Icelandic dust forecasting

Slobodan Nickovic

Republic Hydrometeorological Service of Serbia (RHMSS)

With contributions of:

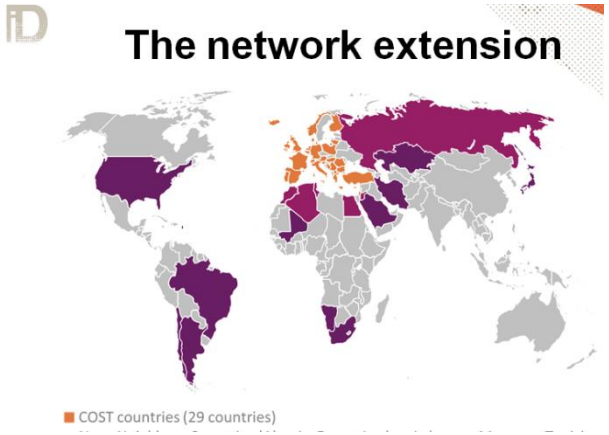
- ***Belgrade DREAM team (RHMSS, U of Belgrade)***
- ***Agricultural U of Iceland, Reykjavik***
- ***NOA, Athens***
- ***CNR, Potenza***
- ***C-CAPS, Mace Head***
- ***Czech Academy of Sciences, Prague***

COST inDust

(International Network to Encourage the Use of Monitoring and Forecasting Dust Products)

Major objectives

- ❑Establish a **network** of research institutions, service providers, and end-users of information on airborne dust.
- ❑Exploit dust monitoring **observations** best suited to needs of end-users.
- ❑Exploit **dust forecast** products best suited to needs of end-users.
- ❑**Coordinate** R&D to assist socio-economic sectors affected by dust.



WMO SDS-WAS

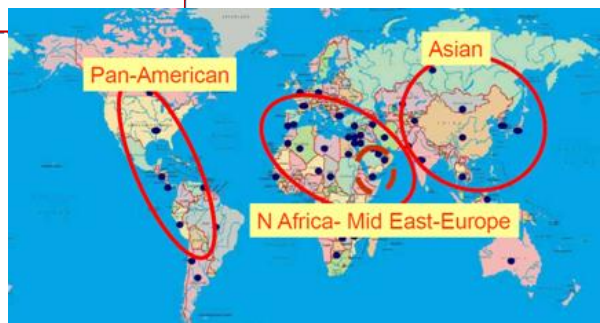
(Sand and Dust Storm Warning Advisory and Assessment System)

Mission

To enhance the ability of countries to deliver timely and quality sand and dust storm forecasts, observations, information and knowledge to users through an international partnership

SDS-WAS components:

- Warning Advisory
  - monitoring/observing
  - forecasting
  - advising on warnings
- Assessment
  - reanalysis
  - sub-seasonal forecasts
  - cimate change projections; trends



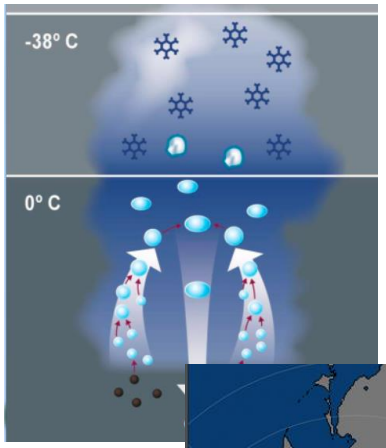
Icelandic dust: basic facts

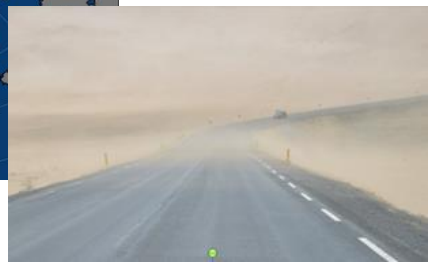
- 130 DUSTY DAYS
- TOTAL EMISSIONS: 30.5-40.1 MILLION T
- OCEAN DEPOSITION: 5.5-13.8 MILLION T
- CALCULATED IRON DEPOSITION: 0.56-1.4 MILLION T

Icelandic dust-atmosphere modeling

Why Icelandic dust model?

- No fully dynamic (Eulerian) prognostic dust model for Iceland in the community
- Purpose: to provide
  - daily dust forecasts
  - studying dust impacts to
    - ❑ Ocean, cryosphere
    - ❑ Cold cloud formation
    - ❑ High-lat-dust (HLD) climate
    - ❑ Local AQ and transport





- **inDust and WMO SDS-WAS have included HLD as a research objective**
- **the newest IPCC statement: dust an important forcer for the HL climate**

Modeling challenges

- Small-scale dust sources
- Volcanic dust origin
- HLD specific thermodynamics
- Larger particle sizes
- Unique dust mineralogy
- Unsufficient observations for model validations

Existing Icelandic dust modeling facilities

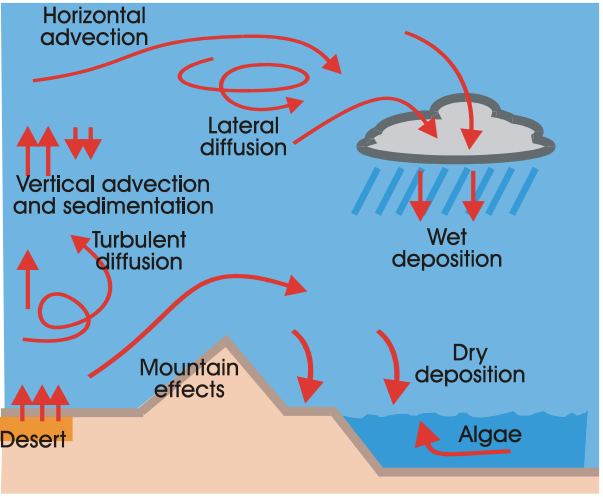
Model	Lagrang/Euler	Offline/Online	Atm driver	Forercasting status
UKMO NAME	Lagrangean	Offline	UK NWP model	/
University of Oslo	Lagrangean	Offline	NCAR WRF-ARW	/
SILAM FHMI	Euler	Online	HIRLAM	/
Iceland Met Office	Euler	Online	WRF-CHEM	/
DREAM	Euler	Online	NCEP NMM	operational
HiLDA **TU Darmstadt**	Euler	?	?	/

A potential to establish a future multi-model forecasting page at WMO SDS-WAS site for Icelandic dust models

DREAM-Iceland model*

*The study to be soon submitted for publication (Cvetkovic et al, 2021)

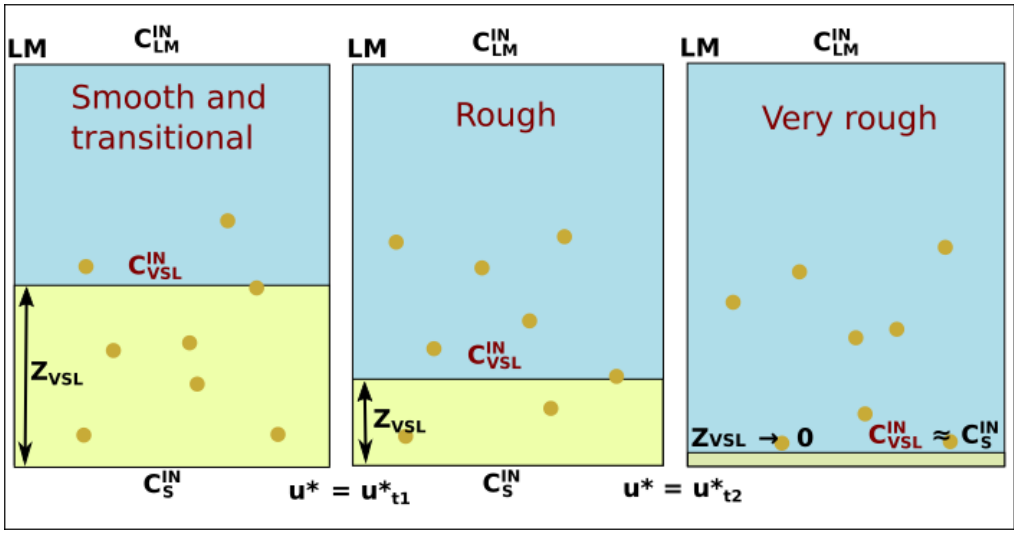
DREAM model dynamics



$$\frac{\partial C_k}{\partial t} = -u\frac{\partial C_k}{\partial x} - v\frac{\partial C_k}{\partial y} - (w - v_{gk})\frac{\partial C_k}{\partial z} - \nabla(K_H \nabla C_k) - \frac{\partial}{\partial z}\left(K_z \frac{\partial C_k}{\partial z}\right) + \left(\frac{\partial C_k}{\partial t}\right)_{SOURCE} - \left(\frac{\partial C_k}{\partial t}\right)_{SINK}$$

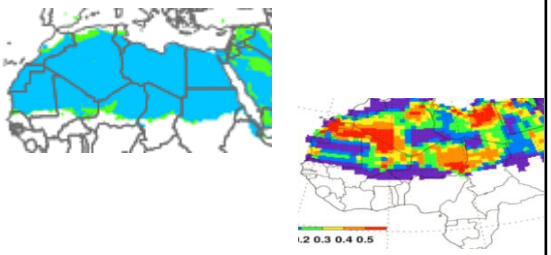
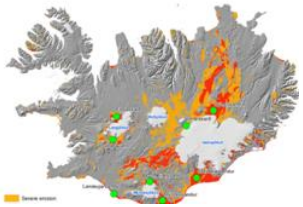
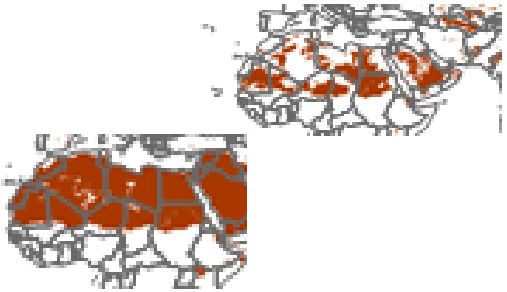
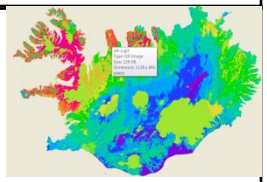
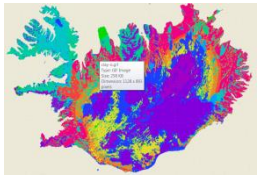
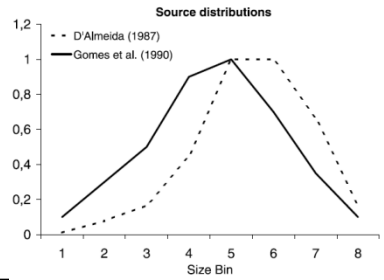
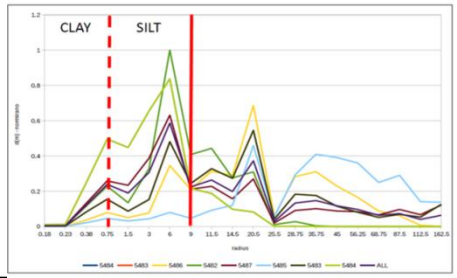
Viscous sub-layer dust emission scheme

$$C_S^{IN} \sim u_*^2\left[1 - \left(\frac{u_{*t}}{u_*}\right)^2\right] \quad for\ u_* > u_{*t}$$



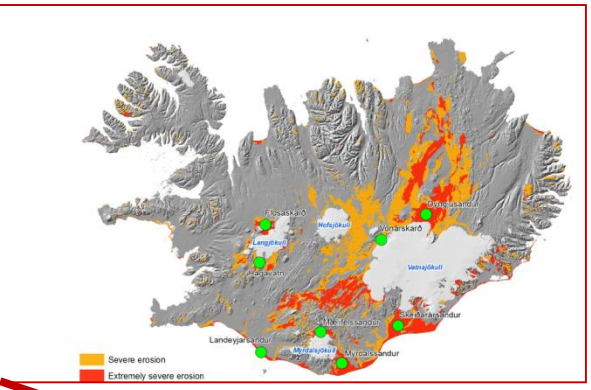
Based on Janjic (1994)

Dust emission components

Model version/ surface params	LLD (low-lat-dust) DREAM	Icelandic DREAM
ALPHA term (dust "mask")	USGS or Ginoux 1km 	Arnalds data 1:100 000 
BETA term (clay/silt)	STATSGO 1km 	Arnalds data 1:100 000  
GAMA term (dust particle size distribution – 8 bins)	D'Almeida or Gomes et al 	Hot-spot measurements 

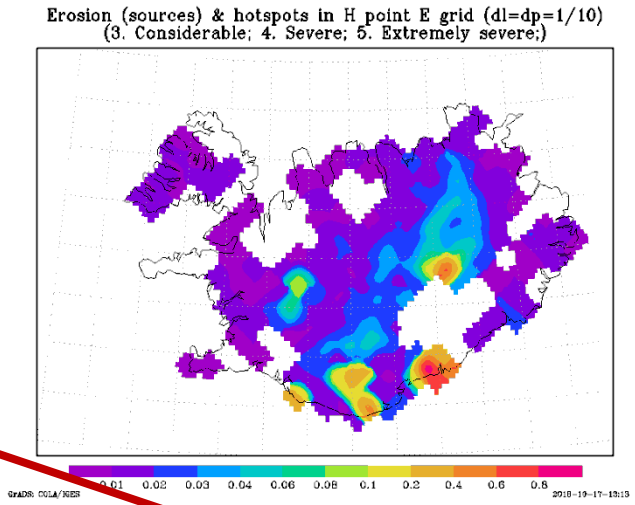
Dust sources: impact of the model resolution

the starting point to develop sources in DREAM (<1km res)

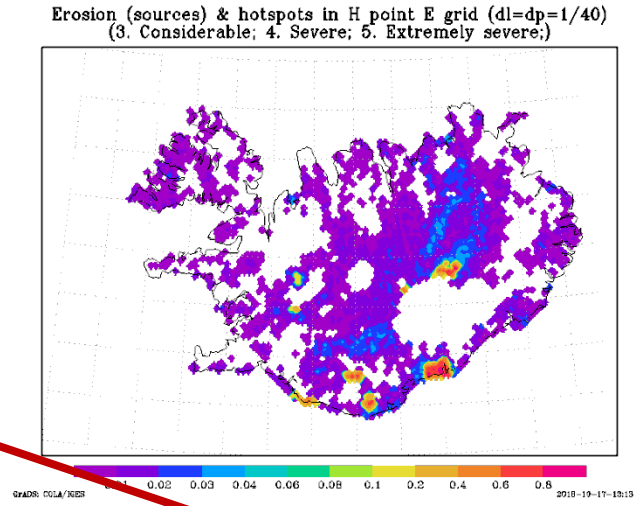


Arnalds, Dagsson-Waldhauserová, Olaffson (2014)

res = 1/10deg



res = 1/40 deg (~3km)



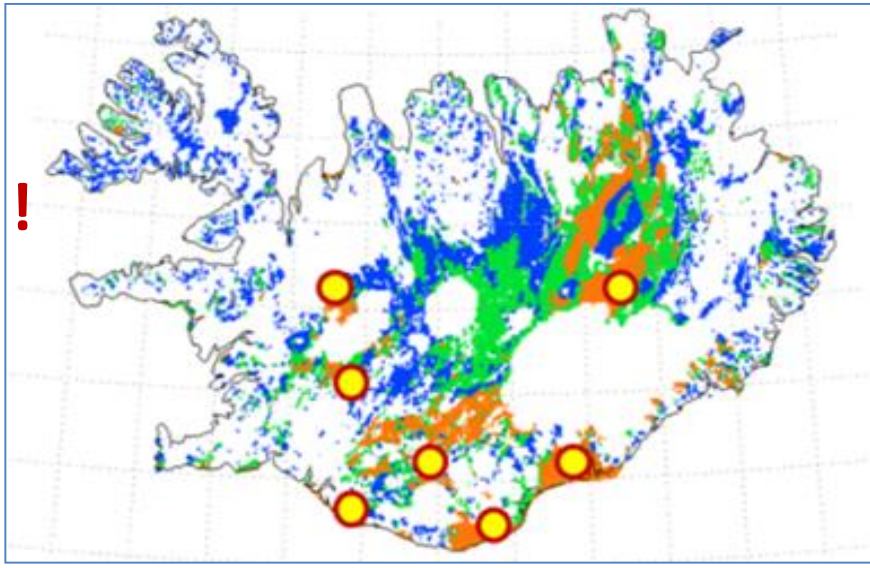
Geo-referenced dust-source-related data

Desert geomorphology

- ❑ Dust hot spots [75%]
- ❑ Large-scale dust-productive desert surfaces classified as
  - *extreme* [20%]
  - *severe* [4%]
  - *considerable* [1%]

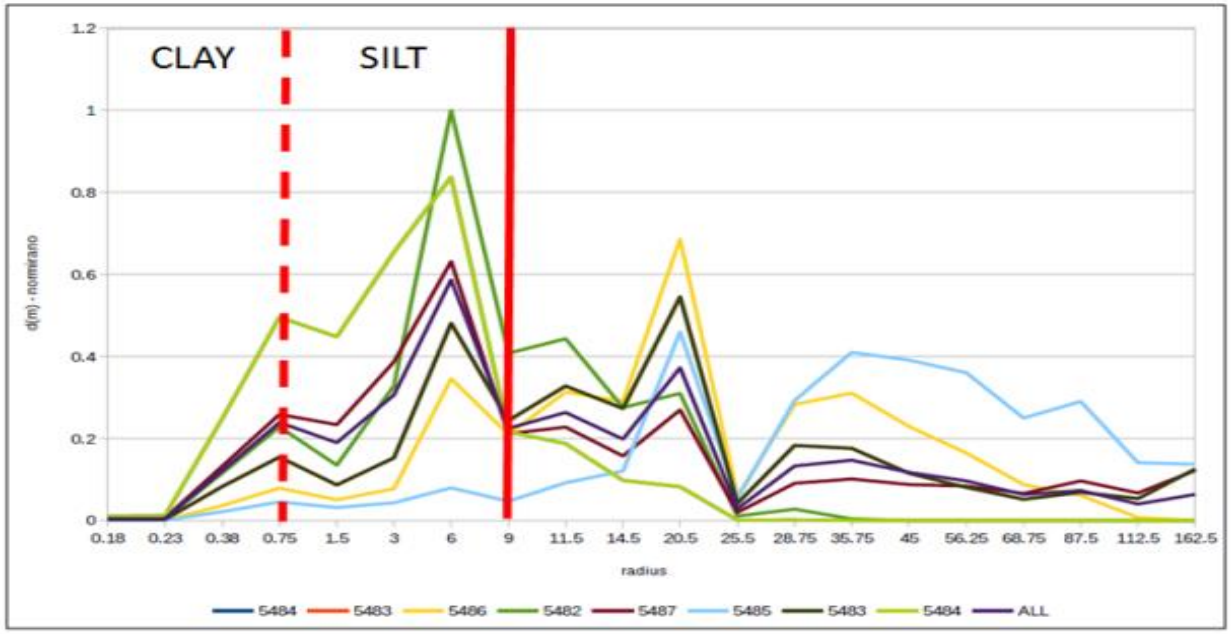
Relative contributions to emission (Arnads, unpublish)

Domination of hotspots in emission !



extreme (green), severe (brown) and considerable (blue), hotspot (yellow)

Dust particle size distribution



Model range

Particle size distribution at 7 hot spots

(cortesy of L. Lisá the Czech Academy of Sciences, unpublished)

radii

clay

0.18, 0.23, 0.38 and 0.73µm

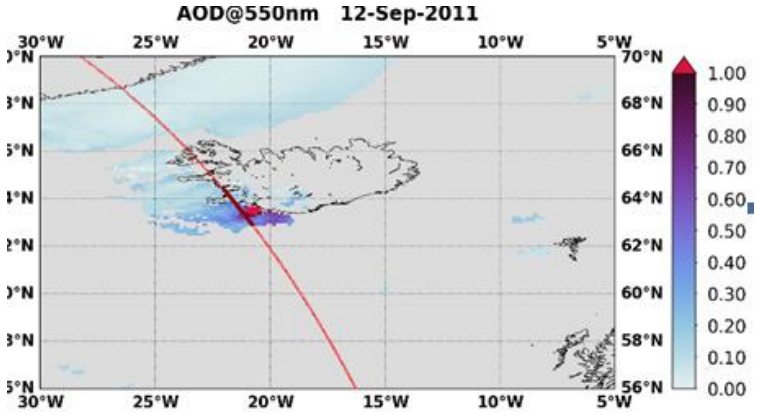
silt

1.5, 3, 6 and 9 µm

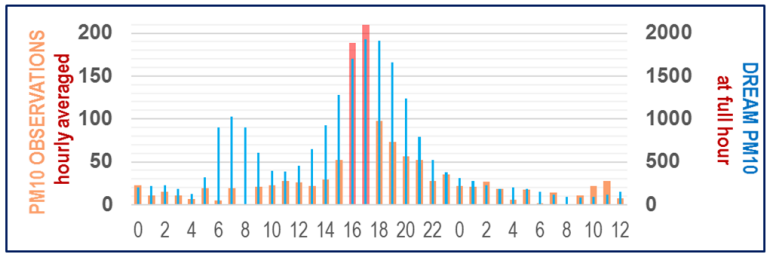
Model experiments

Model tests for dust storms

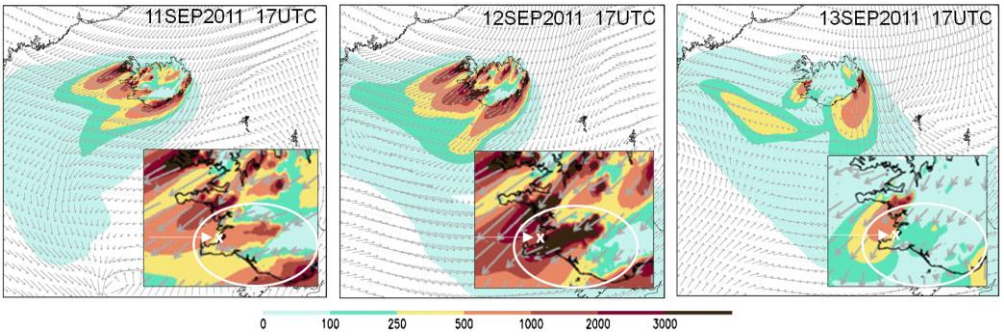
September 2011 case – short-range dust episode; local impacts



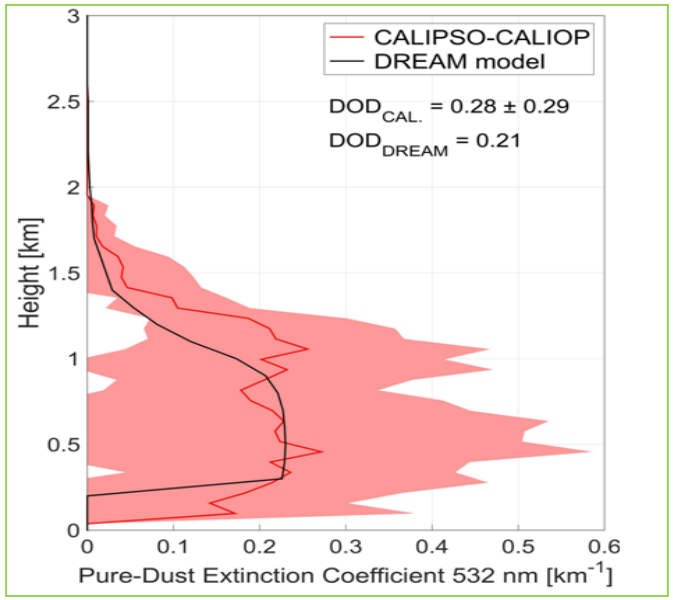
MODIS AOD 12 Sep



Model vs. PM10 12-13 Sep (Reykjavik)



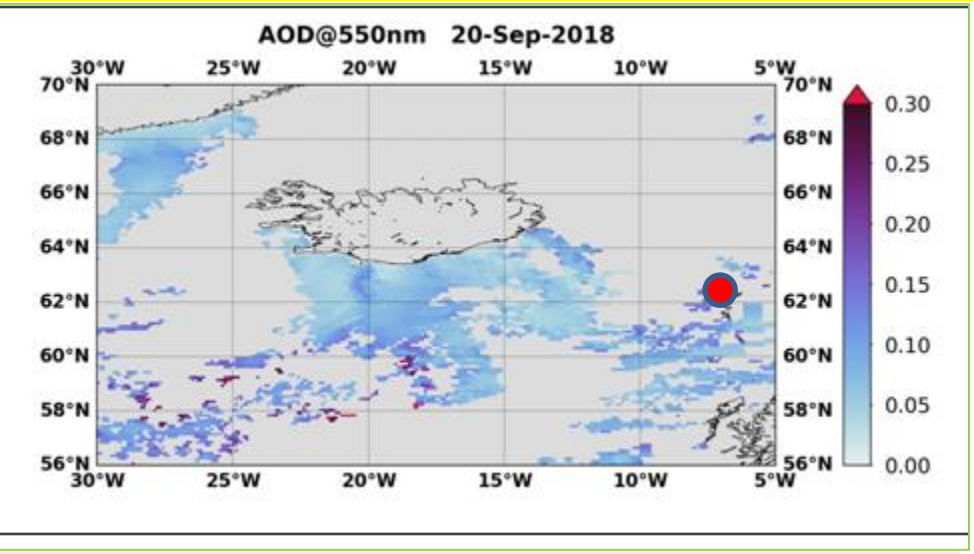
Model dust



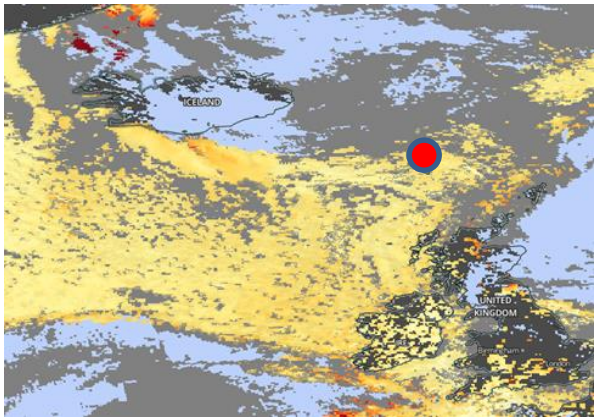
Model vs. CALIPSO extinction

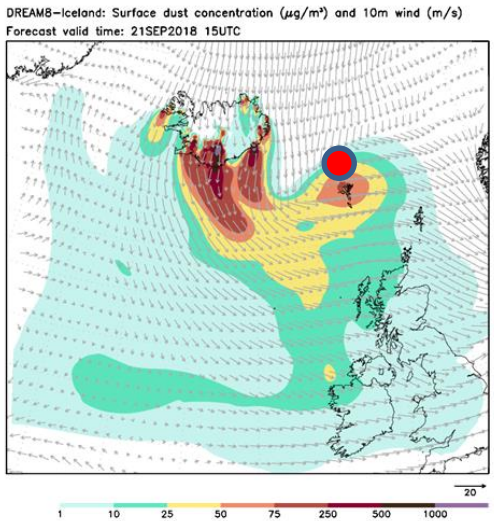
September 2018 case – long-range dust episode

Brit and Faroe isles affected



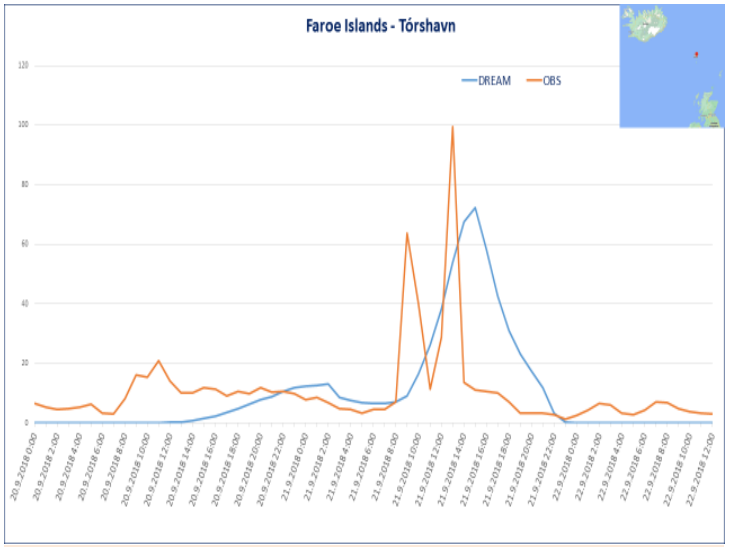
MODIS AOD 20 Sep





Model dust

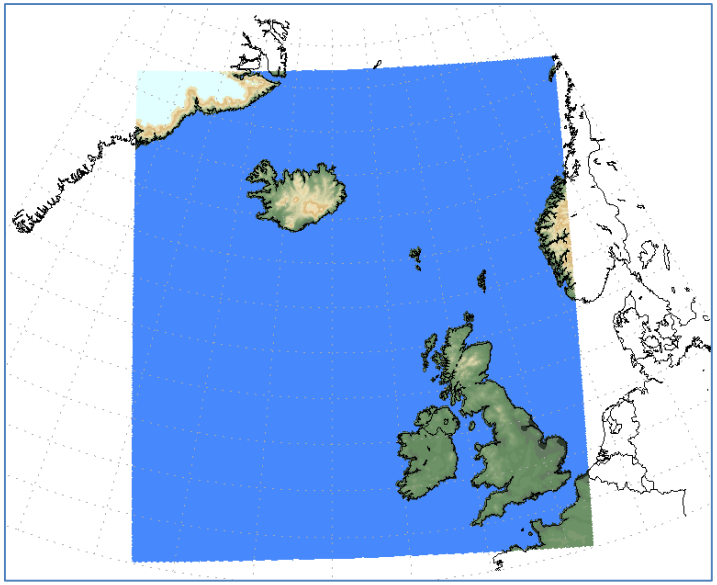
Faroe

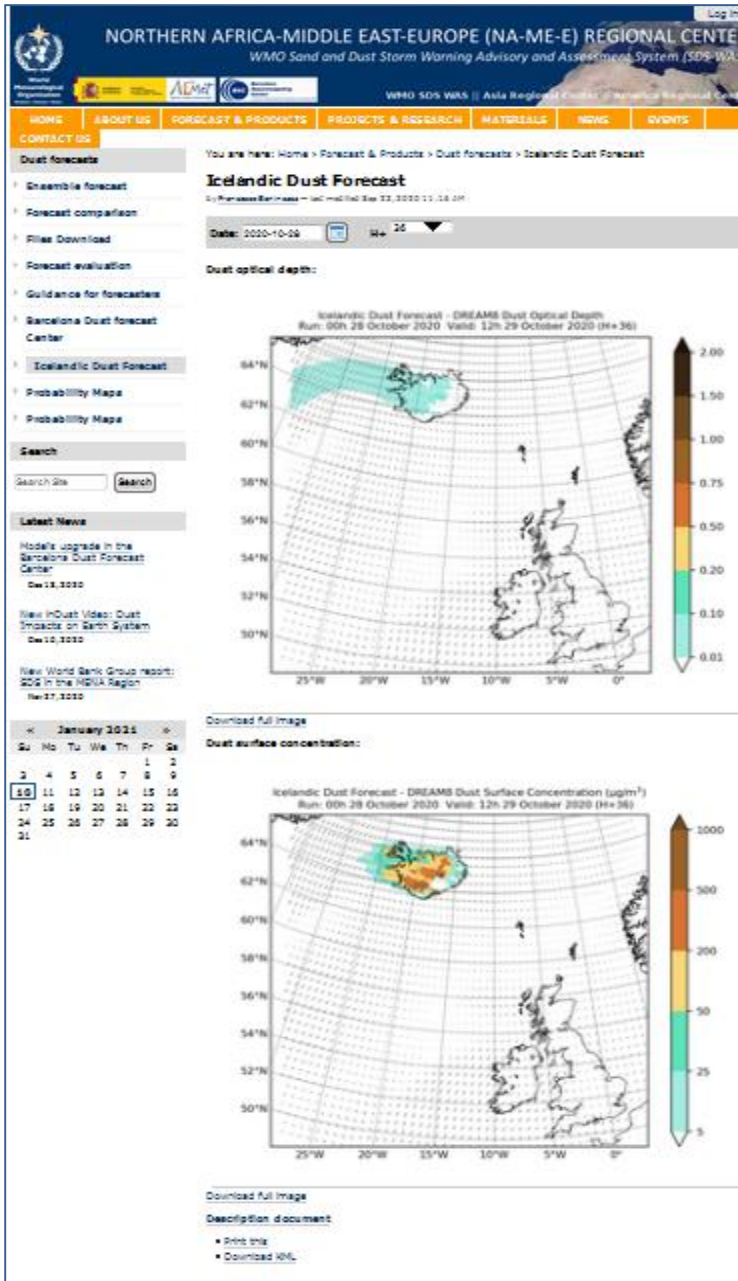


Model vs. PM10 21-22 Sep

Operational model domain for 3-day forecasts

- https://sds-was.aemet.es/forecast-products/dust-forecasts/icelandic-dust-forecast (**SDS-WAS**) or
- http://www.seevccc.rs/?p=8 (**RHMSS**)
- Horizontal res: ~3.5km; 28 vertical levels
- NCEP-NMM atmospheric driver
  - Dust concentration – the additional prognostic equation in NMM





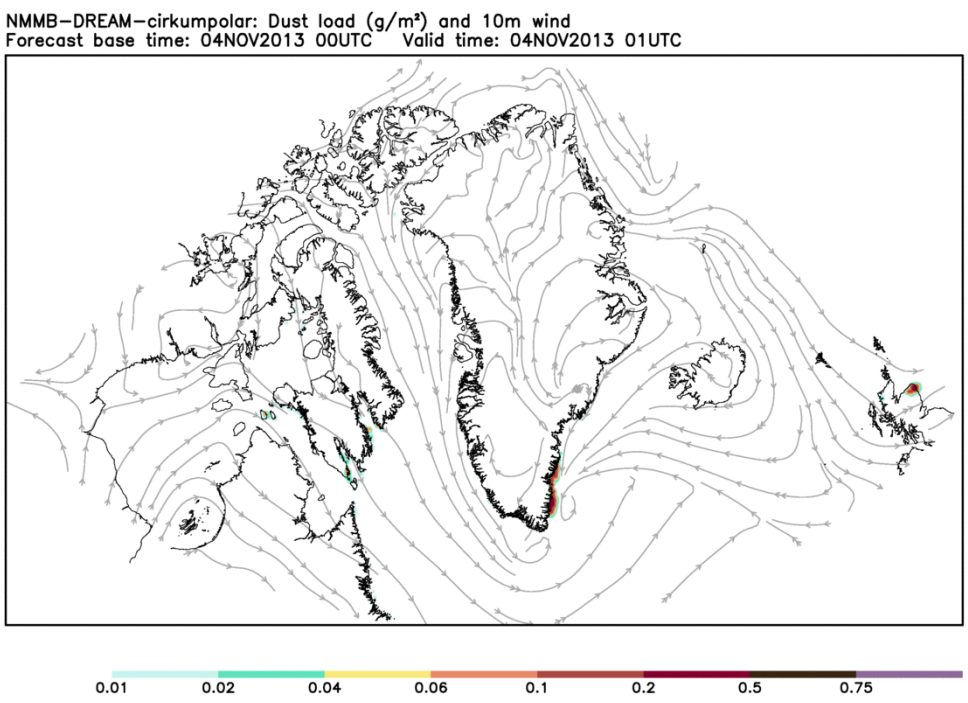
Future plans to use DREAM for HLD research

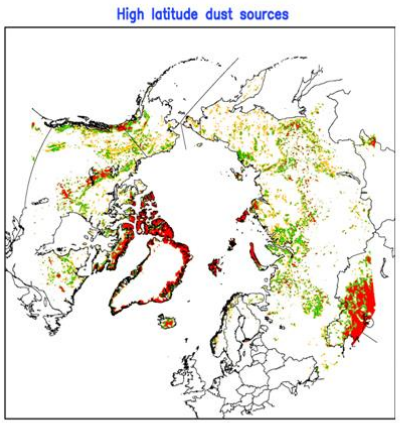
- Development of a circumpolar DREAM
- Dust atmosphere chemical processing (mineralogy)
- Cold-cloud formation by dust
- Transporting dust darkness as an aerosol property

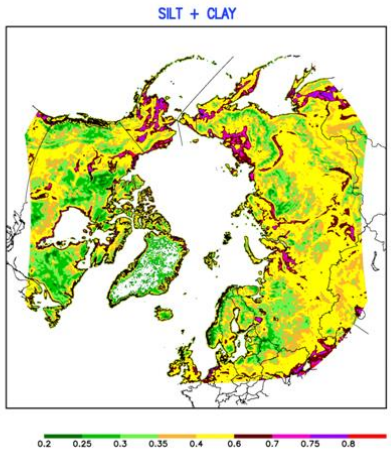
A series of the preliminary tests done to explore model capabilities

Circumpolar HLD DREAM

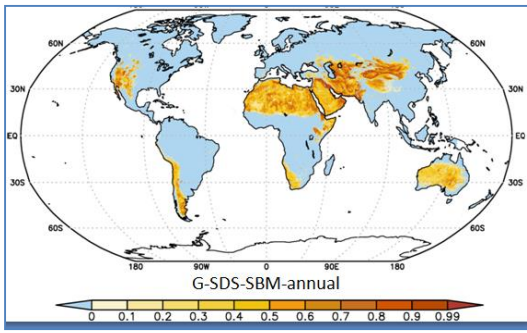
preliminary tests (G. Pejanovic)

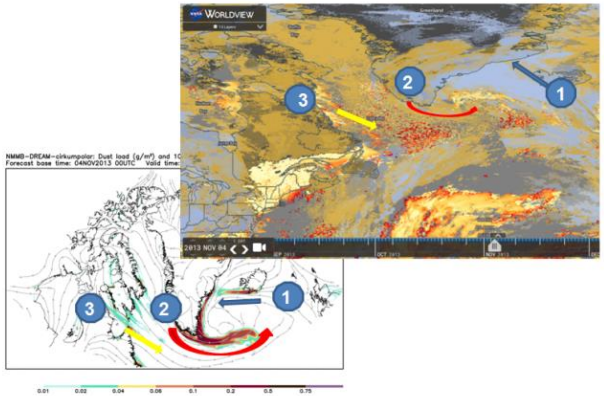






1km global UNCCD dust mask (Vukovic, 2019)
https://maps.unccd.int/sds/



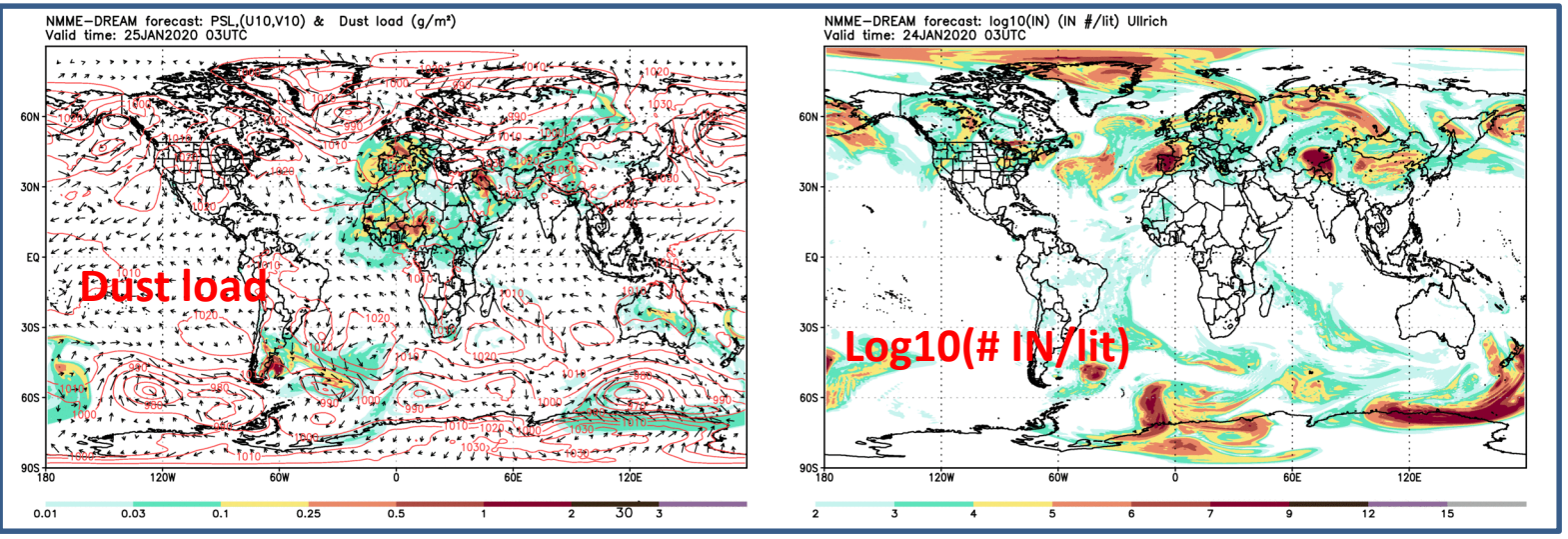


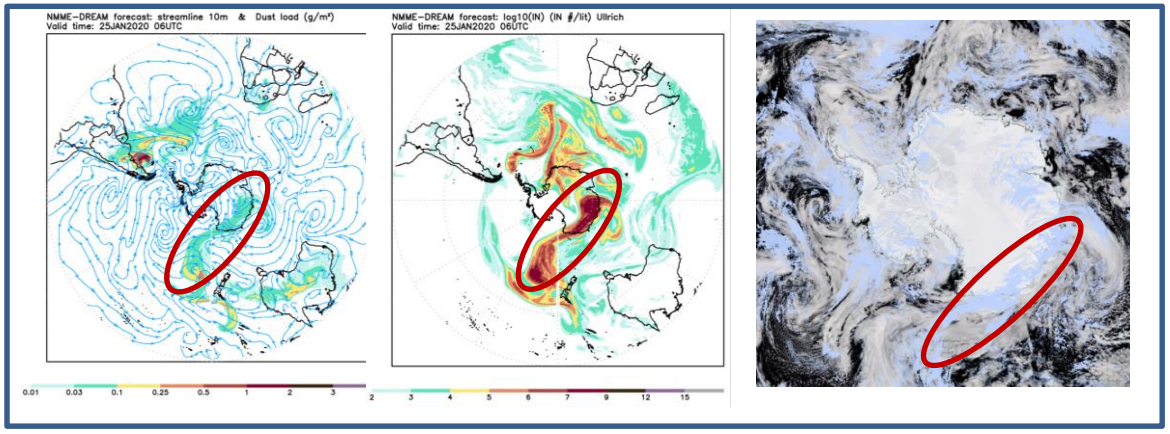
Global DREAM

Australian dust Jan 2020 → Antarctic → ice nucleation

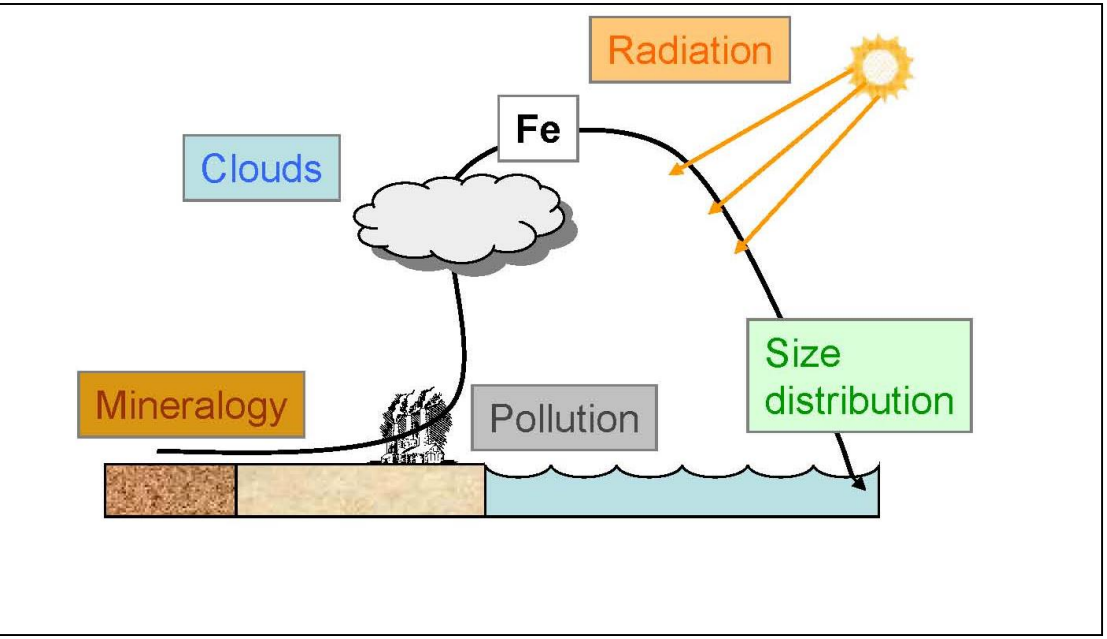
https://public.wmo.int/en/resources/meteoworld/serbia-successfully-models-dust-storm-high-latitudes

preliminary tests (S. Petkovic)





ATMOSPHERIC IRON PROCESSING AND OCEAN PRODUCTIVITY

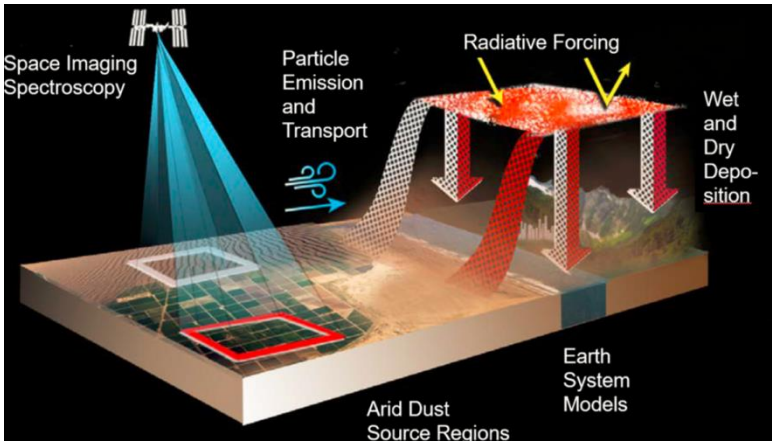


FRAGMENT project

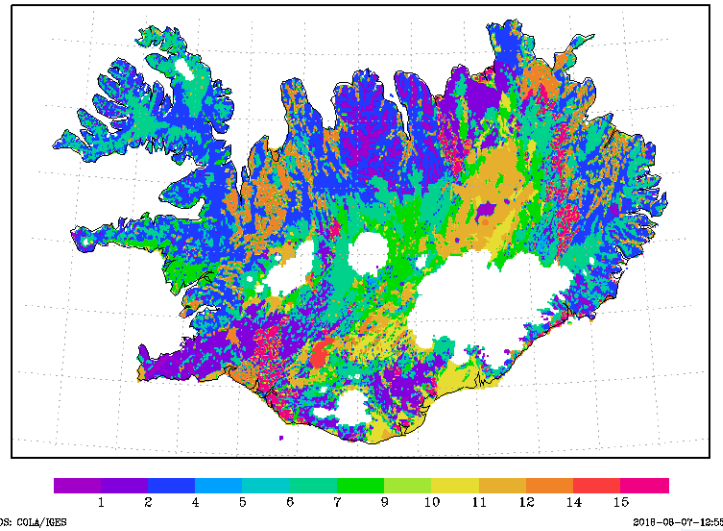
- ongoing research (Perez BSC)
- use of satelitte data
- hi-res mineralogy data set

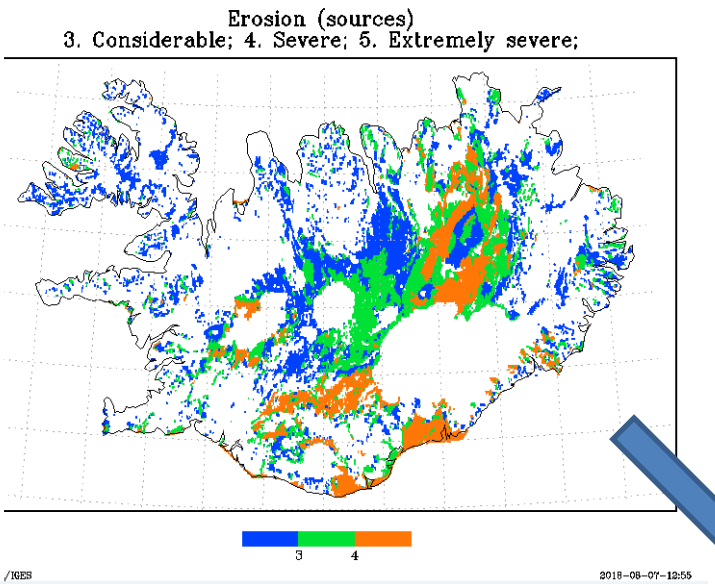
FRontiers in dust minerAloGical coMposition and its Effects upoN climaTe (FRAGMENT)

Carlos Pérez García-Pando (1), Andrés Alastuey (2), Roger Clark (3), Bethany Ehlmann (4), Vicken Etyemezian (5), María Gonçalves (1,6), Adolfo González (1,2), Cristina González-Flórez (1), Robert Green (7), Rebecca Greenberger (4), Oriol Jorba (1), Konrad Kandler (8), Martina Klose (1), Ron Miller (9), Vincenzo Obiso (1), Agnesh Panta (8), and Xavier Querol (2)



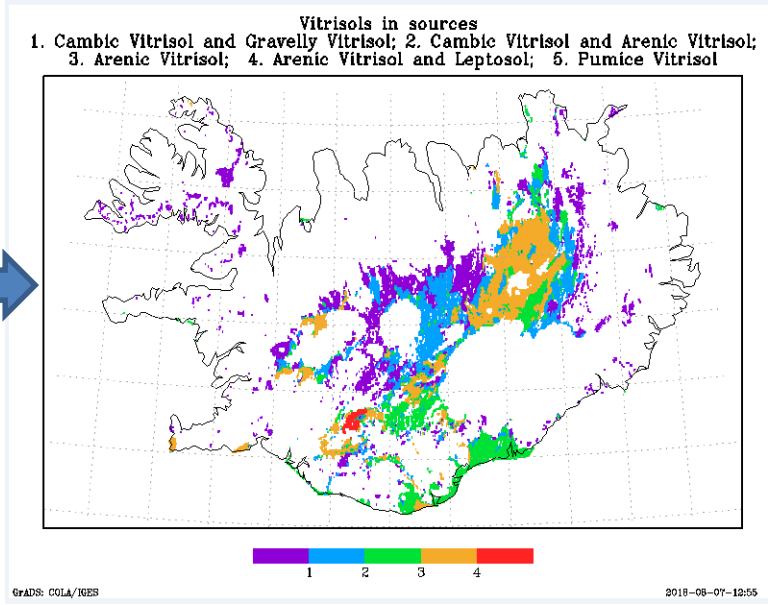
How to assess Fe content in dust-productive soils?





Dust-productive Fe-carrying soils

Cambic Vitrisol and Gravelly Vitrisol
Cambic Vitrisol and Arenic Vitrisol
Arenic Vitrisol
Arenic Vitrisol and Leptosol
Histic Andosol
Pumice Vitrisol



Preliminary DREAM tests: atmospheric chemical dust processing

Adjustments for Iceland to be done:

- ❑ **Fe-oxides in Icelandic soil sources**
- ❑ **needed modification of chemical processing parameterization**
  - ○ **less pollution?**
  - ○ **more clouds?**
  - ○ **low-level dust transport → different particle separation?**
  - ○ **less photo-reduction ?**

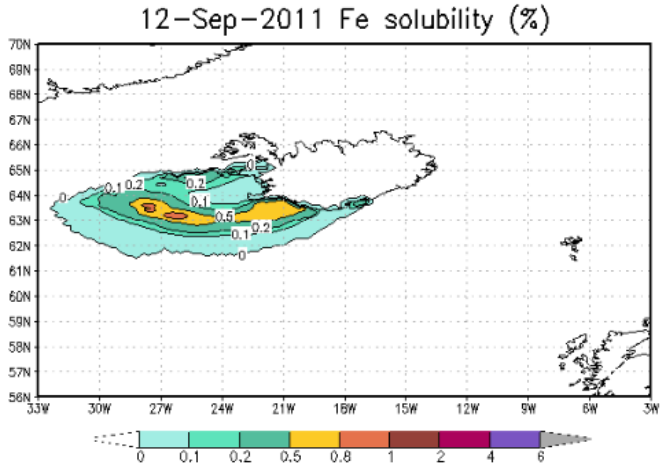
Research plans with the Zongbo Shi group (U of Birmingham)

Sample	fraction	CaO	Fe_2O_3
D3	PM_{10}	11.6	16.3
H55	PM_{10}	12.4	15.1
Land1	PM_{10}	6.9	18.2
Maeli2	PM_{10}	8.5	18.4
MIR45	PM_{10}	8.6	18.8
D3	PM_{20}	10.3	14.8
H55	PM_{20}	11.3	13.8
Land1	PM_{20}	5.8	16.8
Maeli2	PM_{20}	7.6	17.6
MIR45	PM_{20}	8.3	18.8

Note: The data are mean concentrations

Distinct chemical and mineralogical composition of Icelandic dust compared to North African and Asian dust

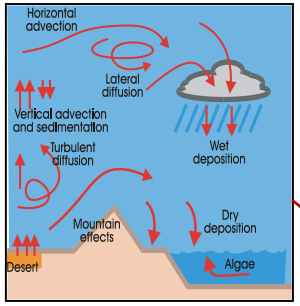
Clarissa Baldo[1], Paola Formenti[2], Sophie Nowak[3], Servanne Chevaillier[2], Mathieu Cazaunau[2], Edouard Pangui[2], Claudia Di Biagio[2], Jean-Francois Doussin[2], Konstantin Ignatyev[4], Pavla Dagsson Waldhauserova[5,6], Olafur Arnalds[5], A. Robert MacKenzie[1], Zongbo Shi[1]



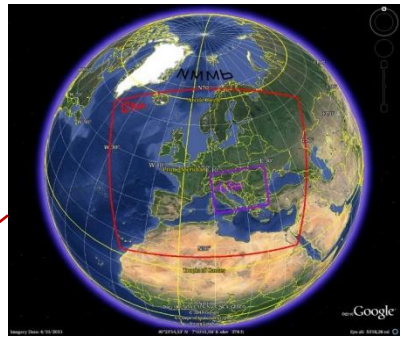
preliminary tests (S. Nickovic)

Icelandic dust cold cloud formation

DREAM ice nuclei parameterization



DREAM model



NMM model

Dust C

T, RH

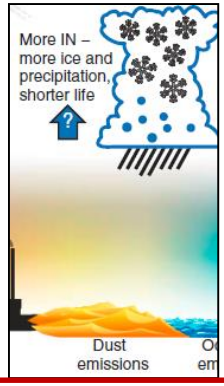
DeMott (2015) [-35°C <T<-5°C]

$$n_{IN} = C(n_{dust})^{(\alpha(273.16-T)+\beta)} \exp^{(\gamma(273.16-T)+\delta)}$$

Steinke et al (2015) [-55°C <T<-35°C]

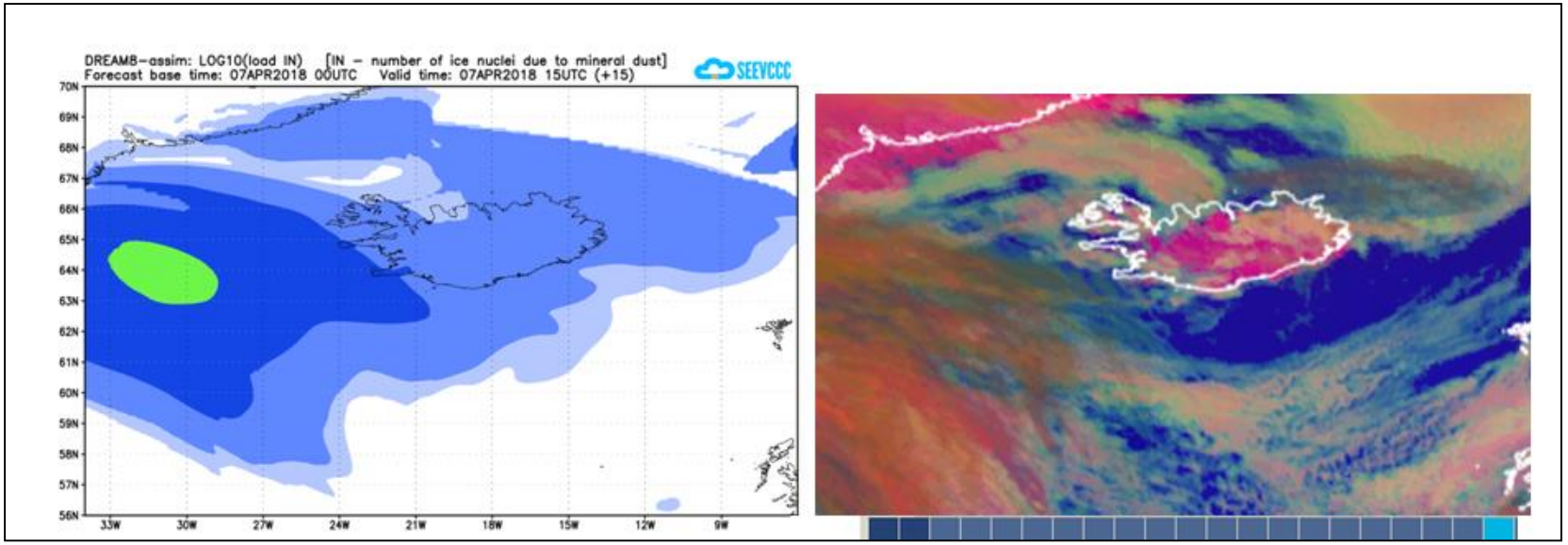
$$n_{IN} = S_{dust} 1.88 \cdot 10^5 e^{-pT+q(RH_{ice}-100\%)}$$

n_{IN}



NMMB Thompson dust-friendly cold cloud micrphysics

Nickovic et al, 2016, ACP



Preliminary test with Ullrich et al. (2017) ice nucleation scheme

Next steps: to replace U2017 with Iceland-specific parameterizations – options: Groups of Ben Murray; Konrad Kandler and Kerstin Schepanski, ...)