Predicting probability of melted dust in turbines

DREAM-MELT: the model for assessing dust melting in aero-turbines

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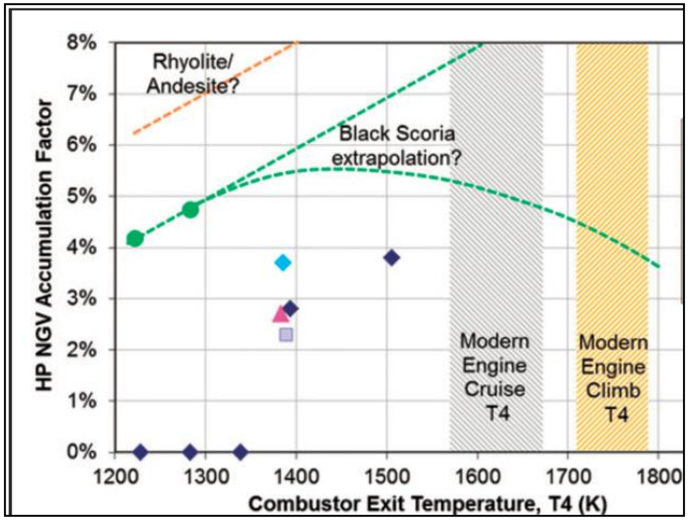
The problem of aerosol melting in turbines

- 10 years ago the focuss was on volcanic ash melting in turbines at T ~1.200 C
- Mineral dust was considered safe for turbines that time because higher meting point (~1.400 C)
- Meanwhile, working turbine T inreased up to 1.800 C → **dust became a matter of concern**



Clarkson, et al. (2016)

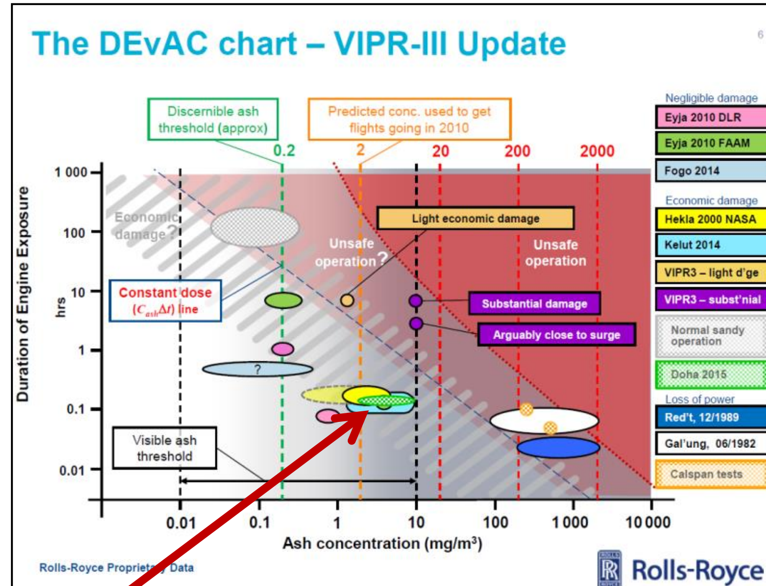
How to assess effects of aerosol melting?

- **DEvAC charts**:

  Melting probability – a function of

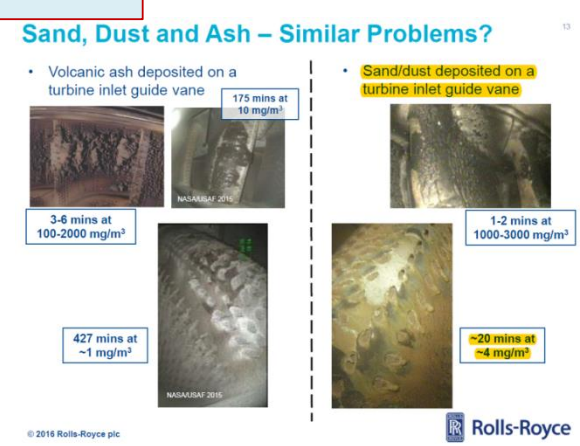
  - exposure time
  - aerosol concentration

- **Diagnostic tool** but **cannot warn/predict** melting conditions
- Melting – strongly depends on **dust mineralogy**!



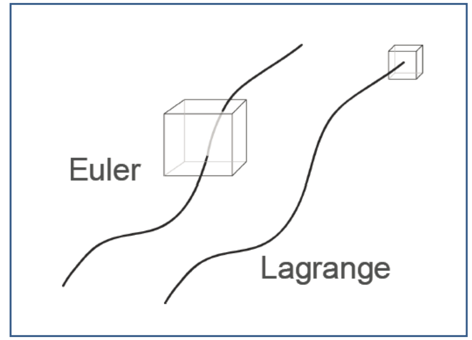
Doha 2015 dust

Clarkson, (2016)



Eulerian models vs Lagrangian/trajectory models

Trajectories cannot succesfully predict mineralogical composition transported from dust sources !!!

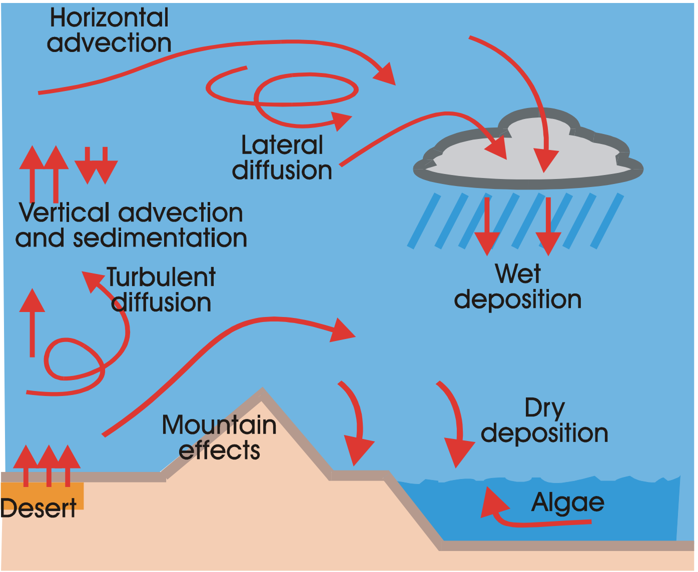


Lagrangean (trajectories)	**Eulerian**
• *Advantages* - Quick looks - CPU efficient - self-evident particle transport path	• *Advantages* - source resolving - fully connected to atm processes - concentration as prognostic param
• *Disadvantages* - disconnected from atm. processes - much less accurate than Eulerian	• *Disadvantages* - CPU demanding

How to predict dust melting?

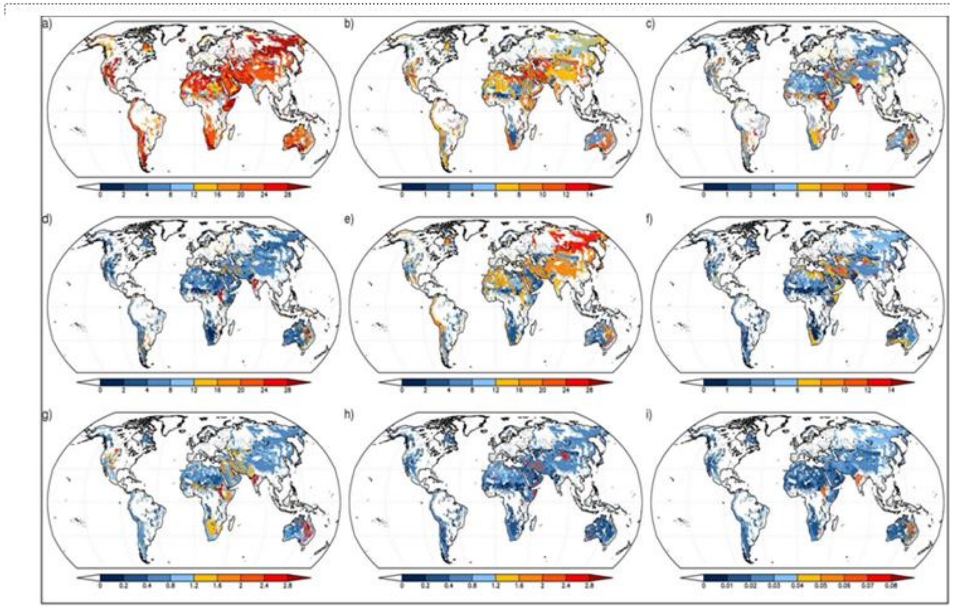
Necessary components:

- numerical dust prediction model
- mineralogical composition of dust



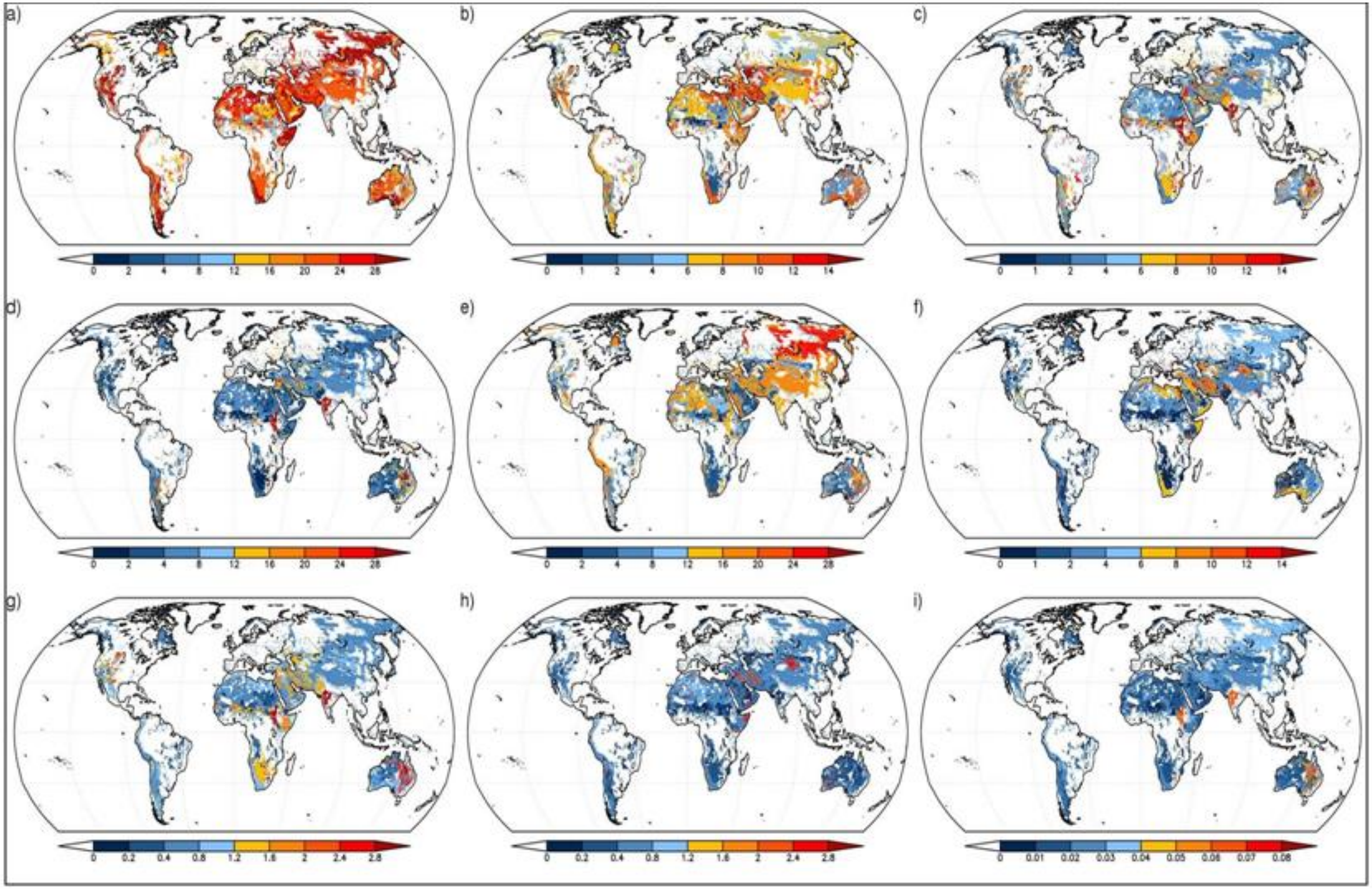
Dust Regional Atmospheric Model (DREAM)

- ***8 particle bins/equations***
- ***Eulerian model***



Geographic distribution of:
a) Quartz, b) Illite, c) Kaolinite, d) Smectite, e) Feldspar, f) Calcite, g) Hematite, h) Gypsum and i) Phosphorus

8 key dust minerals – a gobal data base



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DREAM-MELT
Model for prediction dust melting in aero-turbines

- ❑ developed to predict dust melting in aeroturbines
- ❑ resolution (optional): currently 12km; 28 vertical levels
- ❑ domain (optional): currently a wider area of the East Asia (incl. Saudi Peninsula)
- ❑ tested for the Doha 2015 case
- ❑ available for operational forecasting of locations/times with high probability of dust melting in turbines

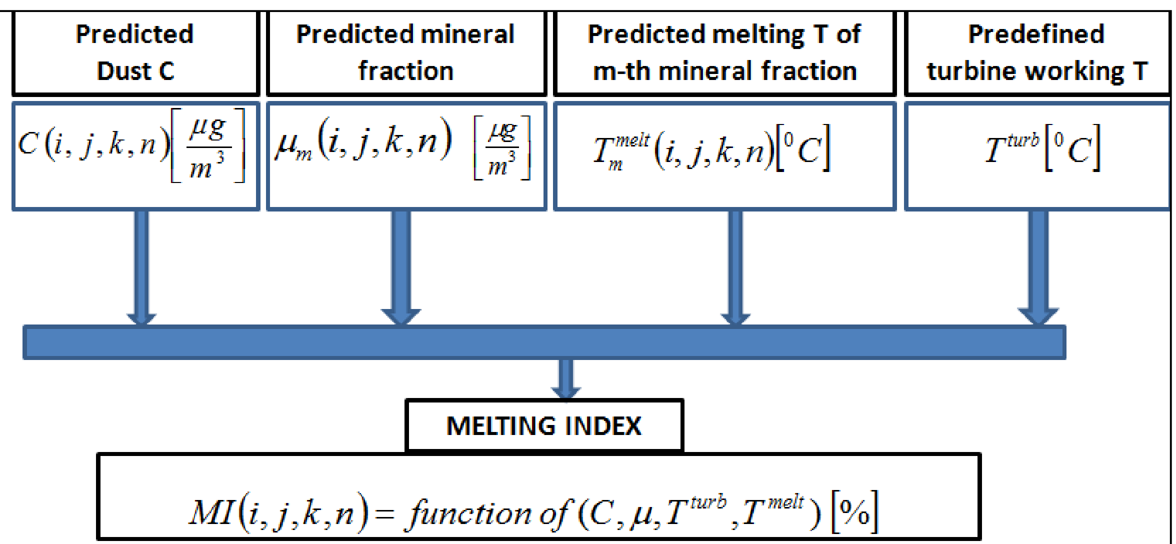
Mineralogy – the key novelty in DREAM model to predict dust melting

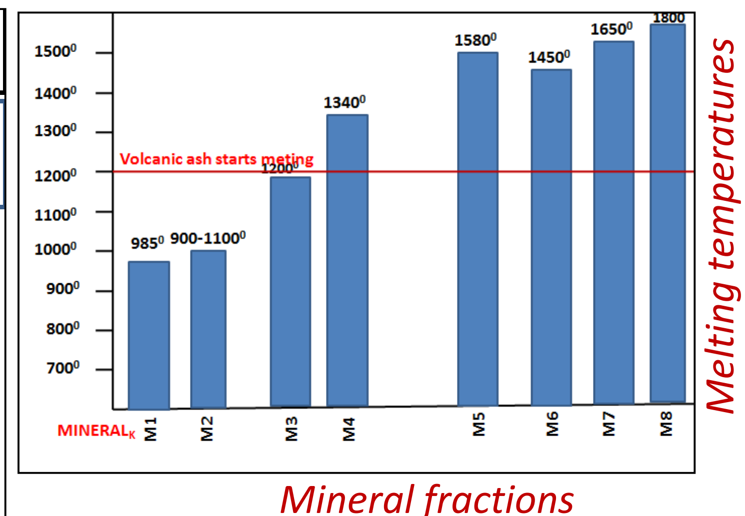
- Dust concentration (C) –necessary but not sufficient condition for predicting dust melting point
- Dust is composed of several typical minerals
- 8 minerals here selected and predicted as C fractions, assuming them to be externally mixed in the model
- Minerals originate from dust-productive clay, silt (or both) soils
- Mineral emission modelled using hi-res (1-km global) data on mineral geographic distribution
- Each mineral has its own melting point
- The method parameterizes the melting point of the mixture

Model structure and execution flow

- DREAM-MELT is online integrating
  - A numerical **weather** prediction model
  - DREAM **dust** prediction model (8 particle bins)
  - Dust **mineralogy** fractions prediction model (8 minerals)
  - **Major output: Melting Index (MI) a function of (x,y,z,t)**

→8 particles x 8 minerals = 64 new prognostic equations (quite demanding CPU operation)





Doha April 2015 event
reported in the Heathrow meeting (May 2015)

Desert Sand Analogy

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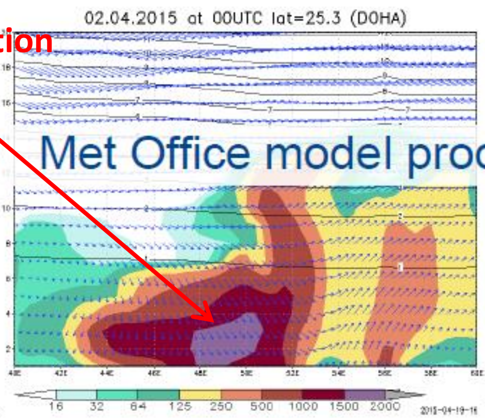
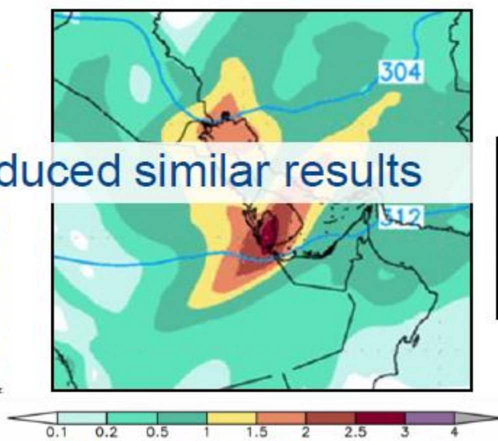
- Severe sandstorm in Qatar 1st/2nd April 2015
  - At times visibility in Doha as low as 50 m
- Met Office model produced similar results

E-W cross section



Dust conc μg/m³



Dust load g/m² and 700 hPa geopotential

Dust forecast by Slobodan Nickovic – Dust Regional Atmospheric Model (Nickovic et al, 2001; Vukovic et al, 2014)
Horizontal resolution – 0.25 deg; 28 vertical levels

- Airport remained open – at least 2 aircraft took off during height of storm
  - One of early 2000's vintage
  - The other a very modern design
- Exposure: ~10 mins at 2-8 mg/m³

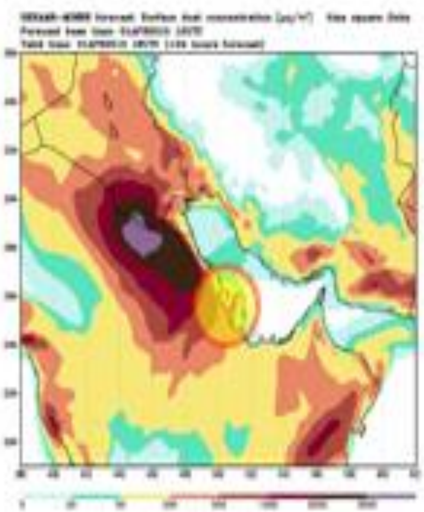
May 2015 Heathrow report

Time evaluation of the storm

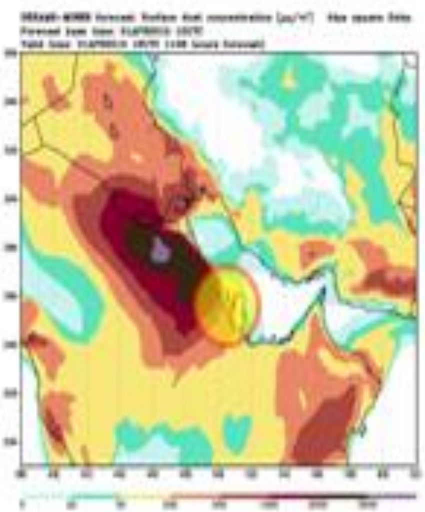
- Origin of the dust storm: Iraq deserts
- Fast moving system
  - Reached Qatar in less than one day, moving dreom Iraq along the Saudi Arabian eastern sea coast
  - Approached Doha as a mesoscale dust haboob-like “wall” between 1-2 April 2015

DREAM high resolution simulation

Surface dust concentration ug/m^3 (Doha – yellow circle)



16UTC 1 April



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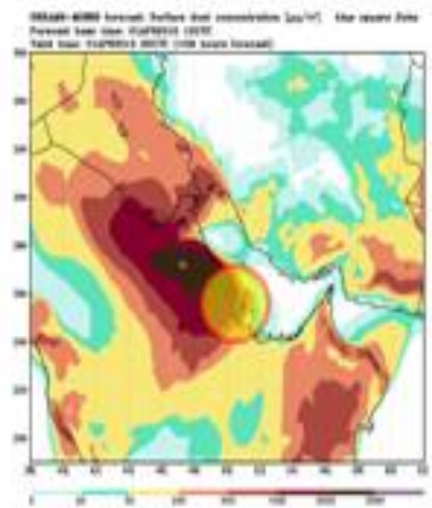

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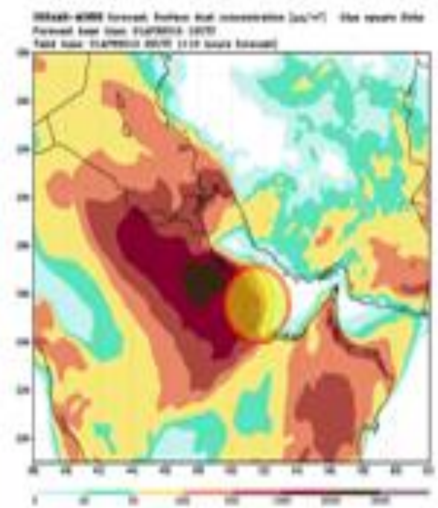

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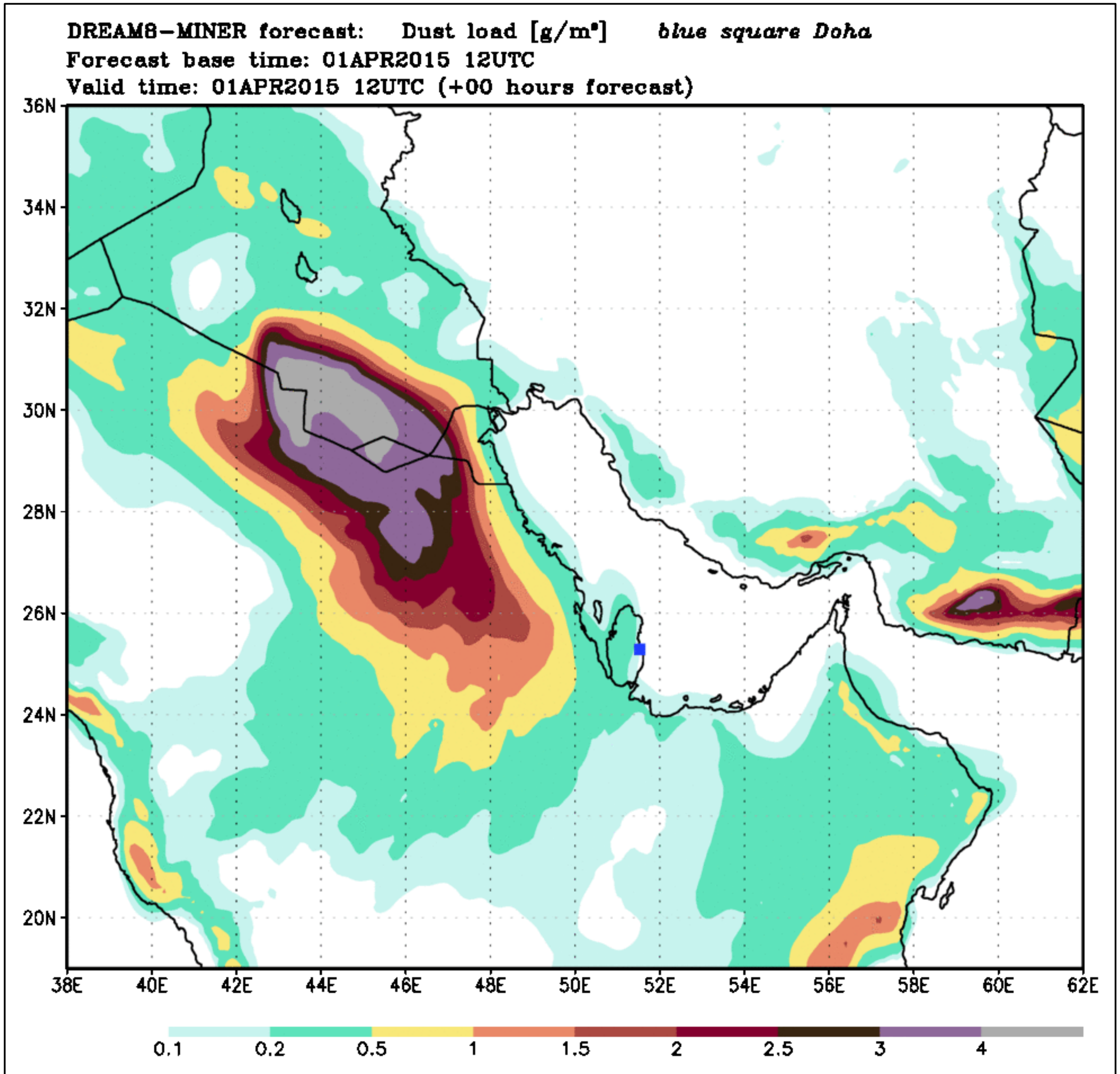
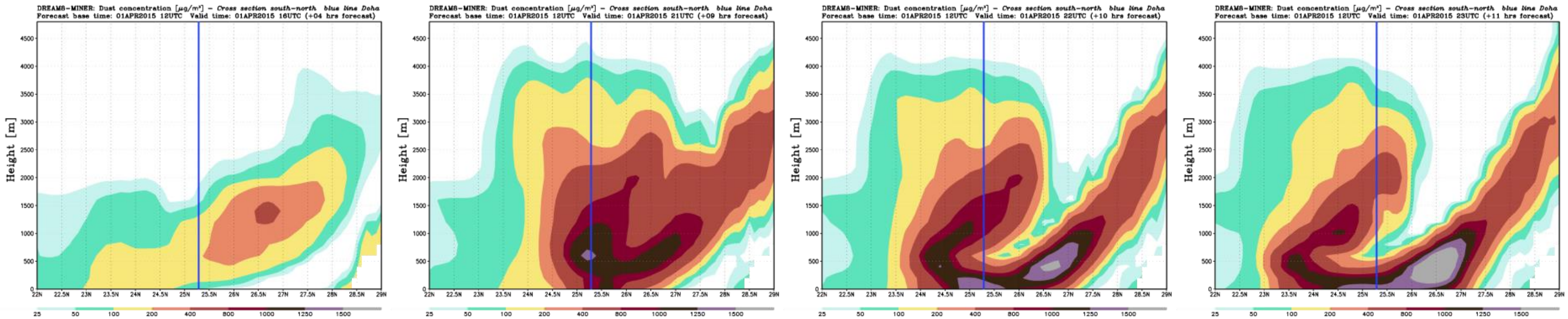
Vertically integrated dust - dust load
(animation)



Dust concentration ug/m^3: S-N cross section (Doha - blue line)



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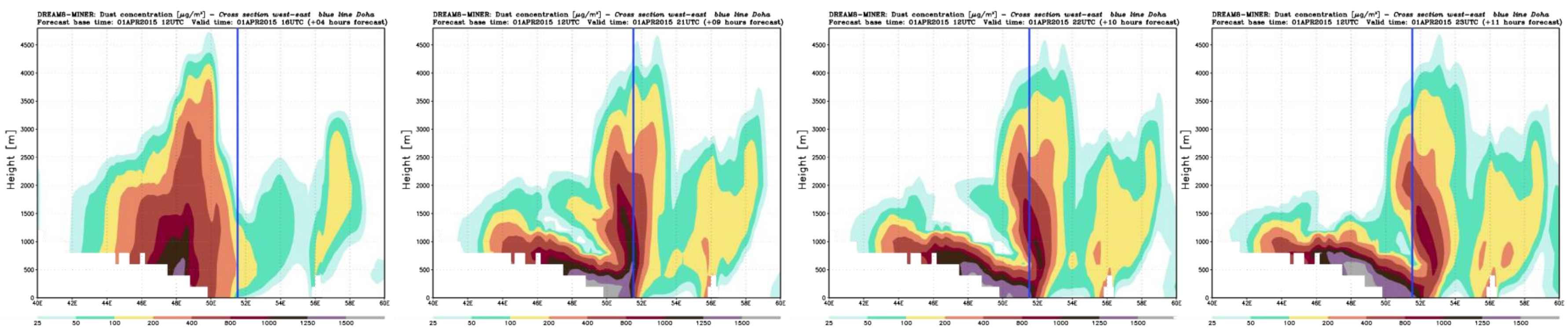
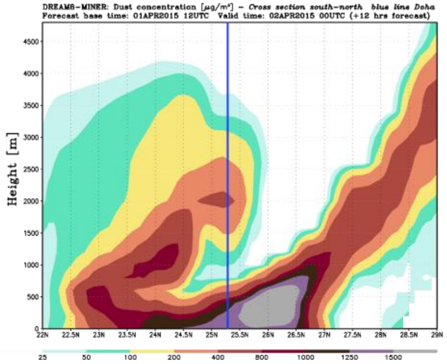
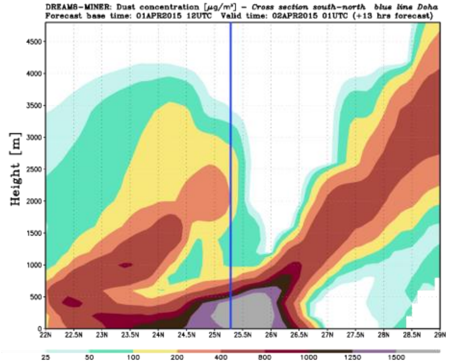
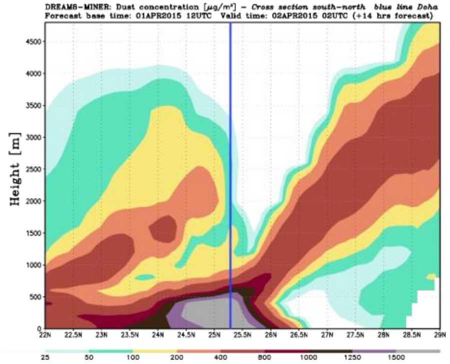
Dust concentration ug/m^3 : W-E cross section (Doha - blue line)

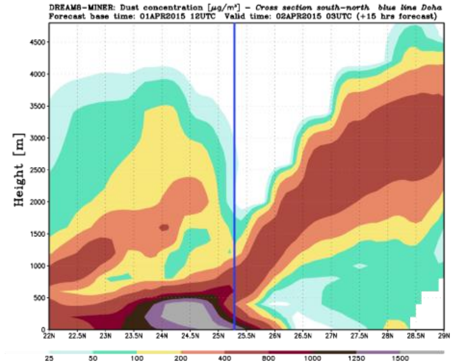


Dust concentration ug/m^3: S-N cross section (Doha - blue line)









00UTC 2 April

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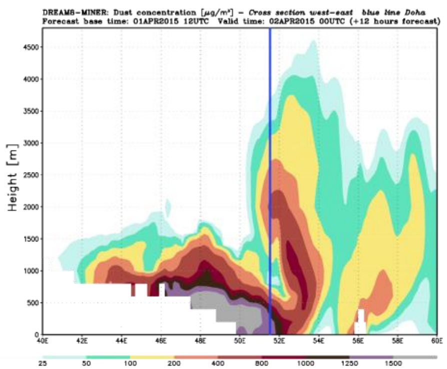
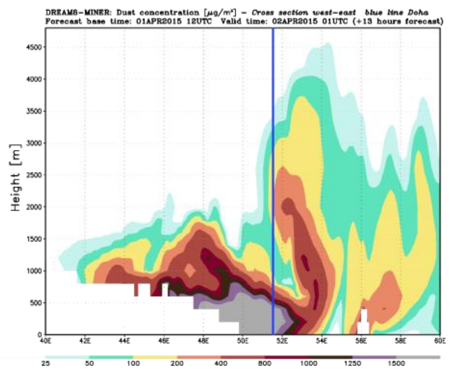
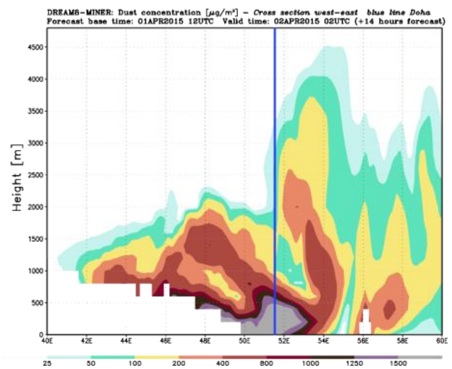
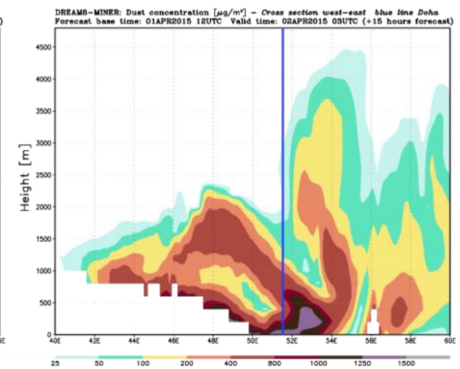
Dust concentration ug/m^3 : W-E cross section (Doha - blue line)





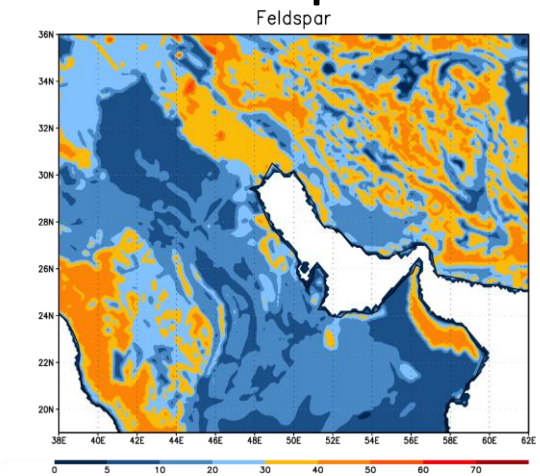




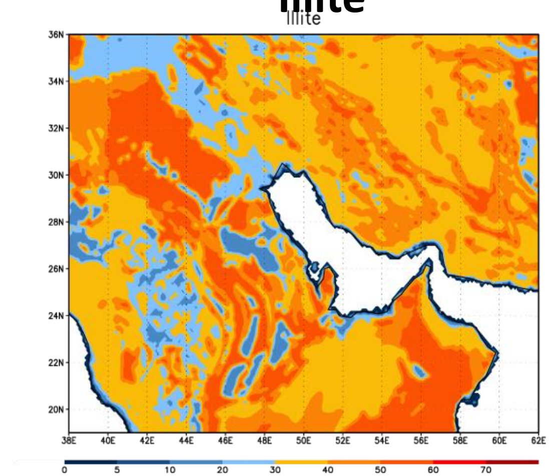
Geograhic distribution of minerals – highly heterogenious!

(below shown some minerals for the area of interest)

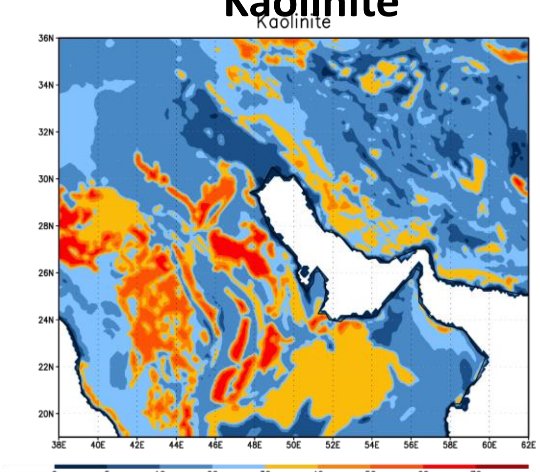
Feldspar



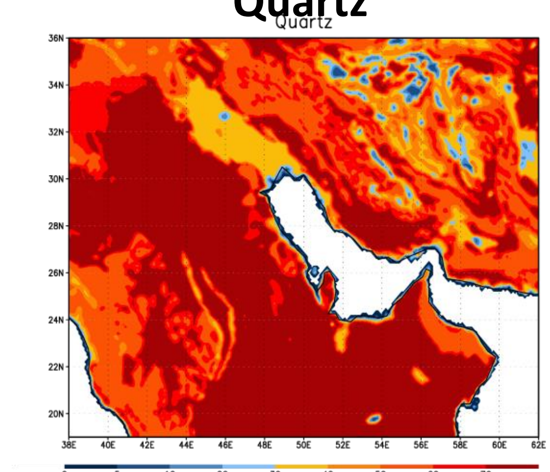
Illite



Kaolinite



Quartz



Melting Index (MI)

- Time-hight graph:1 Apr 12UTC – 2 Apr 12UTC 2015
- Location: Doha
- MI range: 0-100