CENTRE NATIONAL D'ÉTUDES SPATIALES

Aerosol Climatology over Pseudo-Invariant Calibration Sites: Application for African and Arabian Desert Sites

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Summary

- Introduction
- Reminder about desert sites and calibration over PICS
- Methodology
- Data sets
- Processing
- Observations from space data
- Validation using ground data
- Proposed Climatology and Classification
- Conclusion and recommandation

Introduction

- The in-flight calibration of space sensor is necessary to estimate once in orbit the radiometric sensitivity and check its stability with time
- In this context, the use of Pseudo-Invariant Calibration Sites (called PICS) is valuable to address this need
  - as if on-board calibration device is available (need to be validated/supplied)
  - PICS are used to estimate stability but also to cross-calibrate different sensors
- PICS are desert sites, snowy sites, valley…
  - CEOS list of PICS
  - CNES : 20 desert sites + 4 domes in Antarctica
- What is pseudo-invariant with time ?
  - Usually the surface : relatively evident for desert sites as if BRDF effect exist
  - The atmosphere is often assumed stable
    - If not, it is not crucial for long-term trending if repeatable year after year

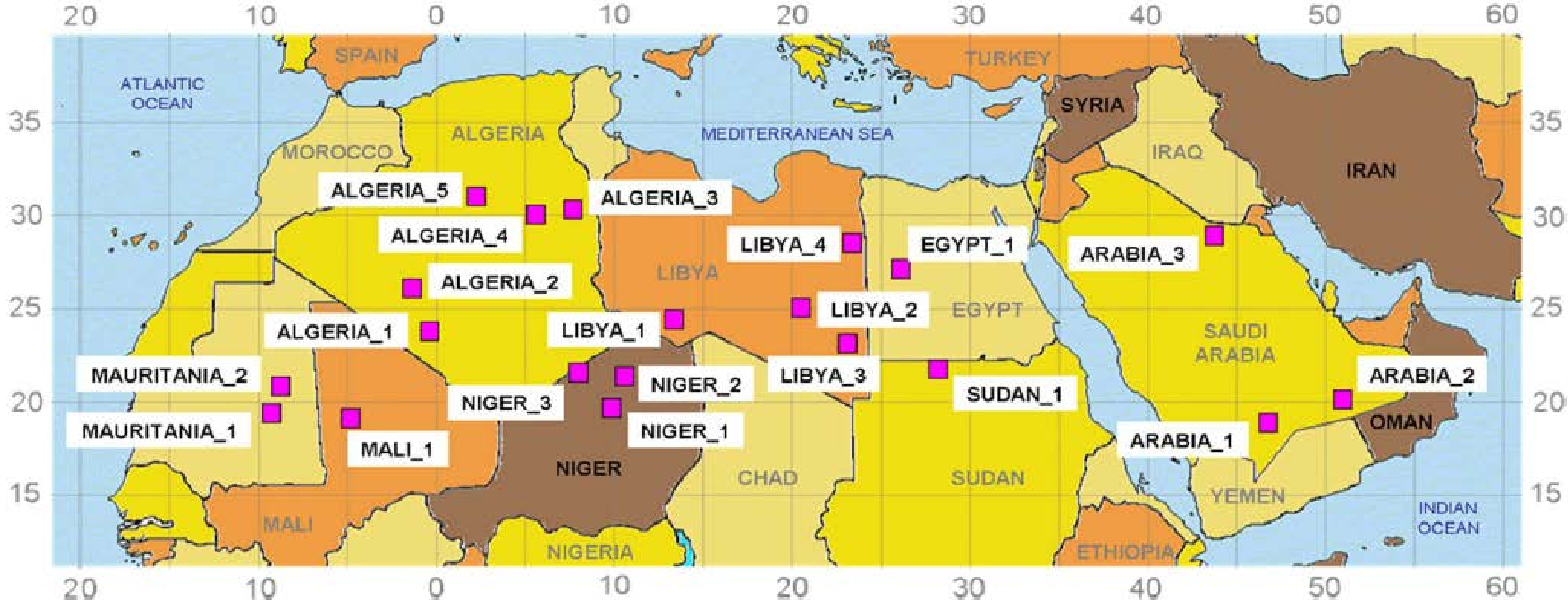
Introduction

- The cross-calibration approach implemented at CNES (Lachérade et al, 2013) considers :
  - geometrical matching between 2 sensors considering : SZA, VZA, RAA
  - no constraint on the temporal simultaneity
  - 2 measurements from 2 different dates could be matched
  - the atmosphere is supposed stable (AOD of 0.2 for a desertic model) in order to consider spectral adjustment between the two sensors to calibrate
  - a non stability of the atmosphere may impact the estimated temporal behavior, especially for shorter wavelength

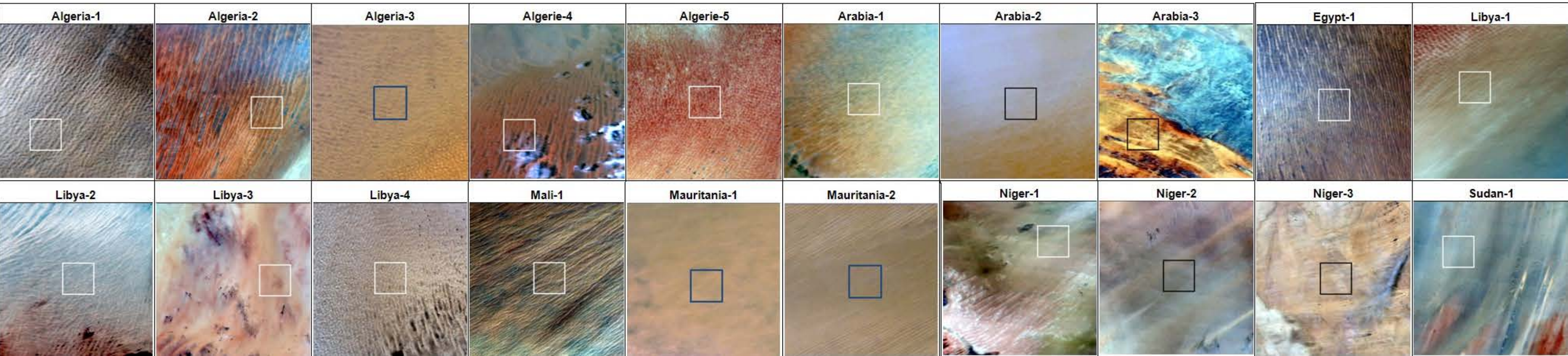
- So what can we do to better understand the atmosphere over PICS ?
  - In general, no sunphotometer or field campaigns (except occasionally)
  - Today : 15 years of space measurements with different dedicated sensors (for aerosol) → A-train since 2002 fully relevant
  - Long term archive for Aeronet measurements : not collocated by check the dynamic + consistency

Definition of desert sites

- Calibration sites used at CNES = 20 desert sites 90x90km² (Lachérade et al., 2013)



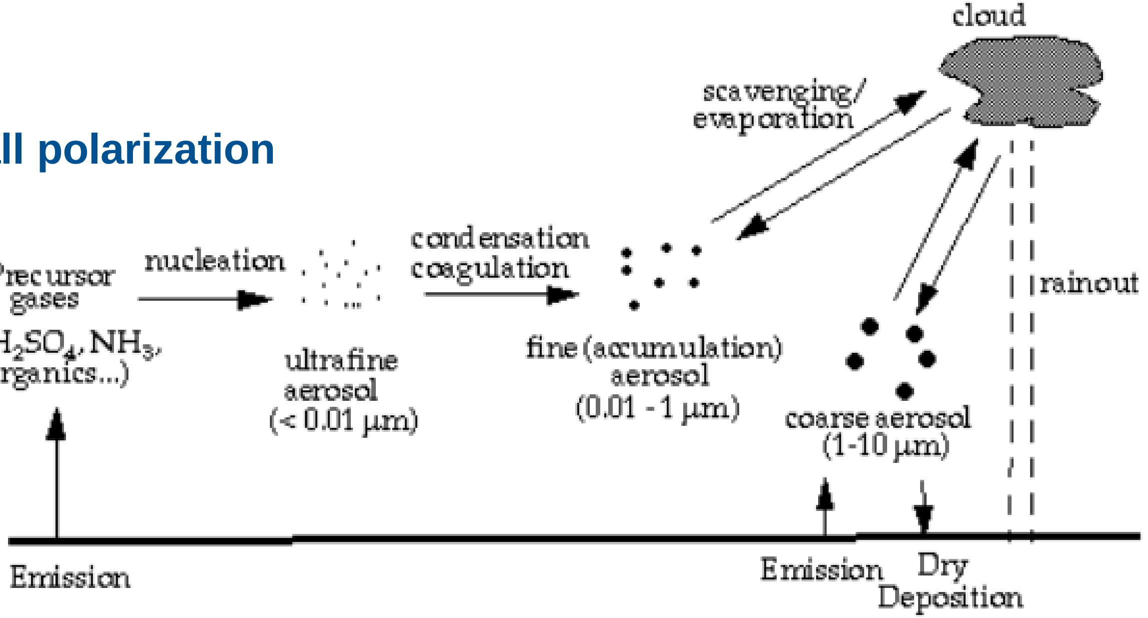
MODIS views



Aerosols

In general aerosols are a mixture of

- **Fine mode :**
  - **gas condensation whatever the origin (accumulation mode)**
  - **radius < less than 1 micron**
  - **strong spectral variation,**
    moderate directionality, polarization
- **Coarse mode :**
  - **wind action at the surface**
  - **radius 1-10 microns**
  - **small spectral variation,**
    sensible directionality, small polarization



From Jacob, 1999

Data source

- In general aerosol are a mixture of
  - Fine mode : strong spectral variation, moderate directionality, polarization
  - Coarse mode : small spectral variation, sensible directionality, small polarization
- Aerosol retrieval from Space : The A-Train opportunity = Complementarity
  - MODIS-Aqua : pushbroom all the reflective domain VIS/NIR/SWIR
    - known to be able to estimate the total aerosol amount
    - completed by MODIS-Terra archive
  - PARASOL only covered VIS/NIR → loss of spectral information
    - but bidirectionality + polarization
    - know to be able to estimate the fine aerosol mode (over land)
  - In general, difficulty over very bright targets
    - Not perfect, but representative for this exercice
- Aerosol retrieval from ground : AERONET complete characterization
  - fine and coarse mode, phase function…
  - time series and common radiometric reference + unified data processing
  - worldwide network but not everywhere (ocean, deserts…)

The Approach

- The approach was to derive time series over desert sites using archive of space sensors : PARASOL, MODIS-Aqua, MODIS-Terra (16 years)
  - Description of typical aerosol load and type
  - Consistency / Complementarity between sensors
  - Description of the seasonal variability + interannual repeatibility
- Use very accurate ground measurements from AERONET (as if not collocated)
  - Validate the observed behaviors (seasonal/load/type)

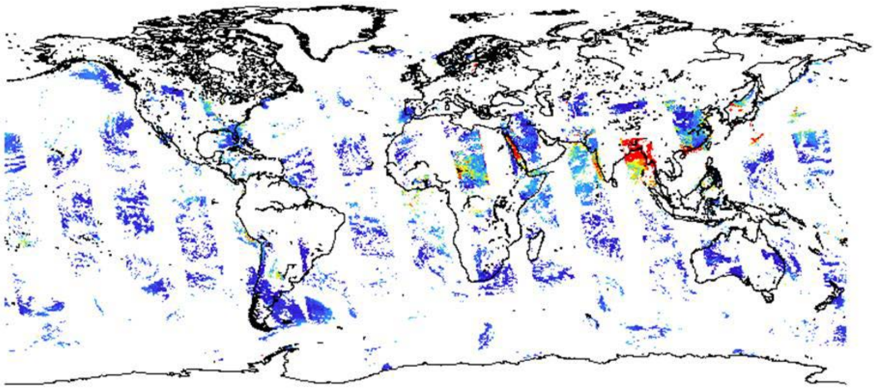
Dataset

- AERONET (GSFC/NASA) : L2 Total and Fine AOD (550nm)
  - Daily/monthly for Total + Fine tau550
  - Available archive (2000-2014) for each considered site
- MODIS (Giovanni) : L3 global “DeepBlue”
  - Resolution 1° x1° in netCDF
  - AQUA (2002-2013)
    - Daily tau550 (4069 products) – no AngExp available
  - TERRA (2000-2007)
    - Daily tau550 (2799 products) – no AngExp available
- PARASOL (ICARE) : L3 global “Fine mode AOT(550nm)”
  - Resolution 18.5kmx18.5km in HDF
  - PARASOL (2005-2013)
    - Daily tau550 (2905 products) + AngExp
- Computation of monthly mean/median using daily + averaging over the site
  - Check that the monthly mean is not dominated by marginal strong events

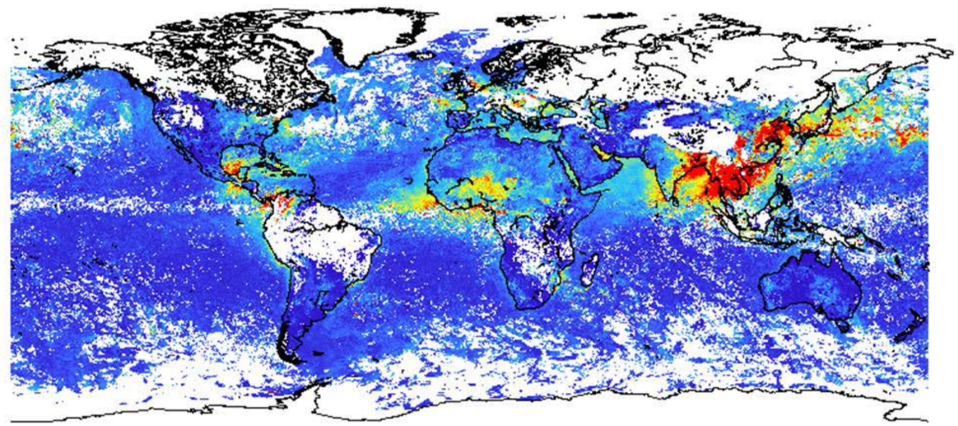
Processing

- **Processing for MODIS & PARASOL**

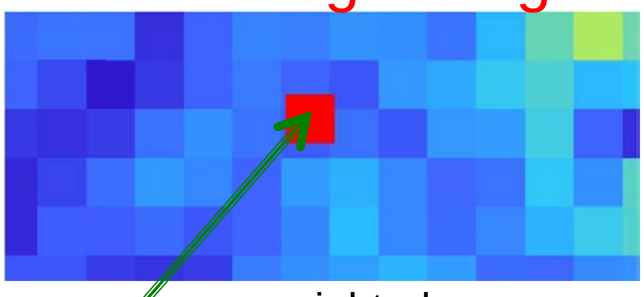
daily



monthly



1° x1° regridding



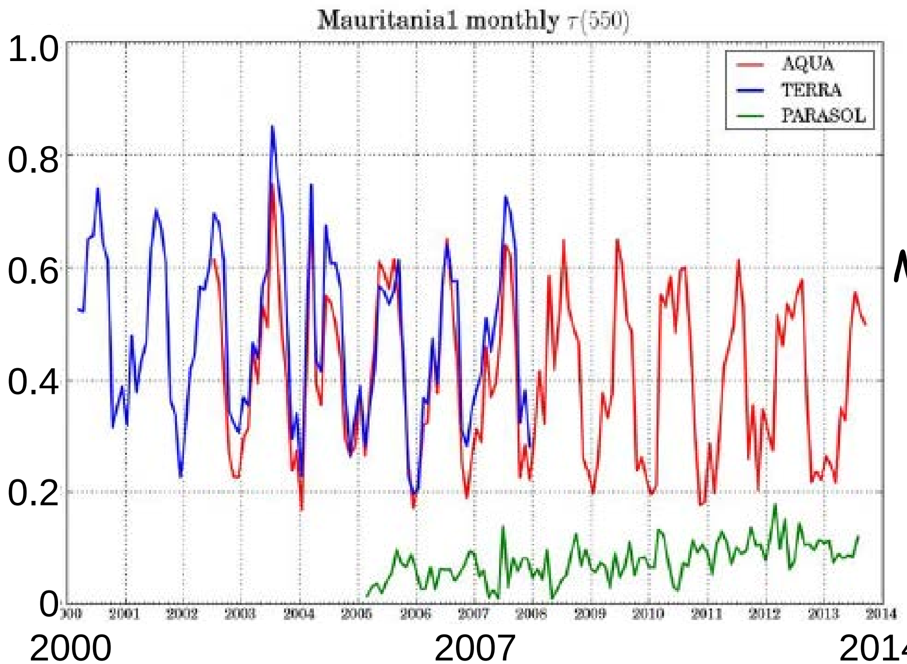
Site

= weighted mean of the 4 pixels

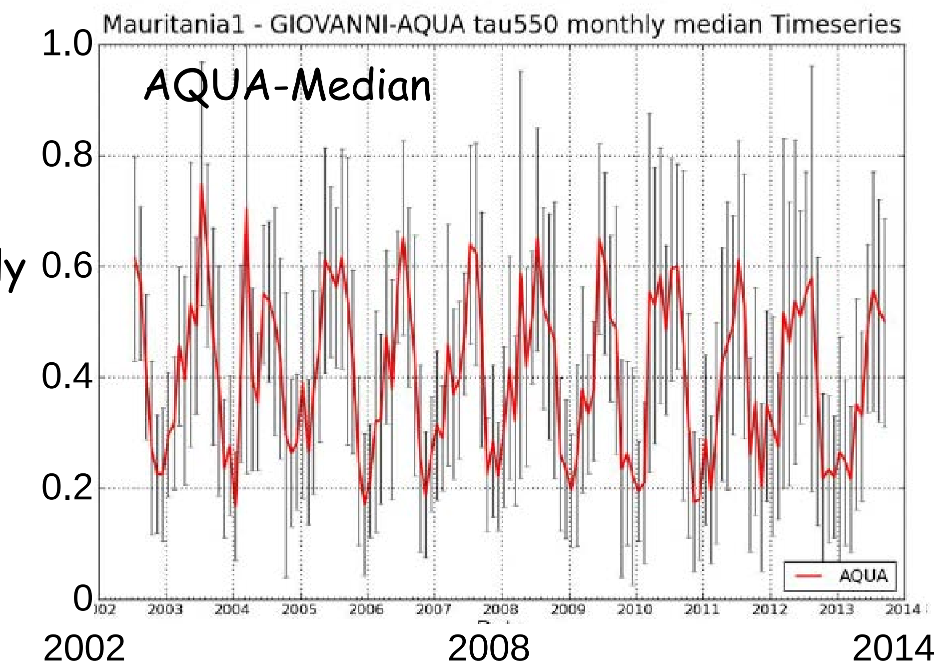
Statistics per site

Checking of Seasonal

- In general, a temporal variation is observed on monthly mean
- Can it be due to marginal & very strong events that impact the mean situation (statistical effect) ?
- Computation of the monthly median (from daily AOD)



Monthly AOD



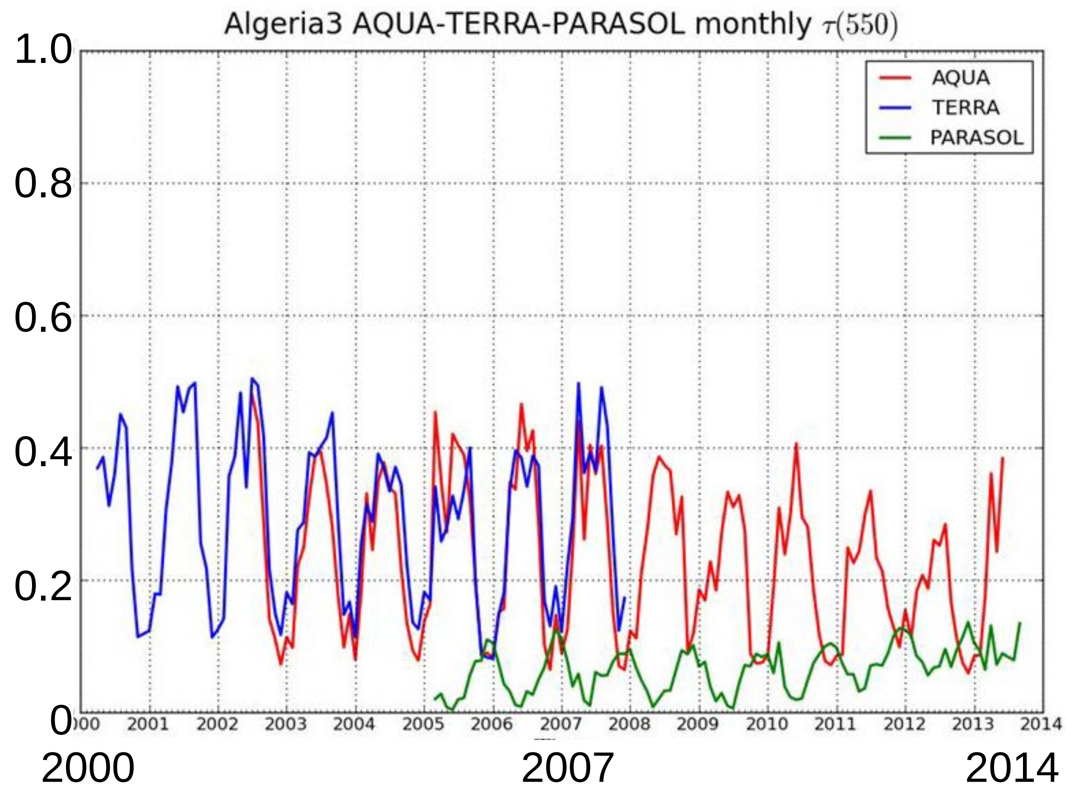
- → The seasonal variation is not due to a statistical effect

Observations

Typical behavior #1 : Exemple of a seasonal Fine/Coarse inversion

MODIS = Coarse+fine
PARASOL = fine

- **consistency Terra/Aqua = no macroscopic variation within the day (from 10:30 to 13:30)**
- **repeatable yearly cycle from 0.1 (Dec.) to 0.5 (June)**
- **opposite cycle for PARASOL = full inversion of the aerosol type from fine mode (Dec.) to coarse (June)**



Source :

- **desertic aerosol (~non-spherical coarse mode) dominant in summer**
- **fine mode dominant in winter → biomass burning influence ?**

cnes

Observations

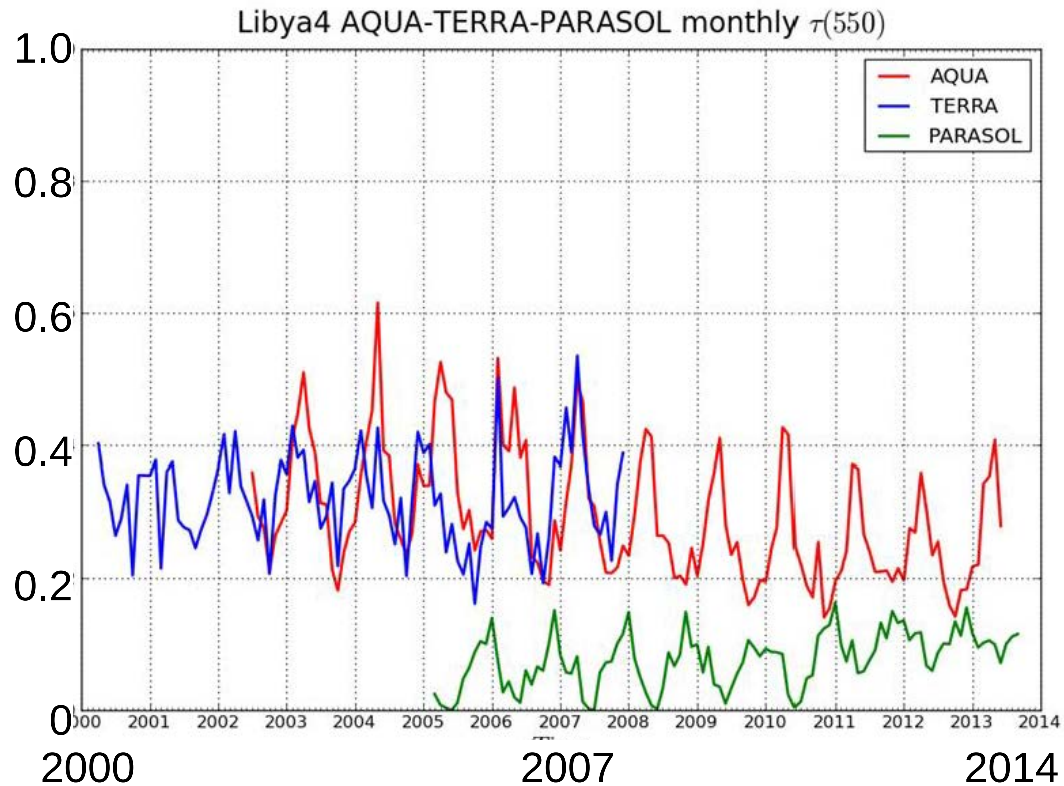
Typical behavior #2 : Exemple of a seasonal Fine/Coarse dynamic

MODIS = Coarse+fine
PARASOL = fine

- consistency Terra/Aqua = no macroscopic variation within the day (from 10:30 to 13:30)
  - however some discrepencies…

- small yearly cycle
  from 0.2 (Dec.) to 0.5 (June)

- opposite cycle for PARASOL =
  strong variation of the aerosol mixture
  from mixed (Dec.) to coarse (June)



Source :

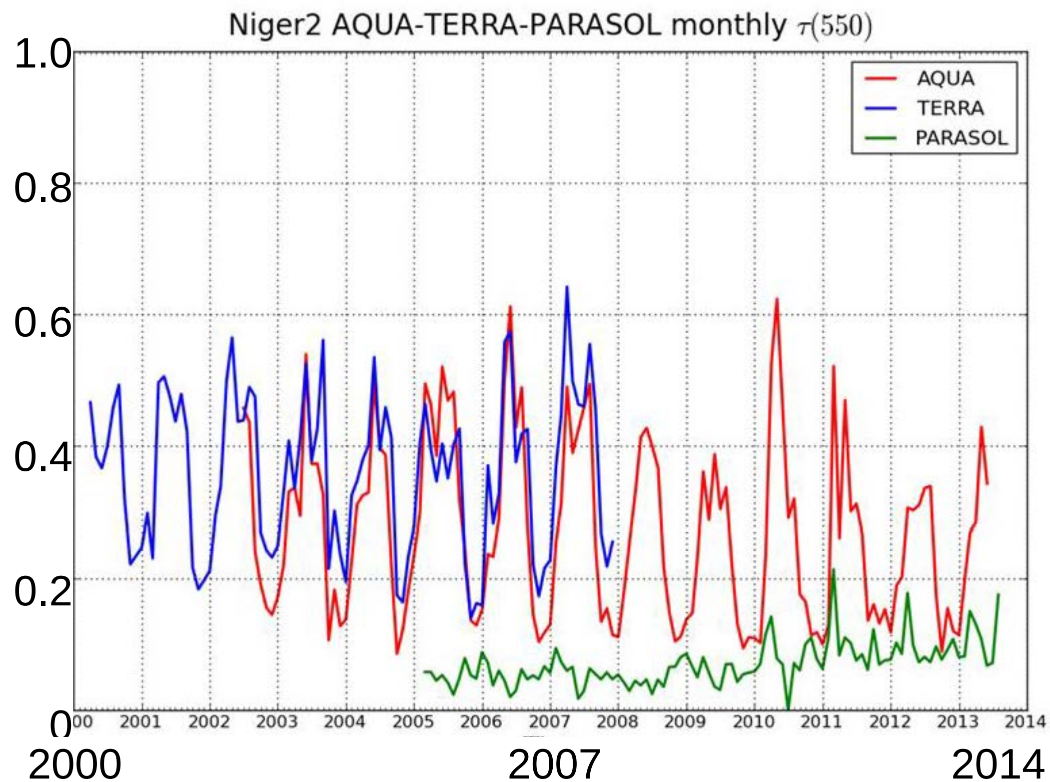
- desertic aerosol (~non-spherical coarse mode) dominant in summer
- mixture with fine mode in winter

Observations

Typical behavior #3 : Exemple of a seasonal Coarse behavior

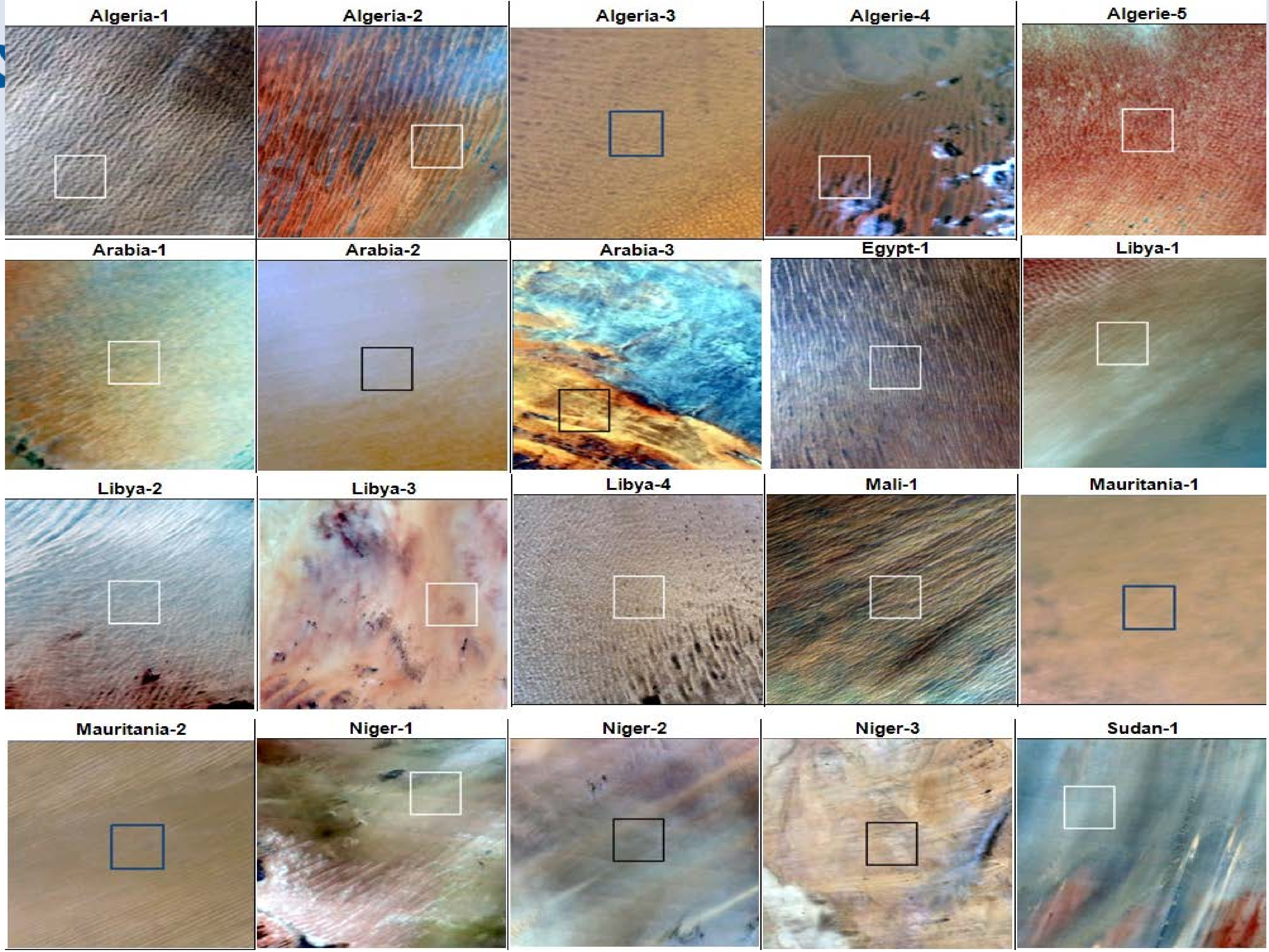
MODIS = Coarse+fine
PARASOL = fine

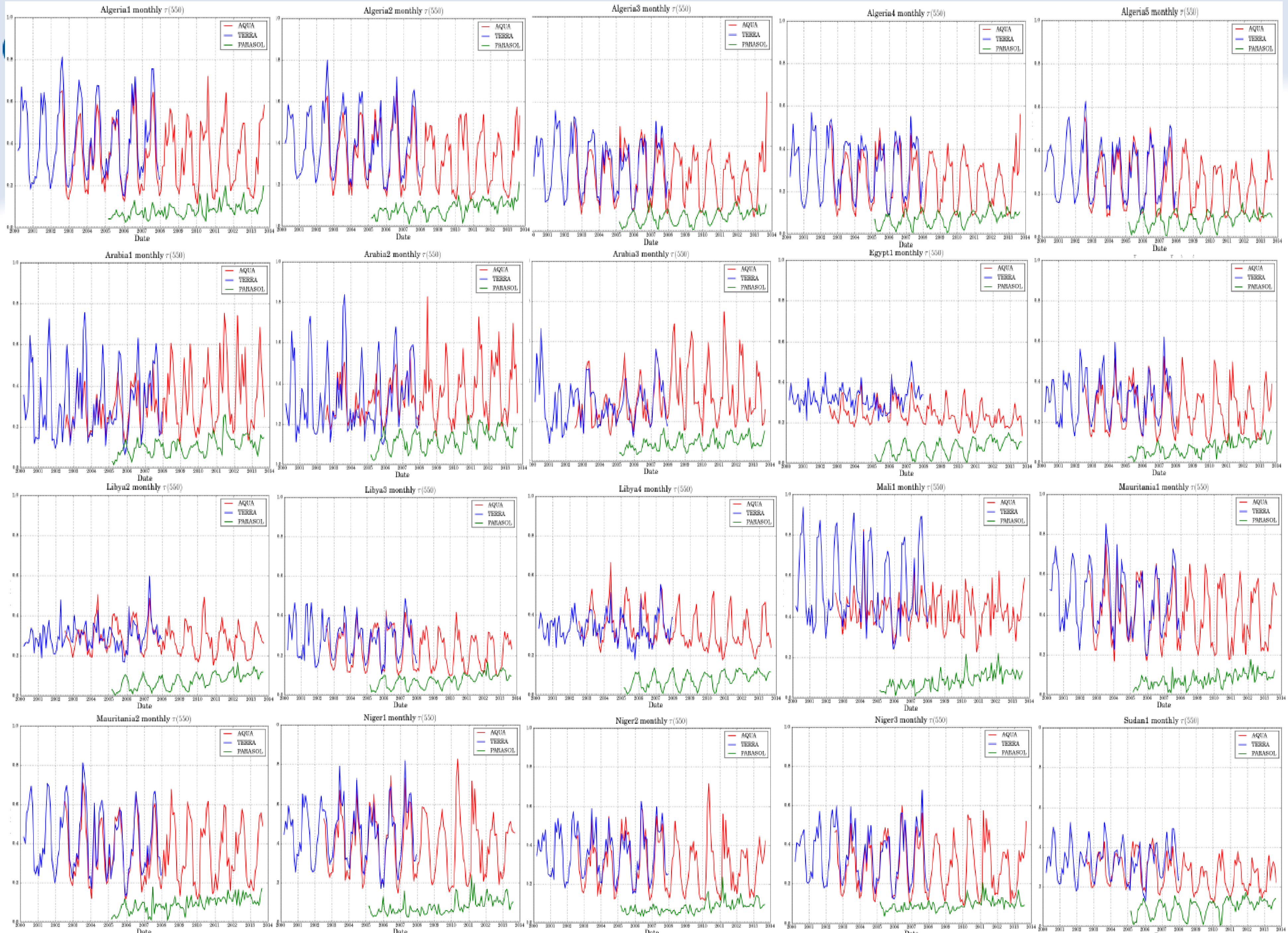
- consistency Terra/Aqua = no macroscopic variation within the day (from 10:30 to 13:30)
- repeatable yearly cycle for coarse mode from 0.15 (Dec.) to 0.5 (June)
- no cycle for PARASOL = nearly constant background of fine mode + seasonal coarse mode



Source :

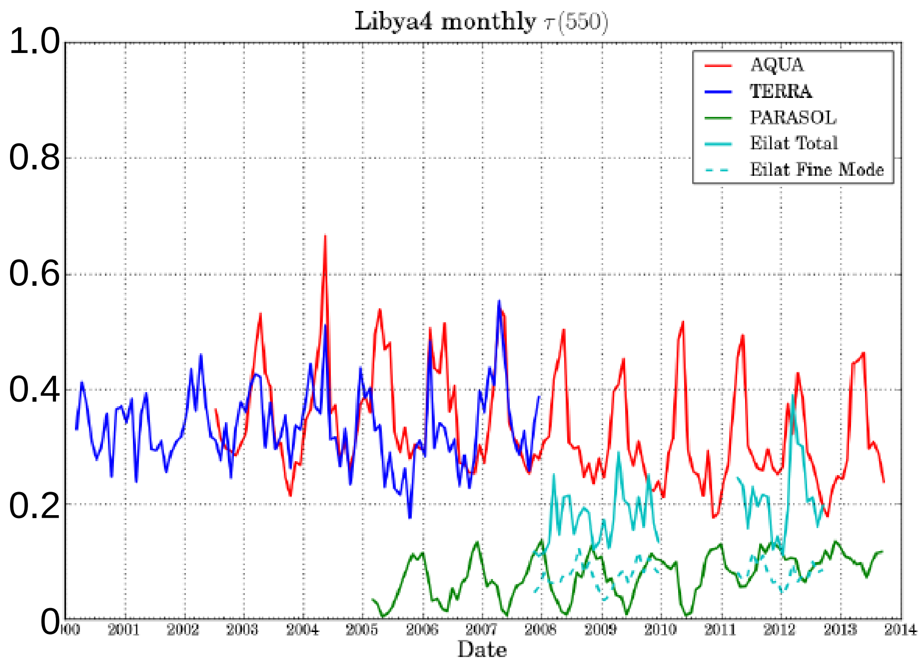
- desertic aerosol (~non-spherical coarse mode) dominant in summer
- fine mode background in addition to coarse


Algeria-1
Algeria-2
Algeria-3
Algerie-4
Algerie-5
Arabia-1
Arabia-2
Arabia-3
Egypt-1
Libya-1
Libya-2
Libya-3
Libya-4
Mali-1
Mauritania-1
Mauritania-2
Niger-1
Niger-2
Niger-3
Sudan-1

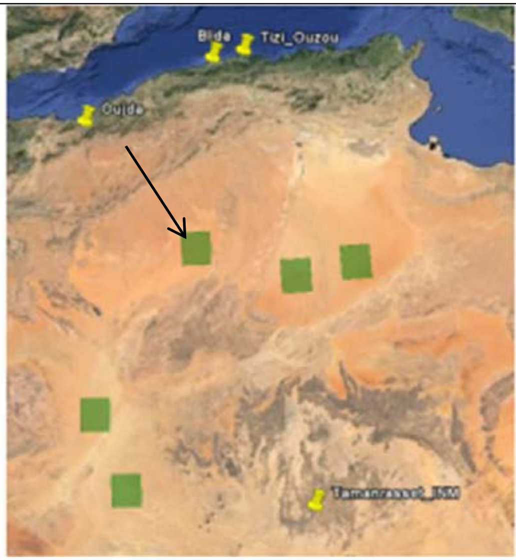

Algeria1 monthly τ(550)
Algeria2 monthly τ(550)
Algeria3 monthly τ(550)
Algeria4 monthly τ(550)
Algeria5 monthly τ(550)
Arabia1 monthly τ(550)
Arabia2 monthly τ(550)
Arabia3 monthly τ(550)
Egypt1 monthly τ(550)
Libya2 monthly τ(550)
Libya3 monthly τ(550)
Libya4 monthly τ(550)
Mali1 monthly τ(550)
Mauritania1 monthly τ(550)
Mauritania2 monthly τ(550)
Niger1 monthly τ(550)
Niger2 monthly τ(550)
Niger3 monthly τ(550)
Sudan1 monthly τ(550)
AQUA
TERRA
PARASOL
Date

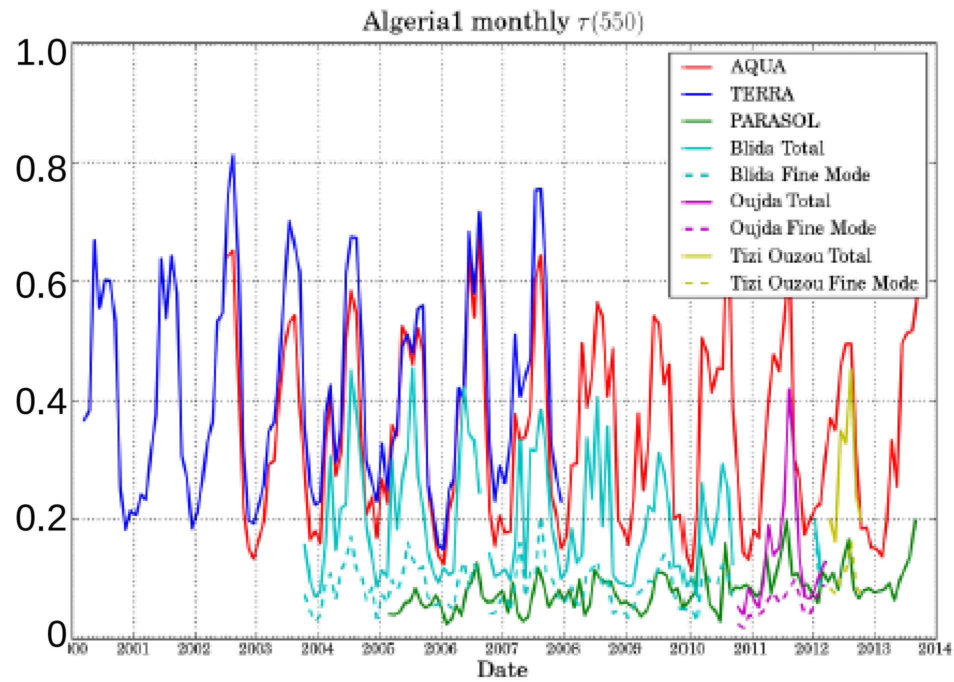
Validation – closest station(s)

- Comparison to in-situ AERONET time series - SITES



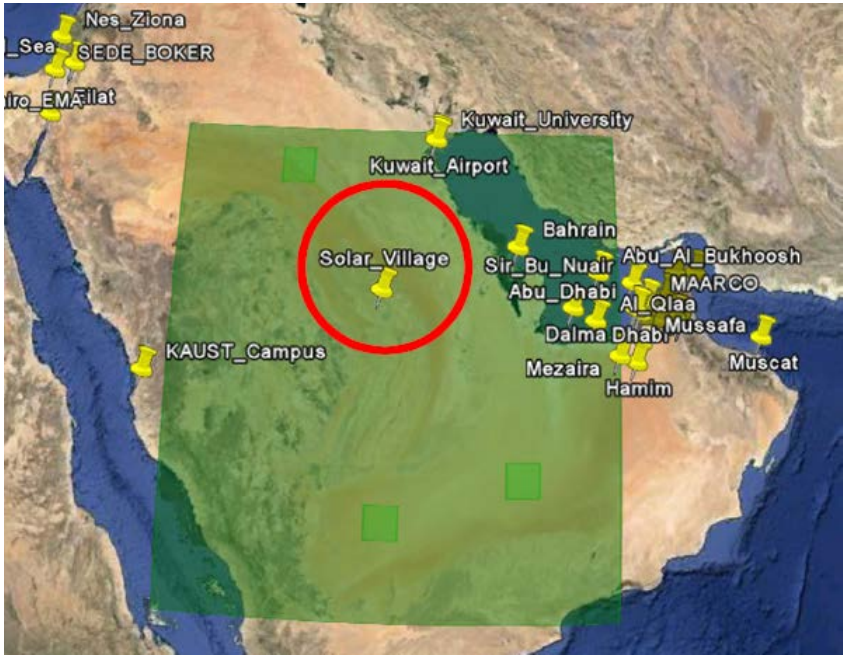
can we believe the satellites ?

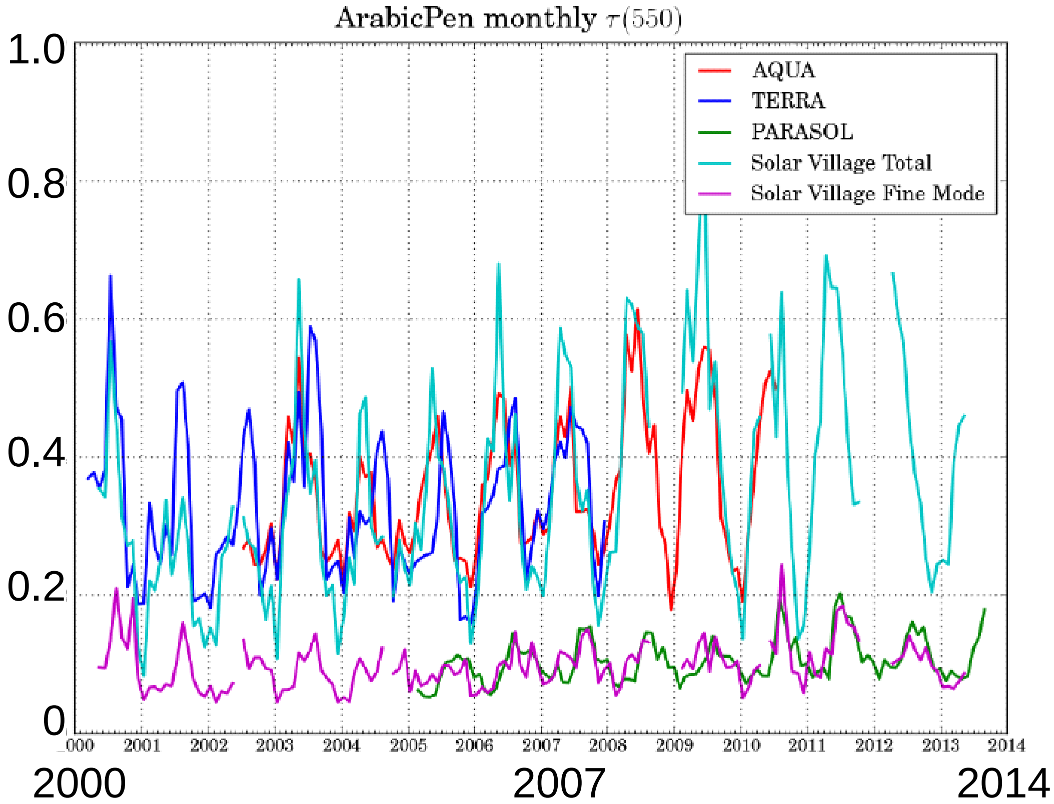




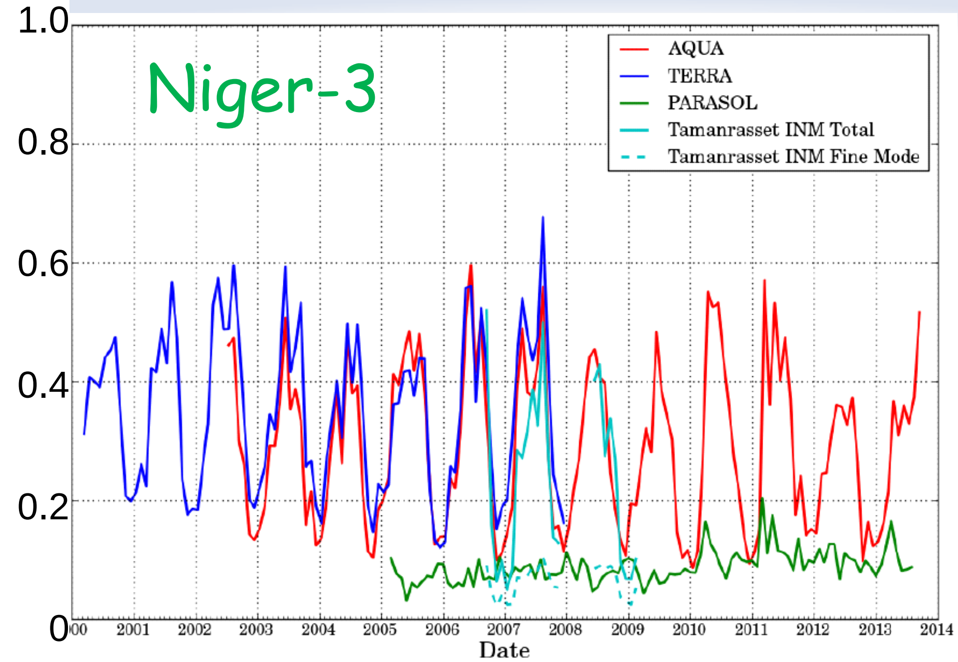
Validation – Regional

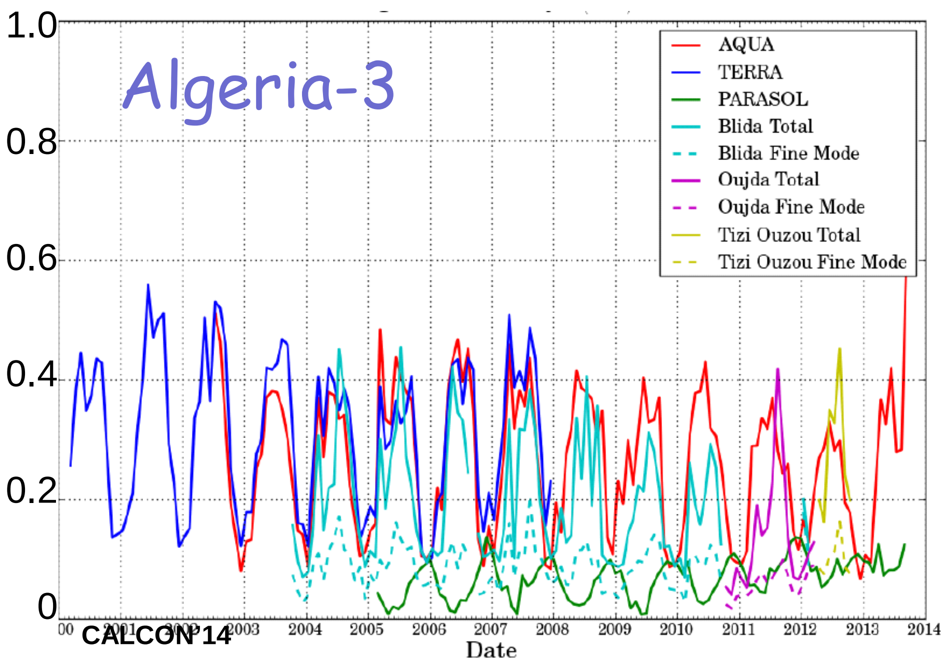
- Comparison to in-situ AERONET time series – REGIONS
  - Satellite statistics computed for a desertic region around sunphotometer

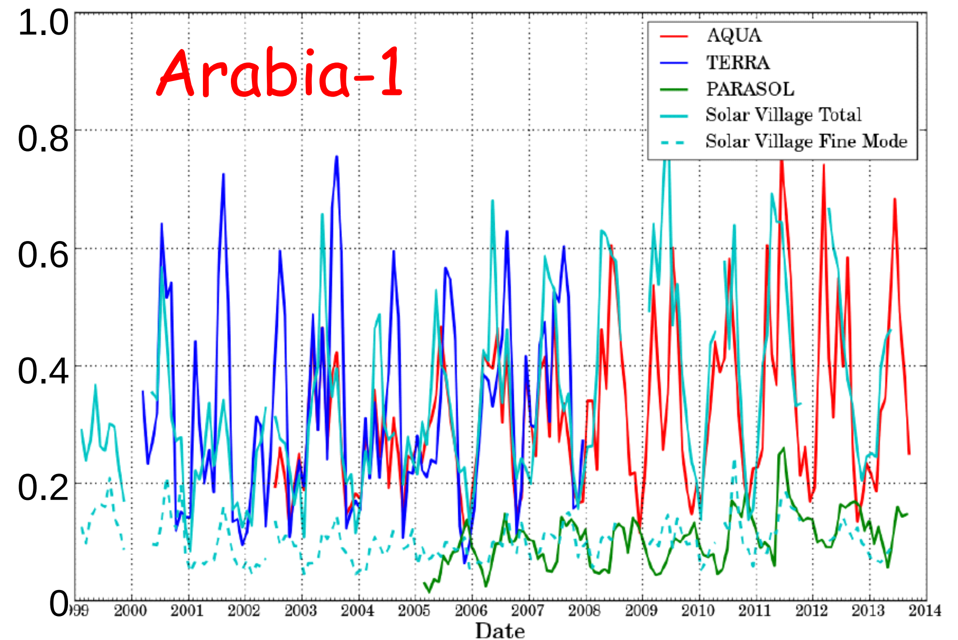




- **Validation over AERONET for 3 typical behaviors**
  - **AOT(550)**
    - **Order of magnitude**
    - **Dynamic**

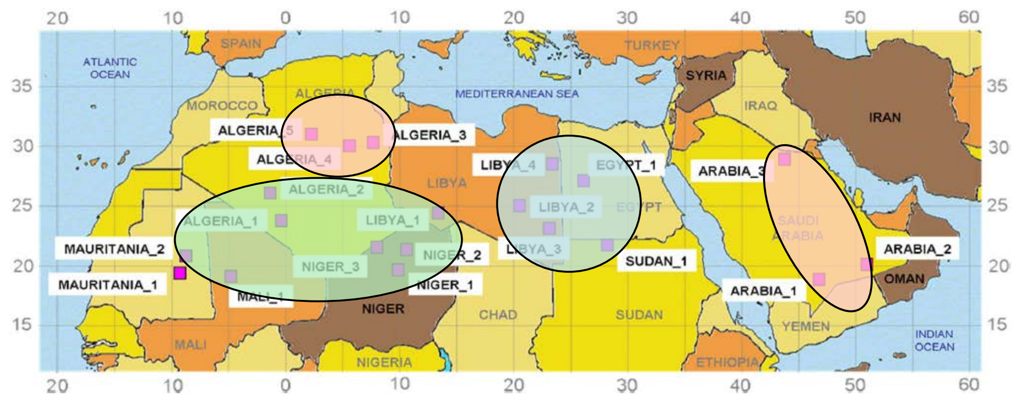






Classification

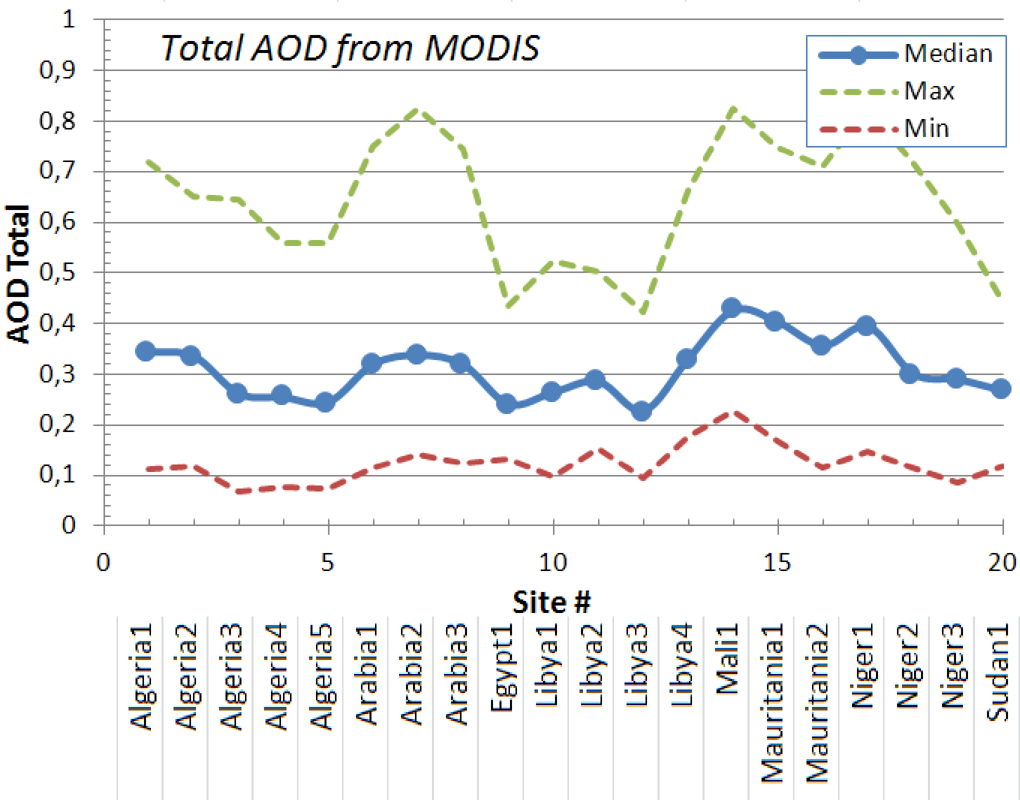
- **Typical classification for the 20 desert sites**
  - **Seasonal cycle for total/coarse/fine modes**
  - **Dominant aerosol type**

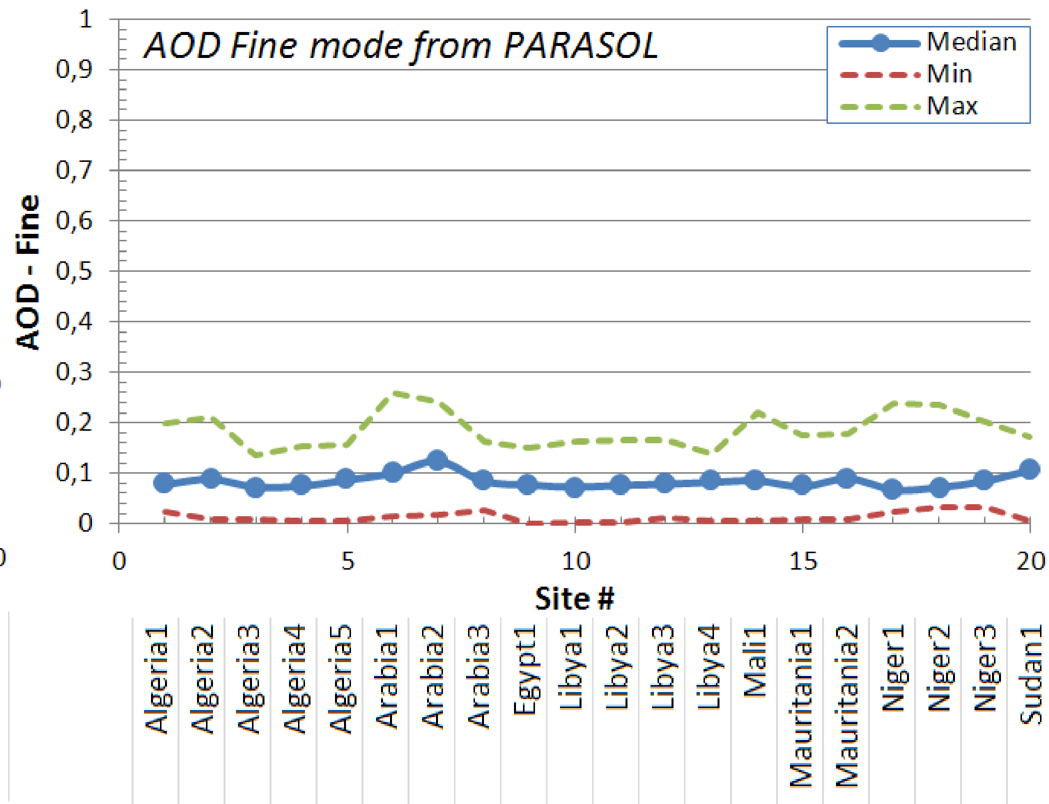


	Seasonal cycle TOTAL	Seasonal cycle Fine mode	Dominant type Winter	Dominant type Summer	Seasonal Change of type	
Libya-2, -3, -4 Egypt-1, Sudan-1	small	strong	Fine	Coarse	sensible	1
Lybia-1	large	small	Fine	Coarse	strong	
Mali-1	small	small	Mix	Mix	no	
Niger-1, -2, -3	strong	no	Mix	Mix	sensible	3
Algeria-1, -2 Mauritania-1, -2	strong	small	Mix	Mix	sensible	
Arabia-3	strong	strong	Mix	Mix	sensible	
Algeria, -3, -4, -5 Arabia-1, -2	strong	strong	Fine	Coarse	complete	2

Climatology

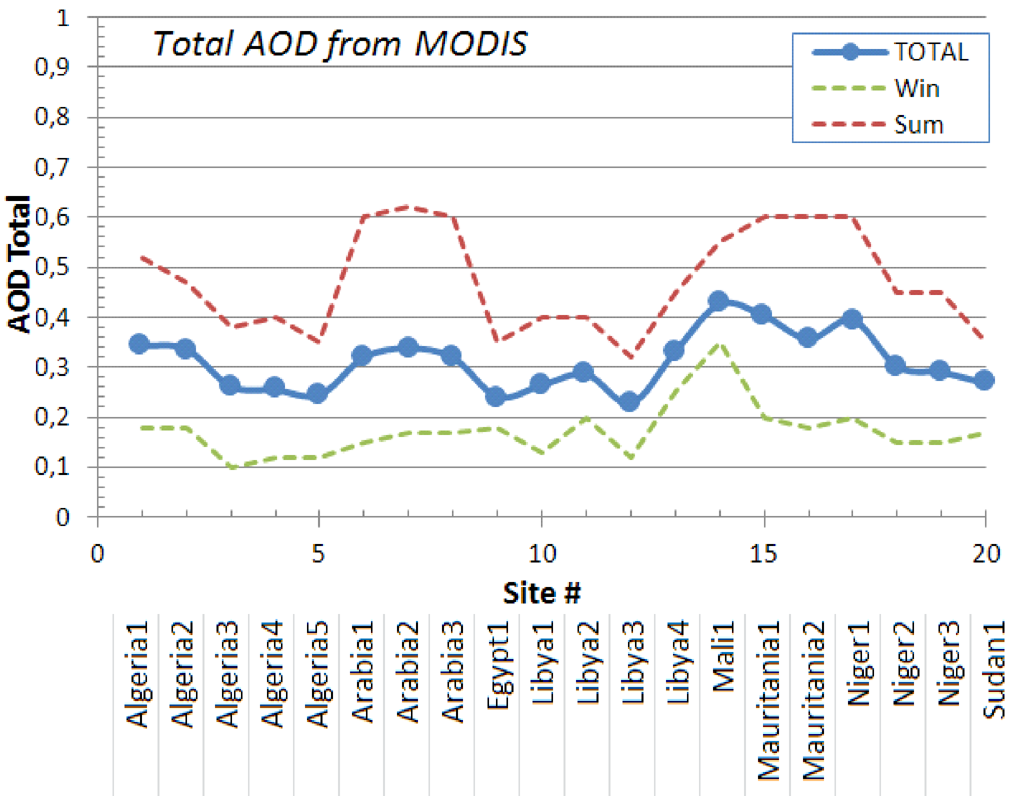
- **Typical climatology of the 20 desert sites**
  - **Mean annual Total AOD + annual min/max variation**
  - **Same for fine mode**

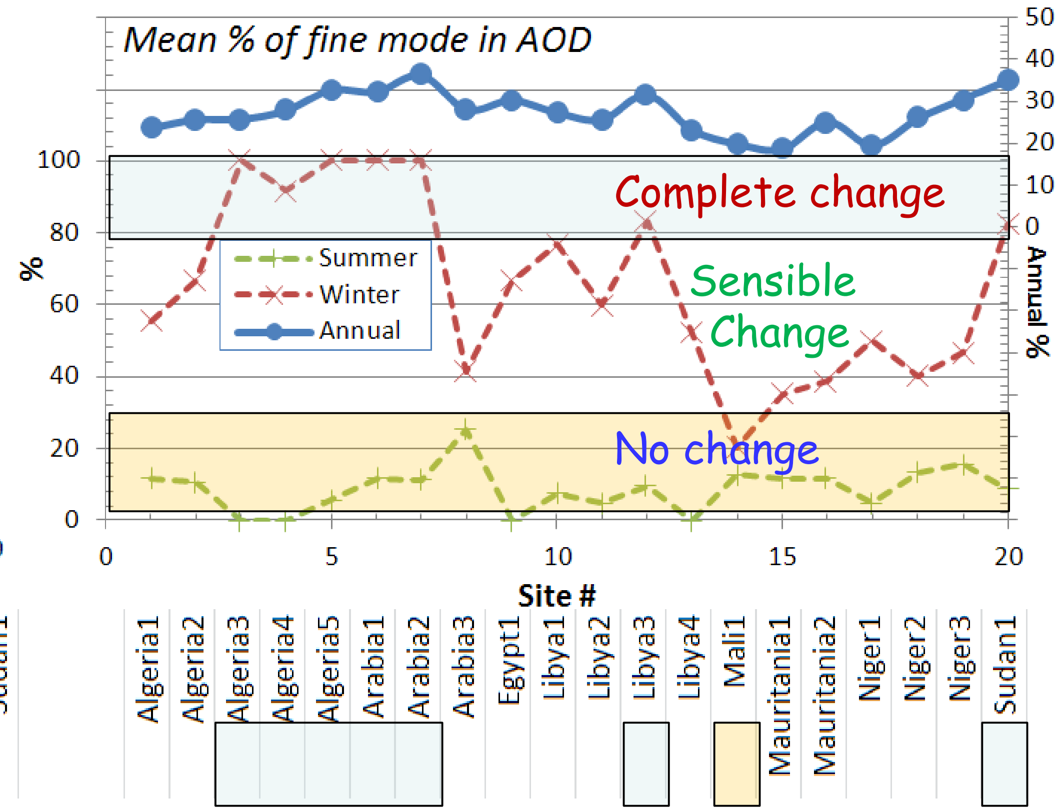




Climatology

- **Typical climatology of the 20 desert sites**
  - **Mean annual Total AOD + Mean in winter and Summer**
  - **Change of aerosol model during the year : Percentage of fine mode in AOD**





Conclusion

- A representative characterization of aerosol content and type has been derived using satellite data from the A-train. PARASOL and MODIS provided very complementary information for a large time series.
- These tendencies were validated using AERONET ground data
- Seasonal cycles and monthly aerosol contents were characterized for 20 desert sites
  - Different behavior for total and fine mode (often opposite)
  - A typical climatology and classification was proposed
  - Differences Aqua/Terra : significant evolution during the day ?

- Recommendation for cross-calibration over desert sites :
  - ✦ The historical 0.2 assumption for AOD is clearly underestimated for all sites
  - ✦ Use of a more realistic aerosol content over the year and for each site
  - ✦ Use of a more realistic aerosol type over the year and for each site
  - → Derive the summary climatology table
  - → Implement it on the operational calibration method (SADE/MUSCLE)

- This approach, i.e. complementary satellite time series + ground validation, could be applied or tested to other Pseudo-Invariant Calibration Sites (PICS) when sunphotometers are not available on the PICS.

Thank you for your attention !