Development and validation of a regional model of desert dust for the study of seasonal and interannual variations over Sahara and Sahel – coupling with satellite observations

« Action Thématique Incitative sur Programme » CNRS/INSU

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Objective of the project

To perform a climatological study of the mineral dust content over Mediterranean Sea and north tropical Atlantic by combining model and satellite observations

Approach

1. Development of a meso-scale model of desert dust cycle with a fine resolution in time (~ 1 hour) and in space (~ 10 kilometers), which can also simulate pluriannual (~ 10 years) variations.

2. Validation based on ground-based measurements and satellite observations over continents and oceans

3. Study of:

- evolution of the emissions (intensity + geographical localization)
- variability of the transport (altitude, direction)
- influence of the precipitations on emissions and deposition

1. Adaptation of the CHIMERE model to desert dust

SHORT DESCRIPTION of CHIMERE

- Chemistry-transport portable model developed at IPSL and available at LISA where it is used to simulate photochemical pollution events at continental scale
- Multi-scale model: domain, resolution, chemistry can be changed.
"continental" scale (domain of 30x20°, resolution of 0.5°x0.5°)
"regional" scale (domain of 150kmx150km, resolution of 6 km)

- Primarily designed to produce daily forecasts of ozone and other pollutants over Europe and make long-term simulations, CHIMERE allows to perform simulations over long periods on a fine meso-scale grid at hourly time step

- Uses the ECMWF meteorological data at the finest resolution (0.5°x0.5°)

- Web site: http://euler.lmd.polytechnique.fr/chimere/

ADAPTING CHIMERE TO DESERT DUST

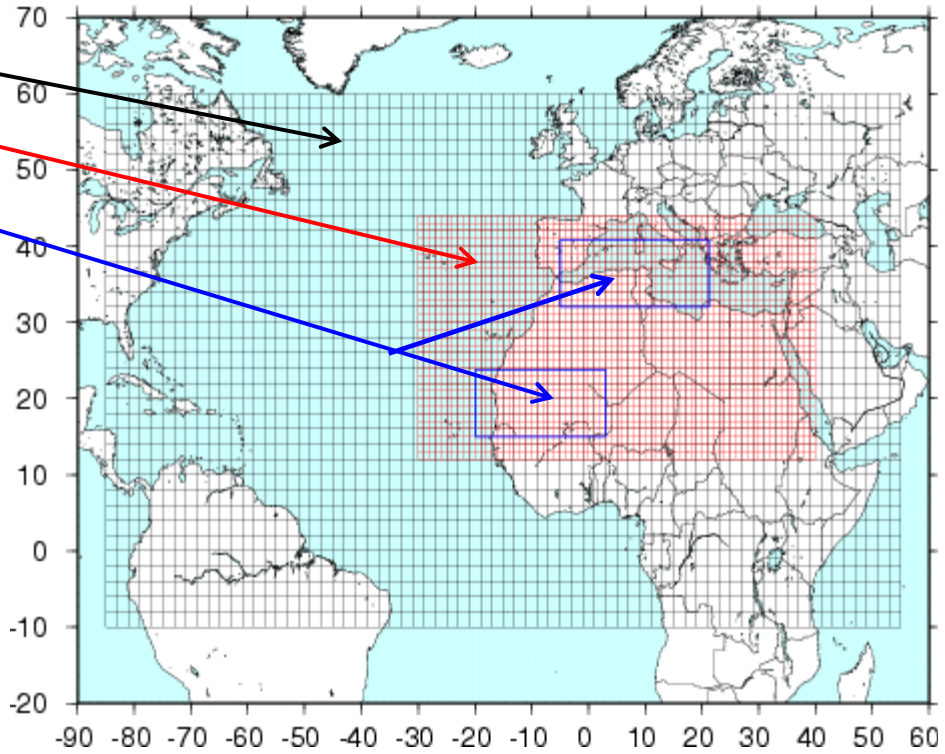
- Complex chemical mecanism replaced by transport of non-reactive tracer. The size distribution of aerosol is split into size bins, each size bin being considered in term of transport as an independent tracer

- Instead of 2 domains of simulations, 3 domains will be used :

synoptic (2°)

continental (1°)

regional (25km)



- Instead of 5 vertical levels in the boundary layer, 10 to 15 levels will be used to account for the high altitude dust transport

SOIL-DERIVED DUST EMISSION SHEME

Developed at LISA [*Marticorena and Bergametti*, 1995, 1997]

Validated by comparison to measurements and satellite data

The physical scheme considers the influence of surface features to compute the erosion threshold and the intensity of dust emissions

Covers the Sahara and north Sahel (16-36°N, 17°W-40°E)

In order to apply this scheme to semi-arid regions
- the influence of soil humidity on erosion thresholds has been parametrized [*Fécan et al*., 1999]
- the model is currently being coupled with a vegetation model (STEP, developed at CESBIO)
- specific parametrizations will also be developed in order to account for anthropic perturbations (cultivation) (specific project in AMMA)

DRY DEPOSITION + WET DEPOSITION [*Balkanski et al*., 1993]

2. Validation of the dust simulations with CHIMERE

GROUND-BASED MEASUREMENTS

- *Concentration and deposition*

Cape Verde Islands (1992-1996) [*Chiapello et al.,* 1995], Corsica [*Bergametti et al.,* 1989], Spain, Canary Islands, Sahelian region (IDAF network),…

- *LIDAR and Sun-photometer measurements*

AERONET/PHOTONS network for daily aerosol optical depth (Dakar, Banizoumbou, Cape Verde Islands, Italy, Crete,…) since 1993

Vertical profiles of aerosols

LIDAR measurements performed in PRIDE experiment (Porto-Rico), SHADE (Cape Verde Islands, sept. 2000)

SATELLITE OBSERVATIONS – VALIDATION OF CHIMERE

(1) "High resolution validation" over land and ocean using "New generation" sensors: POLDER, SEAWIFS and MSG at the maximum resolution of satellites and CHIMERE (~ 10 kilometers)

- over ocean: validation of aerosol optical depth and size distribution over periods of a few days. Method "model to satellite" developed for MSG
- over continent: development of a "new" aerosol optical depth product for POLDER observations at 443 nm

(2) "Low resolution validation" using "First generation" sensors:

- over ocean: METEOSAT/VIS and TOMS
- over continent: METEOSAT/IRT and TOMS

Spatial resolution between 0.5 and 1° (intermediate grid of CHIMERE)
Period from day to year

→ will allow to characterize and constrain the spatial distribution and temporal evolution of the dust plumes

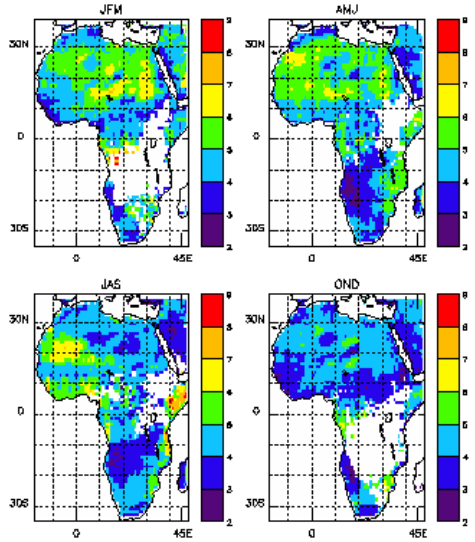
Sensor and Period	Products	Resolution	Cover	Comments
METEOSAT VIS (EUMETSAT) June 1983 - Dec. 1997	Dust optical thickness at 550 nm	Climato: low résolution (30x30 km; ISCCP-B2), Daily image (12h)	Mediterranean – North-east Atlantic 14,5 years	DUST OPTICAL THICKNESS OVER OCEAN
METEOSAT IR (EUMETSAT) 1984-1997 (g 2000)	IDDI (Infrared Difference Dust Index) In thermal infrared	Climato: 0.5° x 0.5° daily	Continental Africa 14 years	DUSTINESS INDEX OVER AFRICAN CONTINENT
TOMS/Nimbus 7 (NASA/GSFC) 1979-1992 TOMS/Earth-Probe nov. 1996-2000	Absorbing aerosol index (UV): Carbonaceous and mineral dust	1° latitude x 1.25° longitude daily	Global oceans and continents 14 + 4 years	AEROSOL INDEX OVER CONTINENT AND OCEAN
POLDER 1/ADEOS 1 (CNES) Nov. 1996 - Jun 1997 POLDER 2/ADEOS 2 Since Dec. 2002	OCEANS: spectral aerosol optical depth – effective radius of particles – relative weight of each mode CONTINENTS: Aerosol Index (fine particles)	18 km x 18 km level 2) daily	Global Oceans Continents except deserts 8 months	AOD AND SIZE VALIDATION OVER OCEAN
SEAWIFS (NASA) Since October 1997	Standard product: Aerosol optical depth and Angström coefficient « Dust » Product ": aerosol optical depth and aerosol model	9 km (possibility of 1 km over some regions) Almost-daily	Global oceans 4 years	AOD AND SIZE VALIDATION OVER OCEAN
MSG (EUMETSAT) Since July 2002	To define: 3 « aerosol » channels (0.6, 0.8, and 1.6 µm)	3 km at the sub-satellite point ≥ 15 min To be defined for the products	Continental Africa (IR) adjacent oceans (VIS)	« MODEL TO SATELLITE » approach

(1) Over oceans: METEOSAT/Vis

Dust optical thickness over clear-sky oceanic pixels, accuracy 10 to 25%

(2) Over continents: METEOSAT/Infrared

Infrared Difference Dust Index (IDDI)

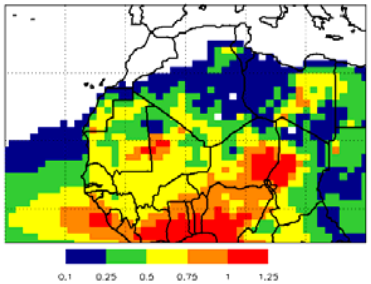


~ 15 years of daily observations (1983-97)

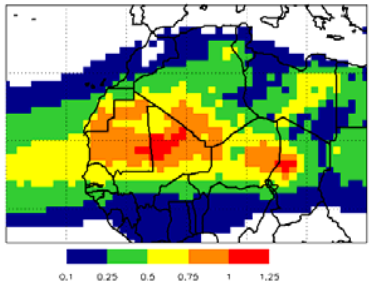
(3) Over continents and oceans: TOMS

Absorbing Aerosol Index (AAI)

Winter (1979-92)



Summer (1979-92)



~ 20 years of daily observations

(1979-92, 96-2002)

→ ANALYSIS OF SEASONAL AND INTERANNUAL VARIABILITY

- "High resolution/small scale" validation

  (1) Over oceans: POLDER, SEAWIFS, and MSG

  - New POLDER products provide accurate retrieval of AOD, size distribution and phase function [*Deuzé et al.,* 2003] – 8 months of POLDER-1 + POLDER-2
  - SEAWIFS allows retrieval of AOD and size distribution over 1998-2000 [*Moulin et al.,* 2001]
  - MSG launched in August 2002: observations every 15 minutes, and channel at 1.6 μm for large particles. Method in development

  (2) Over continents: development of a new algorithm for detection of desert dust from POLDER observations at 443 nm

  - POLDER current algorithm based on polarization measurements allows to detect small particles (pollution, biomasss burning) but not desert dust
  - MODIS does not allow to retrieve dust content above arid surfaces

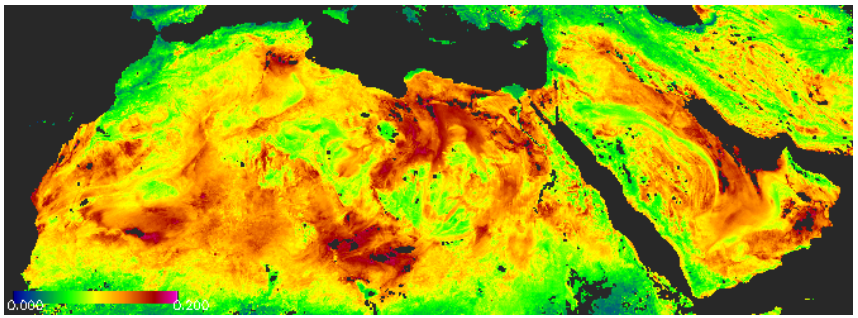
  → we need to develop a new product to validate the simulated dust content over Sahara and Sahel

Preliminary study of inversion of dust optical depth from POLDER-443 nm over Sahara and Sahel [*Colzy and Bréon*, LSCE]

- PRINCIPLE: in the blue, the surface reflectivity of desert surfaces is ~ 0.1 (high spectral signature)

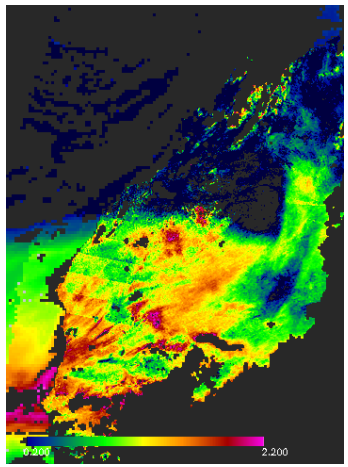
- Preliminary study performed for December 1996 and June 1997 (POLDER-1)

Mean reflectivity at 443 nm June 97

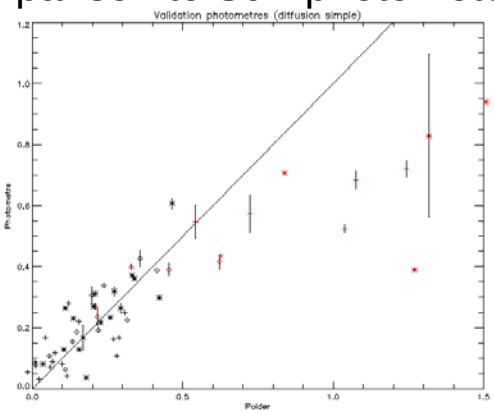


Comparison with inversions over oceans

AOD at 443 nm over land and 865 nm over ocean. Simple diffusion, June 10, 97, North-west Africa



Comparison to Sun-photometer measurements



Dec. 96 (black), June 97 (red), Banizoumbou, Bondoukoui, and Bidi-Bahn

→ Best results in December (reflectivity of 0.7 instead of 0.1 in June, geometry more adapted)

→ Limitation to regions of low reflectivity (~1/3 of North Africa?) – Quality index to be defined.