Earth Observations and quantification of the Atmospheric Dust deposited component

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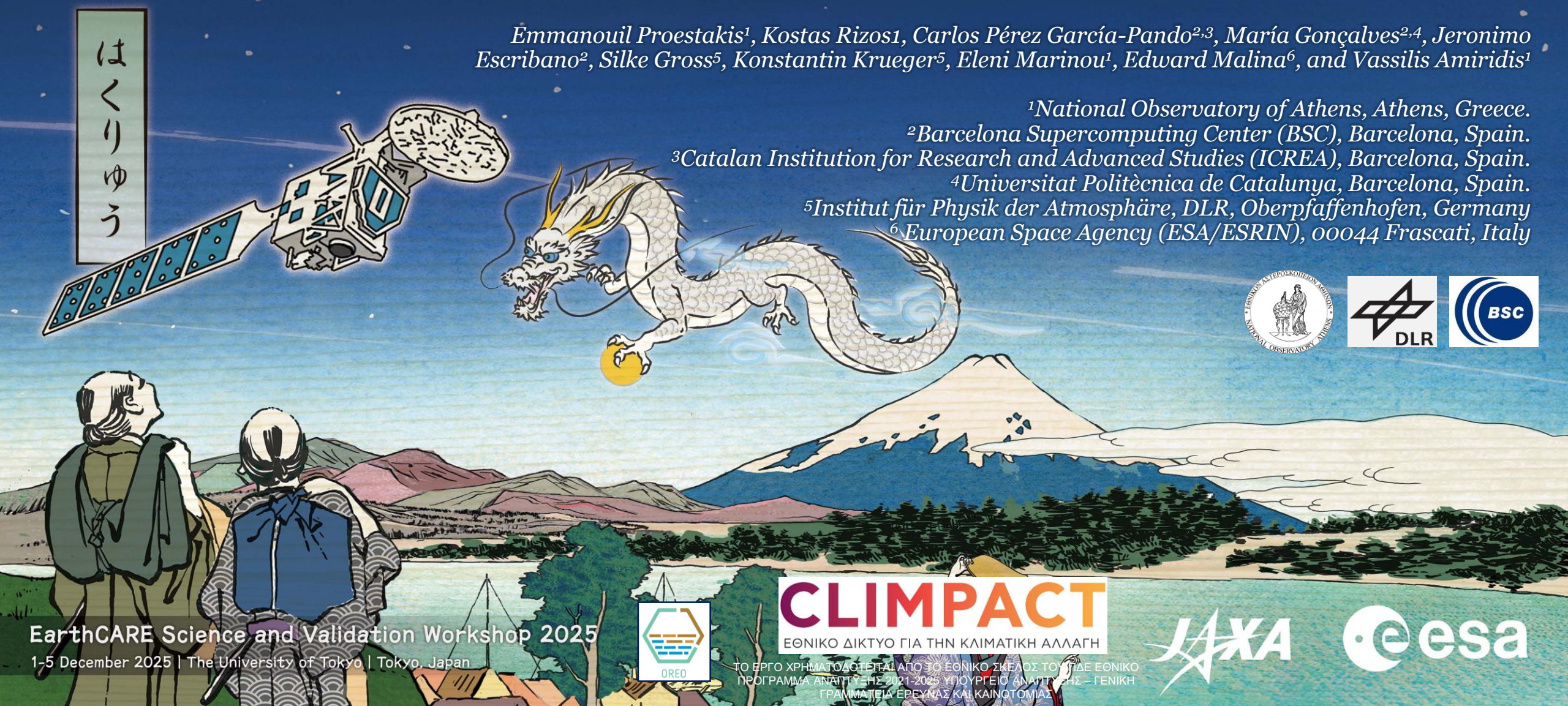
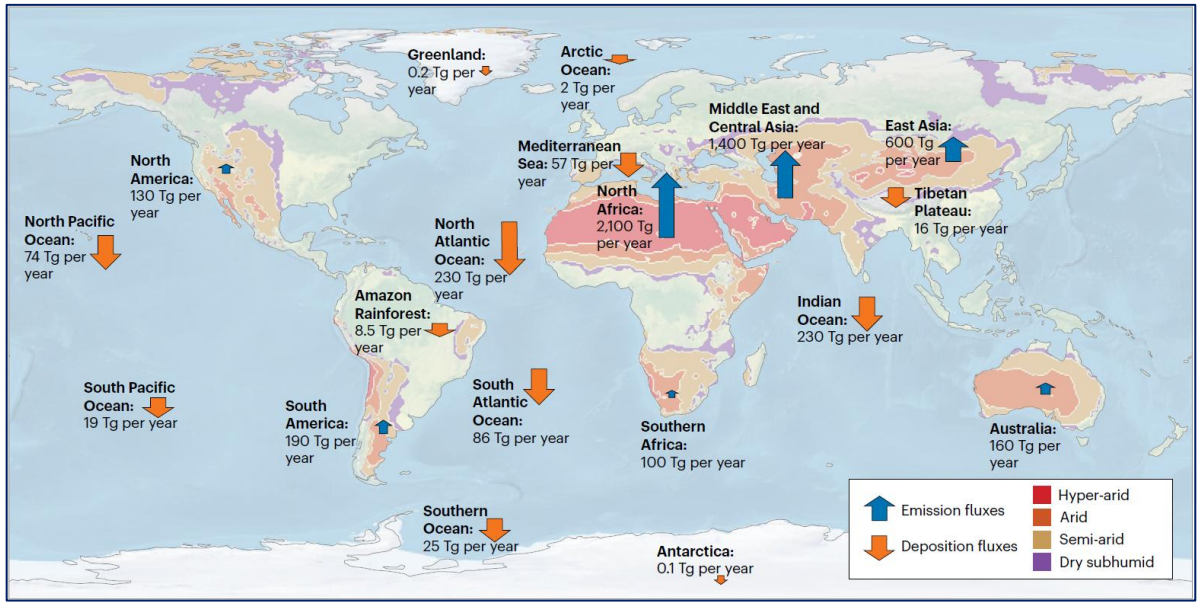


EarthCARE Science and Validation Workshop 2025
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

CLIMPACT
ΕΘΝΙΚΟ ΔΙΚΤΥΟ ΓΙΑ ΤΗΝ ΚΛΙΜΑΤΙΚΗ ΑΛΛΑΓΗ

ΤΟ ΕΡΓΟ ΧΡΗΜΑΤΟΔΟΤΕΙΤΑΙ ΑΠΟ ΤΟ ΕΘΝΙΚΟ ΣΚΕΛΟΣ ΤΟΥ ΠΔΕ ΕΘΝΙΚΟ ΠΡΟΓΡΑΜΜΑ ΑΝΑΠΤΥΞΗΣ 2021-2025 ΥΠΟΥΡΓΕΙΟ ΑΝΑΠΤΥΞΗΣ – ΓΕΝΙΚΗ ΓΡΑΜΜΑΤΕΙΑ ΕΡΕΥΝΑΣ ΚΑΙ ΚΑΙΝΟΤΟΜΙΑΣ

Background – At a glance …



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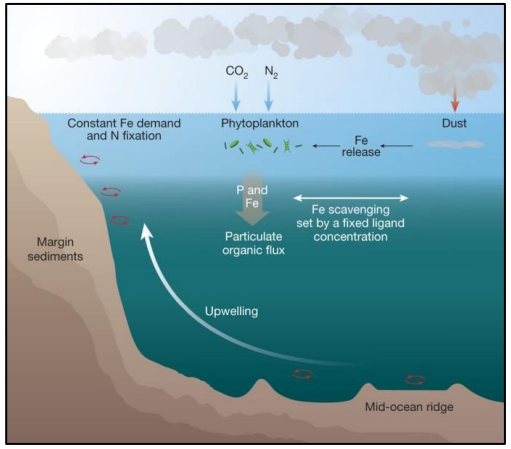
Nature Reviews Earth & Environment **4**, 71–86 (2023) | Cite this article



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Review Article | Published: 02 March 2017

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Alessandro Tagliabue, Andrew R. Bowie, Philip W. Boyd, Kristen N. Buck, Kenneth S. Johnson & Mak A. Saito

Nature **543**, 51–59 (2017) | Cite this article

14 LIFE BELOW WATER

Biogeochemistry

Atmospheric deposited dust impacts ocean biogeochemistry: delivers essential nutrients such as iron, nitrogen, and phosphorus, fertilizes phytoplankton, thereby sustains marine productivity.

13 CLIMATE ACTION

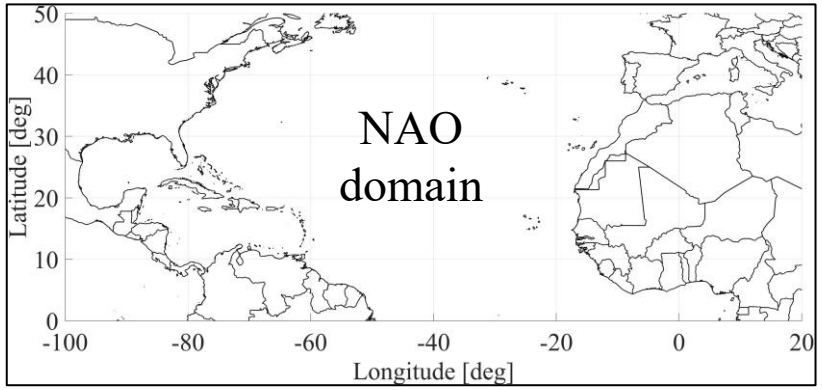
Climate

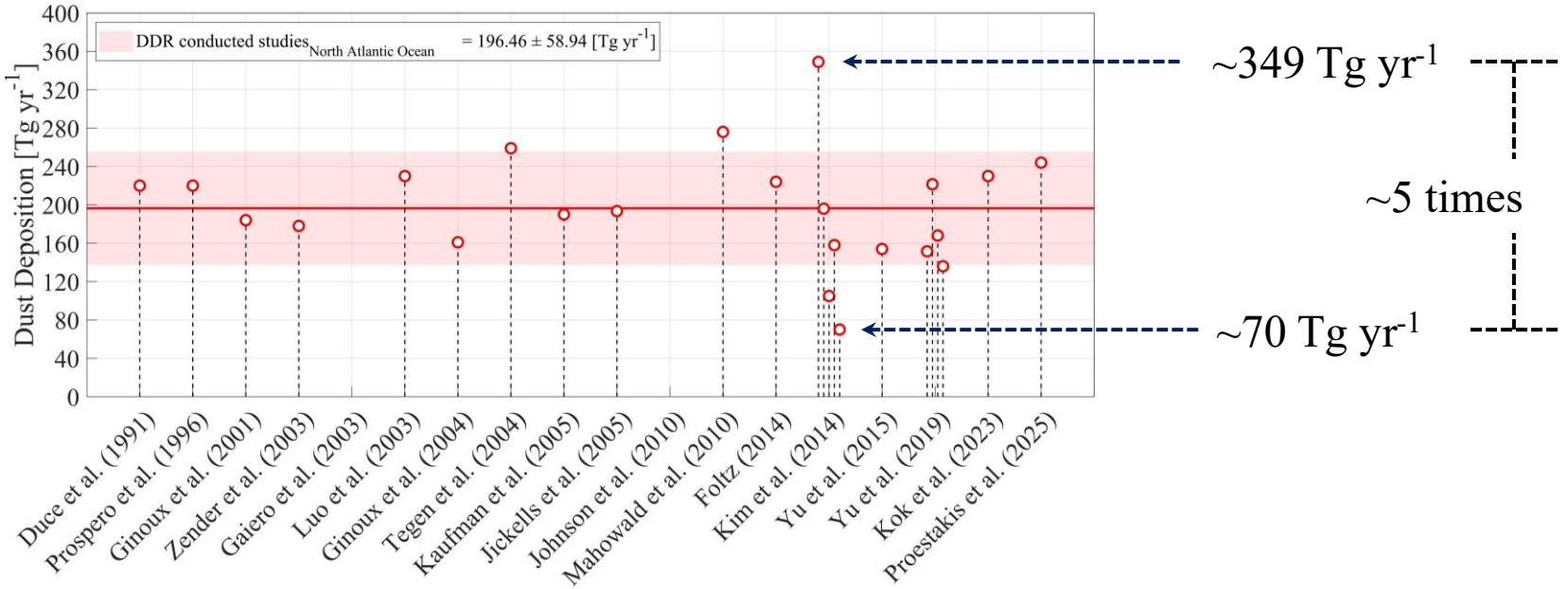
Atmospheric dust by supplying nutrients that stimulate phytoplankton growth, enhances the ocean's ocean role as a sink for greenhouse gases (i.e., facilitates the sequestration of atmospheric CO_2 into the deep ocean).

Weather

Atmospheric dust deposited into the ocean influences weather indirectly by modulating ocean color, affects heat absorption, sea surface temperature, and alters ocean–atmosphere feedbacks that shape weather patterns (i.e., such as tropical storm trajectories).

Dust Deposition estimates and variability in the reported values

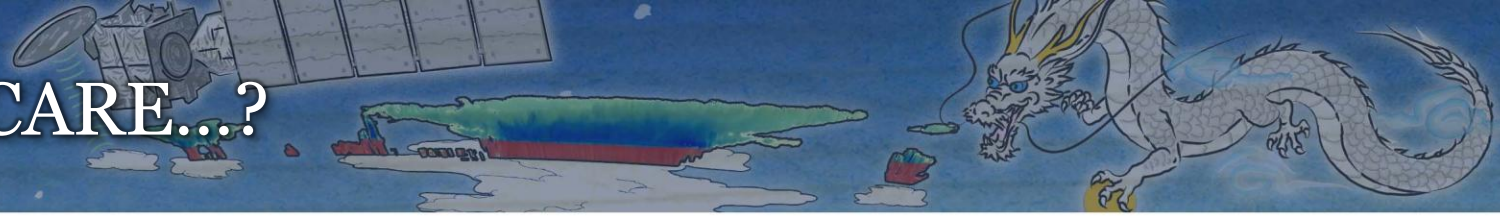




However, dust deposition estimates are characterized by high variability.
(Different estimates, based on diverse methodologies, assumptions, parameterizations, meteorological inputs, temporal coverage, spatial domains, …)

Improving our current state of knowledge on the quantification of atmospheric dust deposition across the ocean is essential for addressing unresolved questions about dust's biogeochemical impacts on marine ecosystems and climate.

Why EarthCARE…?



EarthCARE facilitates for the first time significant breakthroughs in terms of EO-based estimates on dust deposition across the global ocean!

1: ATLID and d355nm ⇢ information on dust!

2: 4D dust CDR ⇢ information on transport!

3: dust LR355nm ⇢ more accurate estimations on the dust load!

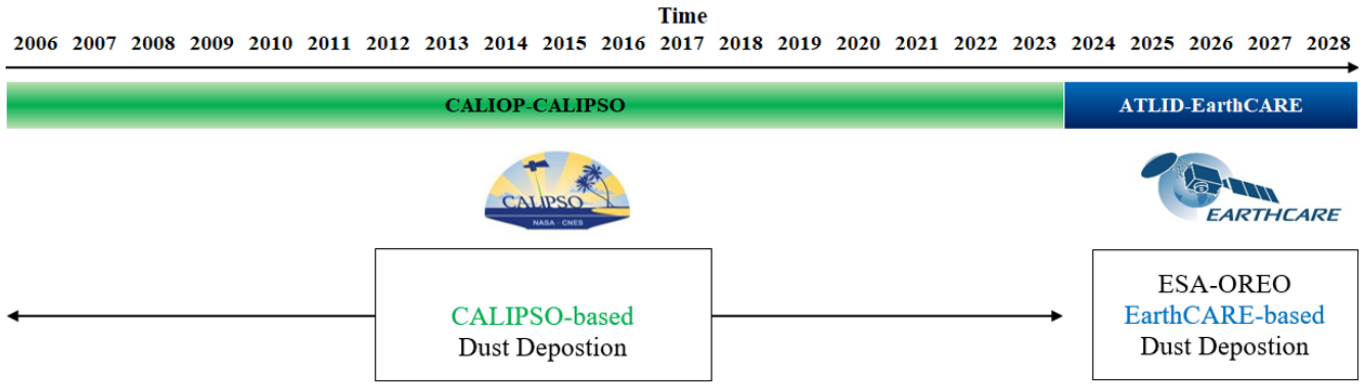
Scientific Questions

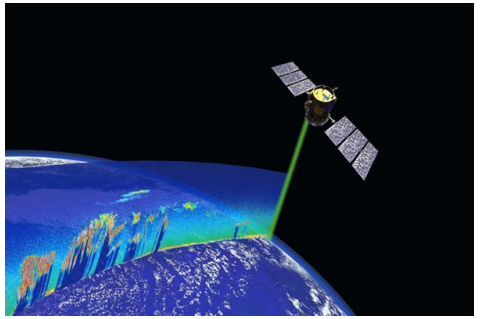
Scientific Questions (SQ):

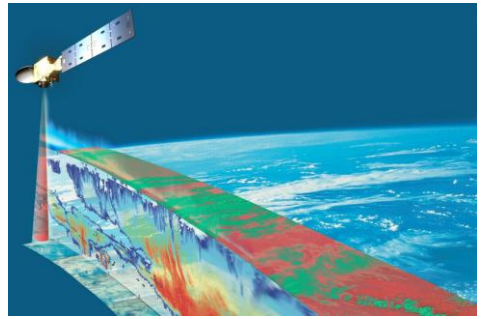
SQ1: To what extent dust deposition over the global ocean has changed over the last 20 years?

SQ2: What is the contribution (1) of soluble iron and (2) of different dust minerals (e.g., Hematite, Goethite, Kaolinite) in dust deposited into the ocean?

SQ3: What are the impacts of dust deposition on marine ecosystems, referring to responses of Chl-a?

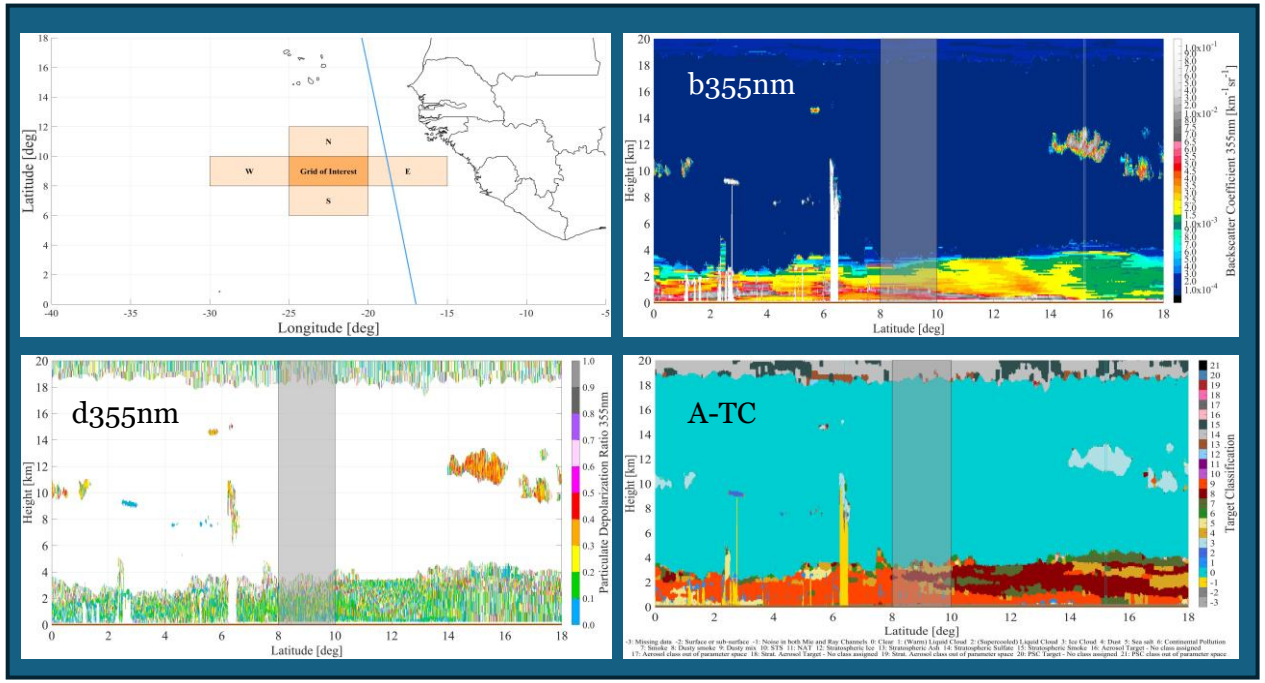






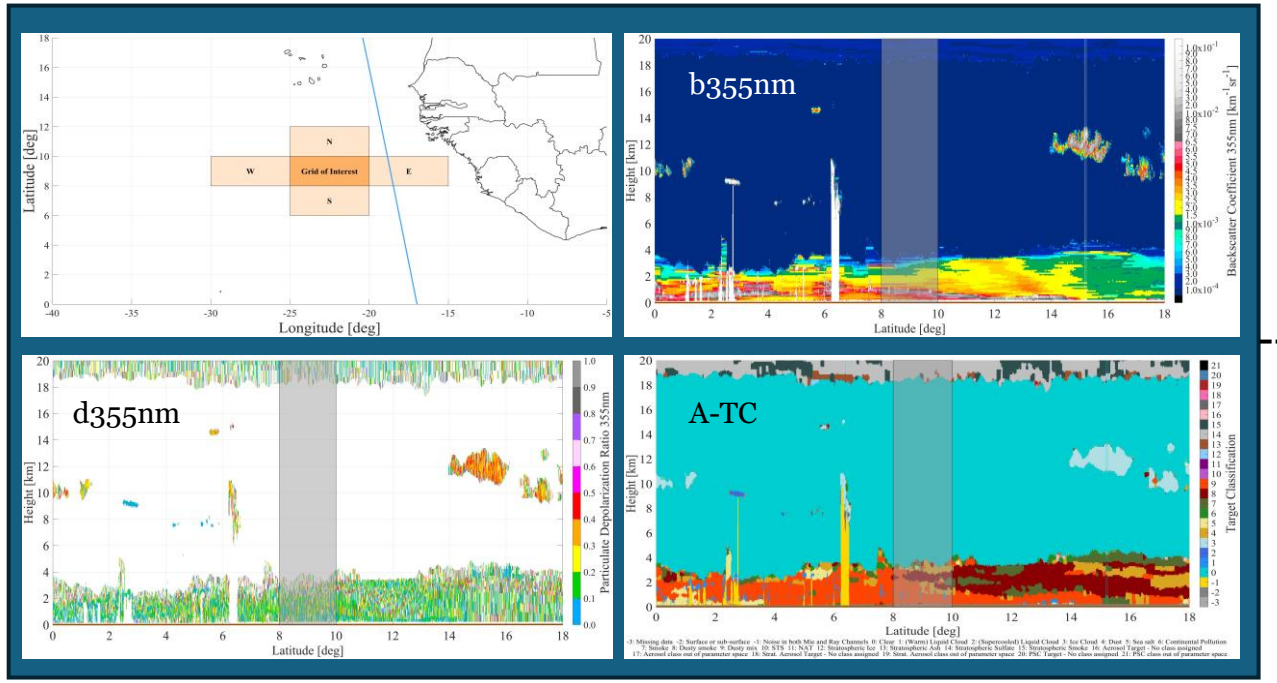
EarthCARE Dust

EarthCARE: 02539A



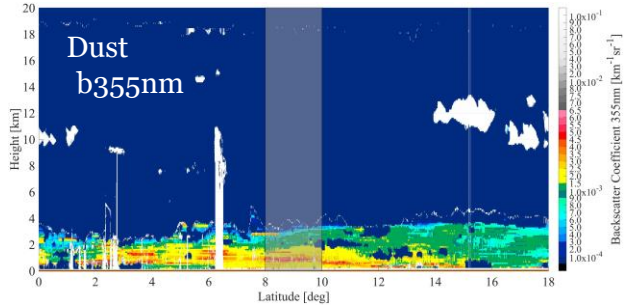
EarthCARE Dust

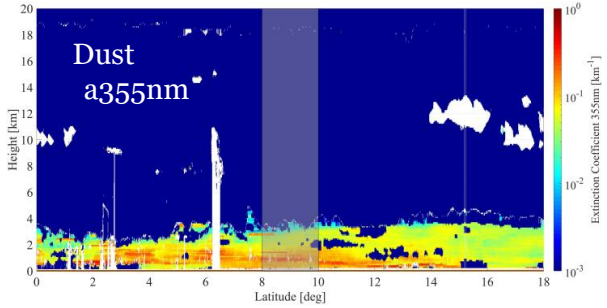
EarthCARE: 02539A

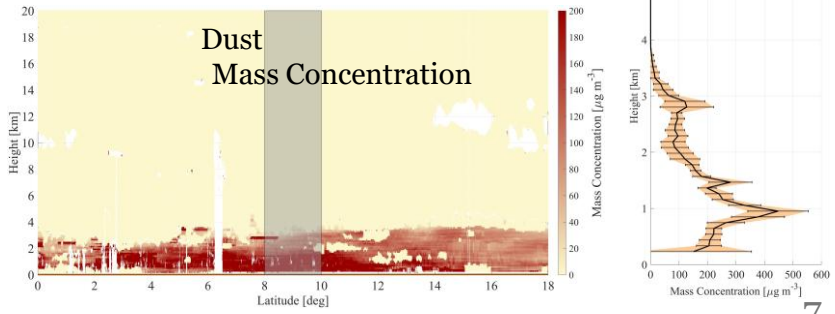


Tesche et al., 2009; 2011
Ansmann et al., 2019
Floutsi et al., 2023

QA

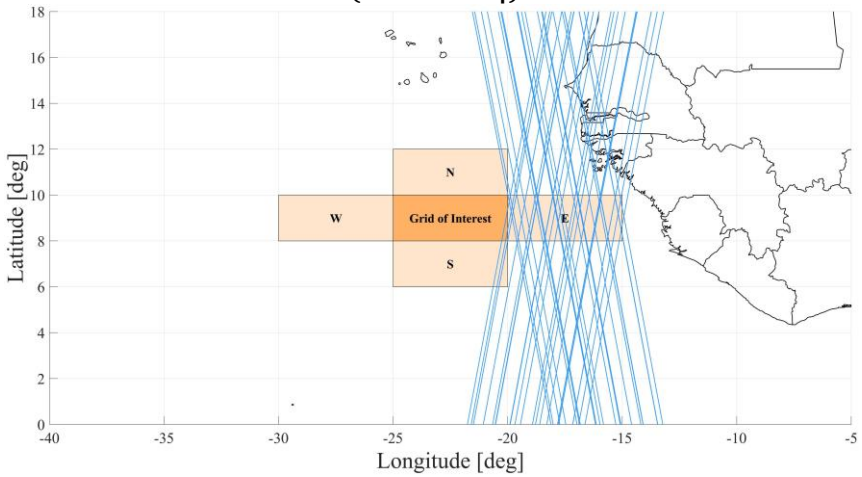




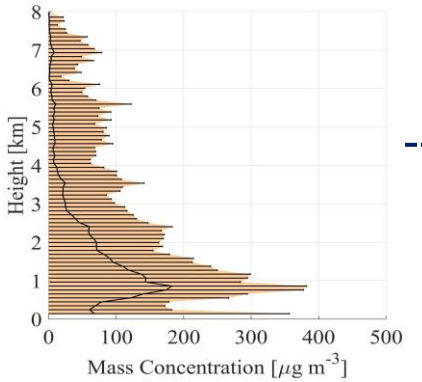


EarthCARE Dust

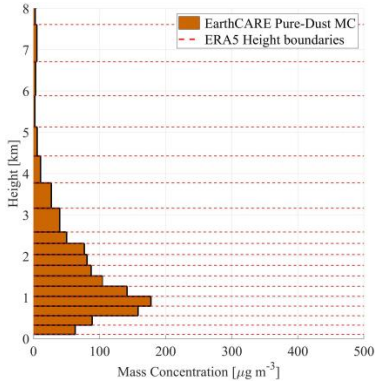
All EarthCARE overpasses
(SON 2024)



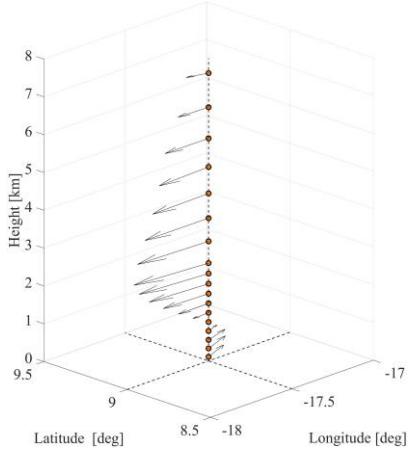
Dust mean MC profile
(SON 2024)



Dust mean MC profile in ERA5
vertical resolution (SON 2024)

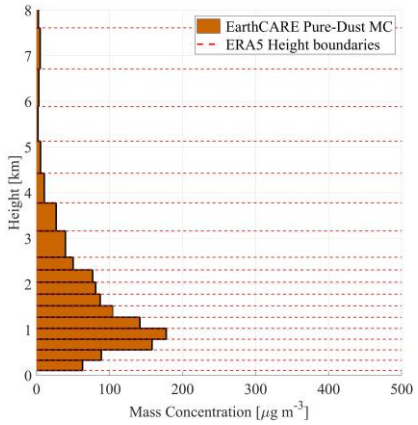


ECMWF ERA5
U/V wind components

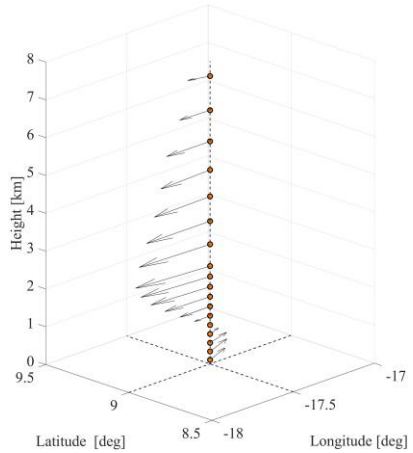


EarthCARE Dust

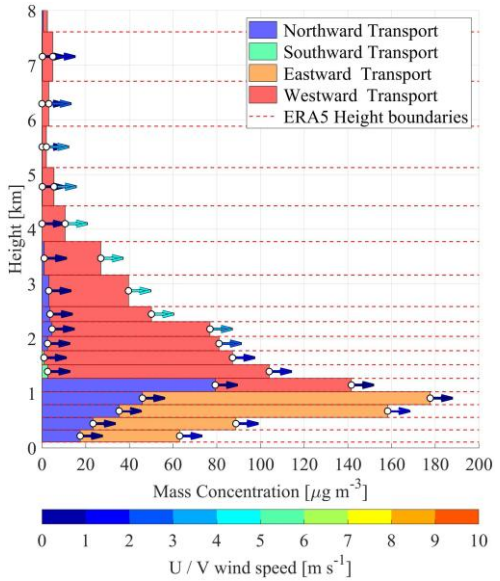
Dust mean MC profile in ERA5 vertical resolution (SON 2024)



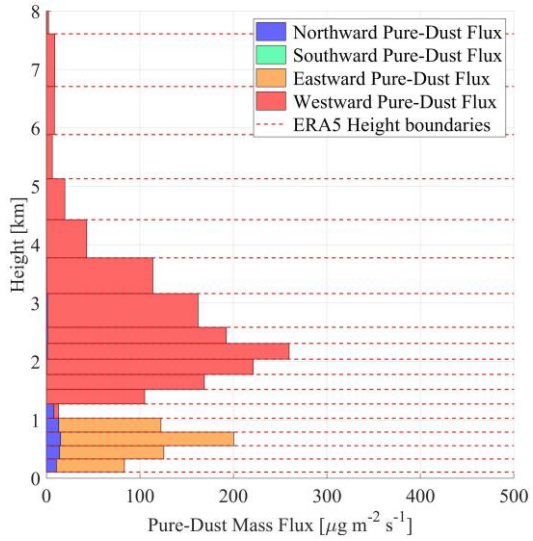
ECMWF ERA5
U/V wind components



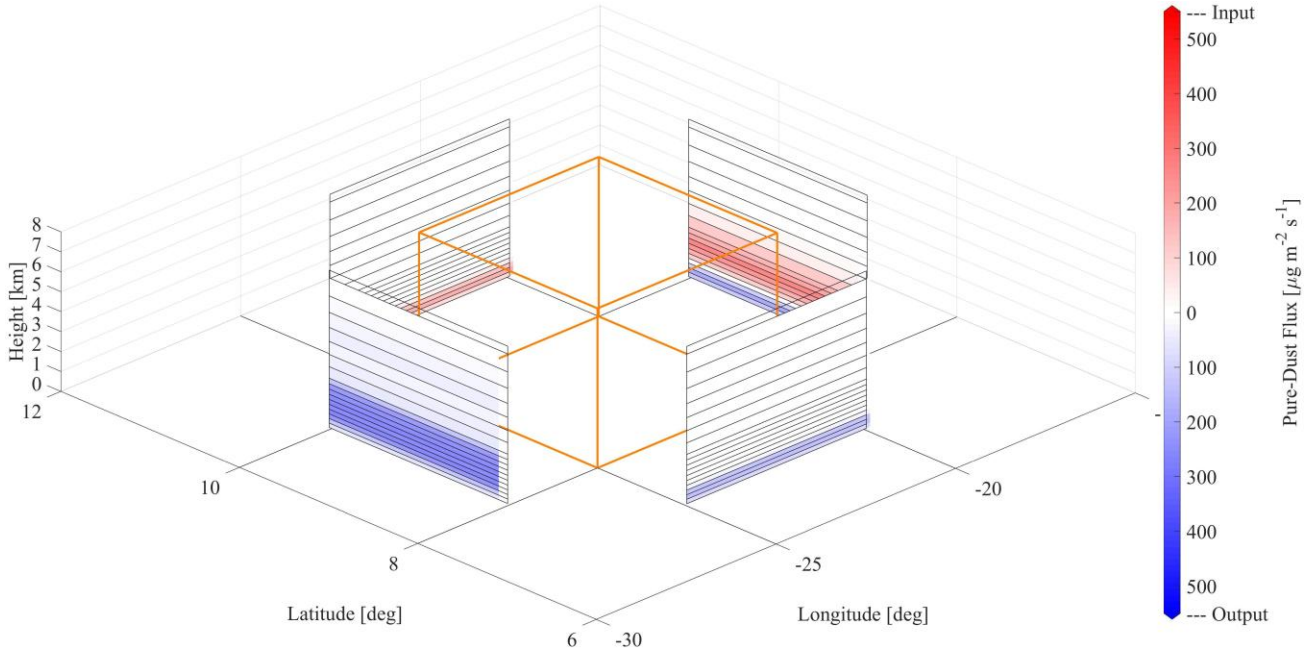
Dust mean MC profile in ERA5 vertical resolution, direction of transport, and U/V wind speed (SON 2024)



Dust meridional & zonal mass fluxes (SON 2024)



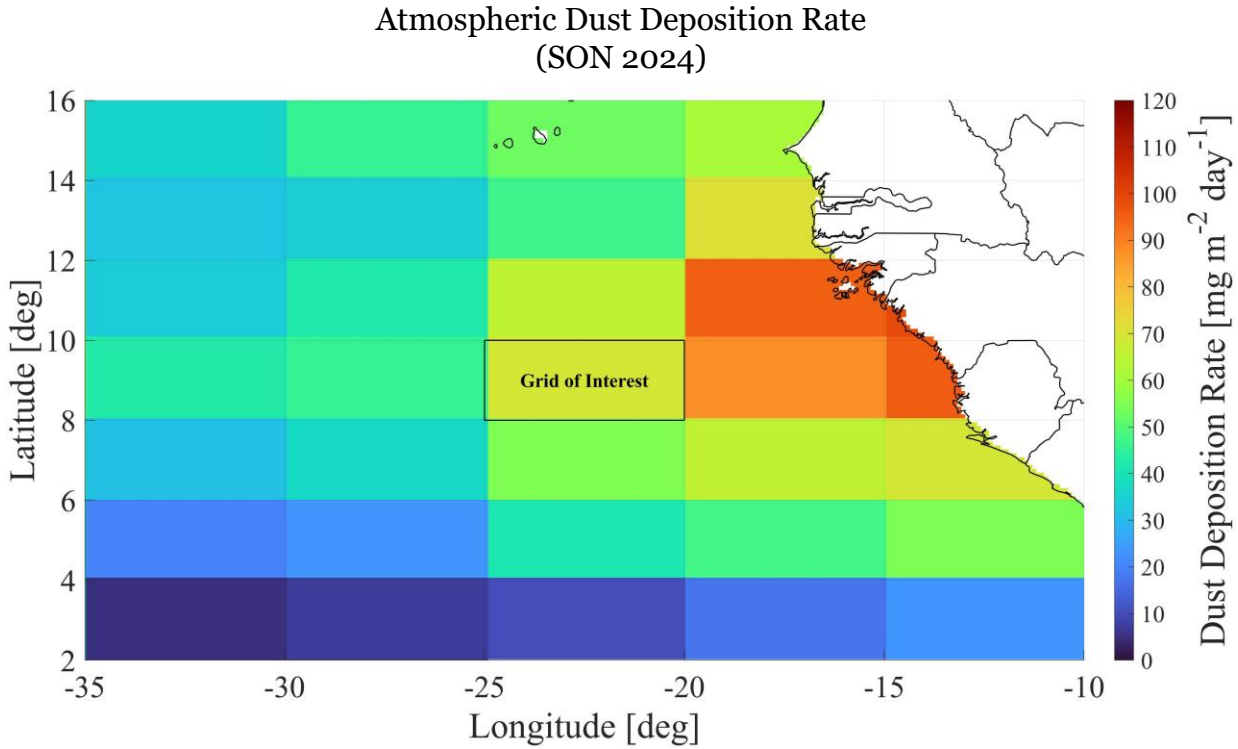
EarthCARE Dust Deposition



$$DDR = All\ input\ fluxes\ - All\ output\ fluxes$$

$$DDR\ = 71.1\ [\frac{mg}{m^2 d}]$$

EarthCARE Atmospheric Dust and Dust Deposition Rate



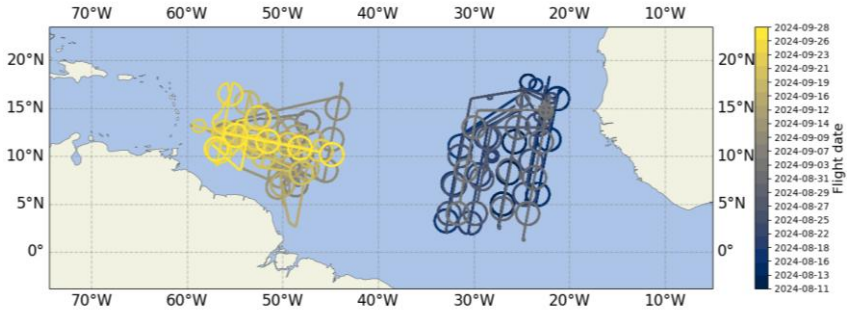
(Future steps)
Validation of EC dust mass concentration profiles

EarthCARE validation campaign PERCUSION with HALO

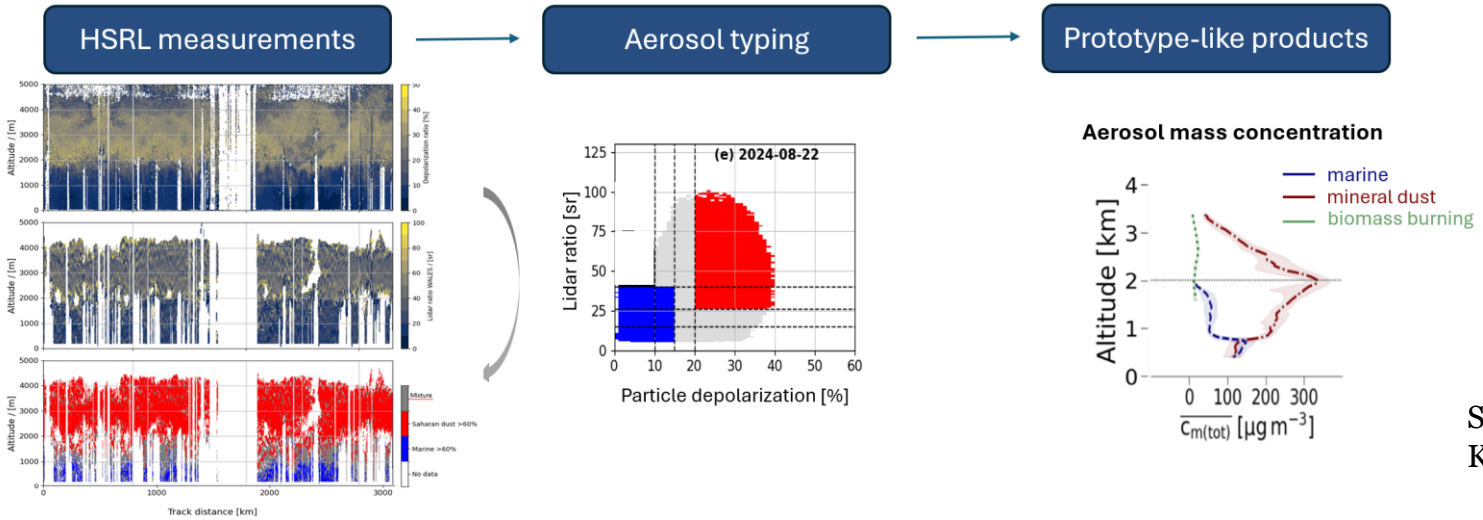
(**P**ersistent **E**a**R**th**C**are **U**nderflight **S**tudies of the **I**TCZ and **O**rganized convectio**N**)

Observations with HSRL WALES

- Cross sections of depolarization ratio, lidar ratio ⇒ aerosol typing!
- Generation of prototype-like products (e.g., atmospheric dust)



21 research flight with EarthCARE underpasses



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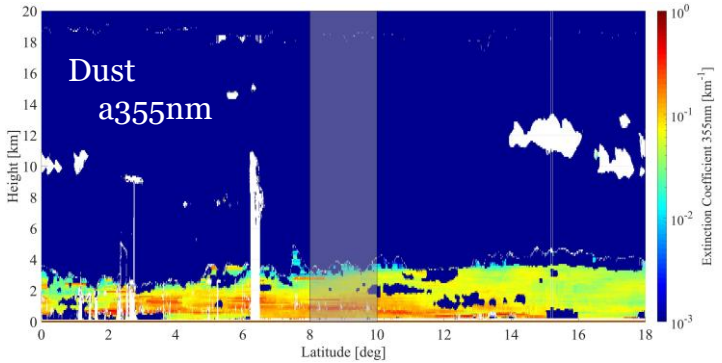
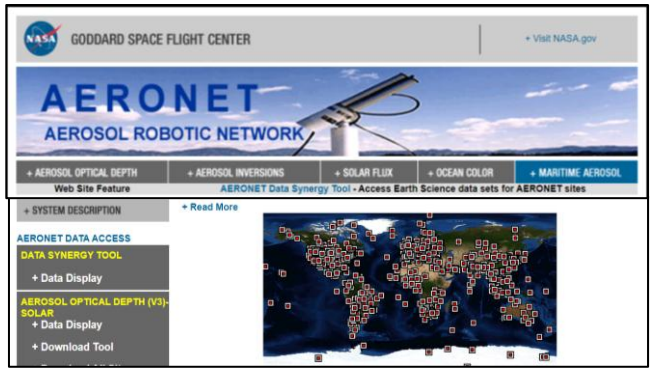
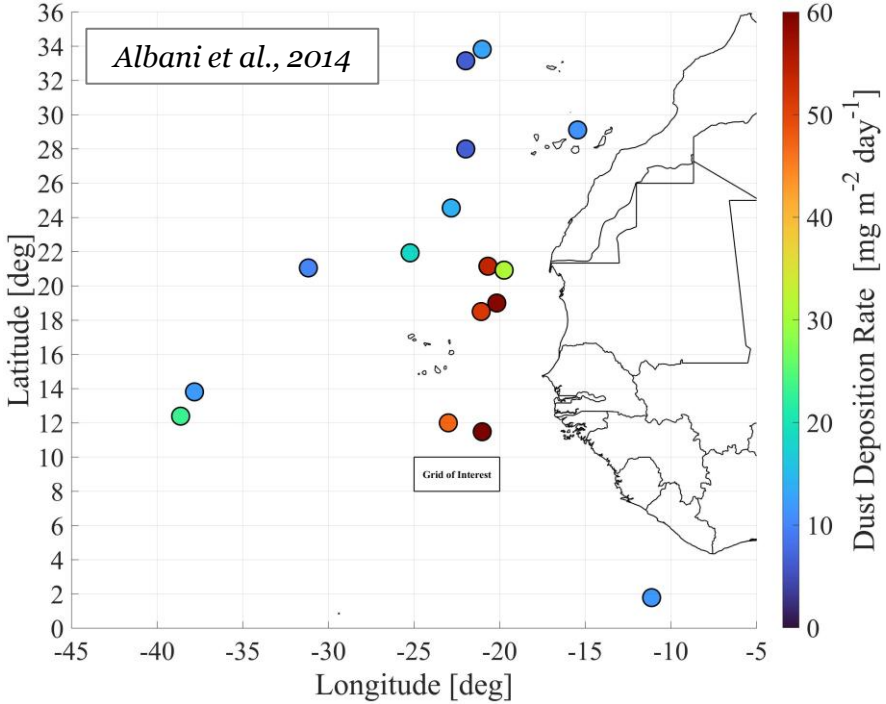
(Future steps)
Validation/evaluation of DOD and DDR)

Evaluation of Dust atmospheric dust
&
Dust Deposition Rate (DDR)







(Future steps)
Model Based global dust deposition and mineralogy evaluation

20 year-long reconstruction of dust and iron deposition fields (monthly outputs) with EC-Earth3-Iron ⇒ Quantification of soluble iron deposition by source, analysis of long-term evolution.

Mineralogy resolved simulations with MONARCH over a period coincident with EarthCare observations ⇒ 3D distribution of key minerals in dust.

MONARCH:

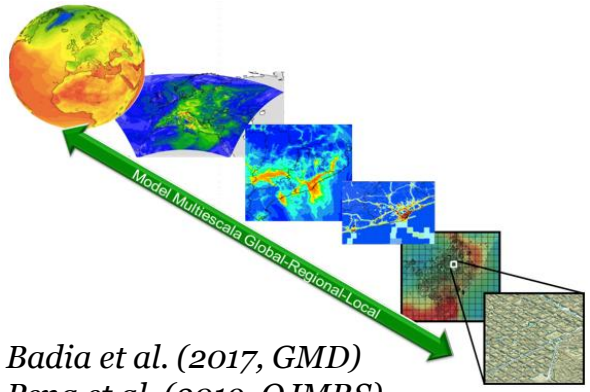
- Atmosphere-chemistry model
- Advanced **dust representation** (Klose et al., 2021)
- **Explicit dust mineralogy** (Gonçalves Ageitos et al., 2023; Obiso et al. in prep. Ilic et al., in prep)

EC-Earth3-Iron:

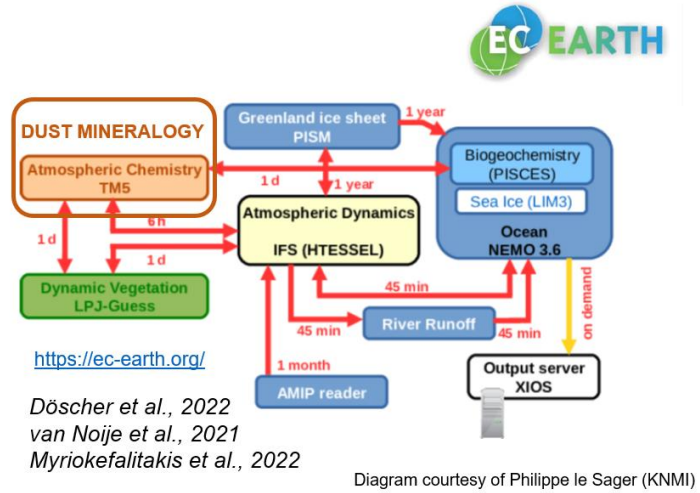
- Earth system model co-developed by different EU institutes
- Detailed **iron atmospheric cycle** (Myriokefalitakis et al. 2022, Bergas-Massó et al., 2023, 2025)

MONARCH

Multiscale: global to local (1km)



Badia et al. (2017, GMD)
Peng et al. (2019, QJMRS)
Klose et al. (2021, GMD)



Döscher et al., 2022
van Noije et al., 2021
Myriokefalitakis et al., 2022

Diagram courtesy of Philippe le Sager (KNMI)

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María Gonçalves: maria.goncalves@bsc.es
Jeronimo Escribano: jeronimo.escribano@bsc.es

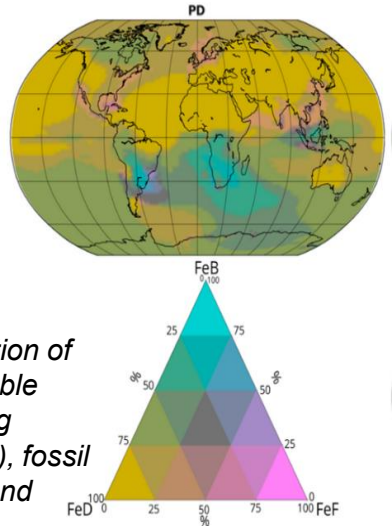
(Future steps)
Model Based global dust deposition and mineralogy evaluation

Both modelling systems will use observationally constrained information on dust sources mineralogy from the NASA-EMIT project.

Thorough evaluation of the model results:

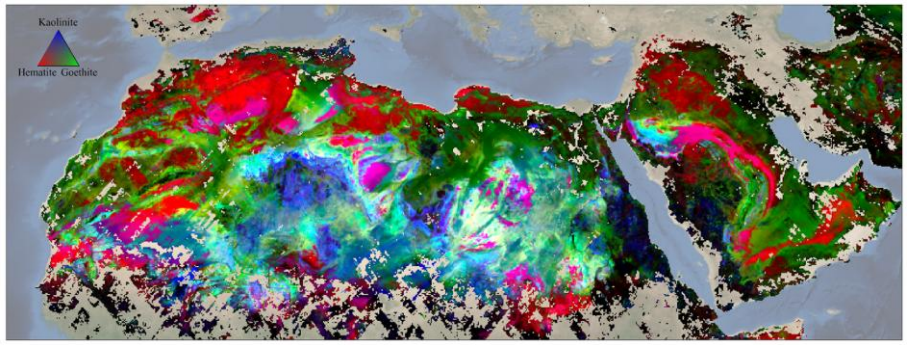
- Vertical profiles of dust – OREO products and MPLNET retrievals.
- AOD, DOD and SSA -- AERONET
- Surface dust concentration and deposition – climatological observations (e.g., Albani et al., 2014)
- Mineral mass fractions – in situ observations (e.g., Perlwitz et al., 2015).

Quantification of the contribution of different sources to soluble iron deposition, evaluation on their trends and variability.

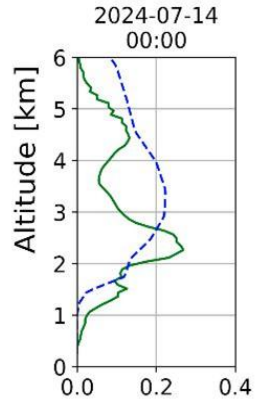


EC-Earth3-Iron allows quantifying the contribution of different sources to soluble iron deposition, including biomass burning (green), fossil fuel combustion (pink) and dust (yellow).
Bergas-Massó et al., 2023

NASA-EMIT products provide soil mineralogy across dust sources



Map courtesy of P.Brodrik (NASA-JPL)



Vertical profile of dust extinction in Tenerife from MONARCH (blue) and MPLNET (green)

C. Gilè (BSC)

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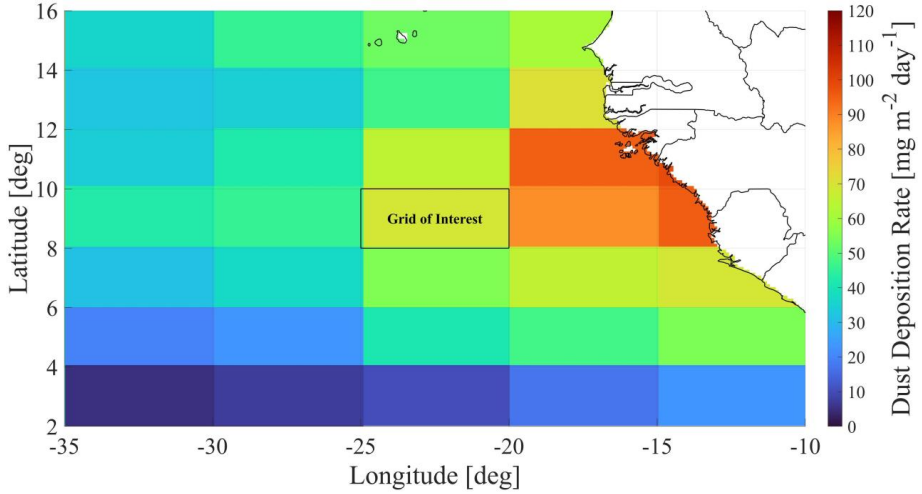
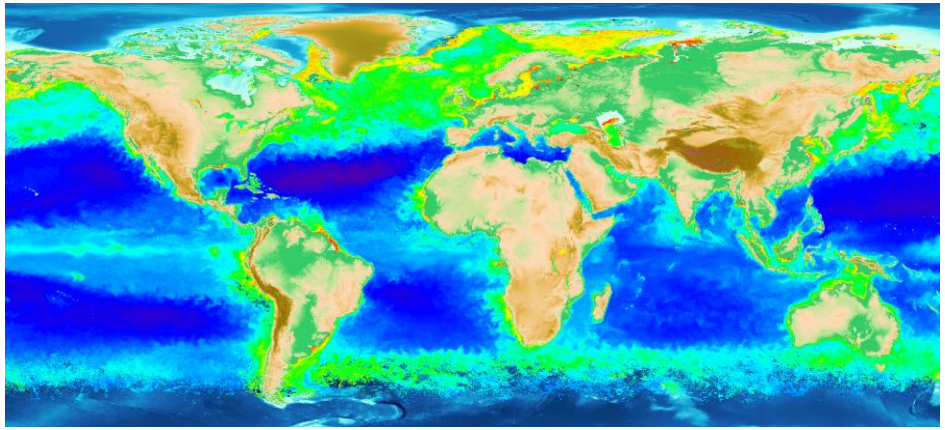
What are the impacts of changes in dust deposition on marine biogeochemistry and their potential effects on ecosystems?

Atmospheric Dust Deposition Rate (SON 2024)



Global and multiyear

ESA Ocean Colour CCI – 05/2019



Thank you for your:

1) time
2) interest
&
3) attention..