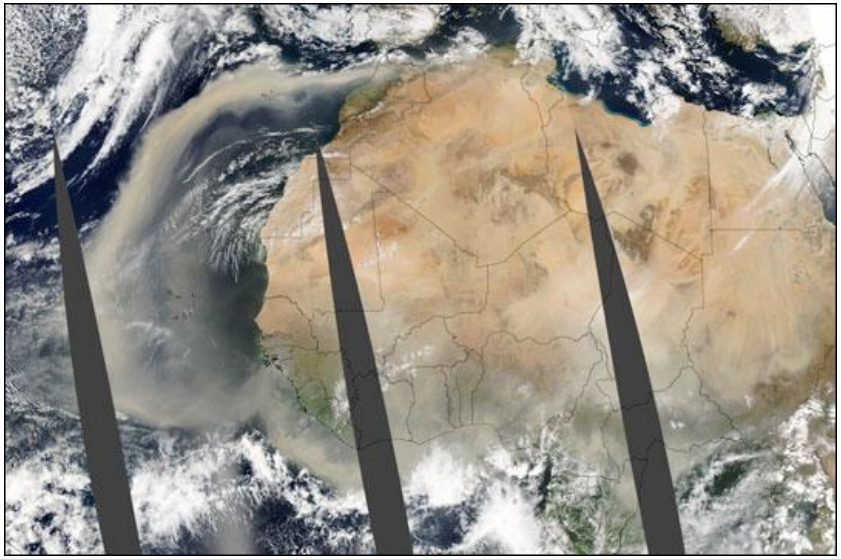
Improving the windblown dust modelling in LOTOS-EUROS



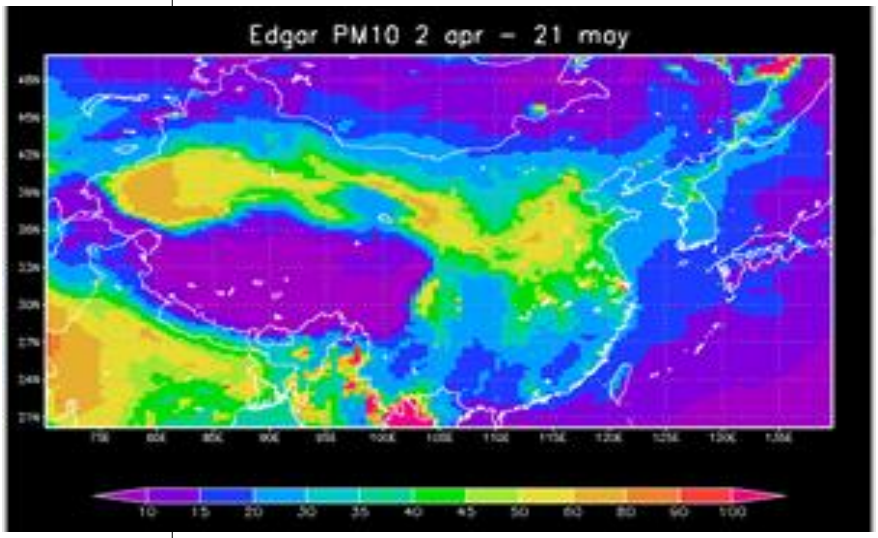
Sjoerd Janson (university Utrecht), Martijn Schaap, Astrid Manders, Arjo Segers, Richard Kranenburg and Renske Timmermans

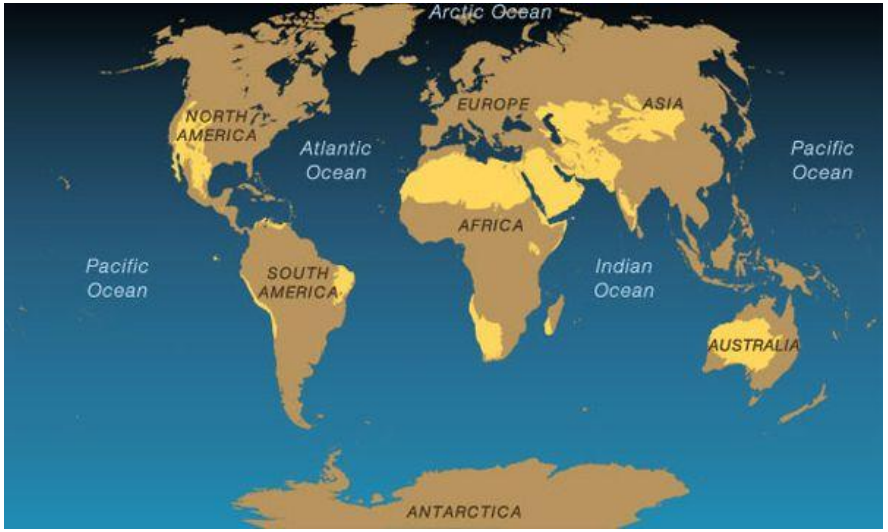
TNO, the Netherlands

Why improve the dust in LOTOS-EUROS?

LOTOS-EUROS regional CTM focusing on Europe

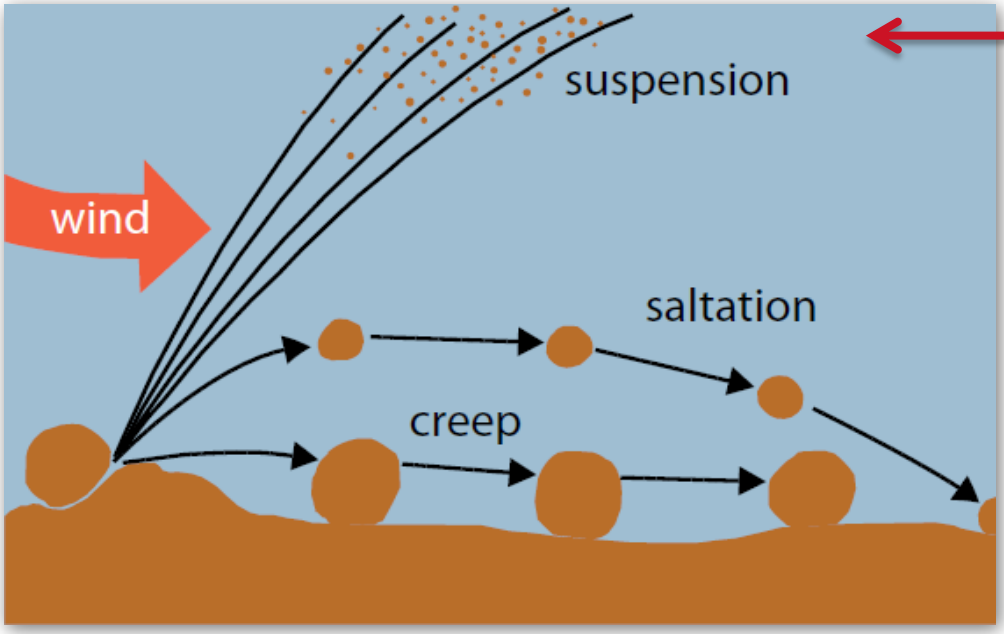
EU-Marcopolo project, source apportionment PM over China





→ Develop and test over Saharan region (more observations, models)

Wind-blown dust basics



Aerosol particles

Soil particles

Emission is depending on

- Windspeed : needs to exceed threshold velocity
- Landuse: Erodible/non-erodible, roughness less
- Soil properties:
  - Soil texture: particle sizes, binding energy particles
  - Soil moist (sticky)


Emission scheme

- Vertical flux

) [kg/m^2/s] *(Marticorena, 1995)*

Horizontal saltation mass flux (soil particles)

Erodible area fraction (landuse, soil texture, preferential sources)

Sandblasting efficiency ( ) *(Mokhtari et al. , 2012)*

- ( ),

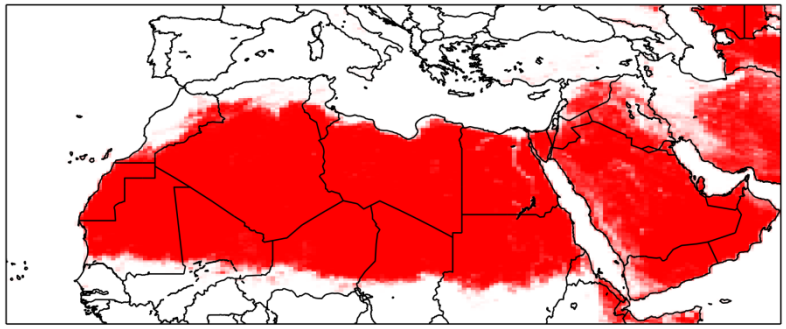
where ( )

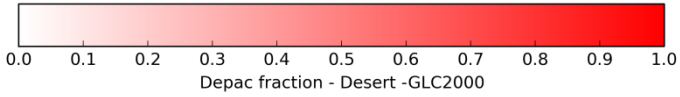
Soil particle diameter

Landuse map – erodible land

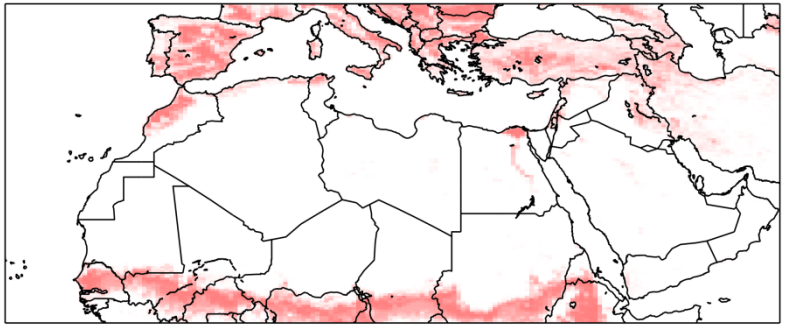
Landuse map 2 Erodible classes: bare and arable

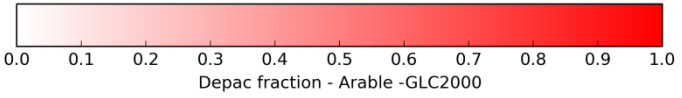
Bare land (desert) fraction





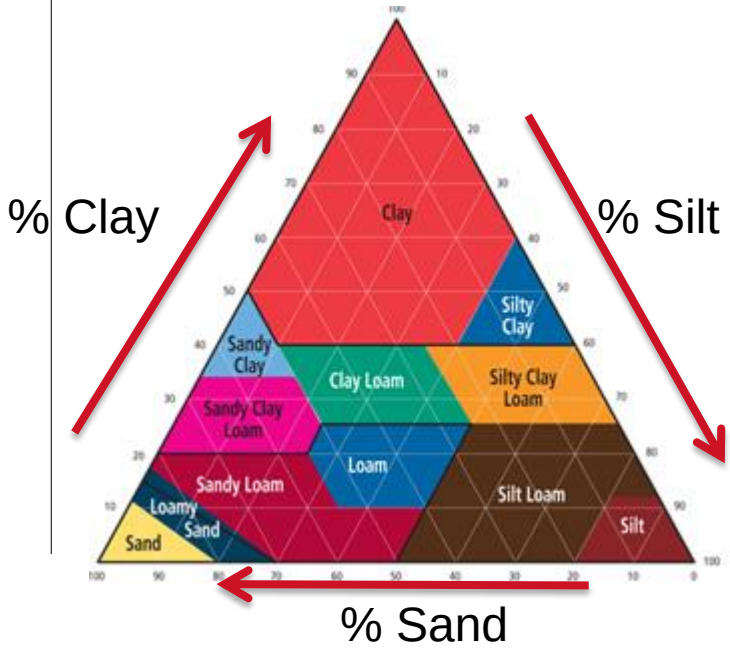
Arable land fraction

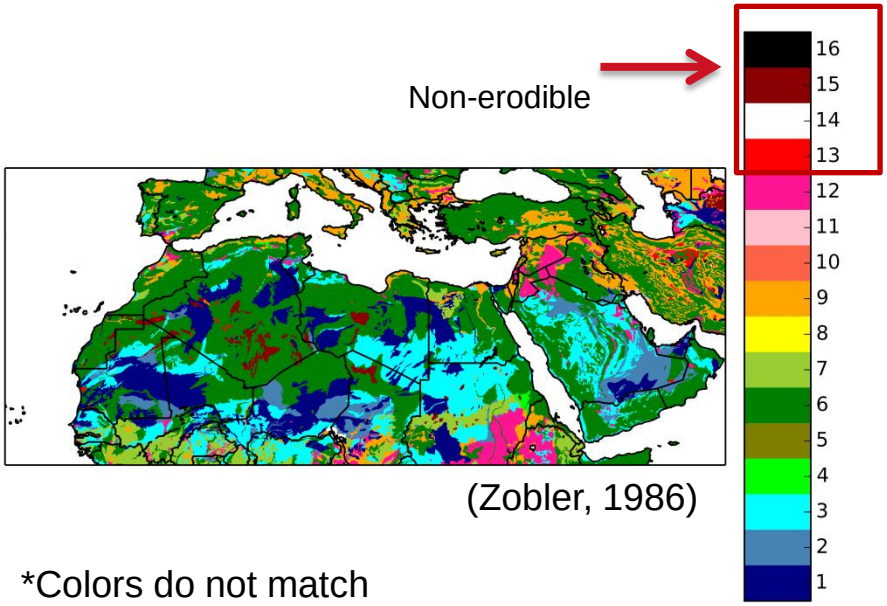




Soil texture

- 12 different soil texture types; sandy to clayey soils *(USDA soil triangle)*
- 12 specific particle properties:
  - Mean particle diameter (largest for sand, smallest for clay)
  - Geometric standard deviation
  - Mass distribution





(Zobler, 1986)

*Colors do not match

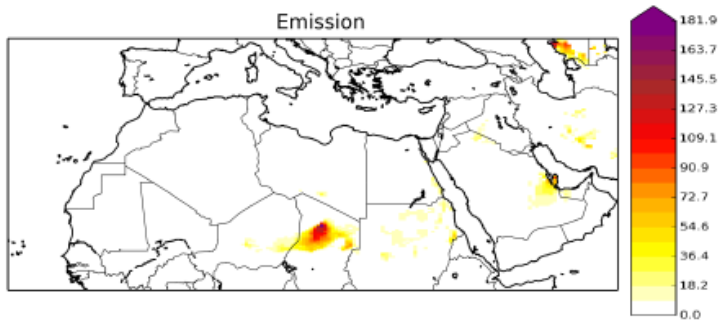
LOTOS-EUROS Model configuration

Characteristic	Setting
Domain	Sahara
Simulated year	2008
Horizontal grid resolution	0.25 °×0.50 ° (latitude/longitude) ±(28×52) km
Vertical grid resolution	10 layers, up to 9.5 km
Meteorological input	3h average ECMWF forecast
Boundaries	Dust inflow ignored
Additional	Dust exclusive simulations

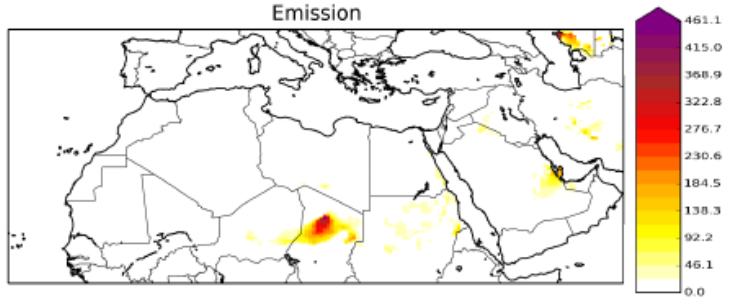
Fine		Coarse		
0 – 2.5		2.5 – 10		
Very fine	Fine	Medium Fine	Medium Coarse	Very Coarse
0 - 1	1 – 2.5	2.5 - 4	4 - 7	7 - 10

Uncertainties - Sensitivity tests

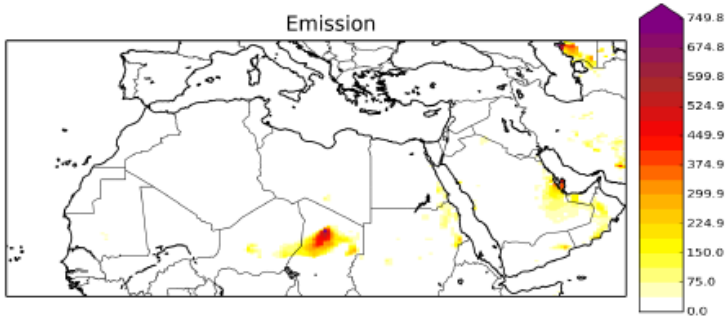
Sandblasting efficiency ratio vertical/horizontal flux



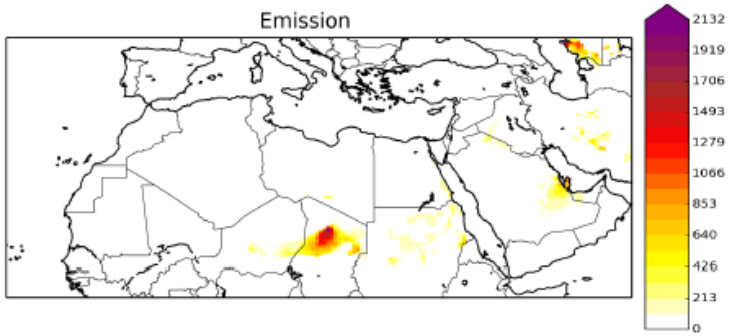
a: *Tegen et al. (2002)*



b: *Marticorena and Bergametti (1995)*



c: *Shao et al. (1996)*



d: *Zender et al. (2003)*

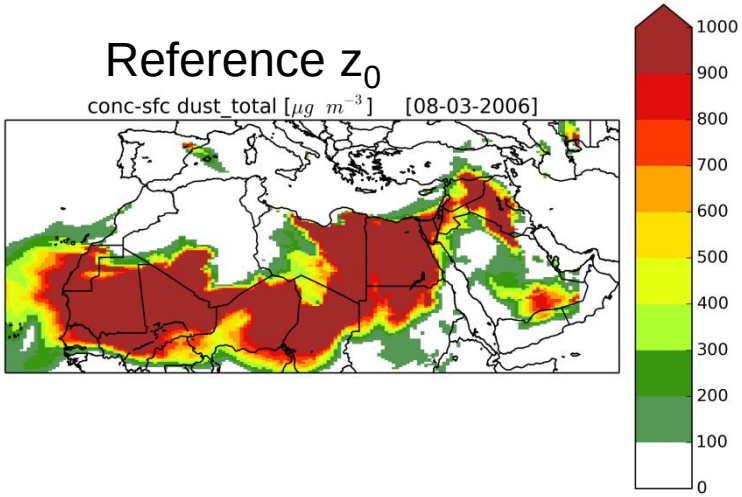
Figure 4.2: *Dust emissions* [$\mu g m^{-2} s^{-1}$] *computed with different sandblasting efficiency methods.*

Uncertainties - Sensitivity tests

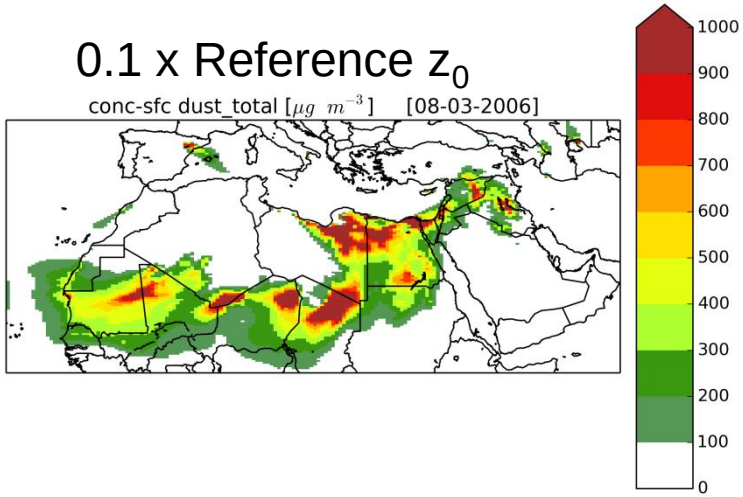
Many uncertainties / sensitivities :

- How to deal with arable land (seasonal)
- How to deal with rainfall
- Dust aerosol size parameters
- Preferential sources (and their accuracy)
- Threshold velocity correction factor (Tegen et al. 2002)
- ; ratio vertical/horizontal flux (many different methods in literature)
- Roughness length sensitivity to found in literature)

Reference z_0



0.1 x Reference z_0



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WMO Sand and Dust Storm Warning Advisory and Assessment System

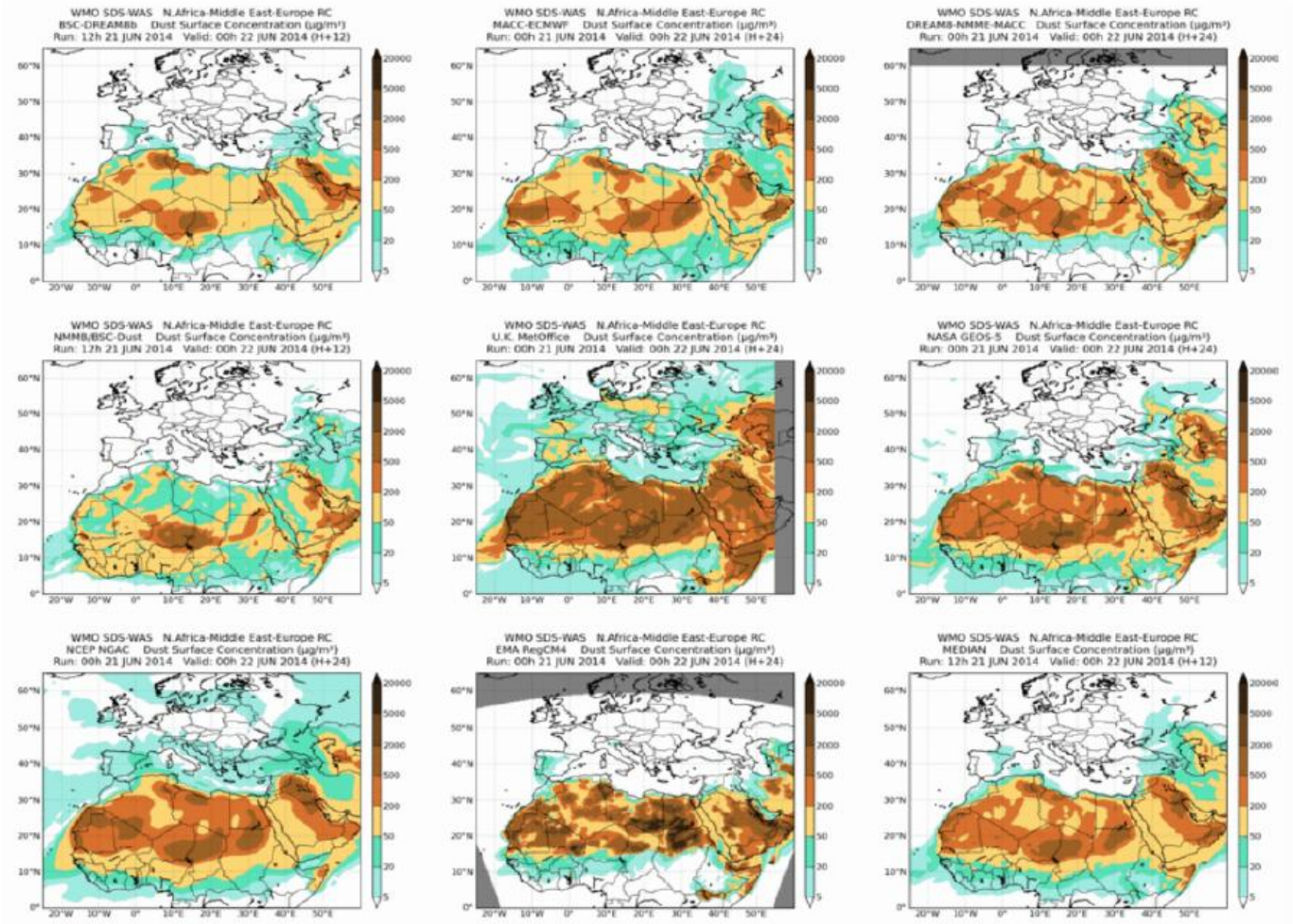

Figure 5.32: *Surface concentrations determined by other models for the forecast of midnight June 22, 2014.*


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Summary parametrizations

Table 4.1: *Collection of selections of parametrizations for LOTOS-EUROS.*

Name	Symbol	Value / Method	Source
Velocity threshold tuning factor	c	0.66	Heinold et al. (2007)
Sandblasting efficiency	α	$2.3 \cdot 10^{-3}$ - $1.8 \cdot 10^{-4}$ m^{-1} $1.8 \cdot 10^{-4}$ m^{-1}	Shao et al. (1996)
Average aerosol diameter	D_a	6.7µm	Mokhtari et al. (2012)
Soil density	ρ_p	$2.65 \cdot 10^3 kgm^{-3}$	Tegen et al. (2002)
Roughness length desert	z_0	30µm	Mokhtari et al. (2012)
Smooth roughness length	z_{0s}	30µm (constant)	Mokhtari et al. (2012)
Tuning factor	C	1.0	-
Aerosol size distribution	-	-	Crumey-rolle et al. (2011)
Landcover map	-	GlobCover	ESA (2009)
Soil texture database	-	USDA	Zobler (1986)
Preferential sources	-	Topographic dependent	Ginoux et al. (2001)
Aerosol size bins	-	0-1, 1-2.5, 2.5-4, µm 4-7, 7-10	-

Comparison model – MODIS AOD

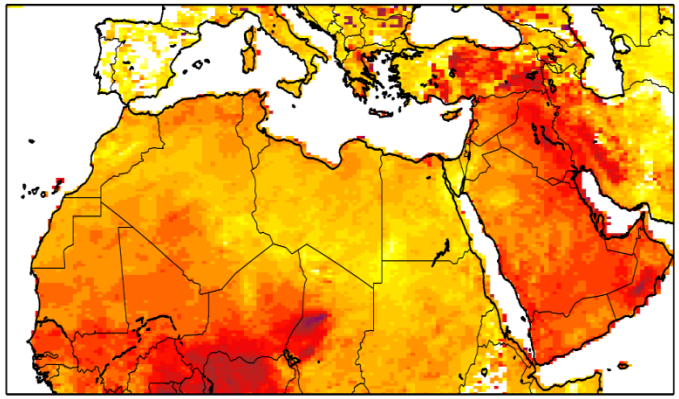
MODIS Deep blue (collection 006)

- Sun synchronous orbit
  (fixed equator cross time at ± 1.30PM local time)
- Clouds filtered
- Highest quality data only
- Resolution of 10x10 km
- Ångström coefficient < 0.3 to exclude
  smaller particles from other sources

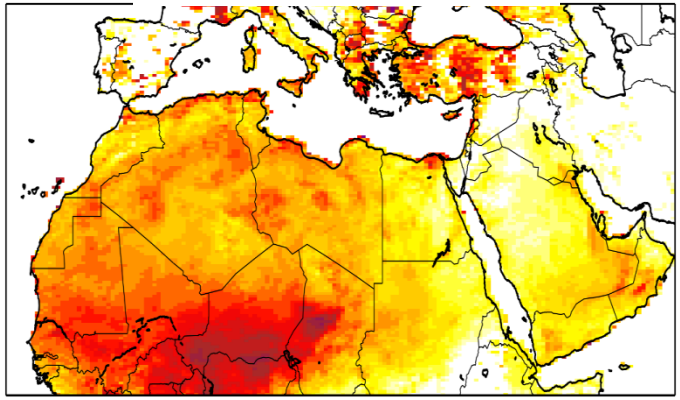
MODIS uncertainty used to add weight to model and retrieval data

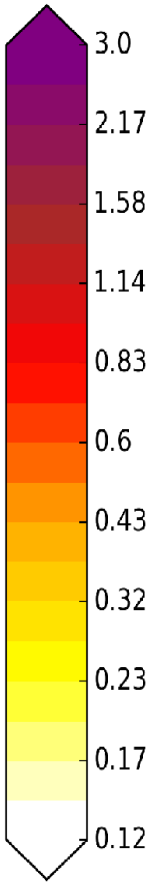
Comparison model – MODIS AOD (2008)

MODIS

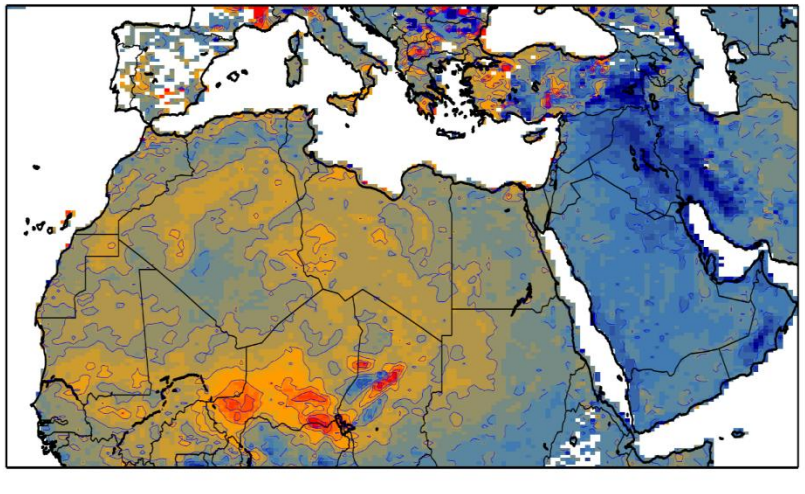


LOTOS-EUROS



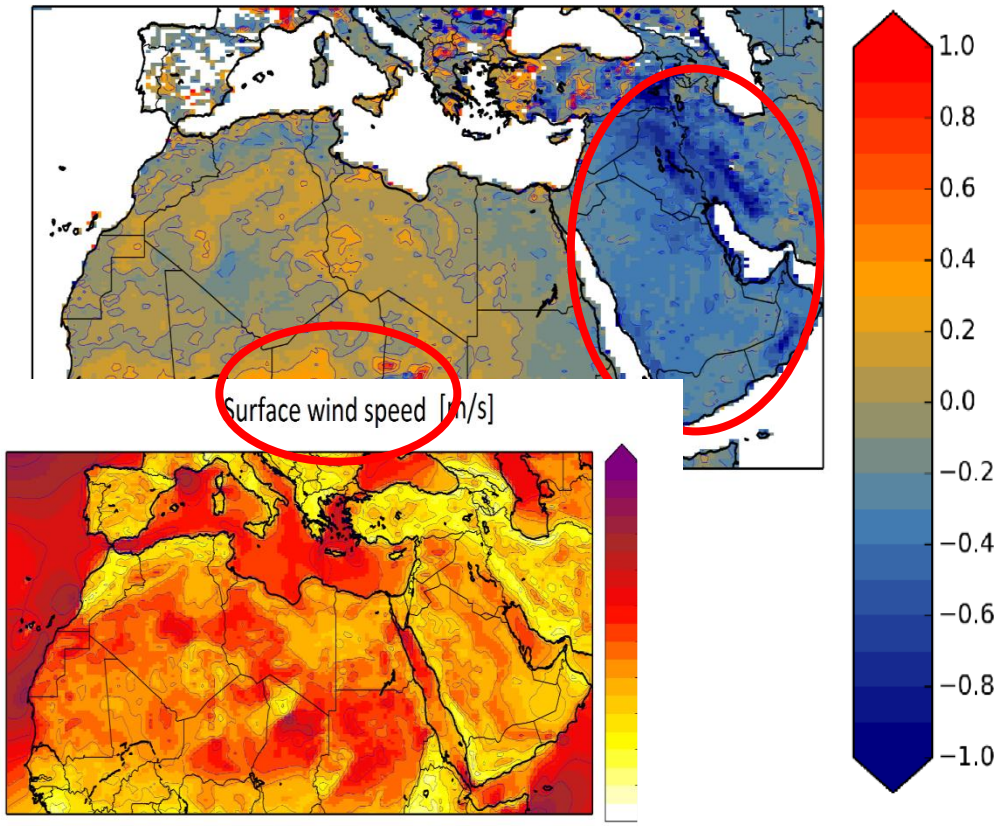


Difference



Comparison model – MODIS AOD (2008)

Difference

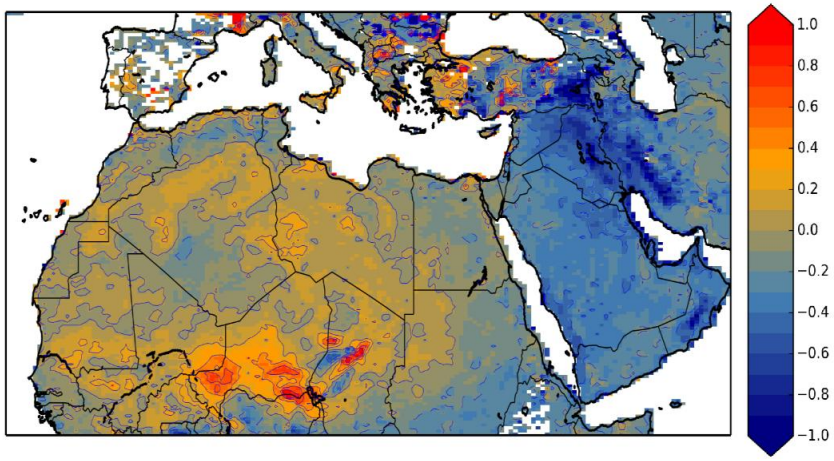


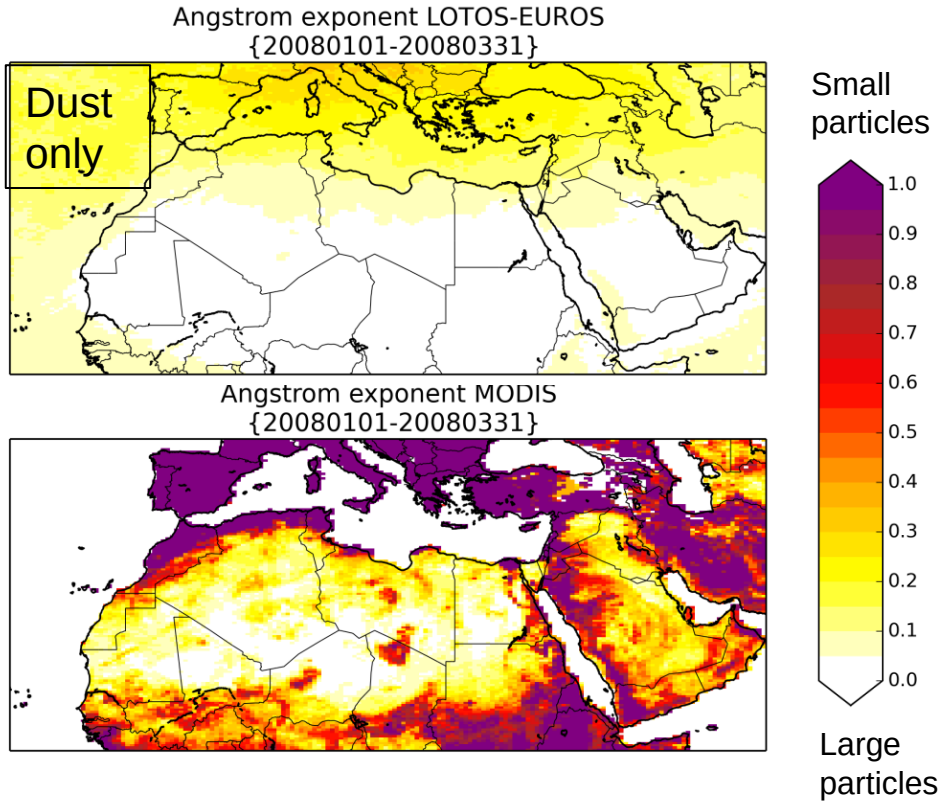
Possible explanations:

- Arabia
  - Low wind speeds; external model
  - Roughness length inaccurate
  - Soil texture map
  - Other aerosol species
- Southern Sahara
  - Too frequent threshold exceedance
- Overall
  - Inaccurate aerosol size distribution

Particle size distribution

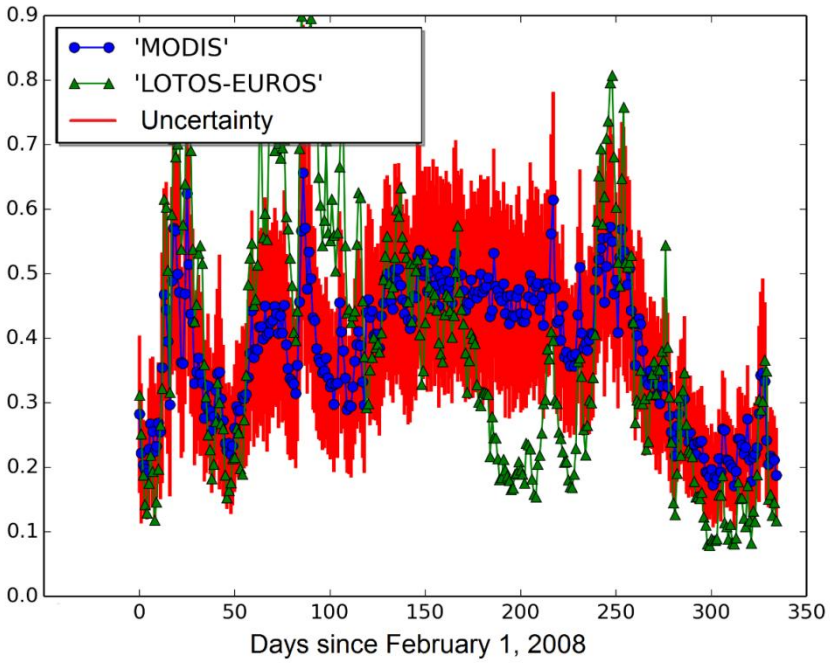
- Aerosol particle size distribution via Ångström exponent



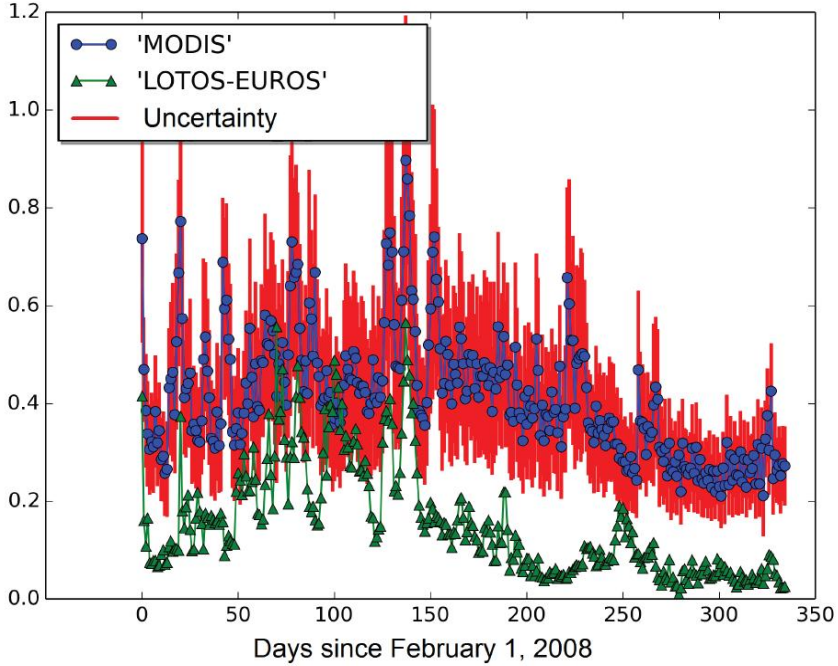


Comparison model – MODIS AOD

Saharan region



Arabian Peninsula

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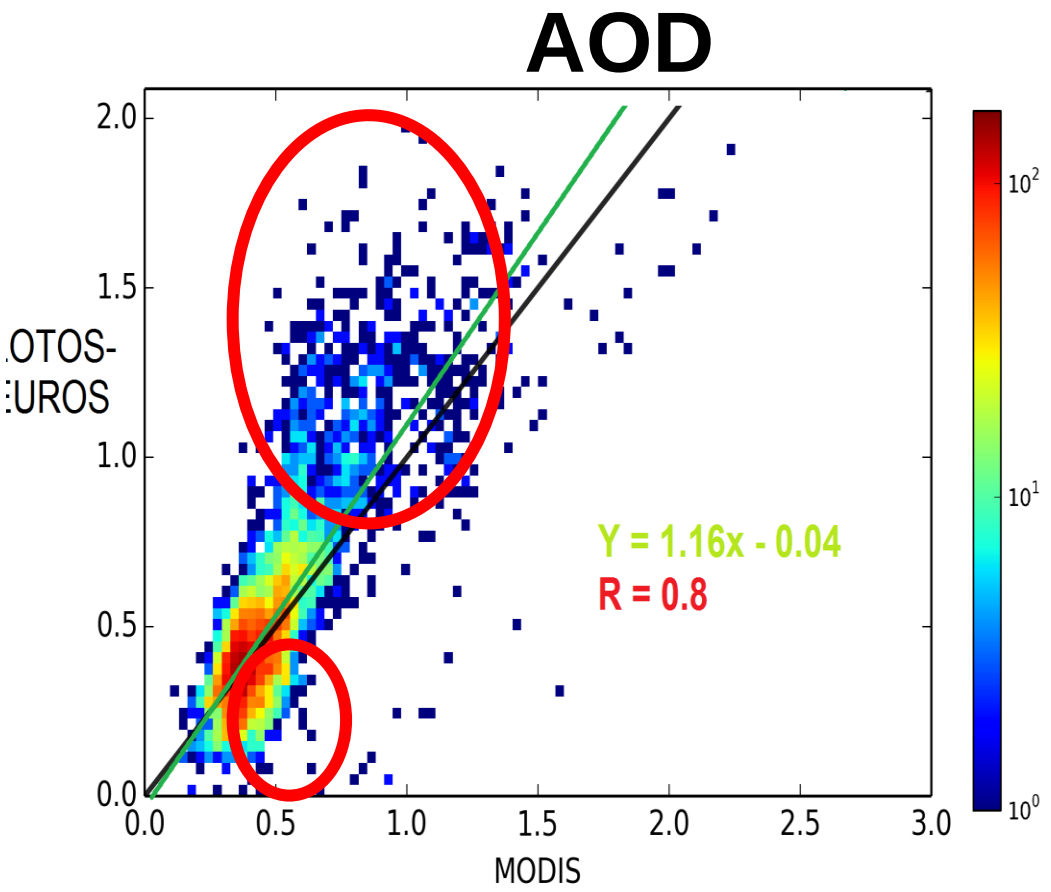
Comparison model – MODIS AOD
Sahara only

- Spring extremes
- Summer underestimation

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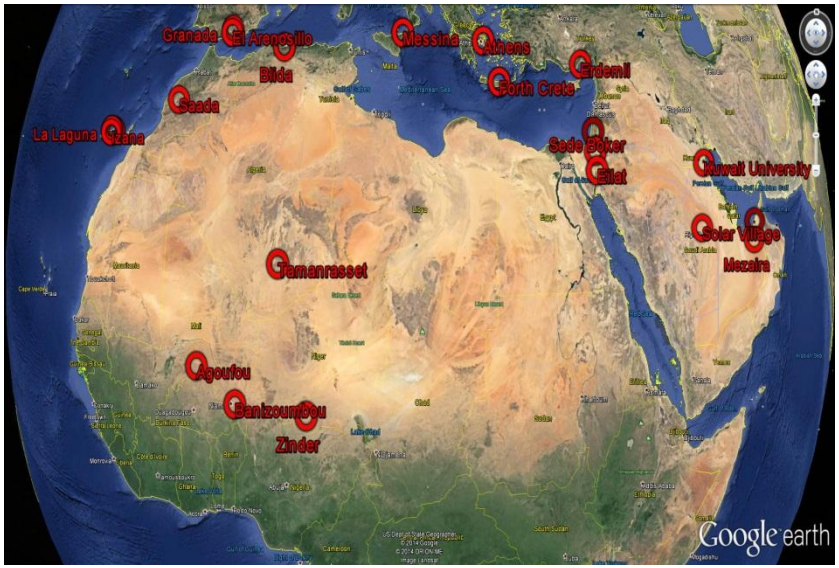
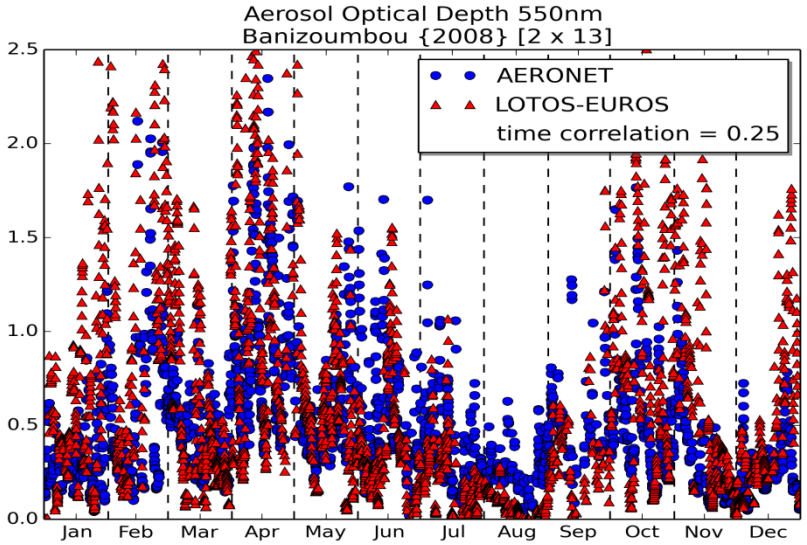
Comparison model - AERONET

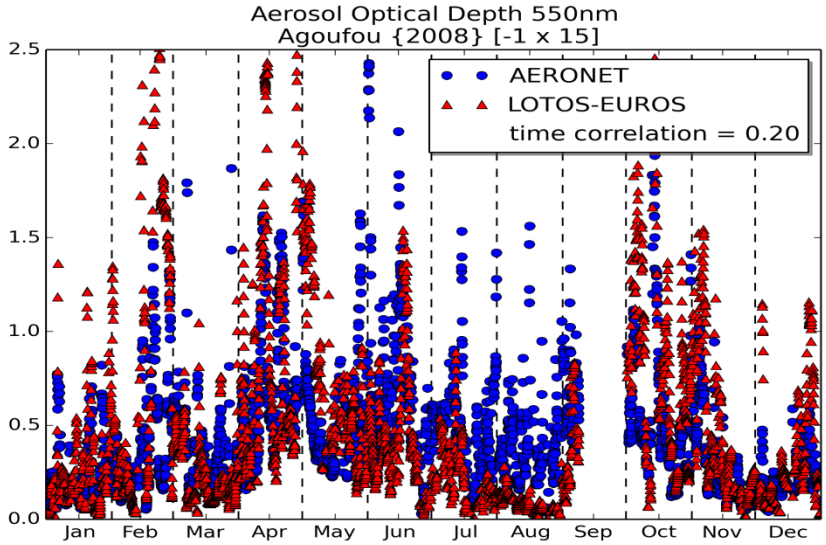
- Automated ground based stations (Sensor directed towards the Sun)
- AOD
- Highest quality used (level 2.0)
- 22 stations selected



Comparison with AERONET – near source

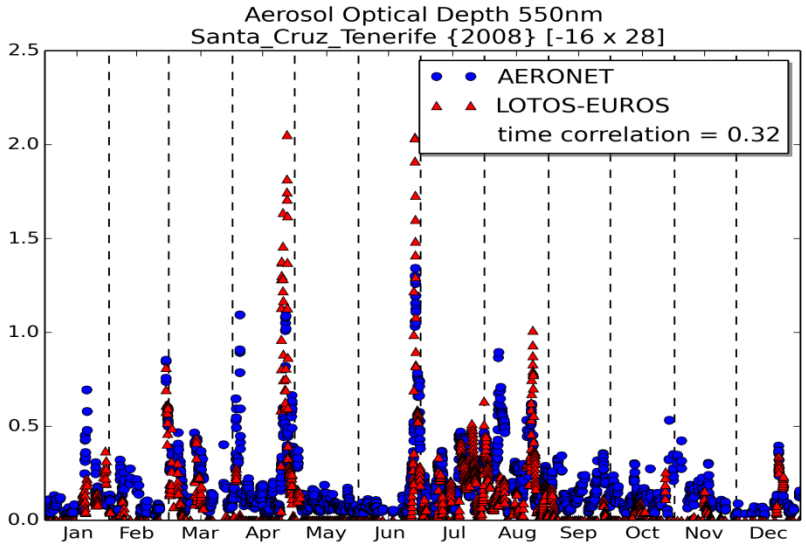


Daily temporal correlation: 0.67

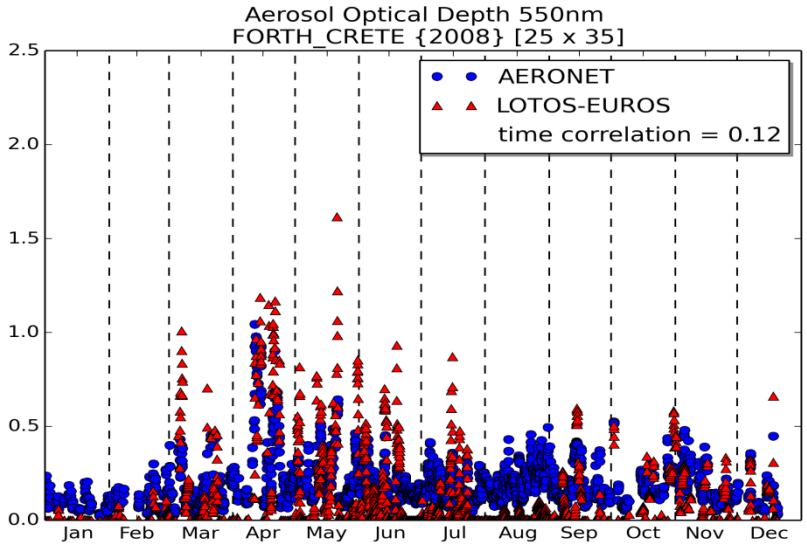


Daily temporal correlation: 0.49

Comparison with AERONET – transport

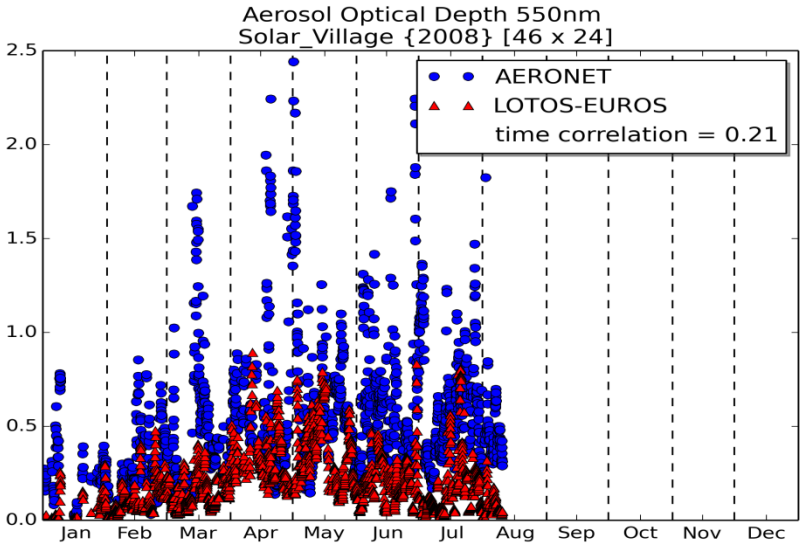


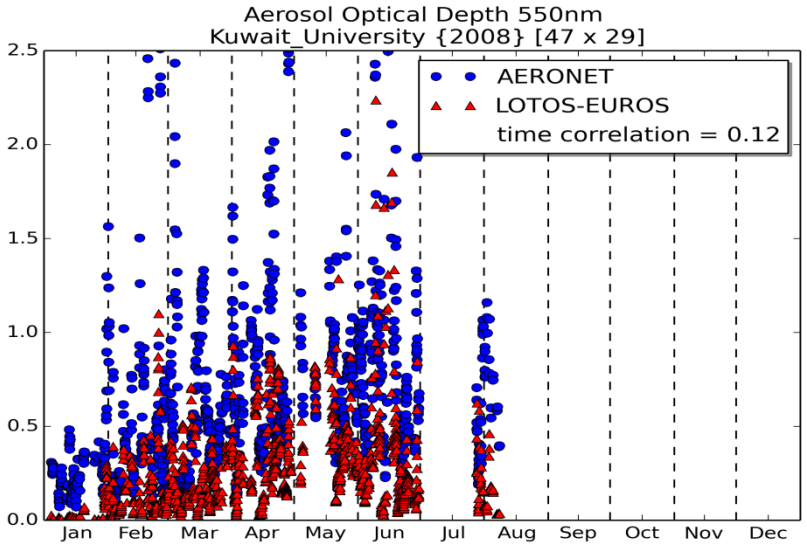
Daily temporal correlation: 0.73



Daily temporal correlation: 0.74

Comparison with AERONET – Arabian Peninsula





Daily temporal correlation: 0.21?

Daily temporal correlation: 0.46


Conclusions

- Improvements succeeded
  - Acceptable AOD over large areas
  - Long distance transport
  - Time correlations
- Underestimation Arabian Peninsula
- Overestimation spring emission Sahara
- Underestimation concentrations summer Sahara


TNO innovation for life

Conclusions

- Underestimation Arabian Peninsula
  - Emission too low
  - Wind? Soil properties? Too large particles?
- Overestimation spring emissions Sahara
  - Emissions too high
  - Frequency of threshold exceedance
- Underestimation summer concentrations Sahara
  - Underestimation u* or threshold too high
  - Overestimation wet deposition?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Recommendations

- Try other aerosol size distributions
- Implement a roughness length map instead of fixed value for entire domain
- Investigate other soil information maps
- Simulate other years
- Include proper boundary inflow of dust
- Investigate atmospheric stability in model

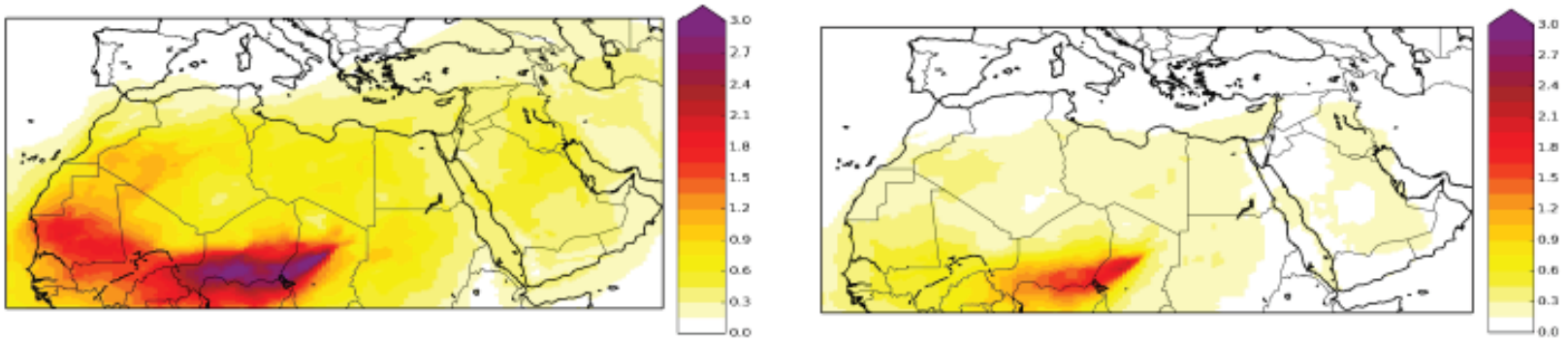

Thank you for your attention!

Questions?

renske.timmermans@tno.nl


Extra slides

Uncertainties - Sensitivity tests
Preferential dust sources (Ginoux 2001)



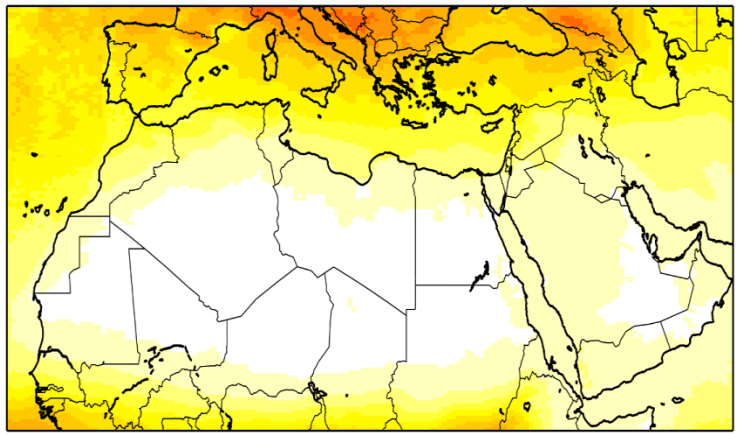
a: *Preferential sources turned off* b: *Preferential sources turned on*

Figure 4.5: *Average aerosol optical depth at* 550nm, *between February 1 and March 31, 2008.*

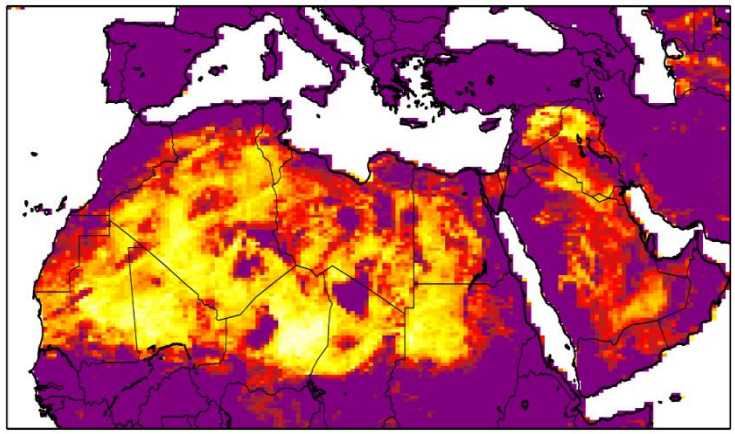
Also preferential sources based on satellite data (Tegen et al., 2002), but not available over China

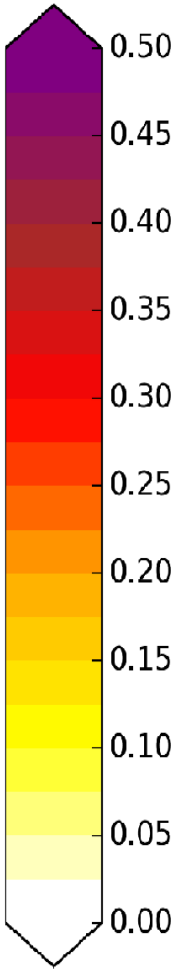
Comparison model – MODIS AOD (2008)
Ångström exponent

LOTOS-EUROS



MODIS

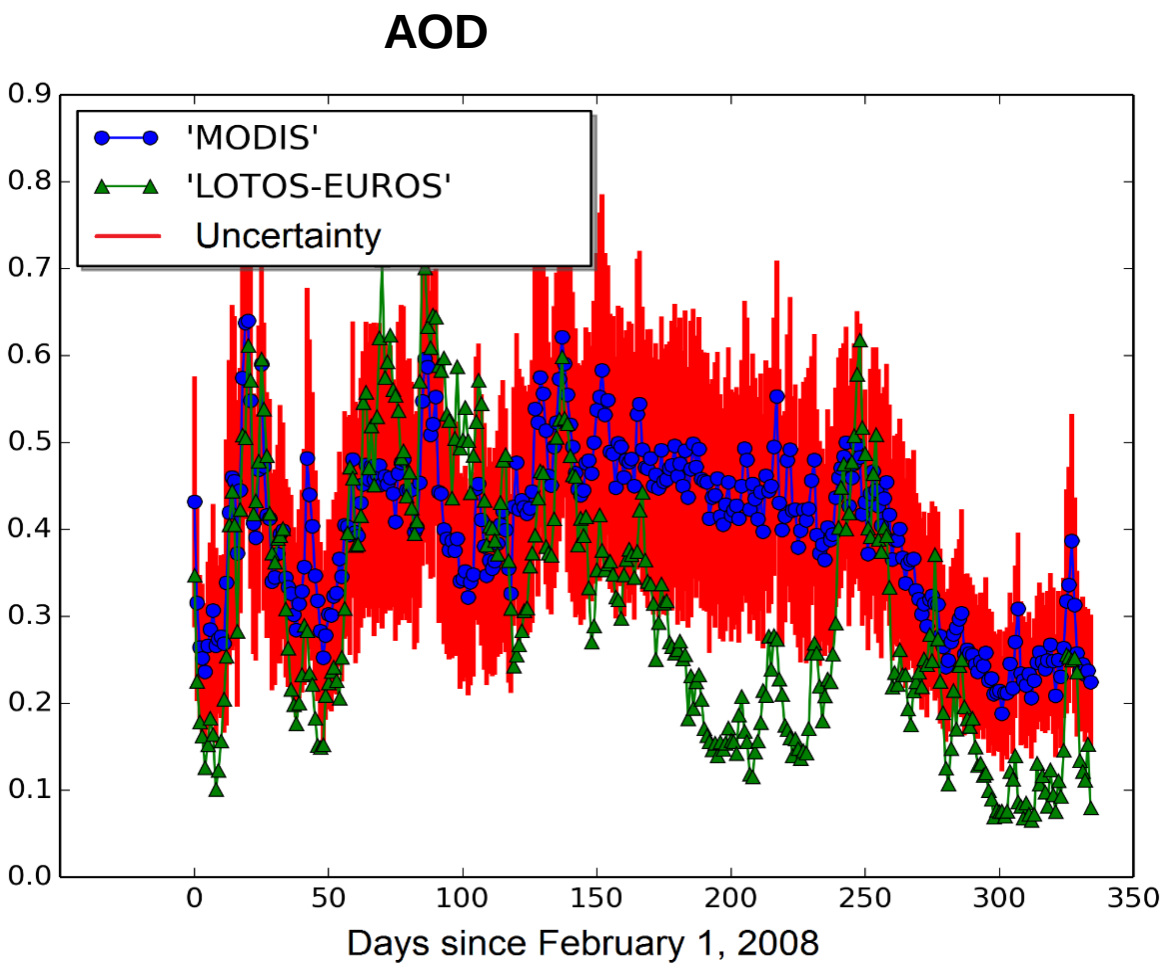




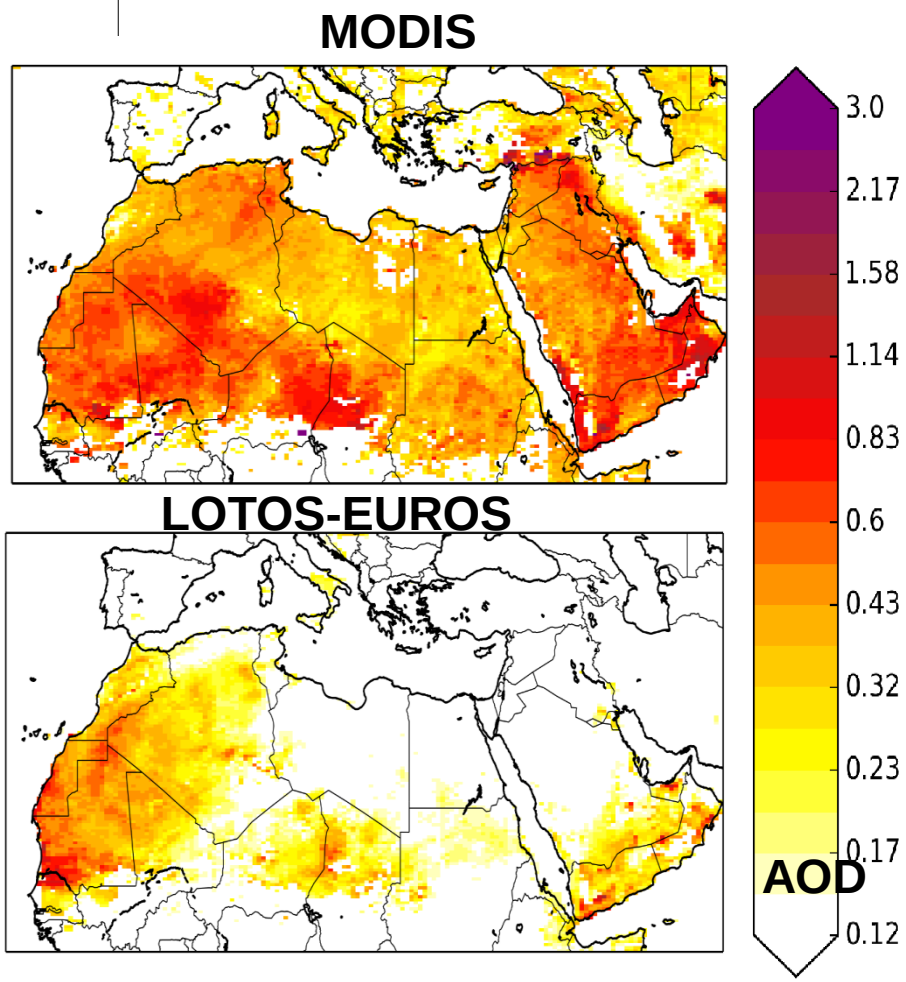
Smaller particles: Higher Ångström exponent

Comparison model – MODIS AOD

- January spin-up period



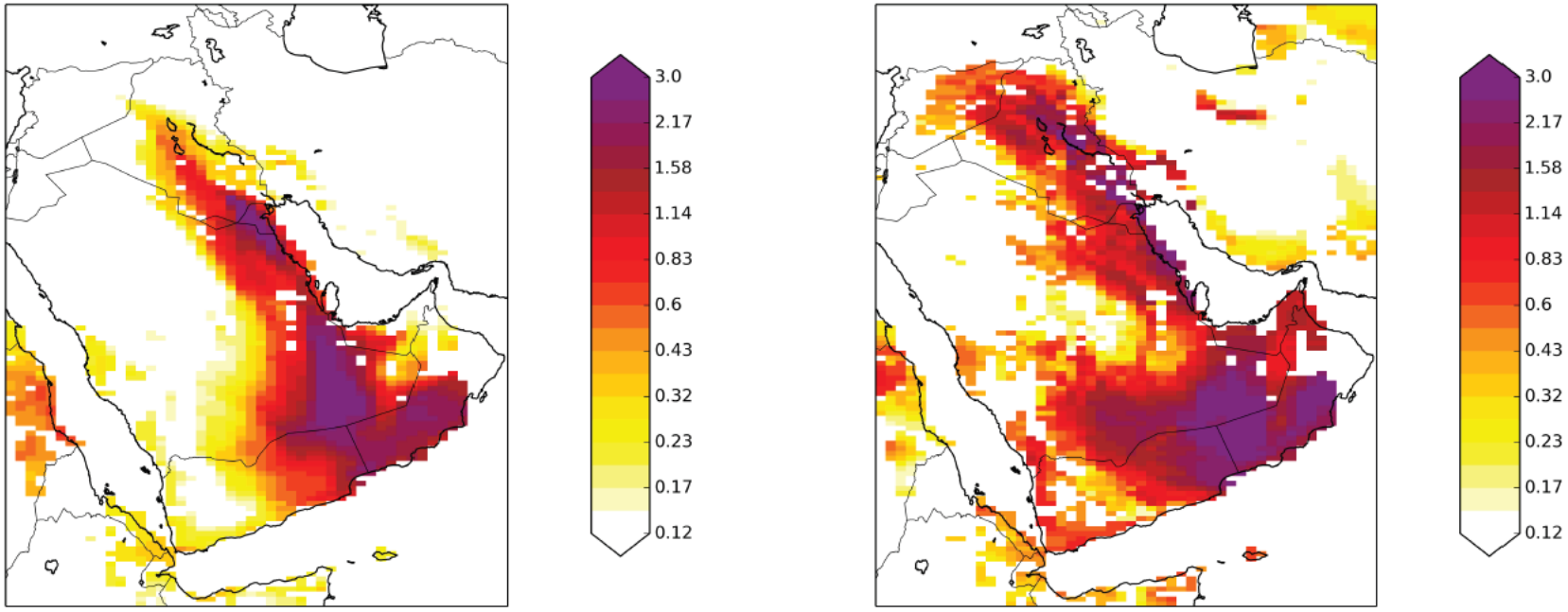
MODIS – Summer underestimation (august)



Possible explanations:

- Low wind speeds; external model
- Inaccurate atmospheric stability calculations

dust event over Arabian Peninsula

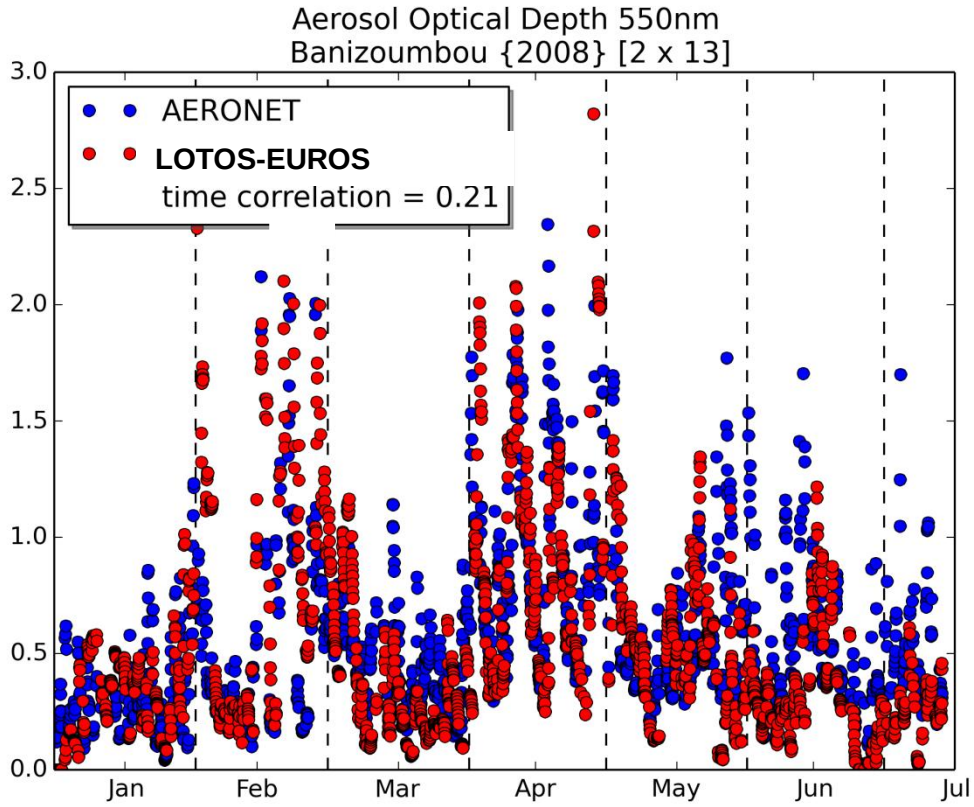


a: *LOTOS-EUROS* b: *MODIS*

Figure 5.17: *Aerosol optical depth at* 550nm, *for June 17, 2008.*

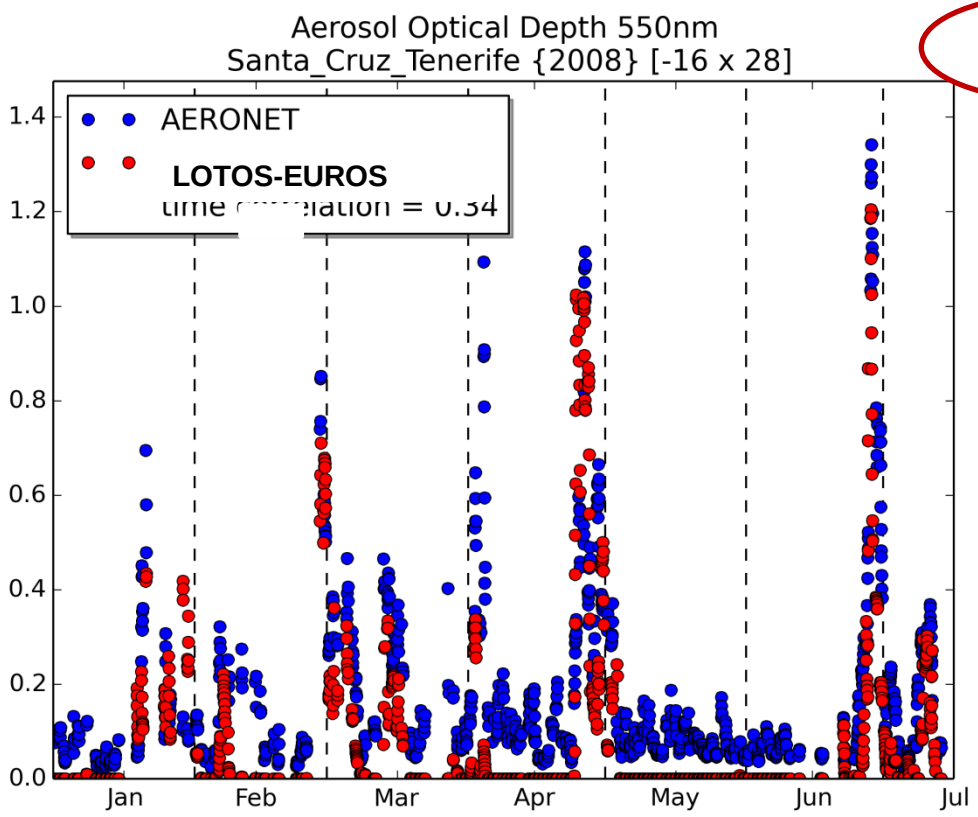
Results + Discussion

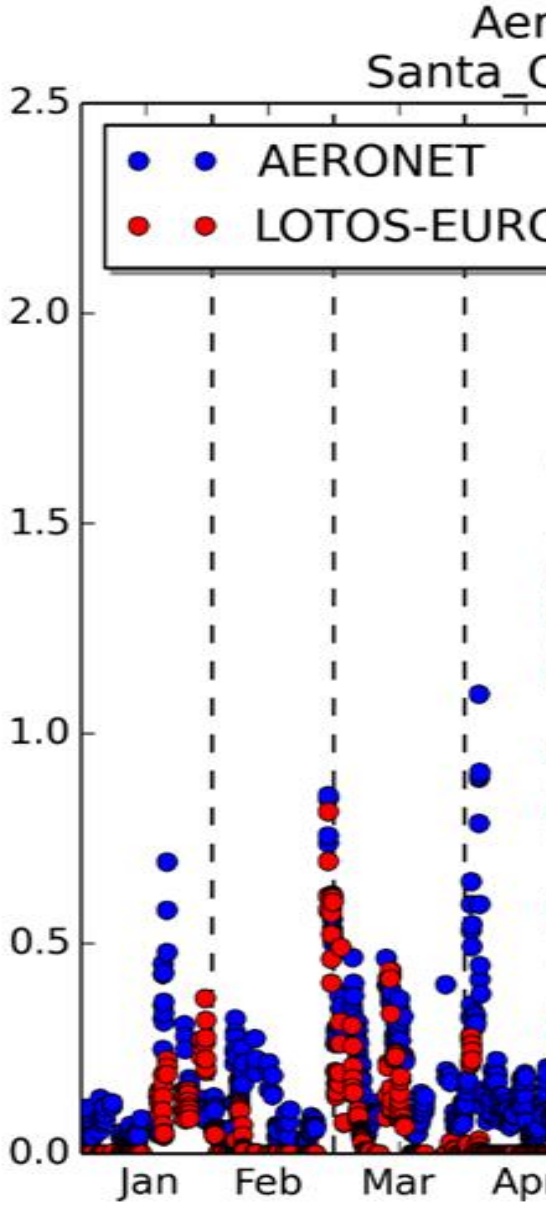
- AERONET



Results + Discussion

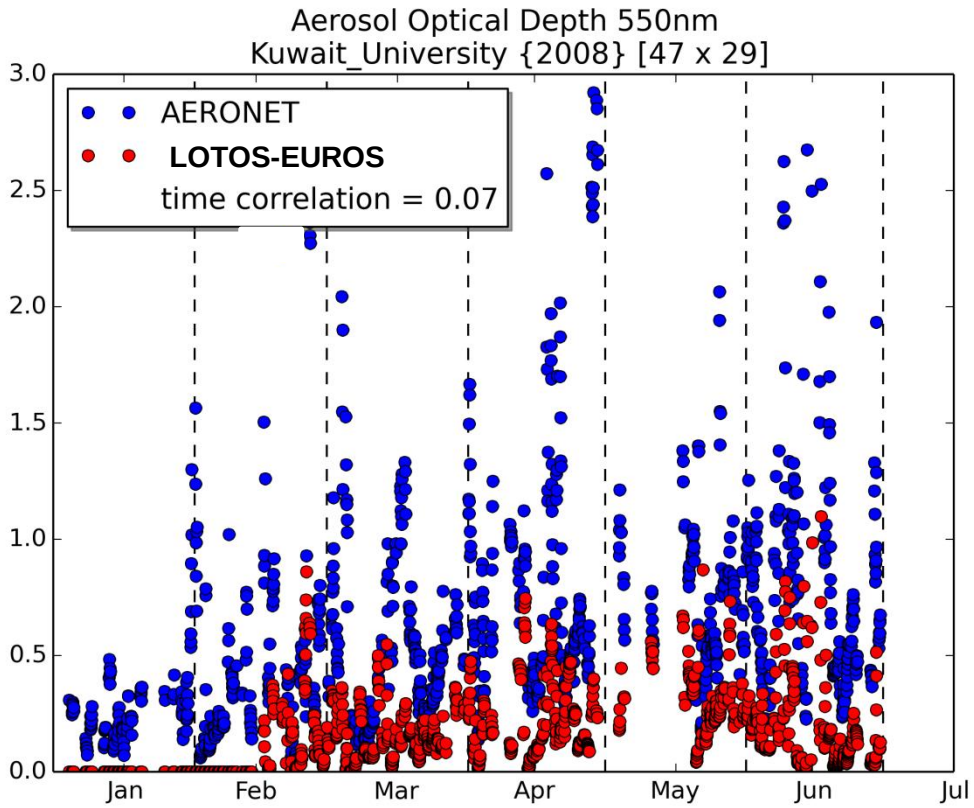
- AERONET



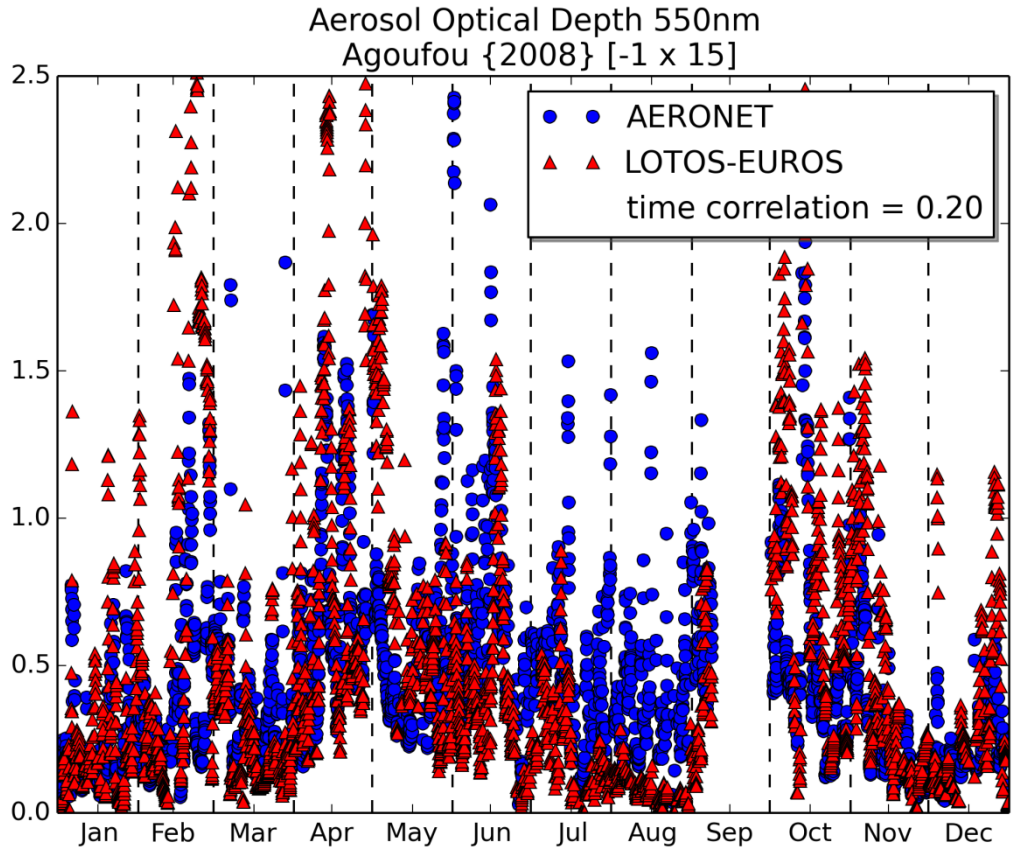


Results + Discussion

- AERONET



Comparison model - AERONET



Comparison model - AERONET