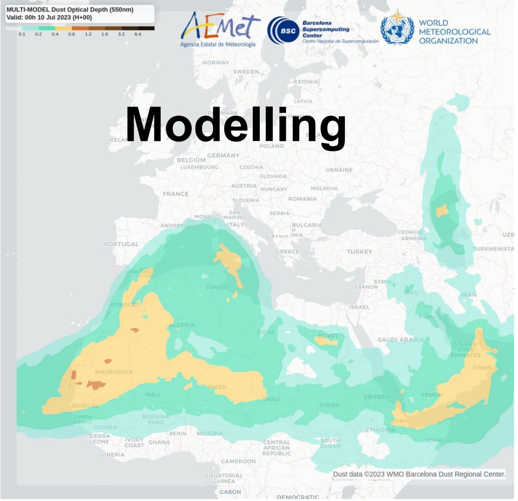
# 12 July International Day of Combating Sand and Dust Storms

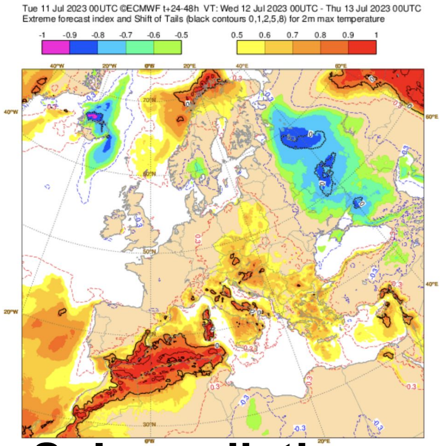
WMO

Barcelona Dust Regional Center

# 12th July 2023

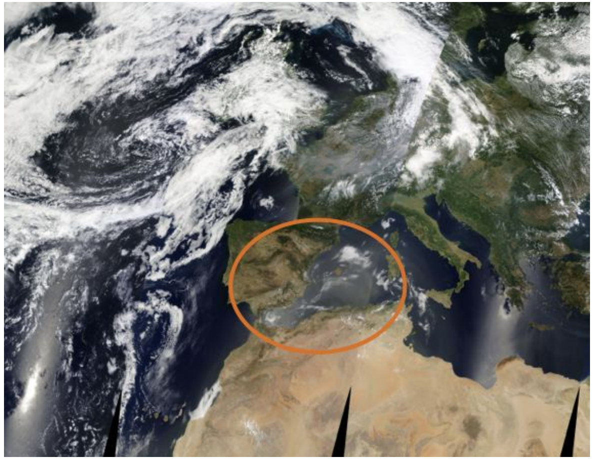
Modelling



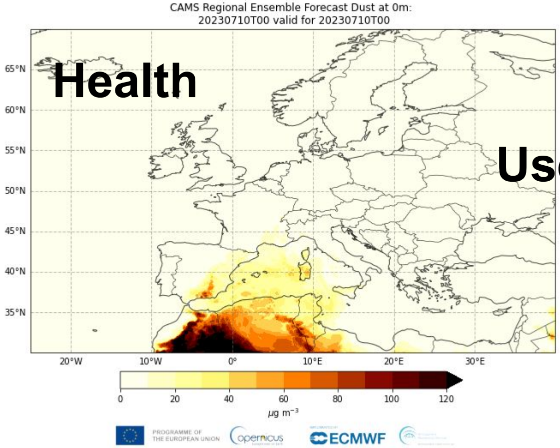




Measurements

Solar radiation



Health




User experience

**Introduction**

- Welcome and introduction to the webinar - ***Emanuele Emili*** (BSC)
- Dust impacts and the context of the international forum | inDust and the webinars - ***Sara Basart*** (WMO)
- History and introduction of SDS-WAS - ***Slobodan Nickovic*** (Republic Hydrometeorological Service of Serbia)

**From Science to Services**

- Measurements – ***Vassilis Amiridis*** (NOA)
- Modeling – ***Ana Vuković Vimić*** (University of Belgrade)
- Health – ***Aurelio Tobias*** (IDAEA-CSIC, Spanish Council for Scientific Research)
- Solar radiation – ***Stelios Kazadzis*** (PMOD/WRC)
- Users experience – ***Lucia Mona*** (CNR-IMAA, Italian Research Council)

**Looking at future**

- Challenges and emerging topics - ***Carlos Pérez García-Pando*** (BSC) and ***Pavla Dagsson-Waldhauserová*** (Agricultural University of Iceland)

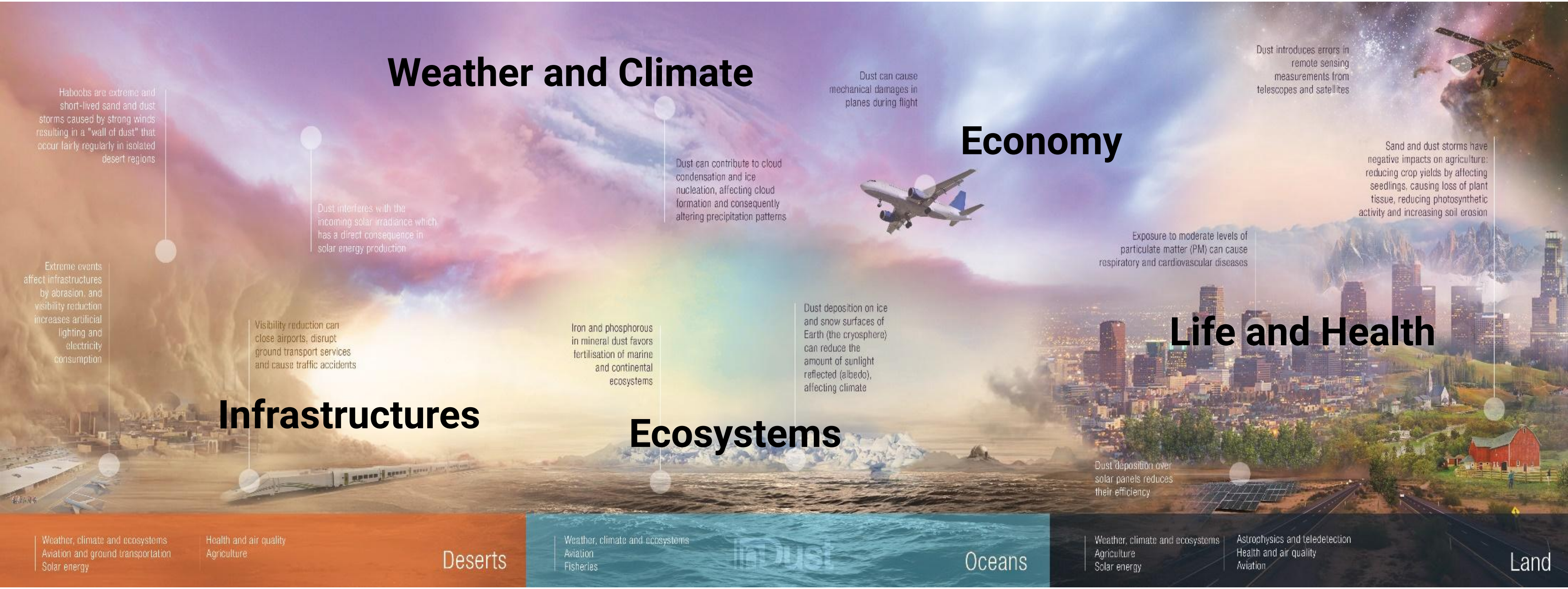
**Open questions from the audience** - ***Mark Parrington*** (ECMWF)

**Closing and moderation** - José Luis Camacho, Ernest Werner (AEMET, Spanish Meteorological Agency)

# Sara Basart

## Dust impacts and the context of the international forum

# Sand and Dust Storms Impacts




*inDust Leaflet available in www.cost-indust.eu/media-room*

inDust

COST EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

# UN General Assembly Proclaimed 12 July International Day of Combating Sand and Dust Storms, Aiming to Raise Awareness about Importance for Health, Sustainability

United Nations

UN Coalition for Combating Sand and Dust Storms


Almería, Spain, 2022


Switzerland, 2022


Crete, 2018


12:00h
15:00h
17:30h
Tenerife 2020


Paris, 2021

WMO launched in 2007 the international research programme on Sand and Dust Storms, the SDS-WAS


WORLD METEOROLOGICAL ORGANIZATION

150 1873 2023 IMO-WMO

# Slobodan Nickovic

## History and introduction of SDS-WAS

# Ancient SDS recordings

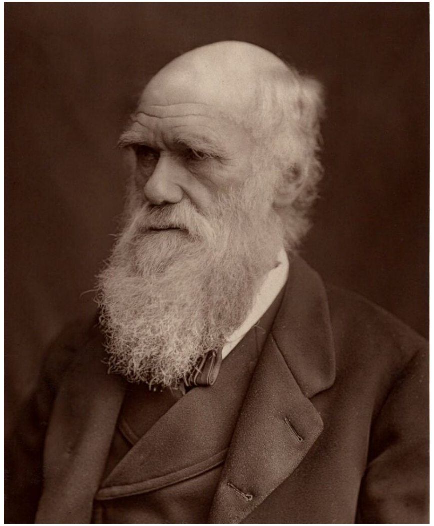
TABLE 1. The records of dust events during the Three Kingdoms period (57 BC–AD 938) in Korea.

| Year | Month[a] | Kingdoms[b] | Original record[c] | Meaning |
|---|---|---|---|---|
| 174 | 2 | Silla | 雨土 | Dustfall |
| 379 | 5 | Baekje | 雨土竟日 | Dustfall for a day long |
| 389 | 3 | Silla | 雨土 | Dustfall |
| 606 | 4 | Baekje | 王都雨土晝暗 | The sky of Baekje's capital was darkened like night by dustfall |
| 627 | 4 | Silla | 大風雨土過五日 | Dust storm lingered over five days |
| 644 | 11 | Goguryeo | 平壤雪色赤 | Snow tinged with red in Pyongyang, Goguryeo's capital |

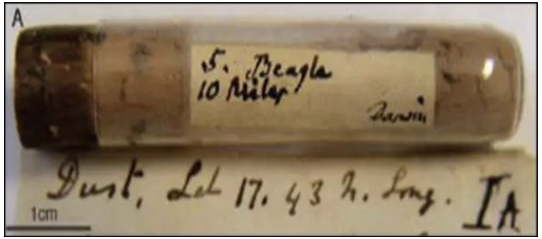
**Ancient dust recording (Korea)    57 BC**

**Dust storm in Sahara**
(painting, George Francis Lyon, 1819)

# Early scientific consideration of SDS



**Charles Darwin**

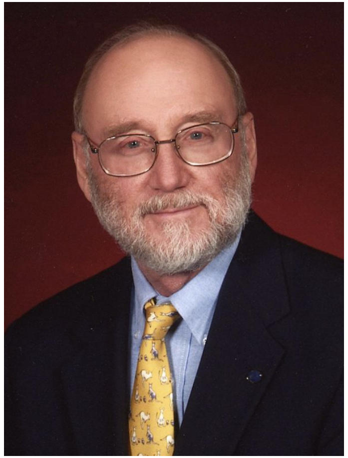



**Beagle cruise dust samples (1832)**

In 1922, Lewis Fry Richardson developed the first numerical weather prediction (NWP) concept. based on „primitive equations“ of motion.

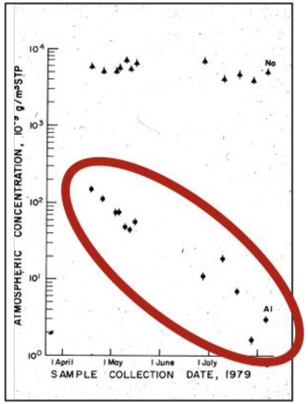
He proposed to add **atmospheric dust as a prognostic variable!**

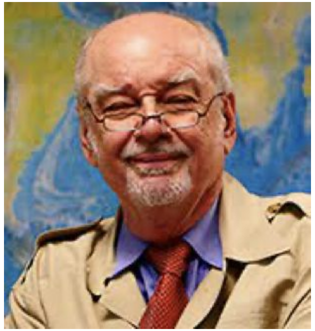
# Early process studies



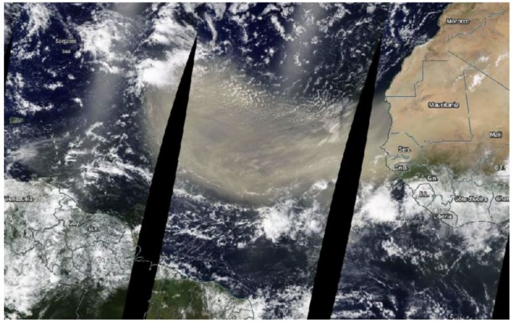
Asian dust unexpectedly observed in Pacific (Robert Duce et al.,Science, 1980)


Atmospheric Al concentration

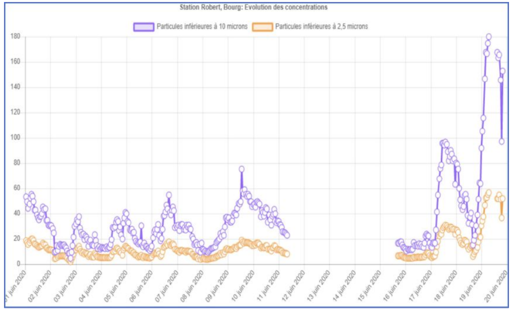


The Discovery of African Dust Transport to the Western Hemisphere (Joe Prospero., BAMS, 2021)



19 June 2020 GOES




Barbados observations since 1966

# Why dust?

Transport

Health

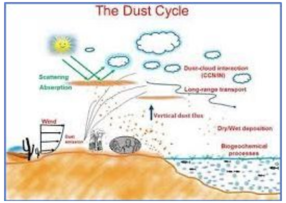
Agriculture

**Mineral Dust**

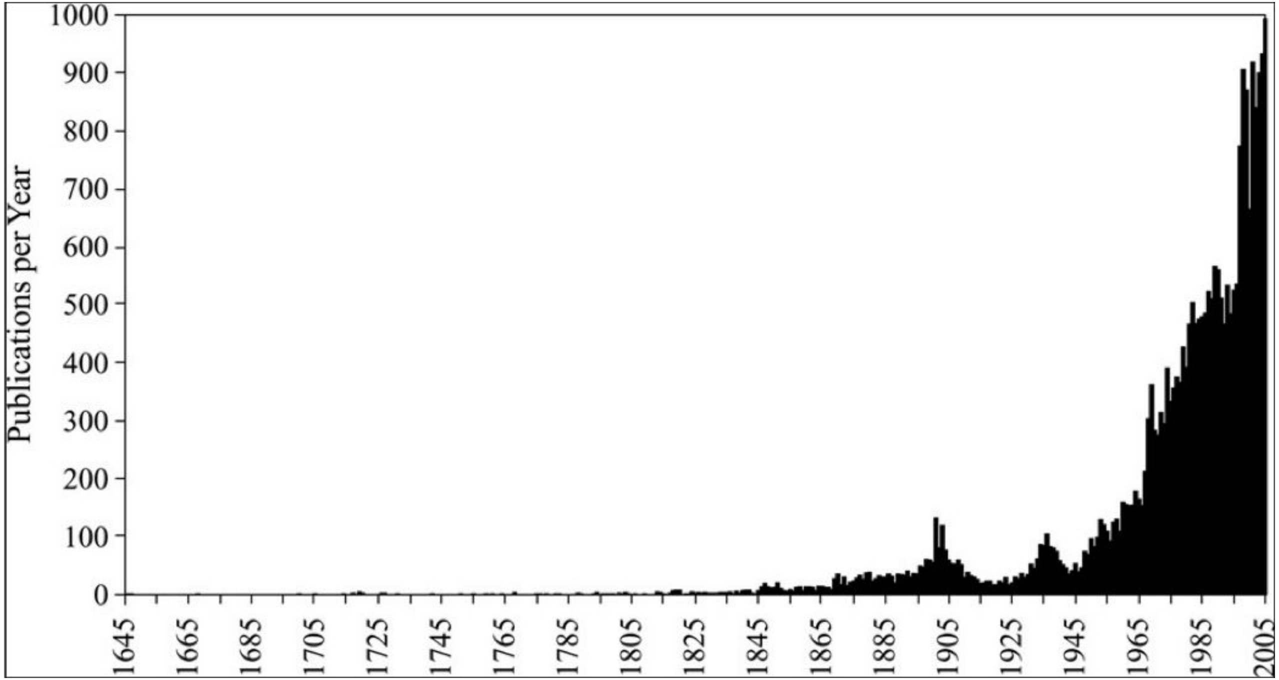
Climate

Energy

Weather



# Exponential growth of dust-related articles

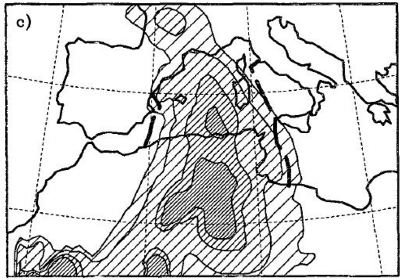



**Knipperz and Stout, 2014**

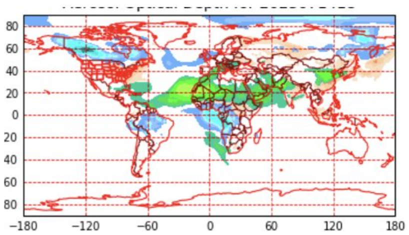
# Early '90s - Accumulated knowledge on SDS process

**First daily numerical dust** model predictions

- Mediterranean
- Global



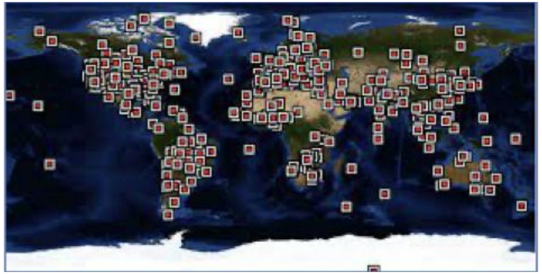

**DREAM regional dust forecasts**



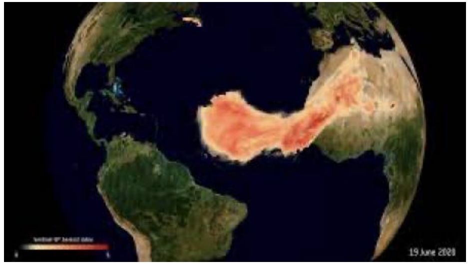

**NRL NAAPS Global Dust Model forecasts**

**Improved aerosol observations**

- Remote-sensing
- Ground-based



**Aeronet sunphotometer network**



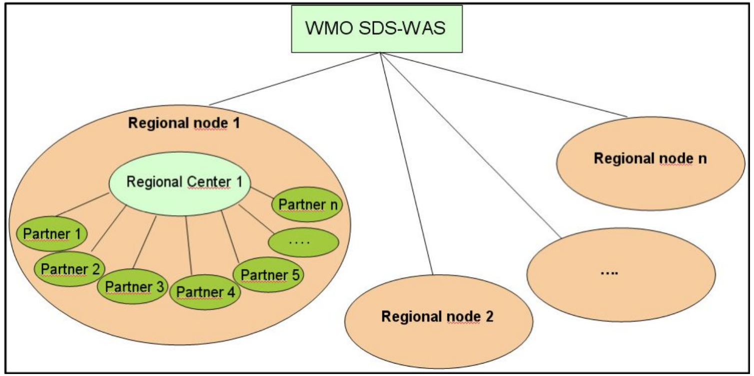
**ESA**

# WMO SDS-WAS: Sand and Dust Storm Warning and Advisory System

- 2005: 46 WMO countries expressed interest for a dust project
- 2007: WMO established SDS-WAS
- The mission: to enhance the ability of WMO Members to deliver timely and quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership of research and operational communities.
- Global and regional infrastructure

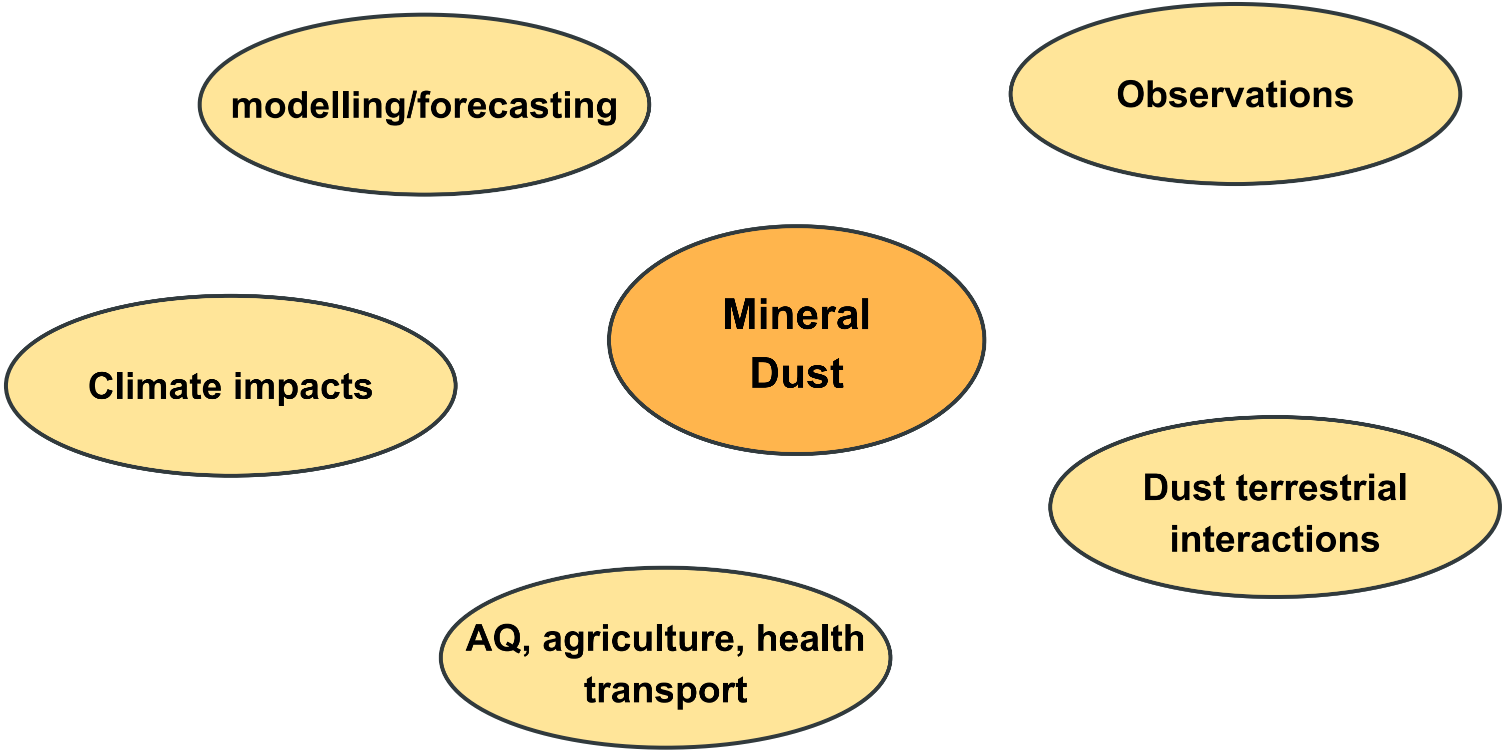
# WMO SDS-WAS: Sand and Dust Storm Warning and Advisory System

**Global and regional infrastructure**




- **Asian** Regional Node
- **North Africa, the Middle and Europe (NAMEE)** Regional Node
- **Pan American** Regional Node
- **Gulf Cooperation Council (GCC)** Regional Node

# Current SDS-WAS emerging research issues



# Vassilis Amiridis

## Measurements

**First in-situ observations of desert dust:**

**Homer mentions red rain in Iliad (8th century BC):**

Zeus shed **a rain of blood upon the earth** in honor of his son whom Patroclus was about to kill during the Trojan war

Mention here how the **red rain** is perceived as **blood rain,** attributed to the supernatural power of Zeus who caused this unnatural event (due to his emotional attachment to his son Sarpedon)

Researchers attribute this Iliad reference to the transport of Saharan dust over Greece

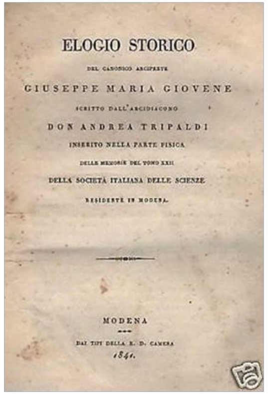

Similar occurrences of **blood rain** are mentioned in other mythologies such as the Indian Mahabharata, the Chinese mythology, as well as the enslavement of Egyptians during the Roman empire **(all regions within the dust belt)**

Numerous reports of blood rain are found also during the Mediaeval period.

1888 illustration of the extreme blood rain in France, July **1608**

The blood-rain phenomenon was first explained in **1803** by the Italian scientist **Giuseppe Maria Giovene**

Giovene studied the rain dust fell on the **Puglia region** of southern Italy. At the time, people believed that the rain was caused by the eruption of the volcanoes Vesuvius and Etna in Italy

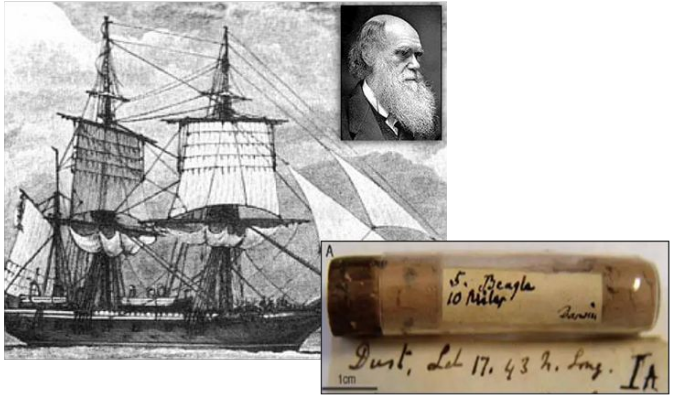
ELOGIO STORICO
DEL CANONICO ARCIPRETE
GIUSEPPE MARIA GIOVENE
SCRITTO DALL'ARCIDIACONO
DON ANDREA TRIPALDI
INSERITO NELLA PARTE FISICA
DELLE MEMORIE DEL TOMO XXII
DELLA SOCIETÀ ITALIANA DELLE SCIENZE
RESIDENTE IN MODENA.

MODENA
DAI TIPI DELLA R. D. CAMERA
1841.

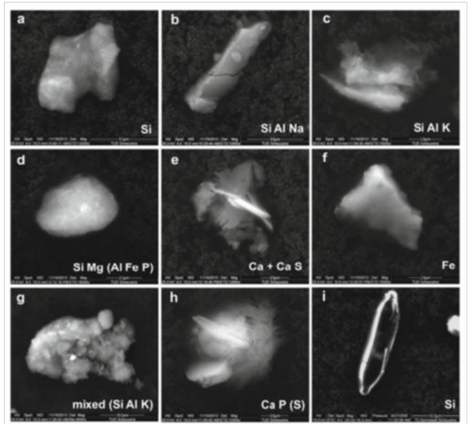
**Andrea Tripaldi (1841).** "Historical eulogy of the Archbishop of the Church, Giuseppe Maria Giovene".

Giovene associated this phenomenon with the wind that preceded the rain and came to the conclusion that **the sand came from Africa and was pushed by winds from the southeast**

**Charles Darwin: Beagle cruise dust samples 1832**



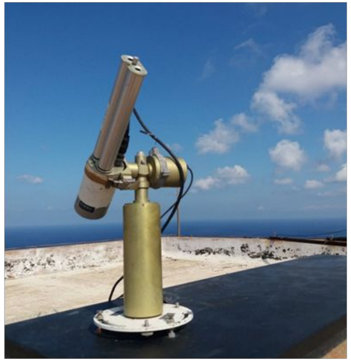

**Electron microscopy, Kandler et al., 2011**

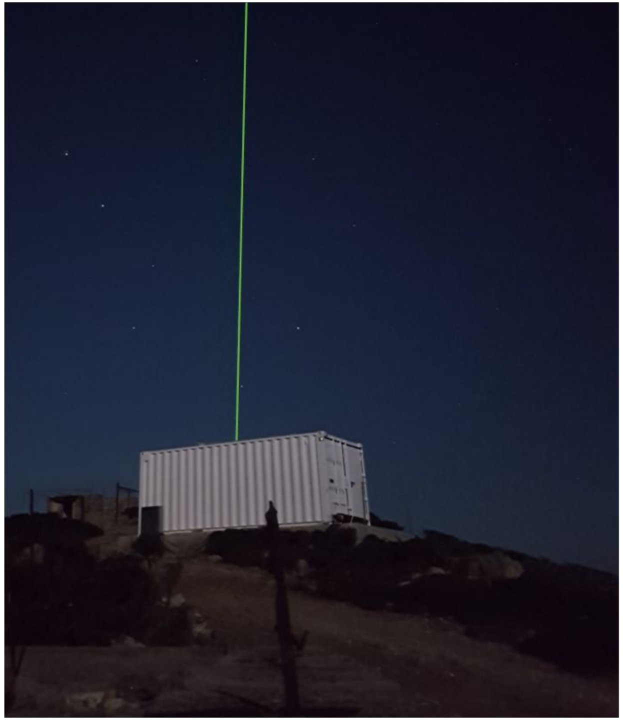


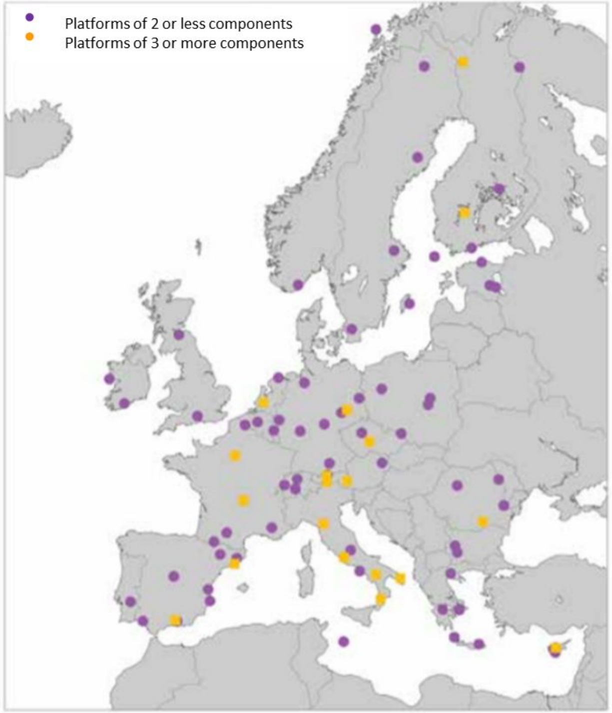
# ACTRIS for desert dust observations

**ACTRIS is a Pan-European Research Infrastructure for the observation of Aerosols, Clouds and Trace Gases**

ACTRIS Aerosol Remote Sensing National Facility consists of multi-wavelength lidar/photometer





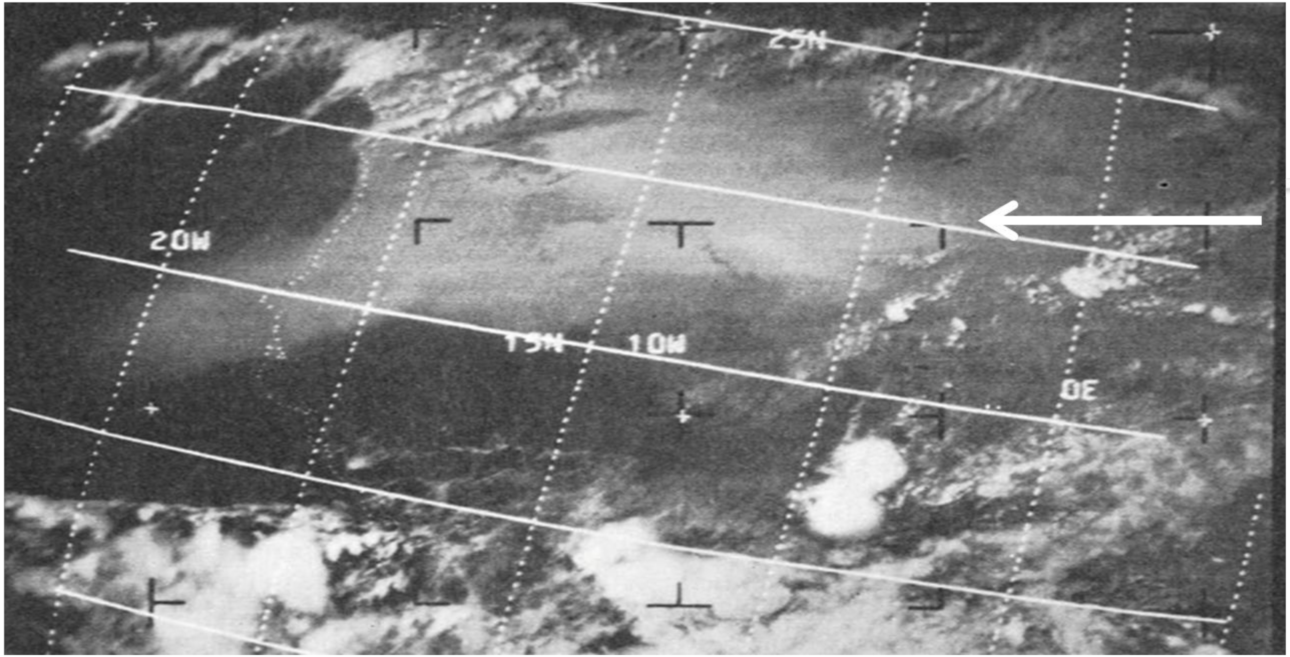


**First remote sensing image of desert dust:** ESSA-5 meteorological satellite, 7th of June, **1967**

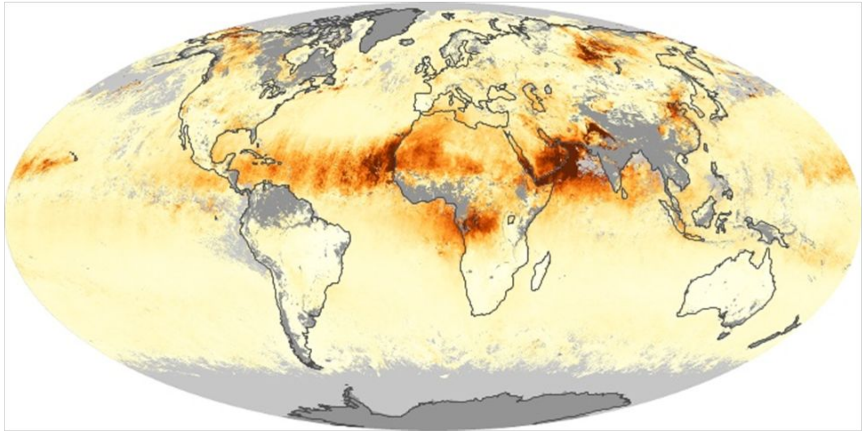
EARTH AND PLANETARY SCIENCE LETTERS 9 (1970) 287-293. NORTH-HOLLAND PUBLISHING COMPANY

DUST IN THE CARIBBEAN ATMOSPHERE TRACED TO
AN AFRICAN DUST STORM

Joseph M. PROSPERO, Enrico BONATTI, Carl SCHUBERT and Toby N. CARLSON*
*School of Marine and Atmospheric Sciences, University of Miami, Miami, Florida 33149, USA*



# Desert dust observations

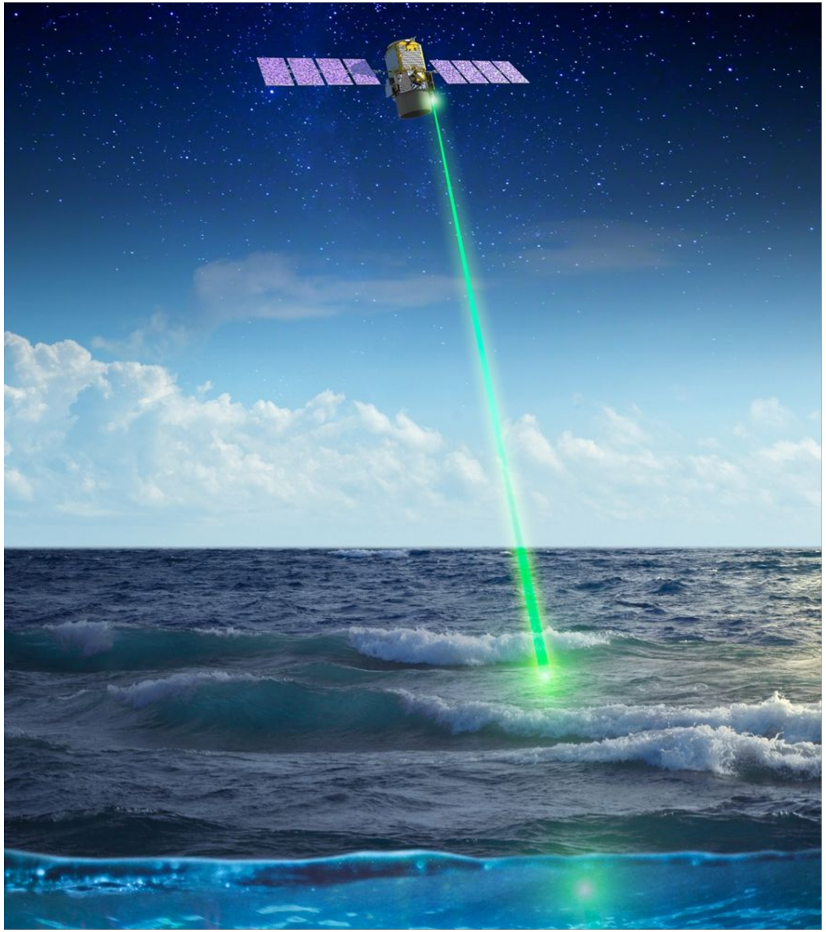


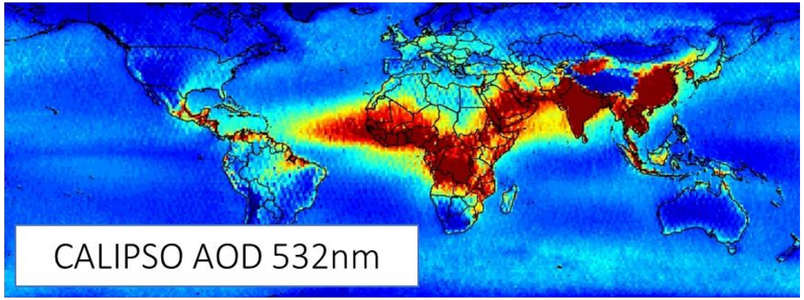
MODIS spectroradiometer onboard Terra satellite of NASA (July 2018)

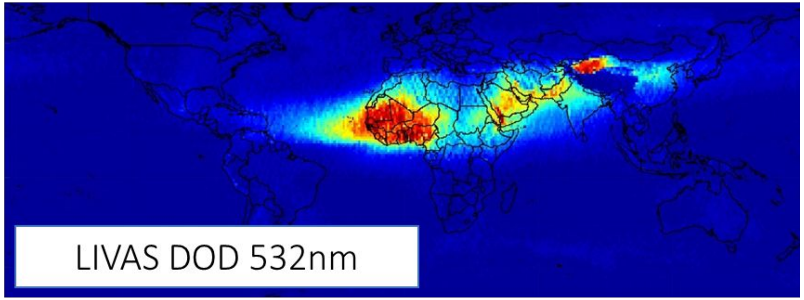
**Remote sensing to directly retrieve DOD**

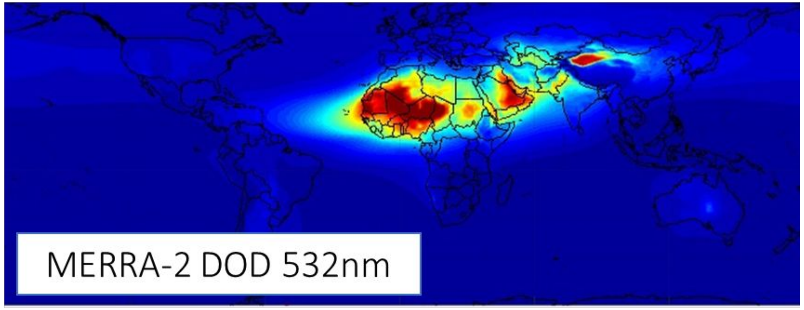
- **Dust particles are larger than other aerosol types:** use of multi-spectral measurements and the Angstrom exponent to estimate the size
- **Dust absorption decreases with increasing wl:** Use of the spectral dependence of absorption to identify dust (from inversions)
- **Dust particles are reach in silicate:** Use of silicate emission features in thermal spectra to identify dust
- **Dust is non-spherical:** Use of polarization measurements to distinguish dust

## Depolarization for discriminating desert dust: CALIPSO, EarthCARE

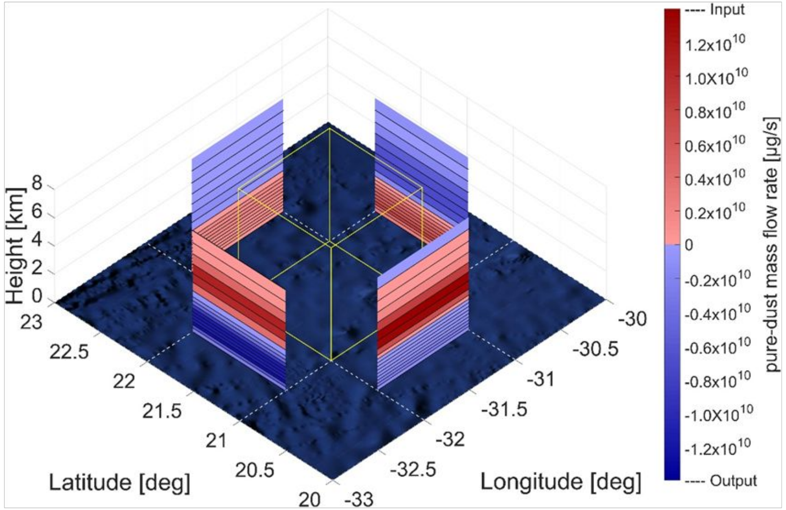


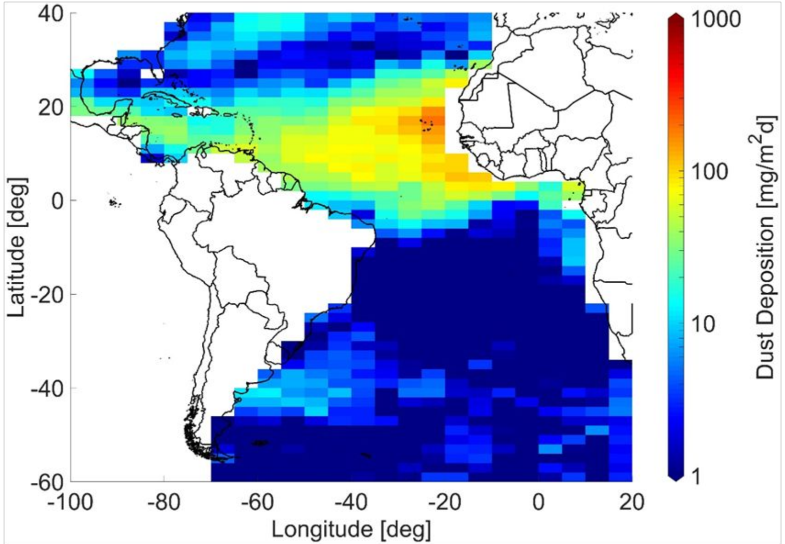


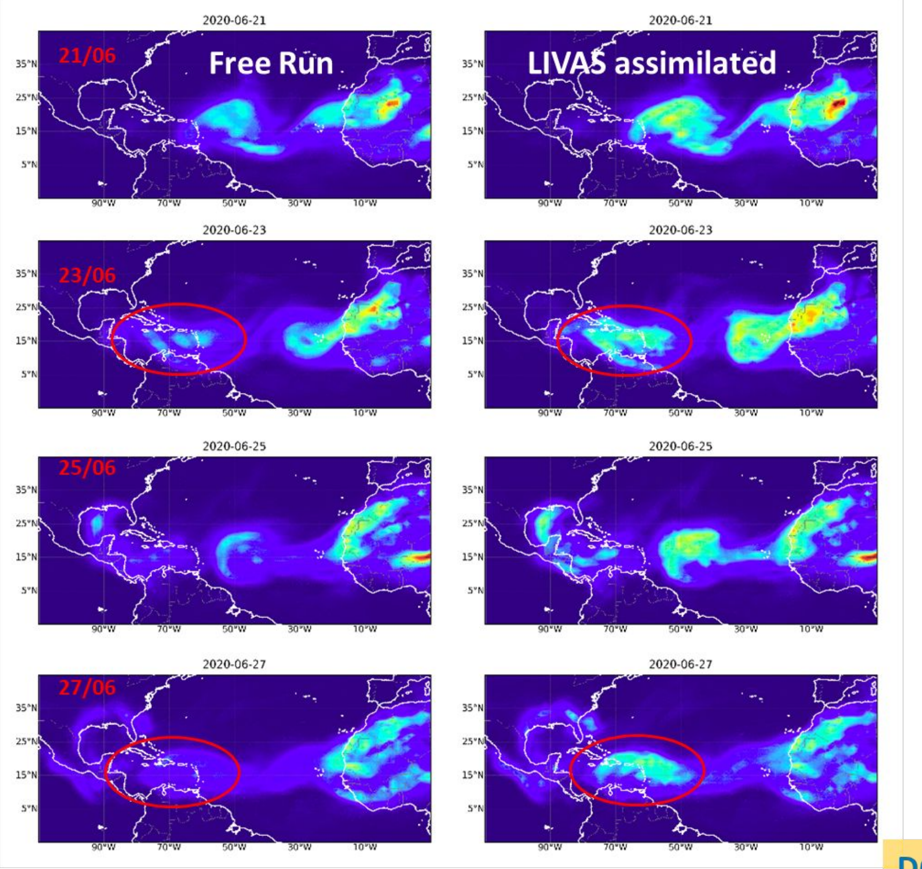
# Dust deposition using the LIVAS dust product and wind information




DOMOS ESA study, NOA product

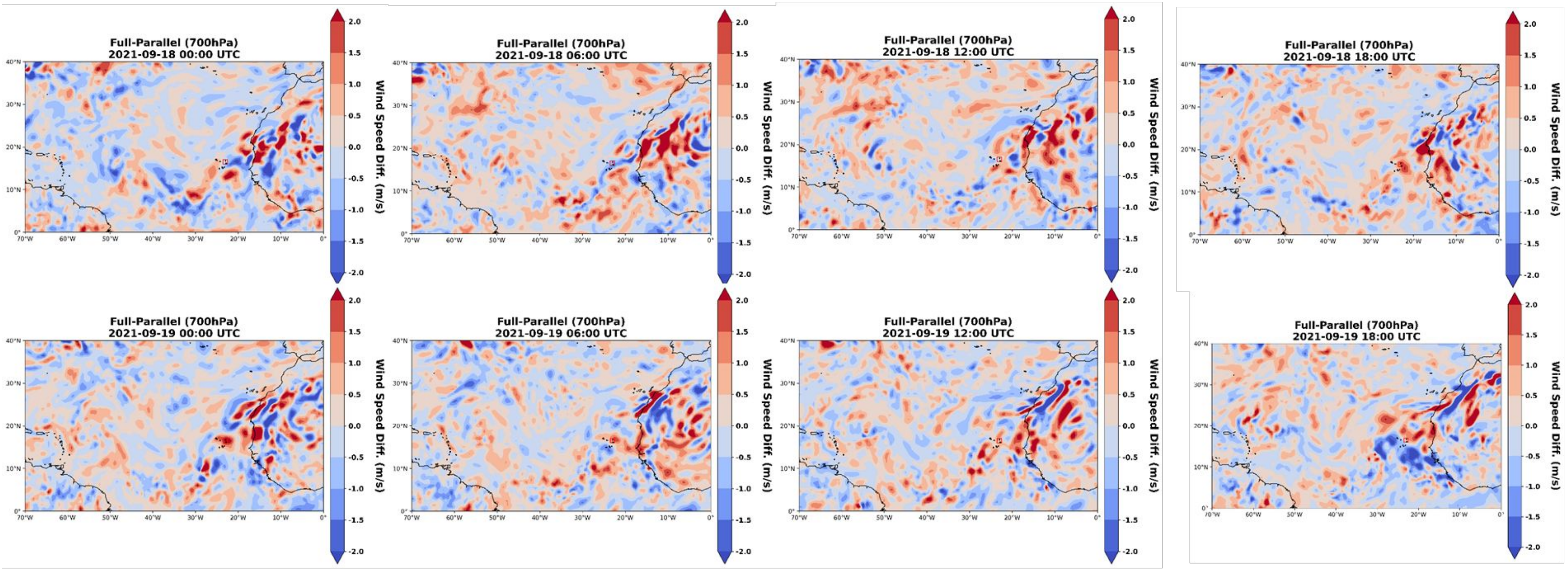
# LIVAS dust product for data assimilation




DOMOS ESA study, courtesy of BSC

# LIVAS dust product impact on NWP

## Spatial distribution of Wind Speed Differences: Full - Parallel




ADD-CROSS EUMETSAT study, ECMWF

# Ana Vuković Vimić

## Modeling

Dust modeling includes:

- definitions of **dust sources** and their dynamical nature related to weather/climate and human activities;
- **emission** of dust from the surface depending on the land surface conditions and surface winds;
- **vertical mixing and transport** of dust particles through the atmosphere;
- **deposition** with gravitational settling and precipitation;
- **interaction** of the dust with the environment
  (during their life cycle in the atmosphere and when deposited at the surface).

**Development of dust models started in 1980ies.**

First results… in Westphal et al. (1988)

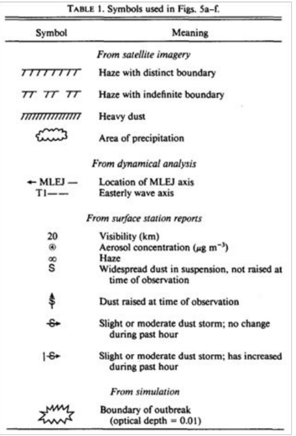


TABLE 1. Symbols used in Figs. 5a–f.

| Symbol | Meaning |
|---|---|
| | *From satellite imagery* |
| TTTTTTTT | Haze with distinct boundary |
| TT TT TT | Haze with indefinite boundary |
| //////////// | Heavy dust |
| (cloud outline) | Area of precipitation |
| | *From dynamical analysis* |
| ← MLEJ — | Location of MLEJ axis |
| T1— — | Easterly wave axis |
| | *From surface station reports* |
| 20 | Visibility (km) |
| (circled number) | Aerosol concentration (μg m⁻³) |
| ∞ | Haze |
| S | Widespread dust in suspension, not raised at time of observation |
| $ | Dust raised at time of observation |
| -S→ | Slight or moderate dust storm; no change during past hour |
| \|-S→ | Slight or moderate dust storm; has increased during past hour |
| | *From simulation* |
| (jagged outline) | Boundary of outbreak (optical depth = 0.01) |

**Analysis of the event from collected observations.**

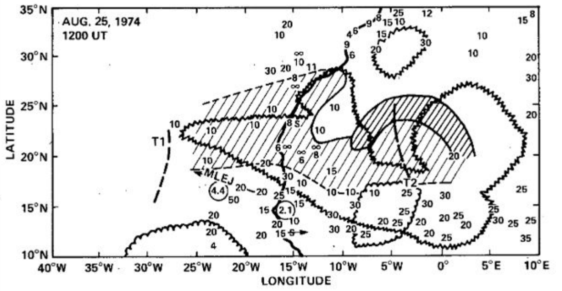



FIG. 5. Analyzed location of dust plumes for 23–28 August 1974: (a) 23 August, (b) 24 August, (c) 25 August, (d) 26 August, (e) 27 August, and (f) 28 August. Analyses were made using satellite imagery, surface observations, and aerosol measurements. The simulated plume outlines are shown also. Symbols are defined in Table 1.

**Results of the modelled dust transport.**

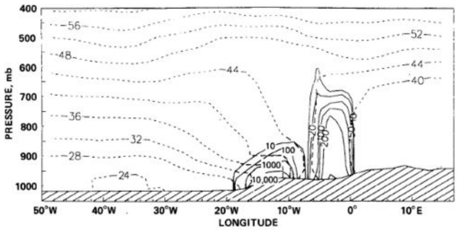



FIG. 20. Zonal cross section of aerosol mass concentration (solid lines, in μg m⁻³) and potential temperature (dashed lines, contour interval of 4°C) along 21°N during mobilization (1200 UTC 26 August). West of 7°W, dry convection is suppressed by the inversion between the SAL and the trade winds and dust is confined to shallow layer. East of 7°W, convection and mixing are stronger.

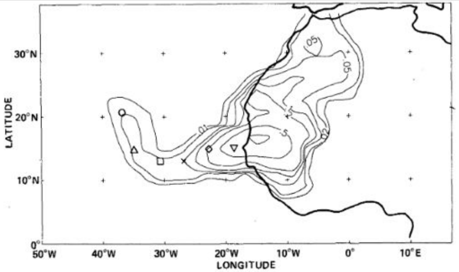



FIG. 23. Distribution of optical depth at 0.55 μm at end of the combined simulation. Symbols show locations of vertical profiles of mass concentration presented in Fig. 27.

Westphal, D.L., Toon, O.B., and Carson, T.N.: A case study of mobilisation and transport of Saharan dust. J. Atmos. Sci. 45, 2145–2175, 1988.

# Tegen and Fung (1994)

## Model scheme

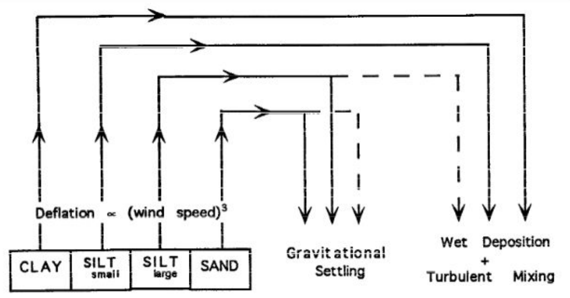
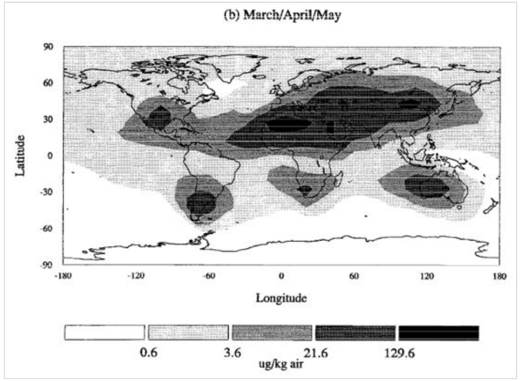
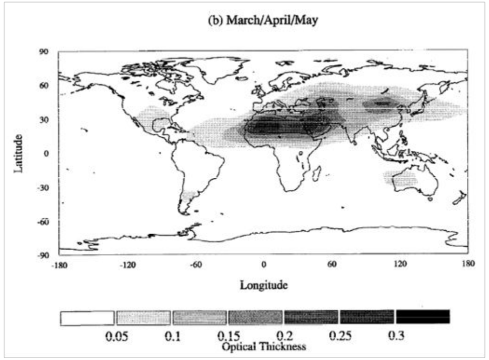



Figure 1. Schematic description of the dust transport model.

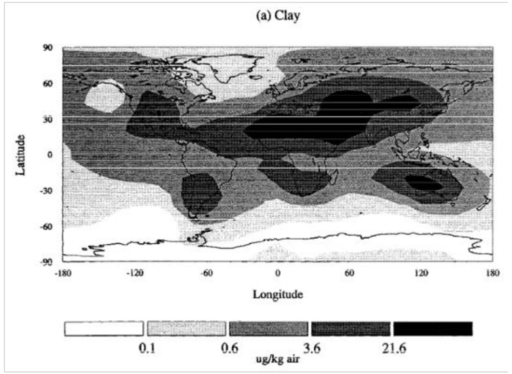
## Seasonal distributions of concentration

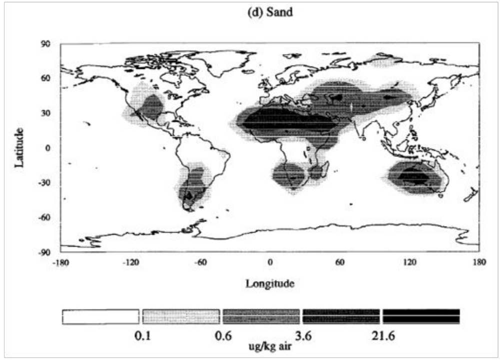



## Seasonal distributions of optical thickness




## Distribution of concentrations by particle size categories




Tegen, I., and Fung, I.: Modeling of mineral dust in the atmosphere: Sources, transport, and optical thickness, J. Geophys. Res., 99(D11), 22897-22914, 1994.

Marticorena and Bergametti 1995; Shao et al.1996; Marticorena et al.1997

- physical representation of the emission and improvement of the results.

Sahao and Leslie (1997); Lu and Shao (1999)

- integrated model model which includes coupled model for surface wind erosion, model for surface processes with included input database on surface characteristics and numerical weather prediction model.

Later, development of other models global and regional, for example:

- Zender et al. 2003; Ginoux et al. 2004 – global
- Nickovic and Dobricic (1994) - dust initialization approach using Total Ozone Mapping Spectrometer (TOMS) aerosol index (AI) data and improved specification of the dust sources
- regional - Ničković et al. 2001; Uno et al. 2006; Perez et al. 2006; Perez et al. 2011
- etc.

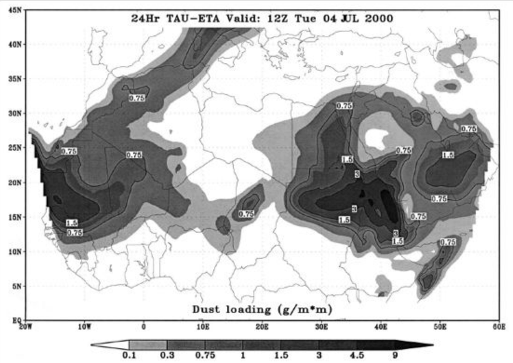


FIG. 2. The 24-h dust prediction at 1200 UTC 4 Jul 2000 over the Mediterranean and North Africa. The variable is the dust loading (g $m^{-2}$) shown in gray shading according to the value in the bar below. The forecast started at 1200 UTC 3 Jul 2000. Initialization with TOMS-INIT.

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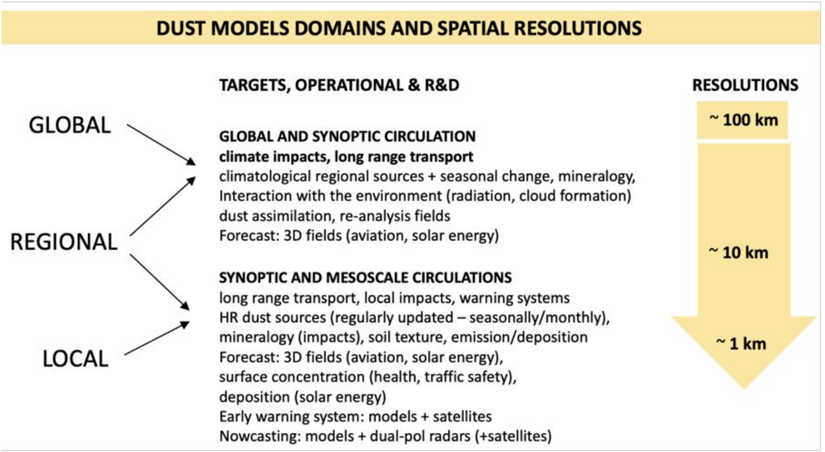
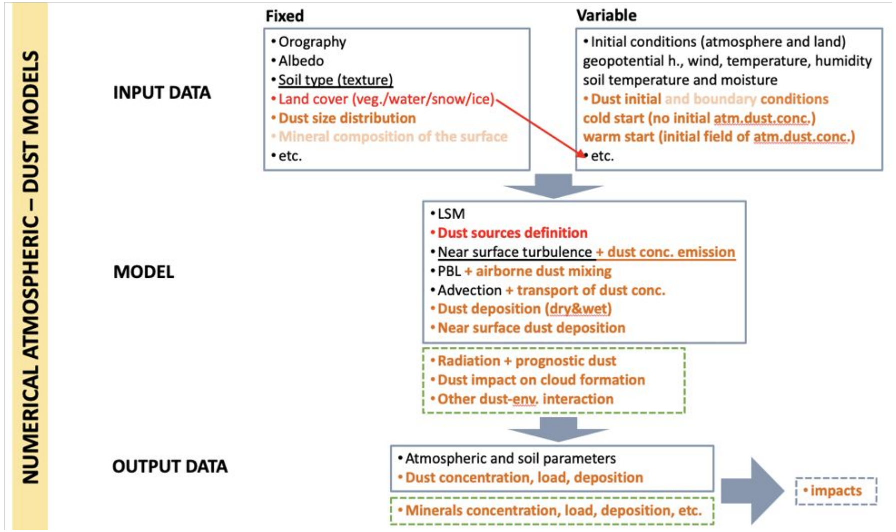
**Development of dust models has accelerated during the last two decades:**

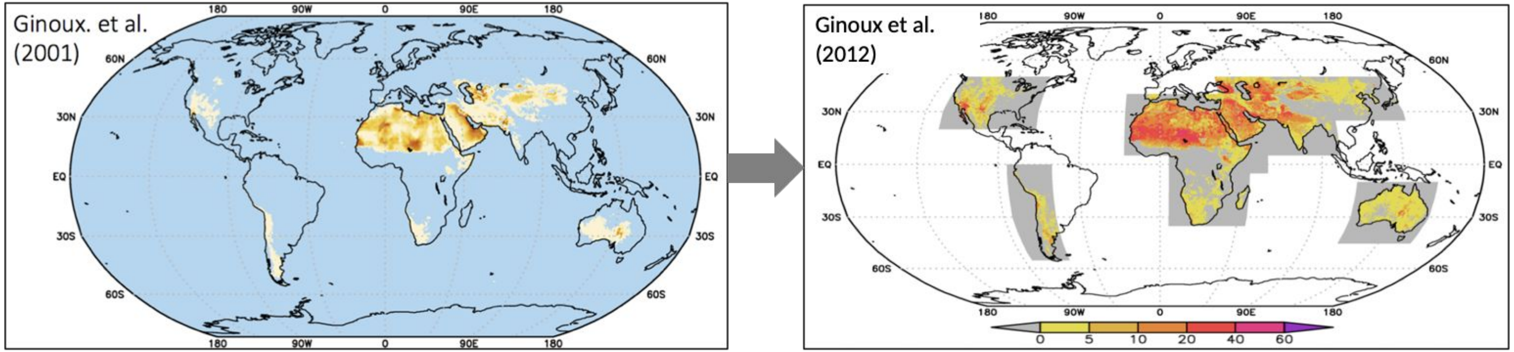
- more observations,
- **more available computer resources**,
- **larger modelling community** engaged in dust modelling,
- developed interdisciplinary collaboration,
- dust storms have been recognized as a global problem,
- **users** of the models products have been identified and introduced to dust modelling,
- dust related process are recognized as one with largest uncertainties in the assessments on climate levels.



Few more comments…

**Large contribution to modeling was implementation of global dust sources map based on Ginoux et al. (2001)**

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Percentage of Earth's land which can produce dust (UNCCD G-SDS-SBM)

| | Emissive surf. total | SDS productive |
|---|---|---|
| permanent | 21.6% | 7.7% |
| permanent + dynamical | 42.8% | **13.2%** |

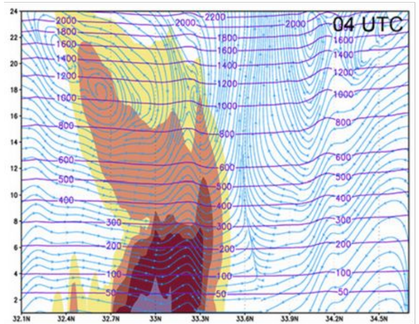
**High latitude dust belts!**

Meinander, O., et al.: Newly identified climatically and environmentally significant high-latitude dust sources, Atmos. Chem. Phys., 22, 11889–11930, https://doi.org/10.5194/acp-22-11889-2022, 2022.

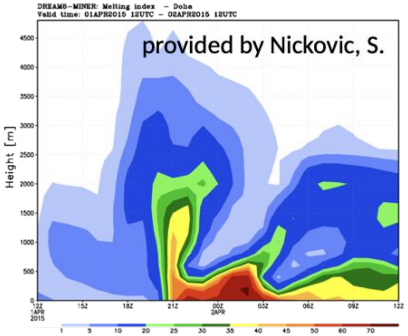
**Improvements in dust modeling led to:**

- development of **multi-model ensemble regional warning system**
- https://dust.aemet.es/products
- improved **understanding of dust – climate system interactions**
- increased capacities to develop **EWS for local severe events** (HR modeling)
- improvements in the **initialization of the dust forecast** (reanalysis)
- **recognition of gaps and priority actions** for futher improvements of dust forecast quality and of products.

HABOOB FORECASTING



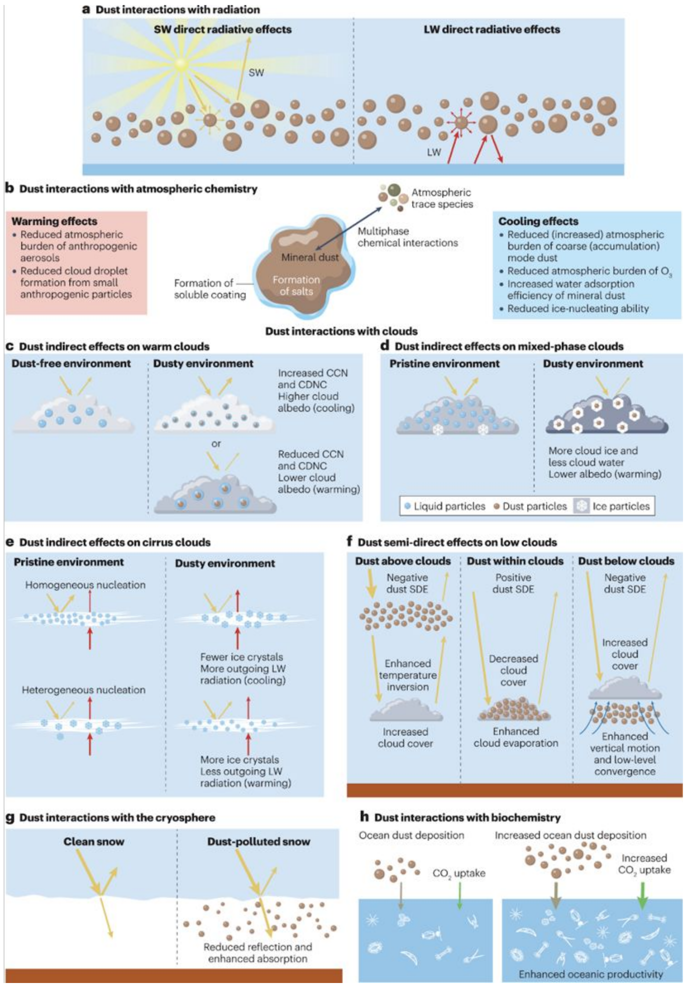

MELTING INDEX (AVIATION)




Vukovic, A., et al.: Numerical simulation of "an American haboob", Atmos. Chem. Phys., 14, 3211-3230, doi:10.5194/acp-14-3211-2014, 2014.

Kok, J.F., *et al.:* Mineral dust aerosol impacts on global climate and climate change, Nat Rev Earth Environ, https://doi.org/10.1038/s43017-022-00379-5, 2023.

DUST AND CLIMATE



# Aurelio Tobias

## Health

# Health effects

- **Health effects** are the changes in health status resulting from exposure to a given risk factor
  - **Short term effects –** Acute impact on health after an  immediate exposure (time-series studies)
  - **Long term effects** – Chronic health effect after a cumulative exposure (cohort studies)
- **Health impact assessment** is the evaluation of potential health effects of proposed actions relative to a given exposure to provide recommendations for decision-making process that will protect health

# Scoping review health effects

GeoHealth

REVIEW ARTICLE

10.1029/2022GH000728

## Effects of Desert Dust and Sandstorms on Human Health: A Scoping Review

**Kaung Suu Lwin[1], Aurelio Tobias[2,3], Paul Lester Chua[1], Lei Yuan[1], Ramita Thawonmas[1], Sophearen Ith[1], Zin Wai Htay[1], Lin Szu Yu[1], Lisa Yamasaki[1,4], Marta Roqué[5,6], Xavier Querol[2], Julia C. Fussell[7], Kari Christine Nadeau[8], Massimo Stafoggia[9], Najat A. Saliba[10], Chris Fook Sheng Ng[1], and Masahiro Hashizume[1]**

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**Key Points:**

- Desert dust and sandstorms are recurring environmental phenomena that are reported to produce serious health risks worldwide
- Inconsistencies in exposure definitions and modeling strategies may have contributed to the observed heterogeneity in the effect estimates
- Developing a standardized research protocol could be a vital step toward better assessing the association between desert dust and health

**Supporting Information:**

Supporting Information may be found in the online version of this article.

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**Citation:**

Lwin, K. S., Tobias, A., Chua, P. L., Yuan, L., Thawonmas, R., Ith, S., et al. (2023). Effects of desert dust and sandstorms on human health: A scoping review. *GeoHealth*, *7*, e2022GH000728. https://doi.org/10.1029/2022GH000728

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**Author Contributions:**

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**Data curation:** Kaung Suu Lwin, Paul Lester Chua, Lei Yuan, Ramita Thawonmas, Sophearen Ith, Zin Wai Htay, Lin Szu Yu, Lisa Yamasaki, Chris Fook Sheng Ng
**Formal analysis:** Kaung Suu Lwin, Paul Lester Chua, Lei Yuan, Sophearen Ith, Zin Wai Htay, Lin Szu Yu, Lisa Yamasaki, Chris Fook Sheng Ng
**Investigation:** Kaung Suu Lwin, Lei Yuan, Ramita Thawonmas



**Abstract** Desert dust and sandstorms are recurring environmental phenomena that are reported to produce serious health risks worldwide. This scoping review was conducted to identify the most likely health effects of desert dust and sandstorms and the methods used to characterize desert dust exposure from the existing epidemiological literature. We systematically searched PubMed/MEDLINE, Web of Science, and Scopus to identify studies that reported the effects of desert dust and sandstorms on human health. Search terms referred to desert dust or sandstorm exposure, names of major deserts, and health outcomes. Health effects were cross-tabulated with study design variables (e.g., epidemiological design and methods to quantify dust exposure), desert dust source, health outcomes and conditions. We identified 204 studies that met the inclusion criteria for the scoping review. More than half of the studies (52.9%) used a time-series study design. However, we found a substantial variation in the methods used to identify and quantify desert dust exposure. The binary metric of dust exposure was more frequently used than the continuous metric for all desert dust source locations. Most studies (84.8%) reported significant associations between desert dust and adverse health effects, mainly for respiratory and cardiovascular mortality and morbidity causes. Although there is a large body of evidence on the health effects of desert dust and sandstorms, the existing epidemiological studies have significant limitations related to exposure measurement and statistical analysis that potentially contribute to inconsistencies in determining the effect of desert dust on human health.

**Plain Language Summary** Desert dust and dust storms are recurring environmental phenomena and have been reported to cause serious health hazards worldwide. A scoping review was conducted of the existing epidemiological literature to identify and categorize the methods used to characterize desert dust exposure and the most likely health effects of desert dust and dust storms. We identified 204 studies that met the inclusion criteria for the scoping review. More than half (52.9%) of the studies employed time series and case-crossover study designs; 84.8% reported a significant association between desert dust and adverse health outcomes. Although most studies reported adverse health effects, existing studies have significant limitations in exposure measurement and statistical analysis, which may lead to inconsistencies in determining the health effects of desert dust.

### 1. Introduction

Desert dust and sandstorms are recurring environmental phenomena that are reported to produce serious health risks worldwide (Goudie, 2014; Shao et al., 2011). Because of the desertification caused by deforestation, climate change, and human activities, these phenomena have increased in frequency and intensity in a wide geographical area in recent years (United Nations Environment Programme, 2016). Desert dust and sandstorms play a significant role in weather, climate, and atmospheric chemistry. (De Longueville et al., 2010; Mahowald et al., 2010). Desert dust may be a serious hazard to the environment and human



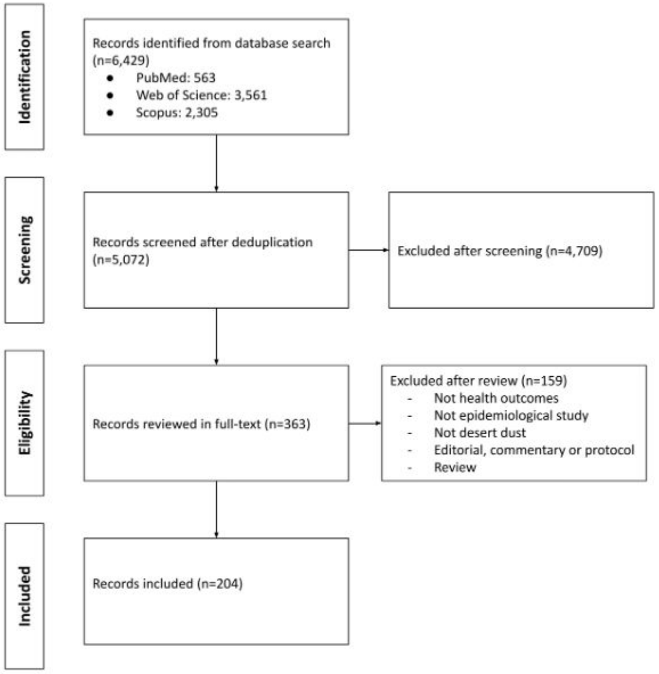



**Figure 1.** Flow chart of selected studies.

# Scoping review health effects

**Table 1**
*Descriptive Characteristics of Selected Studies (N = 204)*

| Characteristic | Number of studies | (%) |
|---|---|---|
| Desert dust source[a] | | |
| Asian | 107 | (52.2) |
| African | 58 | (28.3) |
| Arabian | 26 | (12.7) |
| American | 10 | (4.9) |
| Australian | 4 | (2.0) |
| Study design | | |
| Time-series | 108 | (52.9) |
| Case-crossover | 40 | (19.6) |
| Longitudinal or Cohort | 29 | (14.2) |
| Cross-sectional or Case-control | 24 | (11.8) |
| Other[b] | 3 | (1.5) |
| Health effect | | |
| Adverse | 173 | (84.8) |
| Non-significant | 29 | (14.2) |
| Protective | 1 | (0.5) |
| Not applicable | 1 | (0.5) |

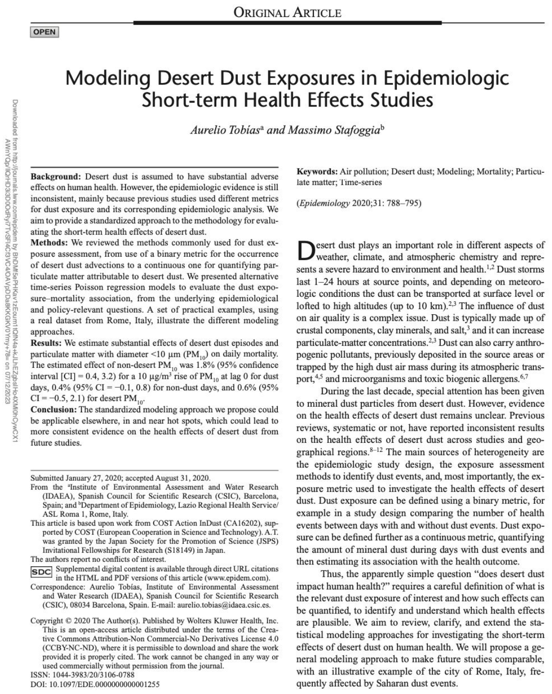
[a]One study examined both desert dust exposure from African and American sources. [b]Others include case reports ($n = 1$), experimental ($n = 1$), and quasi-experimental ($n = 1$) study designs.

**Table 5**
*Health Conditions Characteristics by Desert Dust Source*

| | Asian ($N = 158$) | | African ($N = 88$) | | Arabian ($N = 35$) | | American ($N = 13$) | | Australian ($N = 8$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Health condition[a] | *n* | (%) | *n* | (%) | *n* | (%) | *n* | (%) | *n* | (%) |
| Respiratory ($N = 121$) | 71 | (44.9) | 31 | (35.2) | 12 | (34.3) | 4 | (30.8) | 3 | (37.5) |
| Cardiovascular ($N = 65$) | 31 | (19.6) | 22 | (25.0) | 8 | (22.9) | 2 | (15.4) | 2 | (25.0) |
| All causes ($N = 38$) | 15 | (9.5) | 14 | (15.9) | 4 | (11.4) | 3 | (23.1) | 3 | (37.5) |
| Infectious diseases ($N = 18$) | 5 | (3.2) | 8 | (9.1) | 3 | (8.6) | 2 | (15.4) | 0 | (0.0) |
| Allergic skin and eye problems ($N = 17$) | 15 | (9.5) | 2 | (2.3) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| Cerebrovascular ($N = 10$) | 5 | (3.2) | 4 | (4.5) | 1 | (2.9) | 0 | (0.0) | 0 | (0.0) |
| Adverse birth outcomes ($N = 7$) | 1 | (0.6) | 3 | (3.4) | 2 | (5.7) | 1 | (7.7) | 0 | (0.0) |
| Allergic diseases ($N = 5$) | 4 | (2.5) | 0 | (0.0) | 1 | (2.9) | 0 | (0.0) | 0 | (0.0) |
| Health related quality of life ($N = 4$) | 4 | (2.5) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| Under-5 mortality ($N = 3$) | 1 | (0.6) | 3 | (3.4) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| Accidents and injuries ($N = 3$) | 0 | (0.0) | 0 | (0.0) | 2 | (5.7) | 1 | (7.7) | 0 | (0.0) |
| Maternity and reproduction ($N = 3$) | 1 | (0.6) | 1 | (1.1) | 1 | (2.9) | 0 | (0.0) | 0 | (0.0) |
| Mental health ($N = 2$) | 2 | (1.3) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| Diabetes ($N = 1$) | 1 | (0.6) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| School absence due to sickness ($N = 1$) | 1 | (0.6) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) | 0 | (0.0) |
| Not specified ($N = 2$) | 1 | (0.6) | 0 | (0.0) | 1 | (2.9) | 0 | (0.0) | 0 | (0.0) |

[a]Categories are not mutually exclusive.

# Modelling short-term health effects



ORIGINAL ARTICLE

OPEN

## Modeling Desert Dust Exposures in Epidemiologic Short-term Health Effects Studies

*Aurelio Tobías*[a] *and Massimo Stafoggia*[b]



**Background:** Desert dust is assumed to have substantial adverse effects on human health. However, the epidemiologic evidence is still inconsistent, mainly because previous studies used different metrics for dust exposure and its corresponding epidemiologic analysis. We aim to provide a standardized approach to the methodology for evaluating the short-term health effects of desert dust.

**Methods:** We reviewed the methods commonly used for dust exposure assessment, from use of a binary metric for the occurrence of desert dust advections to a continuous one for quantifying particulate matter attributable to desert dust. We presented alternative time-series Poisson regression models to evaluate the dust exposure–mortality association, from the underlying epidemiological and policy-relevant questions. A set of practical examples, using a real dataset from Rome, Italy, illustrate the different modeling approaches.

**Results:** We estimate substantial effects of desert dust episodes and particulate matter with diameter <10 μm ($PM_{10}$) on daily mortality. The estimated effect of non-desert $PM_{10}$ was 1.8% (95% confidence interval [CI] = 0.4, 3.2) for a 10 μg/m³ rise of $PM_{10}$ at lag 0 for dust days, 0.4% (95% CI = −0.1, 0.8) for non-dust days, and 0.6% (95% CI = −0.5, 2.1) for desert $PM_{10}$.

**Conclusion:** The standardized modeling approach we propose could be applicable elsewhere, in and near hot spots, which could lead to more consistent evidence on the health effects of desert dust from future studies.

**Keywords:** Air pollution; Desert dust; Modeling; Mortality; Particulate matter; Time-series

(*Epidemiology* 2020;31: 788–795)

Desert dust plays an important role in different aspects of weather, climate, and atmospheric chemistry and represents a severe hazard to environment and health.[1,2] Dust storms last 1–24 hours at source points, and depending on meteorologic conditions the dust can be transported at surface level or lofted to high altitudes (up to 10 km).[2,3] The influence of dust on air quality is a complex issue. Dust is typically made up of crustal components, clay minerals, and salt,[3] and it can increase particulate-matter concentrations.[2,3] Dust can also carry anthropogenic pollutants, previously deposited in the source areas or trapped by the high dust air mass during its atmospheric transport,[4,5] and microorganisms and toxic biogenic allergens.[6,7]

During the last decade, special attention has been given to mineral dust particles from desert dust. However, evidence on the health effects of desert dust remains unclear. Previous reviews, systematic or not, have reported inconsistent results on the health effects of desert dust across studies and geographical regions.[8–12] The main sources of heterogeneity are the epidemiologic study design, the exposure assessment methods to identify dust events, and, most importantly, the exposure metric used to investigate the health effects of desert dust. Dust exposure can be defined using a binary metric, for example in a study design comparing the number of health events between days with and without dust events. Dust exposure can be defined further as a continuous metric, quantifying the amount of mineral dust during days with dust events and then estimating its association with the health outcome.

Thus, the apparently simple question "does desert dust impact human health?" requires a careful definition of what is the relevant dust exposure of interest and how such effects can be quantified, to identify and understand which health effects are plausible. We aim to review, clarify, and extend the statistical modeling approaches for investigating the short-term effects of desert dust on human health. We will propose a general modeling approach to make future studies comparable, with an illustrative example of the city of Rome, Italy, frequently affected by Saharan dust events.

Submitted January 27, 2020; accepted August 31, 2020.

From the [a]Institute of Environmental Assessment and Water Research (IDAEA), Spanish Council for Scientific Research (CSIC), Barcelona, Spain; and [b]Department of Epidemiology, Lazio Regional Health Service/ASL Roma 1, Rome, Italy.

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The authors report no conflicts of interest.

SDC Supplemental digital content is available through direct URL citations in the HTML and PDF versions of this article (www.epidem.com).

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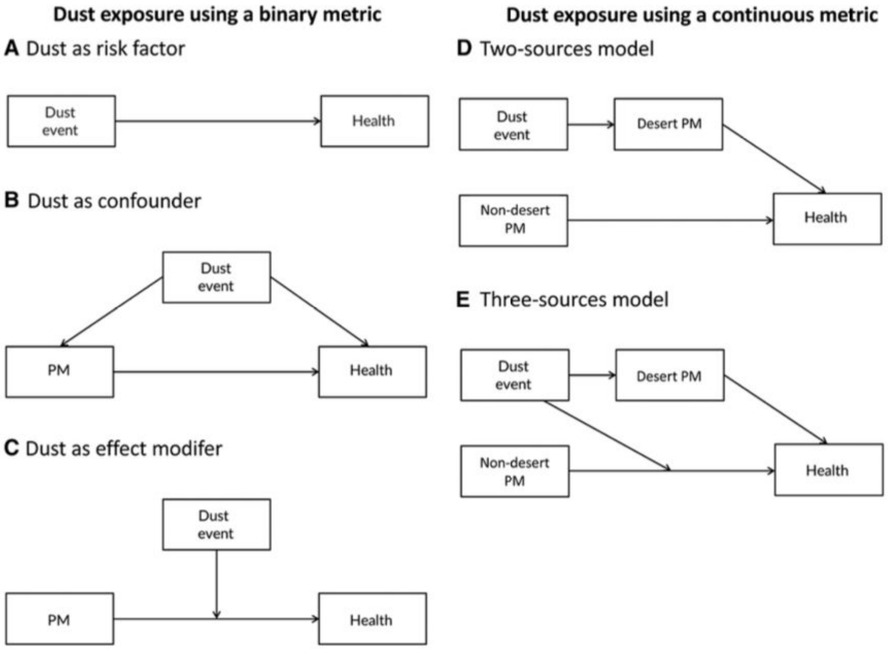


**FIGURE 1.** DAGs for the dust-health association considering dust exposure as binary metric (left panel) and as continuous metric (right panel). PM indicates particulate matter.

# Stelios Kazadzis

## Solar radiation

# Dust/aerosol effects on solar energy

Stelios Kazadzis,
Physical and Meteorological Observatory of Davos,
World Radiation Center, Switzerland

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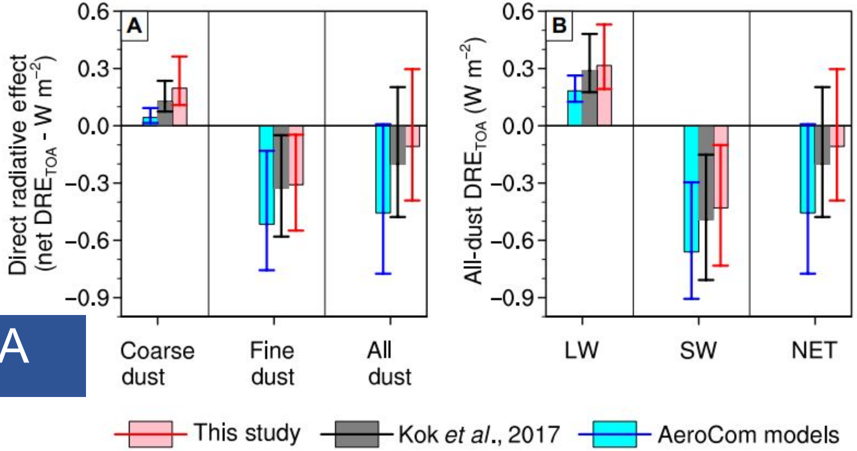
SEVENTY-SEVENTH SESSION, 77TH MEETING (AM) GA/12508
8 JUNE 2023

**General Assembly Proclaims 12 July International Day of Combating Sand and Dust Storms, Aiming to Raise Awareness about Importance for Health, Sustainability**

- Dust effects on earth-atmosphere radiative balance
- Solar radiation attenuation – solar energy fluctuations
- Soiling – dust deposition
- Horizontal attenuation in dusty environment
- Solar radiation/energy forecasting

# Dust effects on earth-atmosphere radiative balance

**Dust size** **SW-LW-NET**

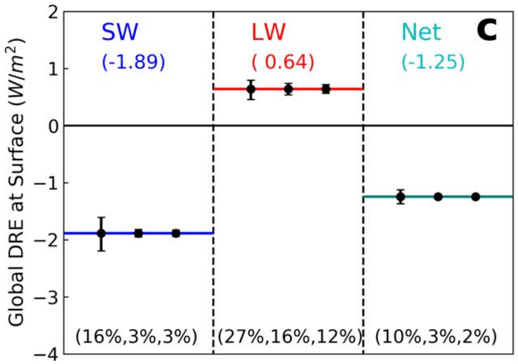



TOA

**Adebiyi and Kok, 2022**

- Taking into account coarse dust (D>5 μm) results in warming at TOA
- More coarse dust for the same AOD □ more warming due to (more) coarse/less cooling due to (less) fine particles
- More warming in the LW/less cooling in the SW □ less cooling (within uncertainty limits)

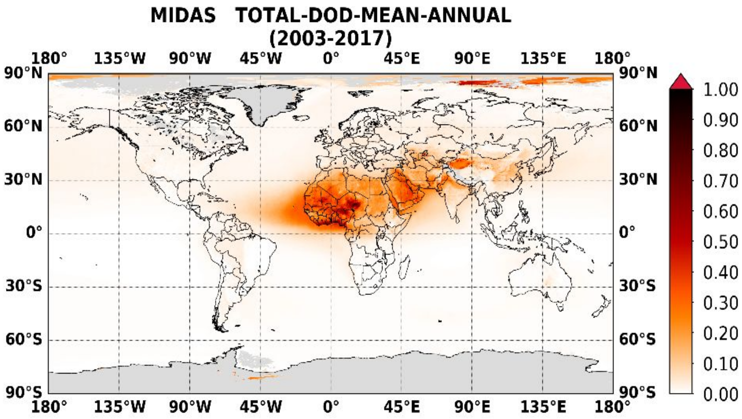
Surface



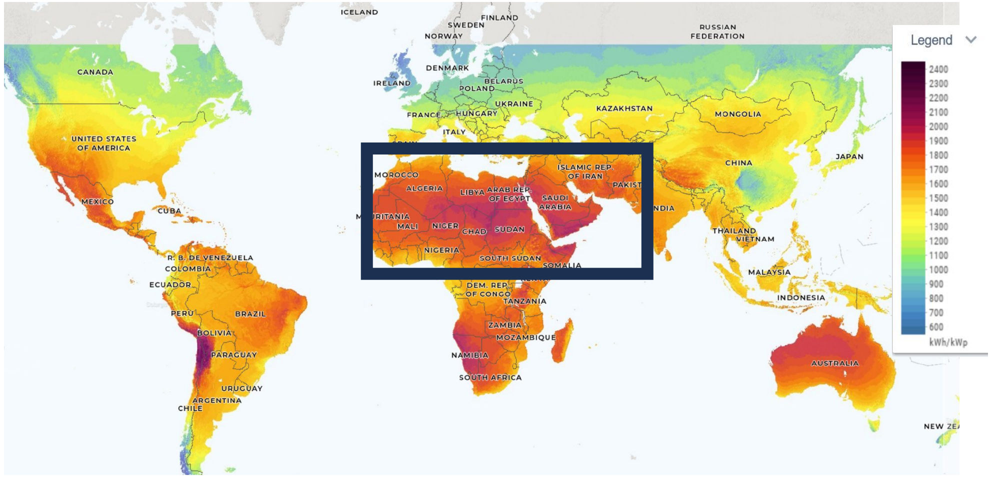

- **Song et al.** estimated that the greatest factor of uncertainty in the DRE estimation is the used RI, i.e. the composition of dust
- Dust size also plays an important role
- Uncertainties due to shape are less significant

# Solar radiation/ energy

## Global solar potential and dust areas




Average dust optical depth from Gkikas et al., 2021




Global Horizontal irradiance yearly potential
World bank global solar atlas

"Solar panels covering 1.2% surface of Sahara is enough to power the world"

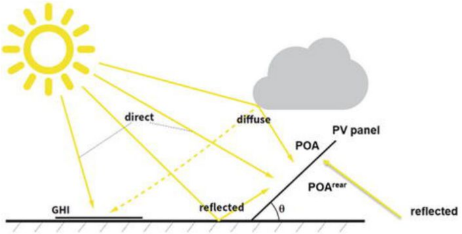
# Technologies for solar energy

**Surface solar radiation used for solar-based energy production**
**Different components**

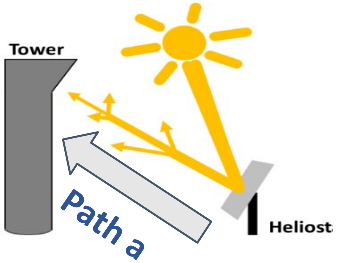


**Global Horizontal Irradiance or Global in tilted surface (PV)**

**Direct Normal Irradiance (CSP)**




- **DNI much more affected by aerosols**
- **Mirror to tower: horizontal attenuation (Path a)**

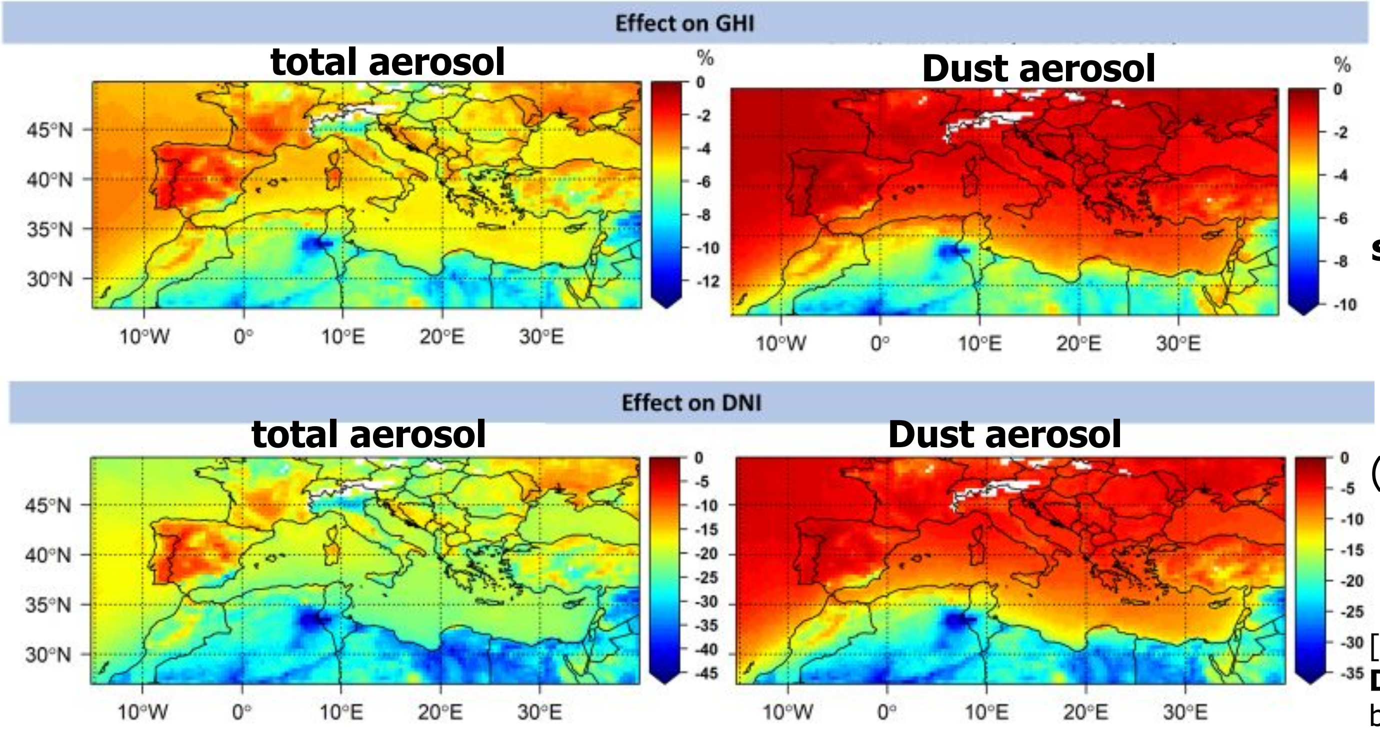


# Long-term aerosol direct radiative effects 15-year climatology (2003-2017)

<u>1–**13**% annual GHI attenuation</u>

<u>(5–**47**% for DNI)</u>

<u>[0.05 to 0.48 mean **AOD**, **MODIS** AOD retrievals]</u>




up to **10%** GHI attenuation attributed **solely to dust**

(up to **37%** for DNI)

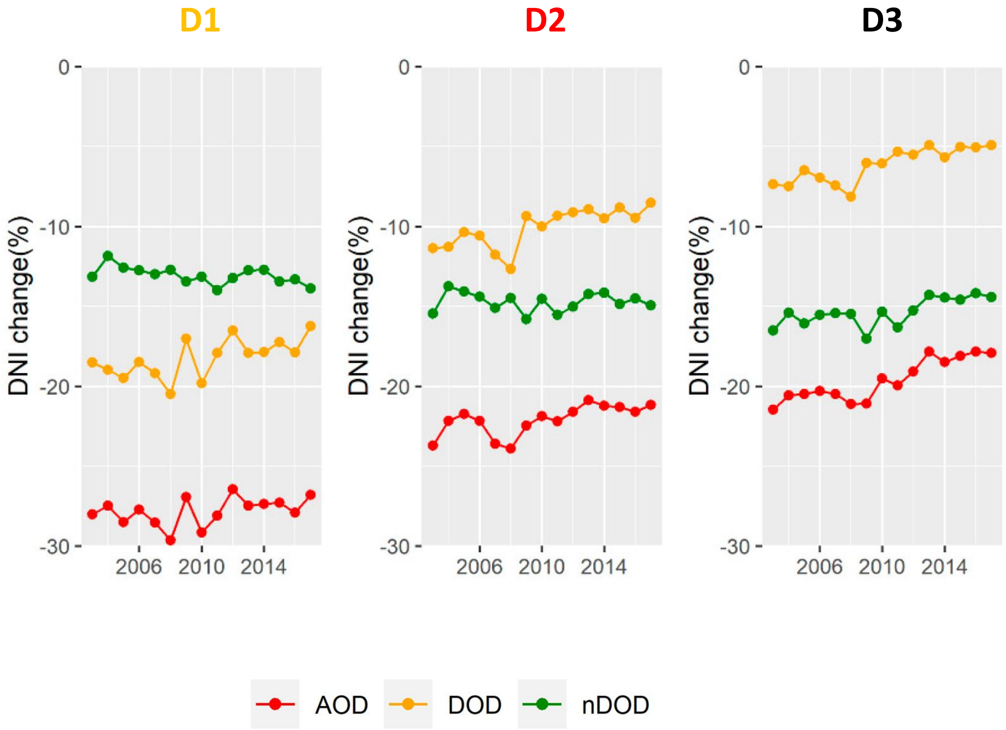
[up to 0.35 mean **DOD**, Satellite based ModIs Dust Aerosol (**MIDAS**) *(Gkikas et al. 2021)*]

**Significant role of SSA** in calculating the radiative effects of aerosols.

*Papachristopoulou et al. (2022)*

# Interannual variability of the radiative impacts

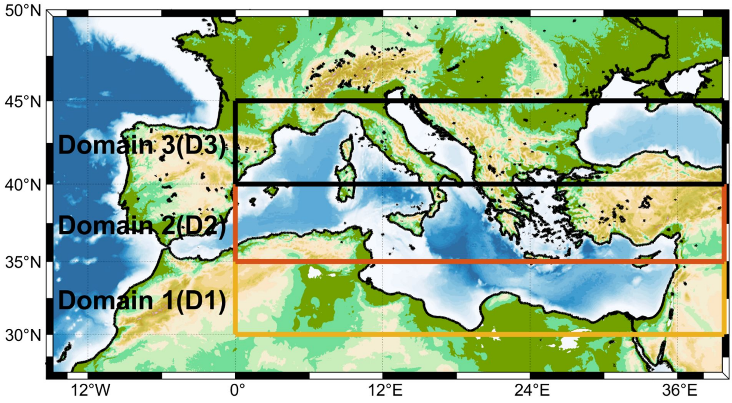
**15-year climatology (2003-2017)**




Dust aerosol effect

Other aerosols effect

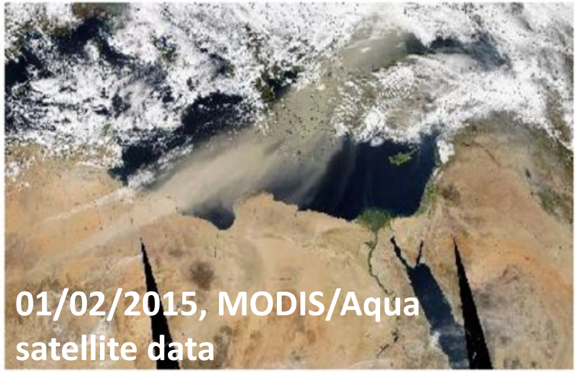
Total aerosol effect



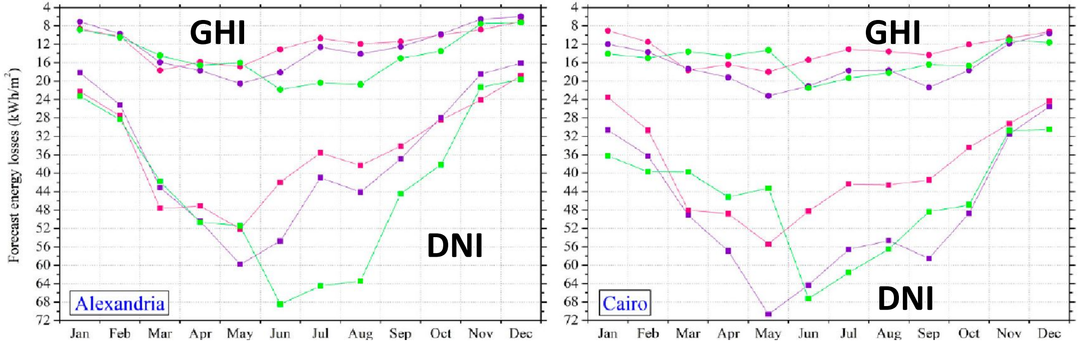

*Papachristopoulou et al. (2022)*

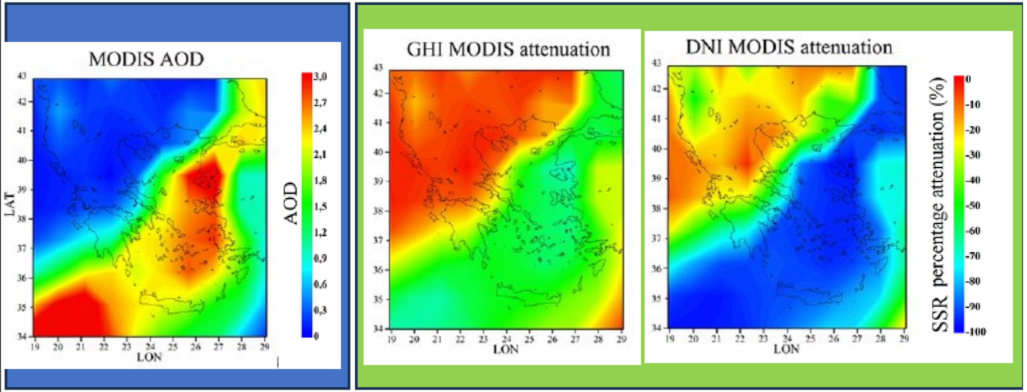
# Solar attenuation by dust episodes

# Losses to financial aspects

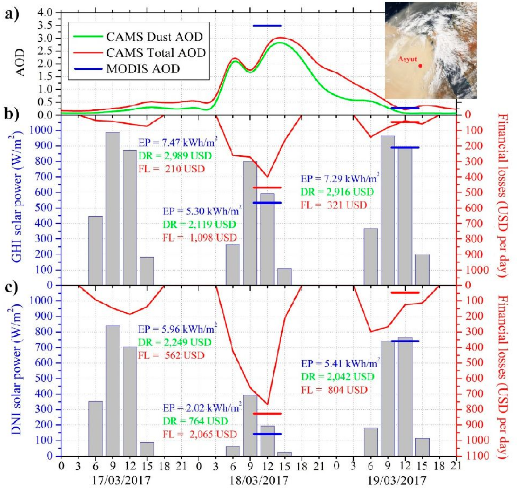



**Energy loss for Alexandria and Cairo for GHI and DNI**



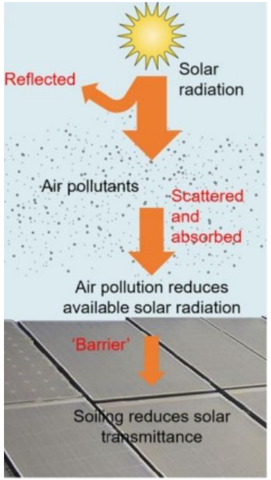




Kosmopoulos et al., 2018




**Economic impact for a 3 day dust episode**

# Soiling – dust deposition

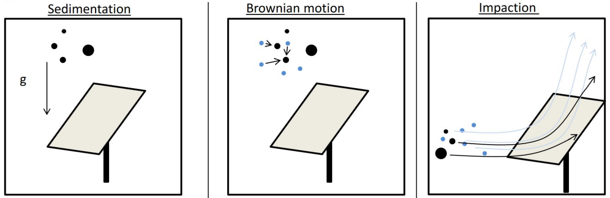




Zhe Song et al., 2021

## DLR's Soiling model: main deposition mechanisms

Model is based on atmospheric aerosol transport literature
Particle deposition there is characterized by the **deposition velocity** towards the ground – not the collector!




- Gravitation

$$v_S = \sin(mirr_{el})\left(\frac{d_p^2 \cdot g \cdot (\rho_{aerosol} - \rho_{air})}{18 \cdot \eta_{air}}\right)$$

- Thermal motion

$$v_B = \alpha_{Brown} \cdot u_{wind}\left(\frac{\frac{v_{air}}{k_B \cdot T}}{3 \cdot \pi \cdot \eta_{air} d_p}\right)^{-\gamma}$$

- Air stream/wind

$$v_{Im} = \alpha_{Im}\left(\frac{\sigma_{orientation} u_{wind}}{1 + \exp(-f_{Im}(St - 1))}\right)$$

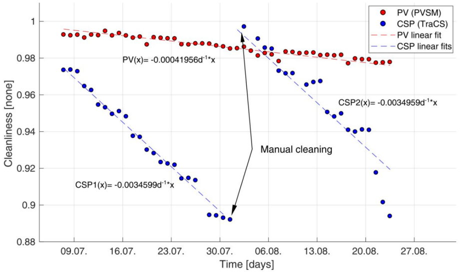
$$v_D = v_S + v_B + v_{Im}$$

**Also considered**: Rebound, resuspension, rain washing, cementation, mirror/panel orientation

N. Hanrieder - DLR, presentation in InDust

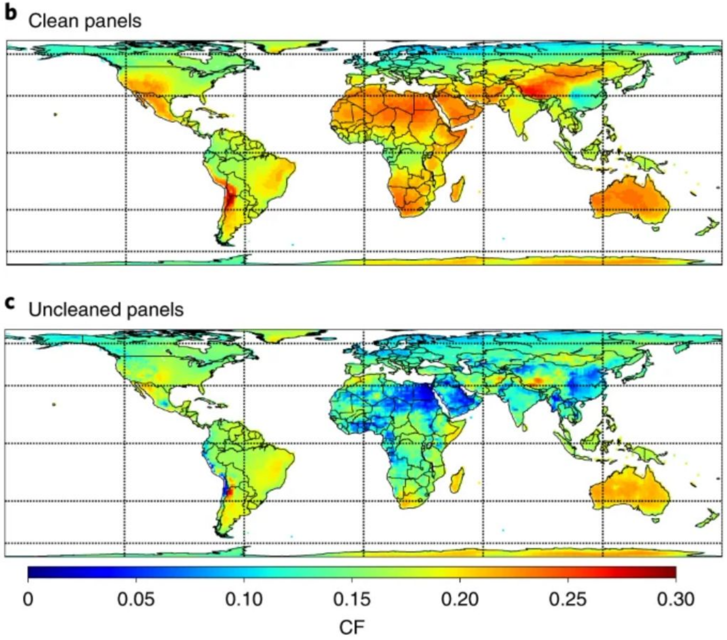
## Soiling for CSP and PV collectors

Parallel measurements of PV and CSP soiling




Source: Bellmann et al. (2020). 2020. Comparative modeling of optical soiling losses for CSP and PV energy systems. Solar Energy 197, 229–237

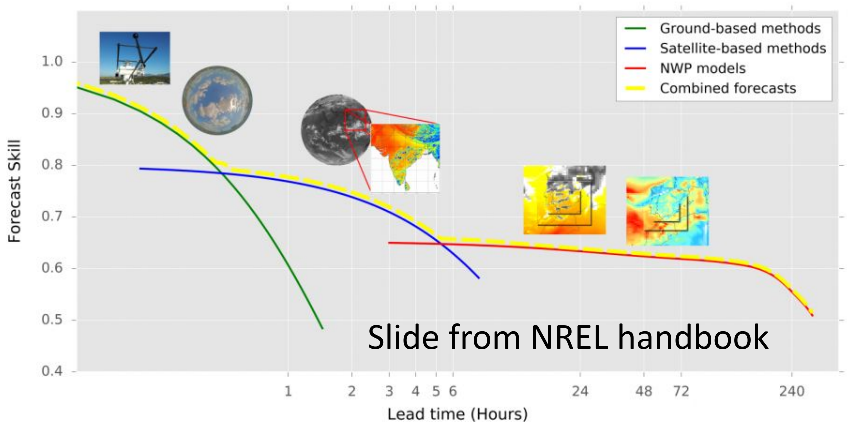
→ CSP soiling rate approx. **8-9 times higher** than PV (0.35%/d and 0.04%/d in Evora, Portugal)




2003-2014 : CF = the actual annual generation divided by the total generation that would occur if the PV panels generated electricity at the nameplate capacity all year round.

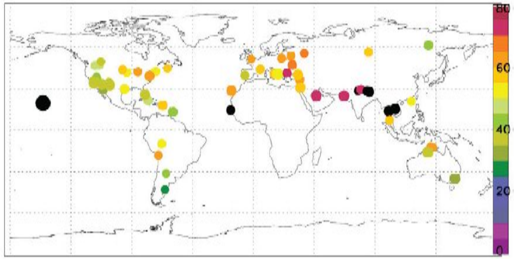
C. Li et al., 2020

# Solar radiation forecasting and aerosols

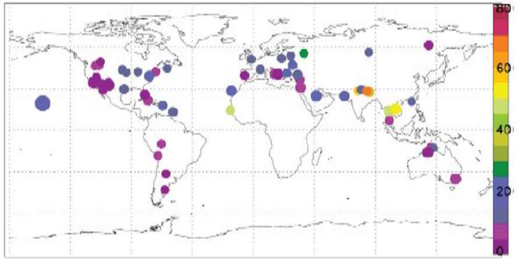



25-48 hours forecast from ECMWF/MACC compared with AERONET

% of hours with DNI deviation > 5%



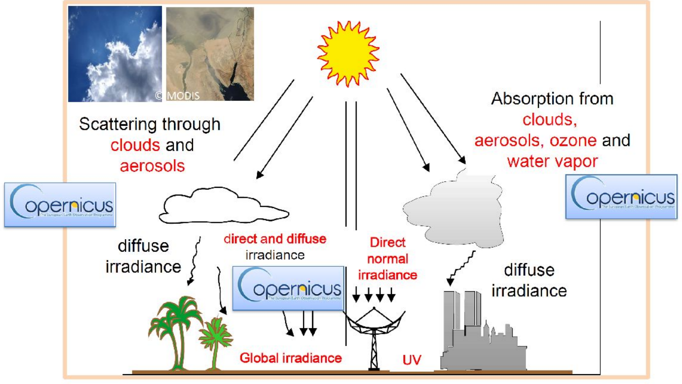

% of hours with DNI deviation > 20%

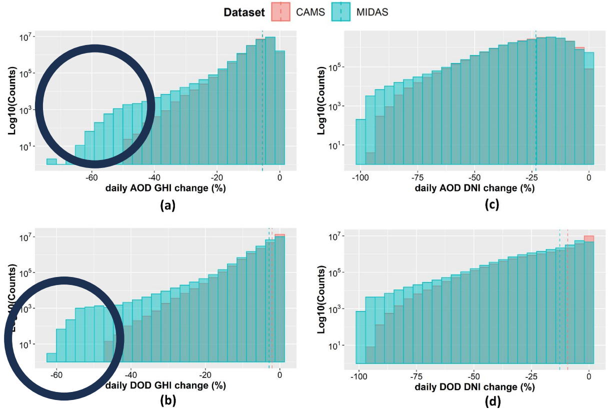



Marion Schroedter-Homscheidt et al., 2013

## CAMS aerosols forecasting

The CAMS McClear and CAMS Radiation services




Papachristopoulou et al., 2022

# Dust/aerosol effects on solar energy

United Nations | Meetings Coverage and Press Releases

Home | Secretary-General | General Assembly | Security Council | Economic and Social Council | International Court of Justice

MEETINGS COVERAGE
GENERAL ASSEMBLY » PLENARY

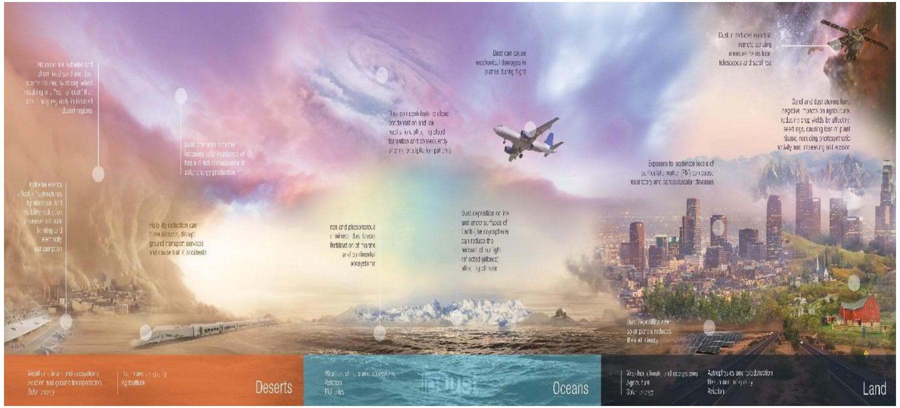
SEVENTY-SEVENTH SESSION, 77TH MEETING (AM) — GA/12508, 8 JUNE 2023

**General Assembly Proclaims 12 July International Day of Combating Sand and Dust Storms, Aiming to Raise Awareness about Importance for Health, Sustainability**

# Thank you

inDust

HARMONIA




Stelios Kazadzis,
Physical and Meteorological Observatory of Davos,

# Lucia Mona

## Users experience

# Interaction with users


- Differences in the scientific communities (vocabulary, approach etc)
- Variety of user community groups (different needs, different languages, education, culture…)
- Often Scientific vs User communities did not know each other
- Separate communities even with specific needs and approaches depending on the Country/Region

# Interaction with users

**How to tackle such issues?**

expertize gained during **InDust**
https://cost-indust.eu

- Wide group of people involved in user connection activities
- Sharing and distributing the work
- Strong link with dissemination activities

Key Actions towards the users:

1. Identifying potential users
2. Understanding how much users know about scientific capabilities?
3. Collecting user requirements
4. Go back to science for tailoring products
5. Check user satisfaction level

# Interaction with users

## Means

- 1-1 interactions
- Workshops

## Actions

- showing different user oriented solutions
- discussing gaps
- brainstorming for new ideas
- further tailoring actions

# DUST IMPACTS ON AVIATION


## Mechanical problems

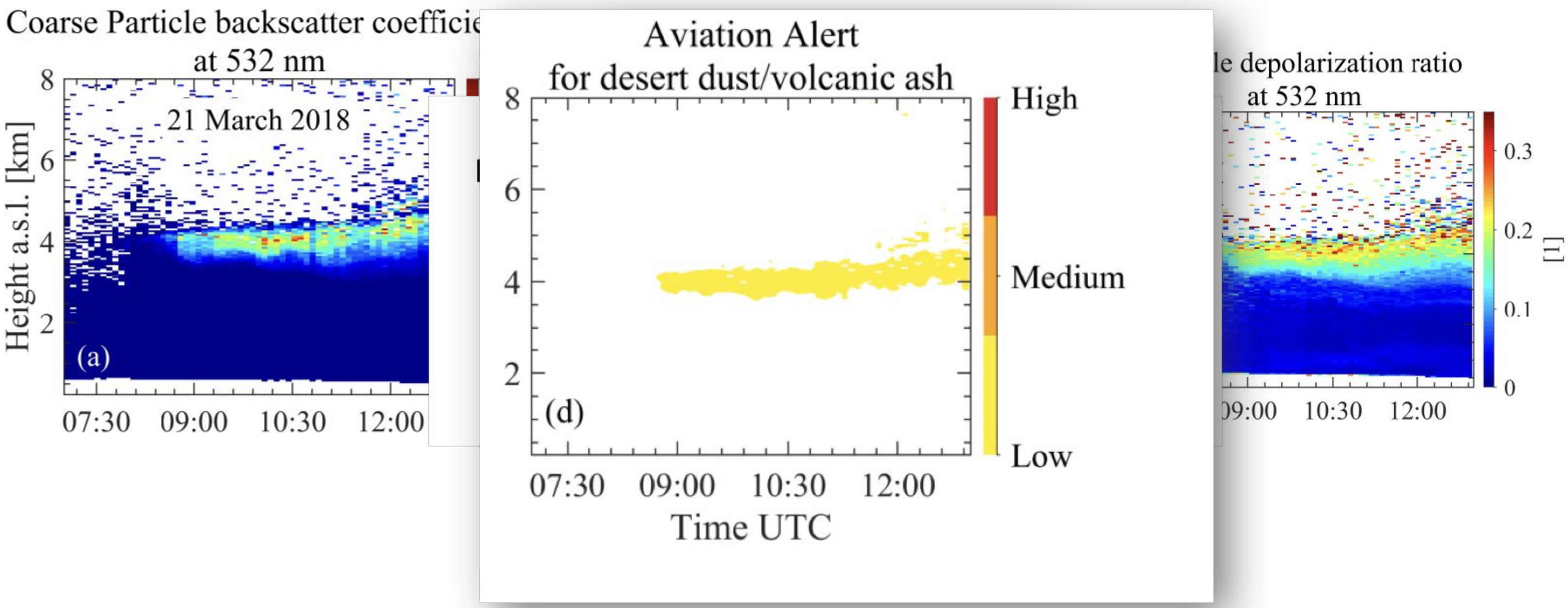
- Ice nucleation
- Dust melting in turbines
- Turbine abrasion

## Reduction of visibility

- Closing airports / Traffic management ⟶Rerouting and cancellations
- Disturbances in airport operations

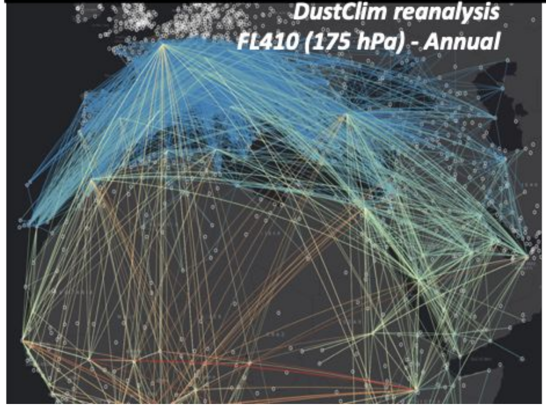
# Aviation
# Tailored product

The EARLINET/ACTRIS dust/ash alerting system
based on High resolution profiles and depolarization capability



# Aviation
# Tailored product

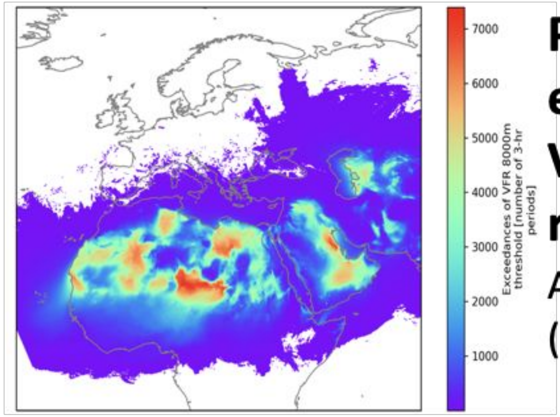
## AIRCRAFT SAFETY




**Aircraft Dust Exposure at Cruise level**

Annual average (2007-2016)

## TRAFFIC MANAGEMENT




**Probability of exceedance of Visual Flight rules (> 8km)**

Annual probability (2007-2016)

Results based on the Dustclim regional reanalysis (2007-2016)

**Votsis et al., FMI's Climate Bulletin: Research Letters**

# Carlos Pérez García-Pando and Pavla Dagsson-Waldhauserová

## Challenges and emerging topics

# MAJOR GENERAL CHALLENGES

- ***Poor understanding of some key physical processes controlling dust aerosols and their effects at multiple spatial and temporal scales,***

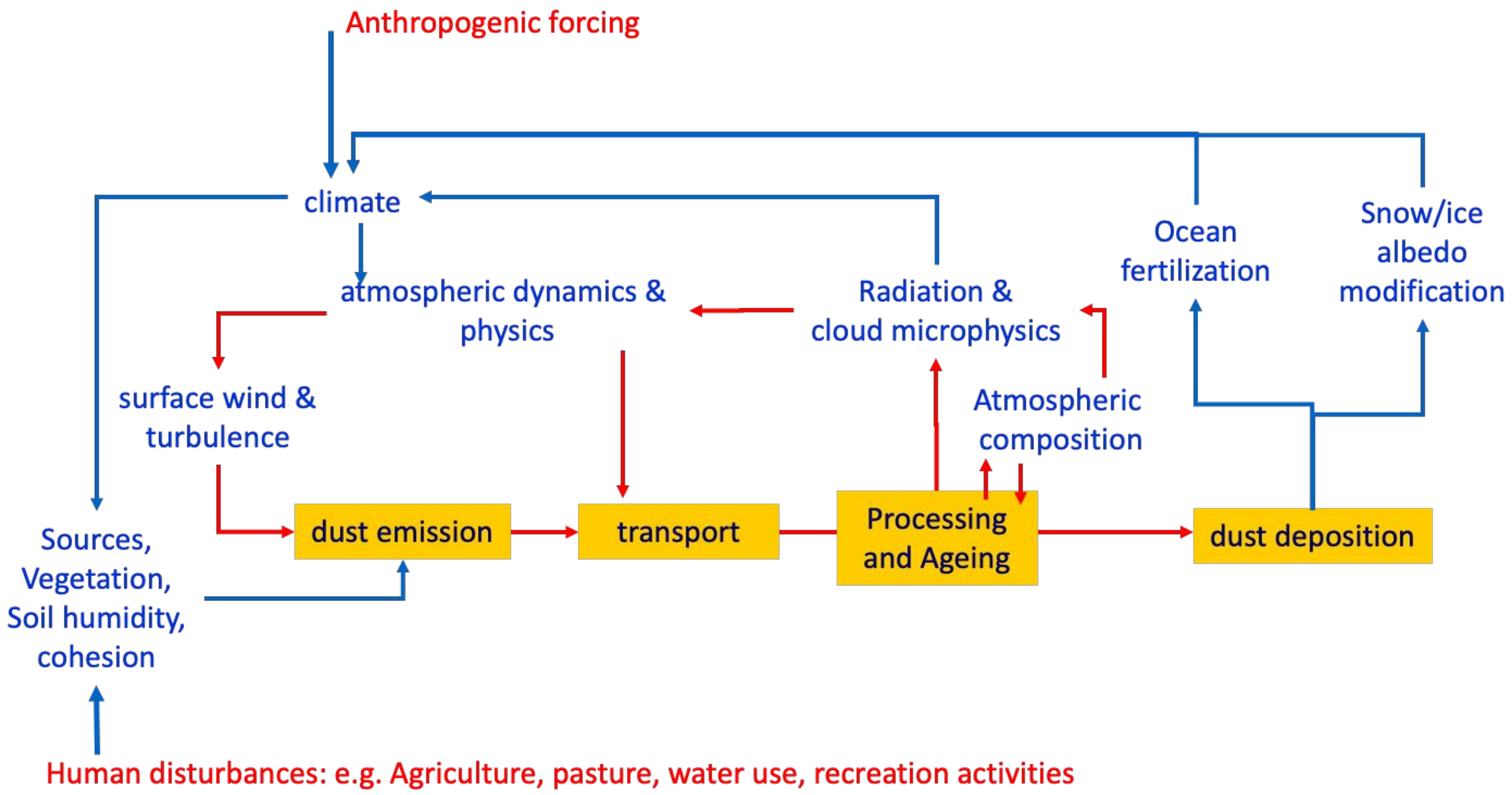
- ***Lack of reliable dust information in many countries affected by SDS,***

- ***Large uncertainties of current SDS forecasts on time scales from days to a week,***

- ***Severe lack of knowledge and capabilities for long-range dust prediction and projections (from months to decades to centuries),***

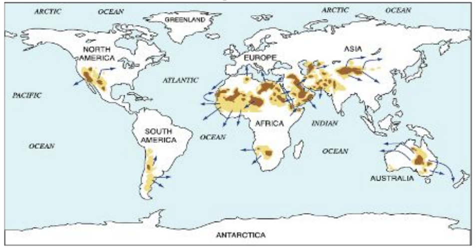
- ***Limited integration of dust information and forecasts into practice and policy.***

# Constraining the dust cycle and its effects upon climate remains a key challenge in many aspects

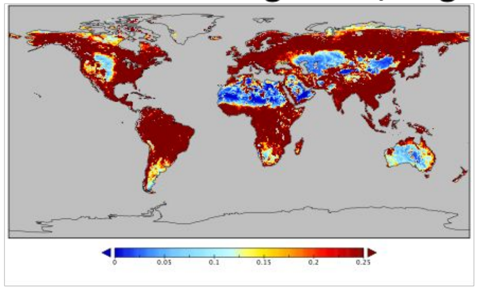


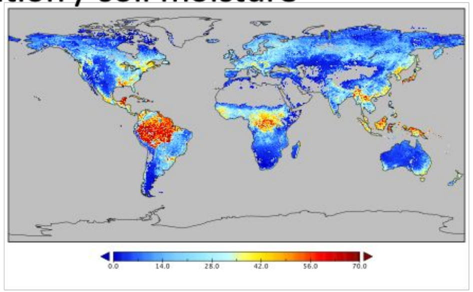
# Examples of key modeling challenges in representing the dust cycle and its effects

## Sources / emission

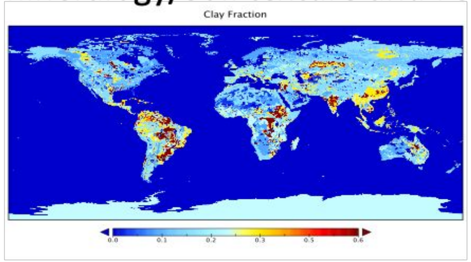



## Roughness / vegetation / soil moisture

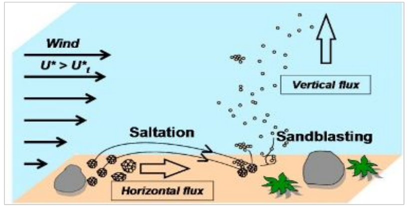



## mineralogy/Soil texture and PSD

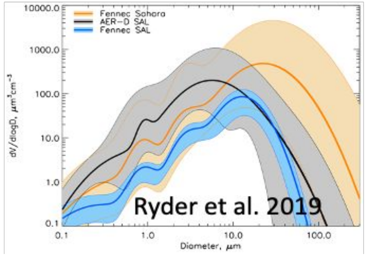



## Size-distributed dust emission

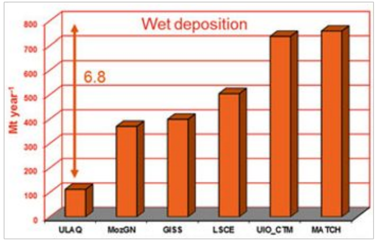



## Wind gusts/haboobs

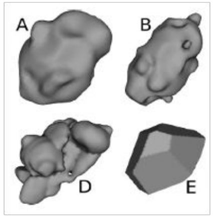
## Coarse dust



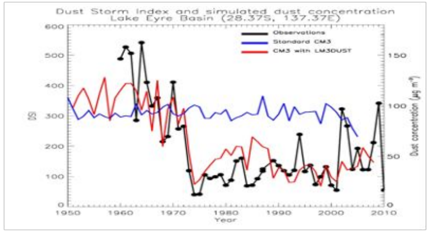

## Deposition

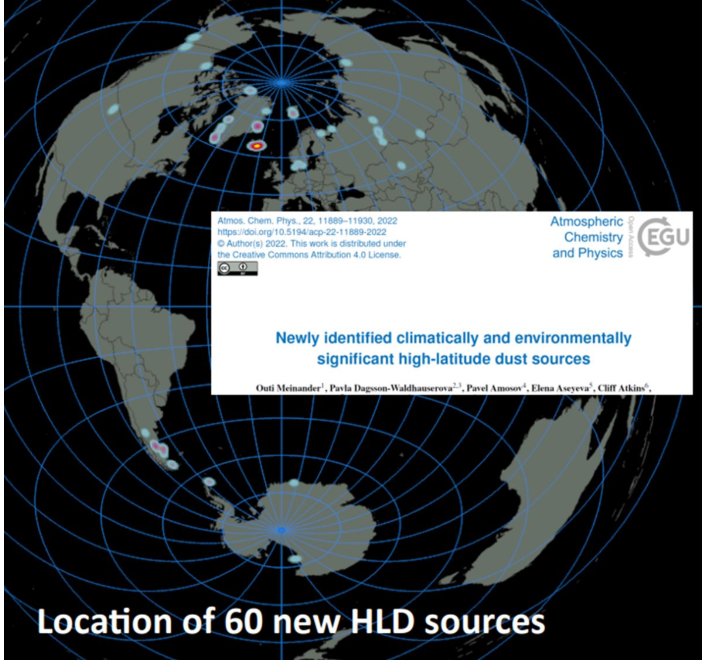


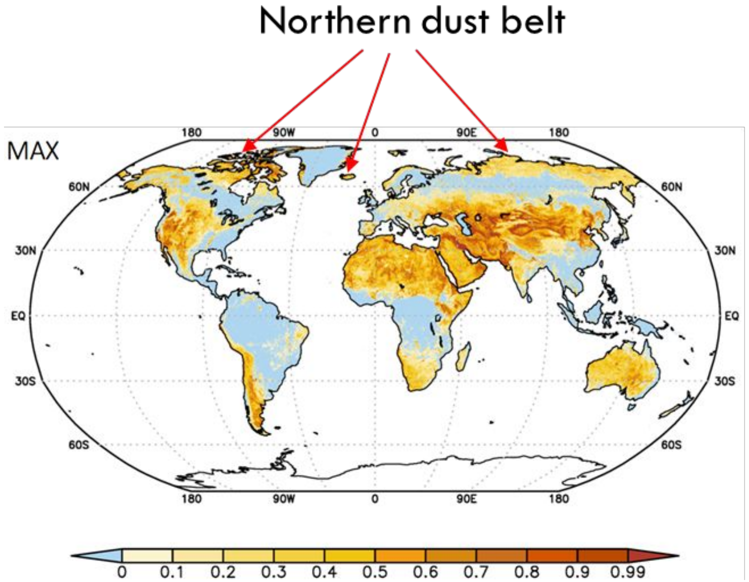

## Shape/optical properties




## Long term variability






High Latitude Dust networks (active today):

•IceDust – Icelandic Aerosol and Dust Association (European Aerosol Assembly)

•UArctic Thematic Network on HLD

HLD forecasting: DREAM_Iceland, SILAM

HLD in-situ observations: Iceland, Canada, Greenland, Antarctica (Alaska, Svalbard, Patagonia, New Zealand)

# Mark Parrington

# Q&A