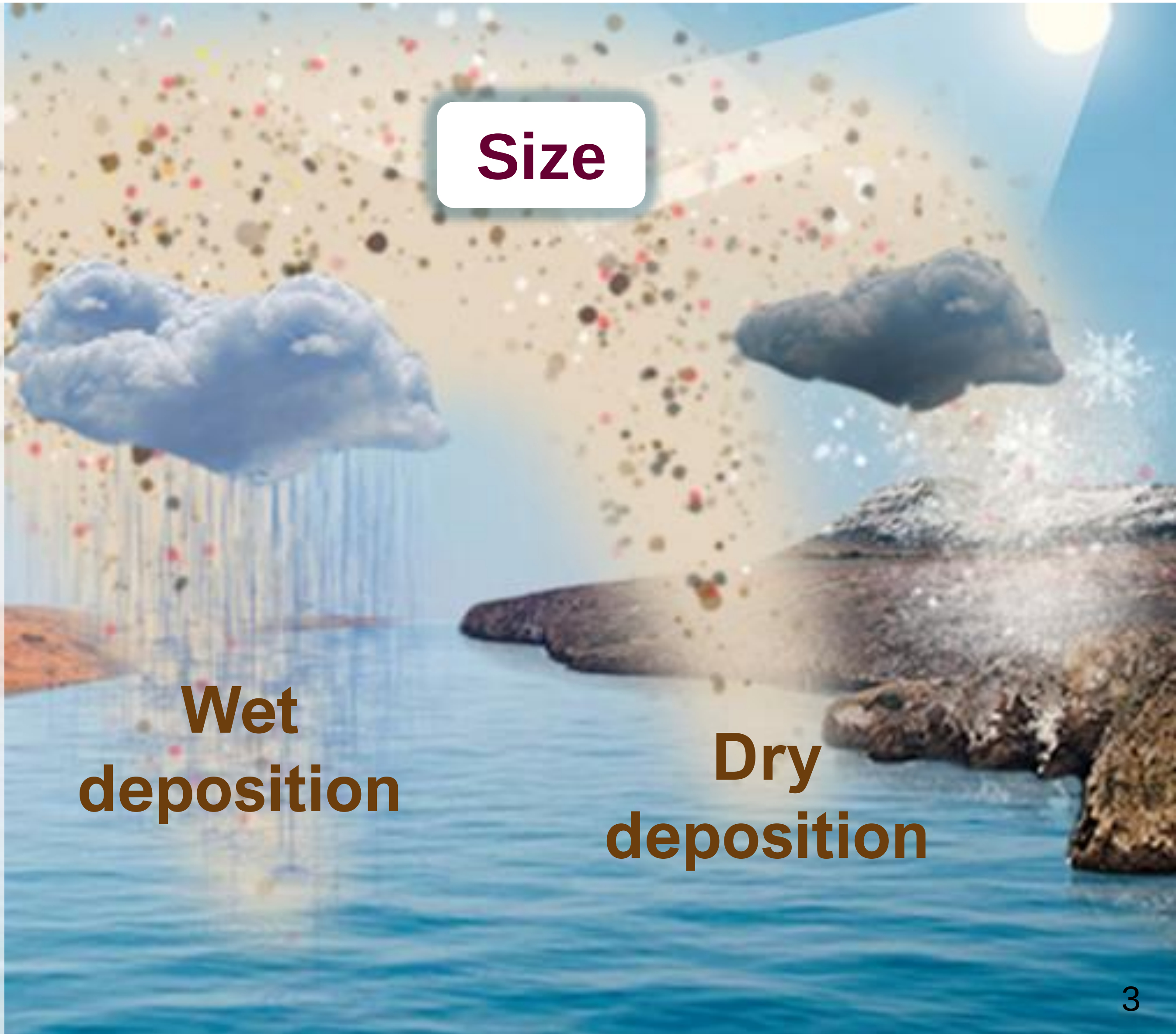
The atmospheric mineral dust cycle

- Larger errors when simulating dust deposition.

Factor 10 between simulated dust deposition and observations
(Huneeus et al., 2011)



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Why study dust?

Effects on Society

Schultz and Meisner, 2009

Saidan et al., 2016

Goudie, 2014; Zhang et al., 2016; Querol et al., 2019

Stefanski and Sivakumar., 2009

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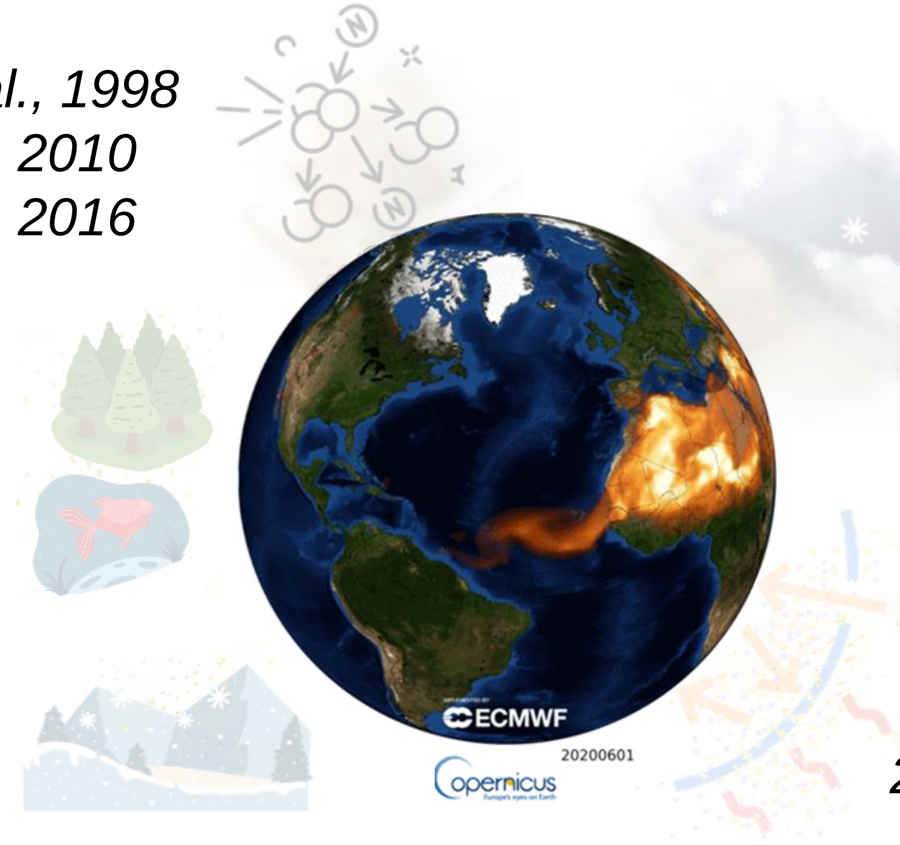
Why study dust?

Effects on Climate

Li-Jones et al., 1998
Tobo et al., 2010
Tang et al., 2016

DeMott et al., 2003
Atkinson et al., 2013
Hawker et al., 2021



Okin et al., 2004
Bristow et al., 2010
Jickells and Moore, 2015

Skiles et al., 2018
Dumont et al., 2020

Net DRE
-0.5 to 0.35 Wm^{-2}
(Scanza et al., 2015; Kok et al., 2017; Di Biagio et al., 2020; Li et al., 2021; Feng et al., 2022)

Net DRE
-0.45 → -0.20 Wm^{-2}

SW → cooling
LW → warming
(Kok et al., 2017)

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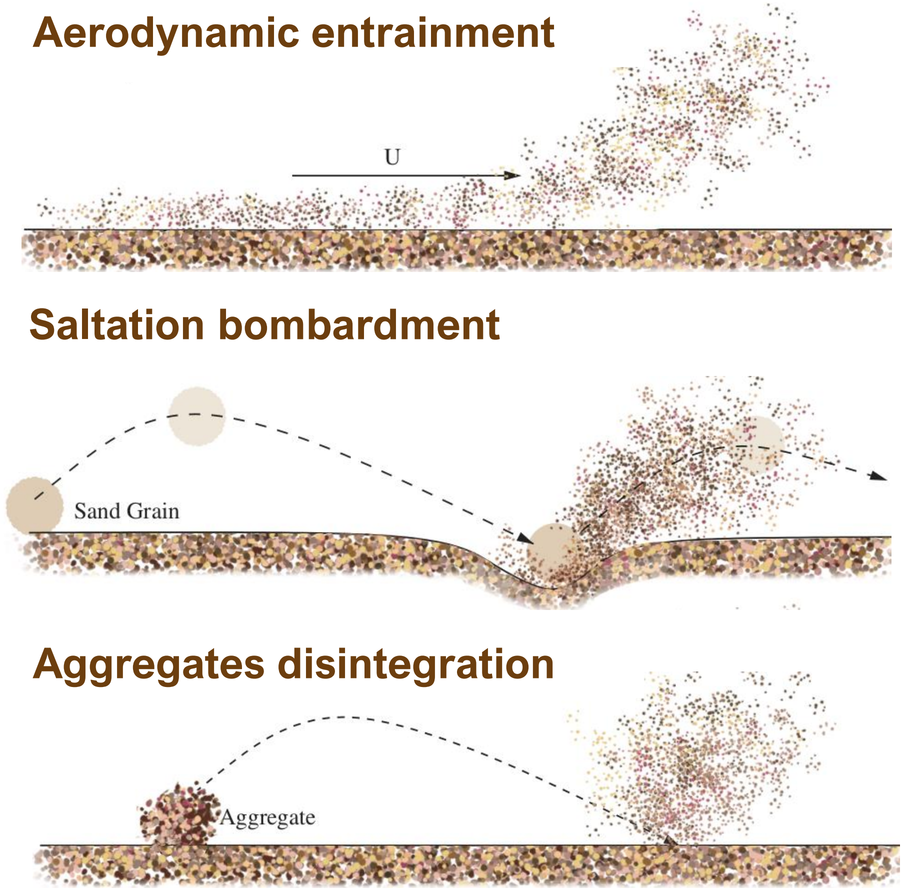
Dust emission



Modified from Shao (2008)

The dust particle size distribution (PSD) and its variability at emission

Variability
In the size range up to ~10µm is the PSD invariant?

Supercoarse dust
What happens for particles >10µm?

Deposition
Is the diffusive flux PSD equivalent to the emitted dust PSD?

Mid latitude vs high latitude dust sources
How different are the PSDs?

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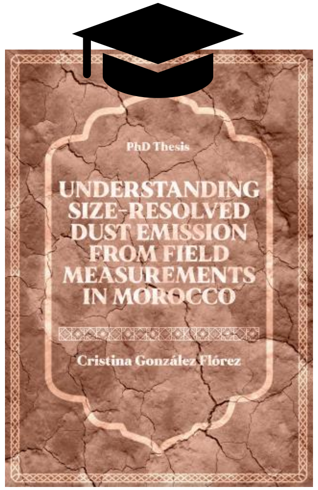
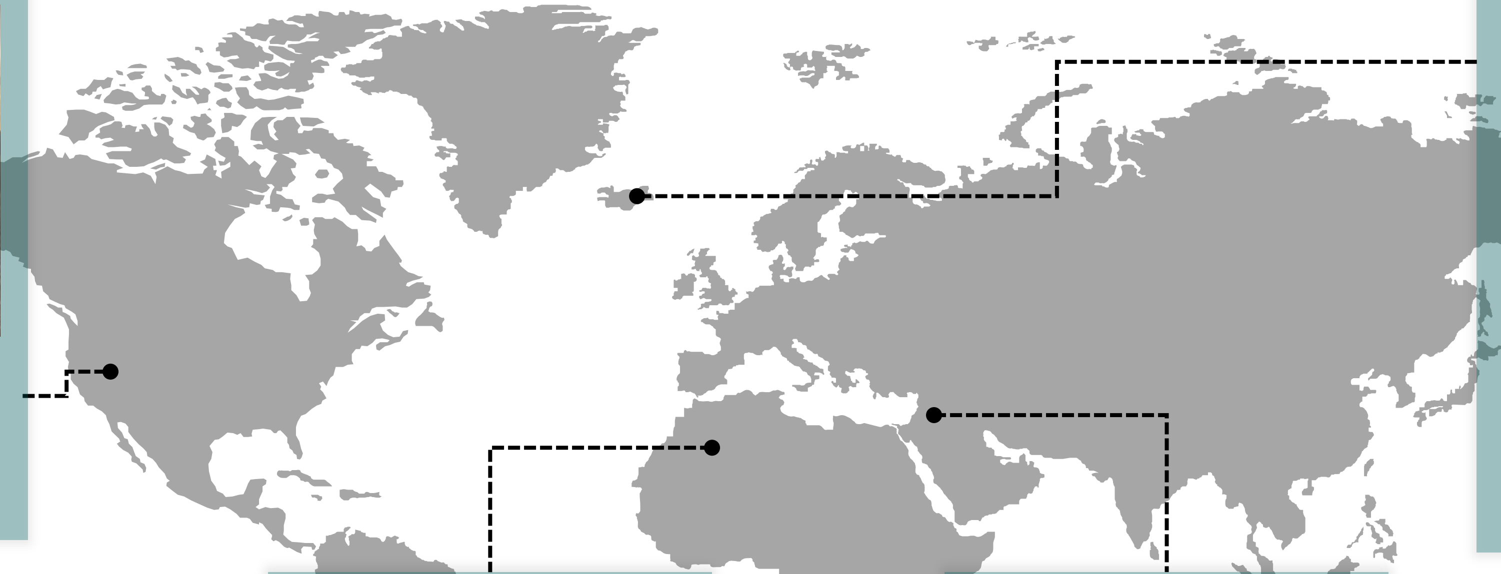


Improve our fundamental and quantitative understanding of **the emitted dust PSD and its variability** based on **measurements from** an intense dust field campaign conducted in **Morocco** in 2019

Compare dust properties from a high latitude volcanic dust source and a mid latitude dust source

Field campaigns



USA
Mojave National Park
(Spring 2022)

Iceland
Vatnajökull National Park
(Summer 2021)

Morocco
"El Bour" (M'hamid)
(Summer/Autumn 2019)

Jordan
Wadi Rum
(Summer/Autumn 2022)

Frontiers in dust minerAloGical coMposition and its Effects upoN climaTe

erc
European Research Council

FRAGMENT

PI: C. Pérez García-Pando

Iceland - Greenland - Jan Mayen - Svalbard - Faeroe Islands
HILDA
High-latitude dust emission

PIs:
K. Kandler
K. Schepanski

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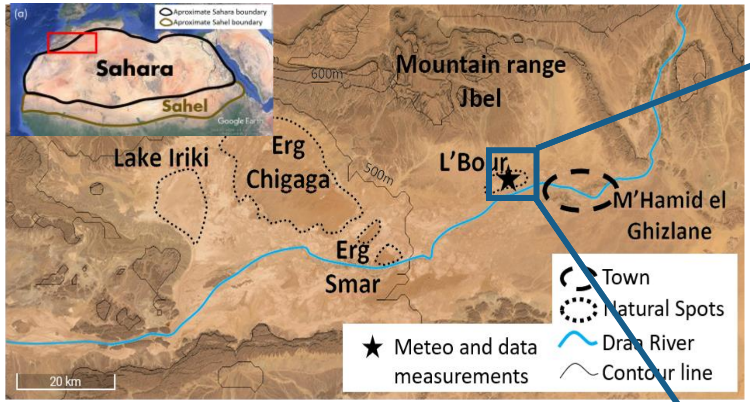
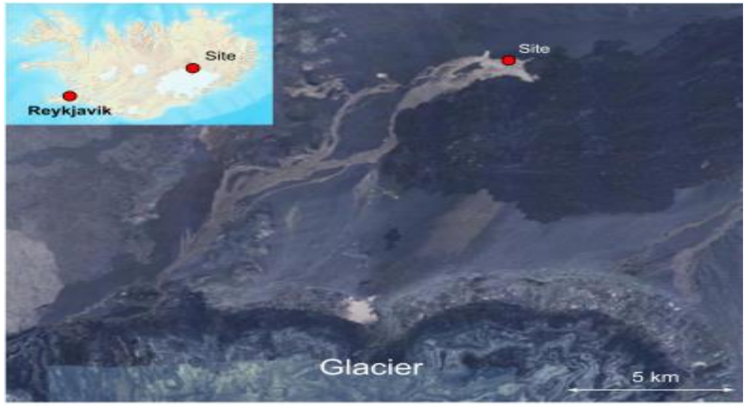
The FRAGMENT dust field campaigns in Morocco and Iceland

Experimental sites





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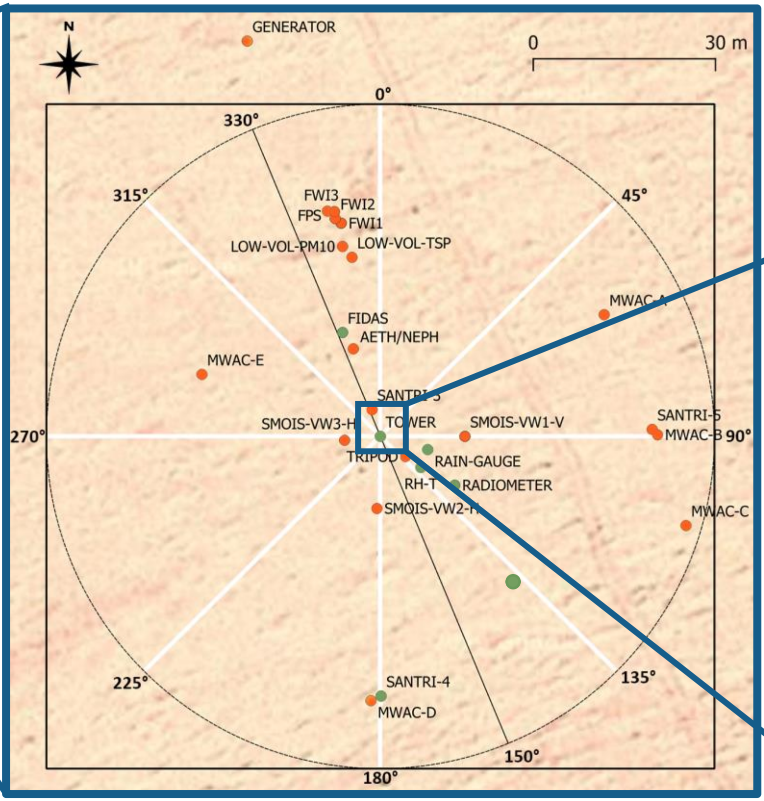
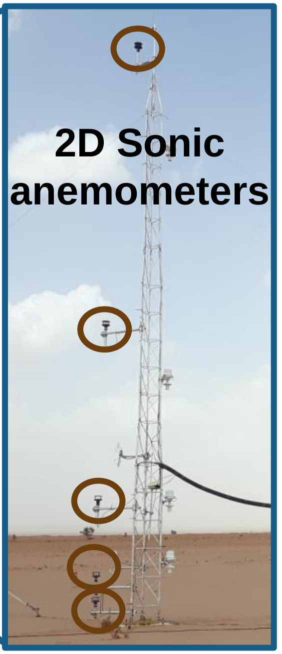
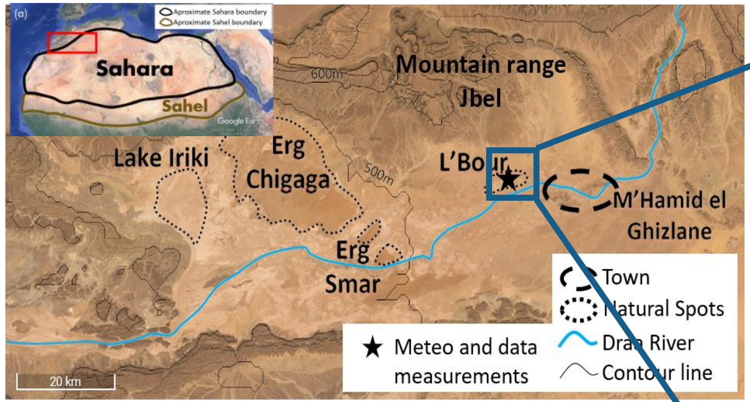


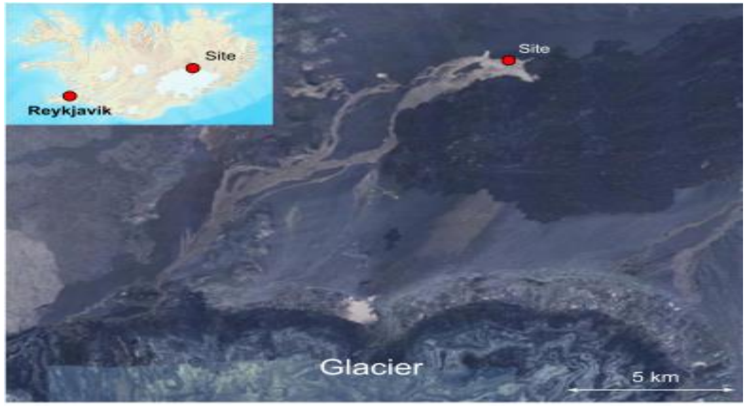
Meteorological measurements



The FRAGMENT dust field campaigns in Morocco and Iceland

Experimental sites





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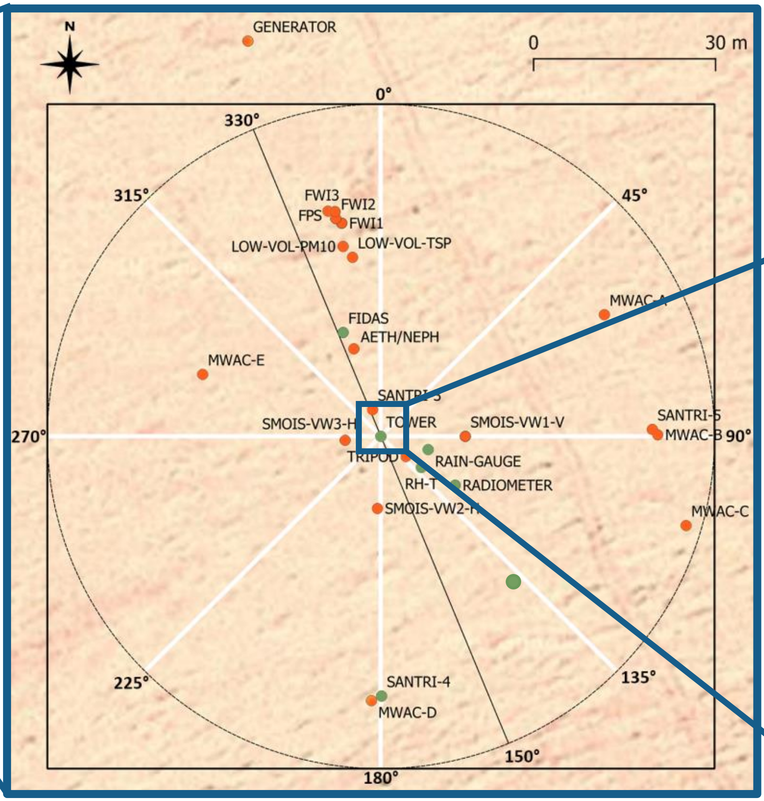
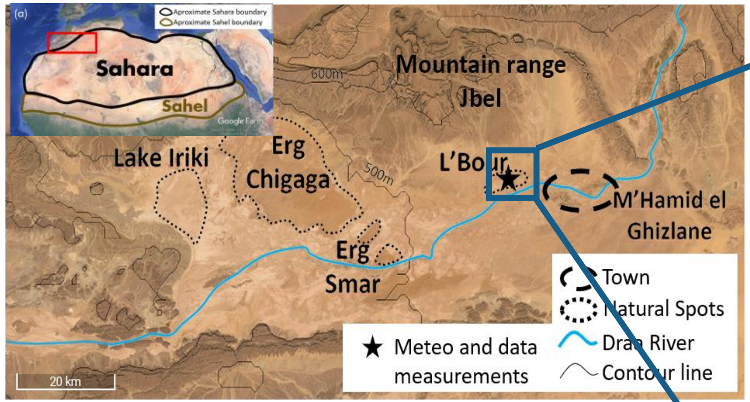
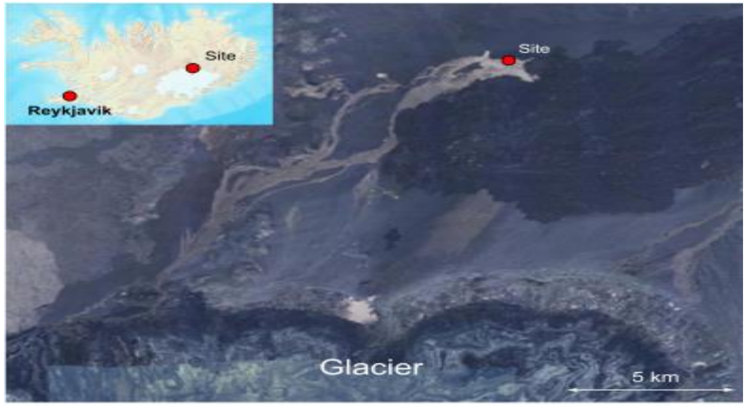


Meteorological measurements

The FRAGMENT dust field campaigns in Morocco and Iceland

Experimental sites





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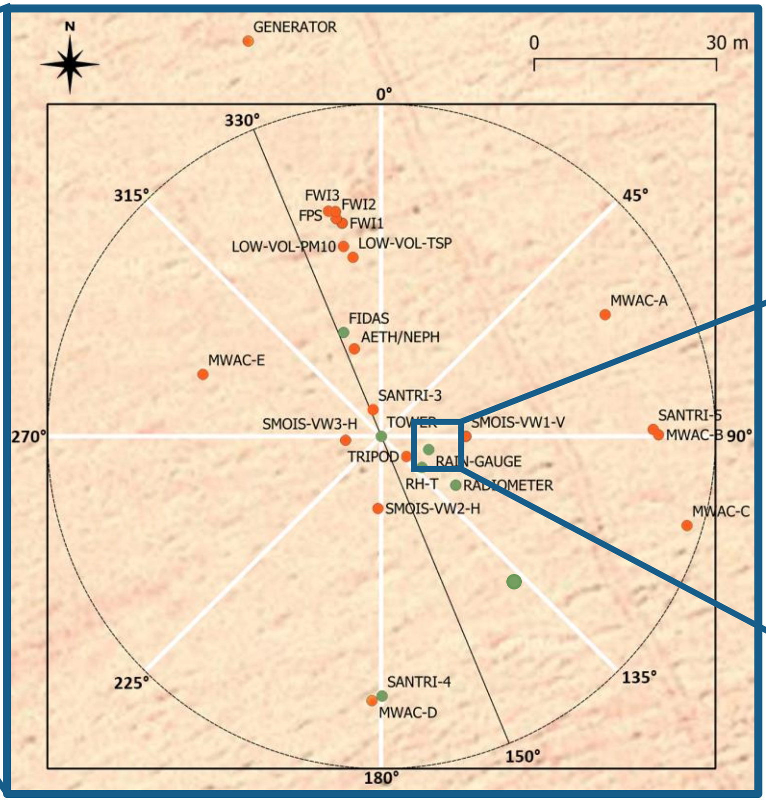

Meteorological measurements

The FRAGMENT dust field campaigns in Morocco and Iceland

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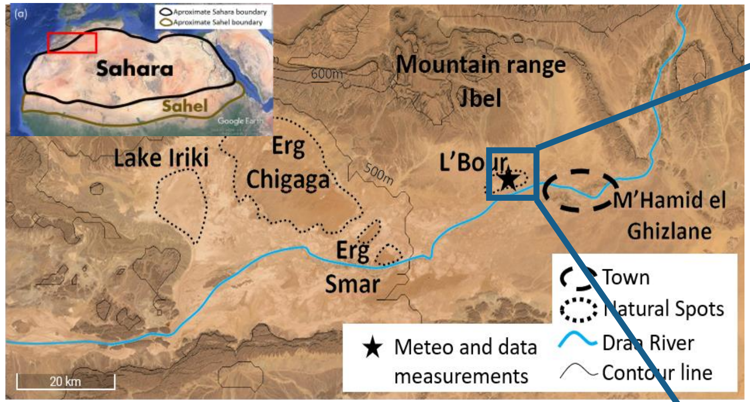

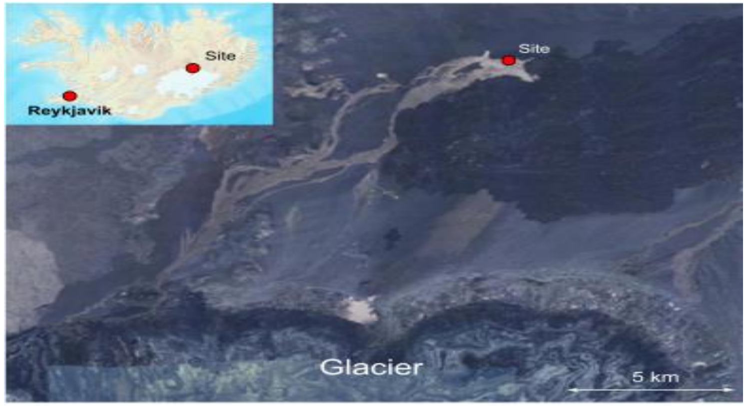

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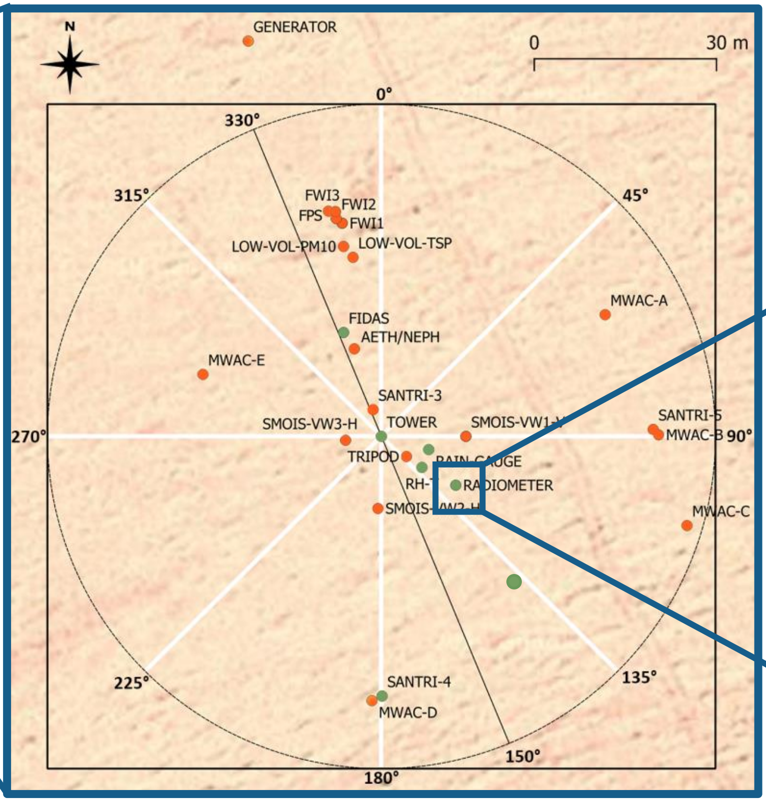
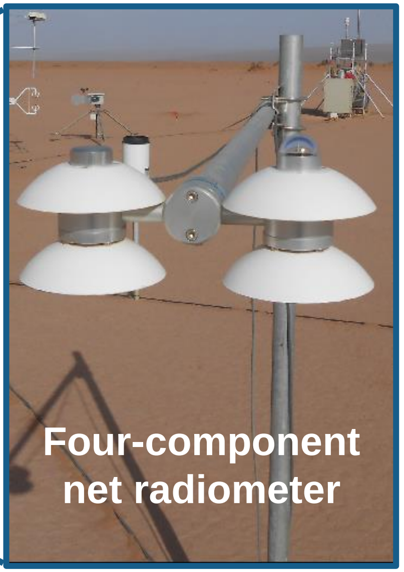


Meteorological measurements



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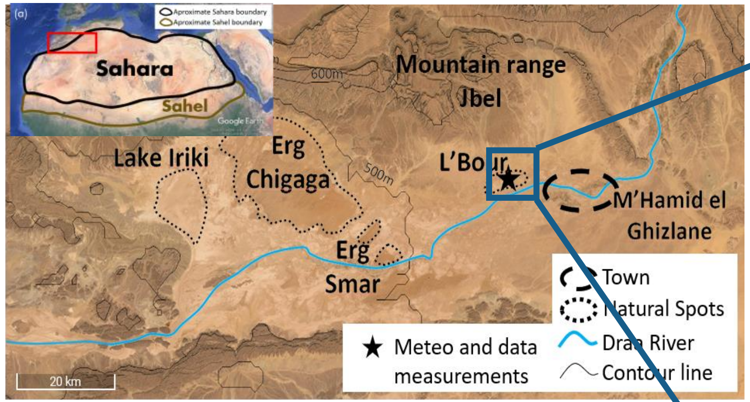
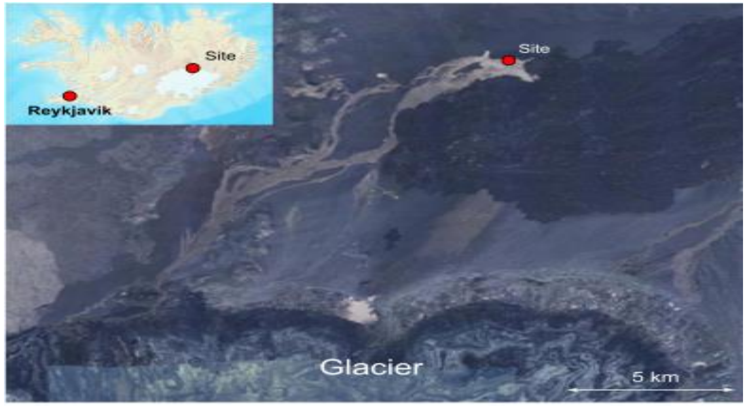
The FRAGMENT dust field campaigns in Morocco and Iceland

Experimental sites





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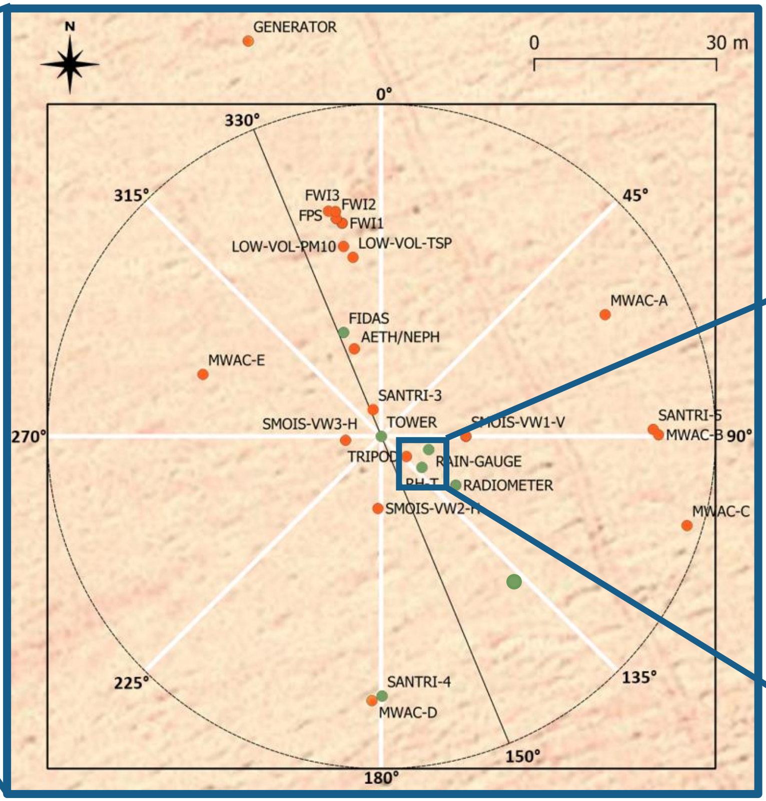

Meteorological measurements

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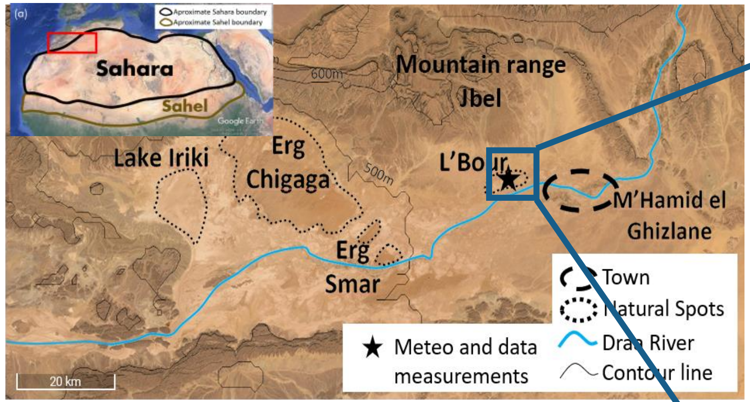

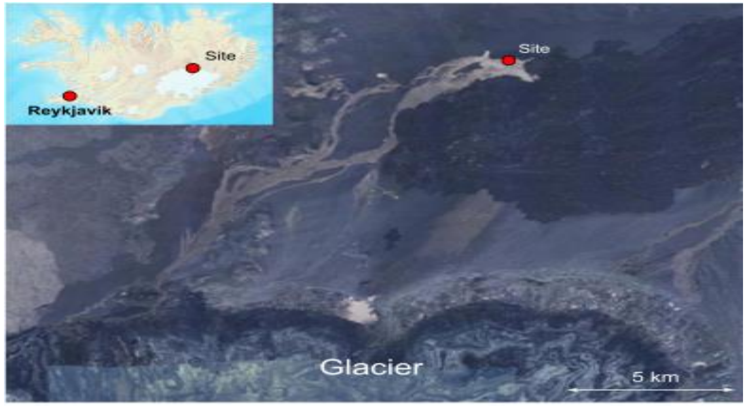

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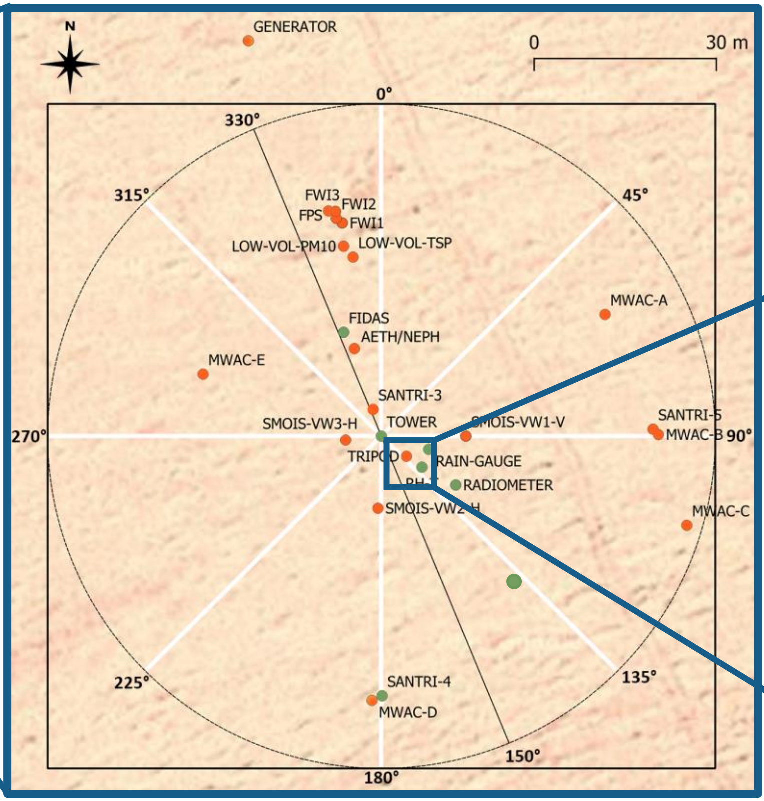

Meteorological measurements

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The FRAGMENT dust field campaigns in Morocco and Iceland

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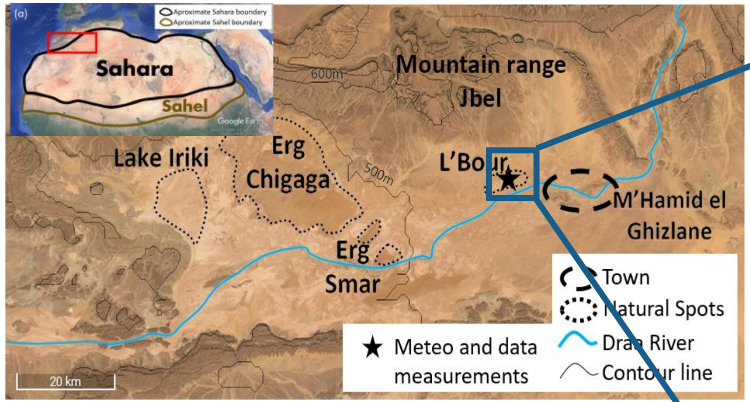

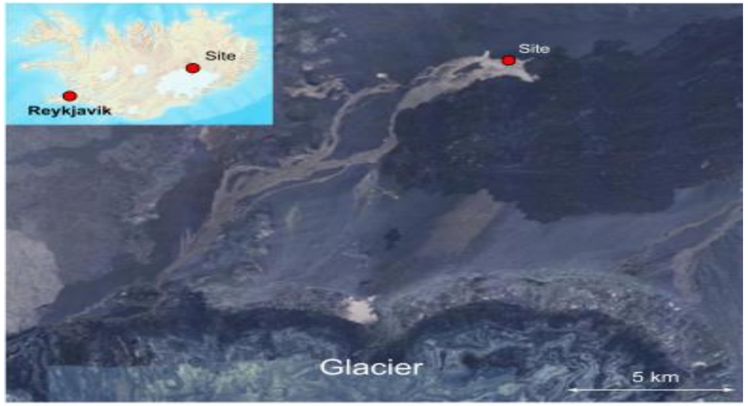

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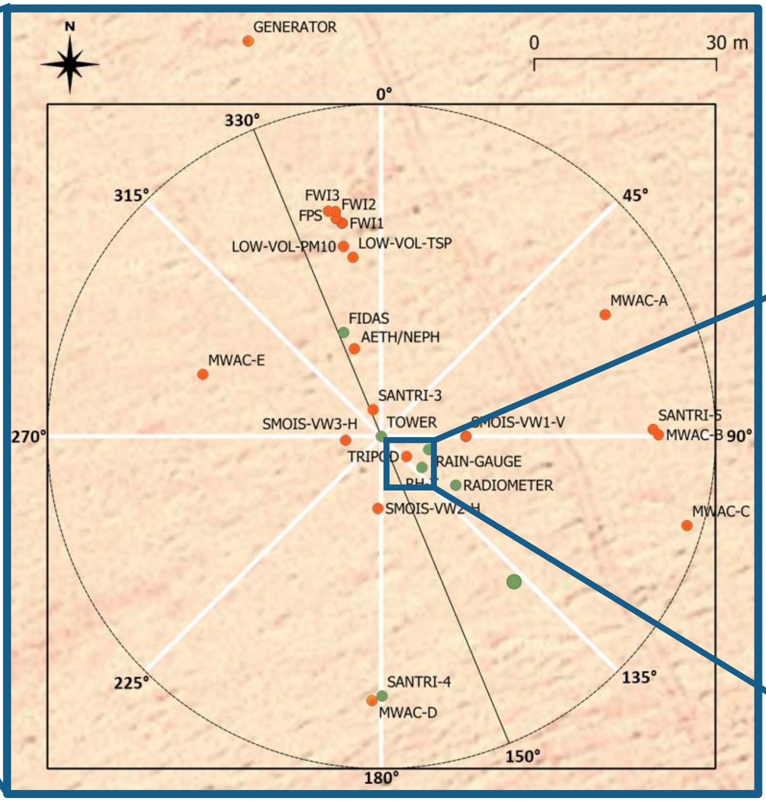

Meteorological measurements

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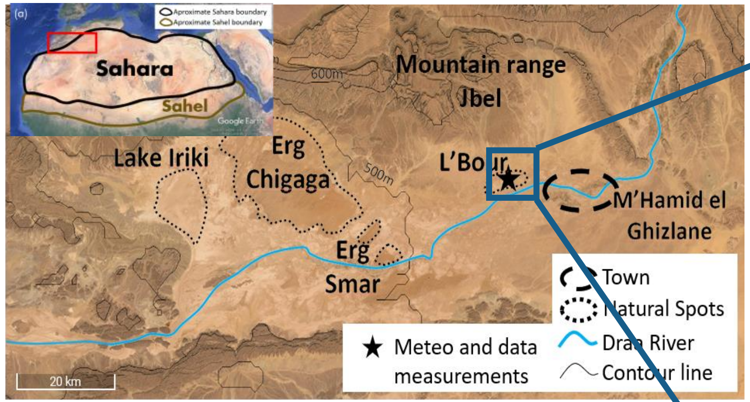

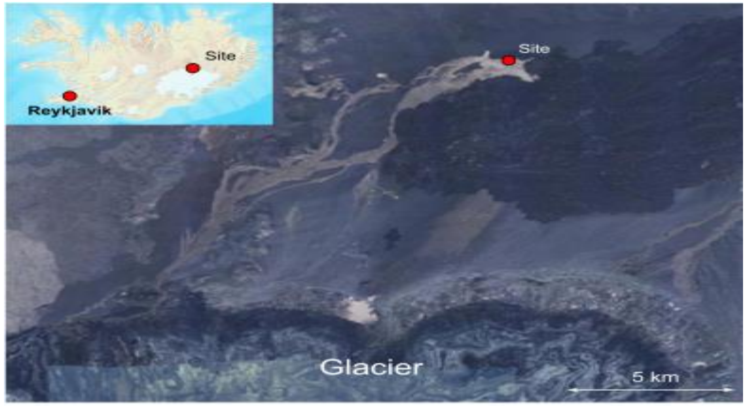

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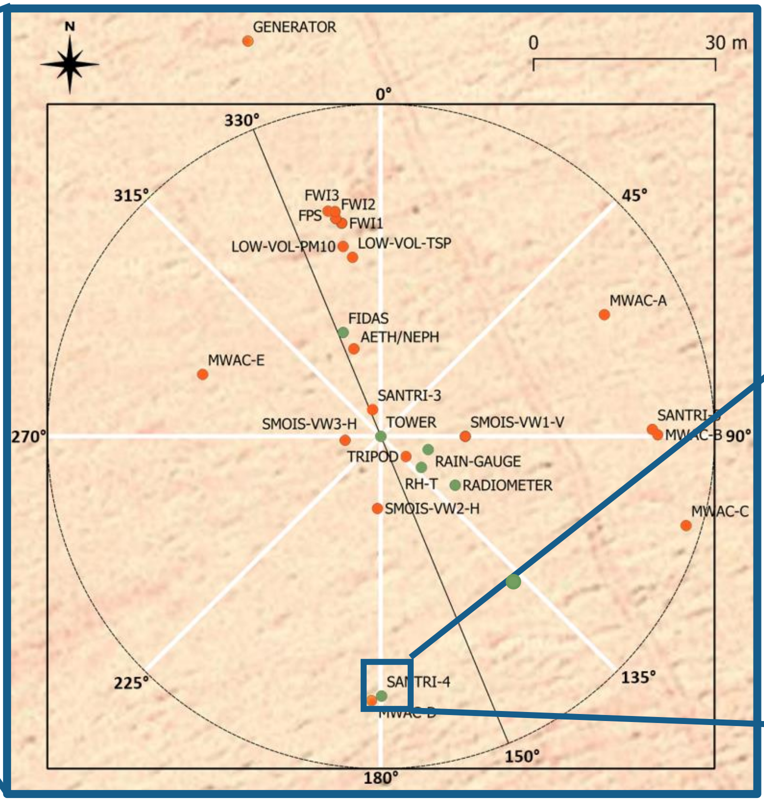
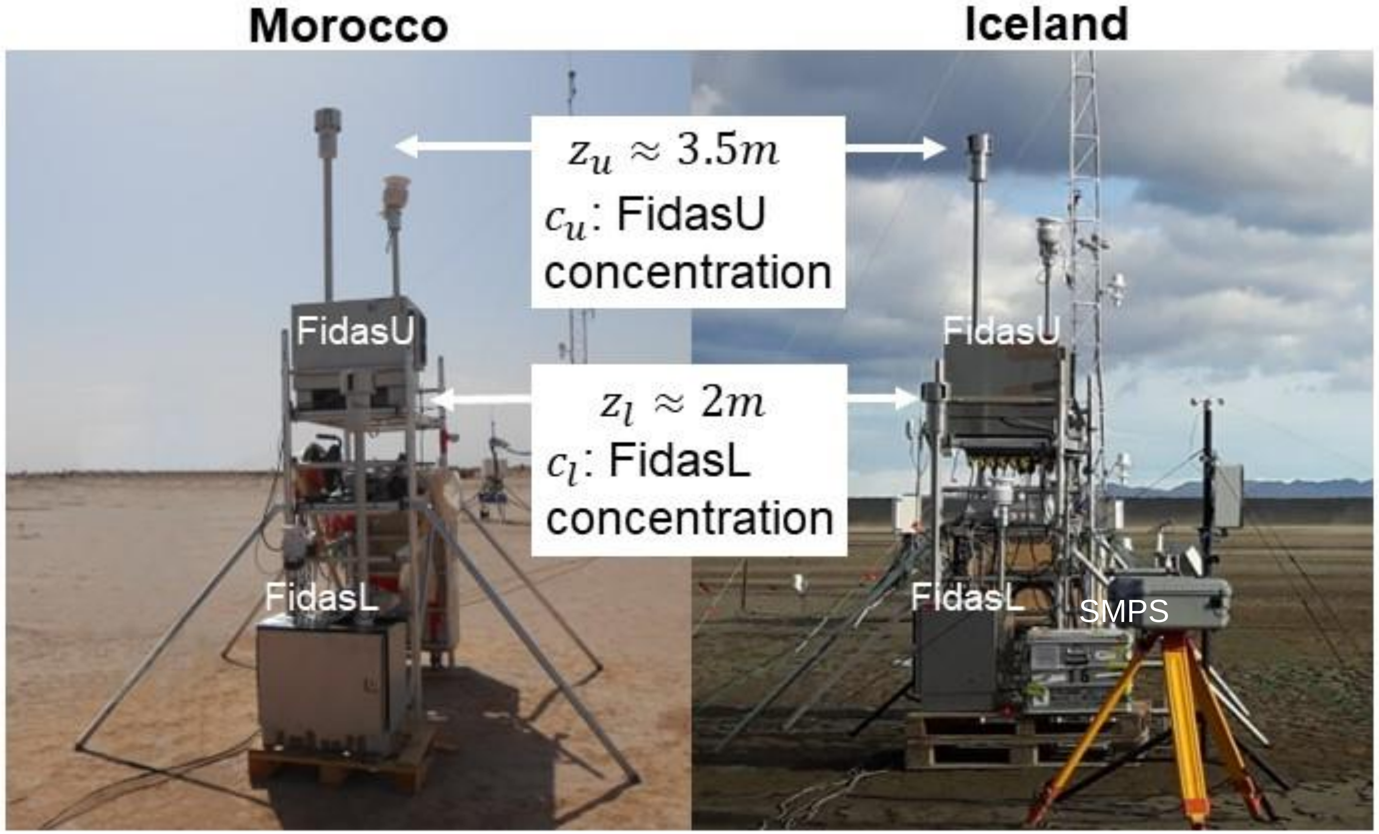


Size-resolved saltation counts

The FRAGMENT dust field campaigns in Morocco and Iceland

Size-resolved dust concentrations

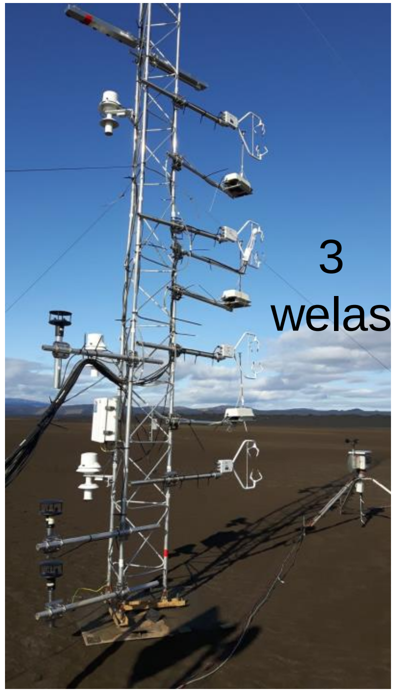
Welas:
Size range
(0.2-19.1)µm



Fidas:
Size range
(0.2-19.1)µm

Fidas:
Size range
(0.49-42.17)µm

SMPS:
Size range
(0.01-24)µm



Welas:
Size range
(0.2-10)µm

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1 **Dynamical parameters characterizing the near-surface boundary layer**

$\boldsymbol{u_*, z_0, L}$

2 Size-resolved diffusive dust flux

3 Sandblasting efficiency

Law of the wall method

Correction for non-neutral conditions

$$\overline{U}(z) = \frac{u_*}{\kappa}\kappa\left[\ln\left(\frac{z}{z_0}\right) - \psi_m\right]$$

Stull, 1998; Kaimal and Finnigan, 1994; Arya, 2001; Foken and Napo, 2008; Shao, 2008

Gradient method

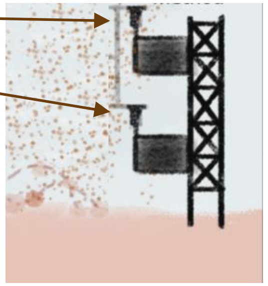
1 Dynamical parameters characterizing the near-surface boundary layer
u_*, z_0, L

2 **Size-resolved diffusive dust flux**

3 Sandblasting efficiency

$$F_d(D_i) = u_*\kappa \frac{c_u(D_i) - c_l(D_i)}{\ln\left(\frac{z_u}{z_l}\right) - \psi_m\left(\frac{z_u}{z_l}\right) + \psi_m\left(\frac{z_l}{z_l}\right)}$$

Gillette et al. 1972



- Removal of the systematic concentration differences between both Fidas.
- In depth characterization of the random uncertainty and propagation to all obtained PSDs.
- Transformation of the default optical diameters into dust geometric diameters.

1 Dynamical parameters characterizing the near-surface boundary layer
u_*, z_0, L

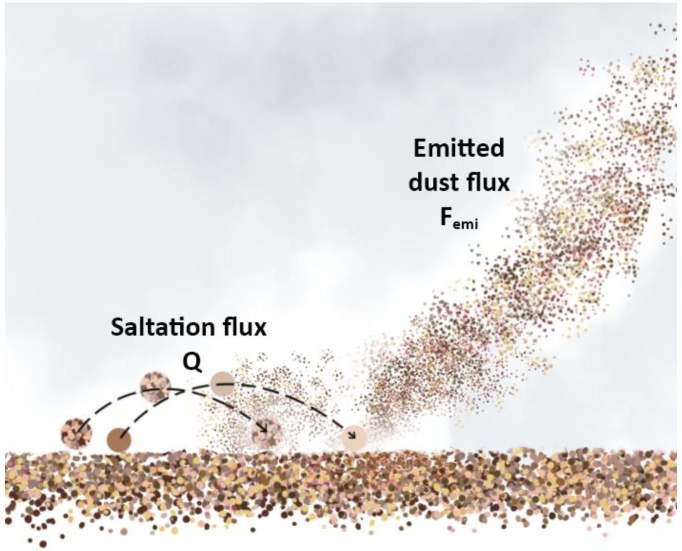
2 Size-resolved diffusive dust flux and its uncertainty

3 **Sandblasting efficiency**

$$\alpha = \frac{F}{Q}$$

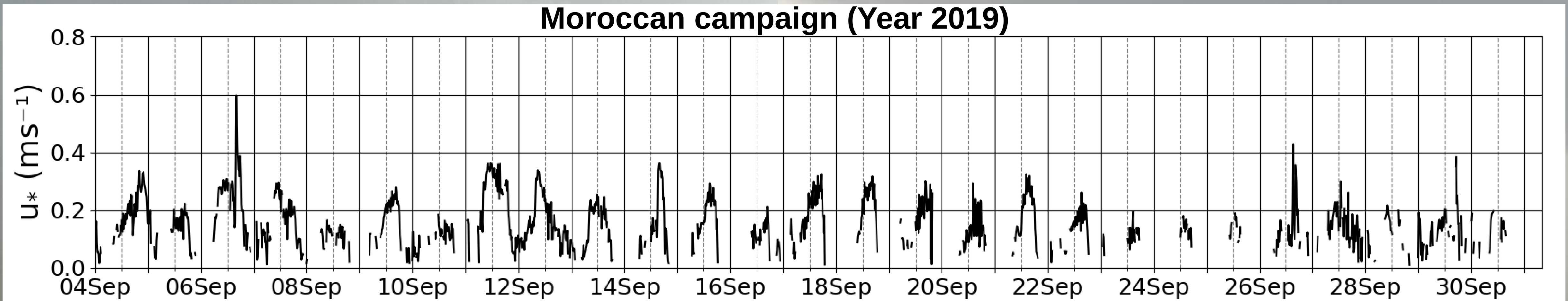
Diffusive dust flux

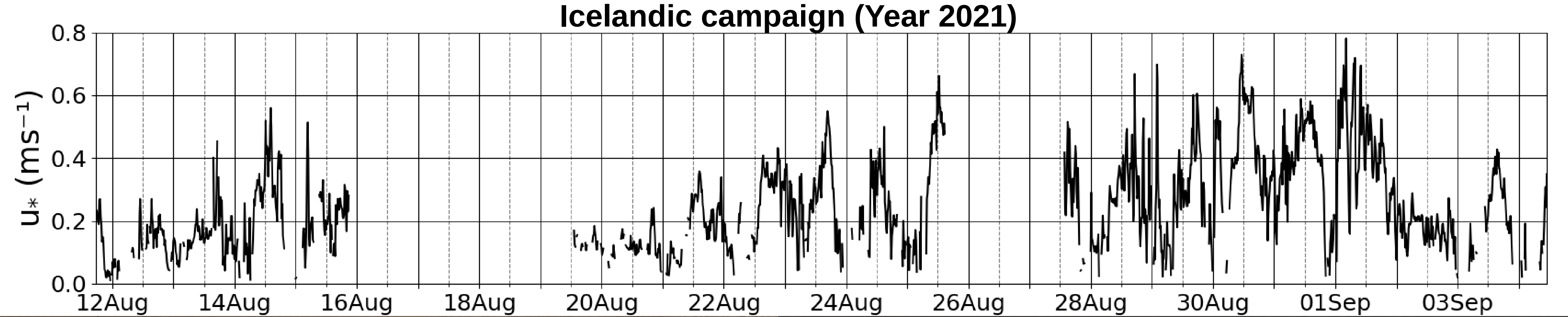
Saltation flux



Overview of the atmospheric conditions during the campaigns

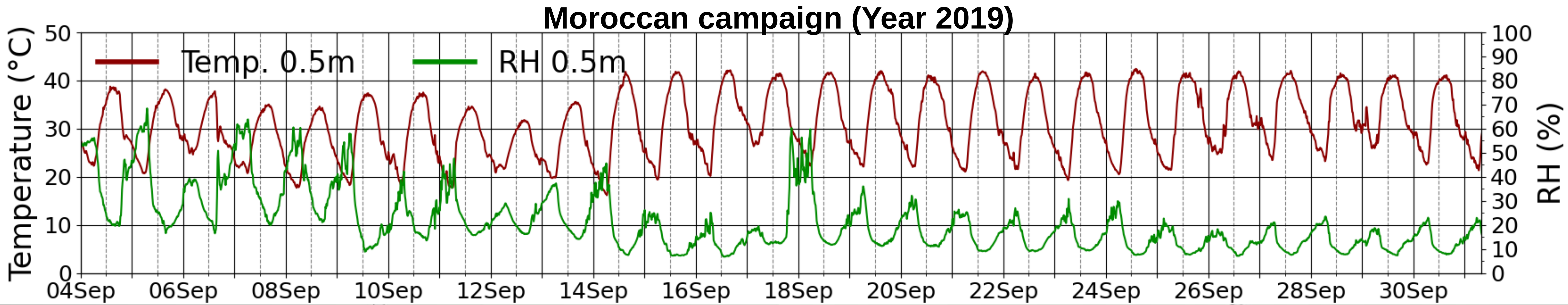
Friction velocity (u_*) from the law of the wall method

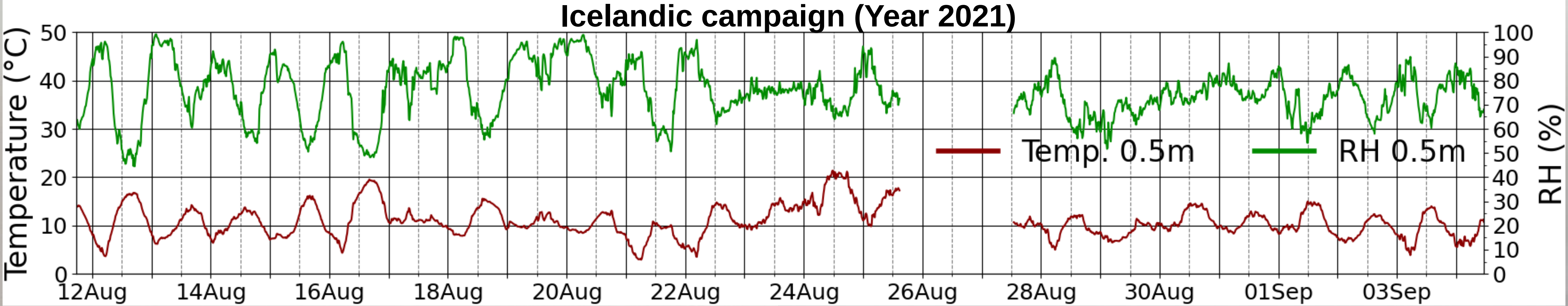




Overview of the atmospheric conditions during the campaigns

Temperature and relative humidity at 0.5 m

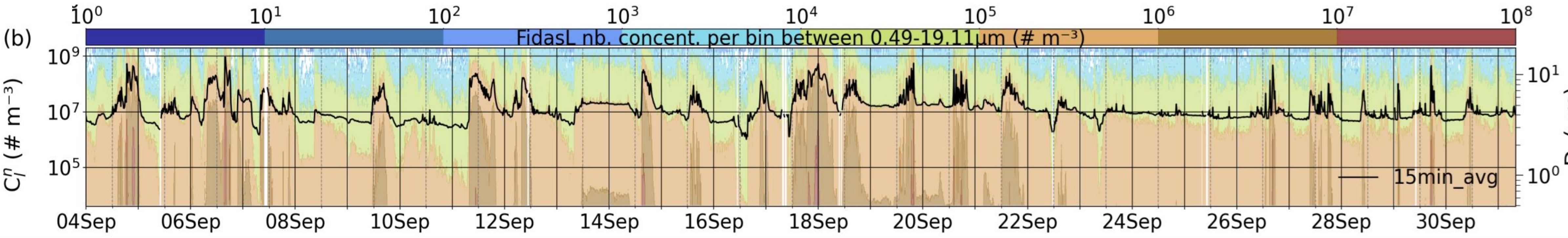




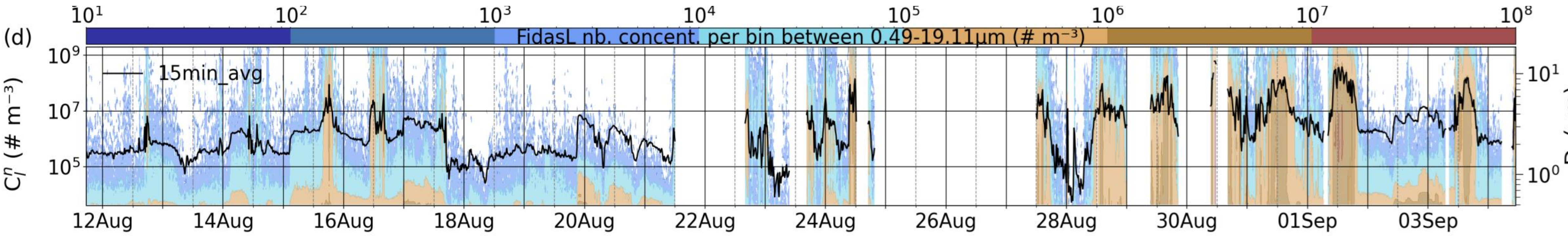
Overview of the atmospheric conditions during the campaigns

Dust concentration at 2 m

Moroccan campaign (Year 2019)



Icelandic campaign (Year 2021)



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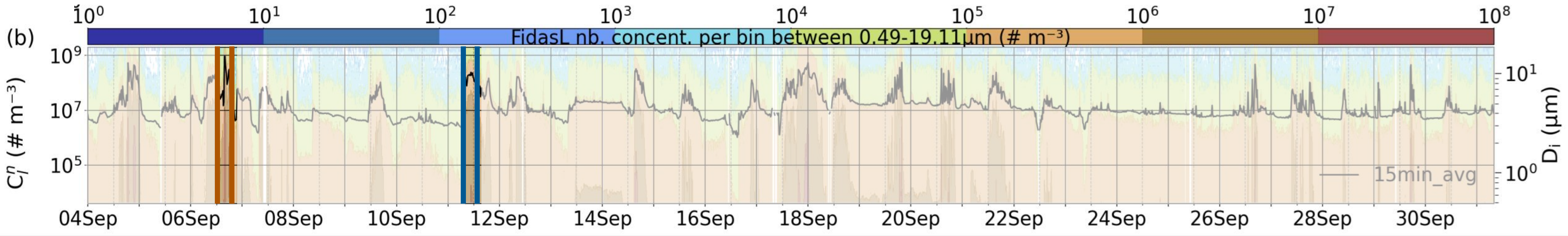
Overview of the atmospheric conditions during the campaigns

Dust concentration at 2 m

Moroccan campaign (Year 2019)



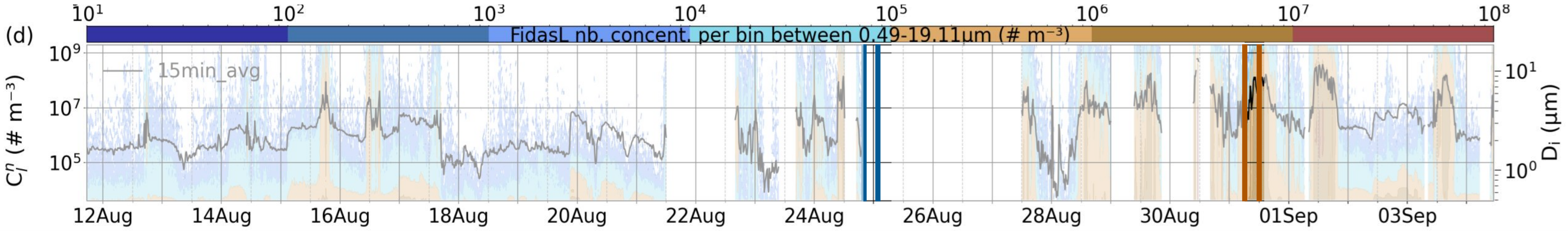

Haboob


Regular dust event

Overview of the atmospheric conditions during the campaigns

Dust concentration at 2 m

Icelandic campaign (Year 2021)



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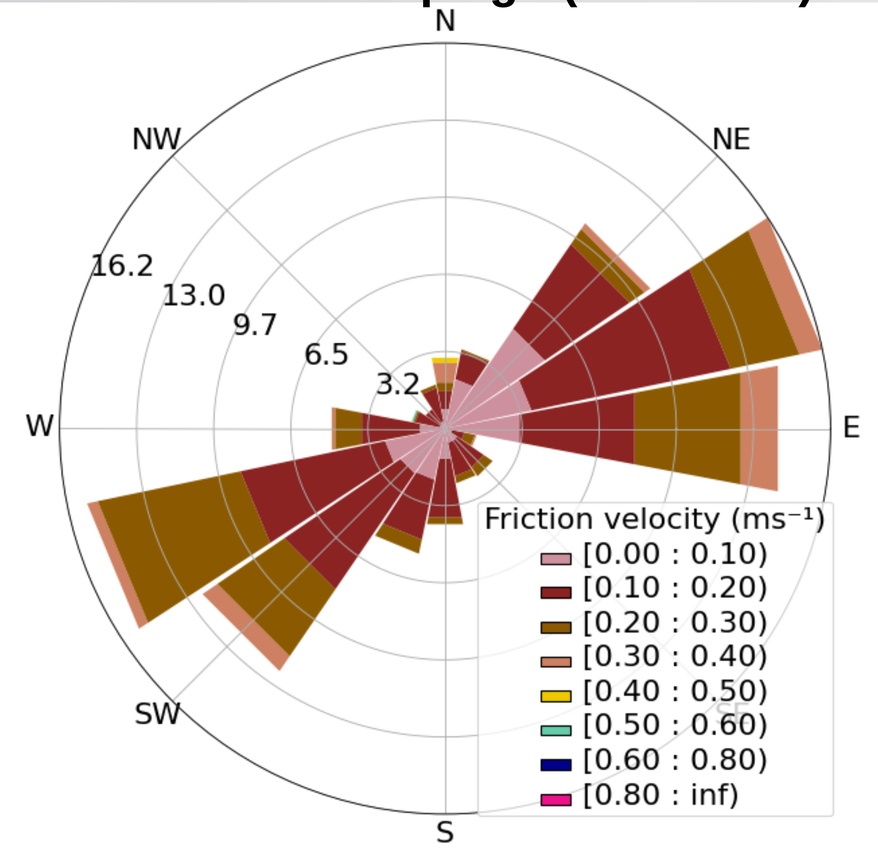
Overview of the atmospheric conditions during the campaigns

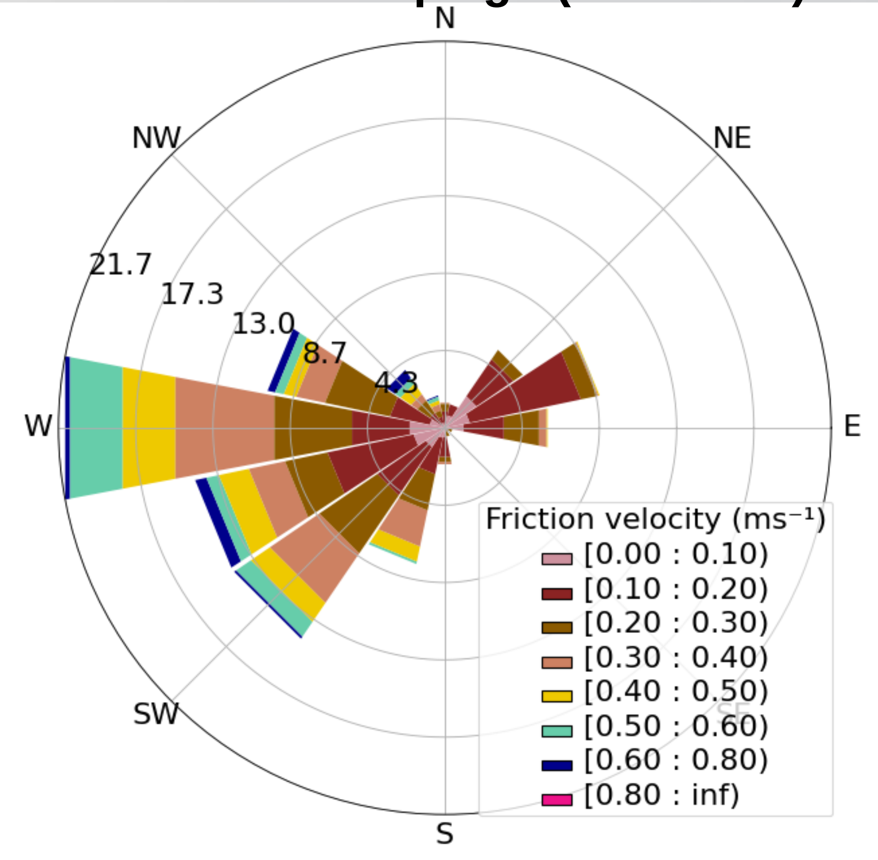
Wind direction at 2m

Moroccan campaign (Year 2019)



Two prevailing wind directions

Icelandic campaign (Year 2021)



One predominant wind direction during erosión conditions

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Key insights from Morocco

1 Accurate PSD variability assessment requires proper consideration of **anthropogenic particles**.

2 Strong **dependencies** of **PSDs** on $\boldsymbol{u_*}$, **wind direction** and **event type**.

3 Effect of **dry deposition**, modulated by differences in fetch length and u_*, upon the diffusive flux PSD but it cannot be fully discarded that enhanced aggregate disintegration plays an additional role.

4 Differences between **regular** and **haboob** events that could be explained by a **shorter "effective" fetch** of the haboob and the **moving haboob dust front**.

5 Differences between concentration, diffusive flux and estimated emitted flux PSDs. The **emitted dust PSD** is **coarser** and **less variable**.

6 Our PSDs show a **higher proportion** of **supermicron particles** compared to observationally constrained theoretical references, especially in the estimated emitted flux PSD.

Efficiency of the OPC inlets, lack of observation-based dry deposition velocity and large uncertainties in its parameterization.

SCAN ME

González-Flórez et al., 2023

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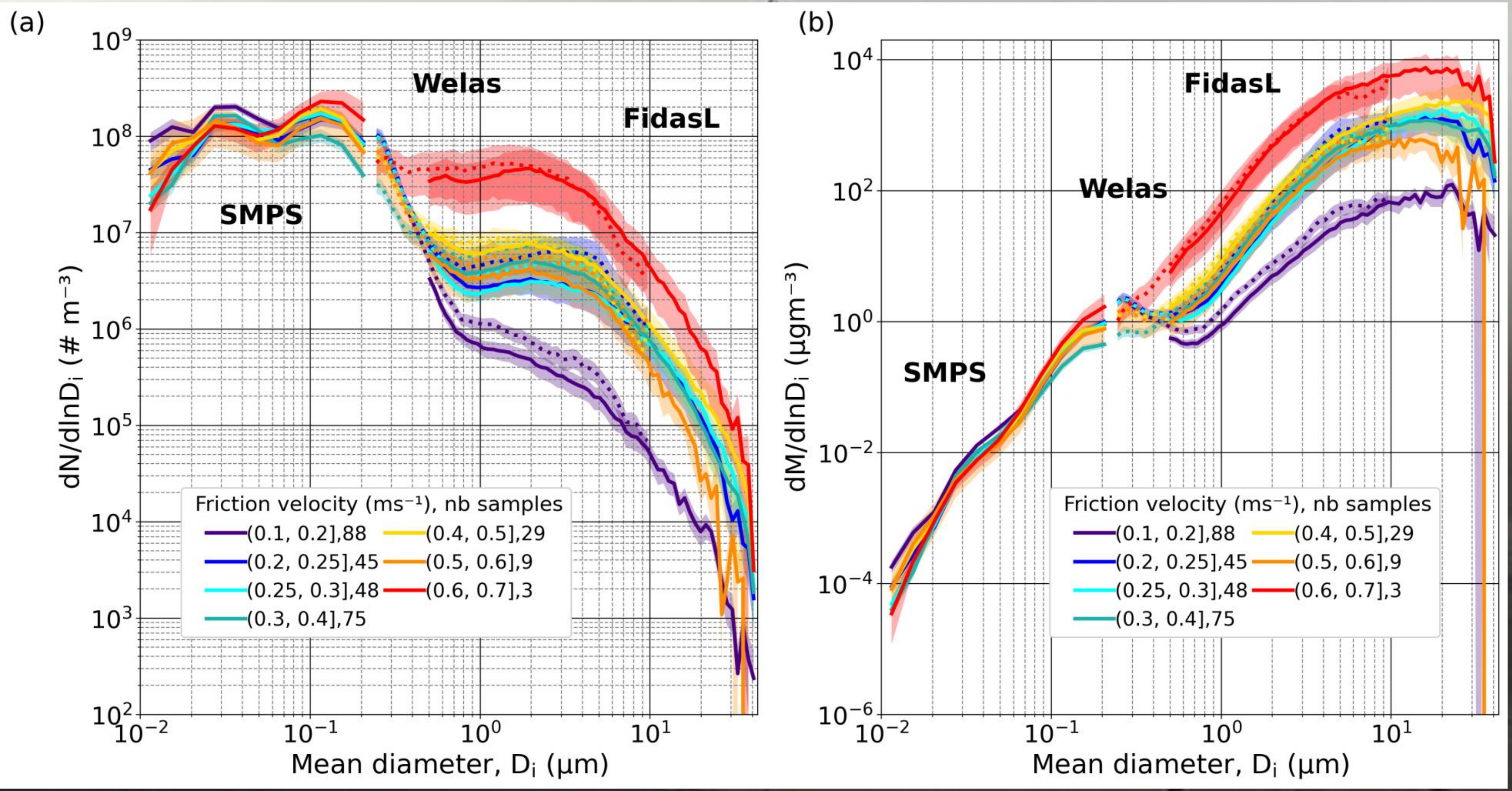
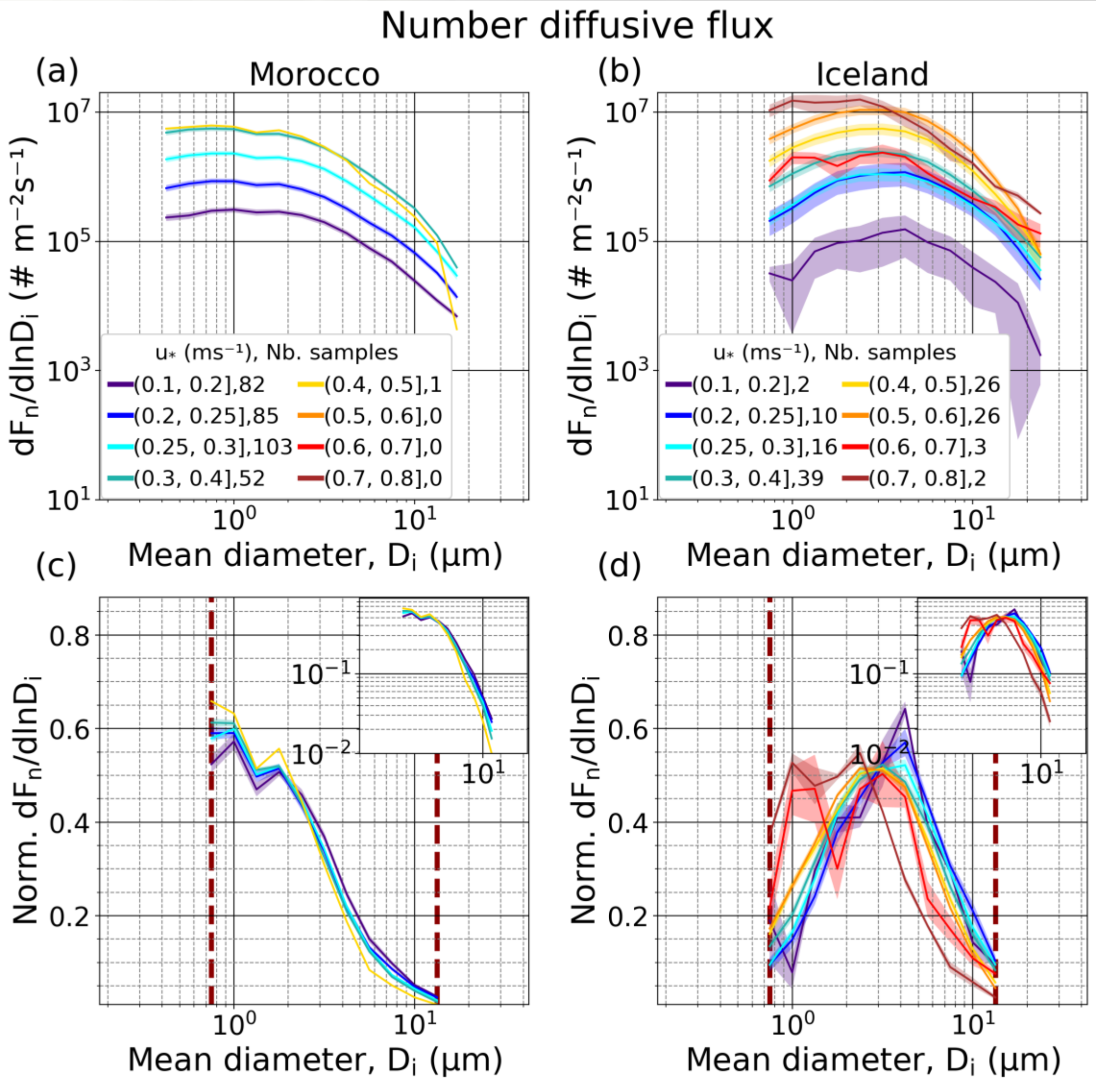
Dust concentration PSDs in Iceland

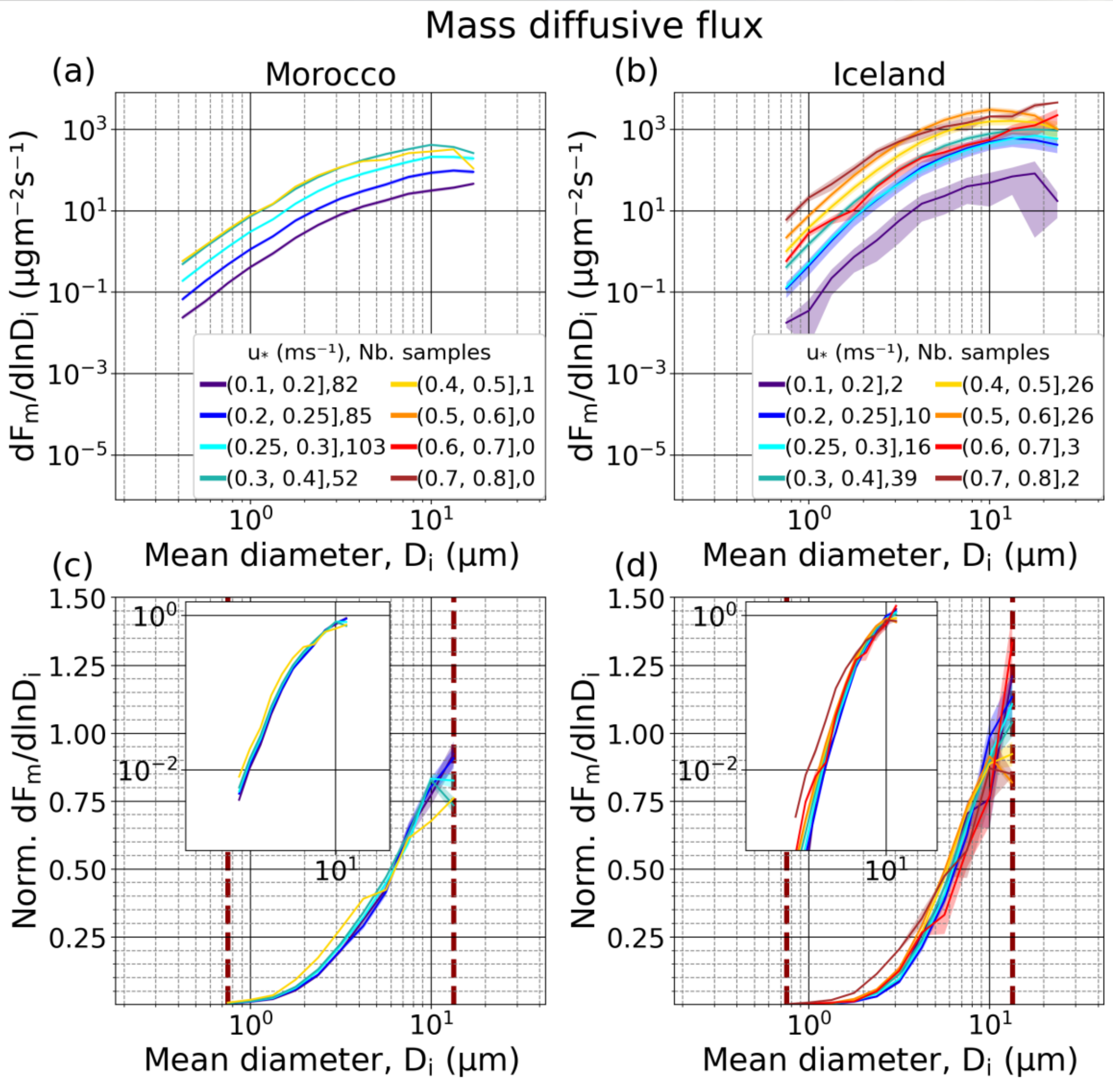
We select the common 15-min samples from the three instruments and averaged them per friction velocity interval.



The PSDs of the three instruments match quite well!

Diffusive flux PSDs

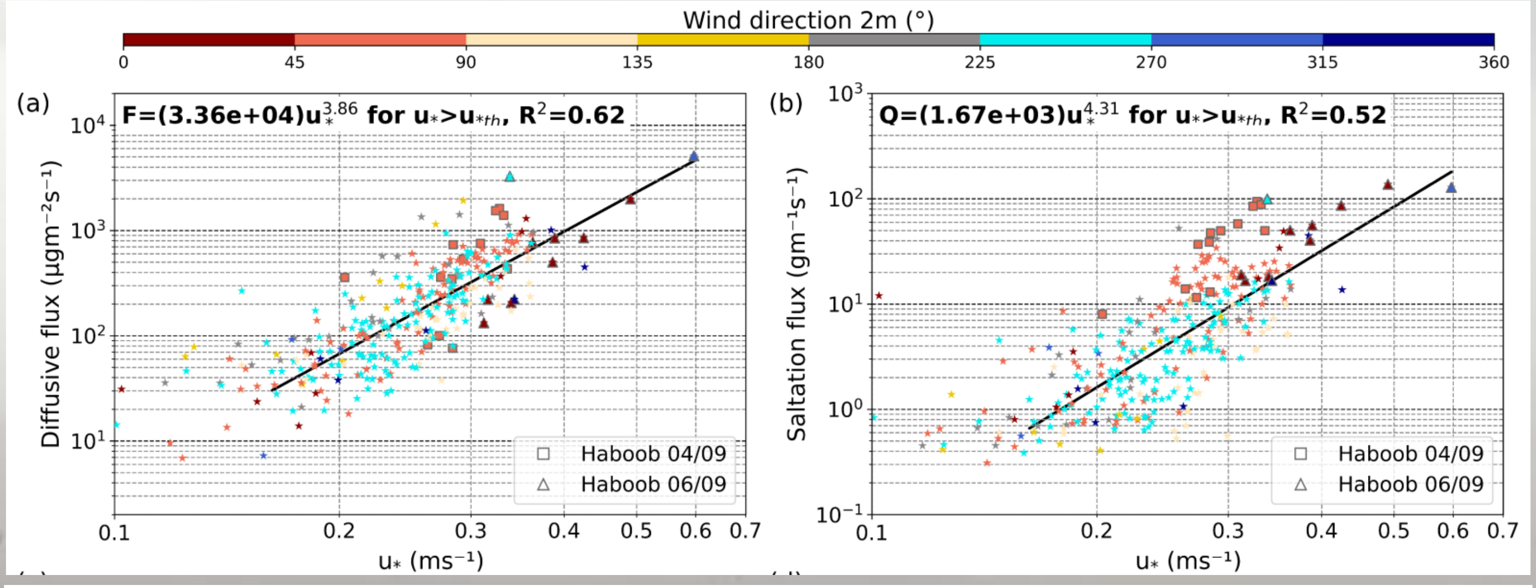




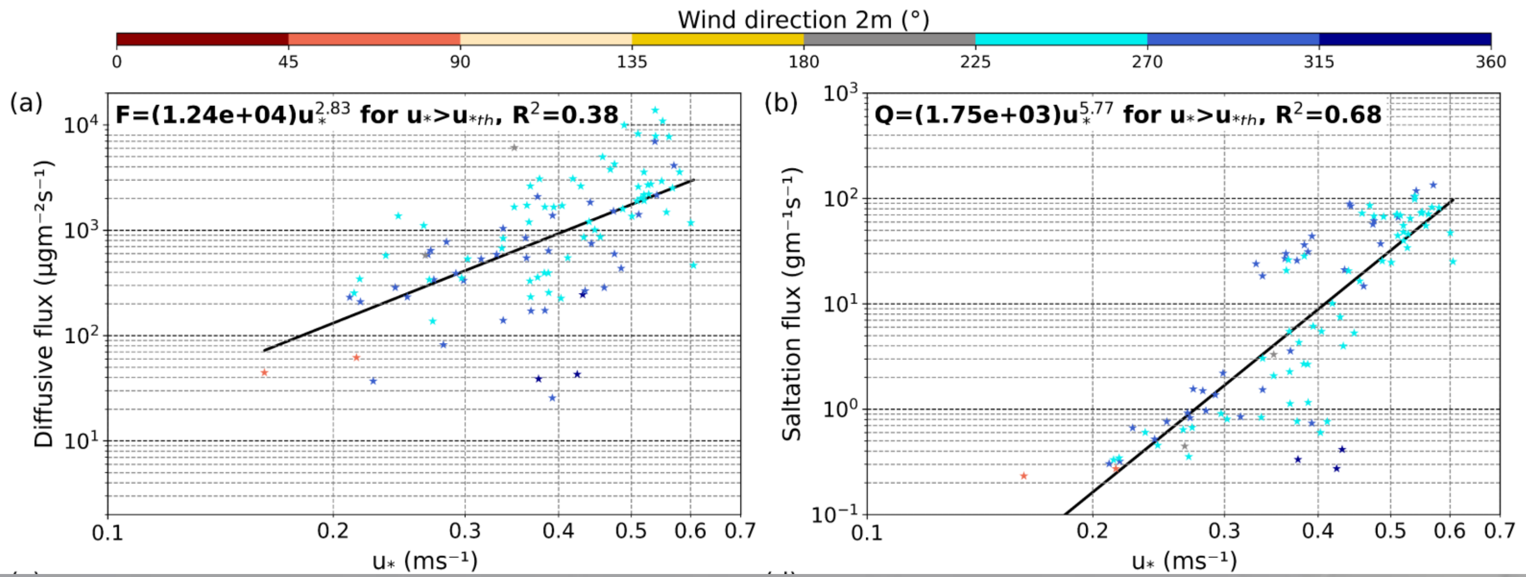
- **Icelandic dust is coarser than Moroccan dust**

Characterization of saltation and sandblasting efficiency

Morocco



Iceland



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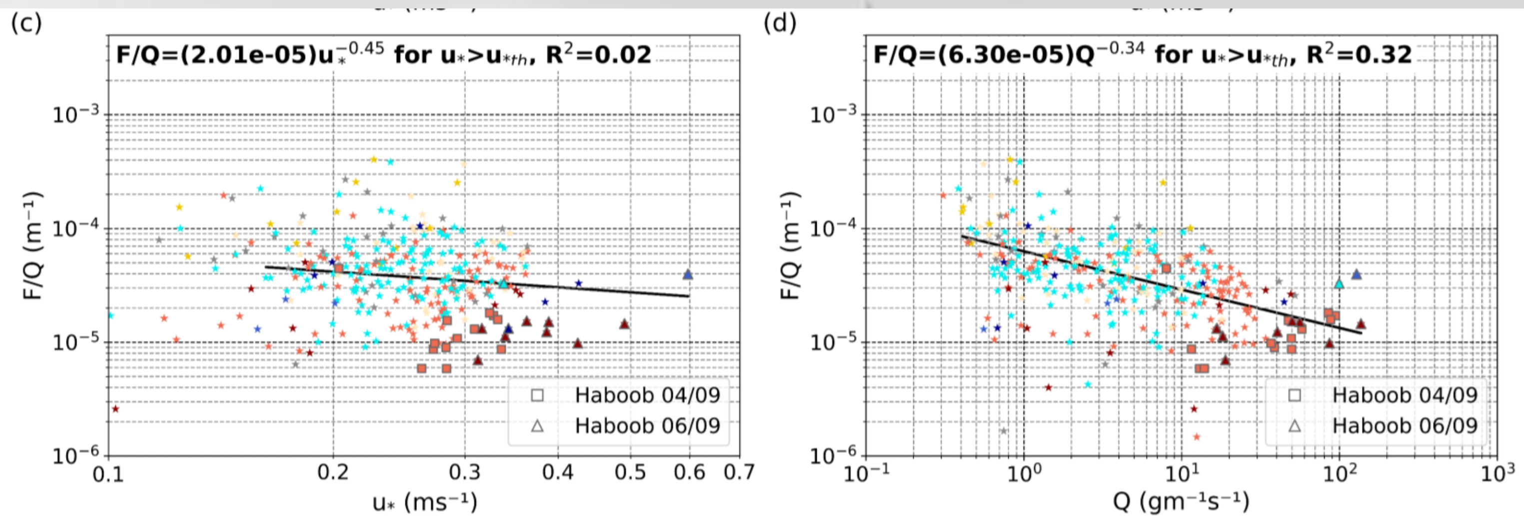
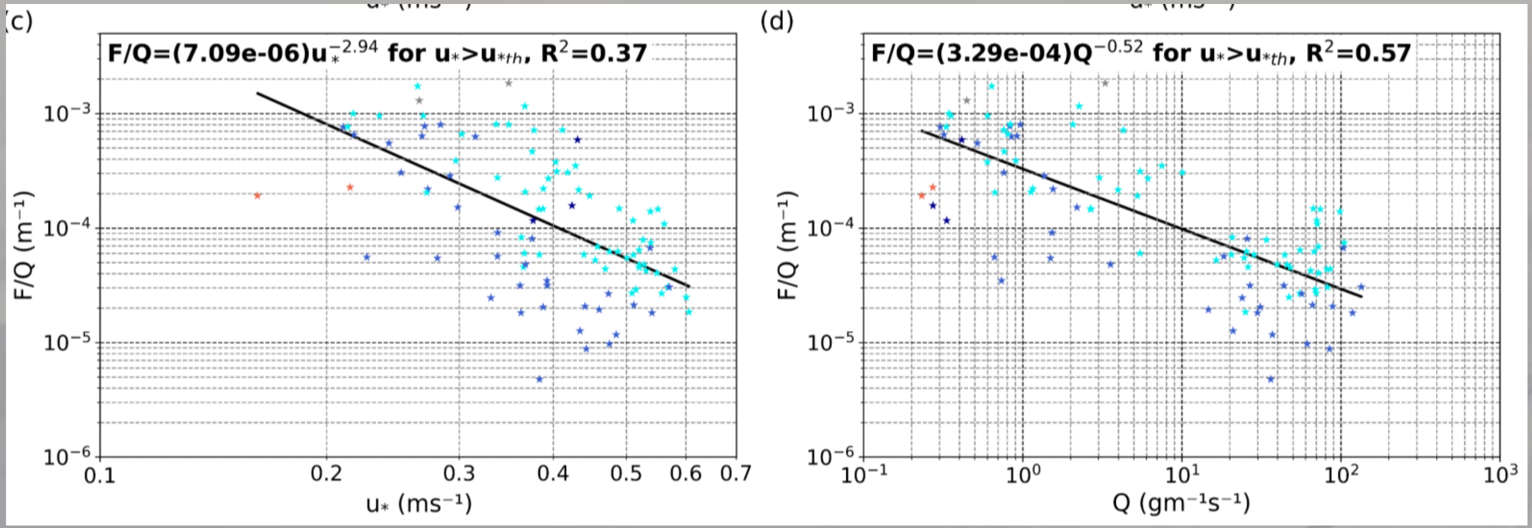
Characterization of saltation and sandblasting efficiency

Morocco



Iceland



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- We have compared here the results from two field campaigns, that took place in **September 2019** at “El Bour”, a dry lake located in the Draa River Basin at the edge of the Sahara desert **in Morocco**, and the largest field dust campaign performed to date **in Iceland**, conducted in **August 2021** in the desert of Dyngjunsandur.

- During the field campaign **in Iceland friction velocity (u$_*$) reached higher values**. The threshold u$_*$ was higher in Iceland than in Morocco.

- During the campaign in **Morocco two prevailing wind directions** were identified, one centered around 80º (more aligned with M'hamid El Ghizlane, the closest town) and the other around 240º (Saharan desert direction) while in **Iceland** there was only **one predominant wind direction** during the erosion events.

- **Preliminary results show that Icelandic dust is coarser than Moroccan dust**

Perspective

- **Comparison** of our measured saltation and diffusive **against current parameterizations in the literature** and eventually **extend** them.

- Evaluate Brittle Fragmentation Theory with the fully dispersed soil PSDs

- **Combination of** the results with **size-resolved mineralogical, chemical and mixing state analysis of the soil and emitted dust samples**.

- **Comparison** with the results of the **other FRAGMENT campaign in Jordan.**

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EXCELENCIA SEVERO OCHOA

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Thank you

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