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Dust Modeling: Challenges and Perspectives

5th International Workshop on Sand and Dust Storms
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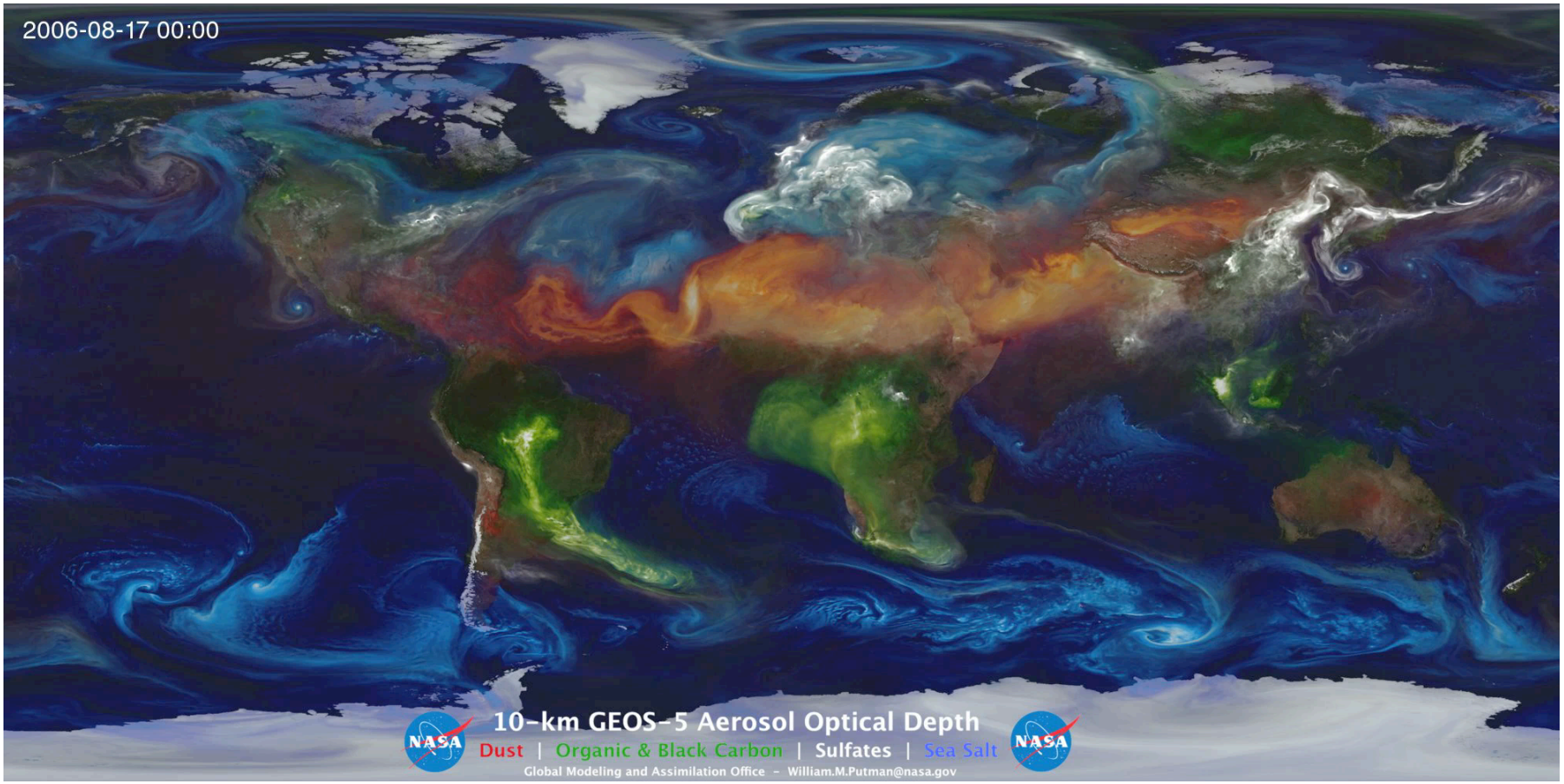
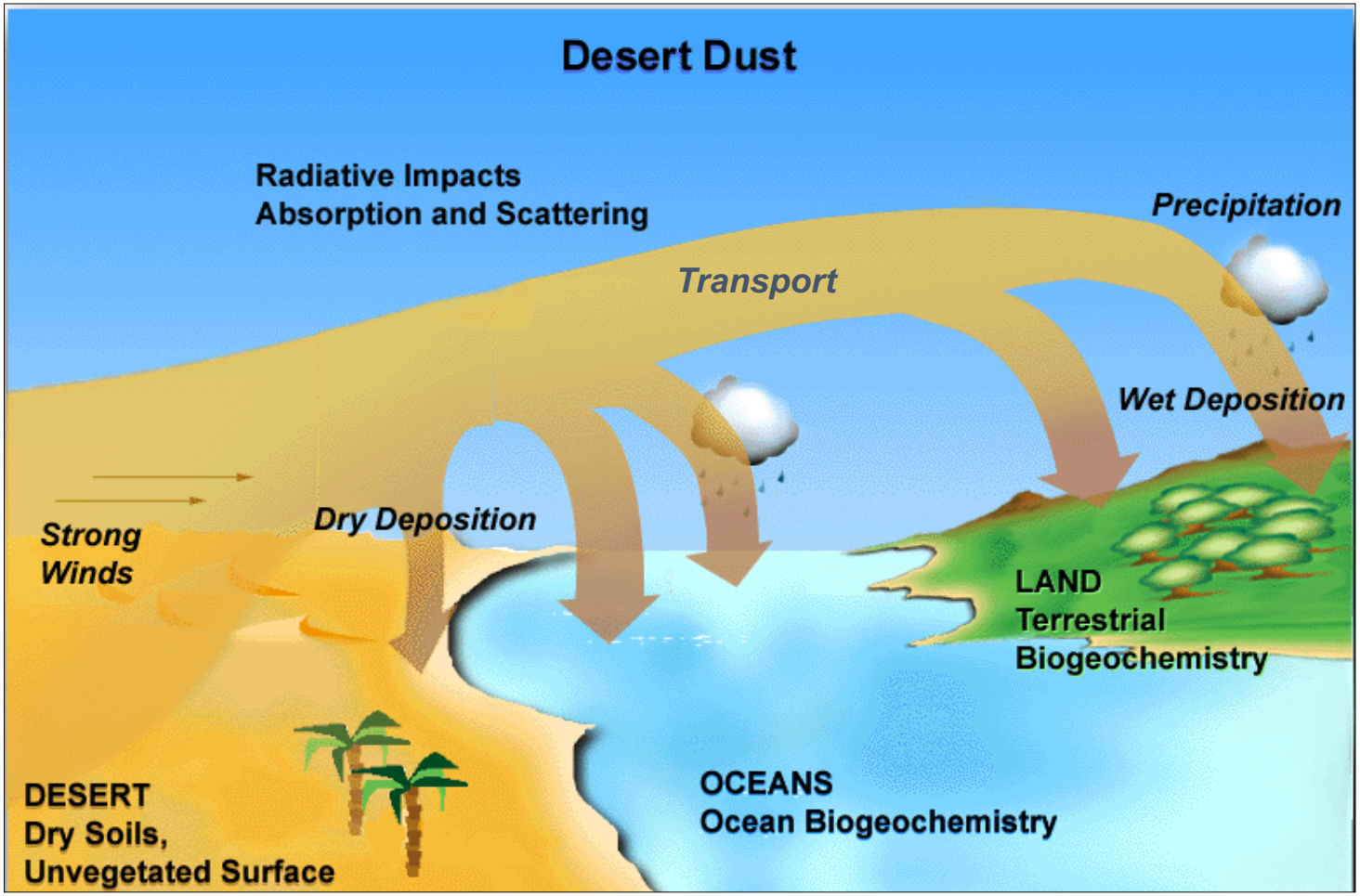
Department of Earth Sciences
Barcelona Supercomputing Center

23/10/2017

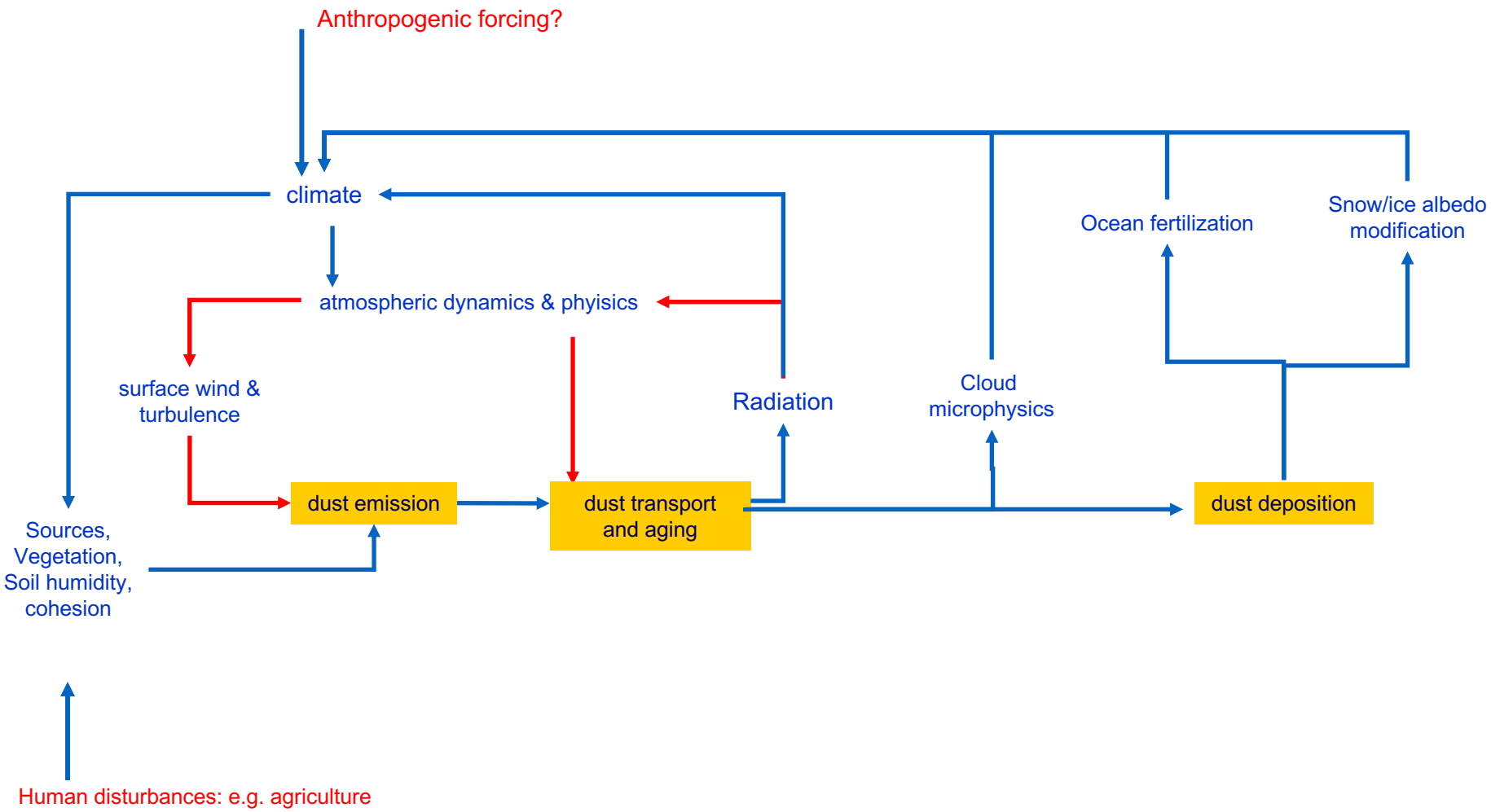
Atmospheric aerosol and the dominance of mineral dust



Dust modeling requires the representation of sources, transport and sinks



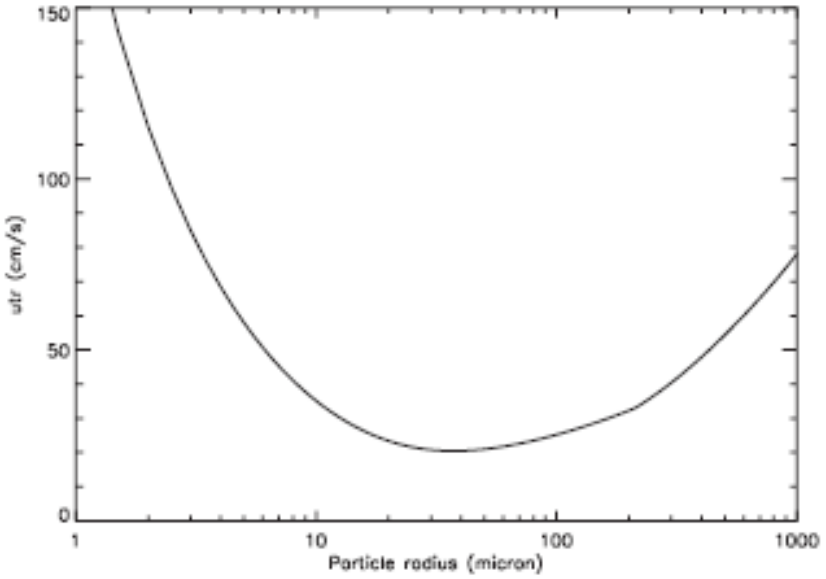
Dust cycle, effects, feedbacks, scales



Dust emission and friction velocity

Dust storm generation requires:

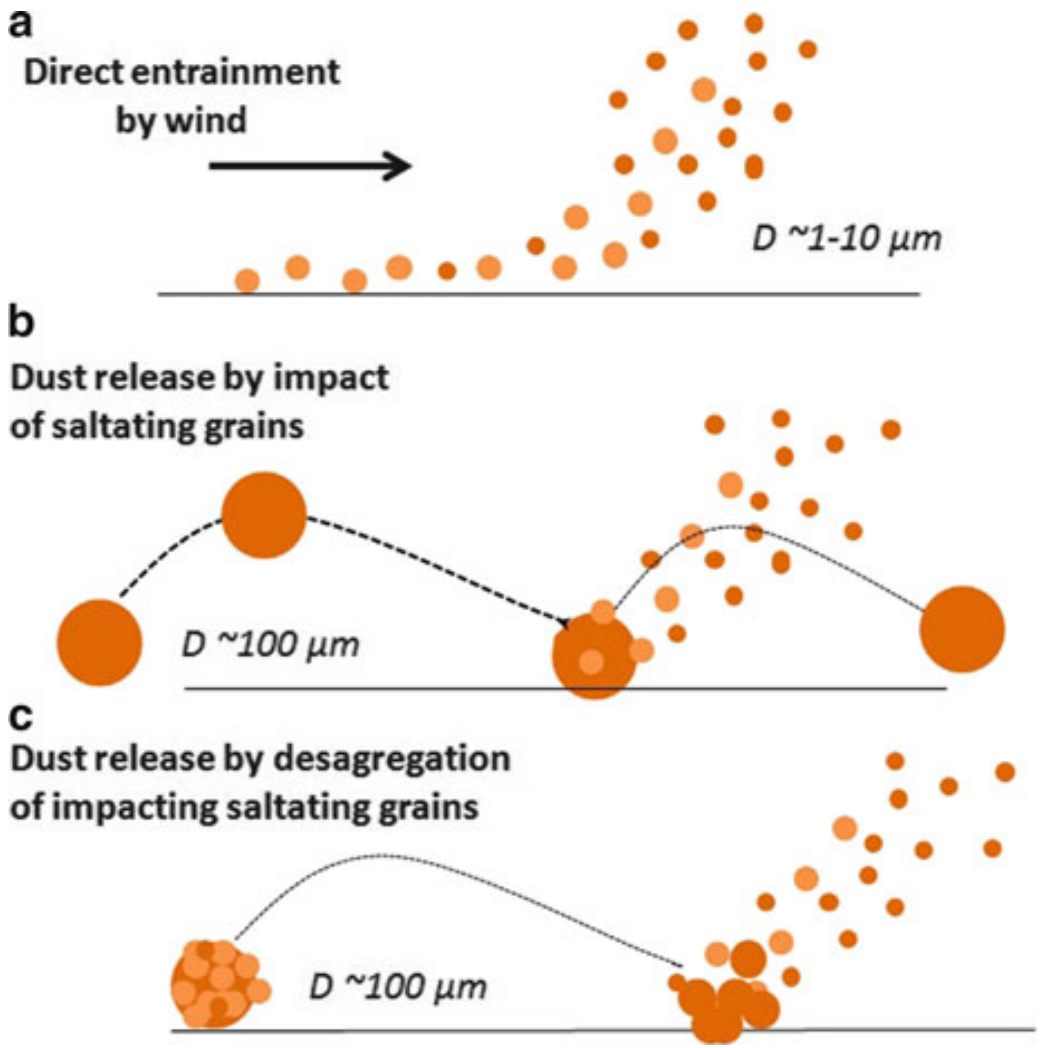
- high wind
- Wind shear and turbulence
- Unstable boundary layer



Threshold friction velocity vs particle radius

Friction velocity is the key parameter as it expresses wind speed, turbulence and stability

Dust emission mechanisms

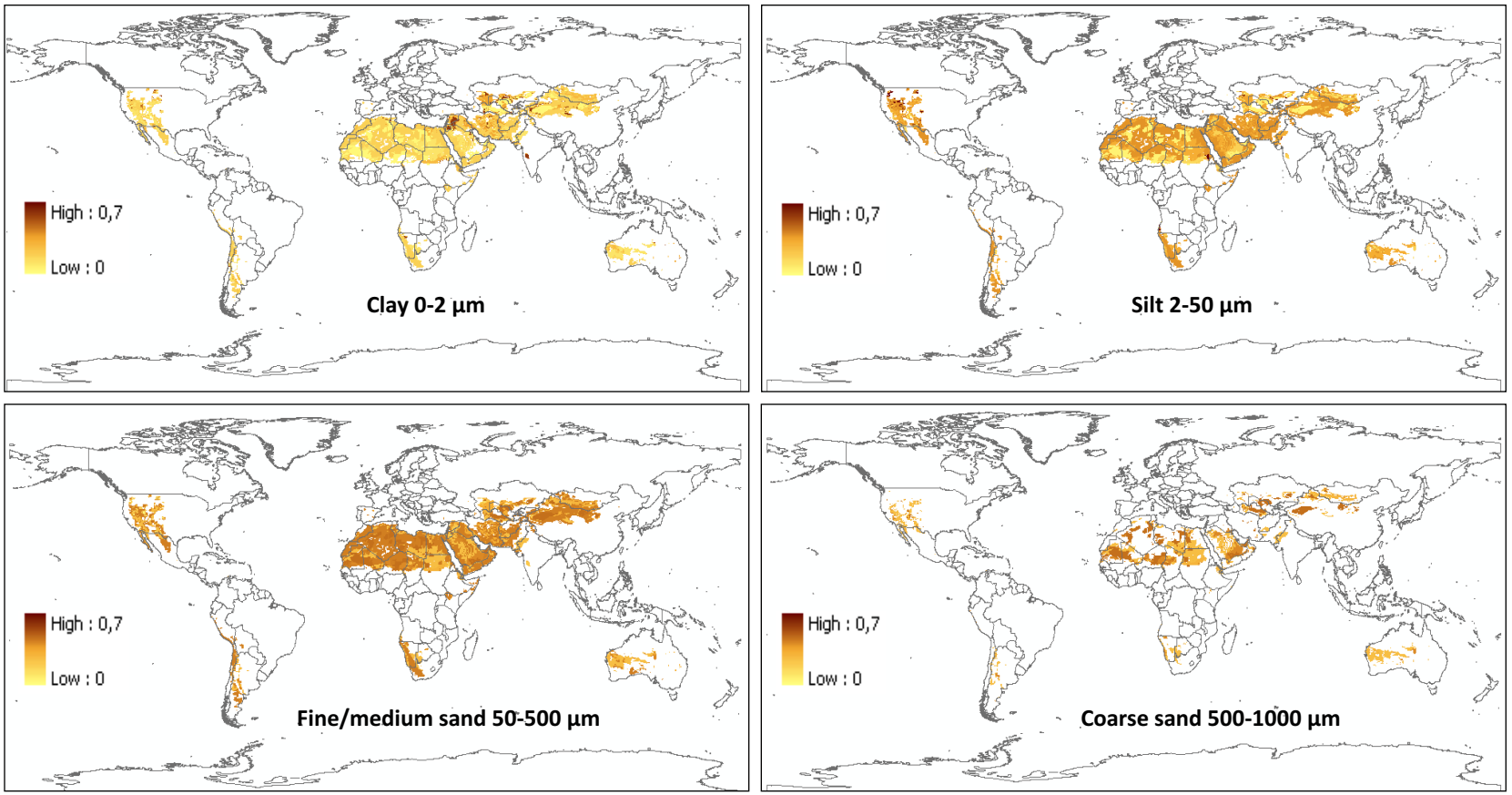


Emitted dust mass

&

Size distribution

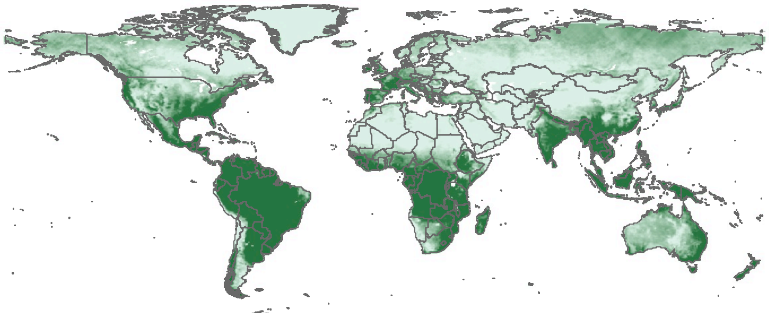
Soil size distribution derived from soil texture



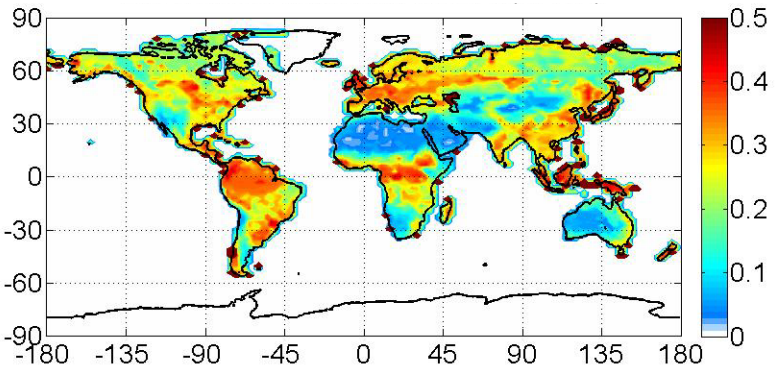
STASGO-FAO database

Vegetation, roughness, soil moisture

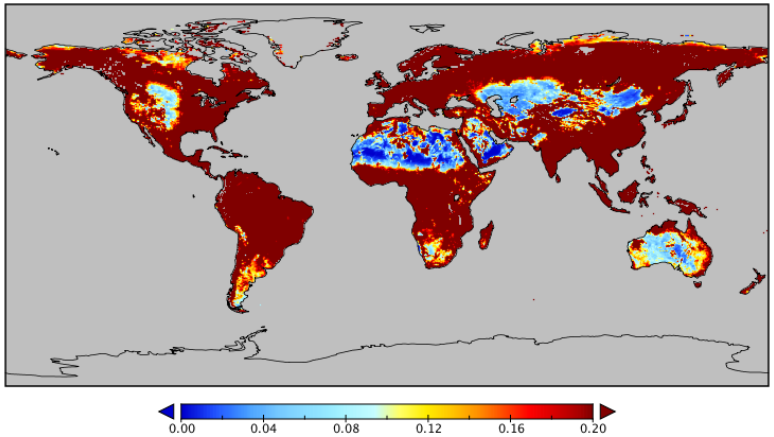
Vegetation fraction
(MODIS)



Soil moisture
(model based)

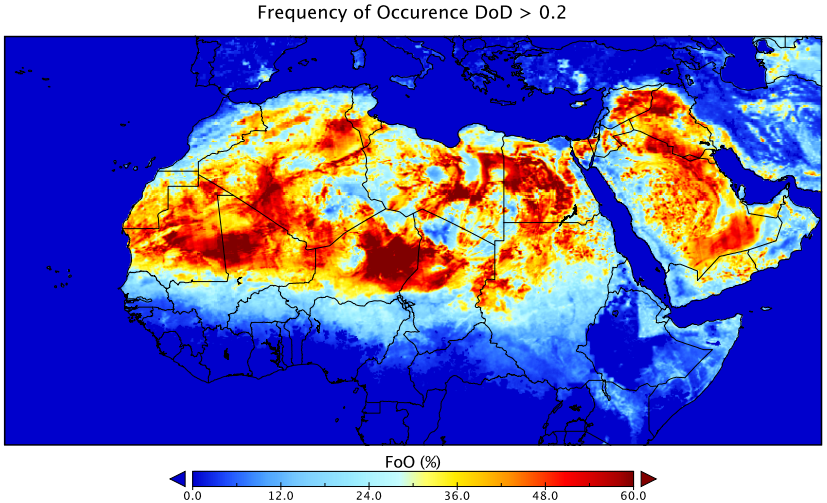


Roughness length
(ASCAT + PARASOL)

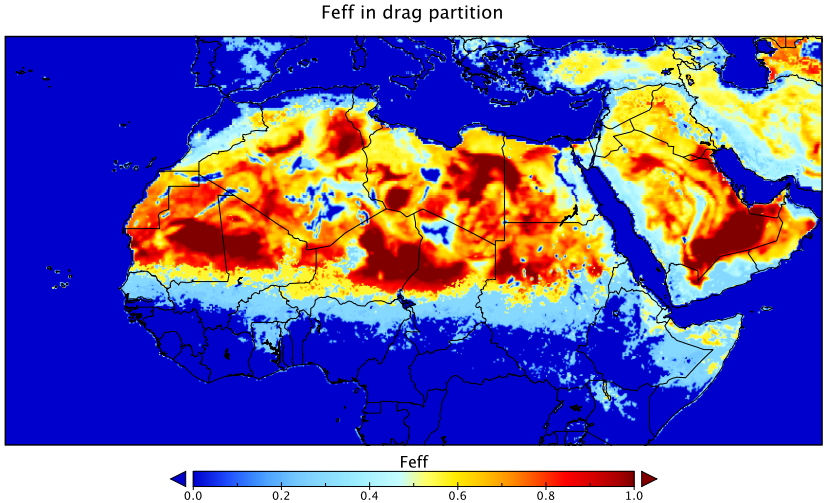


Dry aggregate soil size distribution?
Soil crusting?

Roughness control upon dust emission



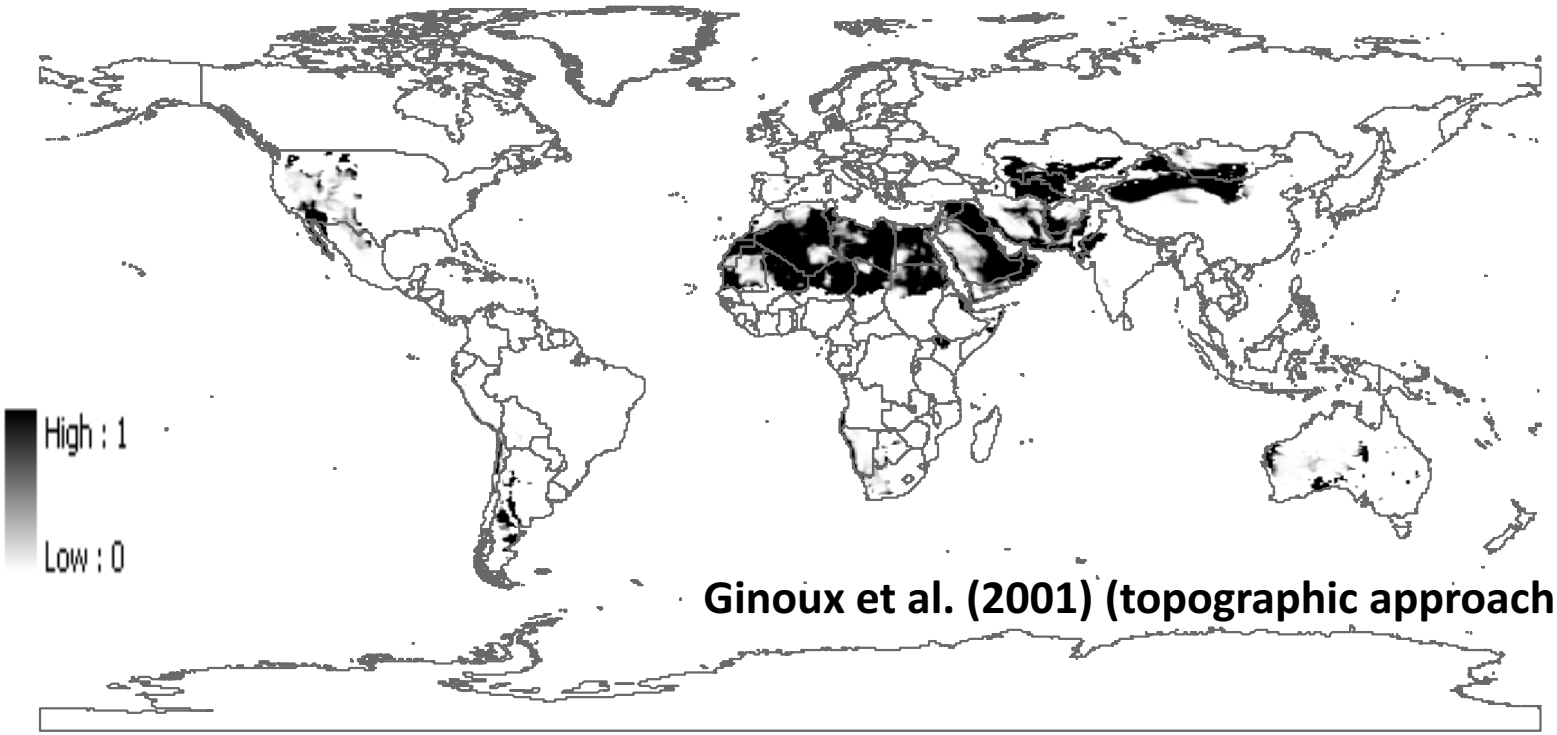
MODIS frequency of occurrence



Degree of reduction in threshold friction velocity based on roughness

Perez García-Pando et al., in prep

Source mapping: why?



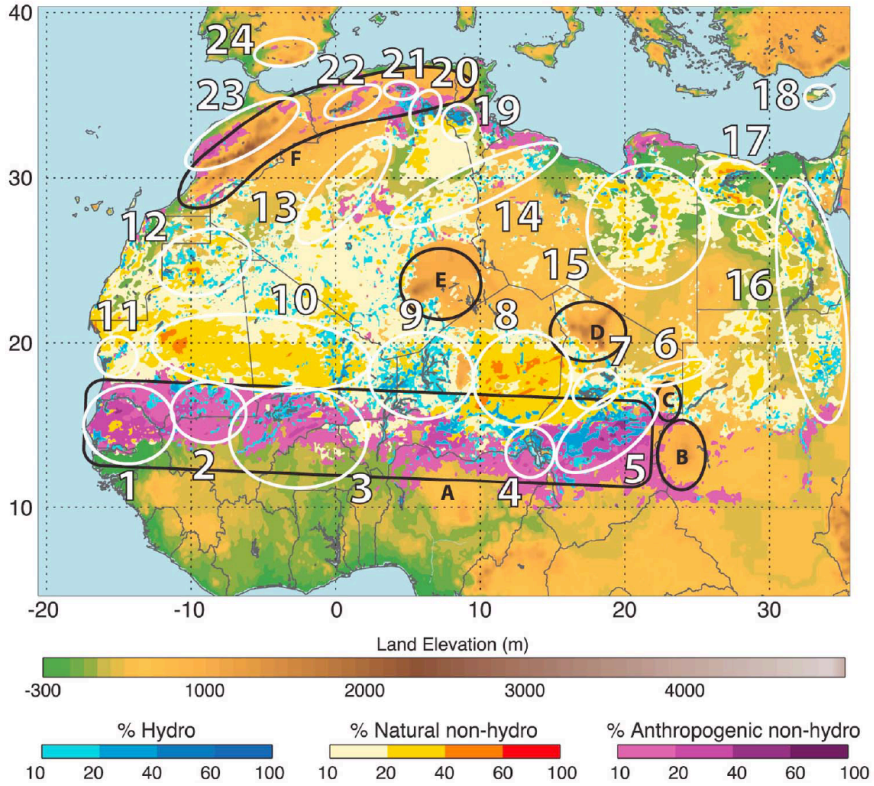
Ginoux et al. (2001) (topographic approach)

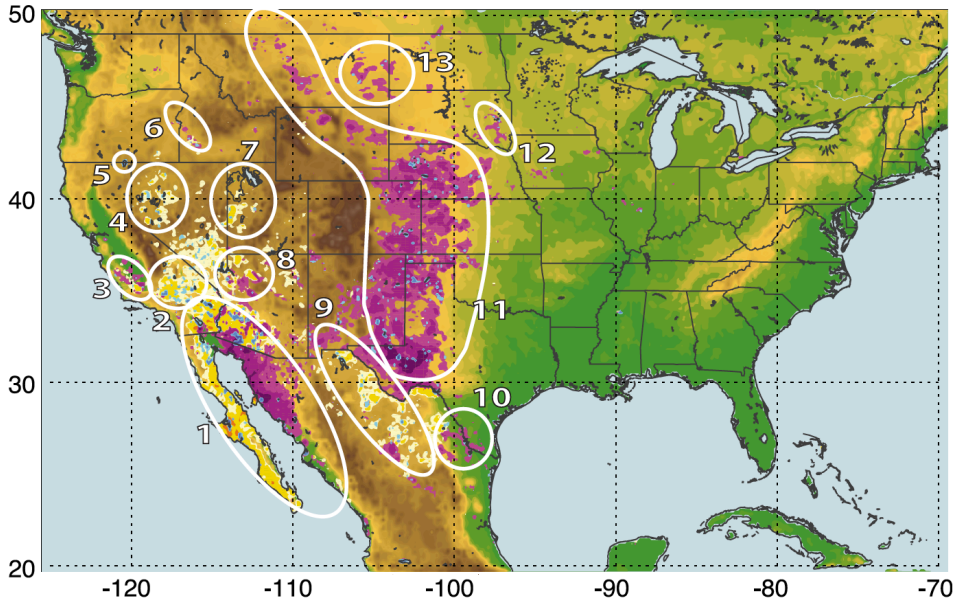
$$S = \left(\frac{z_{\max} - z_i}{z_{\max} - z_{\min}} \right)^5$$

S: probability to have accumulated sediments in the grid cell i of altitude zi

best fit with the sources identified by Prospero et al. 2000

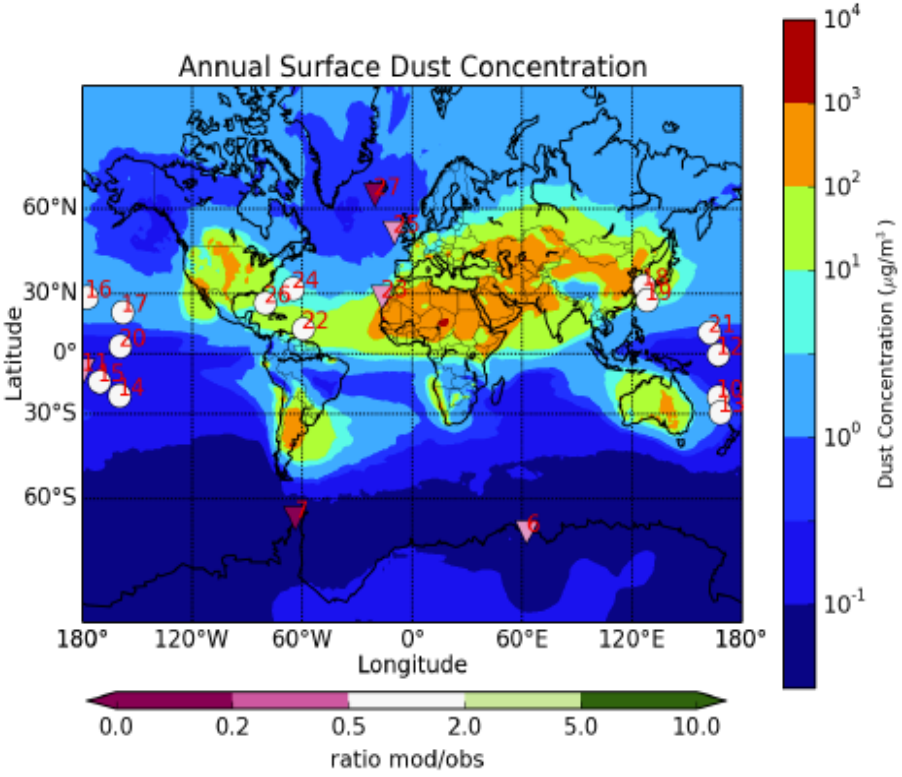
High resolution
Natural and anthropogenic dust sources

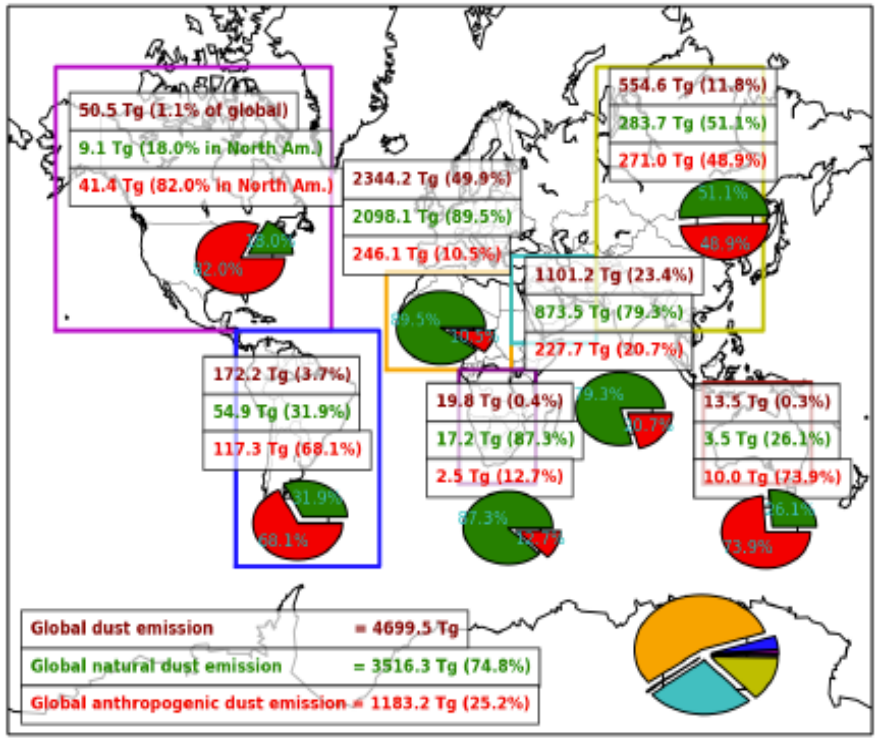




Ginoux et al. 2012

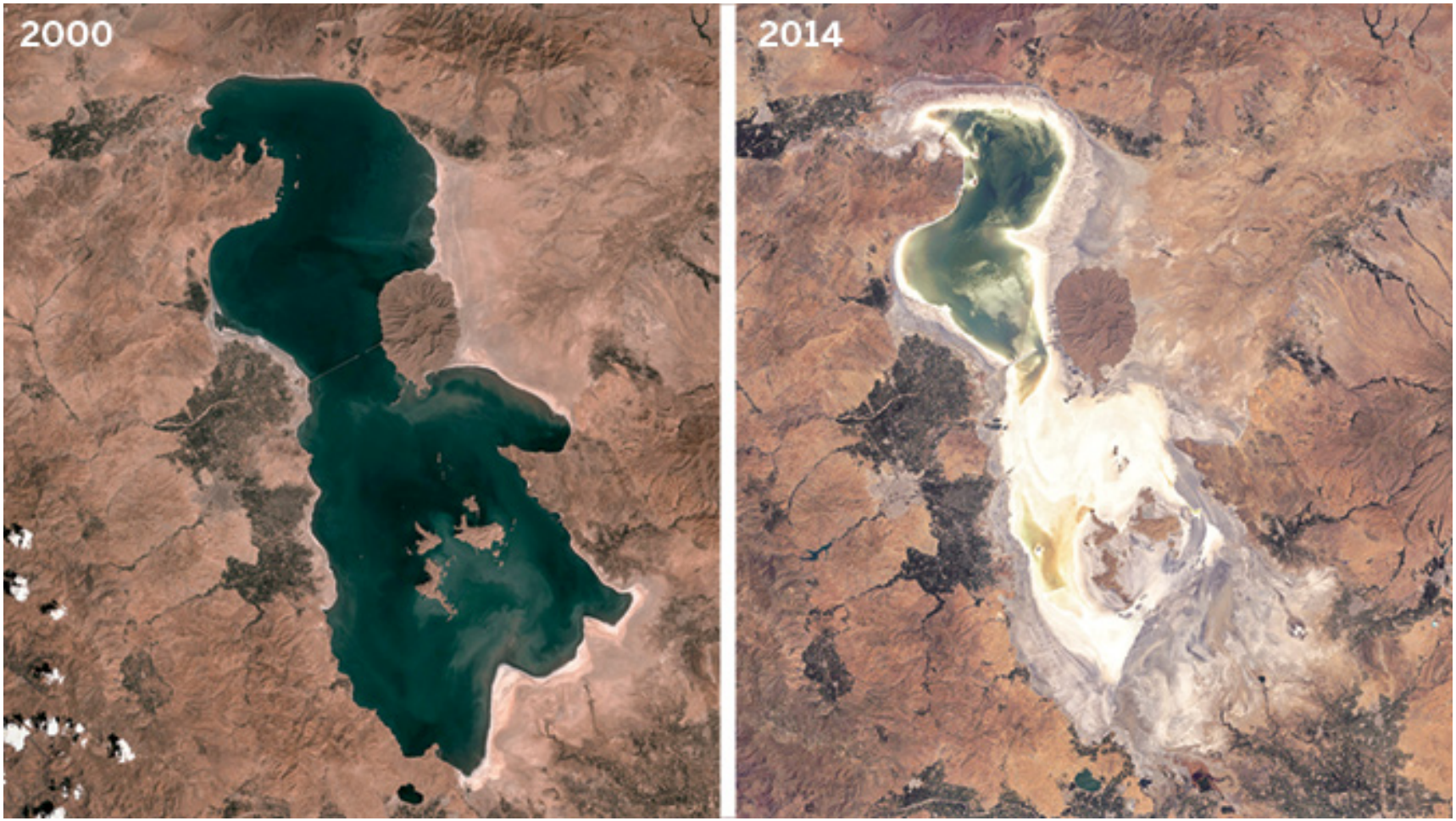
Current quantification



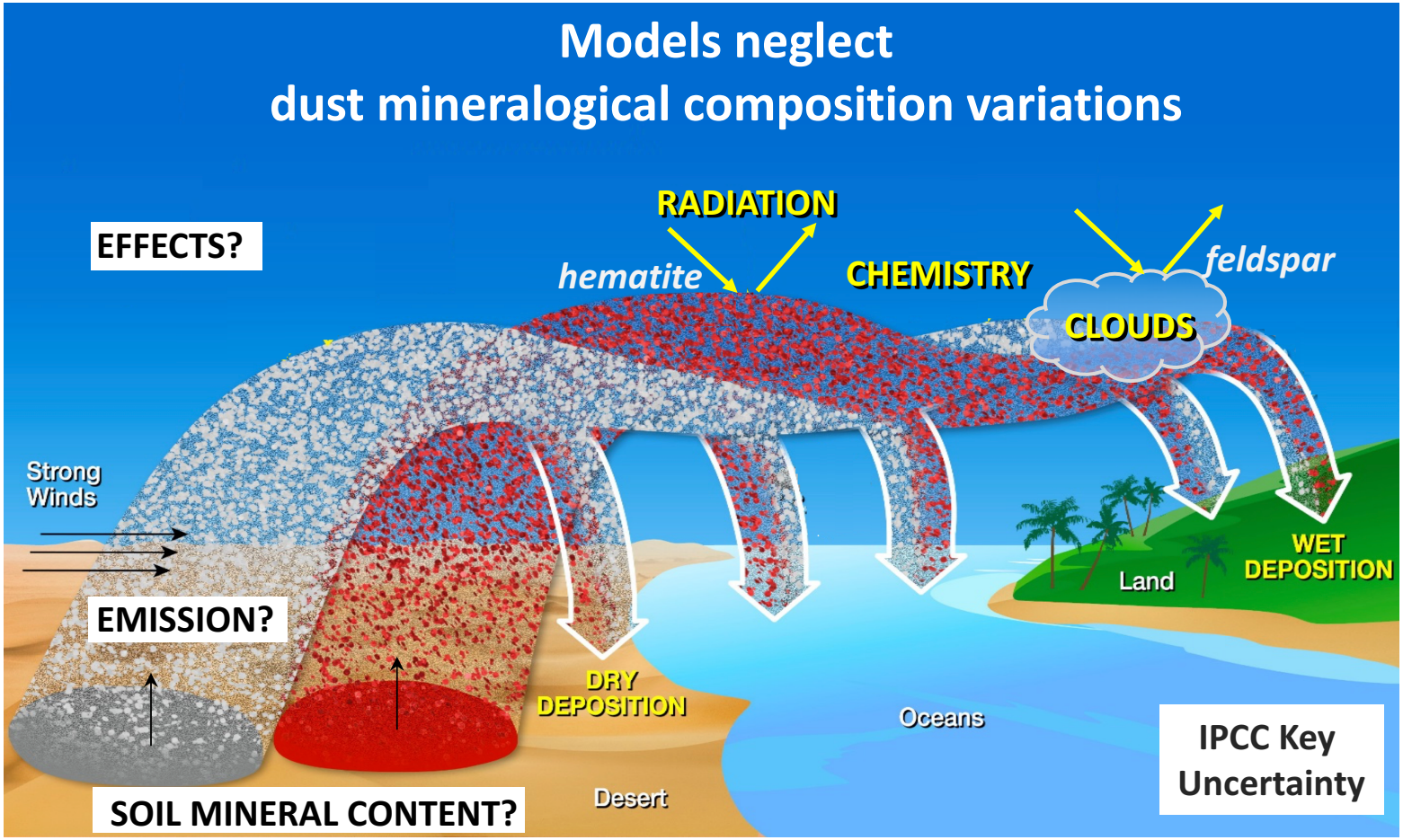


Perez García-Pando et al., in prep

Major challenge for modeling



Mineralogy!

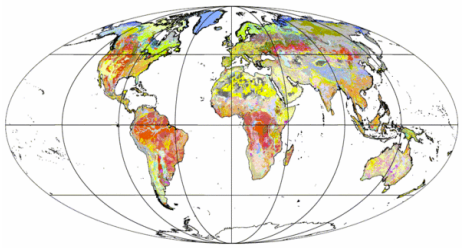

Models neglect
dust mineralogical composition variations
EFFECTS?
RADIATION
hematite
CHEMISTRY
feldspar
CLOUDS
Strong
Winds
EMISSION?
DRY
DEPOSITION
Oceans
Land
WET
DEPOSITION
SOIL MINERAL CONTENT?
Desert
IPCC Key
Uncertainty

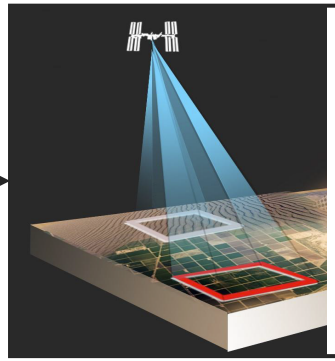
Challenges

Methods

1

Global soil mineral content

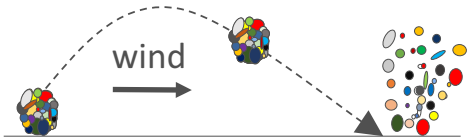




Space-borne spectroscopy
+
Airborne spectroscopy
+
Field campaigns

2

Emission of minerals

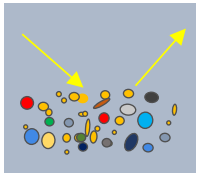


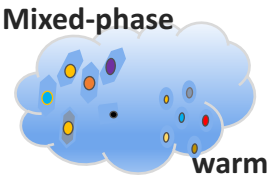
FRAGMENTation of aggregates

Theory
+
field campaigns
+
Laboratory analyses

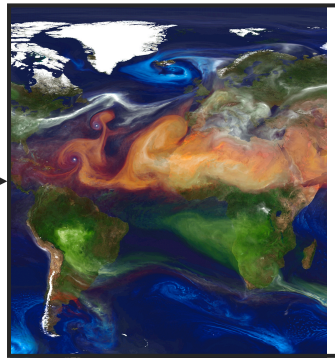
3

Role of mineralogy





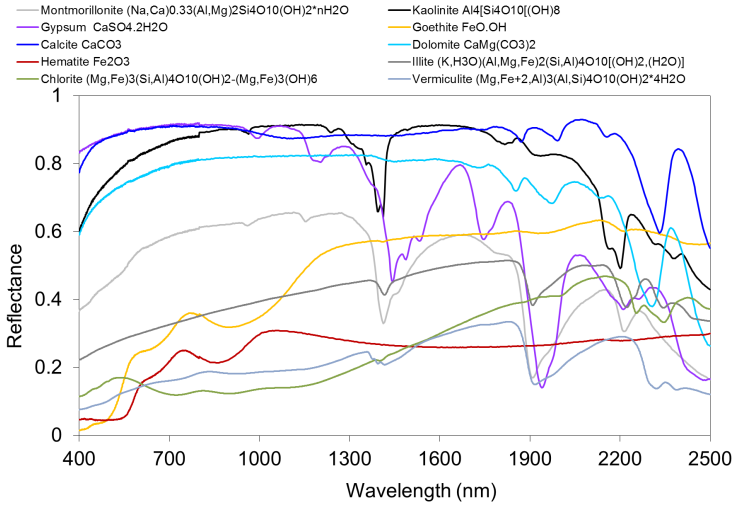
Radiation, Chemistry and Clouds



Modelling
+
State-of-the-art
+
New methodologies

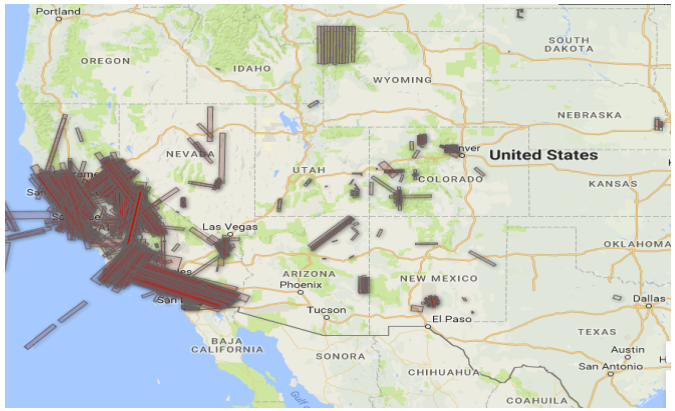
Remote hyperspectral spectroscopy

VSWIR Spectra of Dust Source Minerals

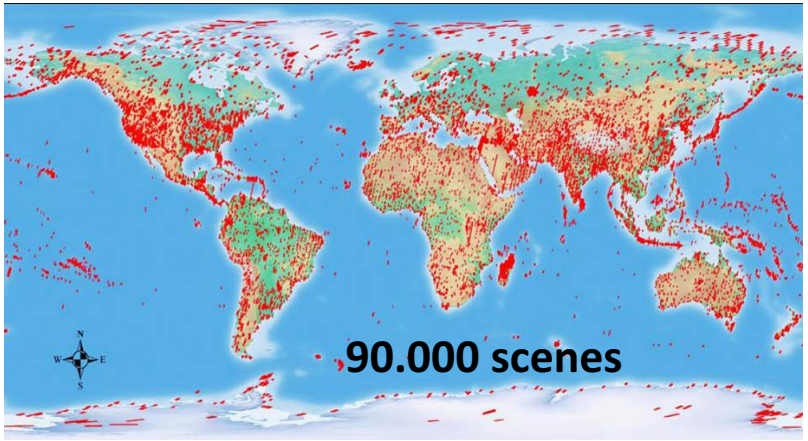


AVIRIS airborne scenes

0.4–2.5 µm, 224 bands, 10 nm spectral resolution, SNR of ~500:1

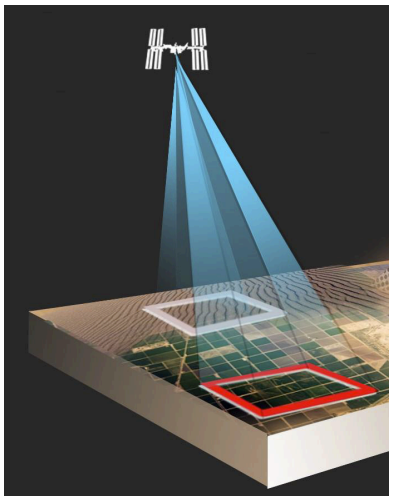


Hyperion: satellite hyperspectral sensor 0.4 to 2.5 µm, 242 spectral bands, 10nm spectral resolution, 30 m spatial with a SNR of ~50:1

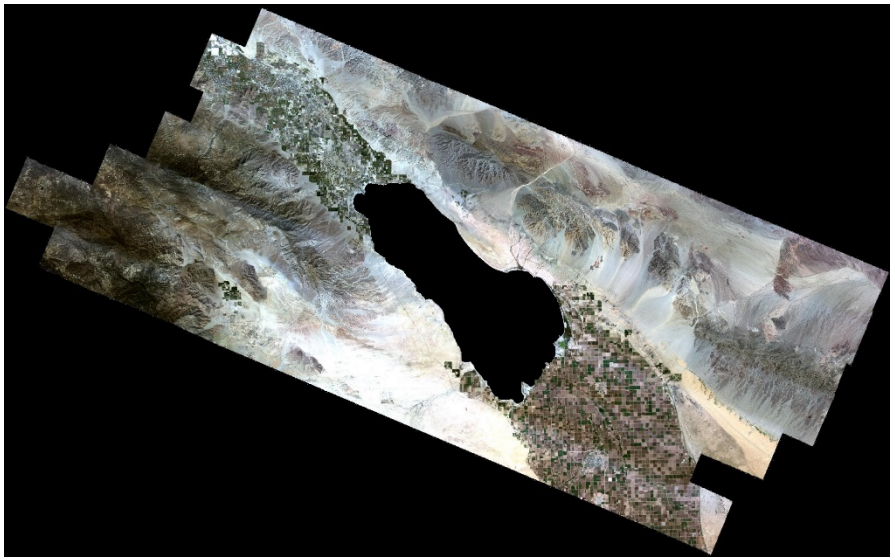


Coming soon, e.g., EnMap (~2019) Germany

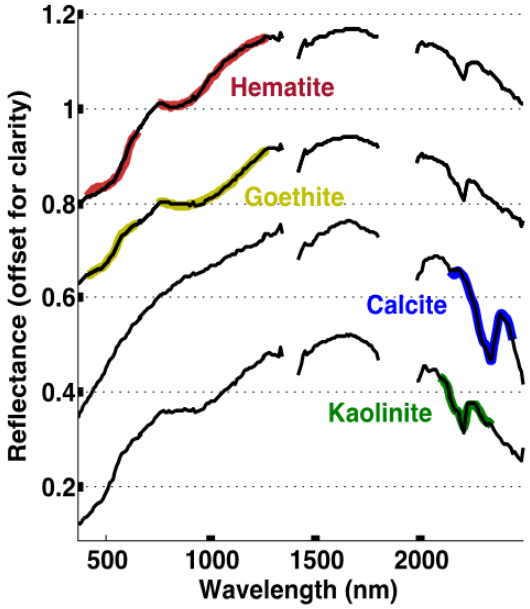
EMIT (under review) NASA, US



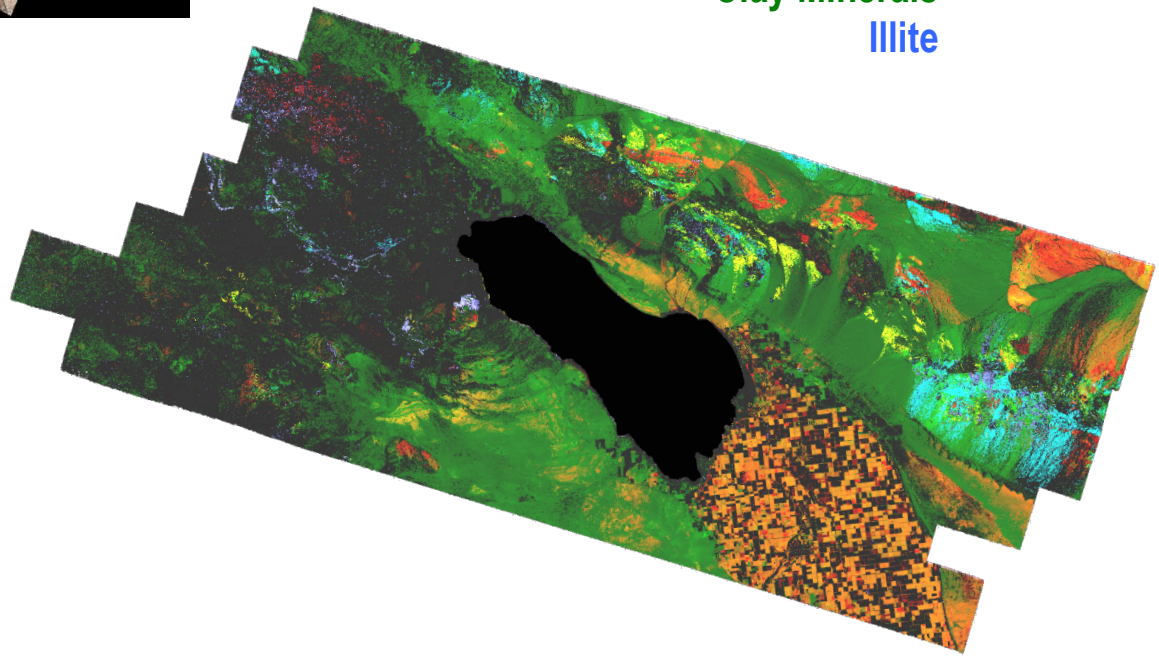
Salton Sea and AVIRIS measurements



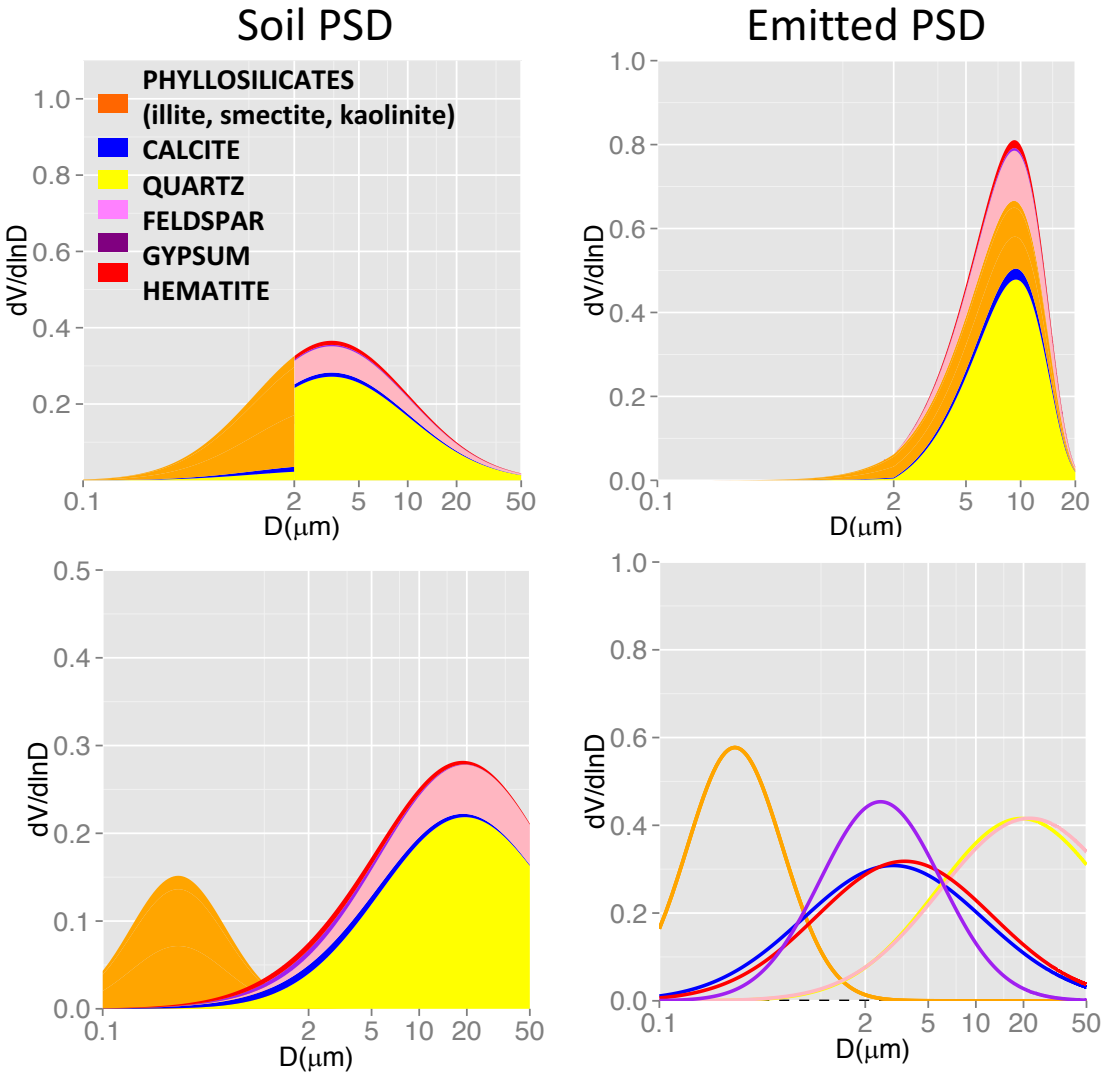
AVIRIS VSWIR imaging spectroscopy measurements of Salton Sea in Southern California block



Hematite
Goethtite
Carbonates
Clay Minerals
Illite



Emitted size distribution of minerals



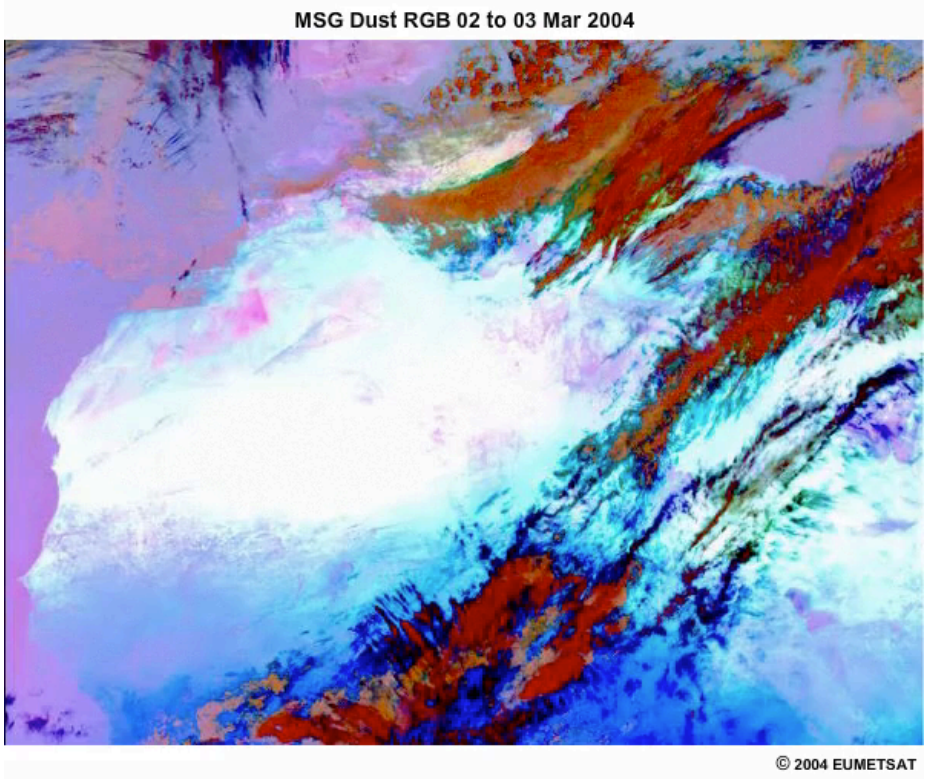
Perlwitz et al., 2015a,b
Pérez García-Pando et al., 2016
Pérez García-Pando et al., in prep

Meteorogical processes

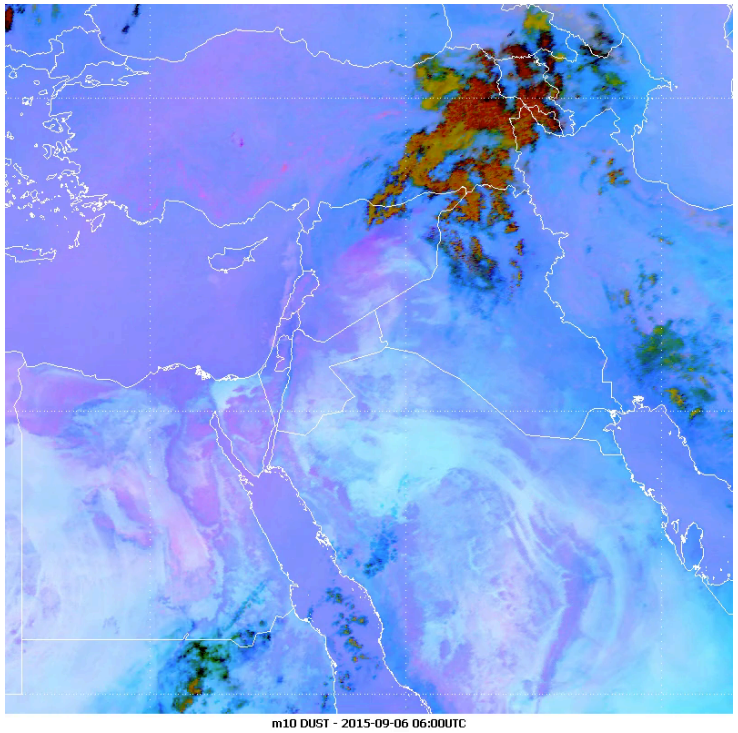
- Synoptic dust storms (large scale weather systems)
  - Prefrontal winds
  - Postprontal winds
  - ….
- Mesoscale dust storms
  - Gap flows
  - Haboobs
  - Inversion downbursts
  - Dust devils
  - …..

Meteorogical processes

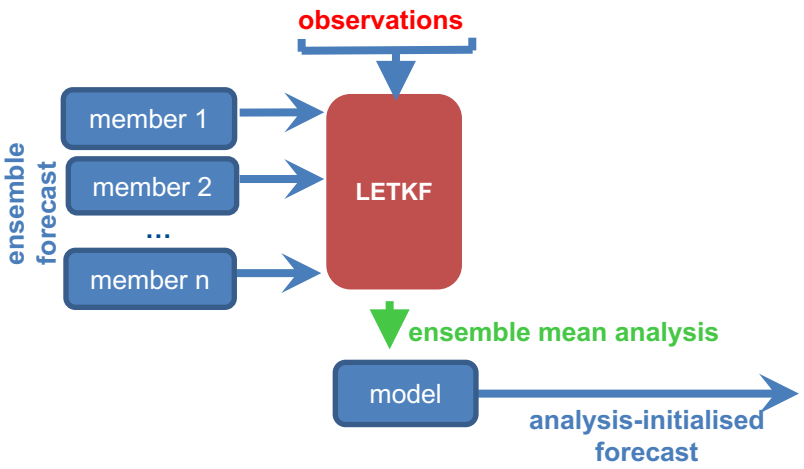
Synoptic dust storm

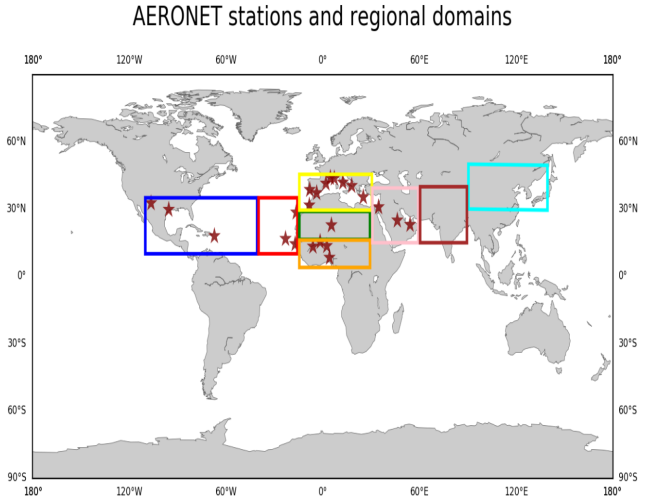


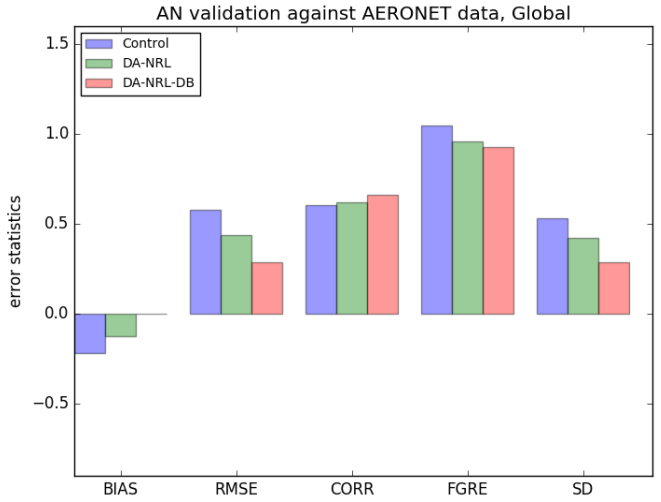
Haboob (moist convection)



Dust data assimilation and ensemble forecasting

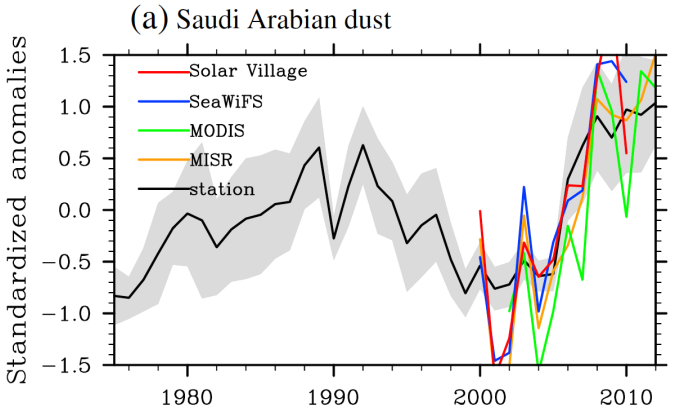




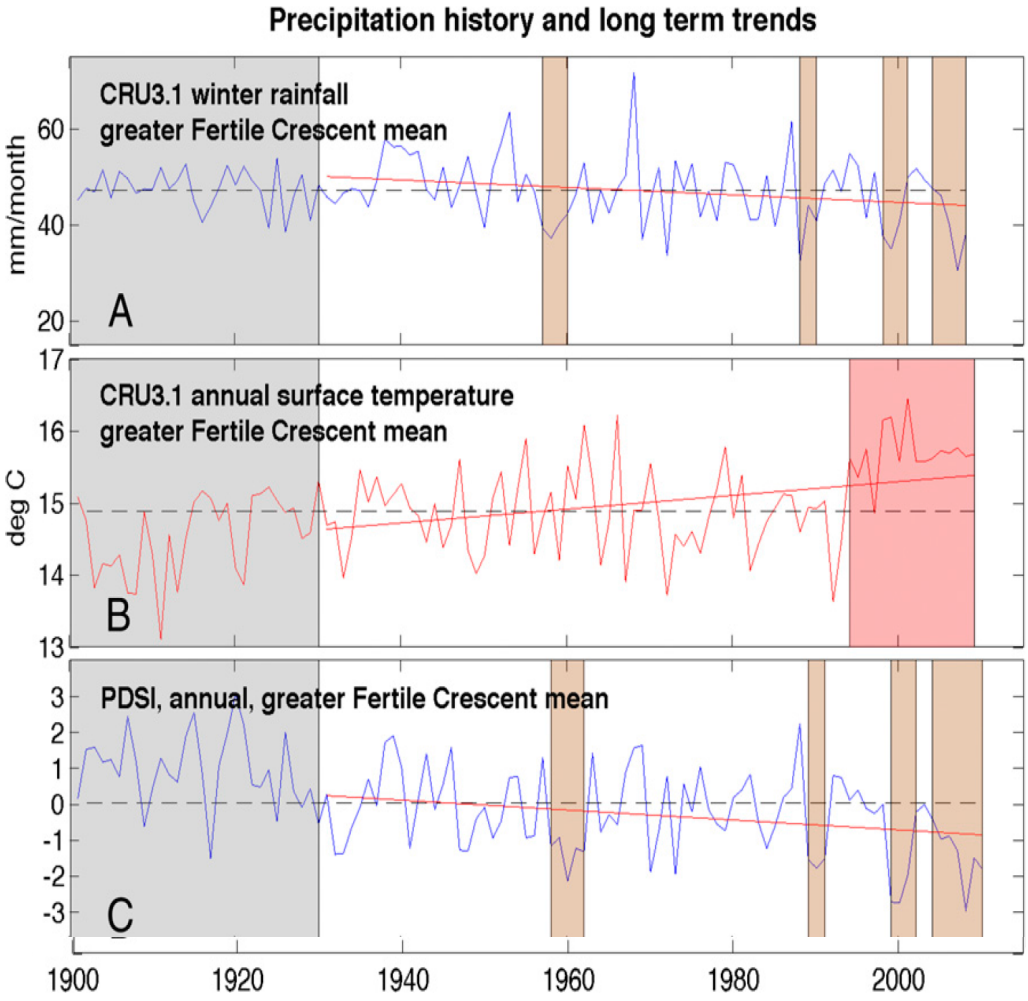


Di Tomaso et al., 2017

Interannual, decadal and long-term trends

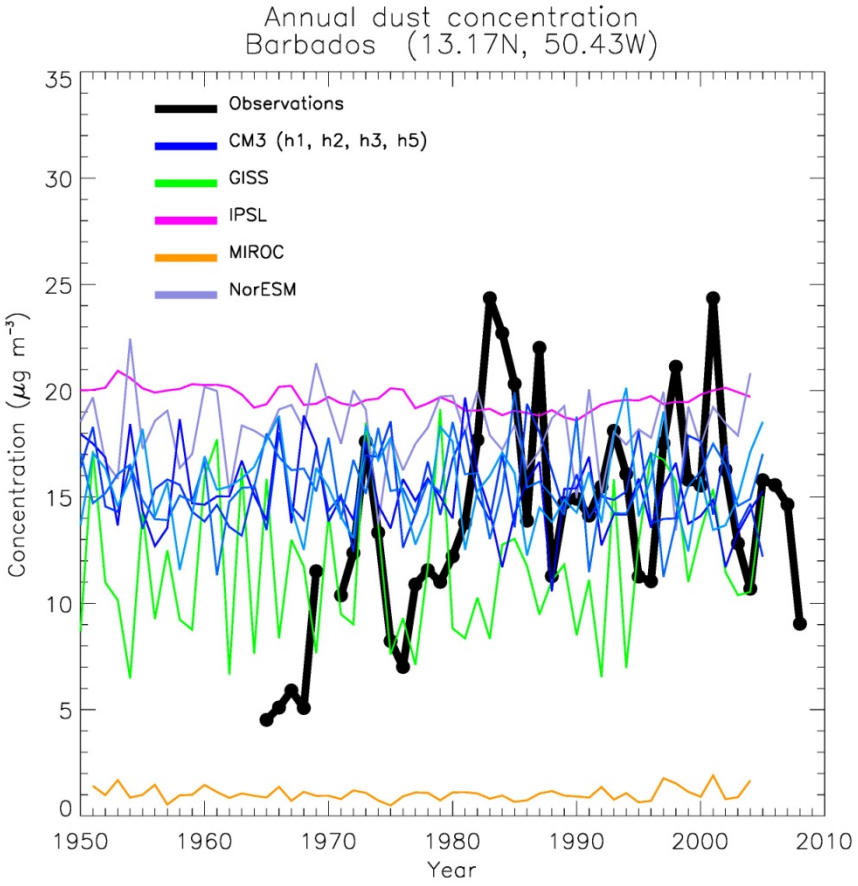


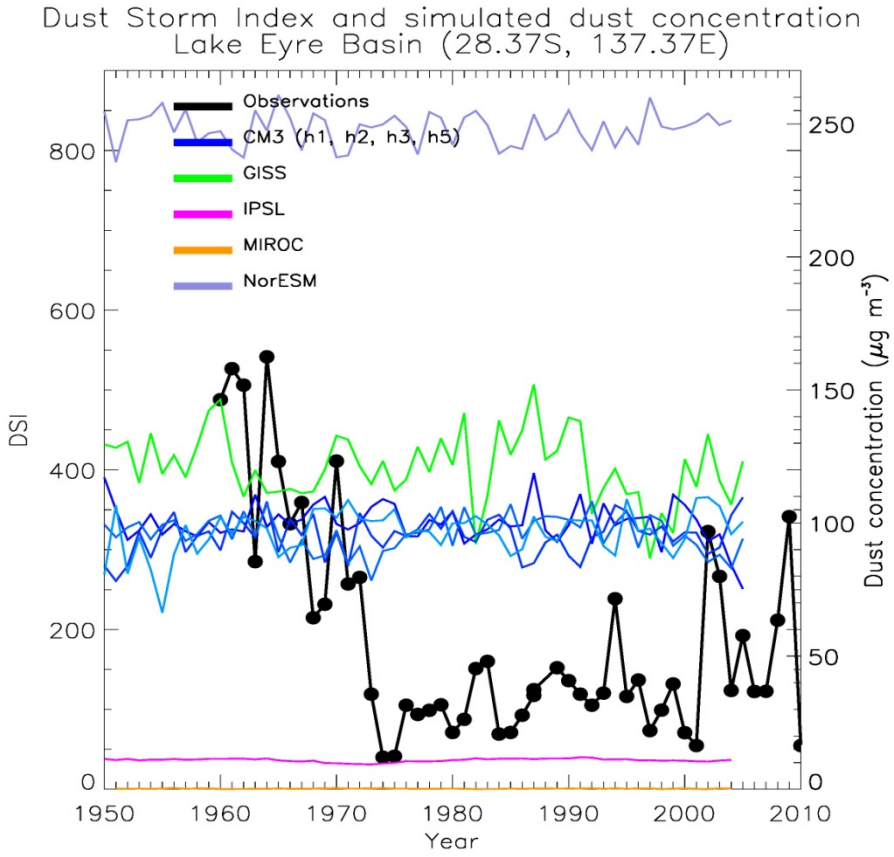
Yu et al., 2015



Kelley et al., 2015 PNAS

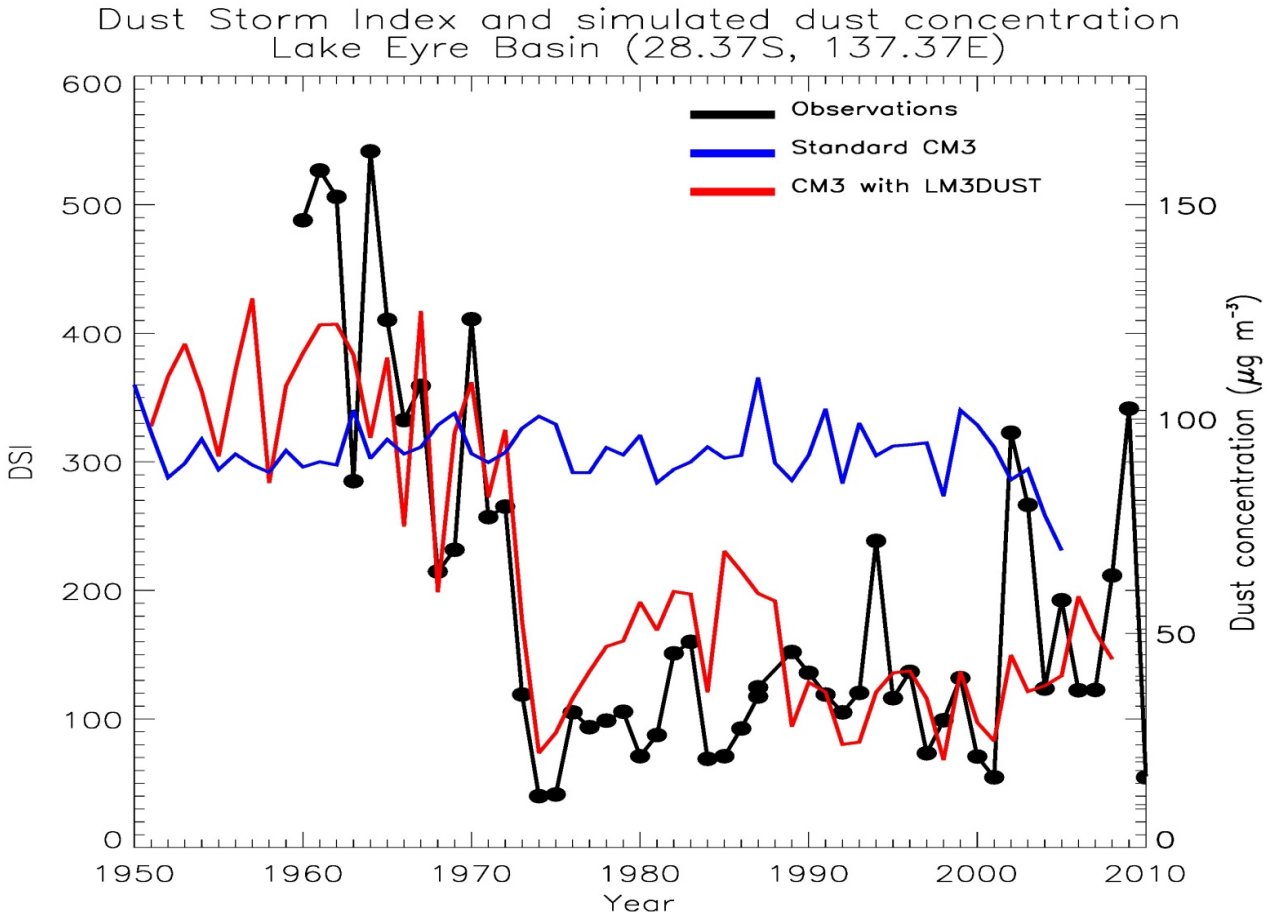
Dust variability in climate models





Courtesy Paul Ginoux

Connecting dust emission to dynamic vegetation model and land use change



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AXA Research Fund
Through Research, Protection

Thank you

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24/10/2017