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Dust predication activies at the Egyptian Meteorological Authority

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Introduction

- Sever Dust Storms (SDS) have a major impact on the air quality and climate of north Africa and Mediterranean. *We must find a solution to reduce the impacts of dust storm on the society and environment*. May be the land use change is the best solution for dust mitigation ???
- In general, the arid and semi-arid area of MENA, the SDS are occurs frequently. In this study we address the following scientific question: *What is the impacts of land-use change on SDS frequencies and intensities?*
- As well, the detection of the dust source region and monitoring of the dust plume from its primary outflow to final deposition will be taken into accounts.
- The main idea of integrated dust storm monitoring and modeling system should be described as a key research areas, including new dust modules (*More understandable Processes*) and techniques in satellite remote sensing and system integration.

What Controls Dust Emissions

MODELED NATURAL EMISSIONS:

- Preferential sources
- Vegetation cover / type
- Surface wind speed
- Soil particle size
- Soil moisture

HUMAN IMPACTS:

Soil surfaces

- Cultivation
- Overgrazing
- Deforestation
- Roads, construction, military activity

Climate

- Meteorology (winds, precip)
- Natural vegetation

Some recent advances in regional dust modeling

- Analyzed wind fields or nudged runs to facilitate model-data intercomparison, improve dust source parameterizations.
- Role of ‘hot spots’ and vegetation for dust emission.
- Observations: Major field campaigns to analyze properties of transported dust (ACE-Asia, PRIDE, SHADE).
- New satellite assessments and instrumentation.

Major remaining problems

- Subgridscale winds, initial vertical transport.
- Soil properties in particular in ‘hot spots’, parameterization of crusting.
- Relation of dust mineralogy to source soil properties.
- Further data compilations, observations near source regions.
- Percentage of dust from agricultural sources (‘anthropogenic dust’)?

Most uncertainties in dust cycle modeling are due to dust emissions

Dust Scheme in RegCM

Key question :

- Dust climatic forcing and impacts are still uncertain (IPCC).
- Potential importance of dust for weather forecast over North and West Africa, China and Atlantic.
- Global climatic impact of dust (impact on SST variability, Paleoclimate).
- Dust aerosol and regional climatic response are still difficult to represent in GCM and RCM.

RegCM-CHEM Model Core

- **Dynamics:**
  MM5 Hydrostatic (Grell et al 1994)
  Non-hydrostatic (MM5 or WRF, in progress)
- **Radiation:**
  CCM3.6.6 (Kiehl 1996)
  RRTM (in progress)
- **Large-Scale Clouds & Precipitation:**
  SUBEX (Pal et al 2000)
- **Cumulus Convection:**
  Grell (1993) + FC80 Closure
  Anthes-Kuo (1977)
  MIT/Emanuel (1991)
  Betts-Miller (1993)
  STRACO (in progress)
- **Boundary Layer:**
  Holtslag (1990)
- **Nesting:**
  Numerous GCM/Reanalysis Interfaces
  One-way nesting
- **Biogenic Emiss:**
  MEGANE (Twffic, 2010)
- **Tracers/Aerosols:**
  Qian et al (2001) – sulfur chem.
  Solmon et al (2005) – BC/OC chem.
  Zakey(2006) dust module
  Zakey(2008) Sea-salt
  Zakey(2010) DMS and sulafte from Ocean
  Shalaby (2010) – gas-phase chem.
- **Land Surface:**
  BATS1e (Dickinson et al., 1993)
  SUB-BATS (Giorgi et al., 2003)
  CLM (Dai et al., 2003, Dai & Bi, in progress)
  IBIS (Foley; Winter in progress)
- **Ocean Fluxes:**
  BATS1e (Dickinson et al., 1993)
  Zeng et al (1998)
  Air-Sea Coupling (MITogcm, OASIS coupler, in progress)
- **Computations:**
  User-Friendly
  Multiple Platforms
  Parallel Code

RegCM-CHEM: Chemistry Core

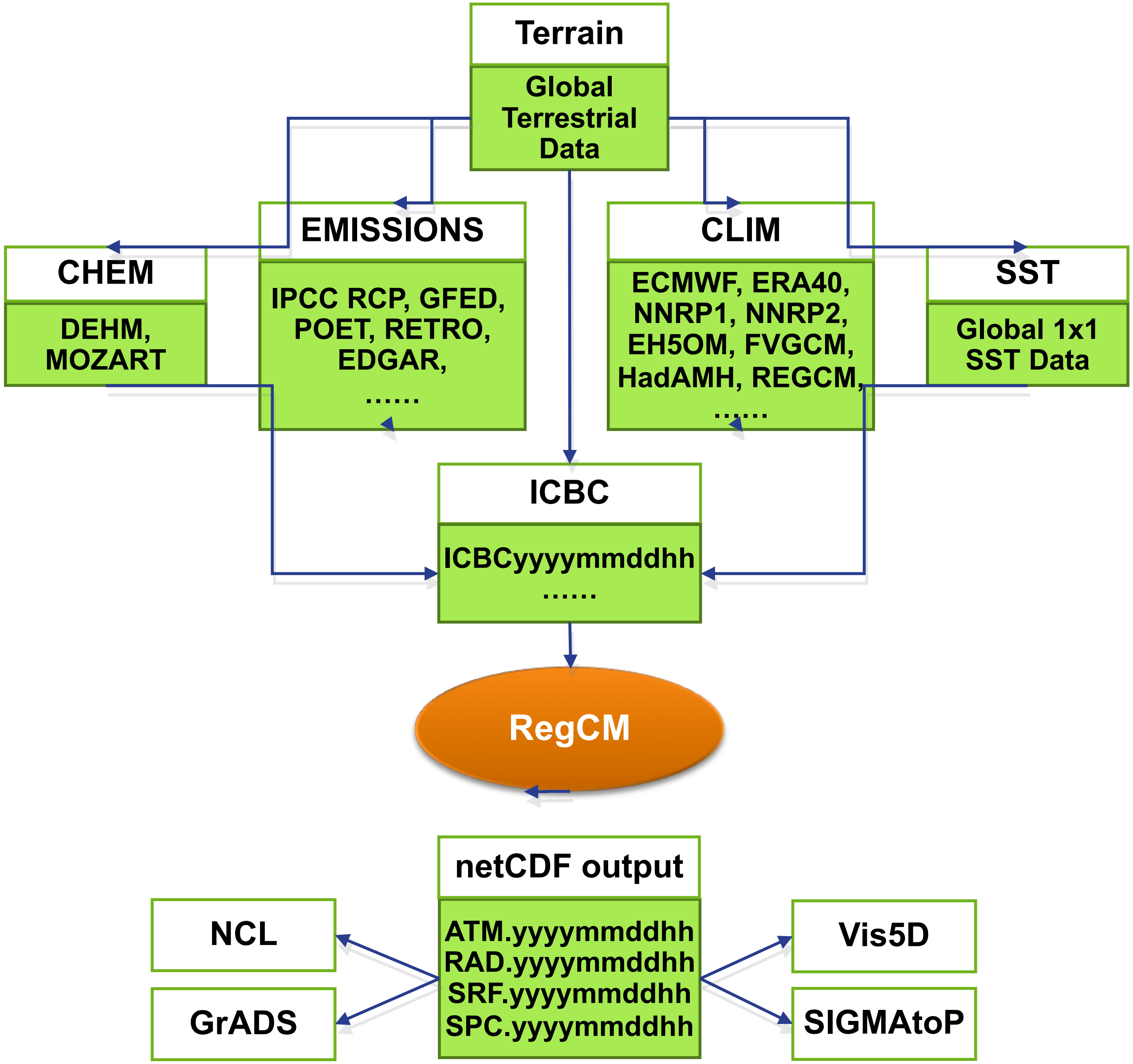
Chemistry:
Condensed CBM-Z gas-phase chemistry (Zaveri and Peters, 1999).

Solver:
Radical balance method (RBM) by (Sillman et al., 1991) and (Barth et al., 2002)

Photolysis rates:
Tropospheric Ultraviolet-Visible Model (Madronich and Flocke, 1999) with cloud cover correction by (Chang et al., 1987)

Dry deposition:
•“big leaf” multiple resistance model with aerodynamic, quasi-laminar layer, and surface resistance for 31 gaseous species.
•uptake resistance for vegetation, soil, water, snow and ice (20 land-use types).
•stomata and non-stomata resistances

RegCM-CHEM: Modeling System Flow Chart



Dust in RegCM

- General approach ⟺ Tracer model / RegDAM

$$\frac{\partial \chi}{\partial t} = -\overline{V}\cdot\nabla\chi + F_H + F_V + T_{CUM} + S_\chi - R_{w,ls} - R_{w,cum} - D_{dep} + \sum Q_p - Q_l$$

Transport — Primary Emissions — Removal terms — Physico – chemical transformations

Strongly dependent on the nature of the tracer

- Particles and chemical species considered.

SO_2	SO_4^{--}	BC (soot)		OC (total organic carbon)		DUST (4 bins)			
Aqueous and gazeous conversion (Qian et al., 2001)		*Hydrophilic (20% at emission)*	*Hydrophobic* (80%at emission)	*Hydrophilic (50%at emission)*	*Hydrophobic(50%at emission)*	0.01-1 µm	1-2.5 µm	2.5-5 µm	5-20 µm

Aerosol dust modeling in RegCM (Zakey et al., 2006 ACP)

Input parameters

Soil texture (12 types, USDA)

Soil erodible dry aggregates distribution (Shao et al. ,2002**)**

Land surface properties (BATS)

(roughness, soil humidity, cover fractions)

RegCM atmospheric variables

(surface wind, air temperature, air density)

DUST emission scheme

Zakey et al., 2006

Saltation (Marticorena et al. 1995)

Roughness and humidity correction

Suspension

Sand-blasting (Alfaro et al., 1997, 2001)

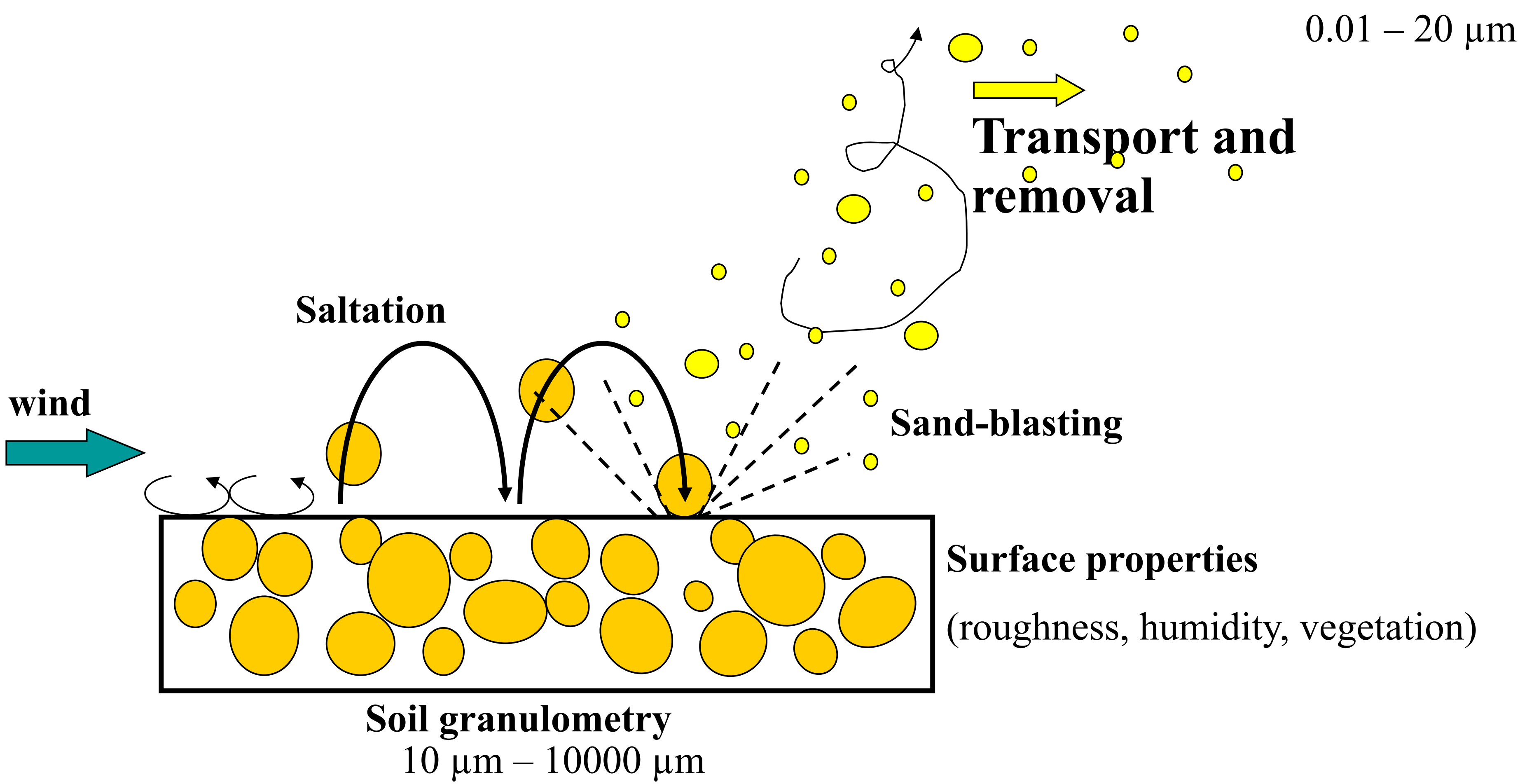
Dust flux distribution

(3 log-normal emission modes)

Transport bins (up to 12), usually 4

Size dependent settling and surface déposition

AOP / radiation



Zakey et al., 2006

RegCM

Regional climate modeling approach

Modeled dust emission

Dust Flux F: $$F = \alpha \cdot A_{eff} \cdot G \cdot (1 - A_{snow}) \cdot I_{\theta}$$

with

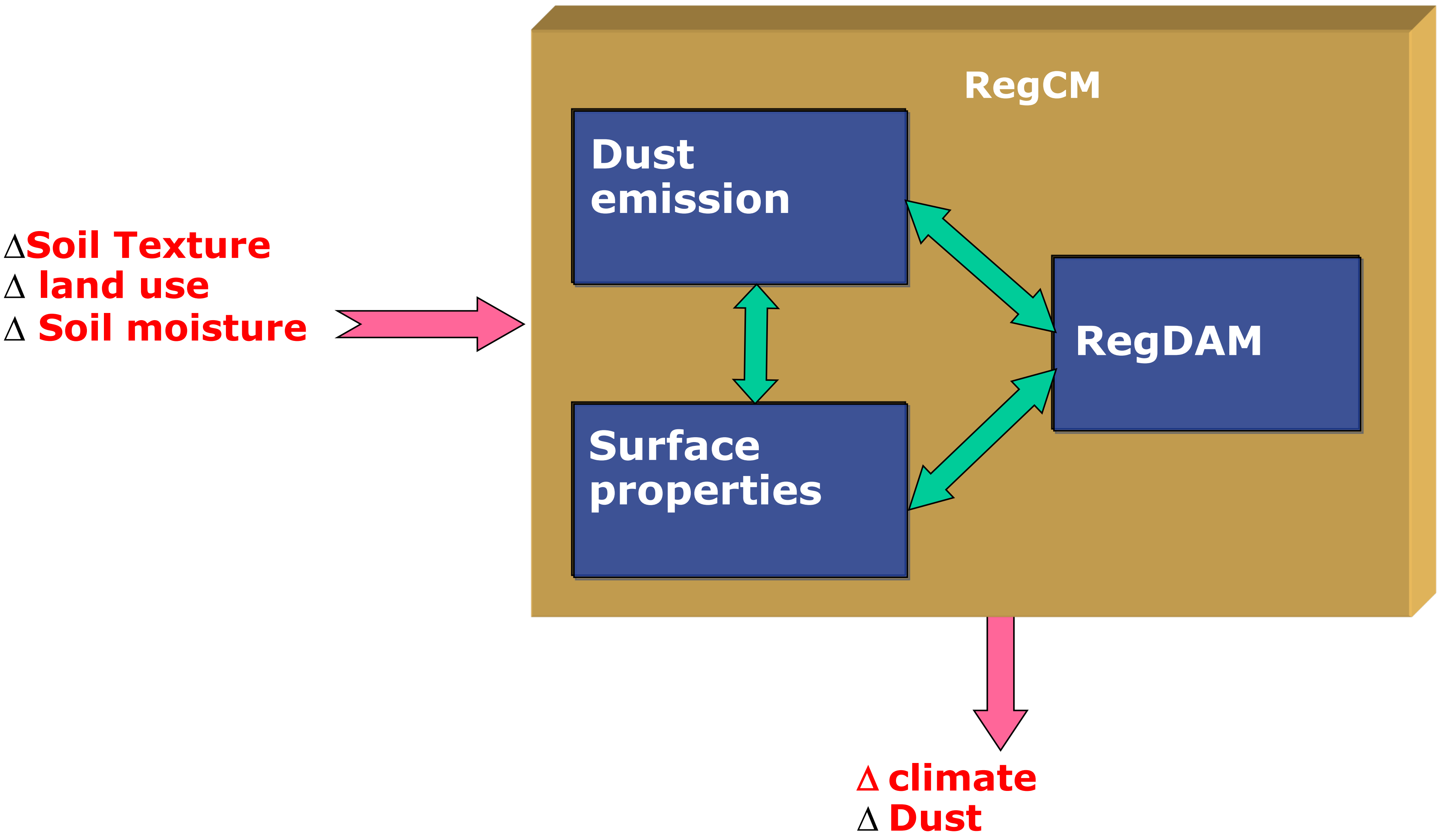
$$A_{eff} = 1 - (FPAR(\mathrm{max}) \cdot f_{shrub} + FPAR(\mathrm{monthly}) \cdot f_{grass}) \cdot \frac{1}{25}$$

$$G = \frac{\rho_a}{g} \cdot u_*^3 \cdot \sum_i [(1 + \frac{u_{*tri}}{u_*})(1 - \frac{u^2_{*tri}}{u_*^2}) \cdot s_i]$$

for $u_* \geq u_{*tr}$

α: uplift constant (depending on texture)
A_{snow}: relative snow cover
I_{θ}: soil moisture dependence
ρ_a: air density
g: gravitational constant
u_*: wind shear velocity
S_i: relative surface of particle size i

Approach: coupled Dust-climate RegCM (RegDAM)



Three Processes Control the dust emissions:

- Aerodynamic lift
- Saltation Bombardment
- Aggregates disintegration

Production of soil dust aerosols depends

- Soil surface properties
  - Soil moisture
- surface wind speed

$$\frac{dn(D_p)}{d(\log D_p)} = \sum_{i=1}^{3} \frac{n_i}{\log \sigma_i \sqrt{2\pi}} \exp\left[\frac{-(\log D_p / D_i)^2}{2(\log \sigma_i)^2}\right]$$

Threshold frication velocity

Soil dust particles are mobilized only for wind speed greater than a threshold values (*Marticorena and Bergametti, 1995*).

The expected threshold frication velocity for the observed smallest size was:

$$u^{*}_{ts} = 0.129K\left[1 - 0.0858\exp\{-0.0617(\mathrm{Re}-10)\}\right]$$

Re>10

$$= \frac{0.129K}{\left(1.928\,\mathrm{Re}^{0.092} - 1\right)^{0.5}}$$

0.3<Re<10

Where

$$\mathrm{Re} = a d_s^{X} + b$$

$$K = \sqrt{\frac{2g\rho_p D_p}{\rho_a}\left(1 + \frac{0.006}{\rho_p g (2D_p)^{2.5}}\right)}$$

Threshold friction velocity Correction: *Drag partition*

Marticorena and Bergametti(1995) showed that the threshold wind friction velocity is strongly dependent on the roughness height. They derived a drag partition scheme from an approach developed by *Arya (1975)*. The drag partition parameterization is expressed by:

$$f_{eff} = \frac{u^{*}_{tr}}{u^{*}_{ts}} = 1 - \left[\frac{\ln\left(\frac{z_0}{z_{0s}}\right)}{\ln\left(0.35\left(\frac{10}{z_{0s}}\right)^{0.8}\right)} \right]$$

Threshold friction velocity Correction: ***Soil moisture***

The threshold friction velocity is also a function of soil moisture content, which has been parameterized (*Fécan et al., 1999*) as :

$$\frac{u^*_{tw}}{u^*_{tr}} = \left[1 + A\left(w - w'\right)^B\right]^{0.5} \qquad \text{for } w > w'$$

$$= 1 \qquad \text{for } w < w'$$

$$w' = 0.0015(\%clay)^2 + 0.17(\%clay)$$

Dust Flux

Vertical

$$F = m_d n N$$

Where : n is the number of saltation impacts per unit area and time; m_d the mass of dust particles

Horizontal

$$G_{tot} = E \frac{\rho_a}{g} u^{*3} \int_{D_{s s}} (1+R)(1-R^2)\, dS_{rel}(D_p)\, d(D_p)$$

$$R = \frac{u^{*}_{tw}}{u^{*}}$$

S_{rel} is the relative surface covered by particles

The kinetic energy flux

In the saltation and sandblasting process, the fine particles released either from saltating aggregates or from the surface depend on the individual kinetic energy (*Alfaro, and Gomes, 2001*).

$$e_c = \frac{\rho_p \pi}{12\left(D_p\right)^3 \left(20u^*\right)^3}$$

The kinetic energy flux $dF_{kin}(D_p)$ of the saltating aggregates with diameters between D_p and D_p+dD_p is proportional to the corresponding horizontal saltation flux $dF_h(D_p)$ (*Gillette and Stockton, 1986; Alfaro et al., 1997; Alaro and Gomes, 2001*) as following:

$$dF_{kin}(D_p) = \beta dF_h(D_p)$$

Total emitted dust flux

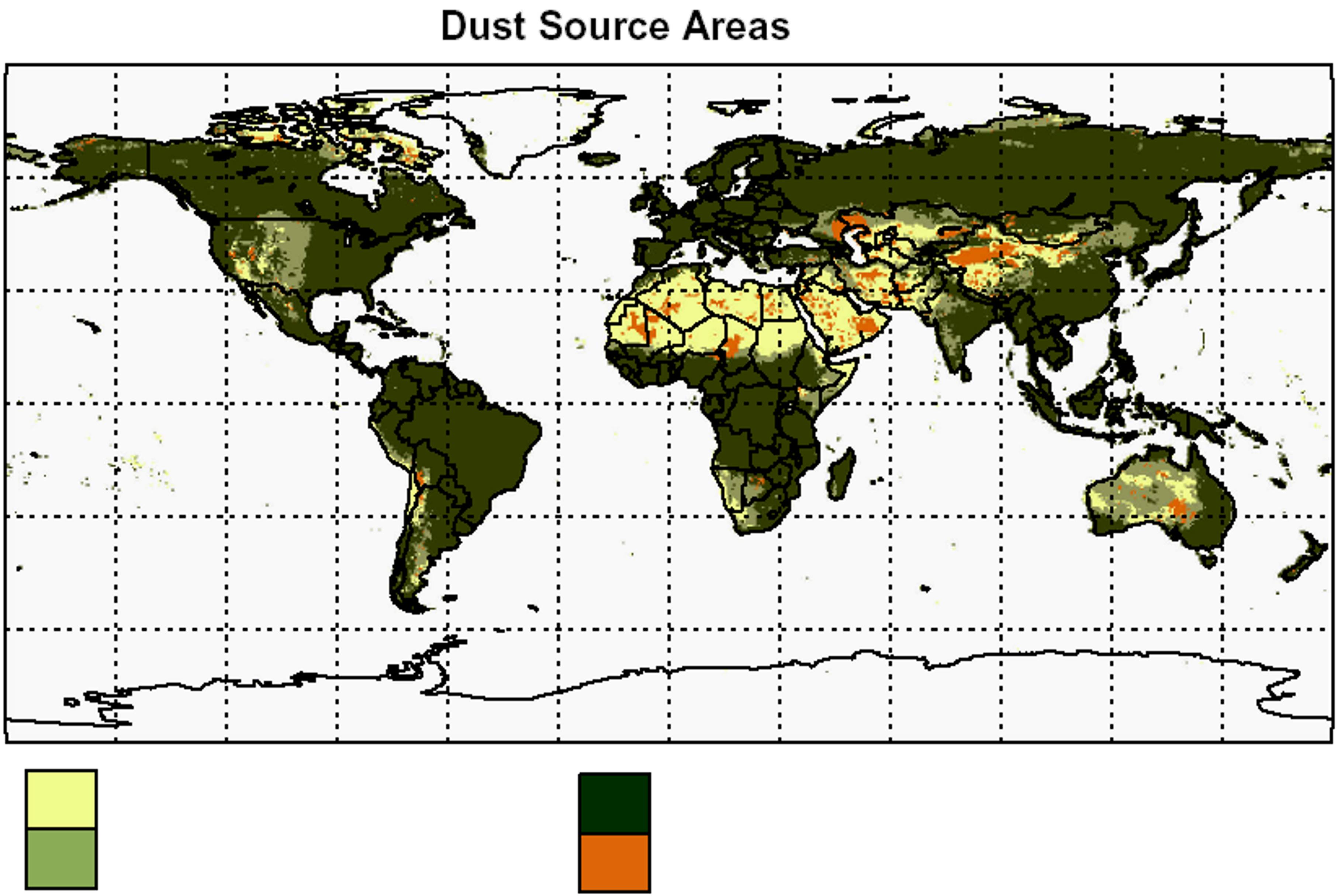
The mass flux $dF_{dust,i}$ (D_p) of the particles of the i^{th} dust mode released by the impacts of soil aggregates of size D_p are :

$$dF_{dust,i}(D_p) = \left(\pi/6\right)\rho_p \beta dF_h(D_p)\left[\frac{p_i(D_p)d_i^3}{e_i}\right]$$

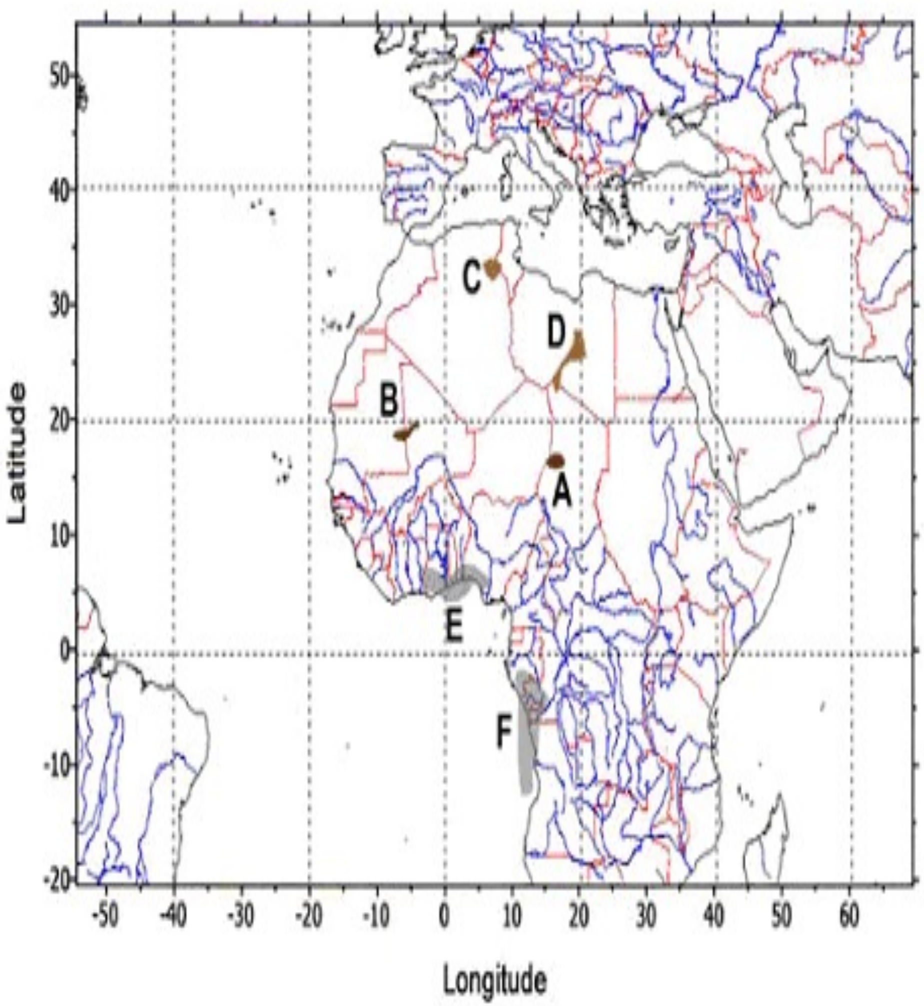
The total dust flux that represents fine transportable dust particles as the dust source strength is:

$$F_{total} = \left[\sum_{i=1}^{3} F_{dust,i}\right]$$

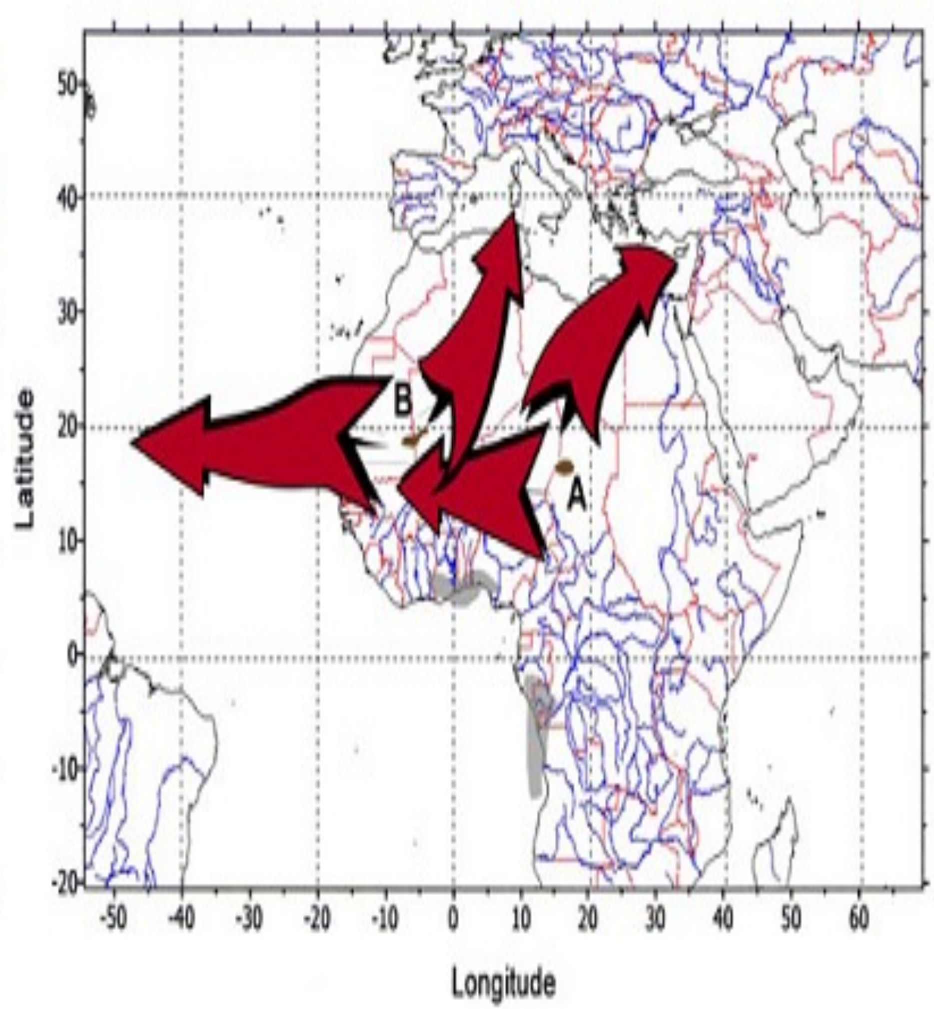
Dust source areas in the RegDAM model



a) The main sources of dust emission



b) dust movements from its sources



Emissions: Dust

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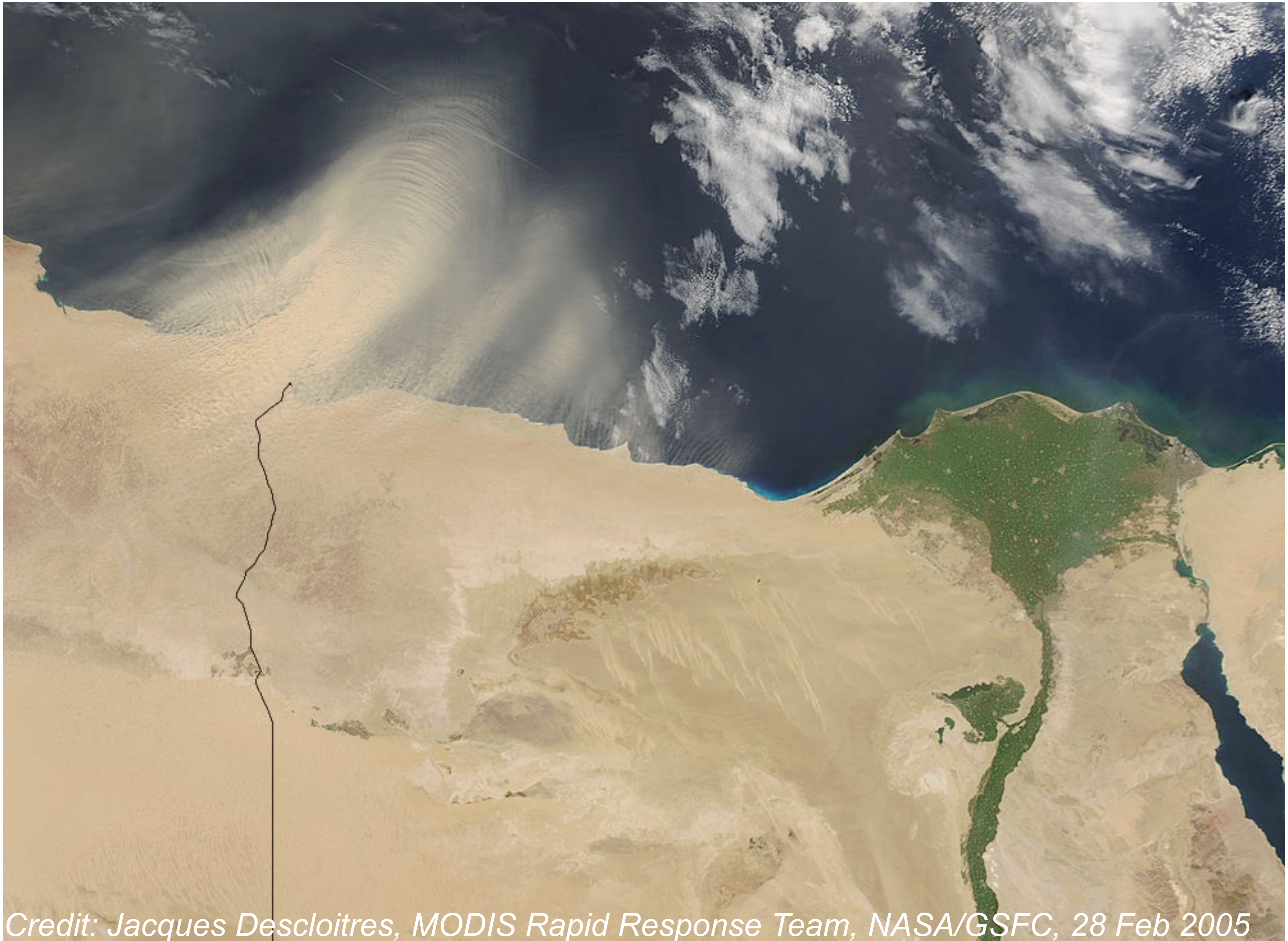
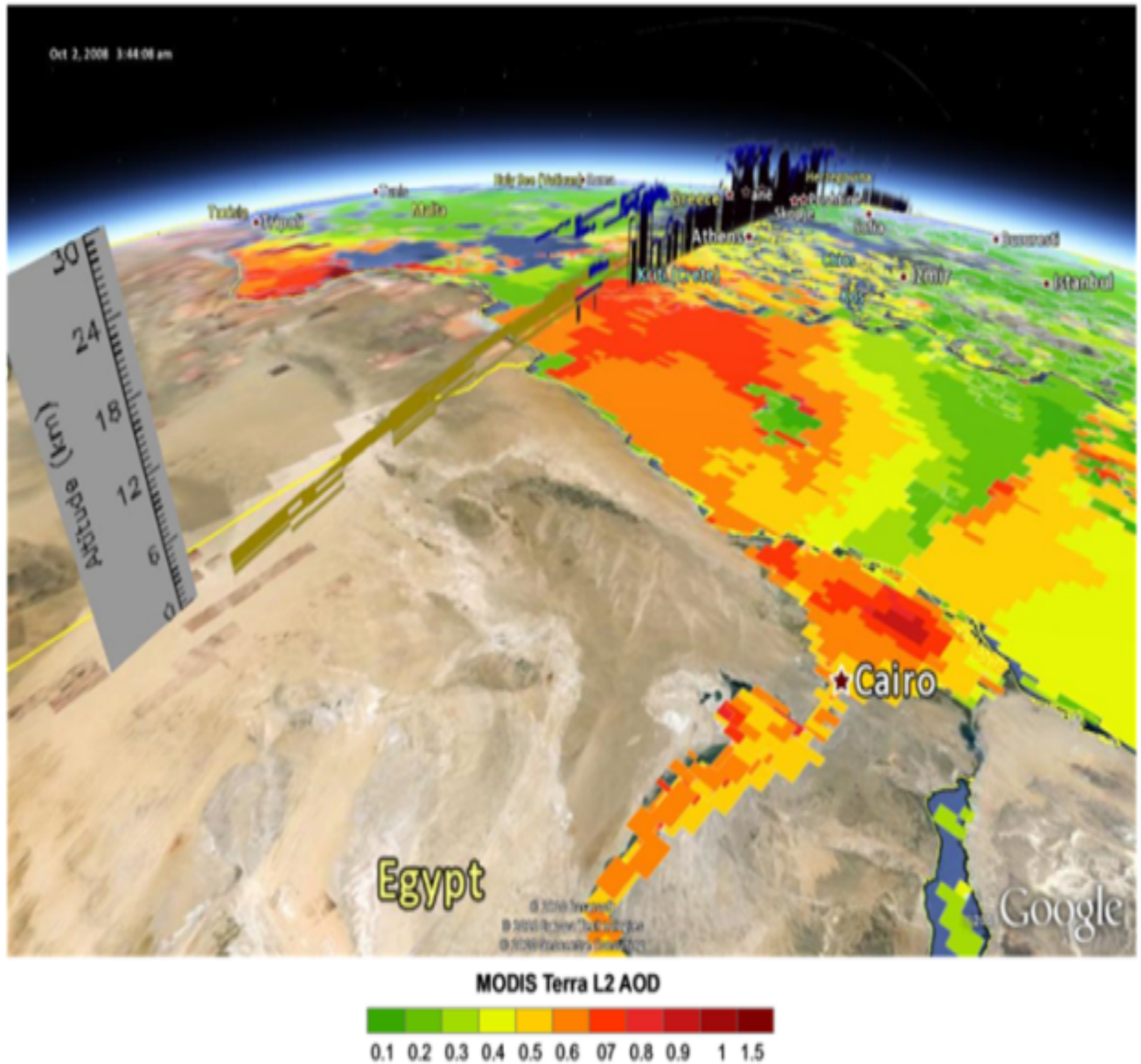
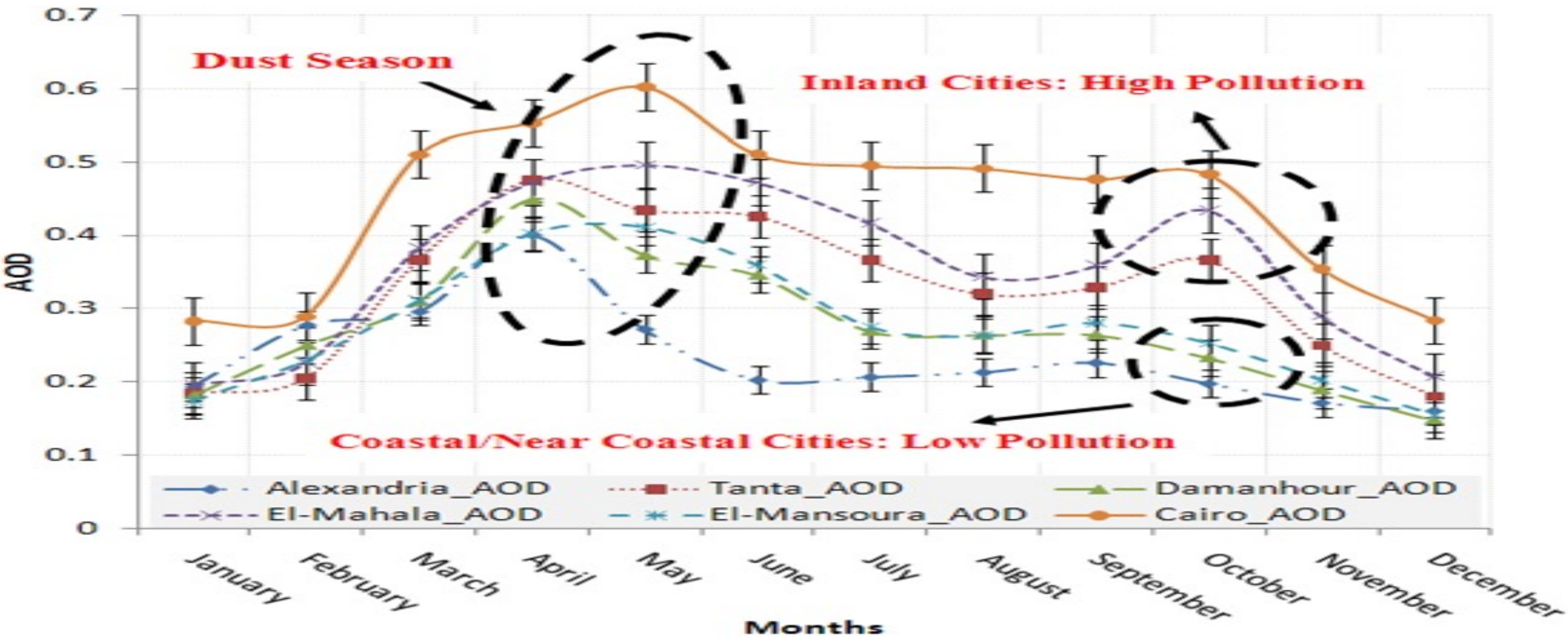


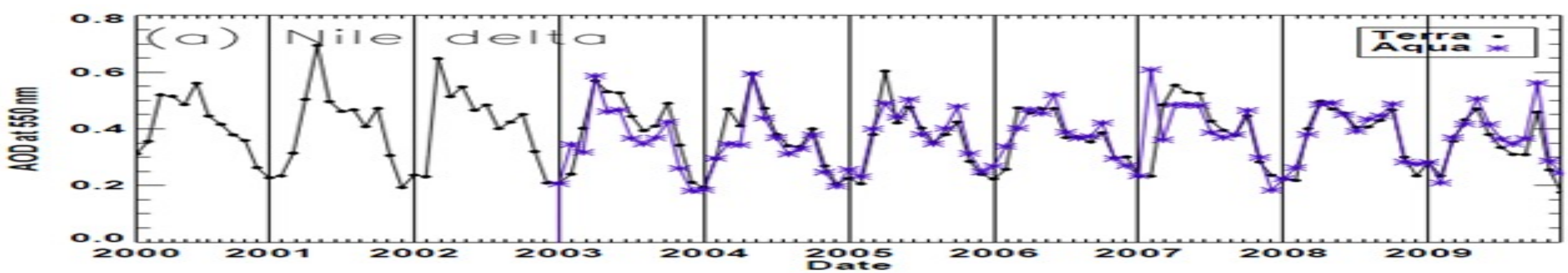
Credit: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC, 28 Feb 2005

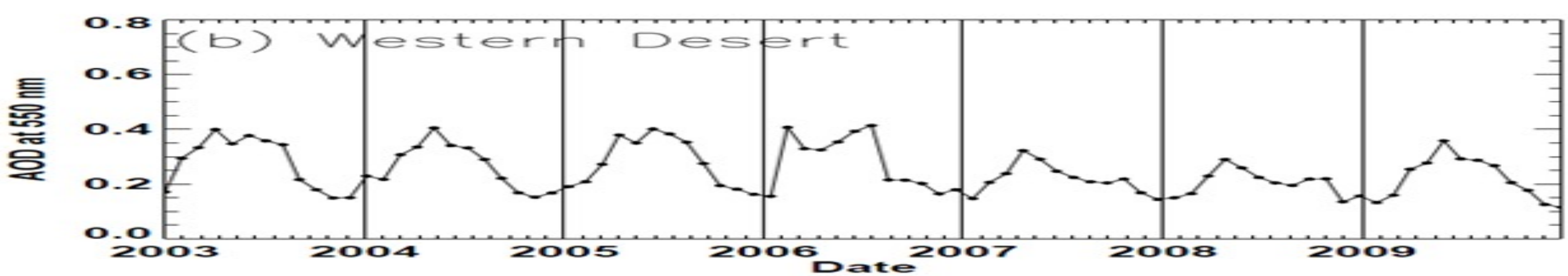
High aerosol loading over Nile Delta and surrounding region as seen in the three day composite of MODIS Terra level-2 AOD (at 10 km spatial resolution) during October 1-3, 2008.

The vertical profile of feature mask obtained from CALIPSO on October 2, 2008 show aerosols at 2.5-6 km height.




Dust Season
Inland Cities: High Pollution
Coastal/Near Coastal Cities: Low Pollution
AOD
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Alexandria_AOD
Tanta_AOD
Damanhour_AOD
El-Mahala_AOD
El-Mansoura_AOD
Cairo_AOD
January
February
March
April
May
June
July
August
September
October
November
December
Months


(a) Nile delta
Terra
Aqua
AOD at 550 nm
0.8
0.6
0.4
0.2
0.0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Date


(b) Western Desert
AOD at 550 nm
0.8
0.6
0.4
0.2
0.0
2003
2004
2005
2006
2007
2008
2009
Date