# The MACC-II 2007-2008 Reanalysis: Atmospheric Dust Validation and Characterization over Northern Africa and Middle East

E. CUEVAS[1], S. BASART[2], J.M. BALDASANO[2,3], C. CAMINO[1,3], E. TERRADELLAS[4], A. BENEDETTI[5], J.-J MORCRETTE[5], P. GOLOUB[6], A. MORTIER[6], A. BERJÓN[1], Y. GARCÍA[1], M. GIL[7]

[1]*Izaña Atmospheric Research Center, AEMET, Spain*
[2]*Earth Sciences Department, Barcelona Supercomputing Center, Spain*
[3]*Environmental Modelling Laboratory, Technical University of Catalonia, Spain*
[4]*SDS-WAS Regional Center, AEMET, Spain*
[5]*European Centre for Medium-Range Weather Forecasts, ECMWF, Reading, UK*
[6]*Laboratoire d'Optique Atmosphérique, Université Lille 1, France*
[7]*Atmospheric Research and Instrumentation Branch, INTA, Spain*

Outline:

1. Introduction: main objectives and motivation
2. AOD and DOD validation with AERONET and satellites
3. PM10 validation with AMMA stations
4. Extinction vertical profiles validation with lidars at M'Bour (Senegal) and Tenerife (The Canary Islands)
5. AOD spatial comparison with satellites
6. Conclusions

Main objectives:

1. Validate dust products in the MACC-fszd reanalysis over desert dust sources

2. Obtain dust patterns with MACC-fszd reanalysis over Northern Africa and Middle East, compare with those obtained with ground-based and satellite-borne remote sensing instruments

Motivation:

Could be used MACC dust reanalysis for dust-related climate studies (to cross with climate indexes)

Could be used MACC dust re-analysis to assess dust impact on health?

Could be used MACC dust climatologies to support feasibility studies for solar energy?

Experimental: MACC-fszd

- MACC re-analysis fszd 2007-2008, T255 resolution (~0.8x0.8 degrees) data set: surface concentration and natural Sea Salt+Dust (SS+DU) aerosol optical depth (AOD) component
- SS and DU sources are linked to prognostic and diagnostic model variables (i.e., 10m wind speed and soil moisture)
- **DU bins** (0.03-0.55-0.9-20 µm) and **SS bins** (0.03-0.55-0.9-20 µm)
- Data assimilation is based on ECMWF-Integrated Forecast System (IFS)
- AOD data assimilation from MODIS (Level 2) over land and ocean (not over high brightness surfaces)

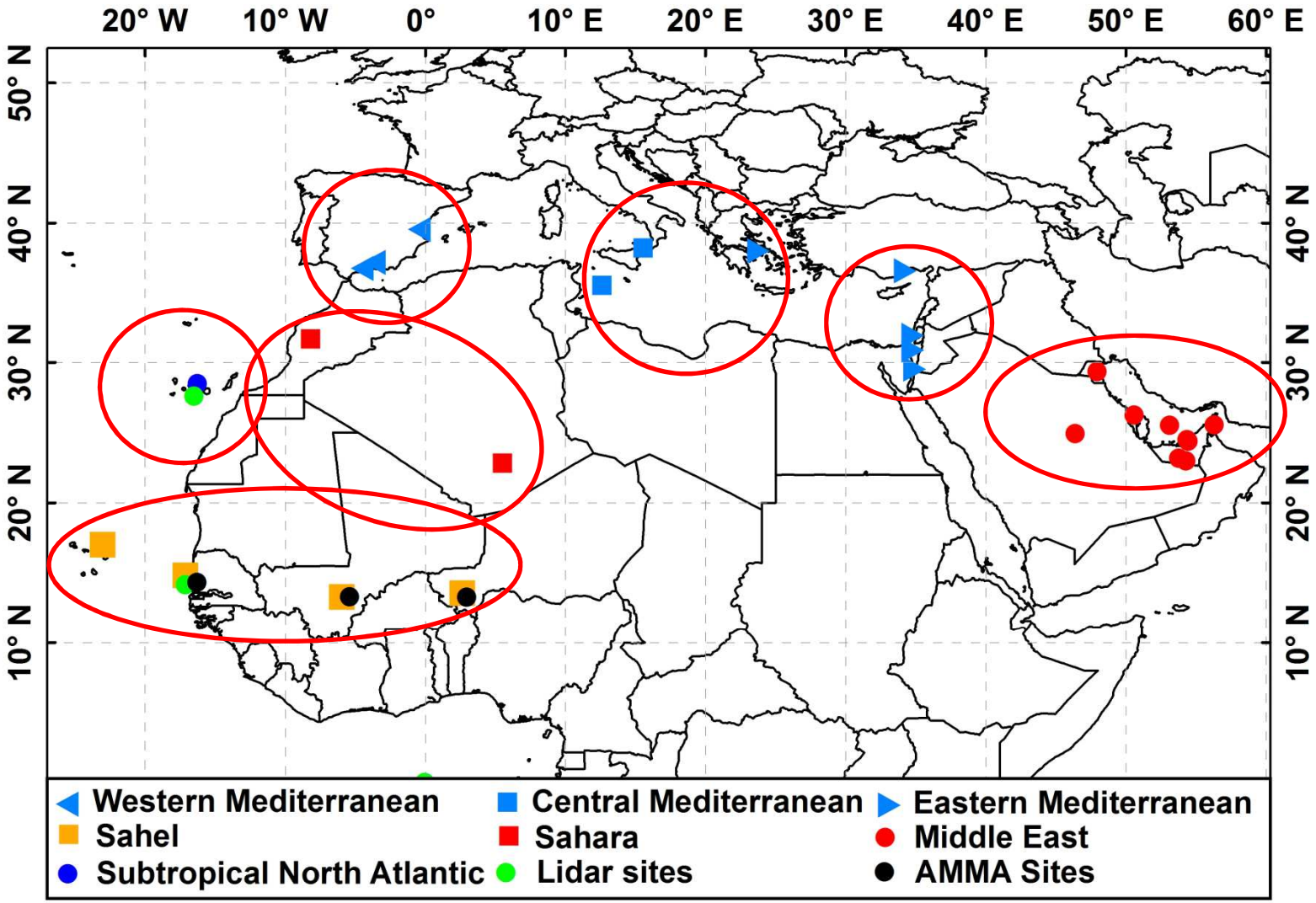
*Morcrette et al. (2009; 2011) and Benedetti et al. (2009)*

**Main improvements in short MACC-II_fszd reanalysis compared to previous reanalysis:**

- Redistribution of dust aerosol content to the finer particles bin
- A more accurate representation of dust sources over the Sahara/Sahel

*(A. Benedetti)*

## Ground-based stations




25 AERONET stations + 3 AMMA $PM_{10}$ stations + 2 Lidars (M'Bour and Tenerife)

## AERONET data

1. AERONET level 2.0 data (assured quality)
2. $AOD_{550} = AOD_{500}\left(\frac{550}{500}\right)^{-AE}$ AE: Angstrom Exponent
3. Coarse mode $AOD_{550}$ from AERONET Spectral Deconvolution Algorithm (SDA) retrieval (*O'Neill et al., 2003*) ≈ DOD (dust optical depth).
4. AERONET-MACC re-analysis intercomparison criteria
   - *Monthly averaged scores from simultaneous hourly AOD/DOD (06, 12 and 18UTC)*
   - *A minimum of 50 AOD/DOD data pairs is required in each region (7 regions) to obtain monthly averaged scores.*

## Total column satellite data

MISR
- *Level-3 data (MILDAE3) daily AOD at 555 nm, 0.5°x0.5° resolution*

OMI
- *Aura/OMI version 3 daily global level 2G AOD at 500 nm data (OMAERUV), 0.5°x0.5° resolution*

MODIS-Aqua
- *Combined AOD products from MODIS-Aqua Daily level-3 data (MYD08 collection 5.1): AOD at 550 nm data (non-cloudy) and Deep Blue (DB) AOD at 550 nm, 0.1°x0.1° resolution*

Statistical metrics used :

$$MB = \frac{1}{n}\sum_i (f_i - O_i)$$

$$MNMB = \frac{2}{n}\sum_i \frac{f_i - O_i}{f_I + O_I}$$

$$FGE = \frac{2}{n}\sum_i \left|\frac{f_i - O_i}{f_i + O_i}\right|$$

$$RMSE = \sqrt{\sum_i \frac{1}{n} f_i - O_i}$$

$$r = \frac{\sum_i (f_i - \bar{f}_i)(O_i - \bar{O}_i)}{\sigma_f \sigma_O}$$

n: number of coincident observation,
$\sigma_f$- $\sigma_i$ : standard deviation of model outputs and observed data respectively,
$f_i$ : model reanalysis,
$O_i$ observed values at the time i.

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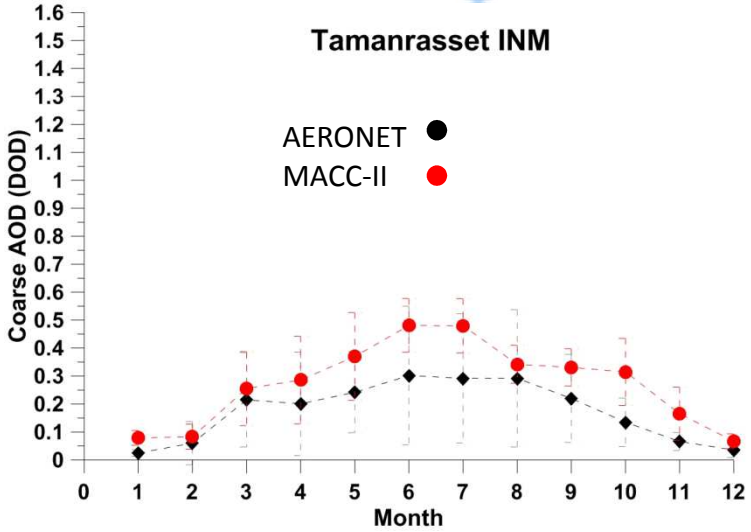
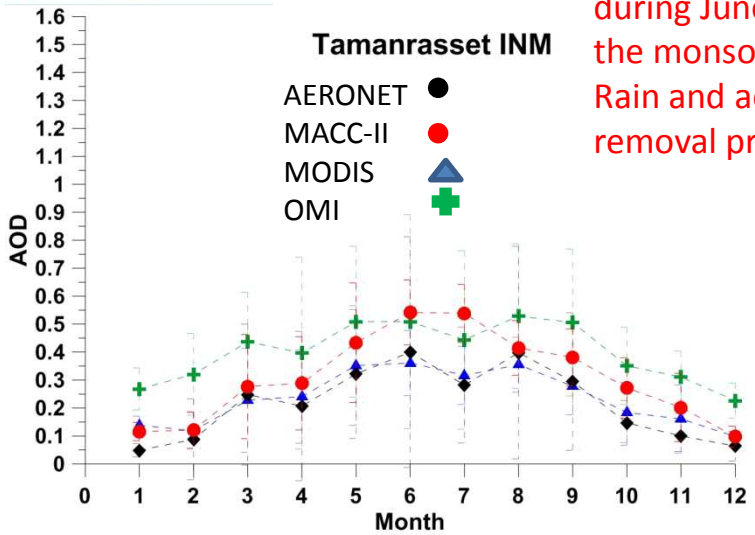
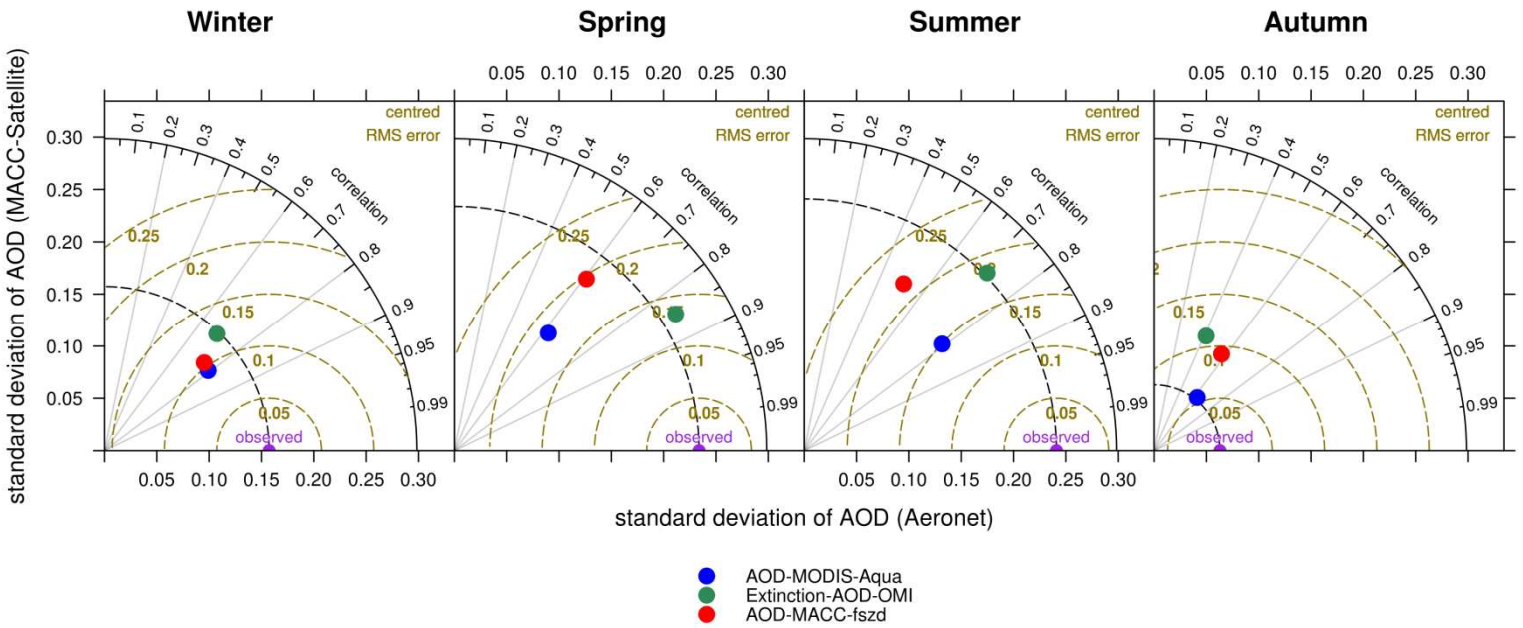
Model overestimates during June-October: the monsoon period. Rain and aerosol removal processes?




## Sahara region



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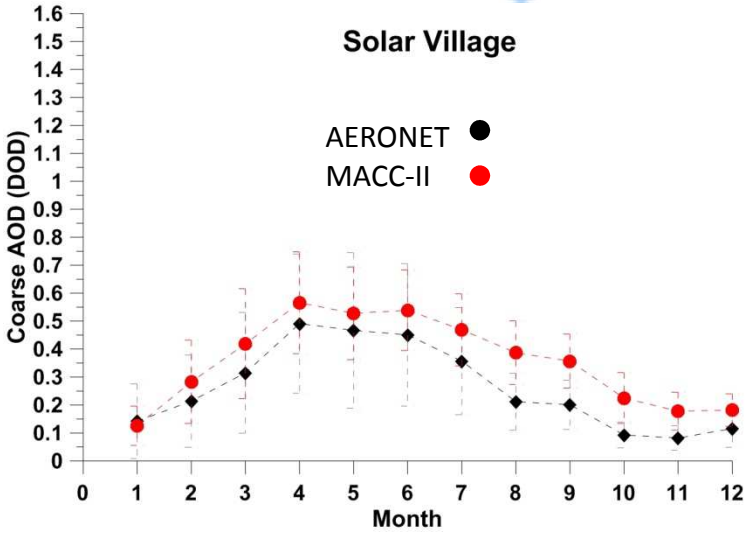
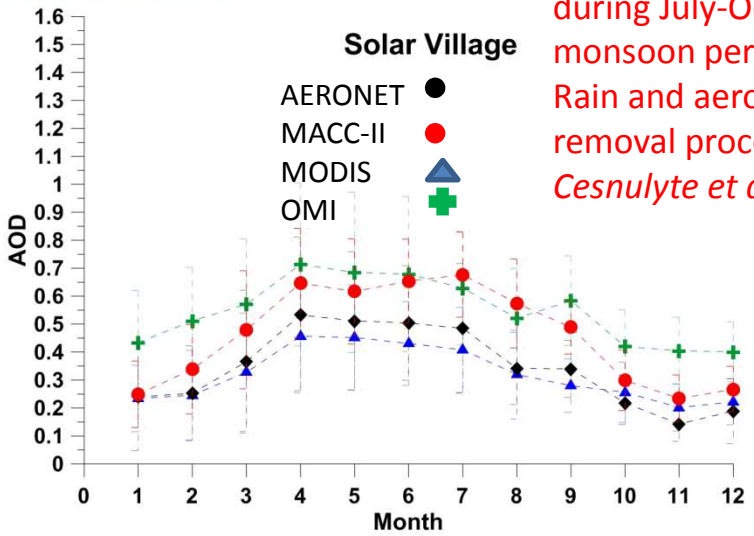
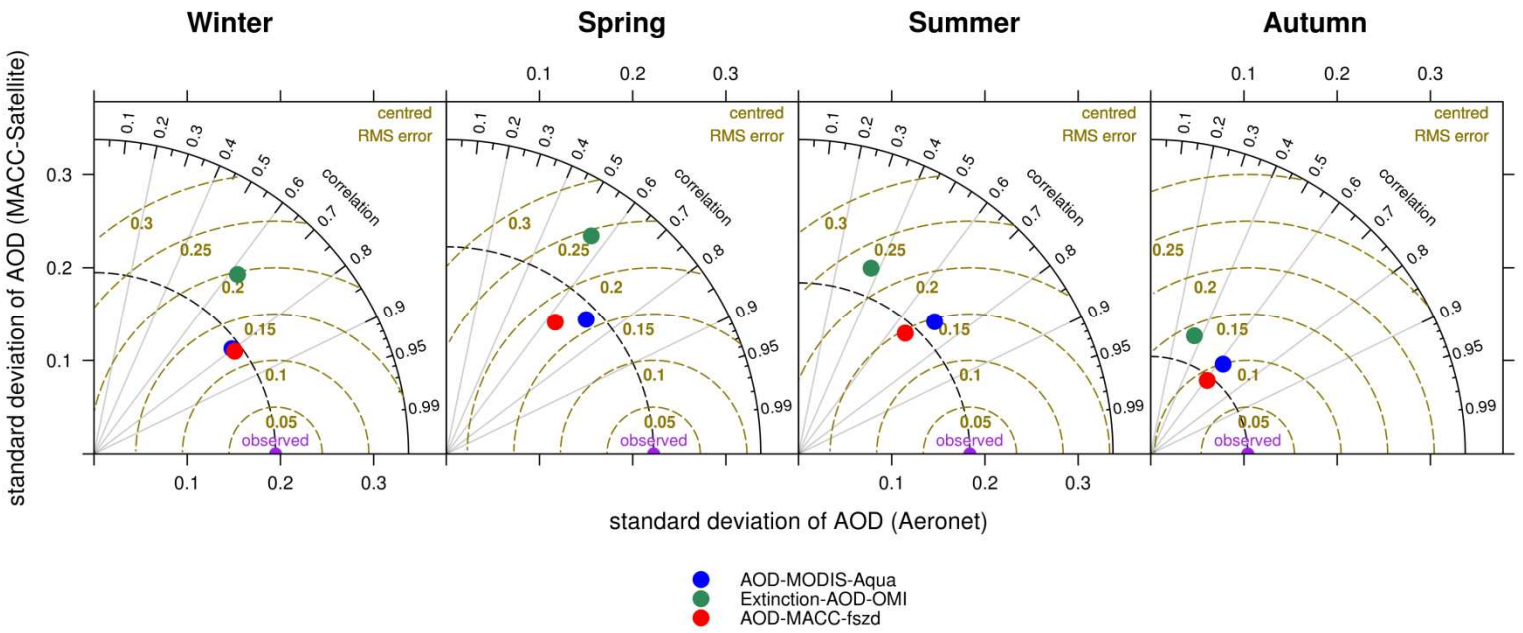
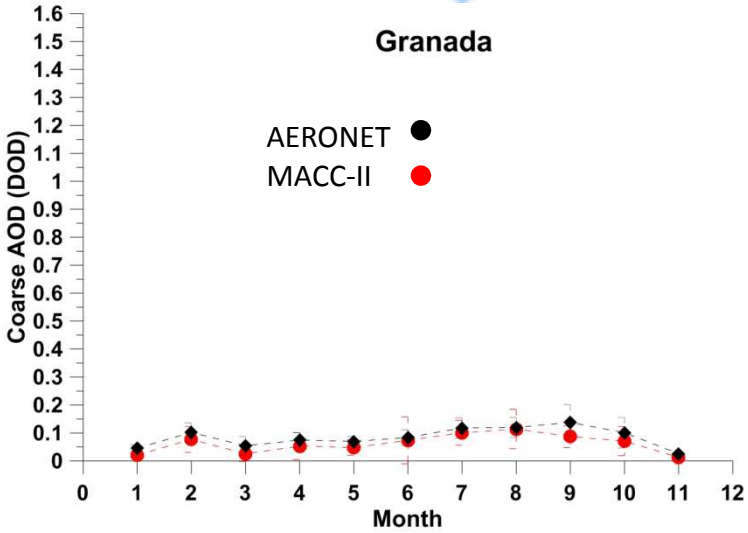


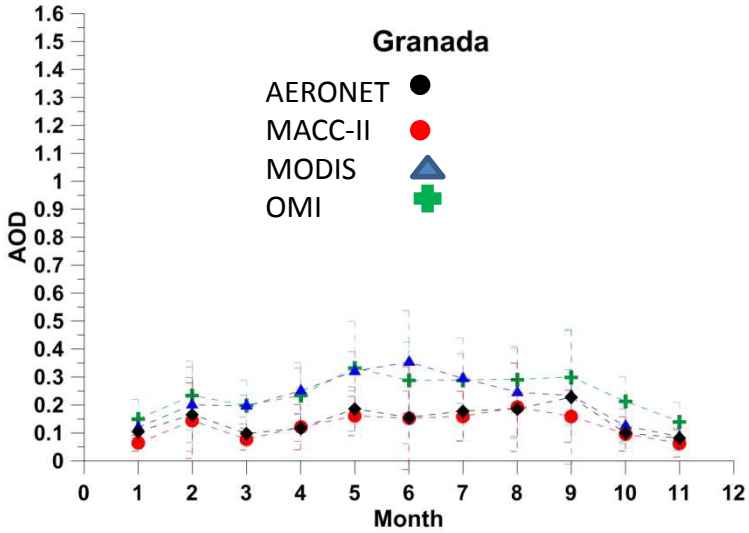




Model overestimates during July-October: the monsoon period.
Rain and aerosol removal processes?
*Cesnulyte et al., 2014*

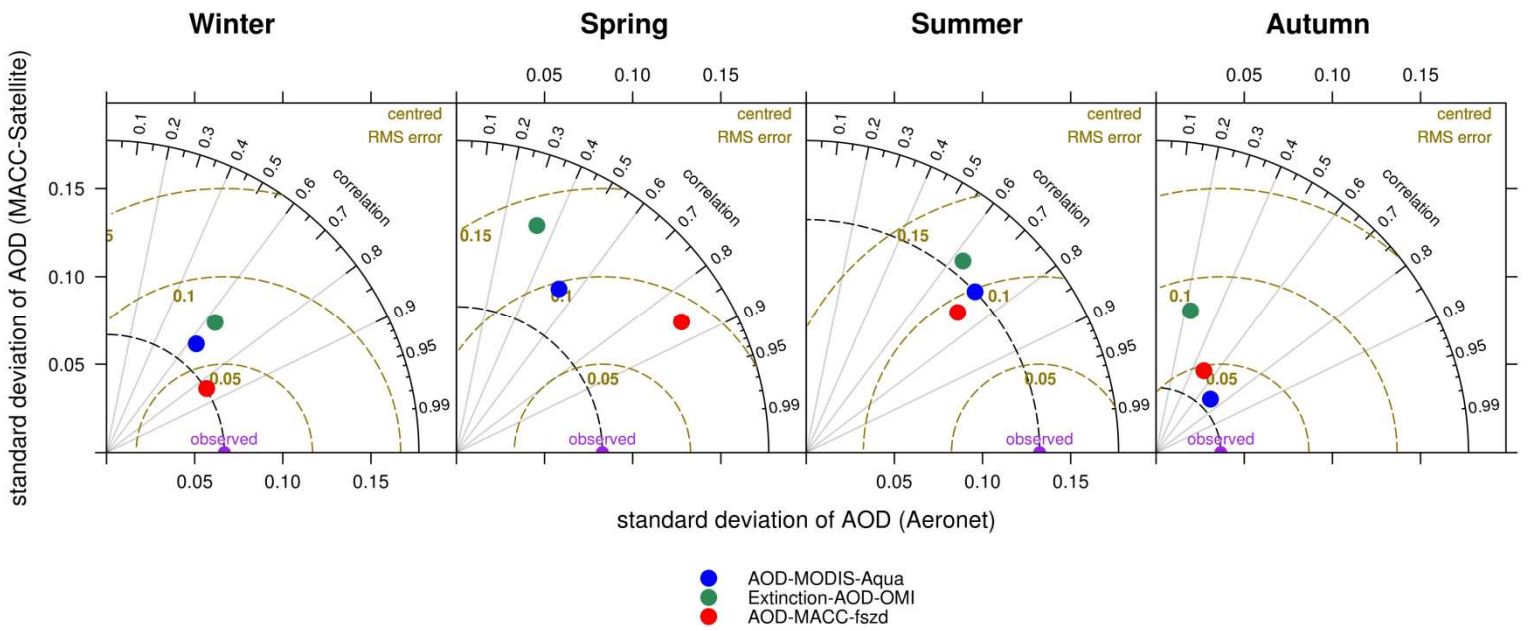
## Middle East region






## Western Mediterranean region



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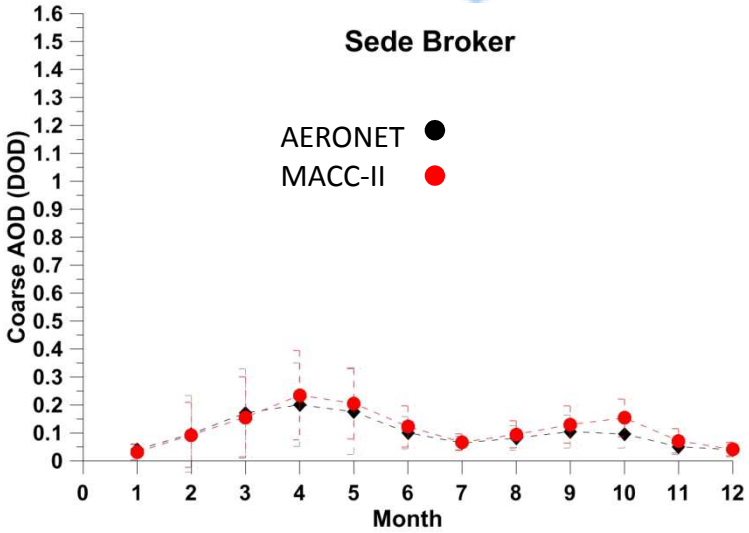
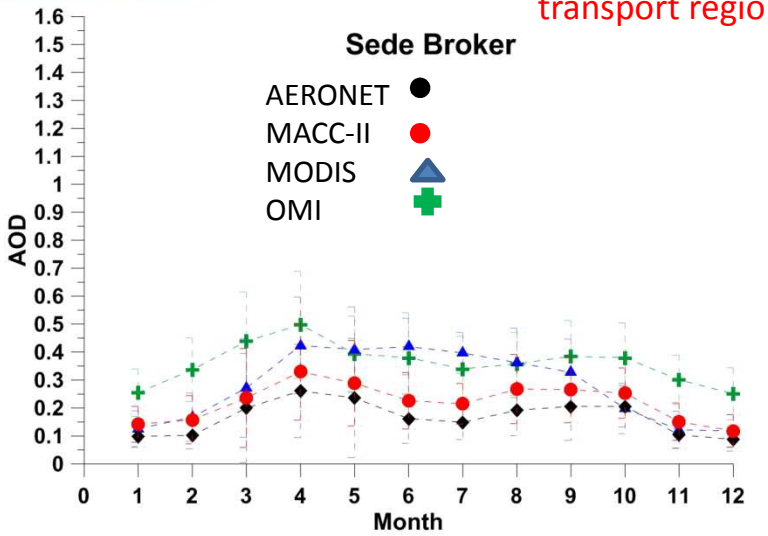
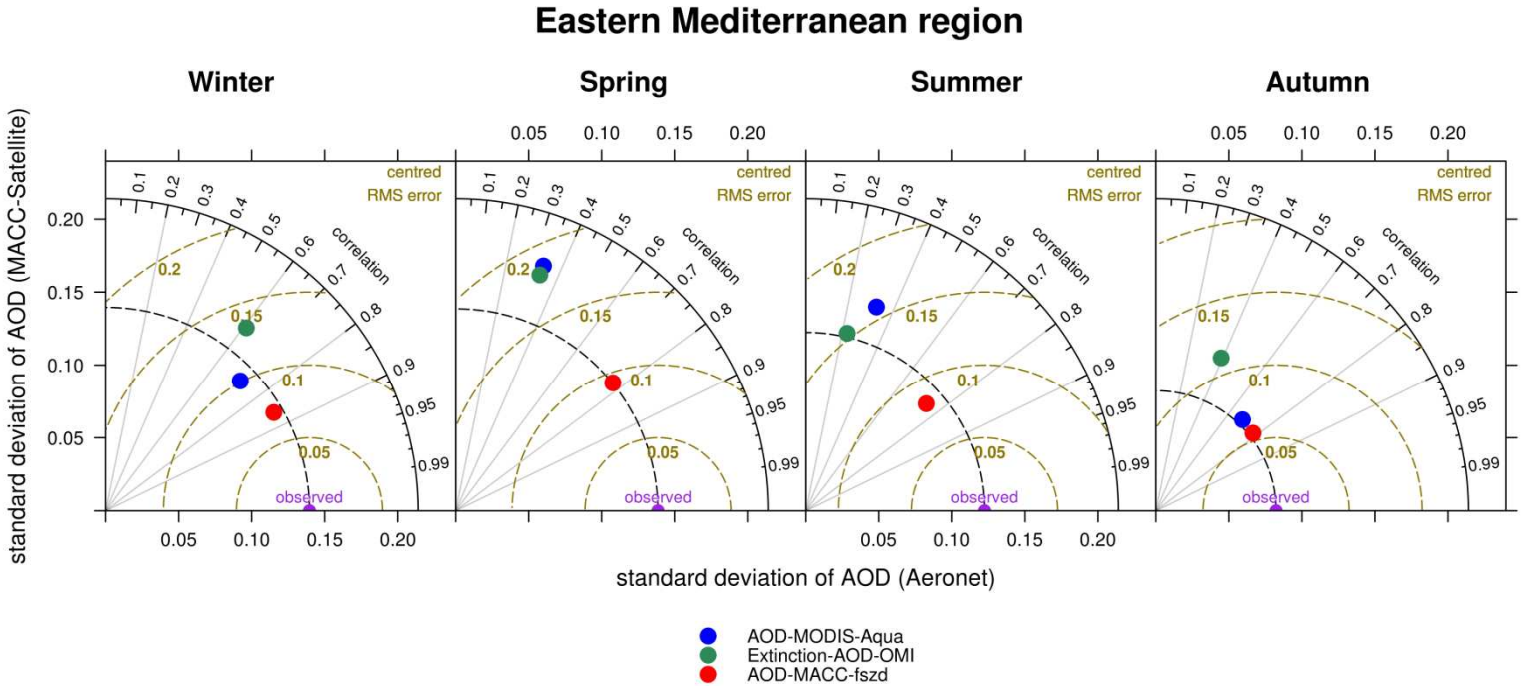
Good agreement in dust transport regions



PM10 data

24-hour daily average of $PM_{10}$ measured at three $PM_{10}$ monitoring stations from the African Monsoon Multidisciplinary Analysis (AMMA; *Marticorena et al., 2010*) International Project .

- *$PM_{10}$ measurements with Tapered Element Oscillating Microbalance (TEOM 1400A). 5 min resolution.*

- *Wind direction has been used to select geographical sectors with dominating mineral dust conditions trying to minimize the impact of biomass burning aerosols in winter (Marticorena et al., 2010)*

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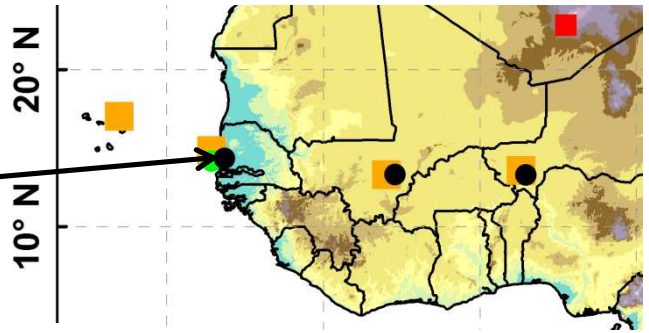
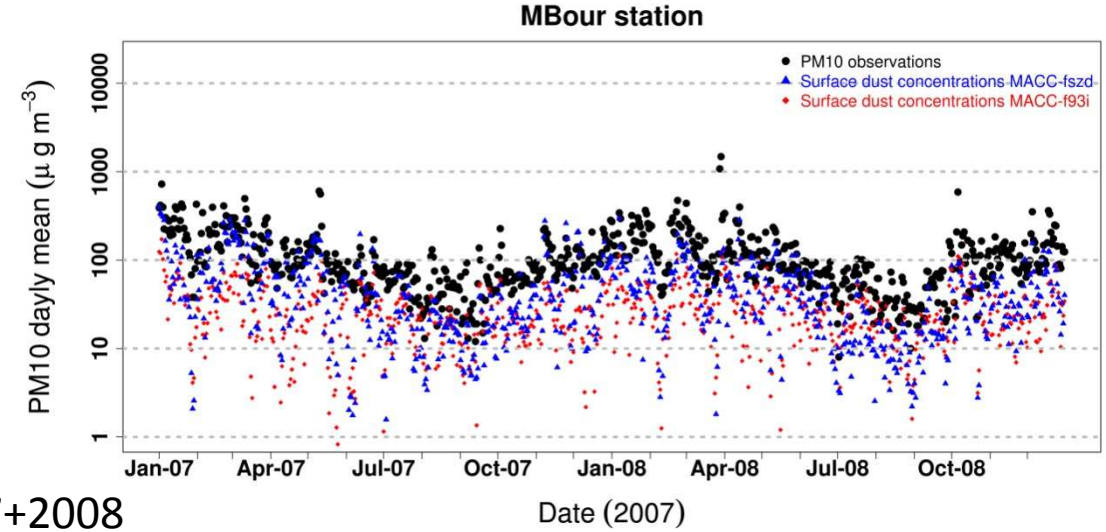
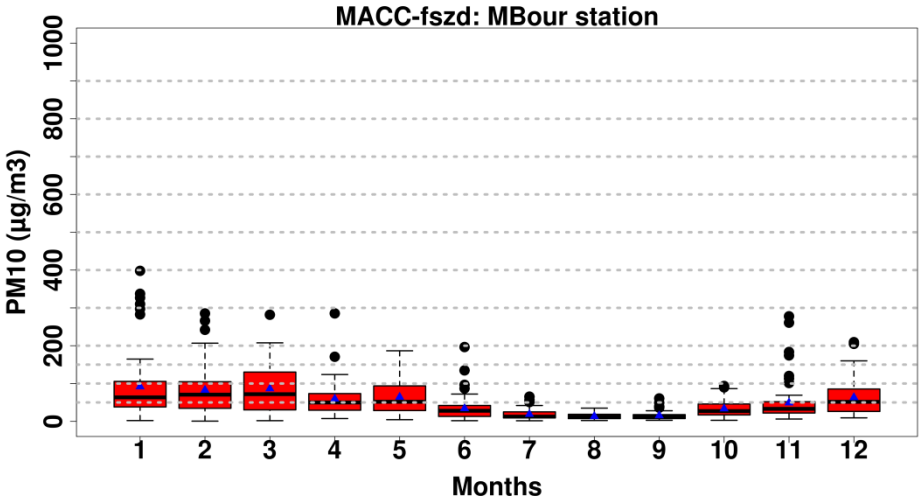
M'Bour-Senegal

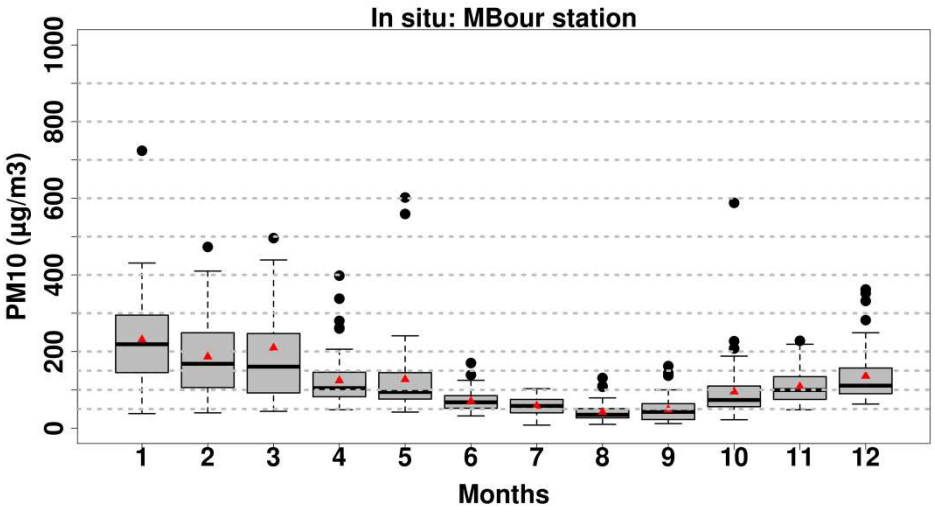



The observed PM10-dust may be overestimated somewhat by unavoidable contributions from biomass burning and sea salt aerosols

2007+2008



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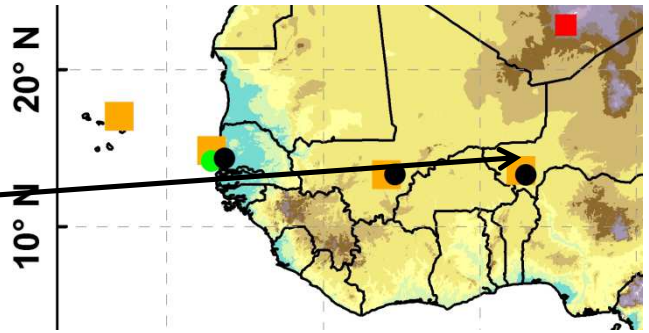
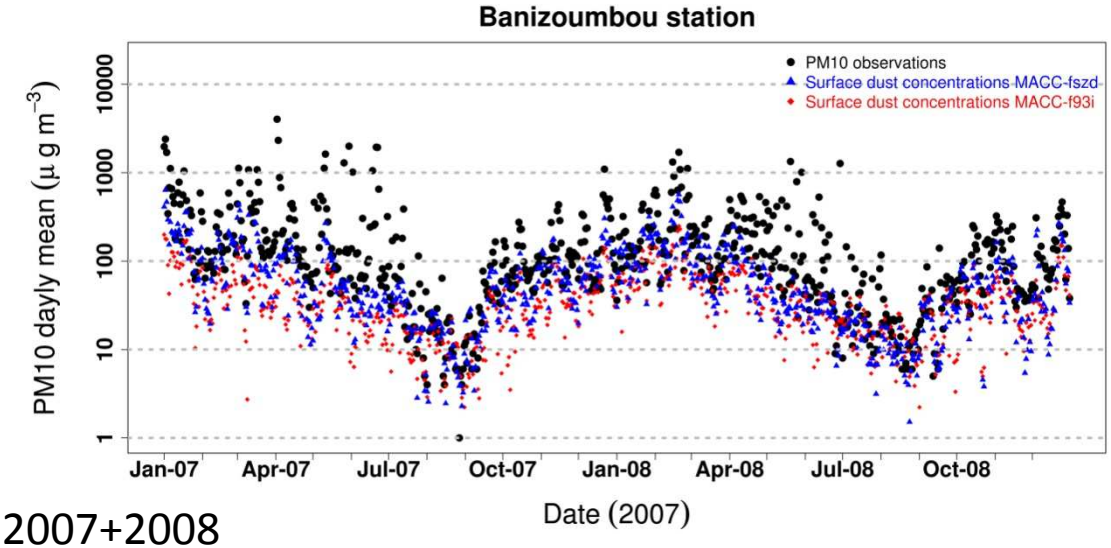
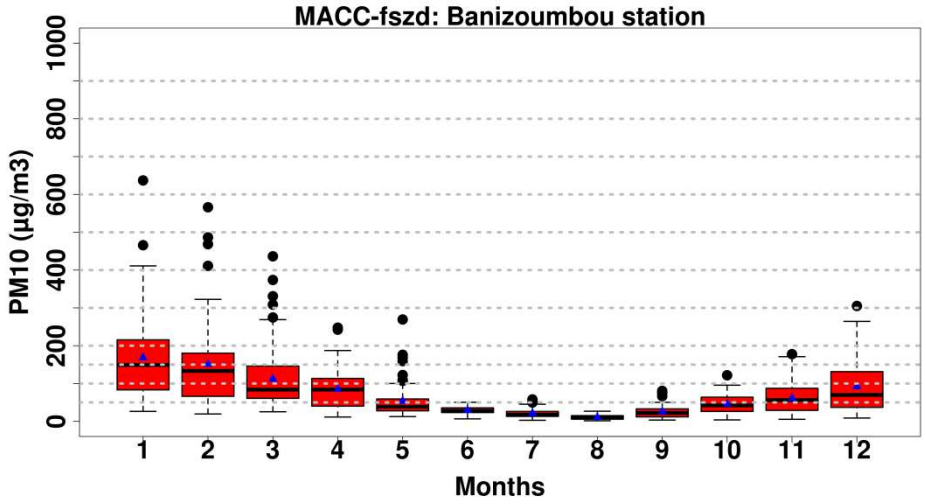
Banizoumbou-Niger

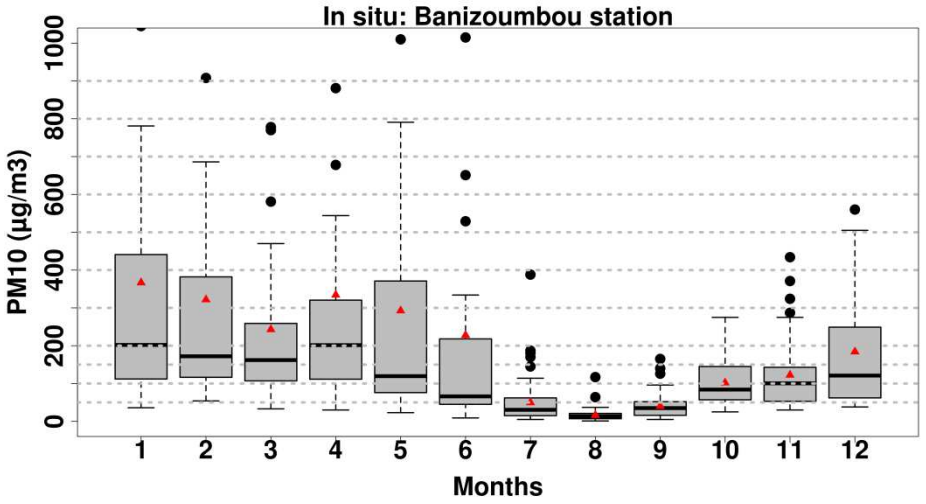



Local dust emissions and transport by meso-scale convective systems *(Marticorena et al, 2010)*

2007+2008



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Lidar data

1. Micropulse lidars (532nm) at M'Bour (Senegal ) and Tenerife (Spain)
   - *Extinction ($km^{-1}$) profiles from MACC-fszd outputs at 09, 12, 15 and 18 UTC were compared with extinction profiles from ground-based lidars within ± 1 .5 h*
   - *Desert dust conditions: AERONET AE≤ 0.35 at M'Bour and AE ≤ 0.75 at Tenerife*

2. CALIOP-CALIPSO over M'Bour and Tenerife
   - *Extinction at 532 nm profiles level 2 version 3.01 (60m vert. res.) 5 km horizontal resolution in an area of 1.5°x1.5° over each station.*
   - *High quality aerosol profiles with a CAD Score below -20 (screen artifacts from data) and an Extinction QC Flag 532 (0 or 1)*

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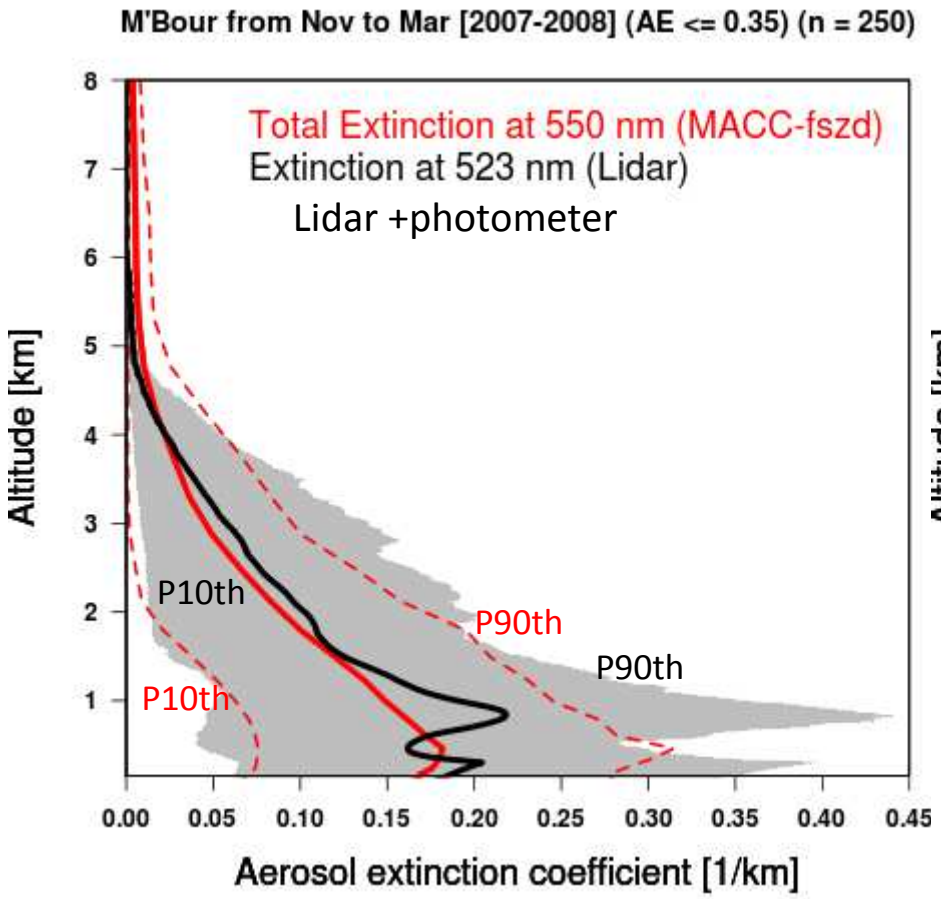
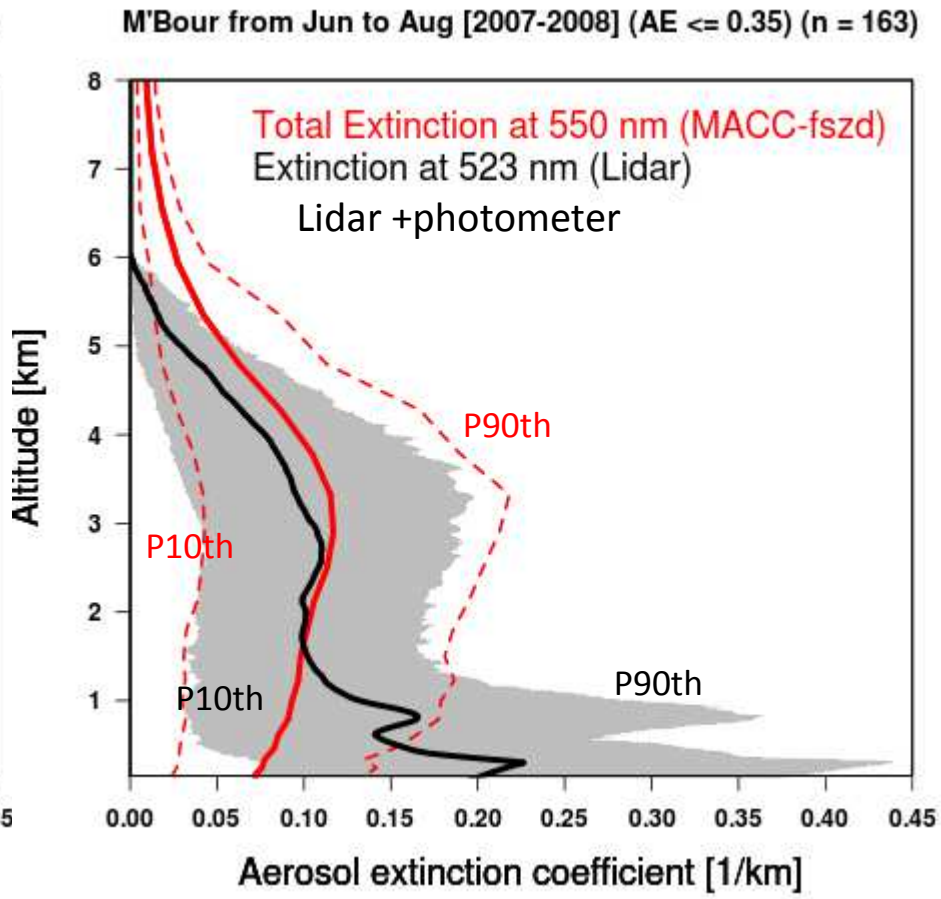
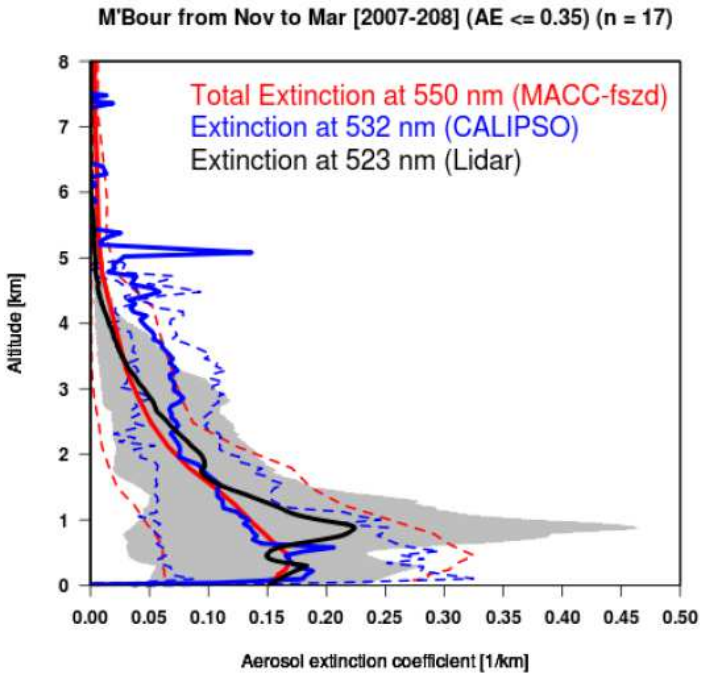
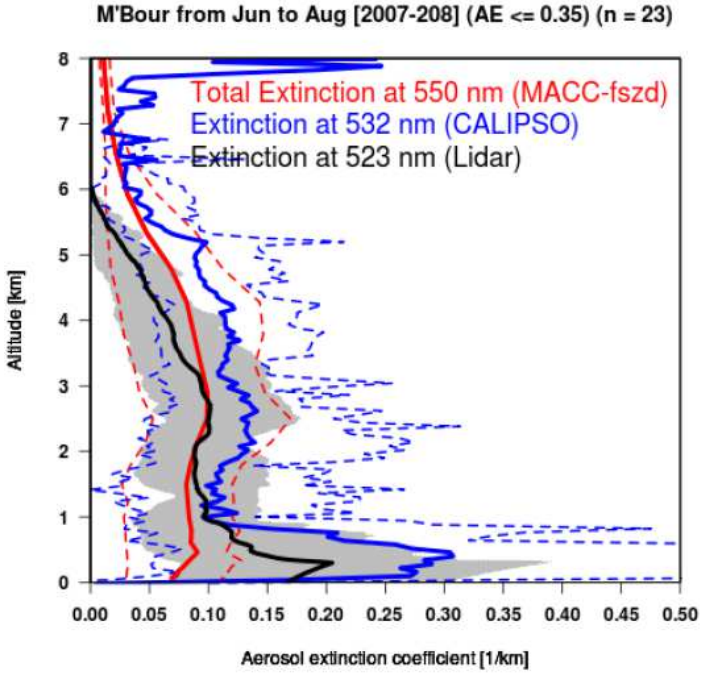
# M’Bour-Senegal






M'Bour-Senegal

**Uncertainties in lidars:**

- Overlap correction
- Lidar Extinction to backscatter ratio $S_\lambda = \frac{\sigma_\lambda}{\beta_\lambda}$

$S_\lambda$ = f (shape, nature and size of aerosols)

| Types of aerosols *(Winker et al., 2009)* | $S_\lambda$ (sr) |
|---|---|
| Urban | 70 |
| Biomass burning | 70 |
| Polluted desert dust | 65 |
| Desert dust | 40 |
| Marine (sea salt) | 20 |

MP lidar uses a constant $S_\lambda$ for each vertical profile
Mean $S_\lambda$ at M'Bour≈ 35 sr (automatic processing)

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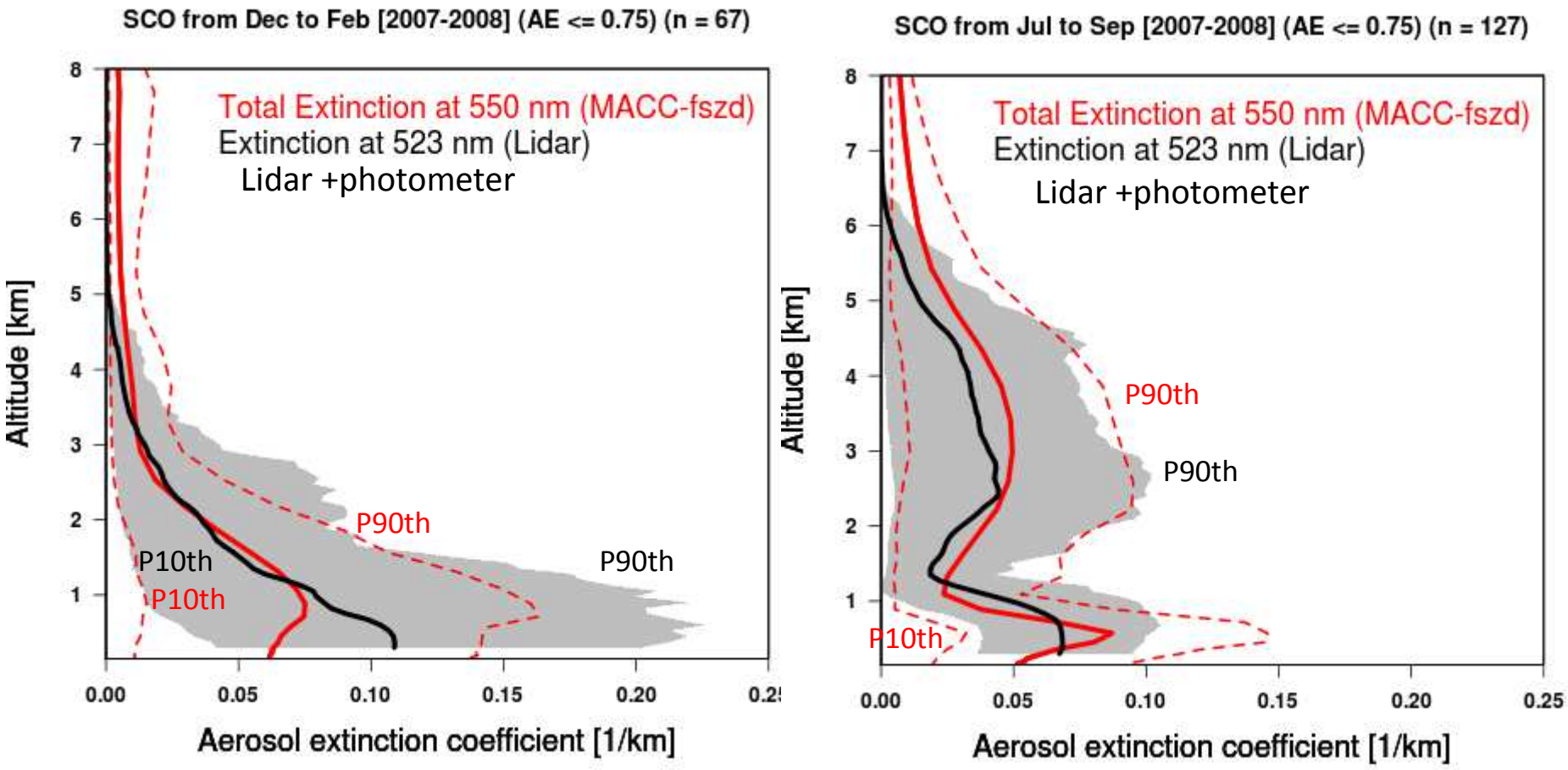
# Tenerife-Spain

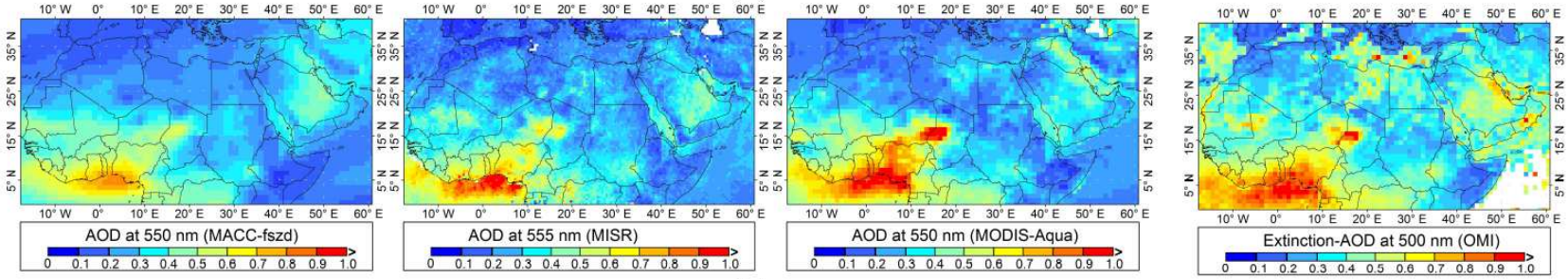


AOD
2007+2008

MACC-fszd | MISR | MODIS-Aqua | OMI

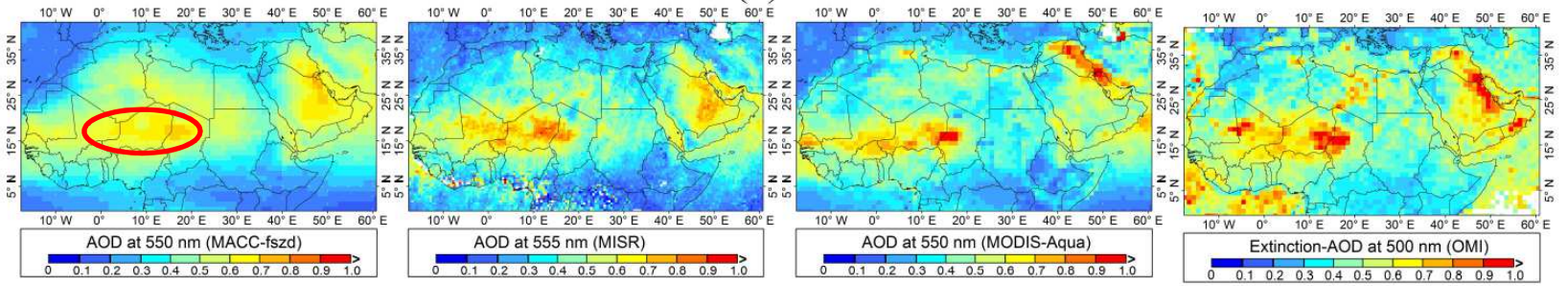
(a)

JFM



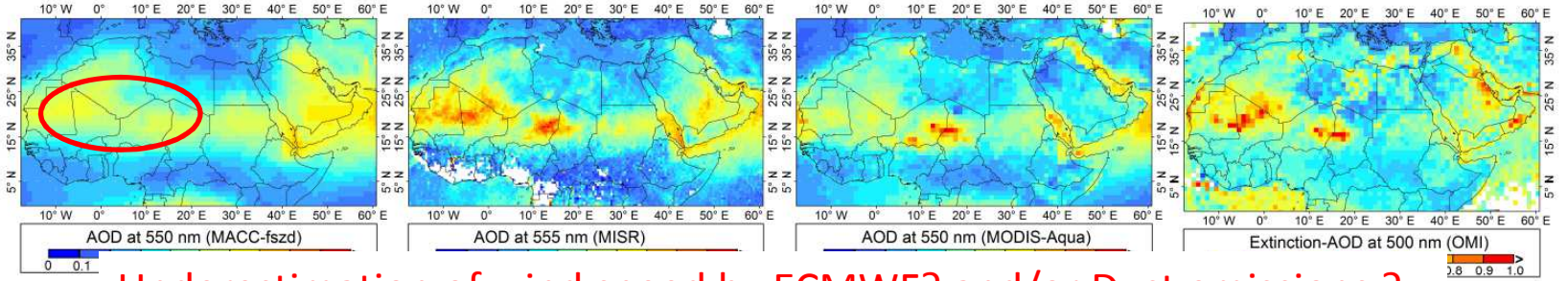

(b)

AMJ



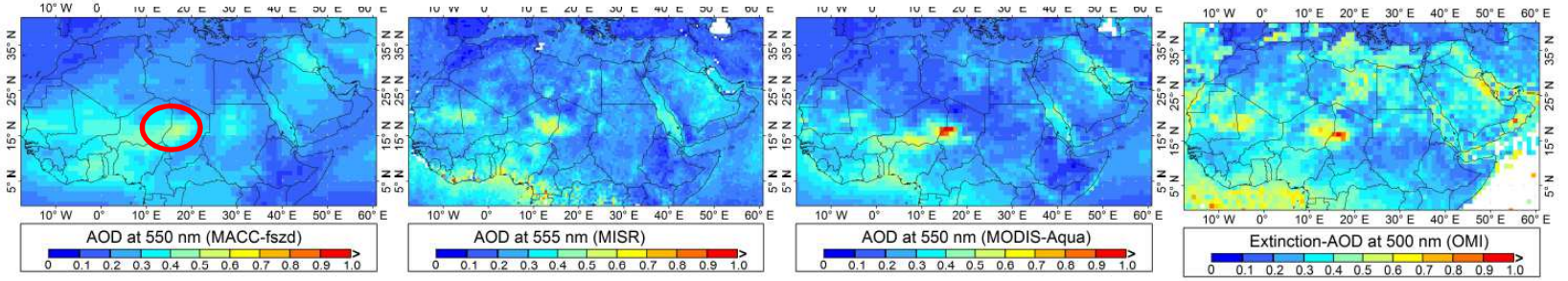

(c)

JAS




Underestimation of wind speed by ECMWF? and/or Dust emissions ?

OND



## Conclusions

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Results of MACC dust re-analysis fszd evaluation for the period 2007-2008 show:

- A good agreement with AERONET AOD/DOD in general.
  - o Underestimation in the Sahel, and overestimation in the Sahara and Middle East mainly during respective monsoons
  - o Good agreement in dust transport regions

- PM10: Acceptable (not in magnitude). Additional PM sites are needed.

- MACC Extinction vertical profiles are excellent compared with ground-based lidars
  - o Difficulties to compare the lower part of profiles by observation limitations
  - o Agreement with ground-based lidars are better than CALIOP-CALIPSO

- Spatial AOD climatologies show good agreement with MISR and MODIS except in the Sahel belt (cleard underestimation)

Long-term MACC dust re-analysis could be a useful tool for conducting climate studies and user-oriented applications (i.e. energy, health sectors)

ACP paper in preparation

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# Thank you for your attention

ecuevasa@aemet.es