

# **PM / Aerosol Retrieval by Synergy between SCIAMACHY / AATSR and GOME2 / AVHRR**

CEOS-ACC Workshop on Air Quality 15-17 June 2009

Thomas Holzer-Popp, **Lars Klüser**



## The challenge

Which information can we extract  
on aerosol parameters

by combining sensors,  
which were not designed for aerosol retrieval?



# Outline

SYNAER AOD and composition: method and results

SYNAER PM: method and results

Conclusions and outlook



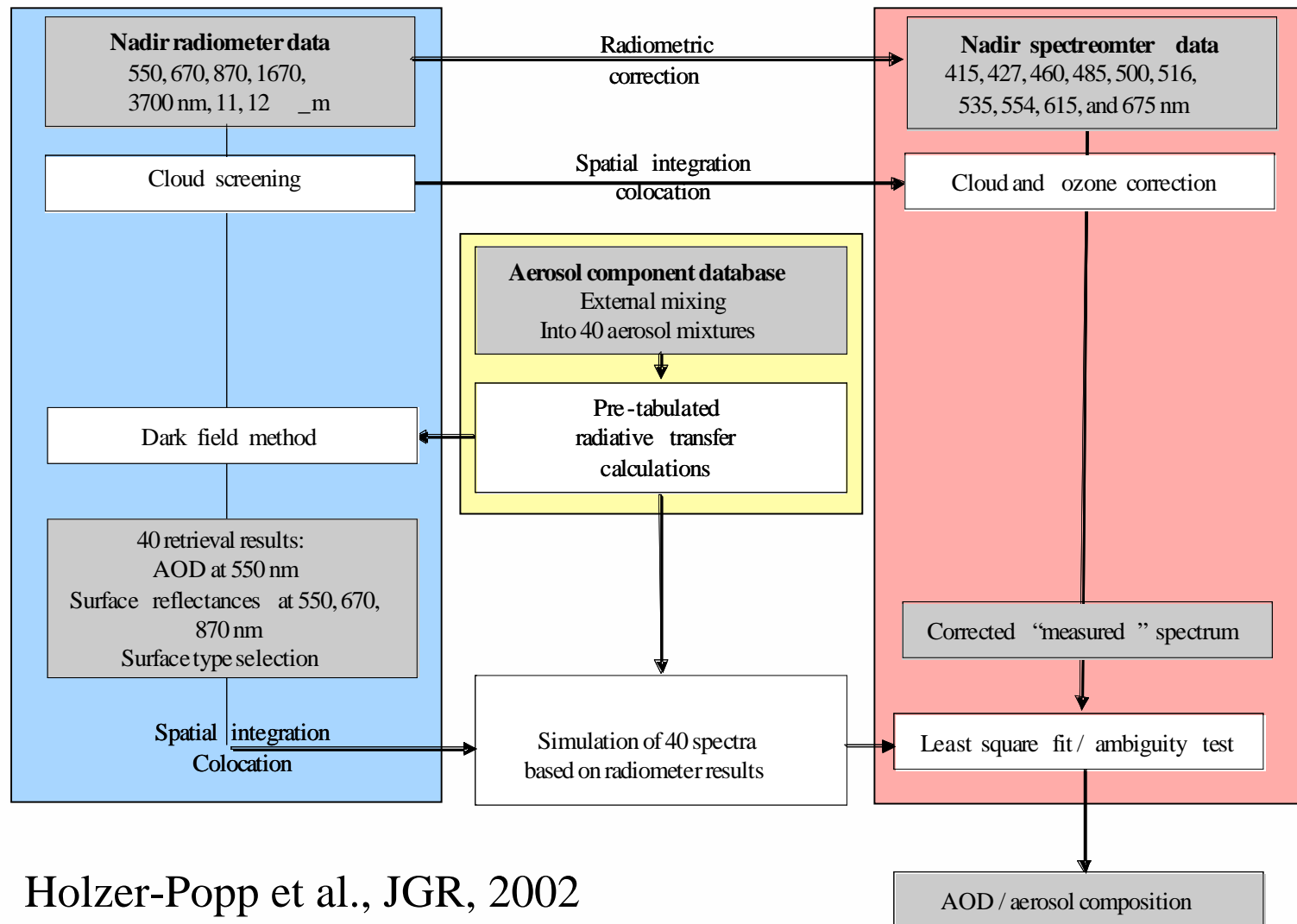
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# SYNAER method



Holzer-Popp et al., JGR, 2002

# SYNAER pre-defined aerosol mixtures

					Component contributions to AOT550 [%]								
No.		Name	Rel. hum. [%]	Vert. Prof. [km]	WASO	INSO	INSL	SSAM	SSCM	BISO	DISO	MITR	MILO
1	21	Pure watersoluble	50/80	2	100								
2	22	Continental	50	2	95	5	5						
3	23				90	10	10						
4	24				85	15	15						
5	25	Maritime	50/80	2	30			70					
6	26				30			65	5				
7	27				15			85					
8	28				15			75	10				
9	29	Polluted watersoluble	50/80	2	90						10		
10	30				80						20		
11	31	Polluted Continental	50	2	80	10	10				10		
12	32				70	10	10				20		
13	33	Polluted Maritime	50/80	2	40			45	5		10		
14	34				30			40	10		20		
15	35	Desert Outbreak	50	2 - 4	25							75	75
16	36			3 - 5	25							75	75
17	37			4 - 6	25							75	75
18	38	Biomass Burning	50/80	3	85					15			
19	39				70					30			
20	40				55					45			

WASO = watersoluble, INSO = insoluble, INSL = insoluble / low hematite, SSAM = sea salt accumul. mode, SSCM = sea salt coarse mode, BISO = biomass burning soot, DISO = diesel soot, MITR = mineral transported, MILO = mineral transported / low hematite

Mixture number N and mixture number N + 20: alternative humidity or mineral composition, respectively





# SYNAER/ENV v1 daily result: SCIAMACHY + AATSR

## Aerosol plume over France, 15 April 2007



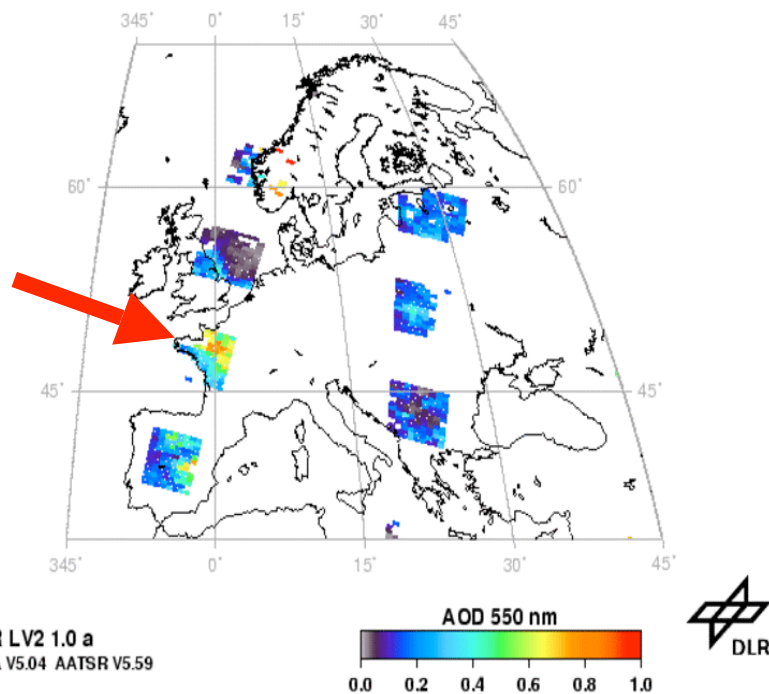
MODIS RGB

ENVISAT

Aerosol Optical Depth 550 nm

Apr 15, 2007

Europe



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

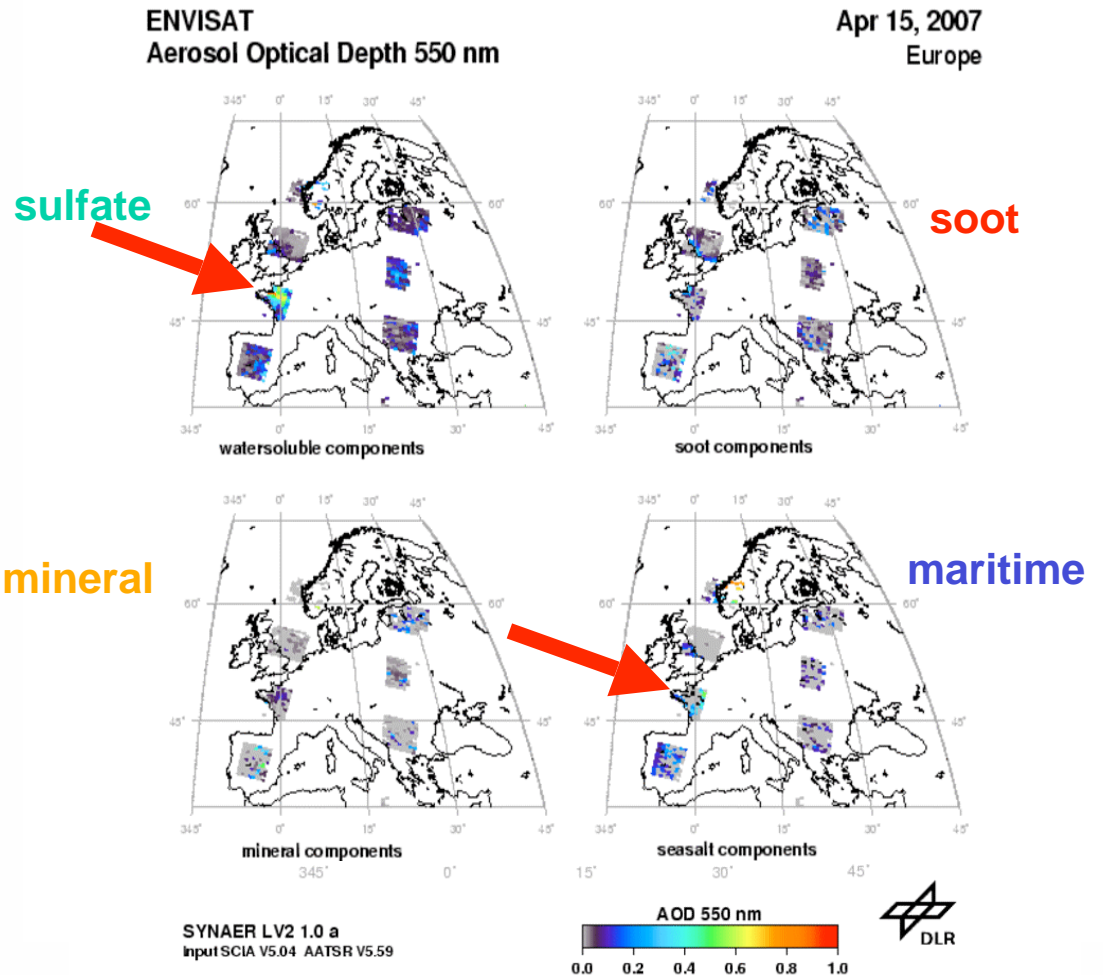
PM / Aerosol Retrieval by Synergy between SCIAMACHY /AATSR and GOME2 / AVHRR – CEOS-ACC 15-17 June 2009

# SYNAER/ENV v1 daily result : SCIAMACHY + AATSR

## Aerosol plume over France, 15 April 2007



MODIS RGB



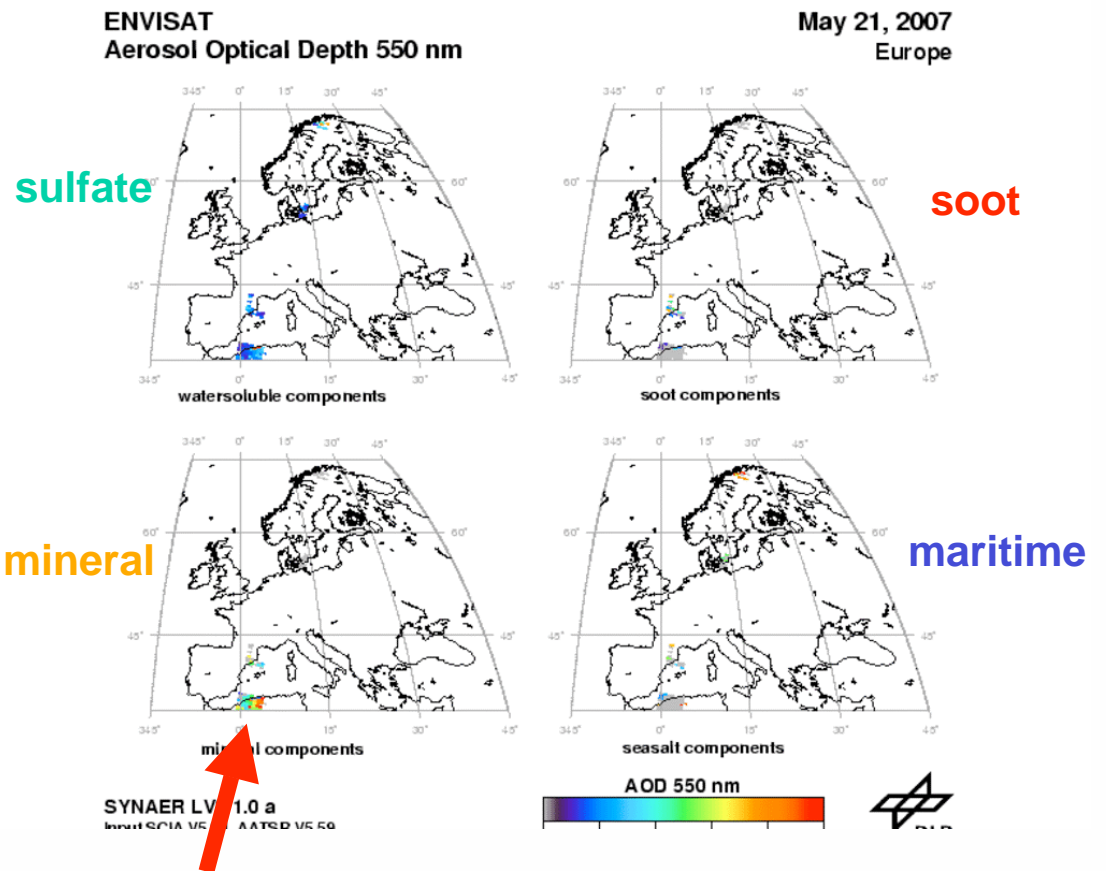


# SYNAER/ENV Episodes

## Dust Outbreak, May 2007



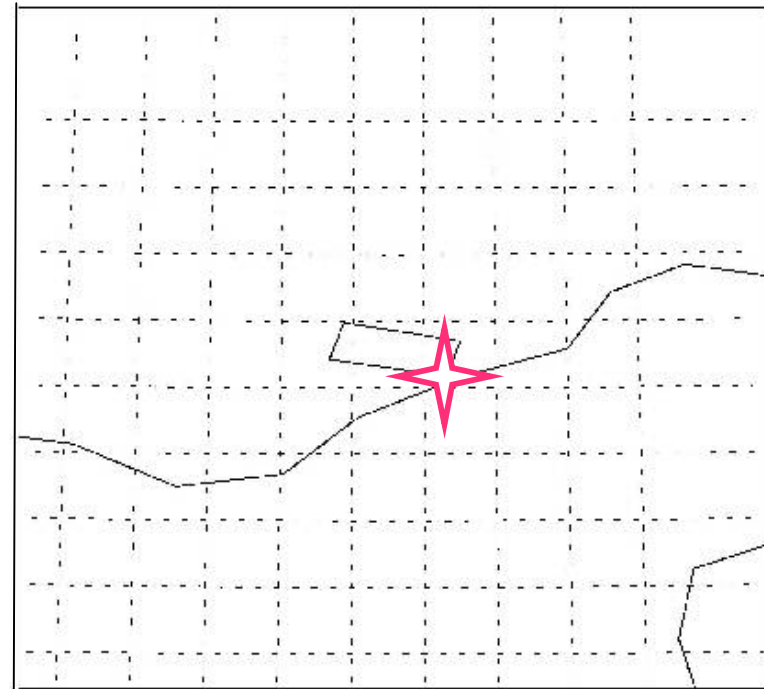
MODIS RGB



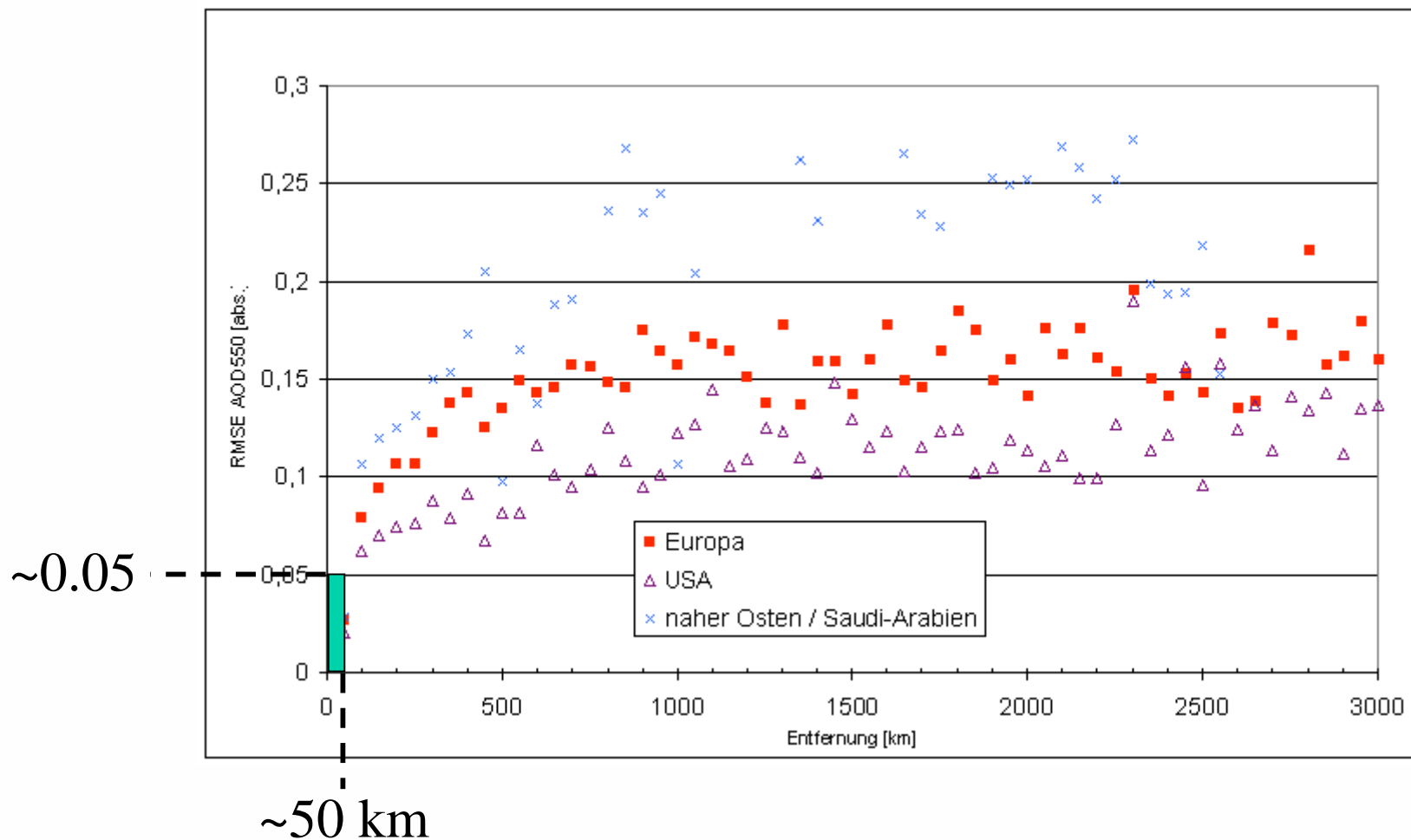
## Validation against ground-based stations

s: 17697e 1802 a: 243

How representative is a station  
for a pixel  $60 \times 30 \text{ km}^2$  ?  
Example: Lannion  
near coast and mountains, traffic



## Variogram analysis – pixel size induced error

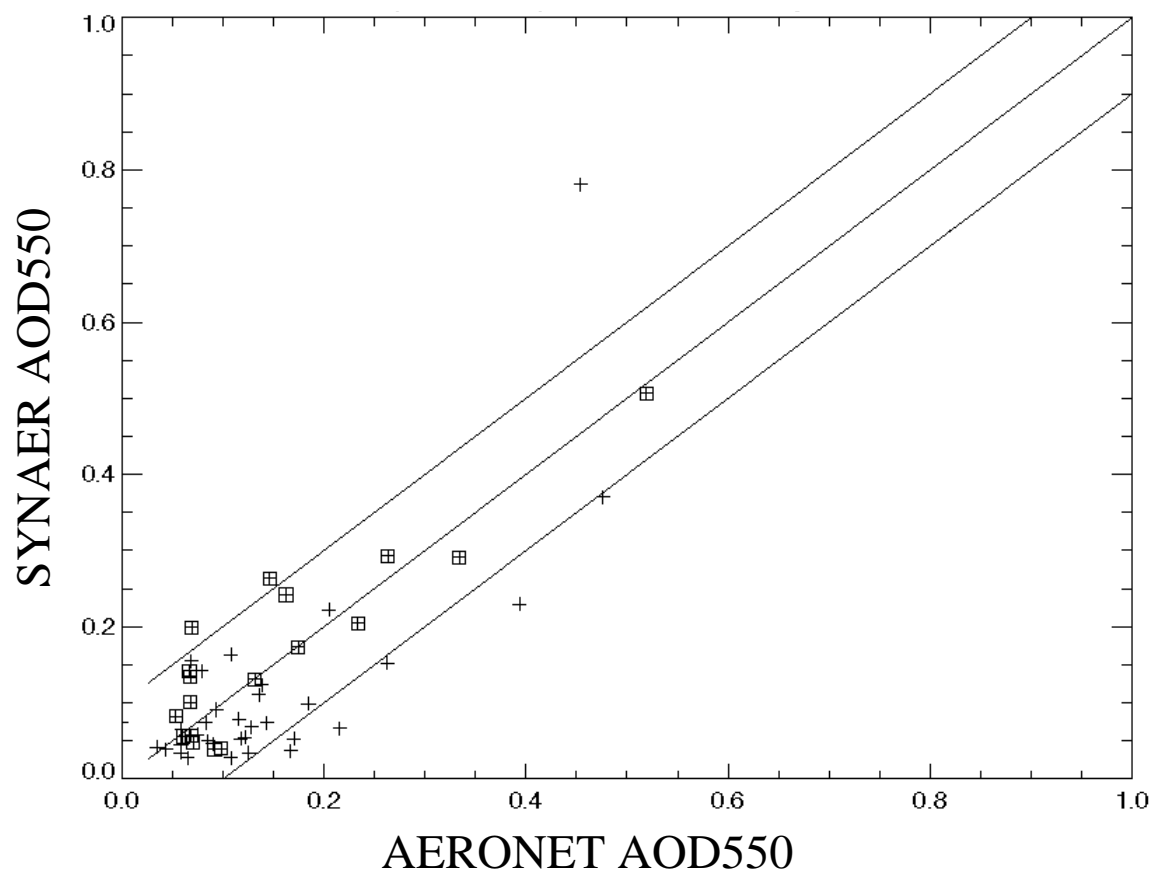




## SYNAER/ENV validation v2.2

### 7-10/2005, Europe (Africa), 50 coincidences

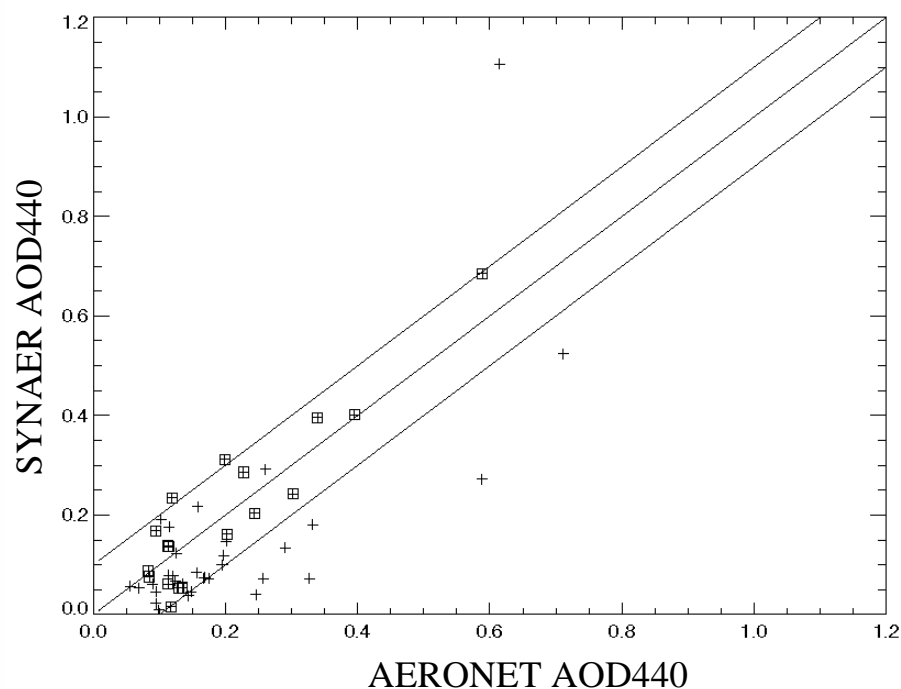
Pairs: 50  
Bias: -0.01  
Sigma: 0.08  
Correl: 0.80



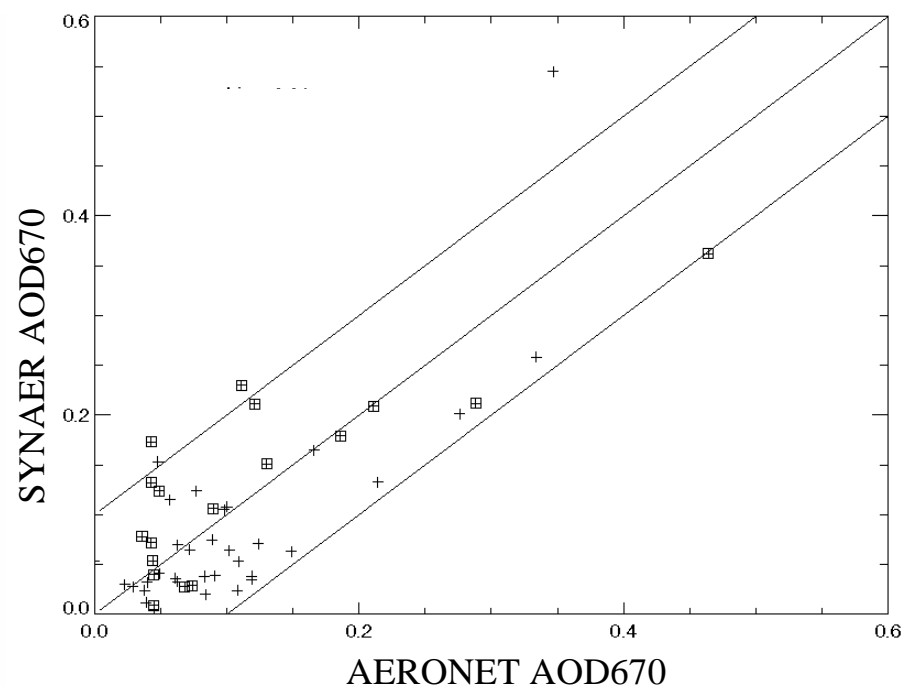


## SYNAER/ENV validation v2.2

### 7-10/2005, Europe (Africa), 50 coincidences



Bias: -0.04 Sigma: 0.12 Correl: 0.78

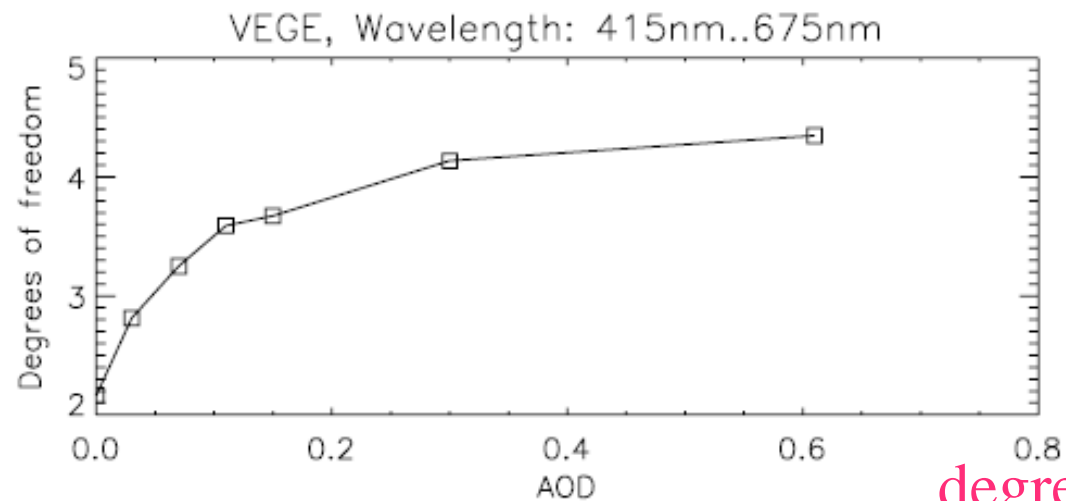


Bias: -0.01 Sigma: 0.06 Correl: 0.78



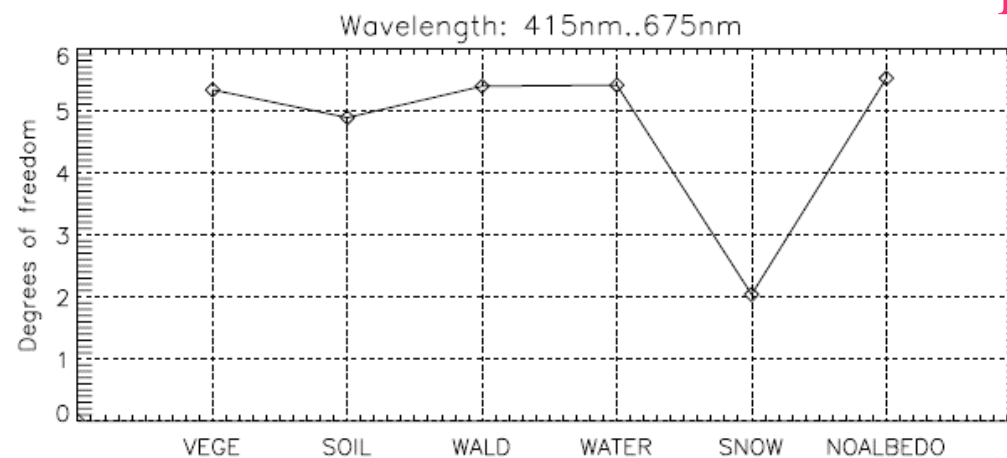
## Analyzed information content of spectrometer

with AOD

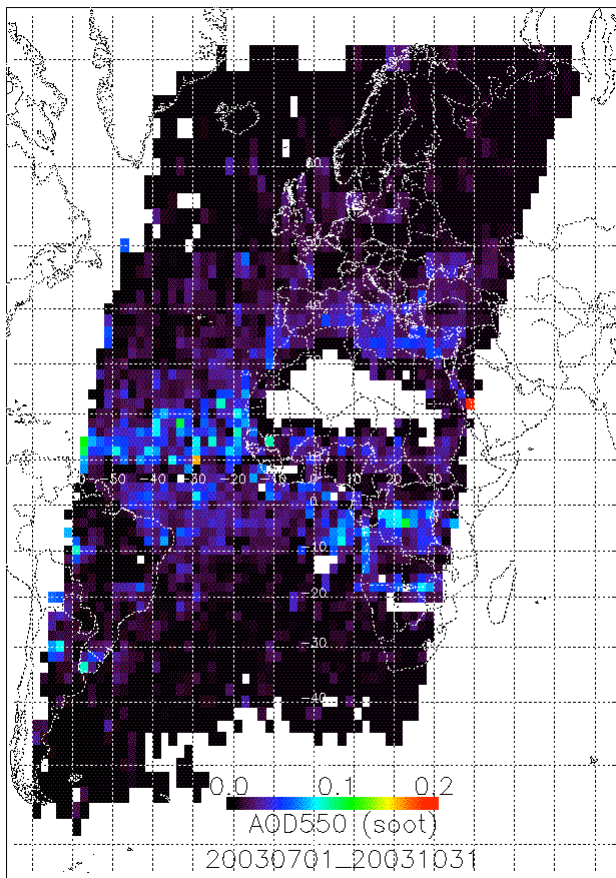


more than 2  
degrees of freedom  
for aerosol, type

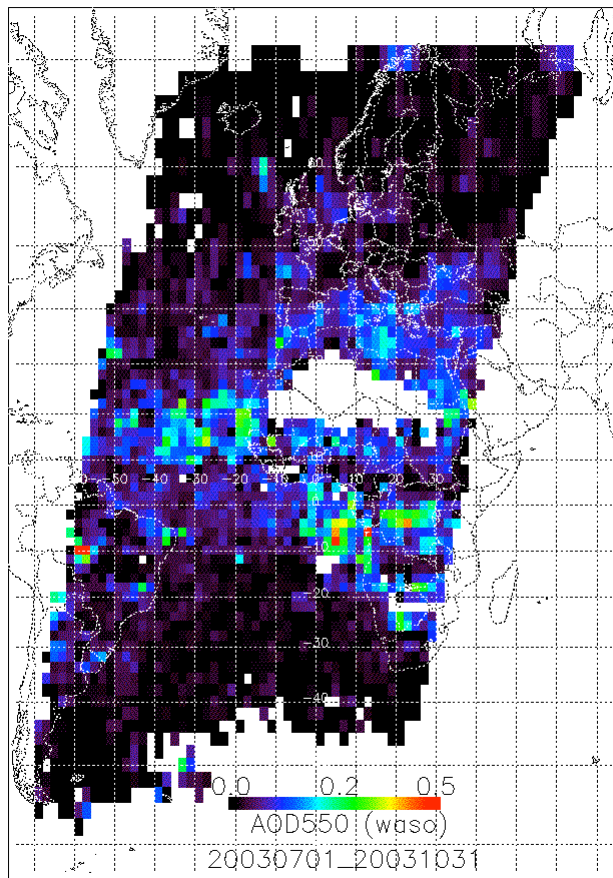
with surface  
type



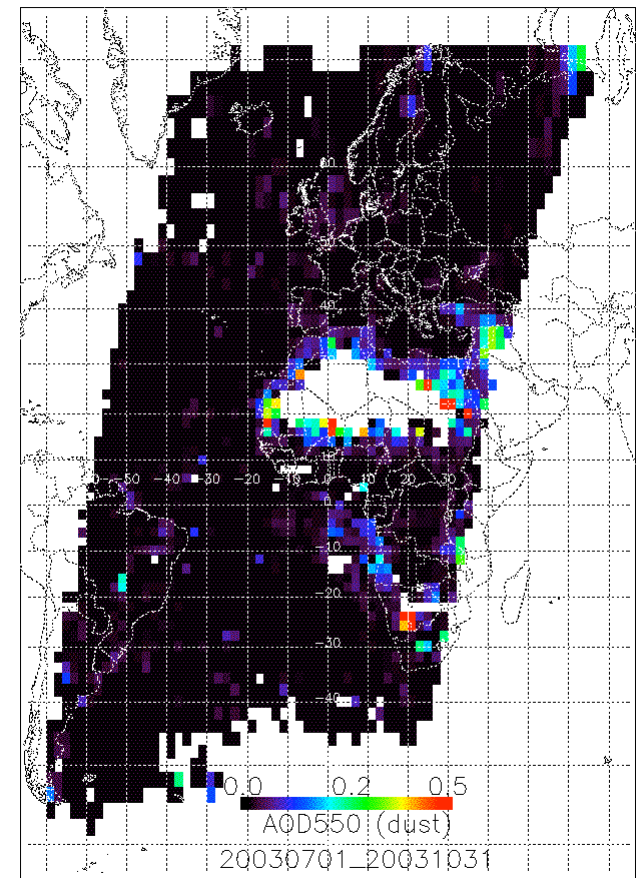
## SYNAER / ENVISAT v2 – seasonal AOD550 (7 – 10 / 2003)



**Soot**



**Watersoluble**



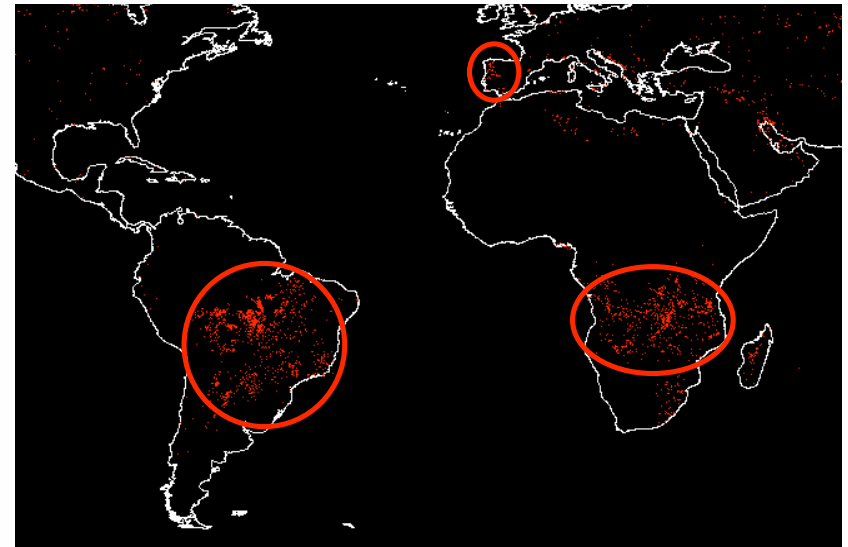
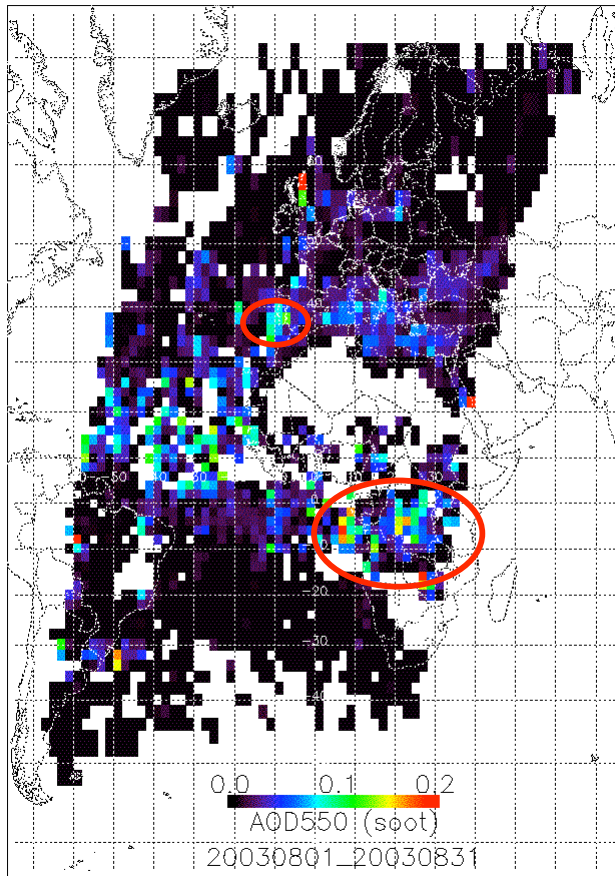
**Dust**

Holzer-Popp et al., ACP, 2008

## SYNAER v2 – soot monthly datasets

August 2003

Fire counts



Portugal wildfires

Africa wildfires moving South

missed South-American wildfires



## SYNAER quality control

- about 1/3 of pixels fail in the retrieval
  - neglected assumptions about homogeneity
  - sub pixel broken clouds
  - cross-sensor calibration issues
- exclusion criteria to automatically reject failed pixels
  - fit error  $> 0.02$
  - intrinsic AOD550 error  $> 0.14$
  - land surface albedo  $> 0.25$
  - cloud fraction in SCIAMACHY pixel  $> 0.35$

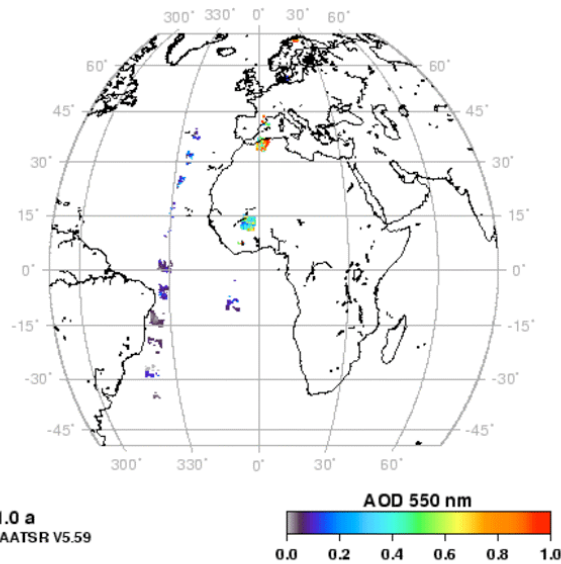


# SYNAER/METOP: GOME2 + AVHRR

Improved spatial coverage

ENVISAT  
Aerosol Optical Depth 550 nm

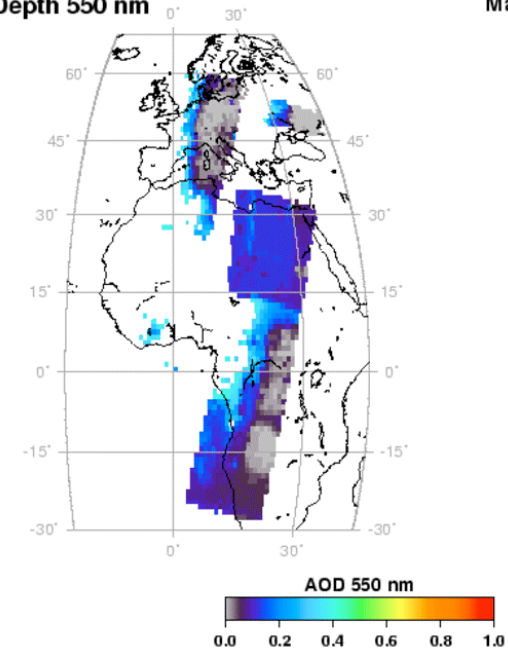
May 21, 2007  
MSG FOV



SYNAER/ENV

Aerosol Optical Depth 550 nm

May 21, 2007  
MetOp



SYNAER/METOP





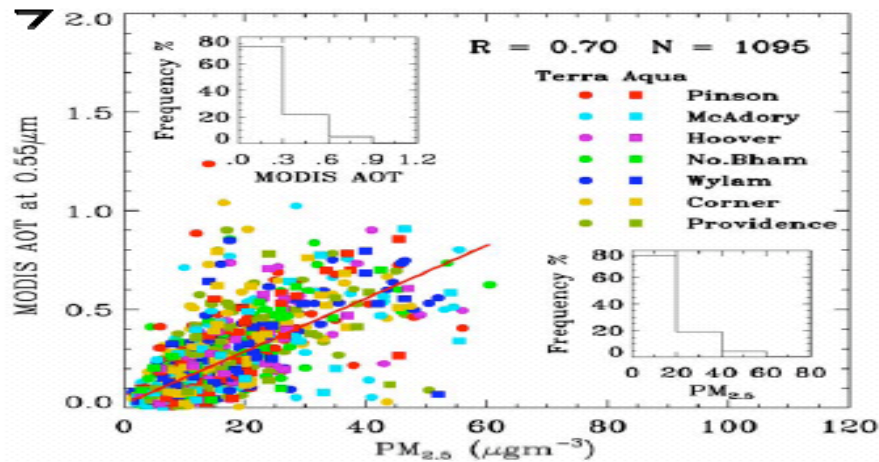
# Outline

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SYNAER PM: method and results

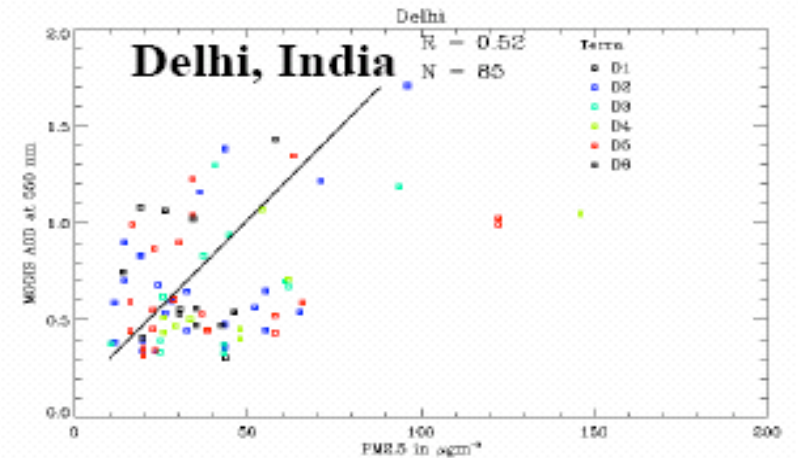
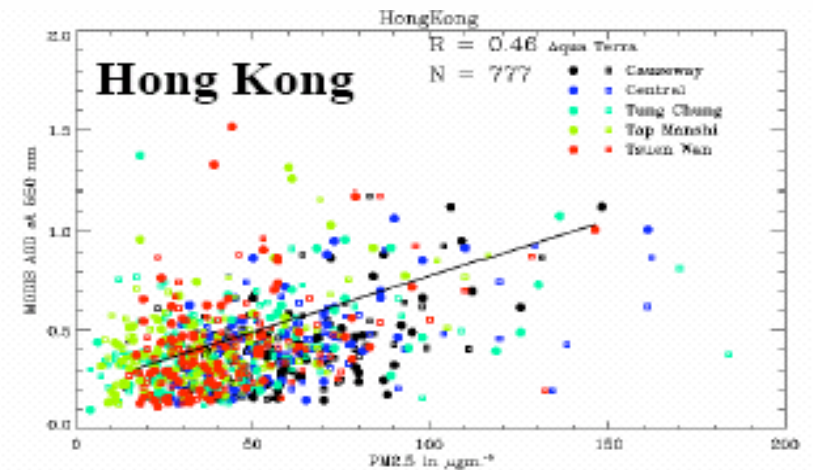
Conclusions and outlook

# Particulate matter



Hourly PM<sub>2.5</sub> correlated well with MODIS Terra and Aqua AOT

No simple universal AOD-PM correlation due to aerosol composition and vertical profile



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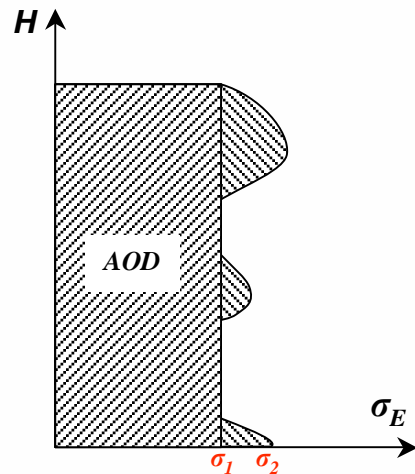
# Converting SYNAER AOD and composition into PM

AOD-PM conversion requires

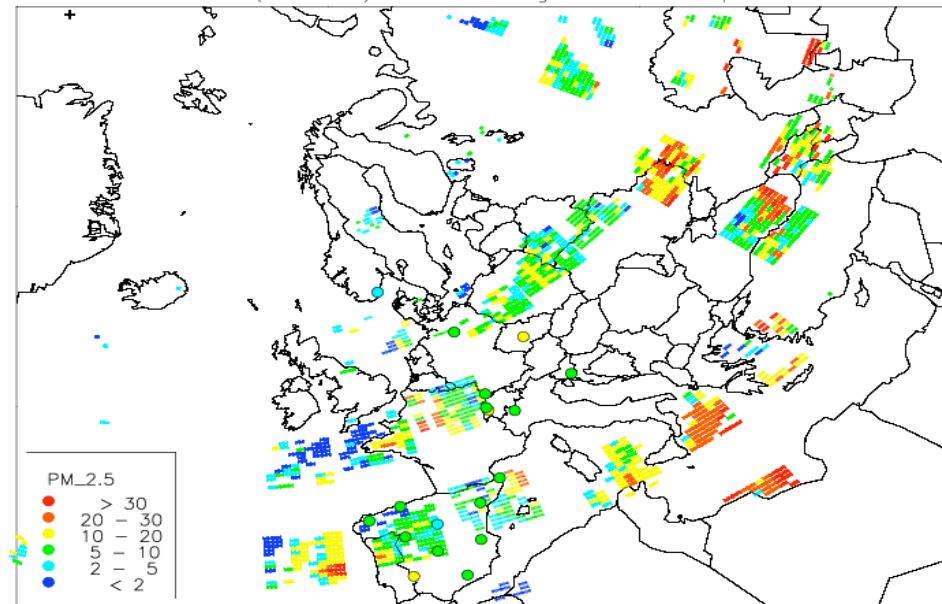
- information on size distribution
- information on vertical profile

SYNAER-PM product uses

- retrieved aerosol composition
- auxiliary CTM profile shape



Correction coefficient:  $k = \frac{\sigma_2}{\sigma_1}$



by NILU: inter-comparison SYNAER EMEP stations (3day map)

auxiliary information: vertical particle profile shape from chemistry transport model



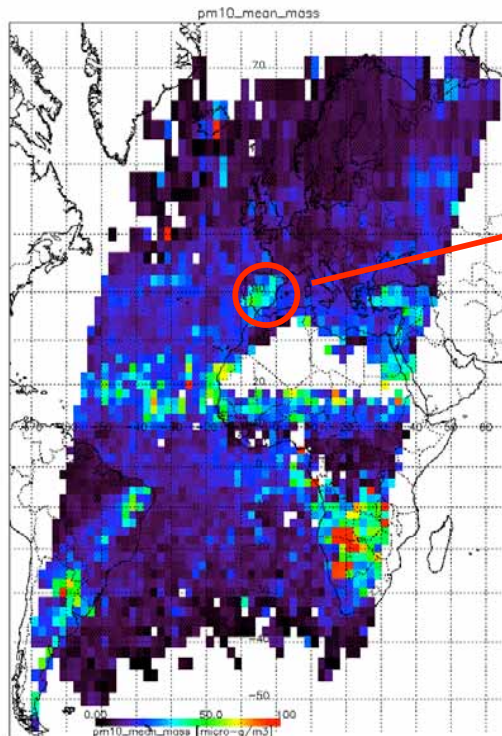
# AOD-PM conversion factors for different aerosol types

Exponential vertical profile assumed

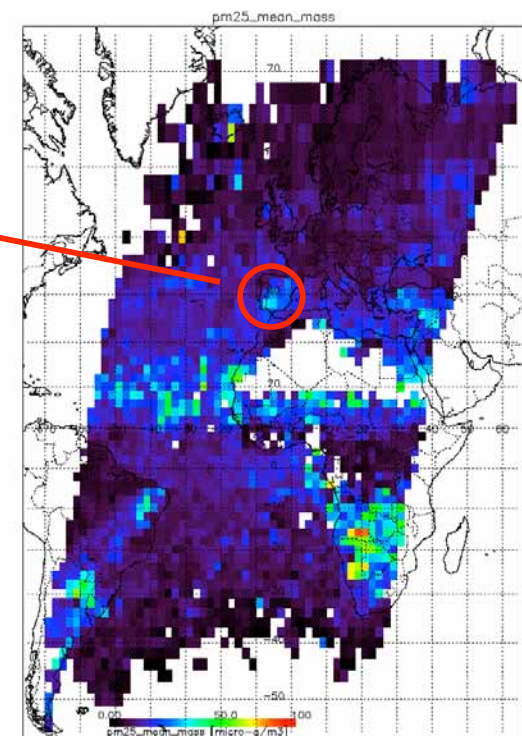
No.	Name	Particle mass concentrations PM10 [ $\mu\text{g}/\text{m}^3$ ]						
		Total	WASO	INSO	SSAM	SSCM	SOOT	MITR
1	Pure Watersoluble	148	148					
2	Continental I	206	140	66				
3	Continental II	265	132	133				
4	Continental III	325	126	199				
5	Maritime I	296	44		252			
6	Maritime II	323	44		234	45		
7	Maritime III	328	22		306			
8	Maritime IV	381	22		270	91		
9	Polluted Watersoluble I	137	132				5	
10	Polluted Watersoluble II	128	118				10	
11	Polluted Continental I	256	118	133			5	
12	Polluted Continental II	247	104	133			10	
13	Polluted Maritime I	272	60		162	45	5	
14	Polluted Maritime II	289	44		144	91	10	
15	Desert Outbreak I	109	109					318
16	Desert Outbreak II	72	72					636
17	Desert Outbreak III	38	38					954
18	Biom. Burn. / High Poll. I	133	126				7	
19	Biom. Burn. / High Poll. II	118	103				15	
20	Biom. Burn. / High Poll. III	103	80				23	

# SYNAER/ENV 7-10/2003: PM<sub>10</sub> and PM<sub>2.5</sub>

PM<sub>10</sub>

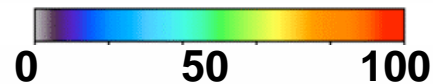


PM<sub>2.5</sub>



Forest fires in Portugal  
August 2003

PM [ $\mu\text{g}/\text{m}^3$ ]







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SYNAER AOD and composition: method and results

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## The response

Synergetic retrieval contains information  
on AOD

plus aerosol composition

and together with model profile shapes on PM



## SYNAER processing and evolution

- reprocessing Europe/Africa 2003-2009 in ESA-GSE PROMOTE-2
- global reprocessing planned in EU-FP7 Core project MACC
- further evolution planned in EU-FP7 DS project PASODOBLE
  - evaluation of PM results for annual compliance monitoring
  - operational transfer to METOP

future perspective: 25 year dataset: ERS-2 – ENVISAT – METOP

<http://www.gse-promote.org> -> air quality -> European Sat-based PM

<http://wdc.dlr.de> -> aerosols -> ENVISAT

**-> Further validation see talk by Aasmund Fahre-Vik on Wednesday**



## References

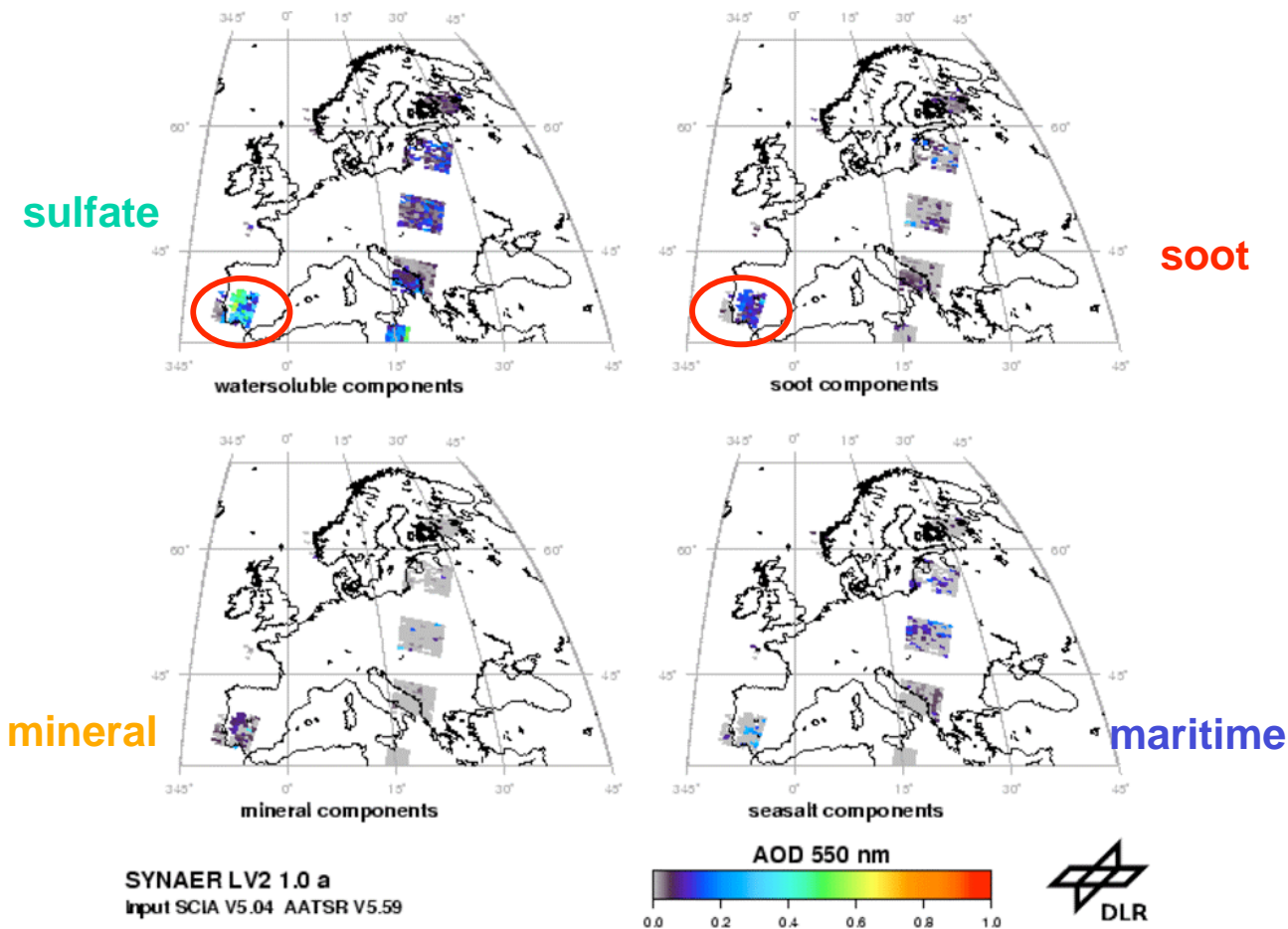
- Holzer-Popp, T., M. Schroedter, and G., Gesell, Retrieving aerosol optical depth and type in the boundary layer over land and ocean from simultaneous GOME spectrometer and ATSR-2 radiometer measurements, 1, Method description, *Journal of Geophysical Research*, 107, D21, pp. AAC16-1 – AAC16-17, 2002
- Holzer-Popp, T., M. Schroedter, and G., Gesell, Retrieving aerosol optical depth and type in the boundary layer over land and ocean from simultaneous GOME spectrometer and ATSR-2 radiometer measurements, 2, Case study application and validation, *Journal of Geophysical Research*, 107, D24, pp. AAC10-1 – AAC10-8, 2002
- Holzer-Popp, T., Schroedter-Homscheidt, M., Satellite-based background concentration maps of different particle classes in the atmosphere, in: C. A. Brebbia, (eds.), *Air Pollution XIII*, WIT Press, Southampton, 2004
- Holzer-Popp T., Schroedter-Homscheidt M., Three years of ENVISAT synergetic aerosol retrieval, in: *Proceedings of ESA Atmospheric Science Conference*, May, 2006, Frascati, ESRIN, 2006
- Myhre, G., Stordal, F., Johnsrud, M., Diner, D. J., Geogdzhayev, I. V., Haywood, J. M., Holben, B., Holzer-Popp, T., Ignatov, A., Kahn, R., Kaufman, Y. J., Loeb, N., Martonchik, J., Mishchenko, M. I., Nalli, N. R., Remer, L. A., Schroedter-Homscheidt, M., Tanre, D., Torres, O., Wang, M., Intercomparison of satellite retrieved aerosol optical depth over ocean during the period September 1997 to December 2000, *Atmospheric Chemistry and Physics*, 5, 1697-1719, 2005
- Holzer-Popp T., Schroedter-Homscheidt, M., Breitkreuz, H., Klüser, L., Martynenko, D., Synergistic aerosol retrieval from SCIAMACHY and AATSR onboard ENVISAT, *Atmospheric Chemistry and Physics*, 8, 7651-7672, 2008

# SYNAER/ENV NRT wildfires in Portugal

## AOD550 of 4 major components

Jun 25, 2005

Europe







# SYNAER/ENV Episodes

## Dust Outbreak, May 2007



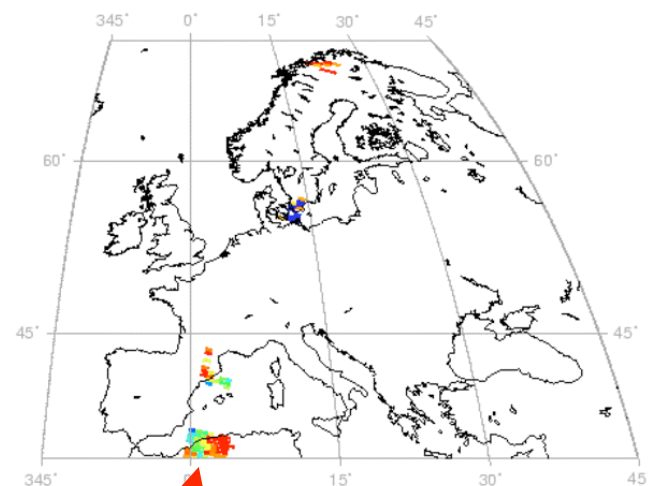
MODIS RGB

ENVISAT

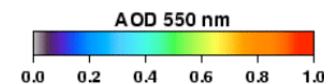
Aerosol Optical Depth 550 nm

May 21, 2007

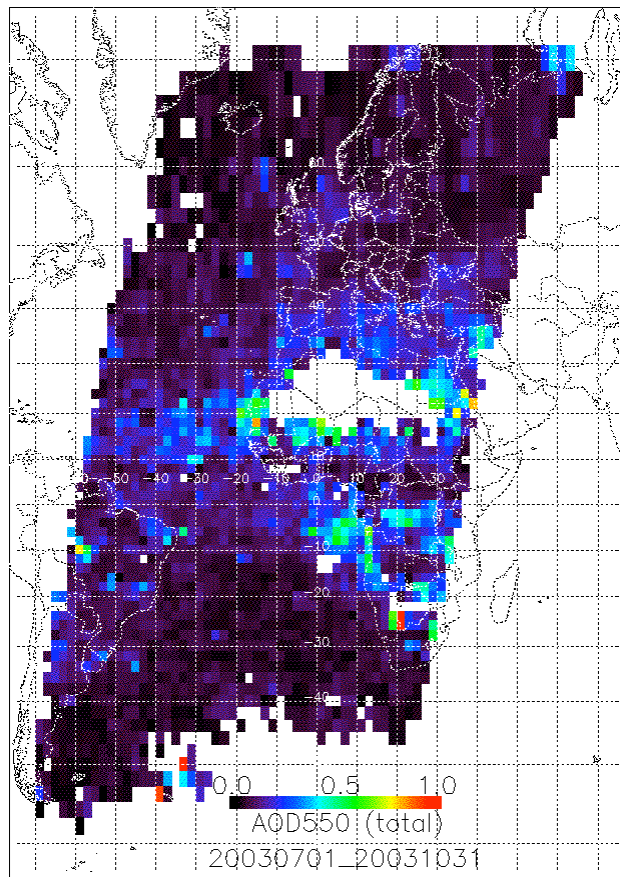
Europe



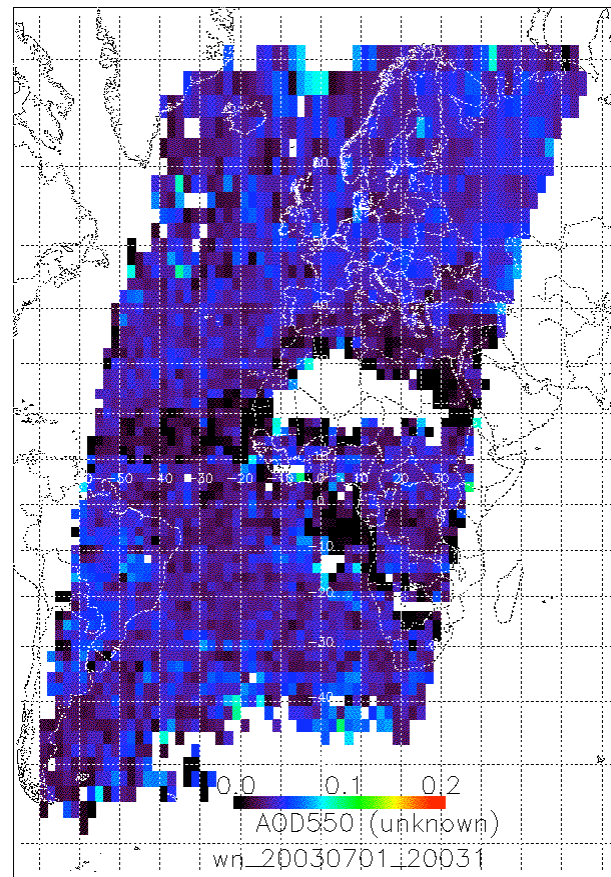
SYNAER LV2 1.0 a  
Input SCIA V5.04 AATSR V5.59



## Using DOF analysis: subtract „unknown“ component



Total



unknown

$$\text{AOD}_{550} < 0.1$$

- ~ 0. at highest AOD
- ~ 0.02 clean oceans
- ~ 0.05 South Atlantic
- ~ 0.05 over land

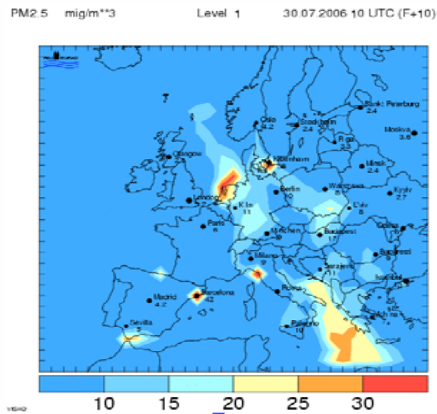


## SYNAER/ENV – limitations and strengths

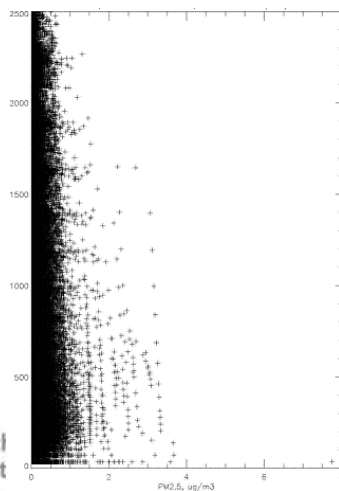
- limitations
  - spatial / temporal coverage and resolution
    - re-visit time: 12 days
    - SCIAMACHY pixel:  $60 \times 30 \text{ km}^2$
  - dependence on pre-defined fixed aerosol mixtures
  - no retrieval over very bright surfaces
- strengths
  - estimation of aerosol composition
  - systematic conversion to  $\text{PM}_x$  values
  - treatment of partially cloudy SCIAMACHY pixels
    - using accurate  $1 \text{ km}^2$  AATSR cloud detection

# SYNAER: profile shape correction for PM

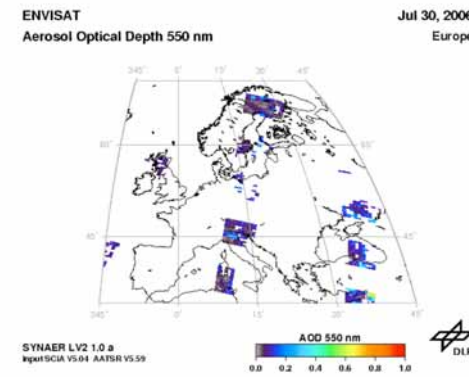
EURAD-MADE:



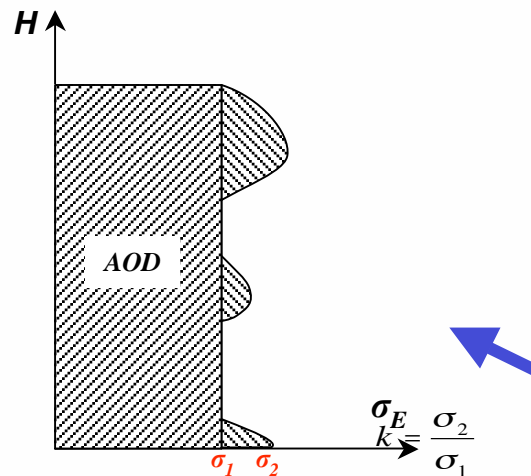
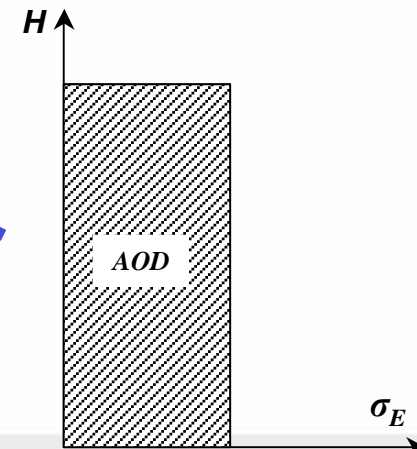
*mass concentration profile:*



SYNAER:



*AOD homogeneous layer:*



*Correction coefficient:*

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## SYNAER achievements in PROMOTE



- evaluation by user NILU in 3 annual cycles
- upgrade of methodology from v1.0 to v2.2  
based on feedback from user NILU
- upgrade of validation and quality control
- provision of pixel-wise error information
- demonstration for METOP
- consistent reprocessing of dataset for Europe/Africa/Atlantic