GlobAEROSOL: Global Aerosol Properties from (A)ATSR and SEVIRI.

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Presentation outline:

What is Globaerosol ?

ATSR-SEVIRI aerosol processor (ORAC)

- Instruments
- Forward Model
- Radiative transfer computations
- Aerosol optical properties
- Retrieval method
- Retrieved parameters

Preliminary results

- Aeronet comparison
- Monthly maps
- Satellite comparison

WHAT IS GLOBAEROSOL

GlobAEROSOL is an ESA Data User Element programme.

Instruments → ATSR- 2, AATSR, MERIS and MSG SEVIRI.

→ The data set will cover 1995 – 2005.

Goal → provide a global aerosol dataset from four European satellite instruments

Products → Aerosol Optical Depth (AOD) at 550nm, AOD at 865nm, Ångstrøm coefficient computed at 550 and 865 (for ORAC)

People and organization

ESA

Simon Pinnock (Technical Officer)

GMV

Celestino Gomez (Project Manager)
Oscar Perez Navarro
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Rutherford Appleton Laboratory

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Barry Latter
Brian Kerridge

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Gareth Thomas
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Don Grainger

ORAC AEROSOL PROCESSOR

ORAC (Oxford RAL Retrieval of Aerosol and Cloud) is a optimal estimation retrieval algorithm for retrieving aerosol (and cloud) from ATSR and SEVIRI.

ORAC has been developed from ATSR cloud retrieval code developed by Phil Watts (RAL & Eumetsat) and is being used in the GRAPE project.

Instruments

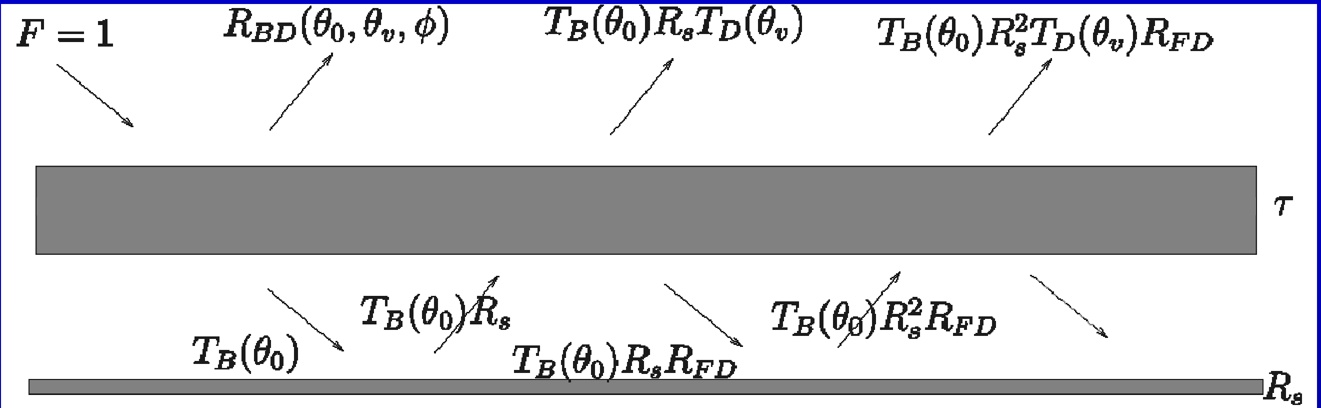
ATSR-2 and **AATSR**
(Advanced Along Track Scanning Radiometer)

ERS-2 - ENVISAT
Polar orbit
Spatial resolution 1 Km
3 days global coverage
7 channels in the 0.5-14μm range
we use 3-4 VIS-NIR centred at
0.66,0.86,1.6 [μm] 1995-2001
and
0.56,0.66,0.86,1.6 [μm] from 2001

SEVIRI
(Spinning Enhanced Visible and Infra-Red Imager)

Meteosat Second Generation (MSG)
Geostationary satellite
Spatial resolution 3 Km.
15 min time resolution.
12 channels in the 0.6-14μm range.
we use 3 VIS-NIR centred at
0.64,0.81,1.6 [μm] from February 2004

FORWARD MODEL



$$R = R_{BD} + T_B T_D R_S \left[1 + R_S R_{FD} + (R_S R_{FD})^2 + (R_S R_{FD})^3 + \ldots\right]$$

$R_{BD}(\theta_0,\theta_v,\phi)$ = direct bidirectional reflectance of the atmosphere

$T_B\ (\theta_0)$ = atmospheric transmission of the incoming beam

$T_D\ (\theta_v)$ = atmospheric transmission of the diffuse reflected radiance

R_S = surface reflectance

R_{FD} = atmospheric reflectance of the diffuse reflected radiance

Approx:
plane parallel atmosphere
$R_S R_{FD} < 1$

$$R = R_{BD} + \frac{T_B T_D R_S}{(1 - R_S R_{FD})}$$

LUTs

RADIATIVE TRANSFER

LUT Computation scheme

Aerosol Microphysical properties

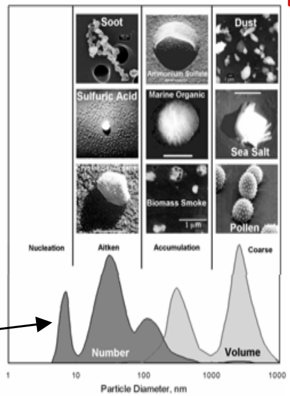
Refractive index

$r(\lambda) + i\, m(\lambda)$

Size distributions

N(r)

Mixing ratio



Mie theory (spherical approx.)

Aerosol Spectral optical properties

$K_{ext}(\lambda)$

$0 < \omega(\lambda) < 1$

$P(\theta, \lambda)$

Molecular scattering

$\tau_m(\lambda)$

$P_m(\theta, \lambda)$

Plane parallel Atmosphere

$\tau_{atm}(\lambda,h)$

$\omega_{atm}(\lambda,h)$

$P_{atm}(\theta,\lambda,h)$

Molecules

Molecules + aerosol

Molecules

Black surface

Gas absorption profile

MODTRAN computations

Instrument's filter characterization

$\tau_{gas}(\lambda,h)$

Radiative transfer model

DISORT

Look Up Tables

DISORT v2.1 with:

32 layer

60 streams

1000 Legendre moments

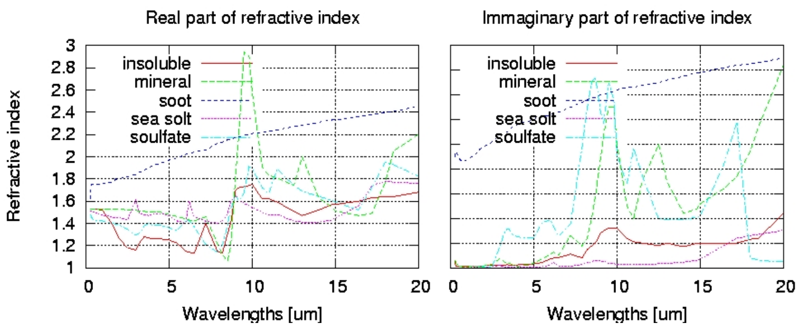
δ-M approximation

MS methods

AEROSOL OPTICAL PROPERTIES

Microphysical properties

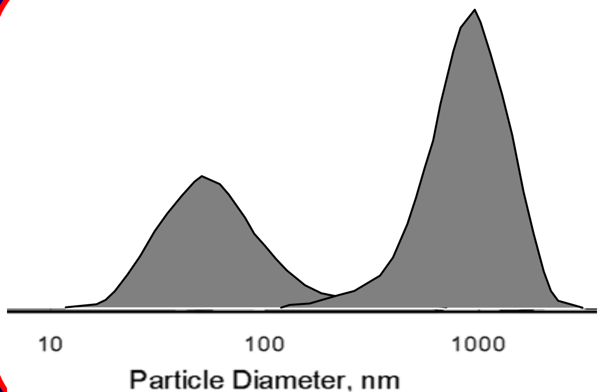
Every component is characterized by:



Spectral refractive index
$r(\lambda) + i\, m(\lambda)$

$$N(r) = \frac{C}{ln(\sigma) r \sqrt{2\pi}} exp\left\{ -\frac{[log(r/r_m)]^2}{2 ln^2(\sigma)} \right\}$$

Mode radius r_m and spread σ
log normal size distribution by number



Changing the mixing ratio between component we obtain the optical properties corresponding to different effective radius

$$r_e = \frac{\int_0^\infty r^3 n(r) dr}{\int_0^\infty r^2 n(r) dr}$$

$K_{ext}(\lambda)$

$0 < \omega(\lambda) < 1$

$P(\theta, \lambda)$

AEROSOL OPTICAL PROPERTIES

Aerosol component from OPAC database [Hess et al. 1998]

Maritime:
- water soluble
- sea salt (acc.)
- sea salt (coa.)

Continental:
- water soluble
- insoluble

Desert:
- water soluble
- mineral (nuc.)
- mineral (acc.)
- mineral (coa.)

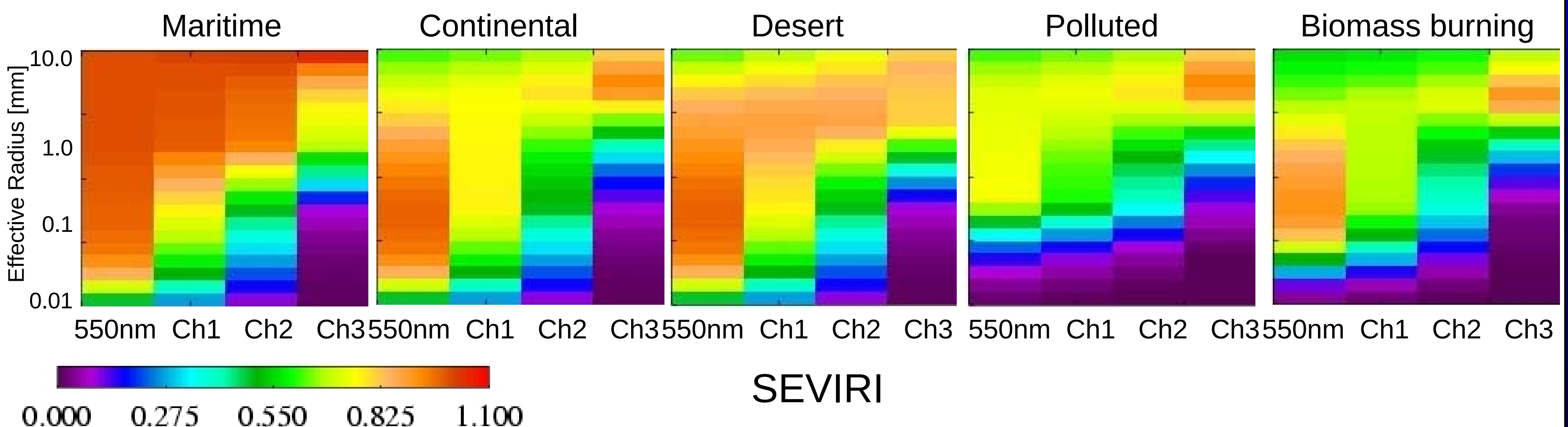
Polluted:
- soot
- water soluble
- insoluble

Biomass Burning (Cerrado):
- fine mode
- coarse mode

[Dubovik et al. 2002]

water soluble and sea salt component RH 50%
mineral, soot and insoluble components are considered non hygroscopic...

Scattering coefficient normalize to 550nm $K_{sca}(\lambda)/K_{ext}(550nm)$



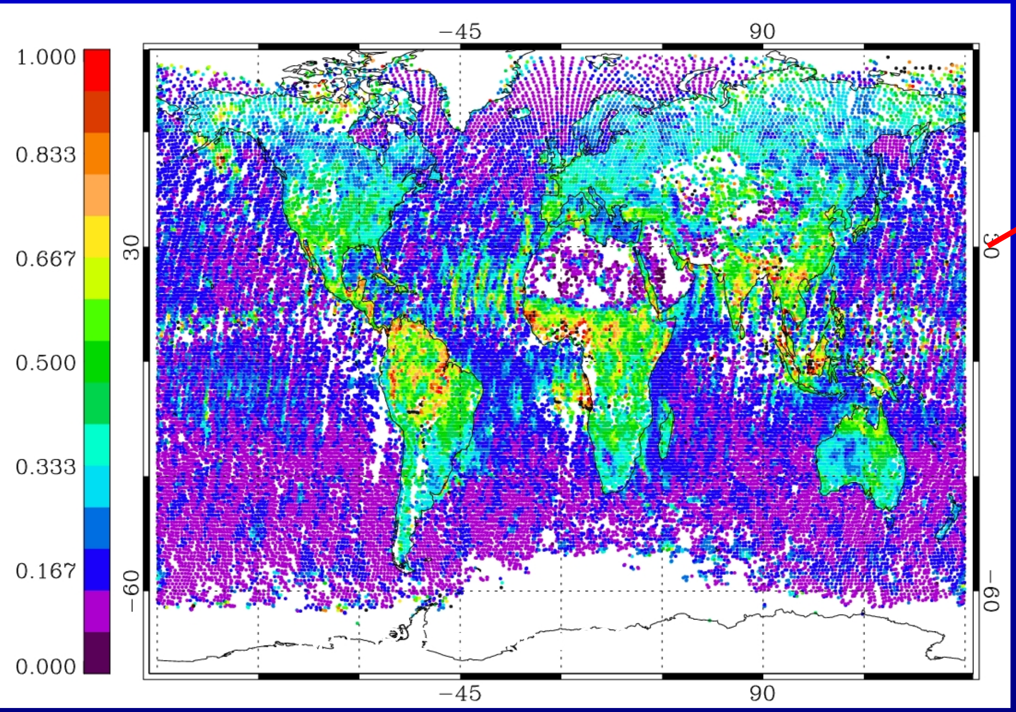
RETRIEVAL METHOD

OPTIMAL ESTIMATION [Rodgers 2000]

Guess	a priori	x_0 x_b
Observations		y_m
Simulated measurements		$y(x_n)$
Compare		$J=[y_m-y(x_n)]\, S_y^{-1}\, [y_m-y(x_n)]^T$ $+[x_n-x_b]\, S_x^{-1}\, [x_n-x_b]^T$
Adjust (minimise J)		$\delta J = -\,(J'' + \alpha I)^{-1}\, J'$ (Marquardt method)
Stop!		$\delta J < 0.05$ or $n > 25$

NB Optimal estimation method provides quality control   n = iteration number

RETRIEVED PARAMETERS

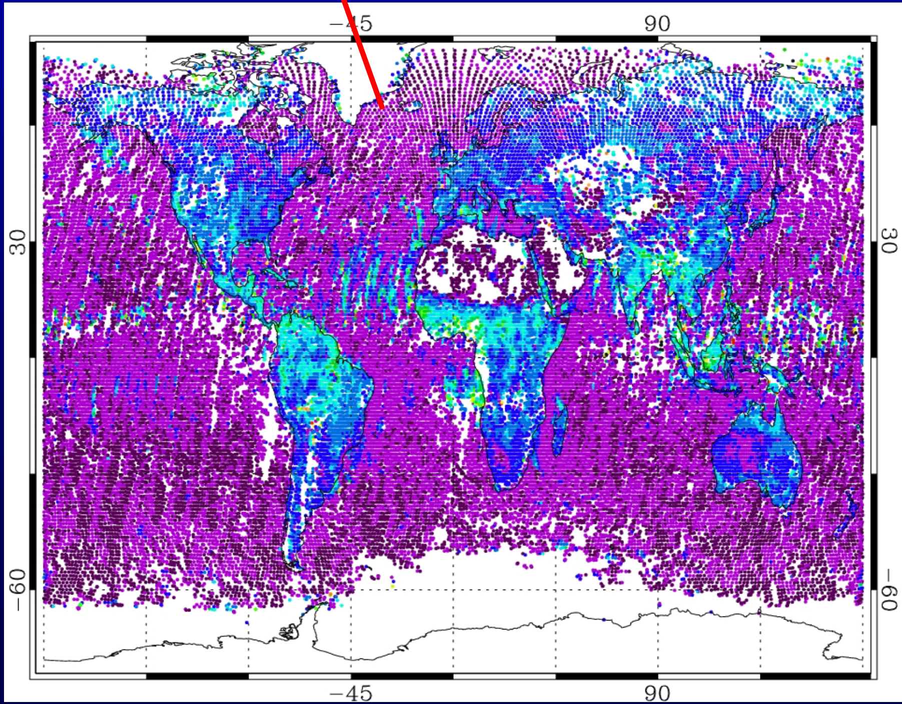


Aerosol retrieved parameters:

AOD at 550nm and effective radius R_{eff}

Reff ⟷ $K_{ext}(\lambda)$

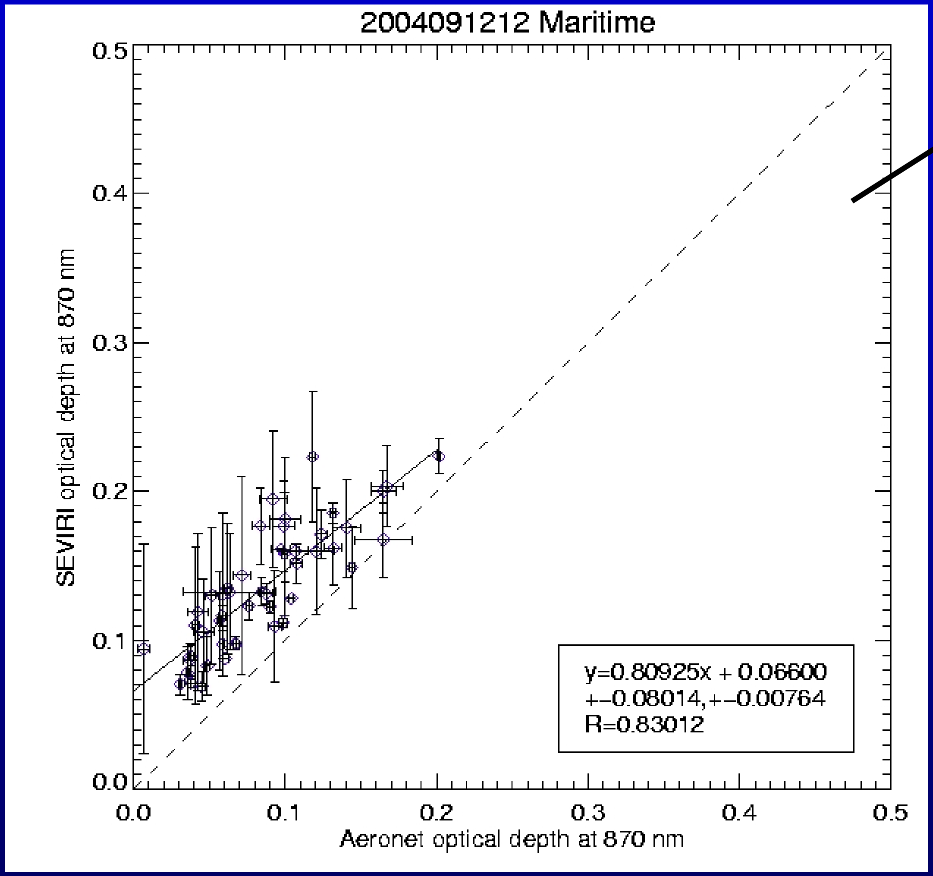
➡ AOD at 870 nm



One month case study for each instrument analysed until now.

The ORAC processor also retrieves surface reflectance at 550nm but with strong a priori constraint (based on MODIS over land).

AERONET VALIDATION



SEVIRI September 2004, maritime

Criteria and data selection:

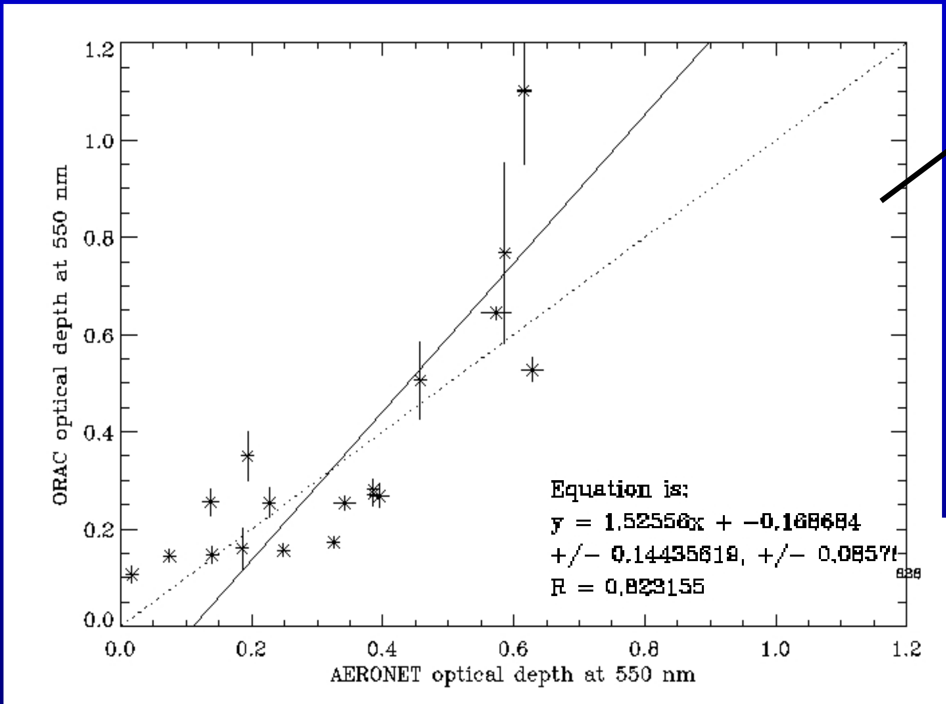
- Aeronet level 2 quality assured data (cloud screened)

- Space coincidence < 20 km

- Time coincidence < 30'

Initial validation performed on preliminary GAP
26 August - 30 September 2004
Whole 10 year data-set validated by end of study

AERONET VALIDATION



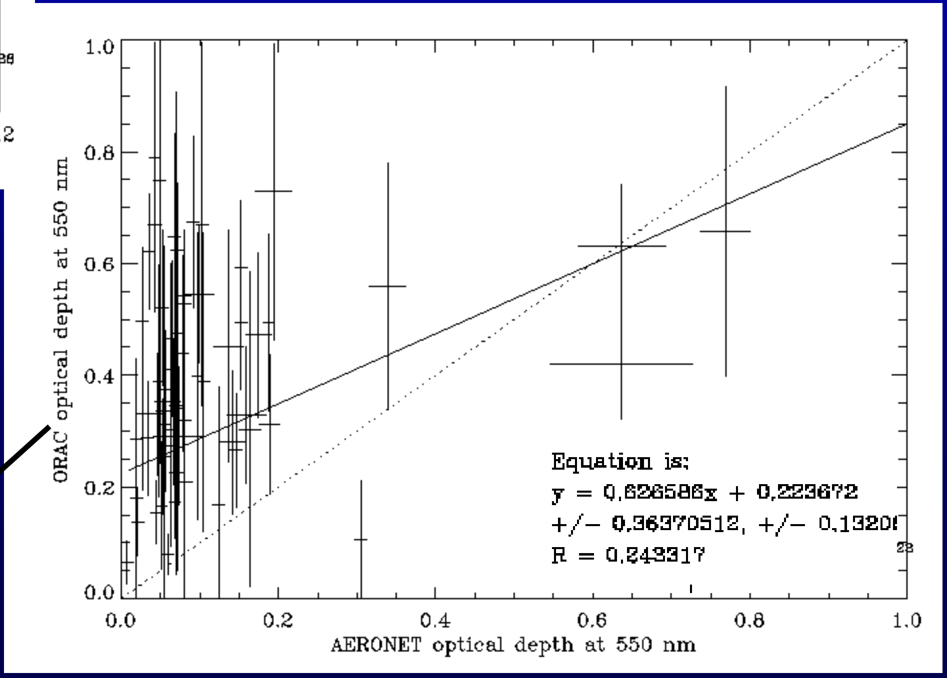
AATSR over ocean

At present one month is analyzed: September 2004

Few coincidence for AATSR that overpass the same site every 3 days

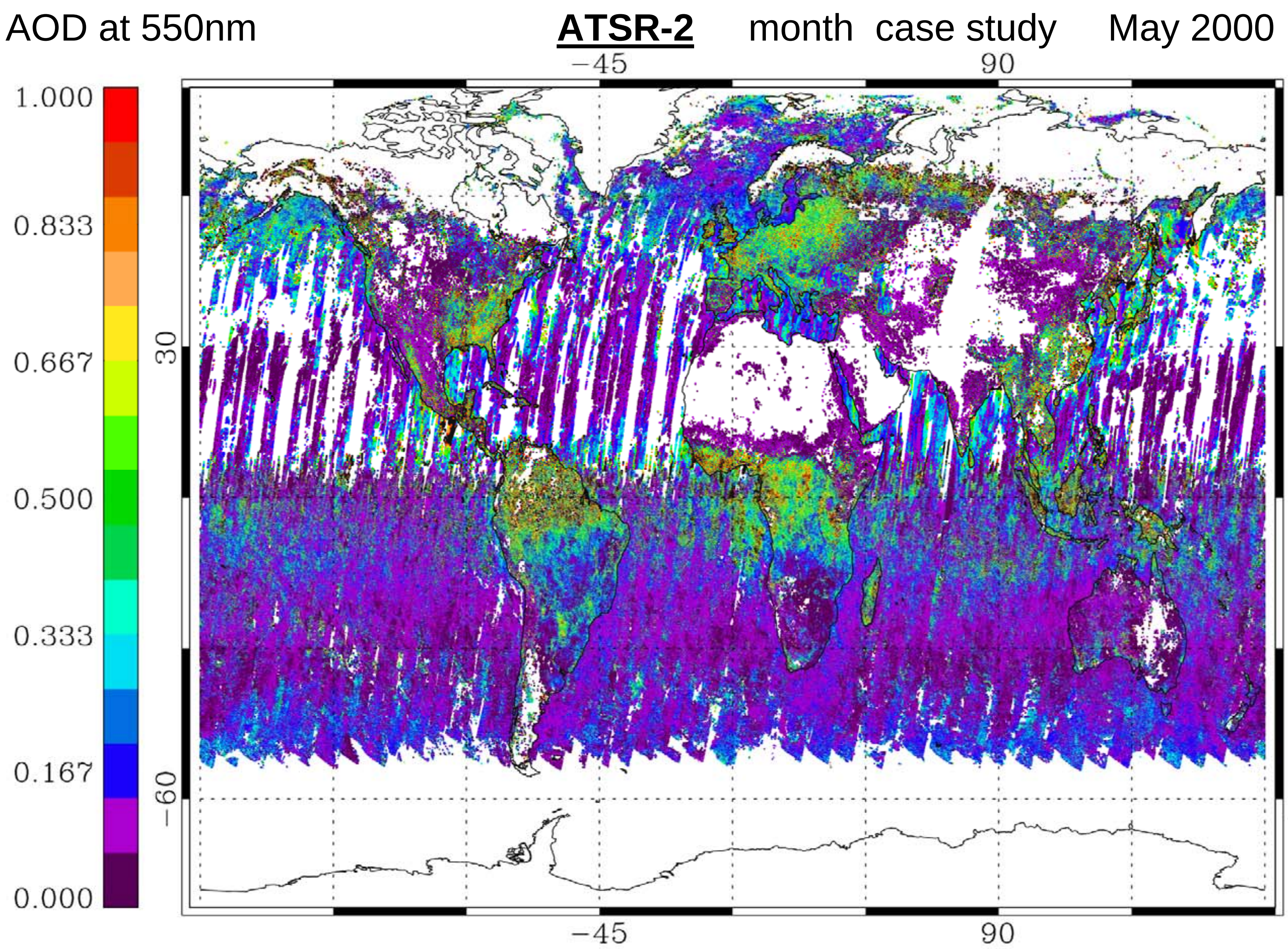
Preliminary result !!

A complete validation will be performed after 10 year dataset is produced



AATSR over land

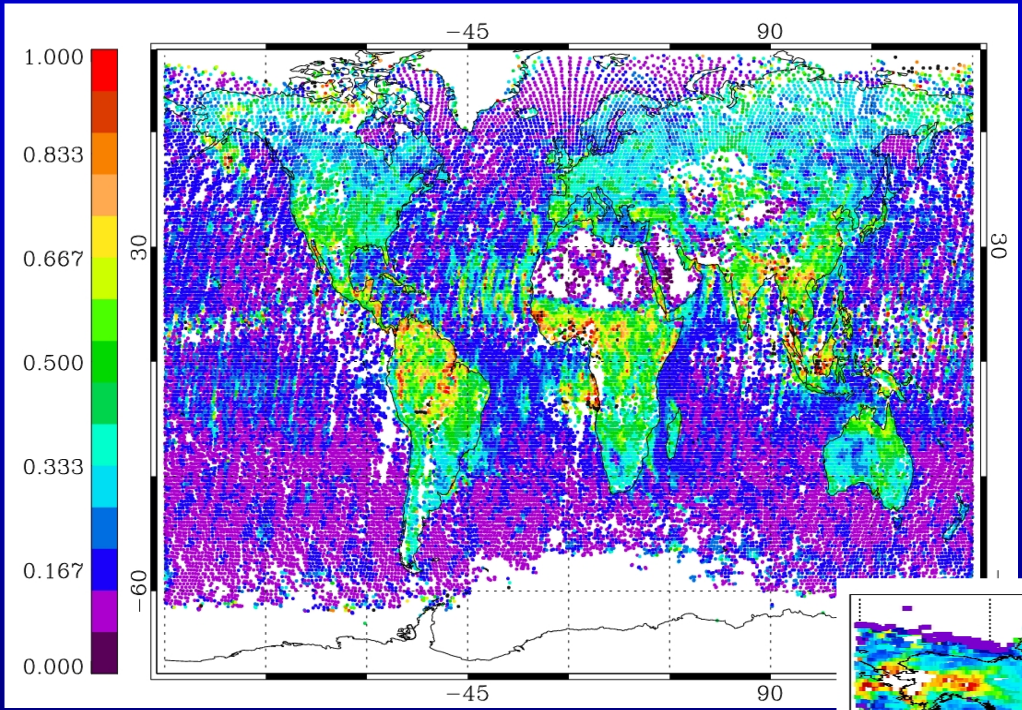
(A)ATSR MONTHLY MAPS

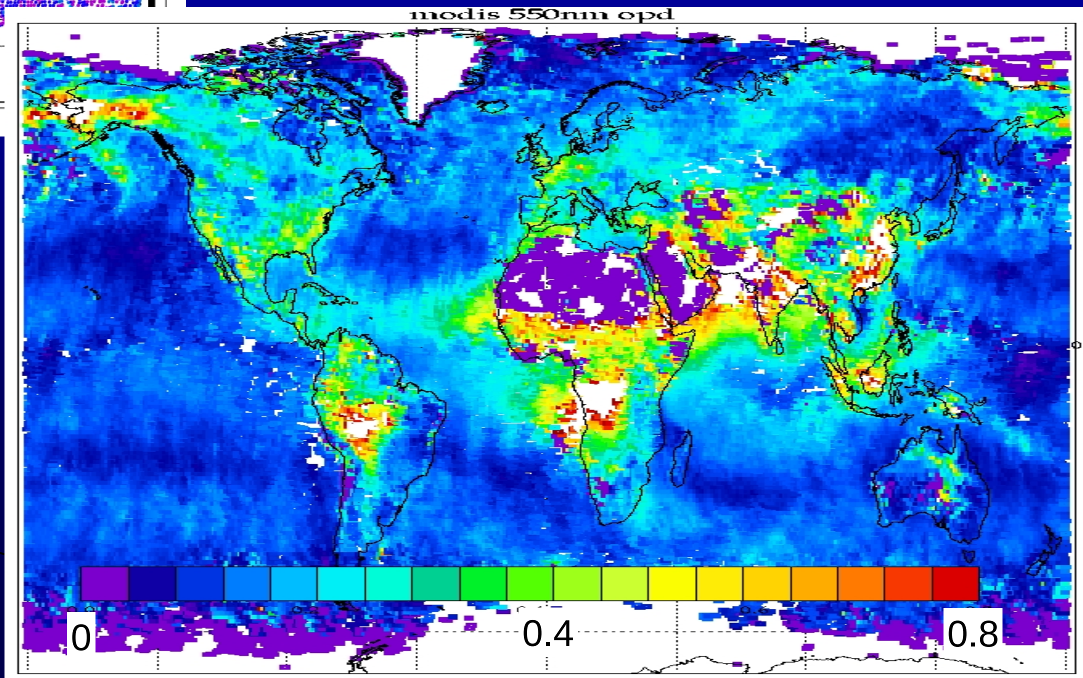


(A)ATSR MONTHLY MAPS

AATSR AOD at 550nm

September 2004

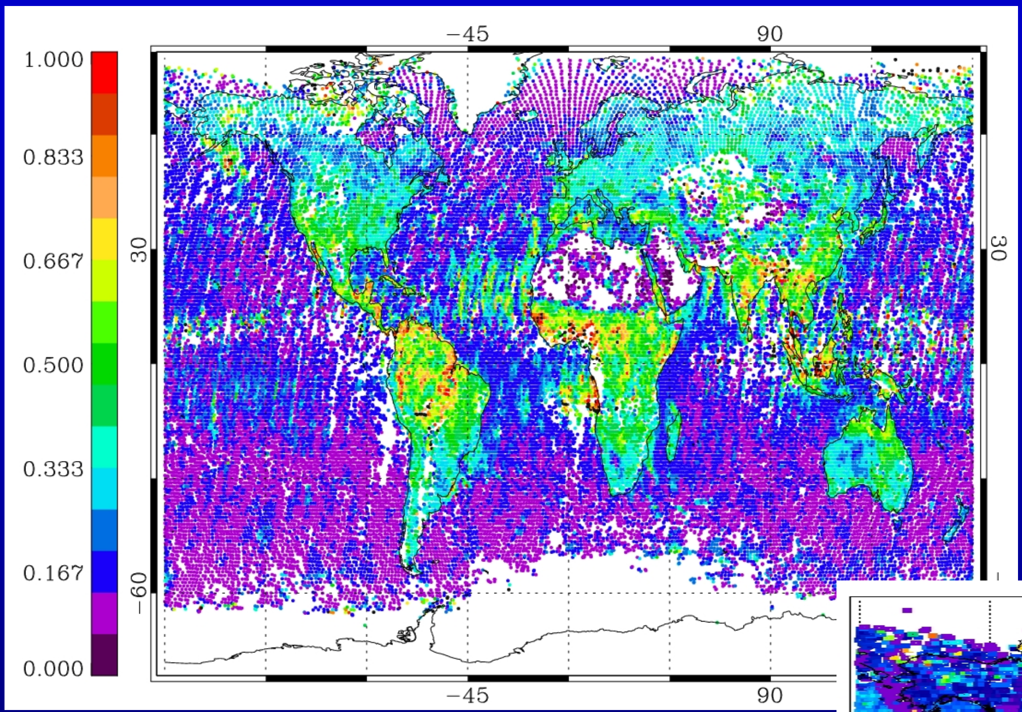




MODIS AOD at 550nm

Note: different colour bar

(A)ATSR MONTHLY MAPS

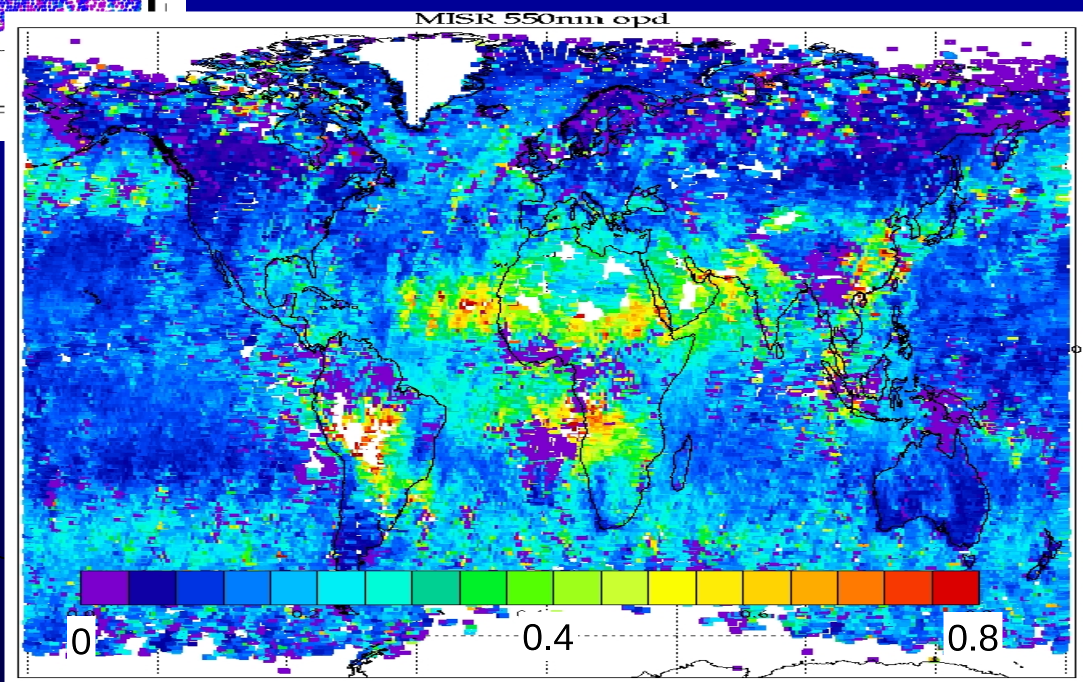


AATSR AOD at 550nm

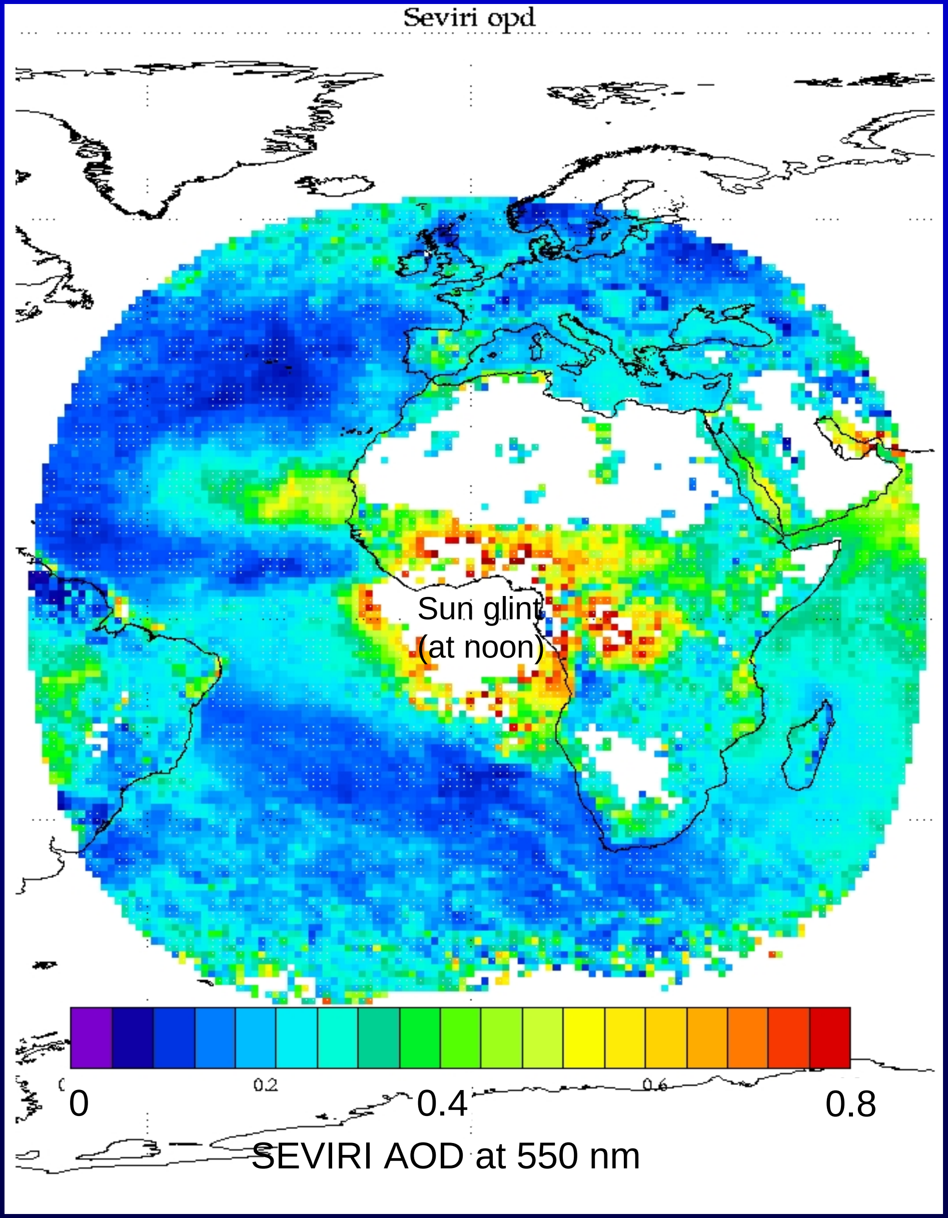
September 2004

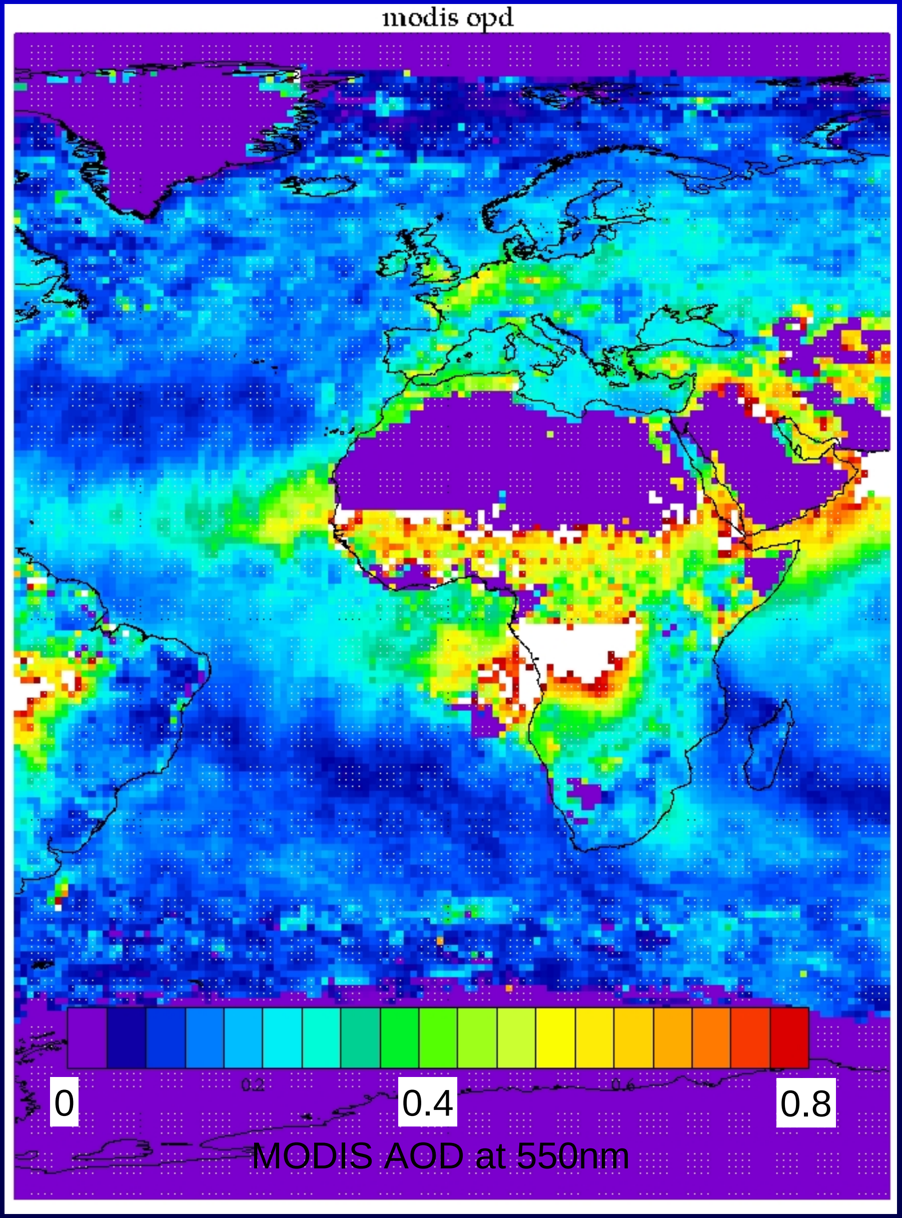
Note: different colour bar

MIRS AOD at 550nm

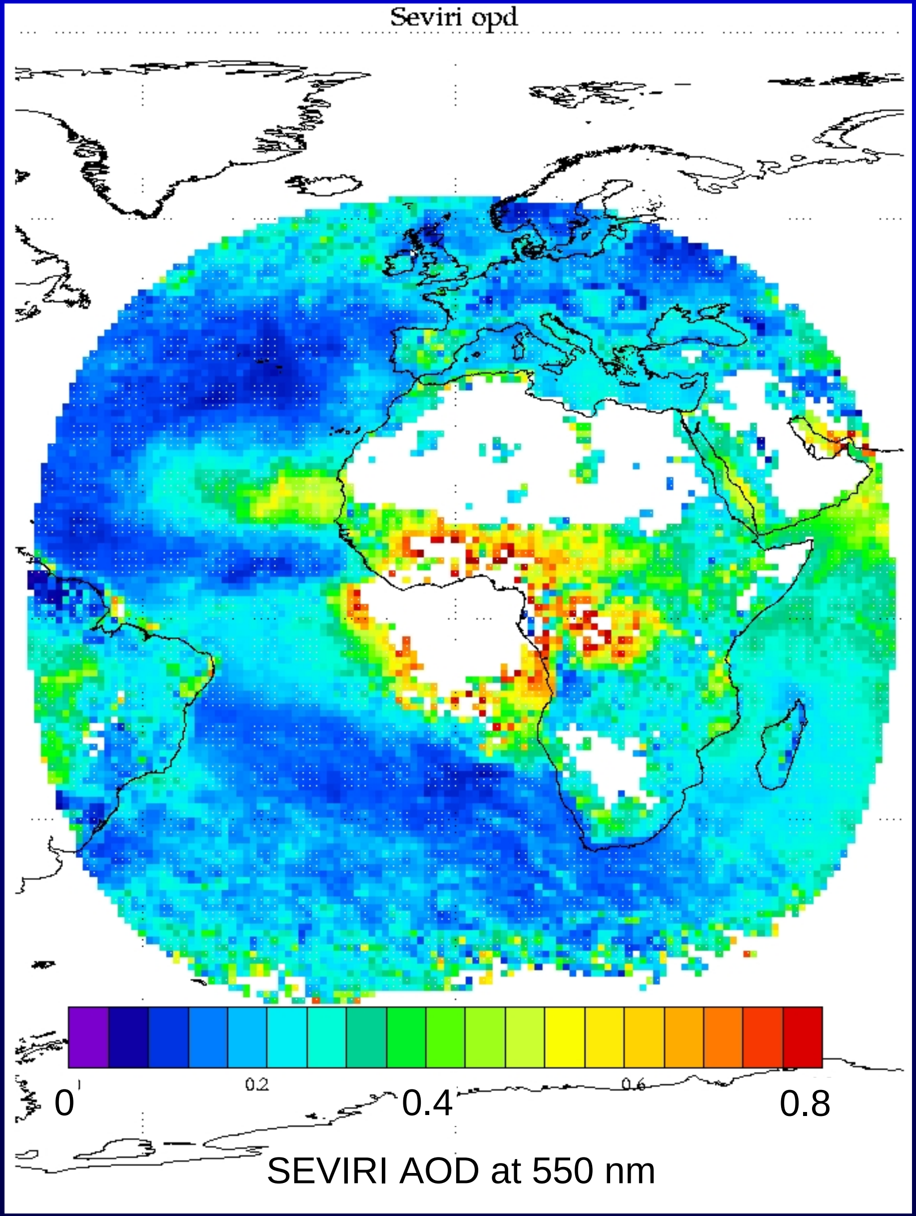


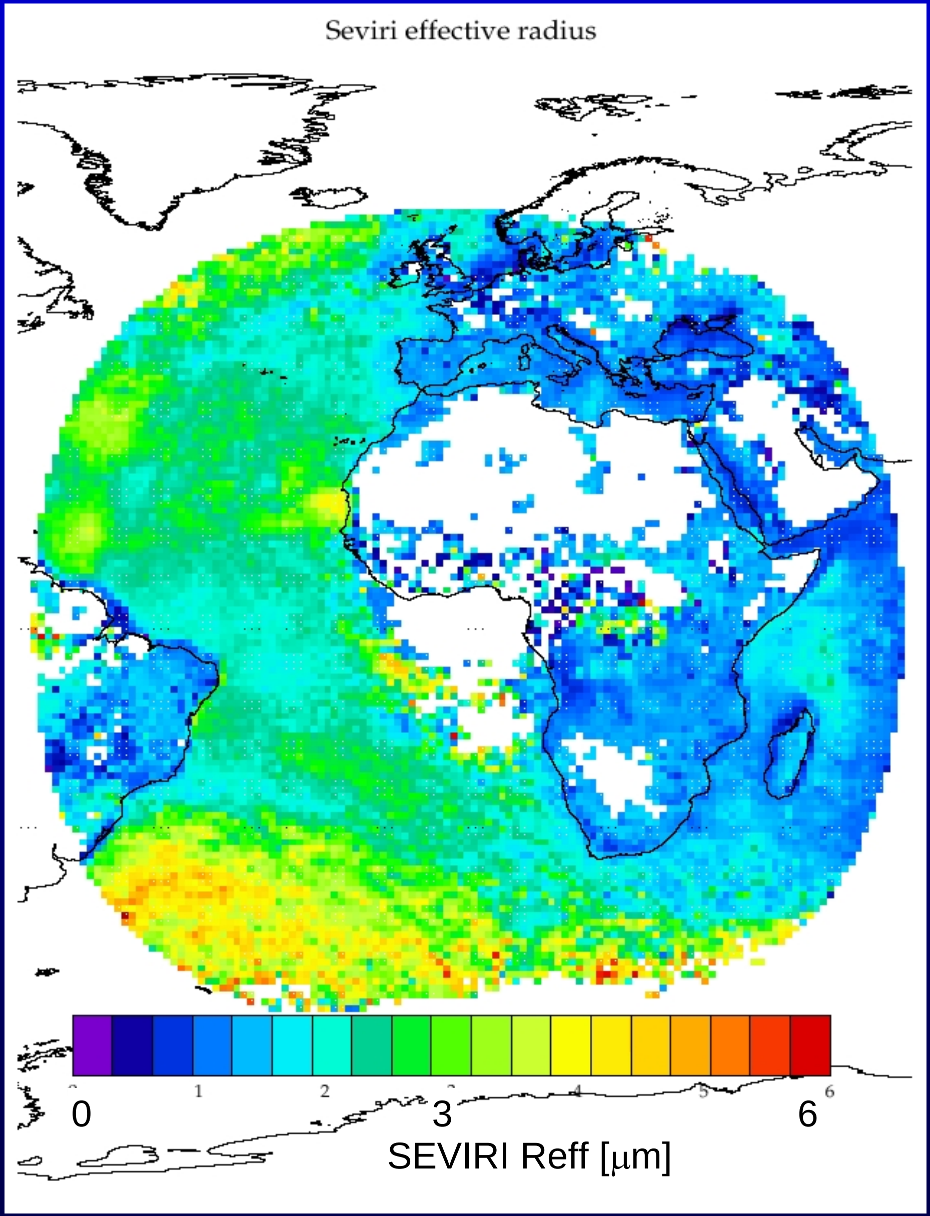
SEVIRI MONTHLY MAPS





SEVIRI MONTHLY MAPS





ORAC NOTE

Main limitations:

- Retrieval over land (especially bright surfaces)
- Identification of aerosol type
    - Retrieval performed for 5 aerosol types
        - Type chosen with lowest retrieval cost
        - This is often ambiguous and does not always work

Both could be improved by use of

- ATSR dual view (Andy Sayer PhD)
- Observations at multiple times of day for SEVIRI
- Add IR channels at 11 and 12 mm (NERC Sahara dust project)

But not feasible within GlobAerosol

SUMMARY

- ORAC algorithm is going to be applied to the full mission
  - Self consistent data set on aerosols from1995-2005

- Products from individual sensors + a merged products combing the four different instruments

GlobAEROSOL will be one of the few long-term, global aerosol datasets derived from multiple satellite instruments available.

Complete data set (10 years) available by 2007

For more information on GlobAerosol project:
http://www.globaerosol.info/index.htm

THANK YOU!

Retrieval method

• MERIS aerosol products will be based on the standard level 2 processing.

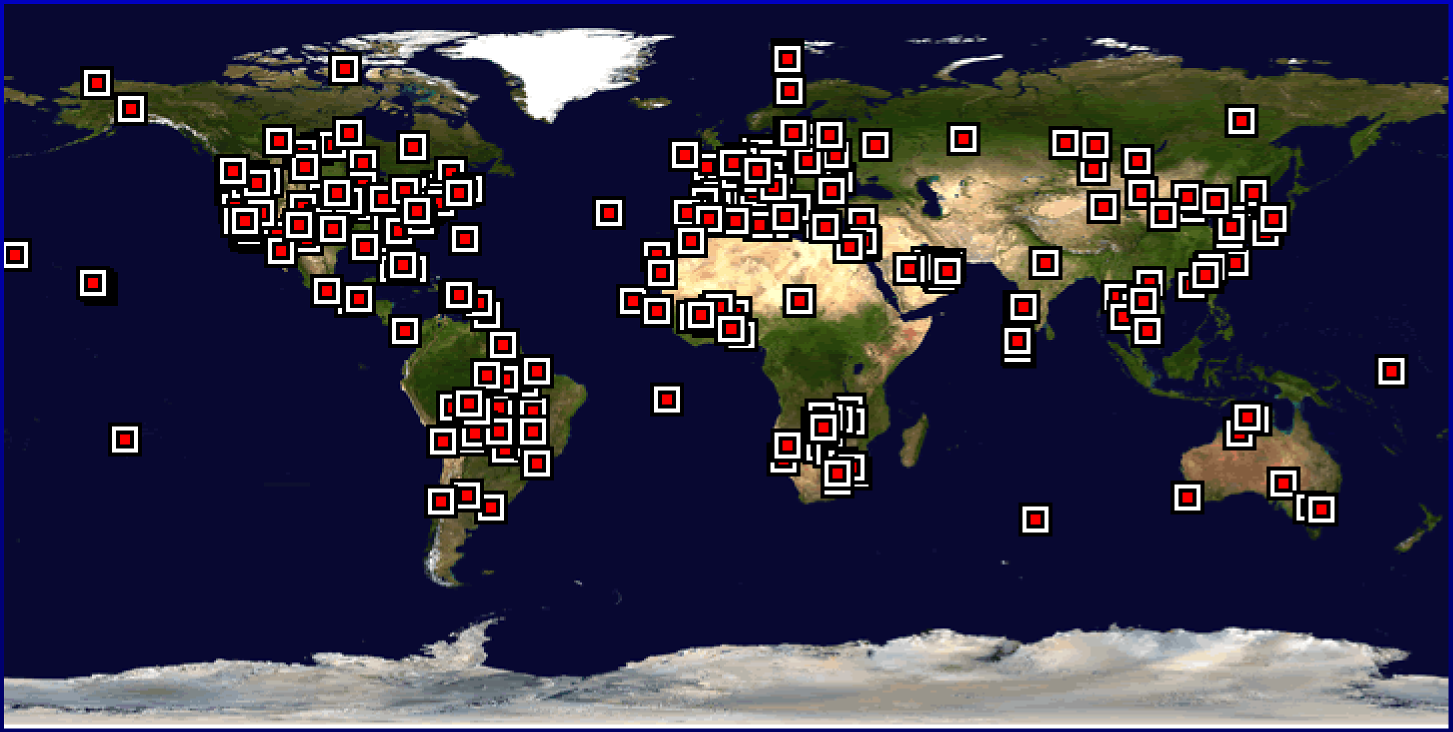
• ATSR- 2, AATSR and SEVIRI aerosol products will all be derived using the Oxford- RAL Aerosol and Cloud retrieval scheme (ORAC).

- The scheme uses the optimal estimation method.
- The forward model uses the DISORT radiative transfer model in conjunction with a set of aerosol models from OPAC database.
- The aerosol retrieval makes use of the visible channels only:
  - ATSR- 2: 0.67, 0.87, 1.6 µm
  - AATSR: 0.55, 0.67, 0.87, 1.6 µm
  - SEVIRI: 0.64, 0.81, 1.6 µm
- Cloud properties will not be retrieved for GlobAEROSOL.

• ORAC has already been used extensively for cloud retrievals and the aerosol retrieval is currently being used in the GRAPE* project.

* See http:// www- atm. physics. ox. ac. uk/ group/ grape/

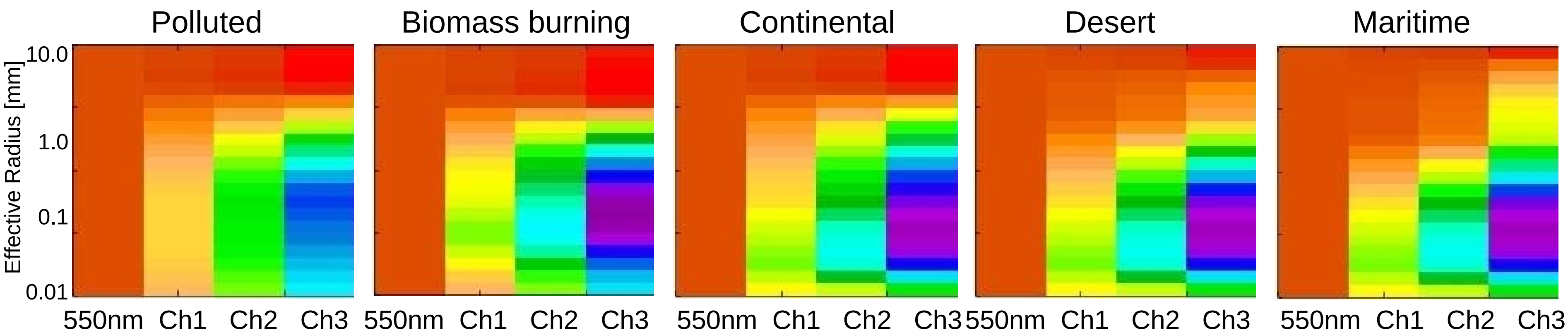
AERONET VALIDATION



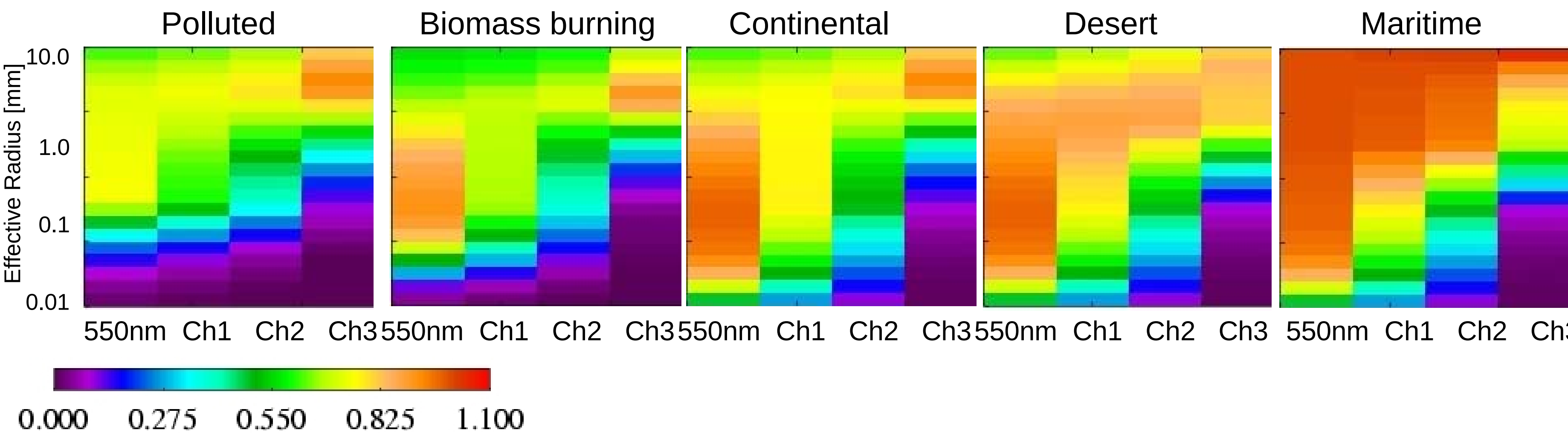
AERNET sites (http://aeronet.gsfc.nasa.gov/)

AEROSOL OPTICAL PROPERTIES

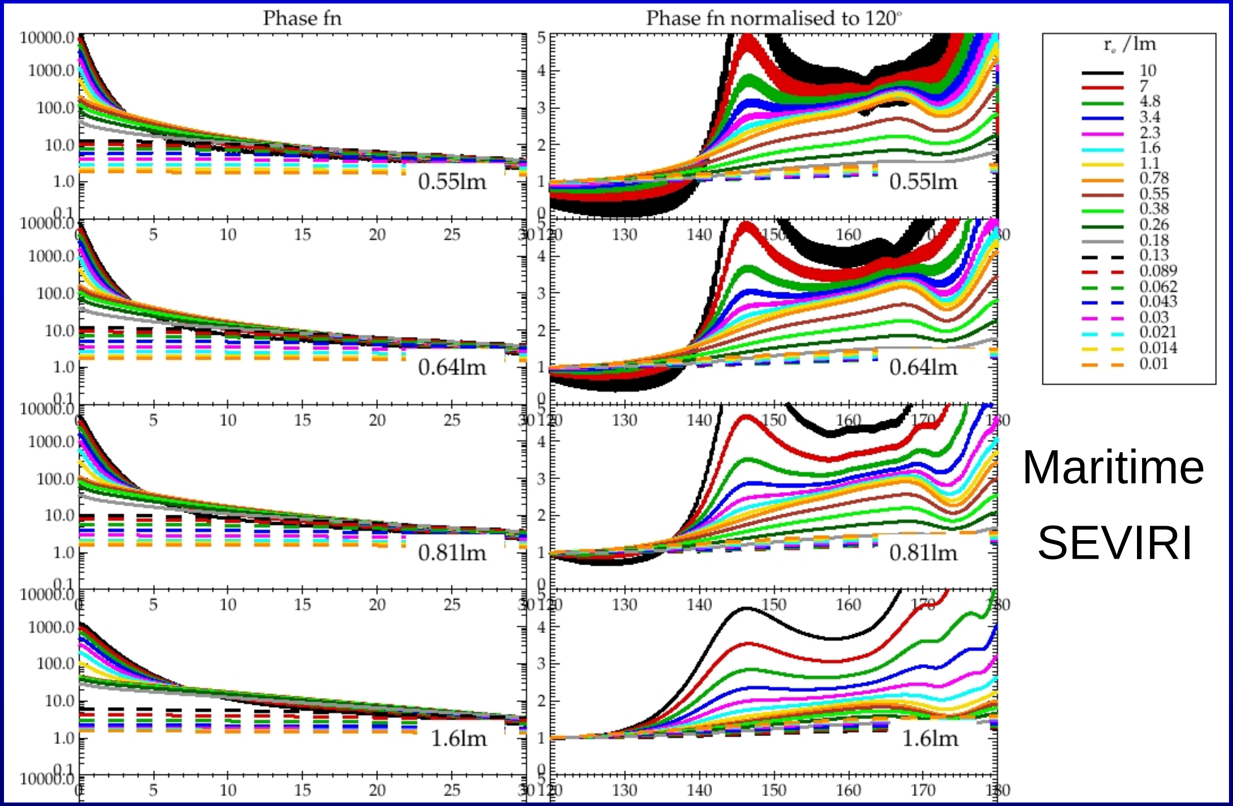
Extinction coefficient normalize to 550nm $K_{ext}(\lambda)/K_{ext}(550nm)$



Scattering coefficient normalize to 550nm $K_{sca}(\lambda)/K_{ext}(550nm)$



AEROSOL OPTICAL PROPERTIES



$$\tau_{atm} = \tau_a + \tau_m + \tau_g$$

$$\omega_{atm} = \frac{\tau_a\omega_a + \tau_m}{\tau_a + \tau_m + \tau_g}$$

$$P_{atm}(\theta) = \frac{\tau_a\omega_a P_a(\theta) + \tau_m P_m(\theta)}{\tau_a\omega_a + \tau_m}$$

$$L^i_{atm} = (\tau_m L^i_m + \omega_a\tau_a L^i_a)/(\tau_m + \omega_a\tau_a)$$

m = molecular (scattering)
a = aerosol (scattering and absorption)
g = gas (molecular absorption)

atm = atmospheric

QUALITY CONTROL

Pre-processing

Cloud flag — EUMETSAT operational

Sun glint — Cox and Munk - wind correction (ECMWF)

Optimal estimation method provides quality control

- Model fit ⇨ Cost function threshold $J < n_y + n_x$
- Linear error analysis

assuming radiative transfer model linear in the vicinity of the solution

$$S^T=(S_x^{-1}+K_x^T S_y^{-1} K_x)^{-1}$$

Error covariance matrix (smoothing and measurements errors)

- Convergence

AERONET MEASUREMENTS

- Each ground station is equipped with CIMEL sun-photometers
  - measure at 340, 380, 440, 500, 675, 870, 940 and 1020 nm
  - angular field-of-view of approx. 1.2 degrees.
  - spectral widths: 2nm at 340nm, 4 at 380nm, others 10nm.

- Direct sun measurement every 15 mins
  - comprising triplet of 3 x 8s observations

- AOD from direct sun measurements. Few approximations
  - Beer's law + Rayleigh scattering + trace-gas correction
  - Abs. accuracy <0.01, relative cf other photometers <0.004

- Angstrom coefficient fitted to AOT at 440, 500, 675, and 870nm

Slide courtesy Caroline Poulsen: RAL Laboratory

NOTE

- Before 2001 the only instrument available is ATSR- 2, hence the first half of the data set will have considerably poorer coverage.

- After 2001 ATSR- 2 data will not be used, due to the pointing issues with ERS- 2.

- The SEVIRI Level 1.5 data required for GlobAEROSOL processing is only available from February 2004 onwards.

- ORAC only uses the nadir view of ATSR- 2 and AATSR: it is not a dual view retrieval *(at present*).