esa

Lessons learned from 3 years ESA Climate Change Initiative on improving aerosol retrieval algorithms

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Introduction to ESA Aerosol_cci

- The goal of the ESA climate change initiative is to produce essential climate variables (ECV) using satellite data, following GCOS requirements
- Users and advisors: climate change community
- Focus on European satellites; not exclusively
- 13 different areas, among which aerosols

Aerosol-cci:

- Started July 2010, 3 years
- Work closely with AEROCOM
- Independent validation
- Initial focus on understanding differences between different algoritmhs and algorithm improvement

Aerosol_cci partners

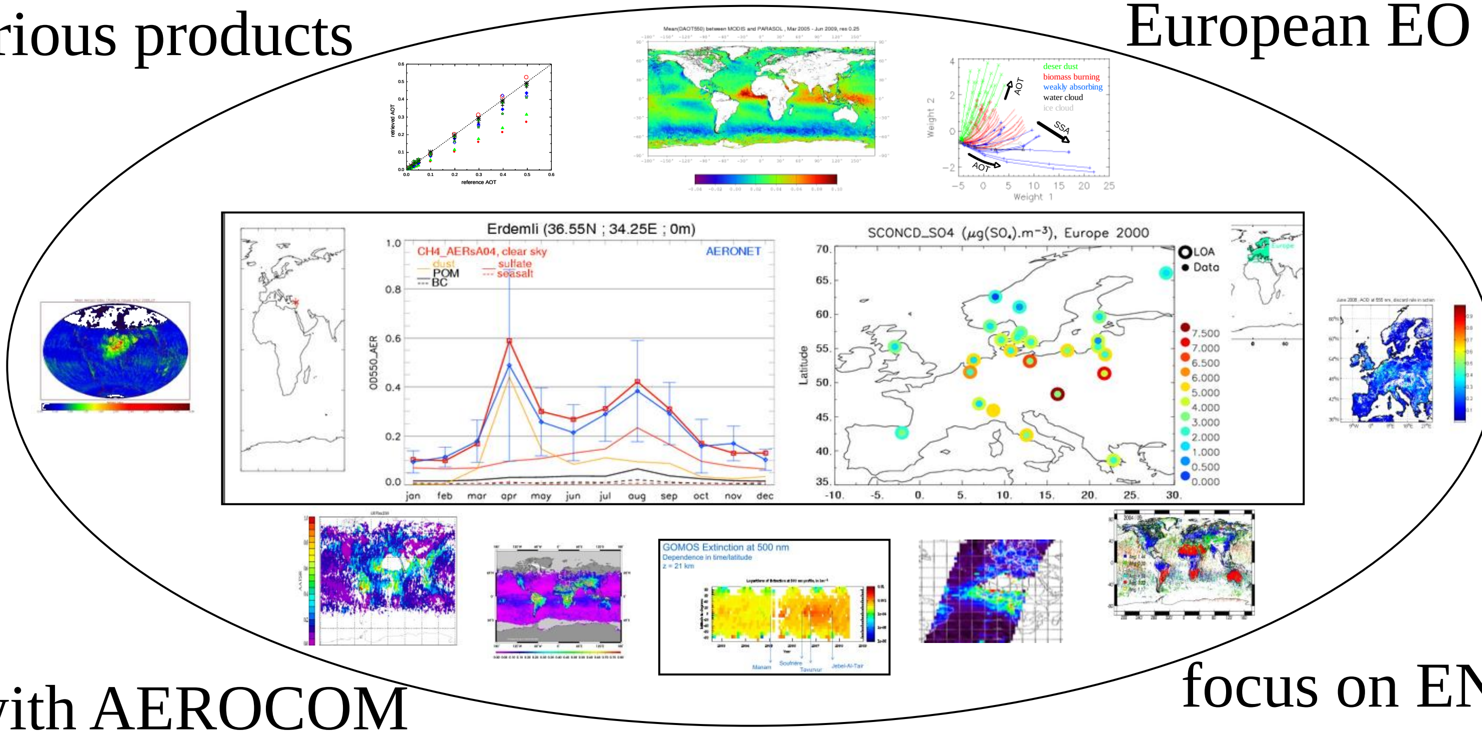
Aerosol-cci brings together the most prominent European aerosol retrieval groups

Non-European groups contribute

Concept

understand differences
of various products

integrate major
European EO teams



work with AEROCOM
user community

focus on ENVISAT
and European sensors

Aerosol_cci products

Parameter	Sensor (Algorithms)	Coverage
AOD, Ångström	ATSR-2 + AATSR (ADV, SU, ORAC)	2008 (2000), global (1995 – 2012)
AOD, Ångström	MERIS (ALAMO)	2008, over ocean
AOD, Ångström	POLDER	2008, over ocean
Absorbing Aerosol Index	OMI (GOME, TOMS)	1978 – 2012, global
Stratospheric extinction	GOMOS (SCIAMACHY)	2008, global
AOD, Ångström	MERIS (BAER, STD)	2008, global
AOD, aerosol type	SCIA/AATSR (SYNAER)	3/6/9/12 2008, global
AOD, Ångström	AATSR/MERIS	3/6/9/12 2008, global
Stratospheric extinction	GOMOS/OSIRIS (merged)	2003, global
AOD, aerosol properties	POLDER (multi-pixel algorithm)	Example scenes, land
Absorbing AOD (SSA)	AATSR	Examples, glint areas

All products contain pixel level uncertainties / flags

Analysis steps

- Improve algorithms: Workshops + experiments (1 month)
  - Optical models, cloud masks, (surface)
  - Post-processing (cloud contamination, bright surface)

Holzer-Popp, et al., AMT 2013

- Select algorithms: Round robin exercise (4 months)
  - Best versions for all algorithms

de Leeuw et al., RSE 2013, in press

- Produce selected ECV products (entire 2008)

Kinne, et al., in preparation

- At all steps application of the same validation tools and statistics
  - Level 2 and level 3
  - Global + regional statistics
  - Scoring (spatial / temporal correlation)
  - Against AERONET / MAN + MODIS / MISR / CALIPSO

Aerosol-CCI working groups

- Aerosol models
  - Choose common aerosol models
  - Non-sperical dust model
- Aerosol climatology:
  - Use common aerosol climatology for the algorithms, where aerosol mixture is not retrieved
- Surface reflectance treatment
  - compare and improve surface treatment
- Cloud detection/screening
  - Common cloud mask
  - Dust detection
  - Sun glint
  - Consistency between Aerosol-CCI and Cloud-CCI cloud masks

Aerosol components

aerosol component	refract index real p. (55μm)	refract index imag p. (.55μm)	reff (μm)	geom. st dev (σ_i)	variance (ln σ_i)	mode#. radius (μm)	comments	aeroso layer height
Dust	1.56	0.0018	1.94	1.822	0.6	0.788	non-spherical	2-4km
sea salt	1.4	0	1.94	1.822	0.6	0.788	AOD threshold constraint[#]	0-1 km
fine mode weak-abs	1.4	0.003	0.140	1.7	0.53	0.07	(ss-albedo at 0.55 μm: 0.98)	0-2 km
fine mode strong-abs	1.5	0.040	0.140	1.7	0.53	0.07	(ss-albedo at 0.55 μm: 0.802)	0-2 km

Dubovik et al., 2002

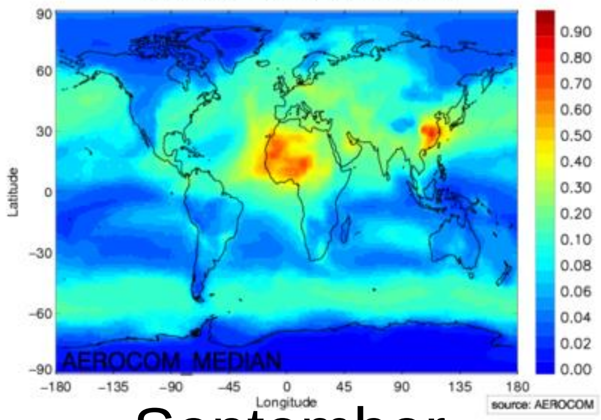
Possible Combinations:

1. Mix FM1 & FM2 > FM
2. Mix CM1 & CM2 > CM
3. Mix FM & CM

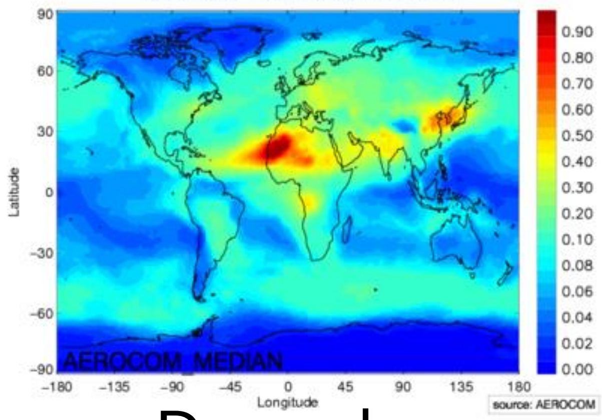
AEROCOM climatology

AEROCOM median, monthly distribution of aerosol components, derived from 12 global models

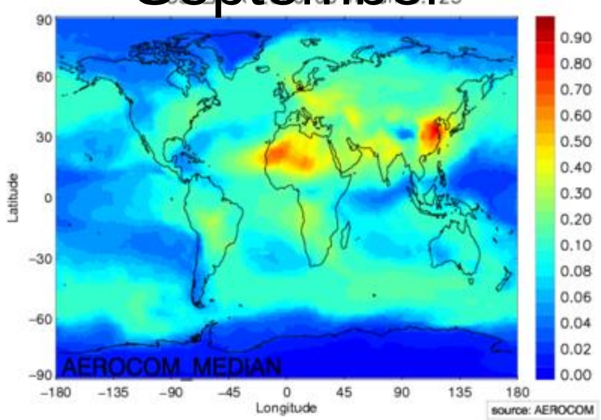
March



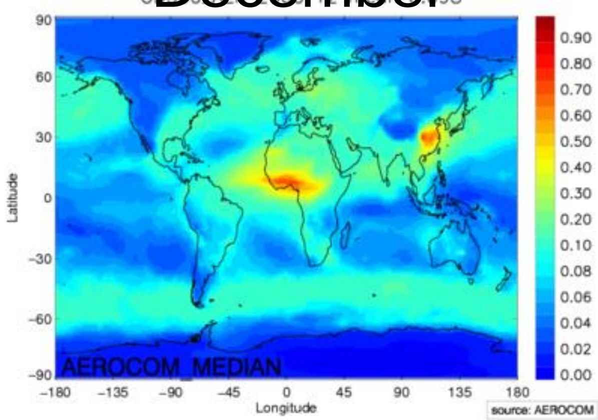
June



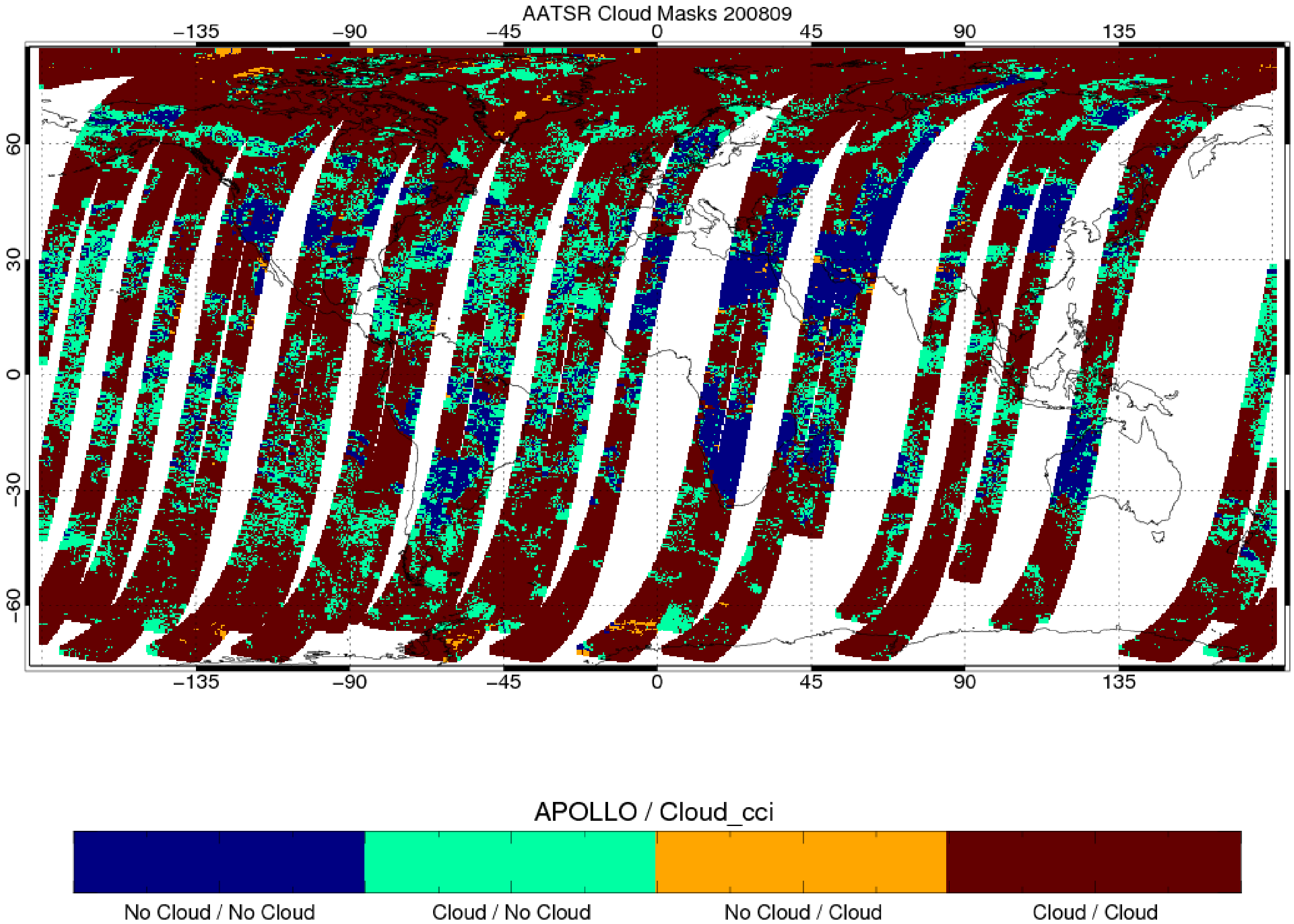
September



December

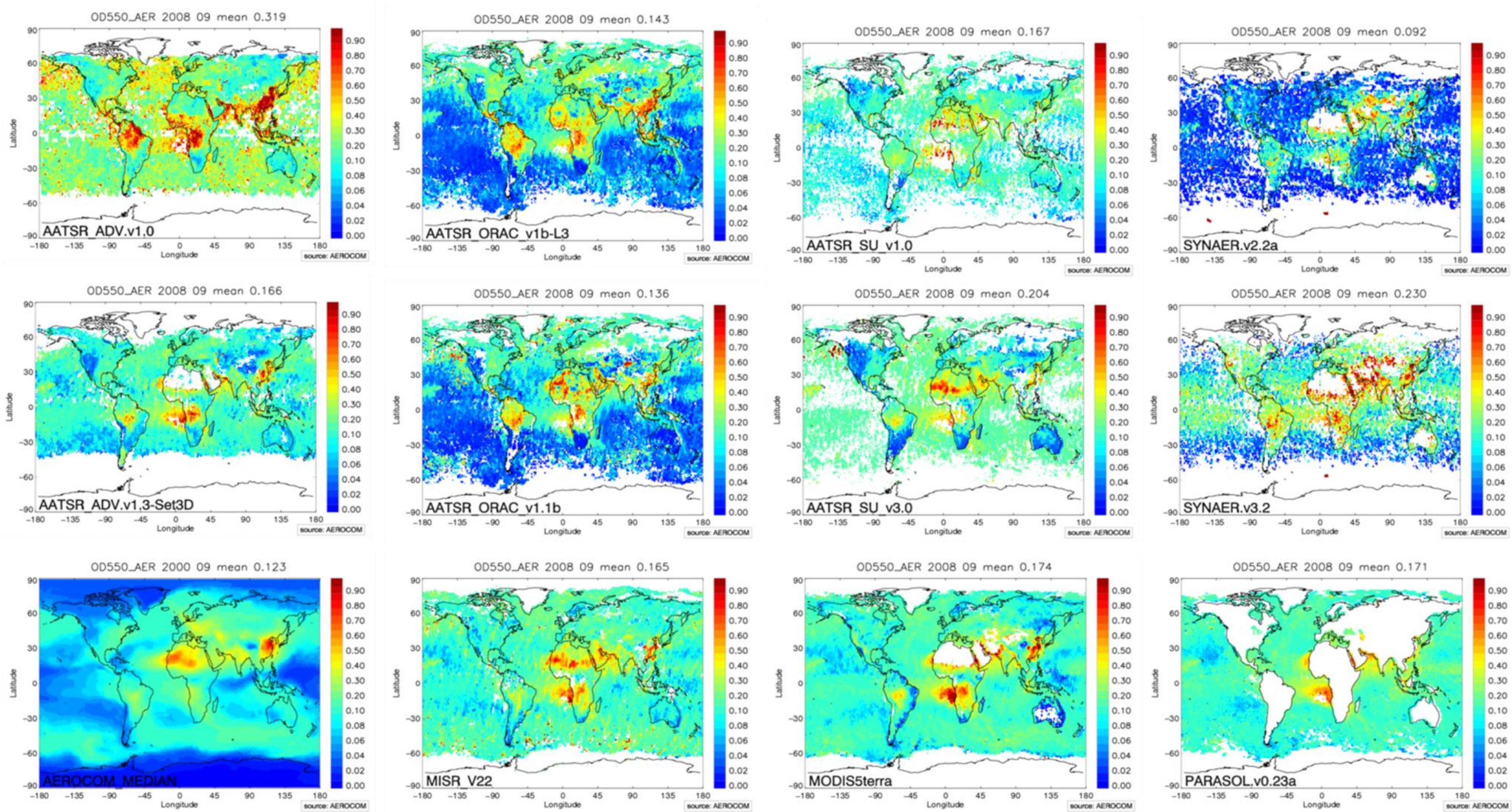


Consistency between Aerosol-CCI and Cloud-CCI cloud masks



L3 comparison for AATSR algorithms

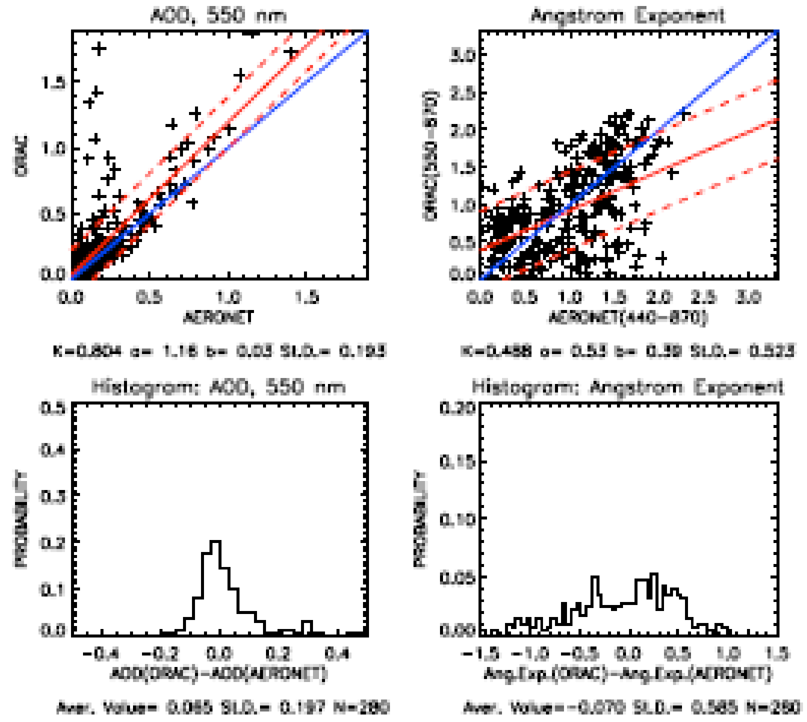
Top to bottom: Baseline,
RR results (best algorithm selected by each group),
Comparisons with AEROCOM median and other algorithms



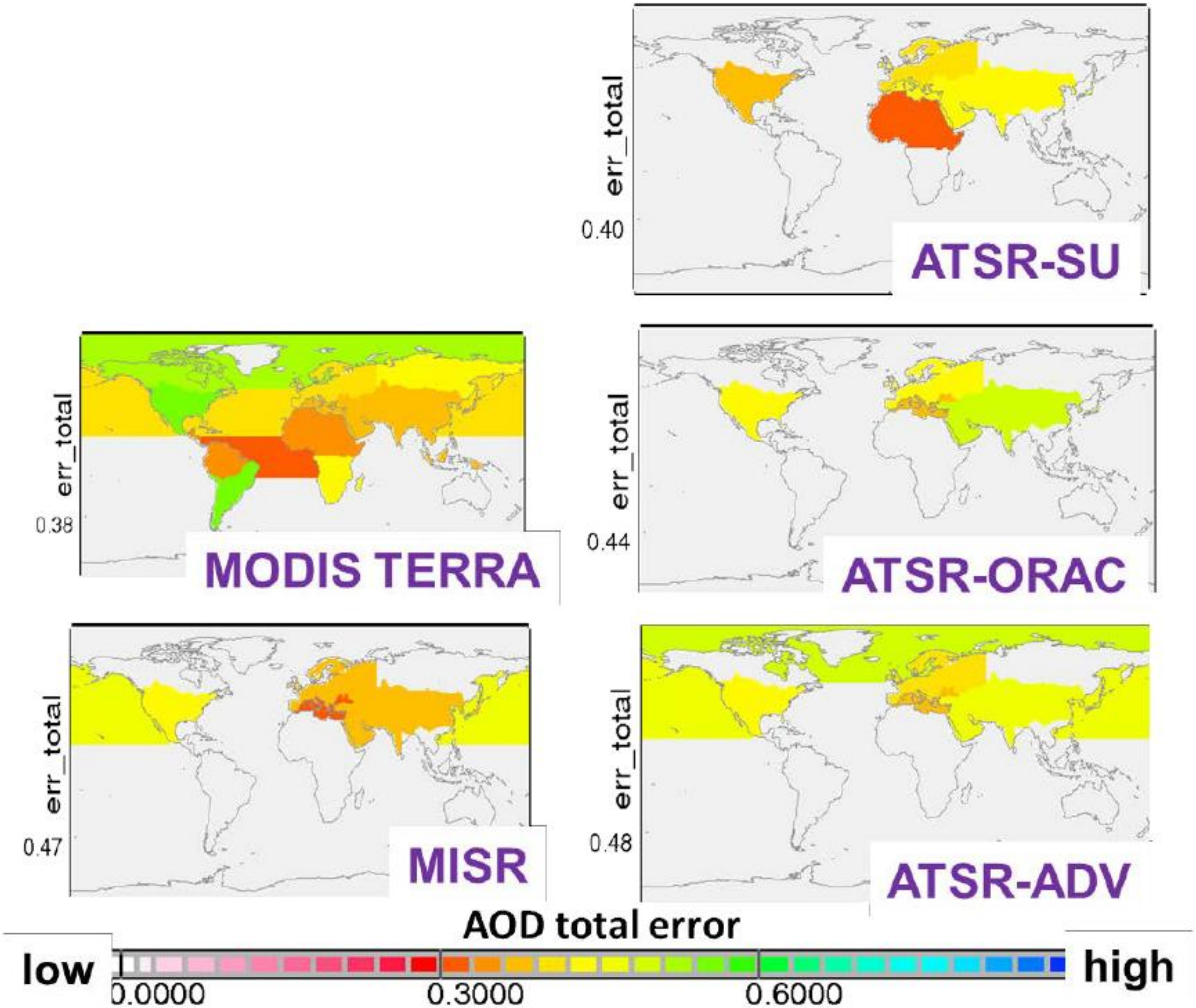
Analysis tools

- ICARE statistical inter-comparison (level2)
  - versus AERONET
  - versus other satellites (MODIS, MISR, POLDER)
- MPI scoring (level2)
  - Spatial and temporal patterns, bias, noise
  - versus AERONET
- AEROCOM model inter-comparison (level3)

ICARE L2 for ORAC, 4 months over ocean:

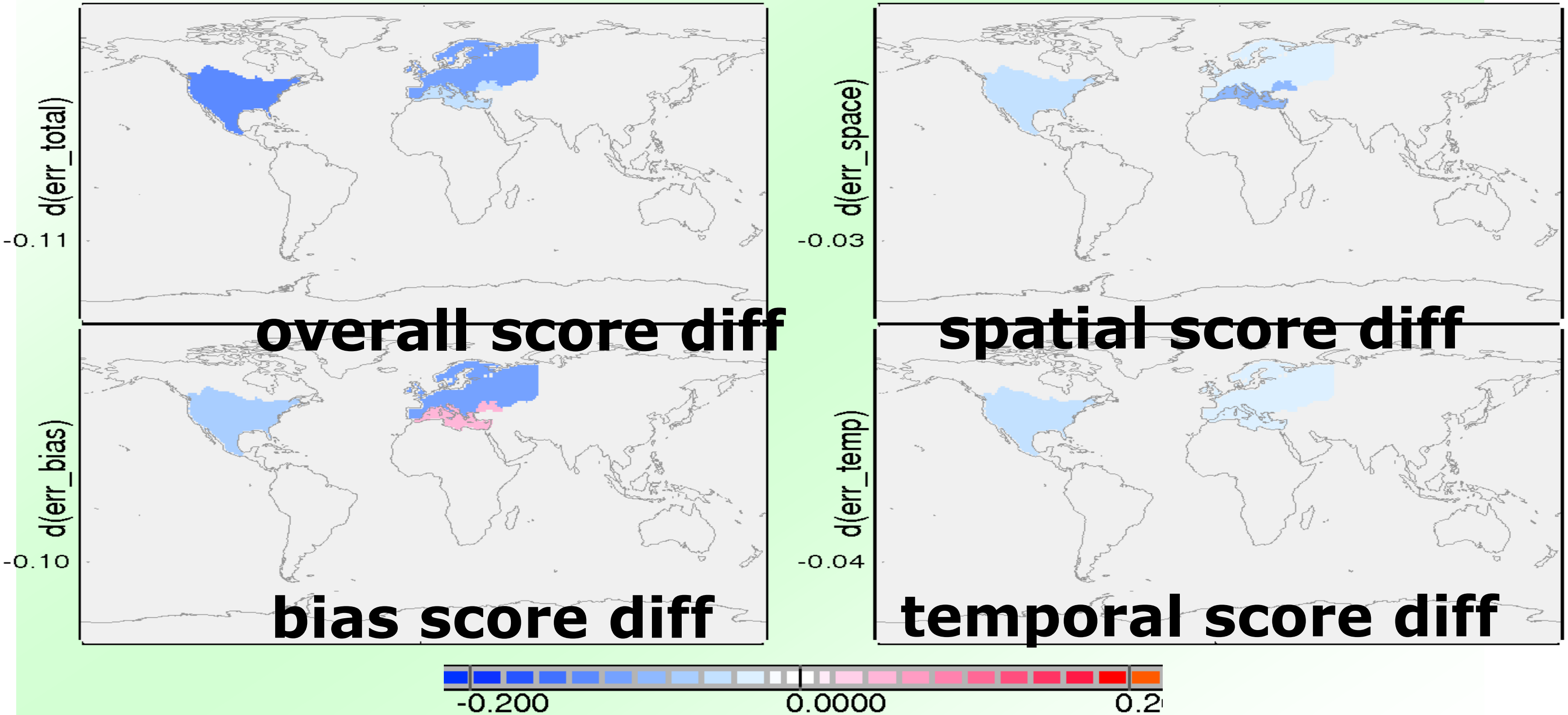


Validated products: Lv3 scoring (correlations x,t)



Improvements (SU v4.0-1.0) vs. AERONET

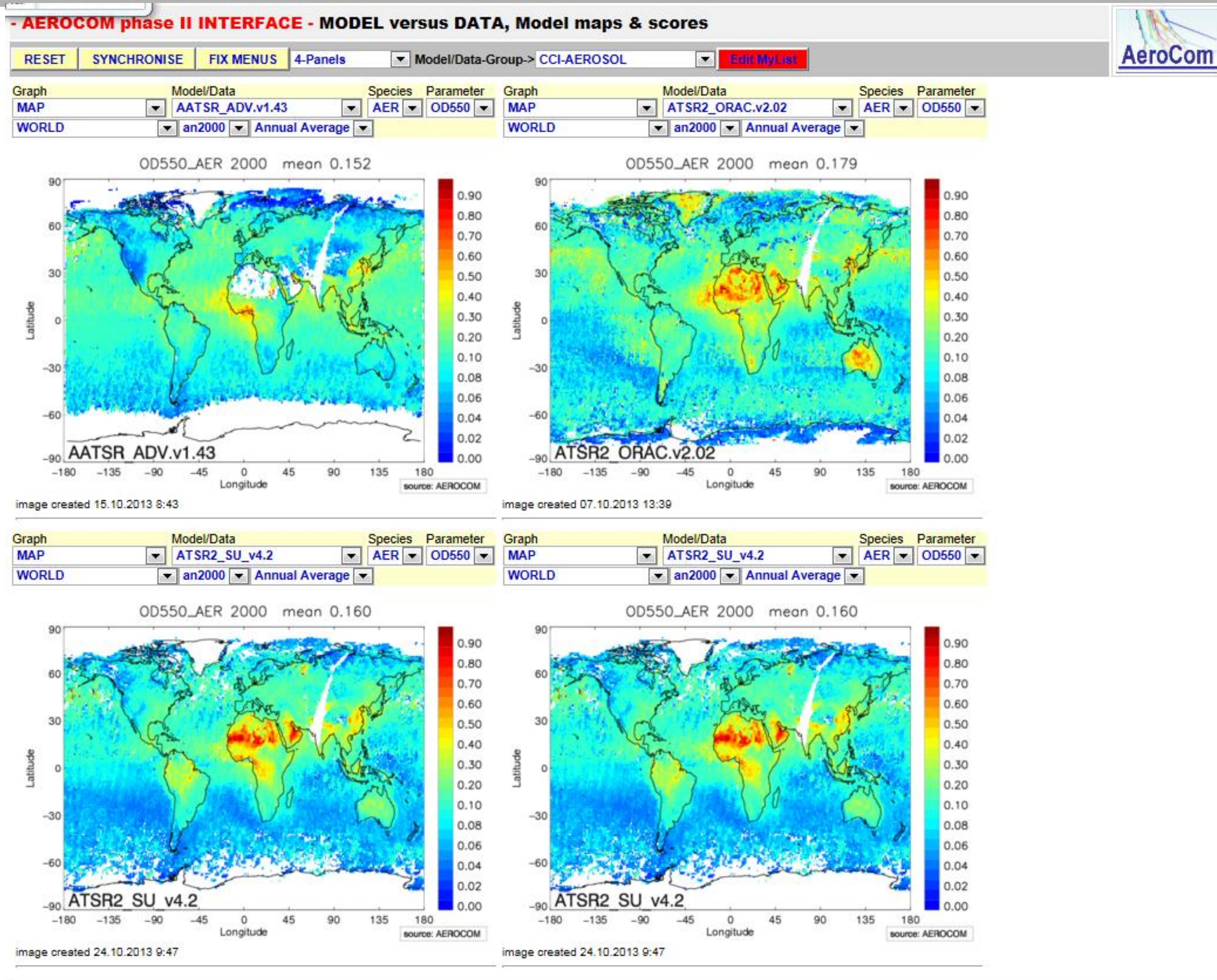
- Scores ATSR Swansea 4.0 versus Swansea 1.0 established against AERONET



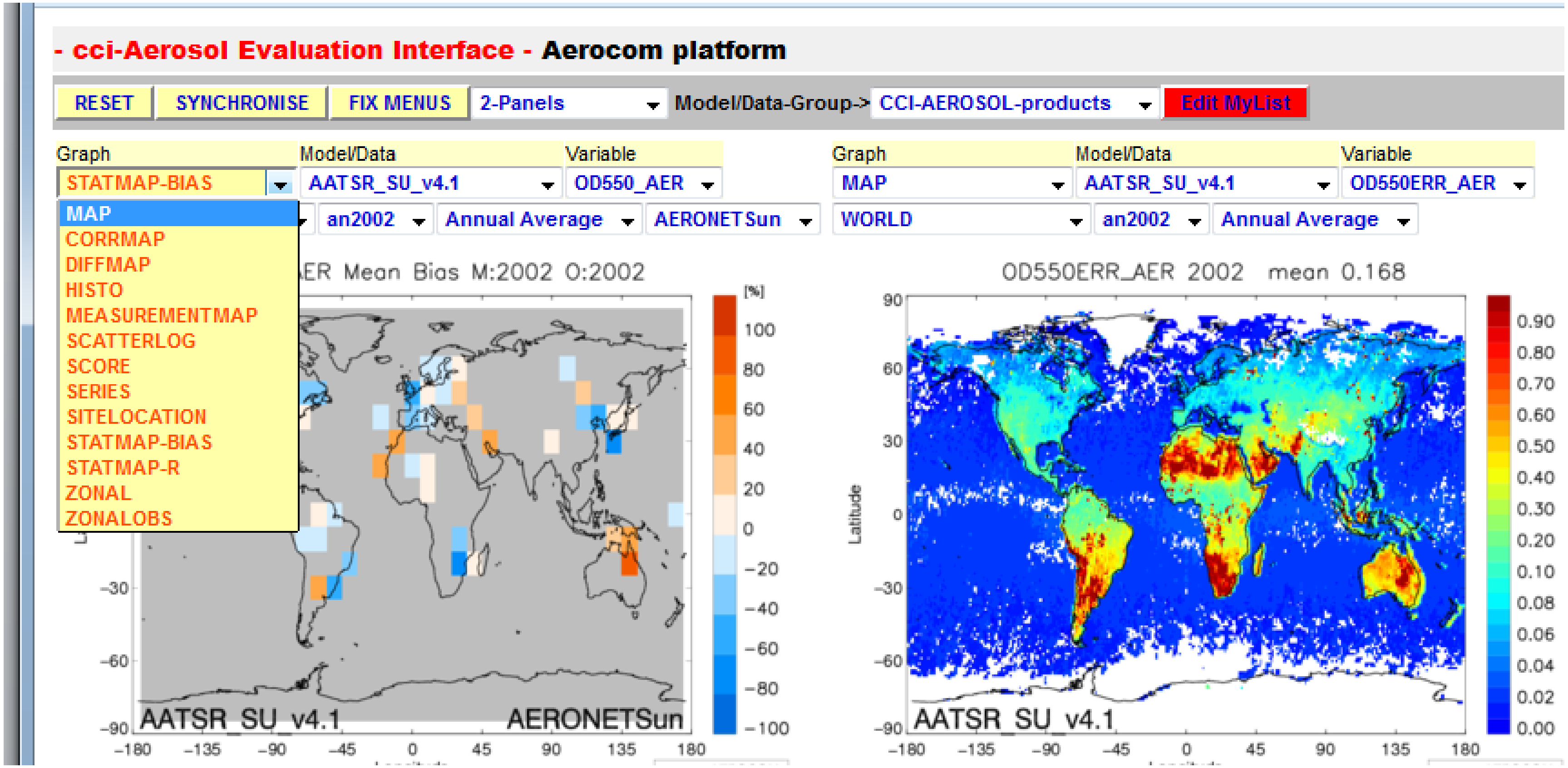
← **Better** **worse** →

AEROCOM interface

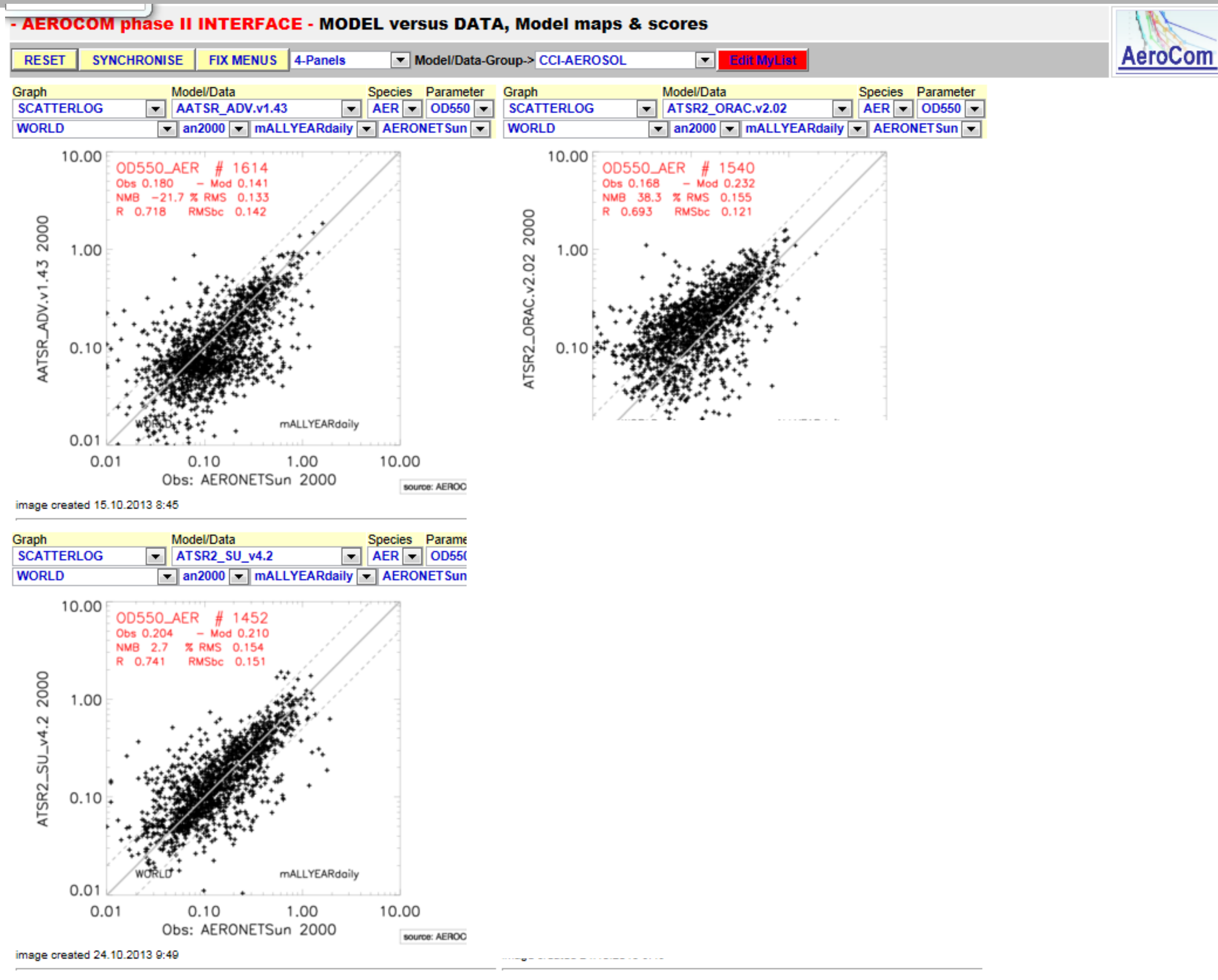
http://aerocom.met.no/cgi-bin/aerocom/surfobs_annualrs.pl?MODELLIST=CCI-AEROSOL-products



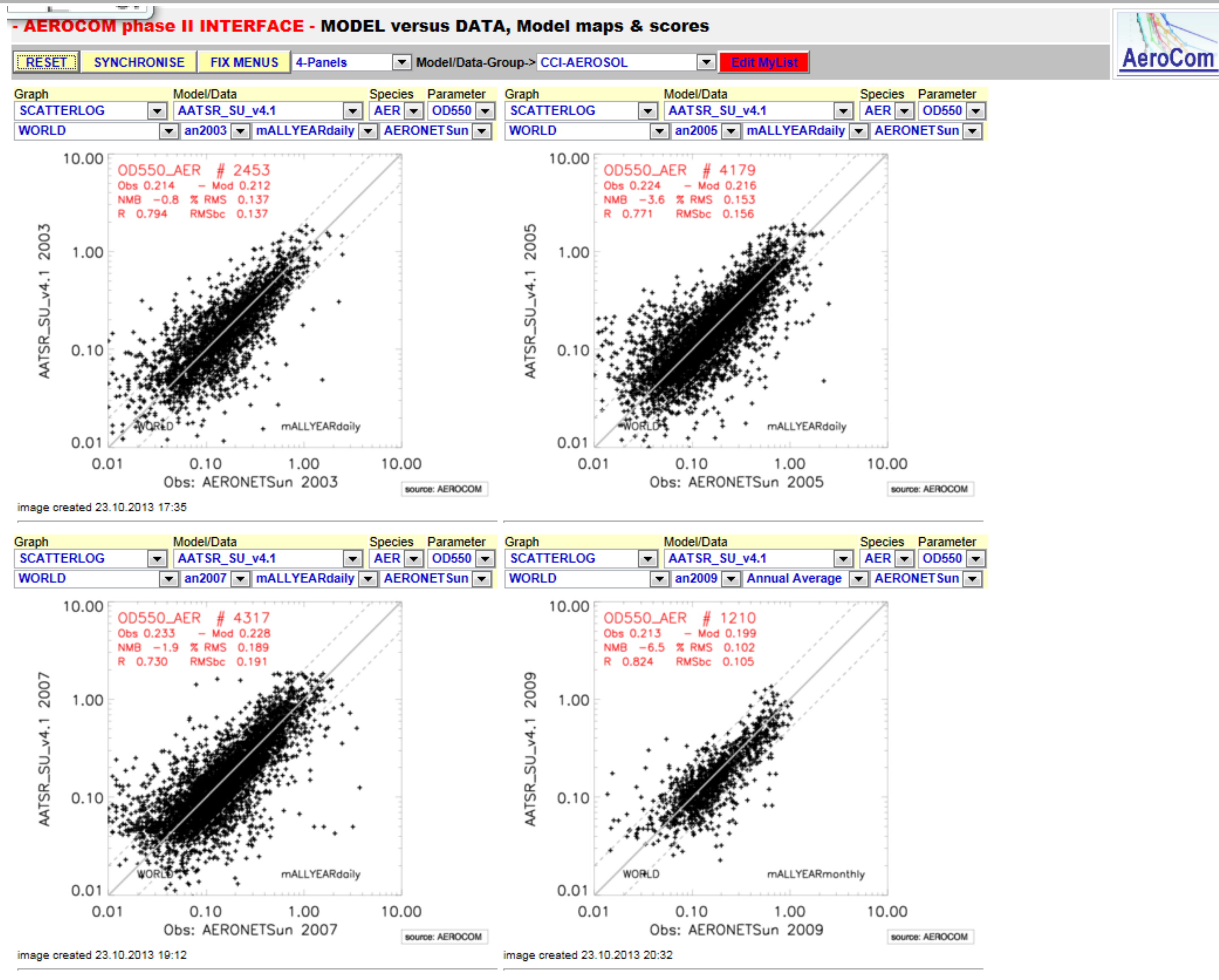
AEROCOM interface



AEROCOM interface



AEROCOM interface



Select algorithms: AATSR4Land
Common point filter

Algorithm name	NumObs #	R-CORR	RMS	NMB %	RMSbc
AATSR_ADV.v1.42	1394	0,822	0,102	-29,7	0,105
AATSR_ORAC.v2.02	1394	0,823	0,091	-9,4	0,091
AATSR_SU_v4.0	1394	0,863	0,081	-7,7	0,083
MISR_V31_1x1	276	0,856	0,085	-11,2	0,081
MODIS5.1aqua	1185	0,749	0,114	7,1	0,108
MODIS5.1terra	1285	0,744	0,114	1,5	0,113

- Common point filter reduces number of data points
- AATSR: in general high correlation, low RMS
- SU v4.0 has highest R, lowest RMS, better than all reference data sets
- All AATSR retrievals outperform MODIS5.1
- AATSR has significantly less coverage

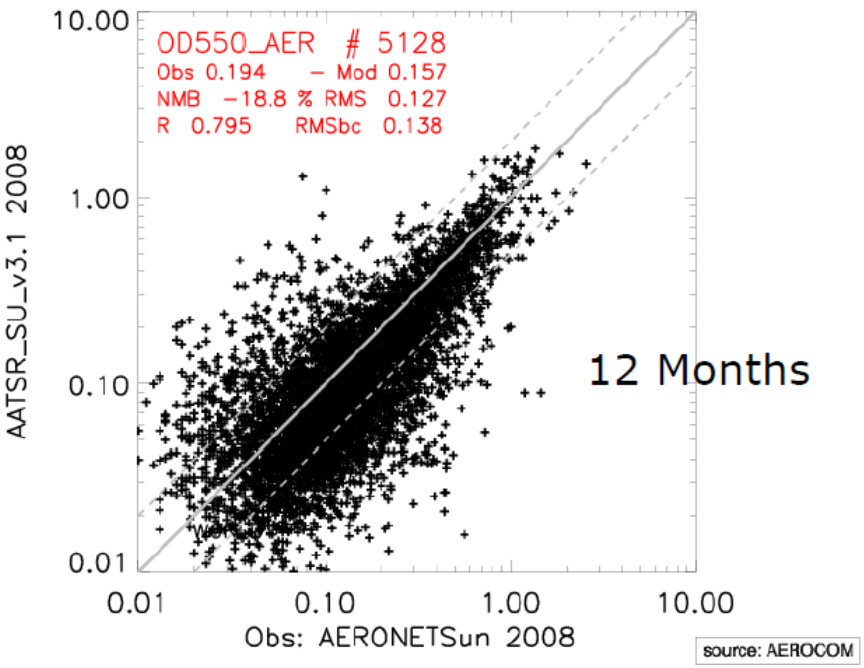
Lv3: AATSR4Sea
Common point filter

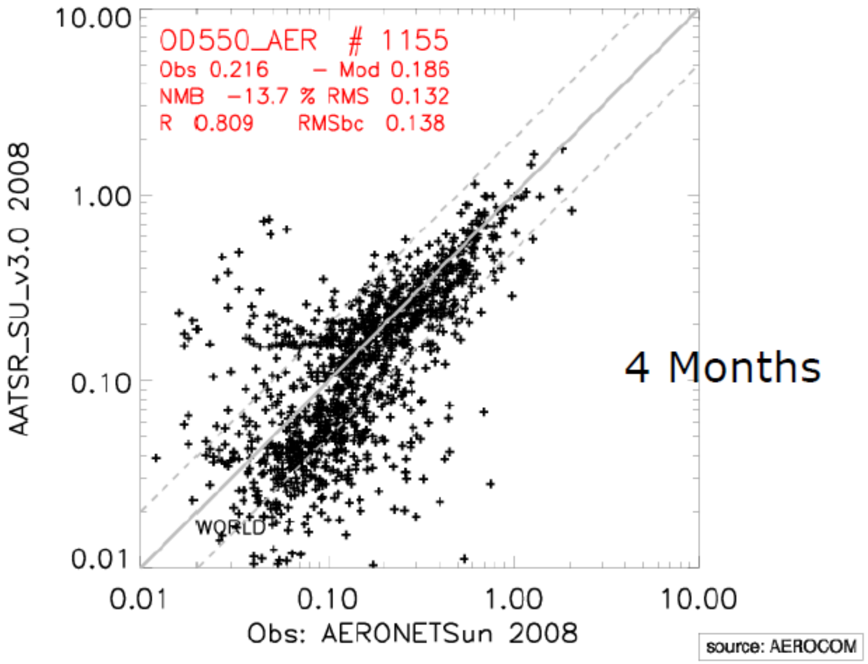
Algorithm name	NumObs	R-CORR	RMS	NMB	RMSbc
AATSR_ADV.v1.42	87	0,884	0,06	21,10	0,06
AATSR_ORAC.v2.02	87	0,889	0,09	17,90	0,06
AATSR_SU_v4.0	87	0,781	0,08	-11,50	0,08
MISR_V31_1x1	5	0,984	0,06	3,64	0,07
MODIS5.1aqua	64	0,916	0,05	4,79	0,05
MODIS5.1terra	57	0,905	0,05	1,39	0,05

- Low number of reference measurements!
- AATSR: in general high correlation, low RMS
- ADV1.42 and ORAC 2.02 have highest R
- AATSR retrievals are weaker than reference datasets

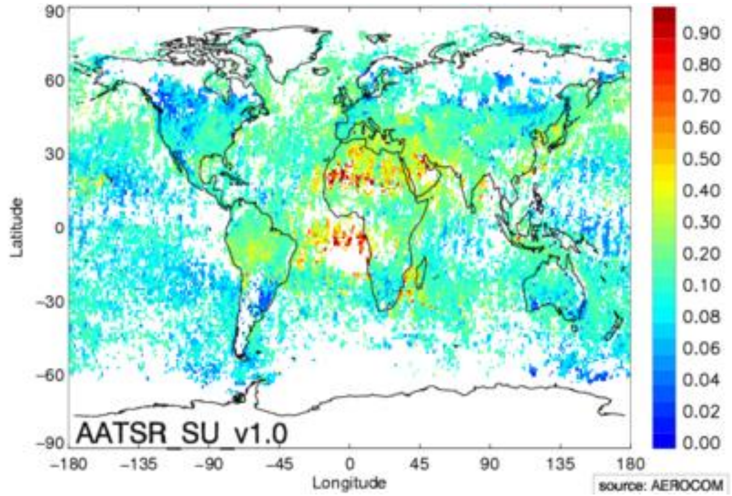
Was the 4 months analysis representative for the 12 months?

Model name	NumObs	R-CORR	RMS	NMB	RMSbc
AATSR_SU_v3.0	1155	0,809	0,132	-13,7	0,138
AATSR_SU_v3.1	5128	0,795	0,127	-18,8	0,138

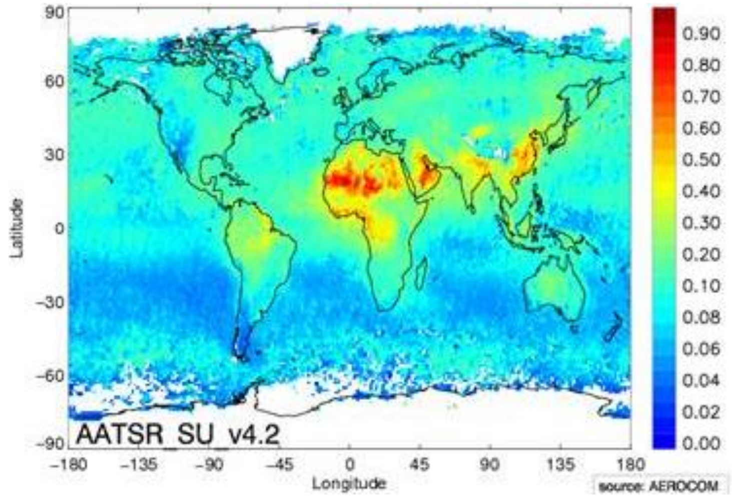




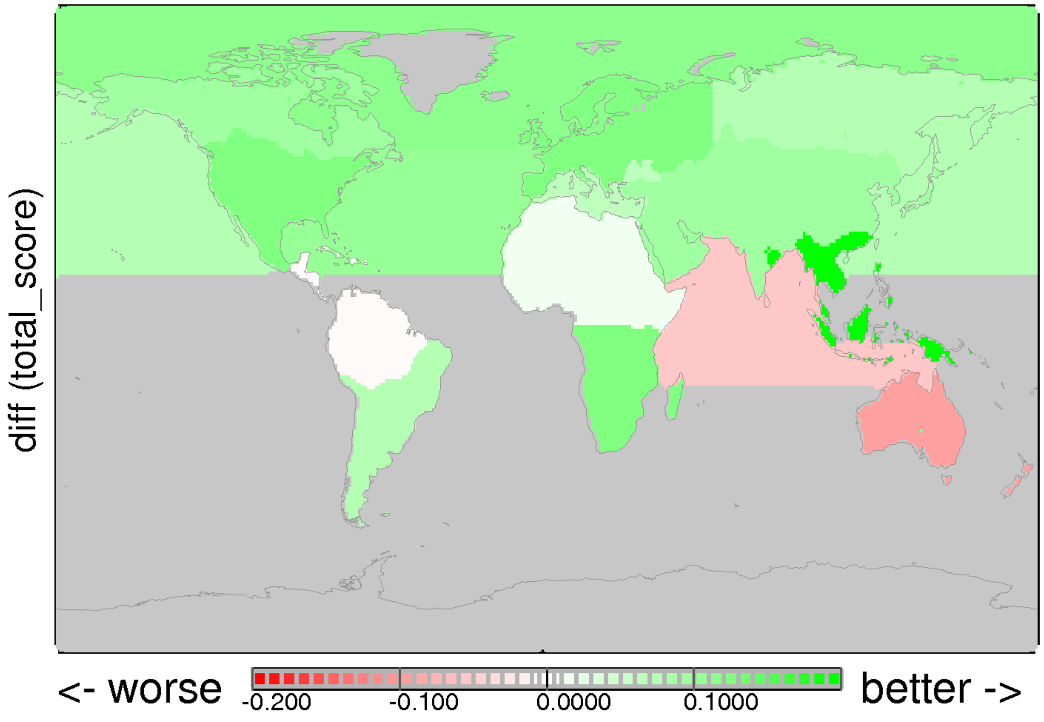
Major improvements over precursor AOD datasets



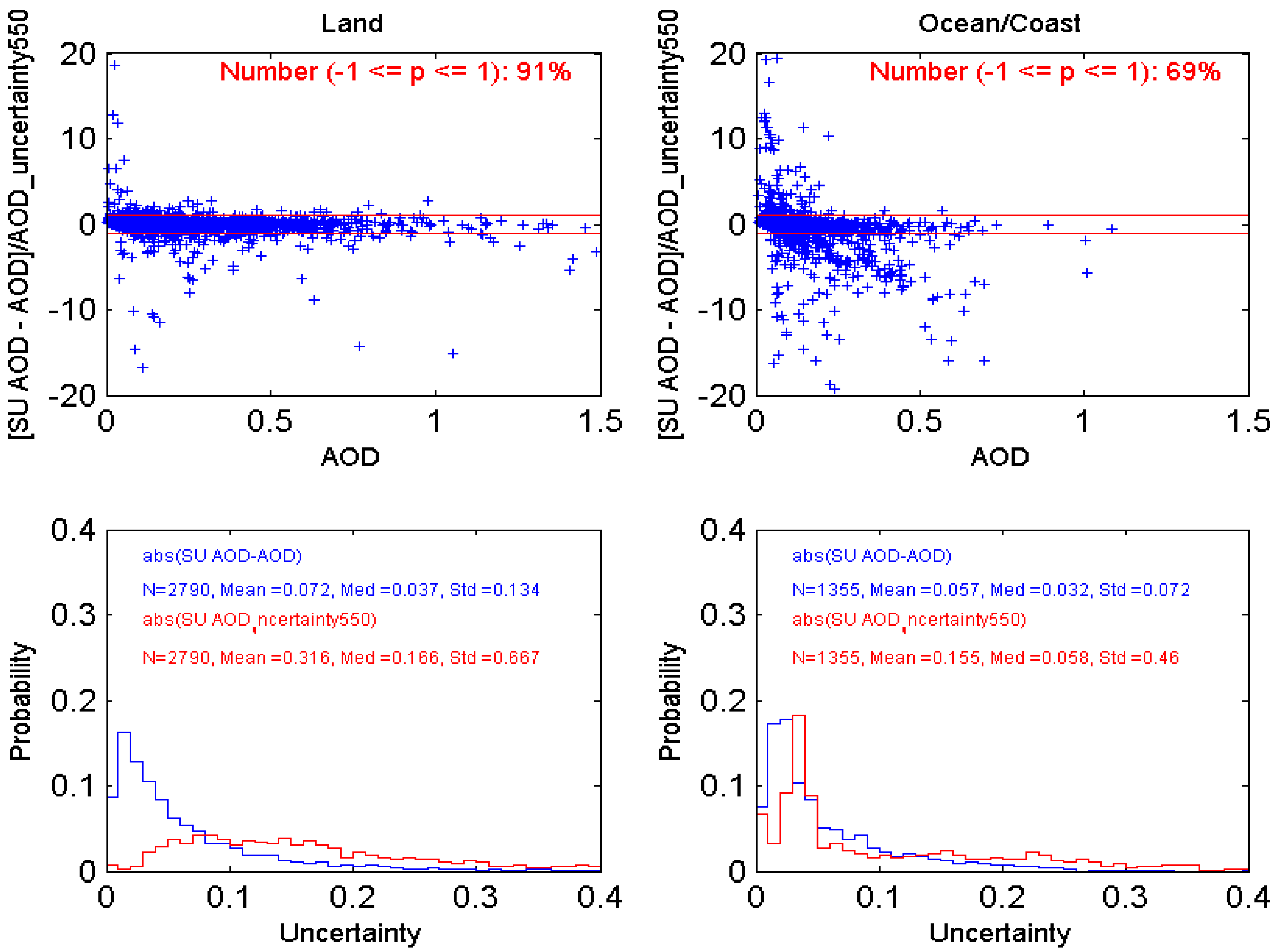
Precursor dataset
2008 Aerosol Optical Depth maps
Aerosol_cci final dataset



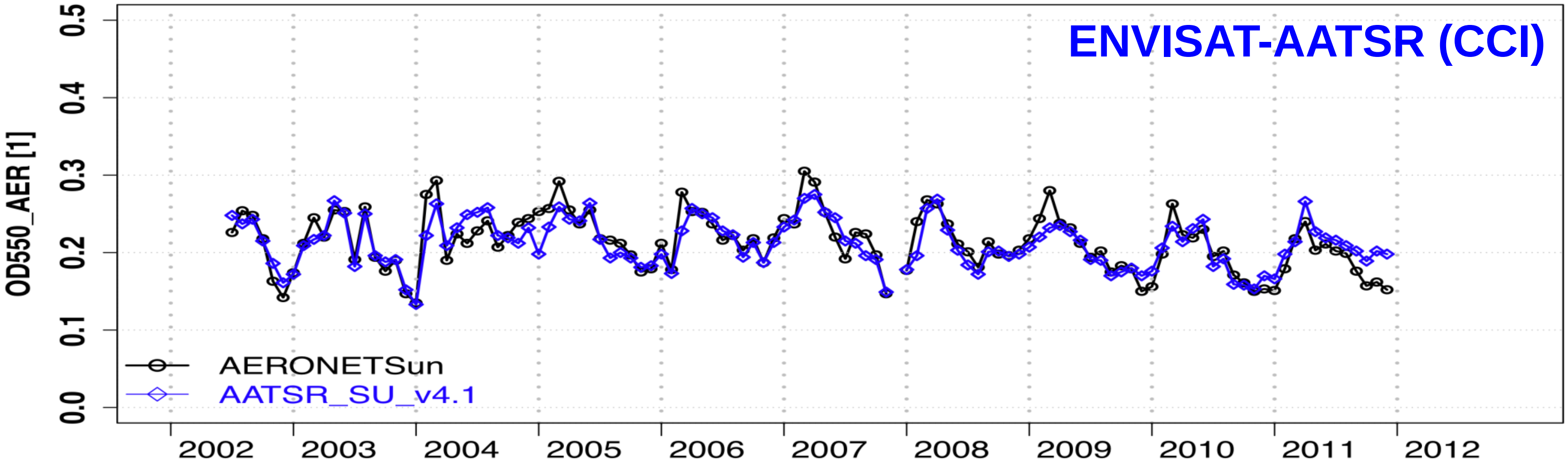
Regional scoring differences between both versions (scoring grows with increased spatial + temporal correlations and decreased bias; based on daily data)



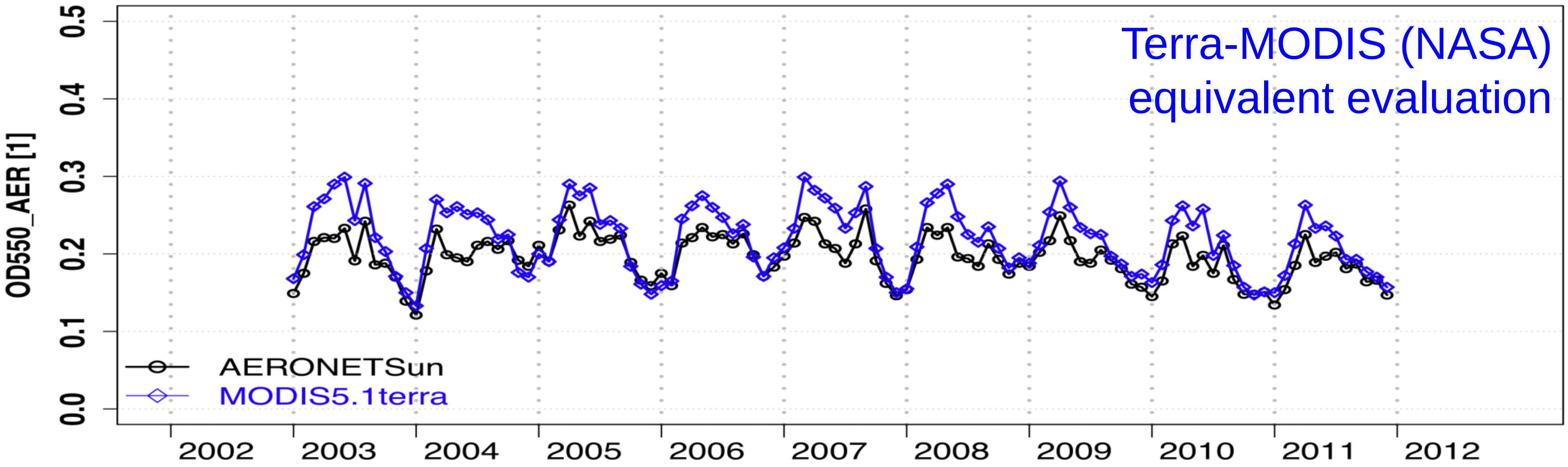
Pixel level uncertainties



Global AOD time series

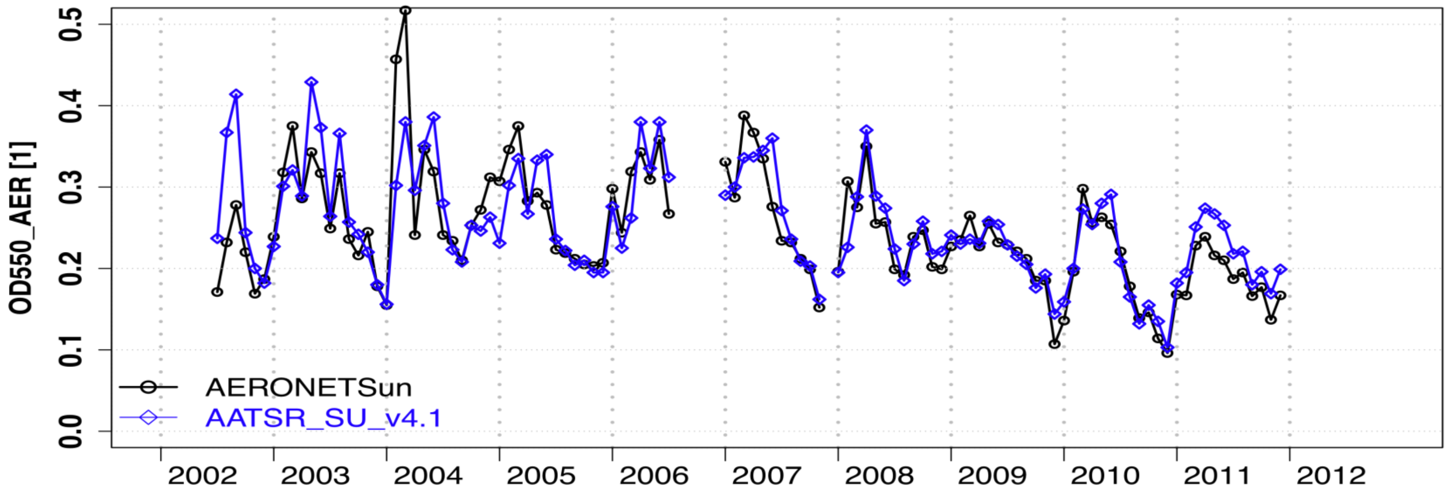


Evaluated against ~150 AERONET sun photometer surface sites

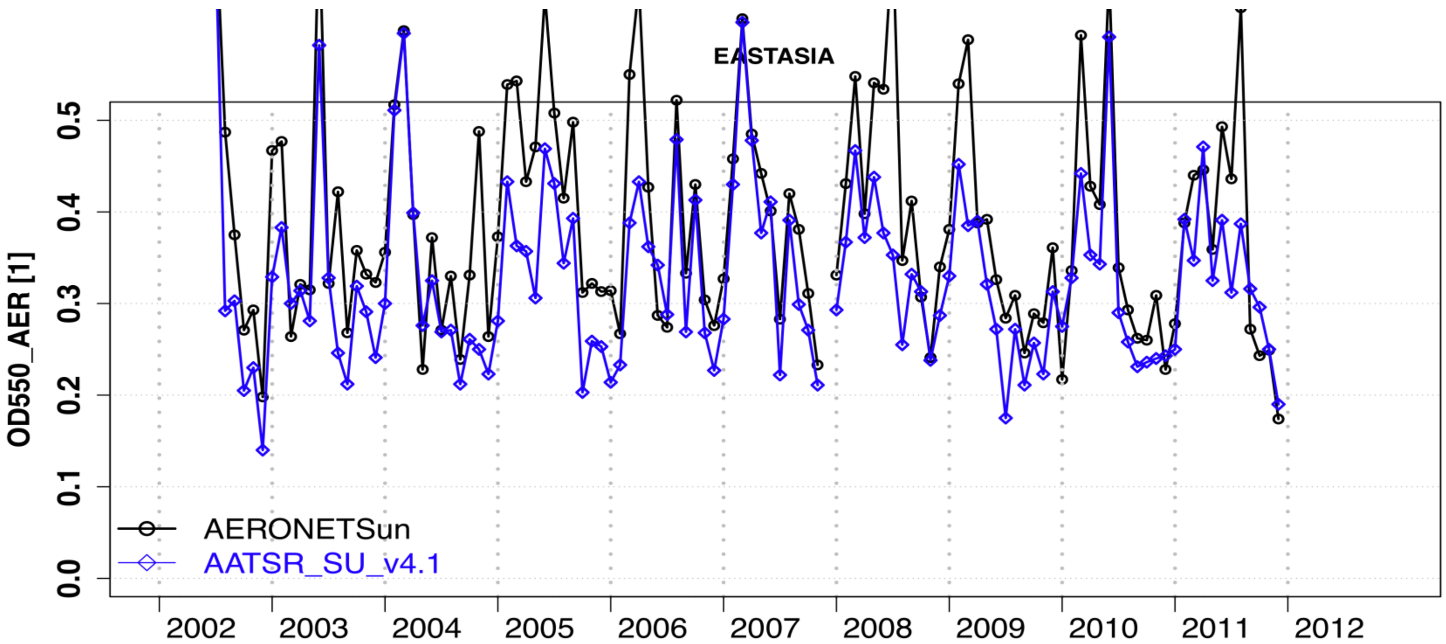


Regional time series

N Africa

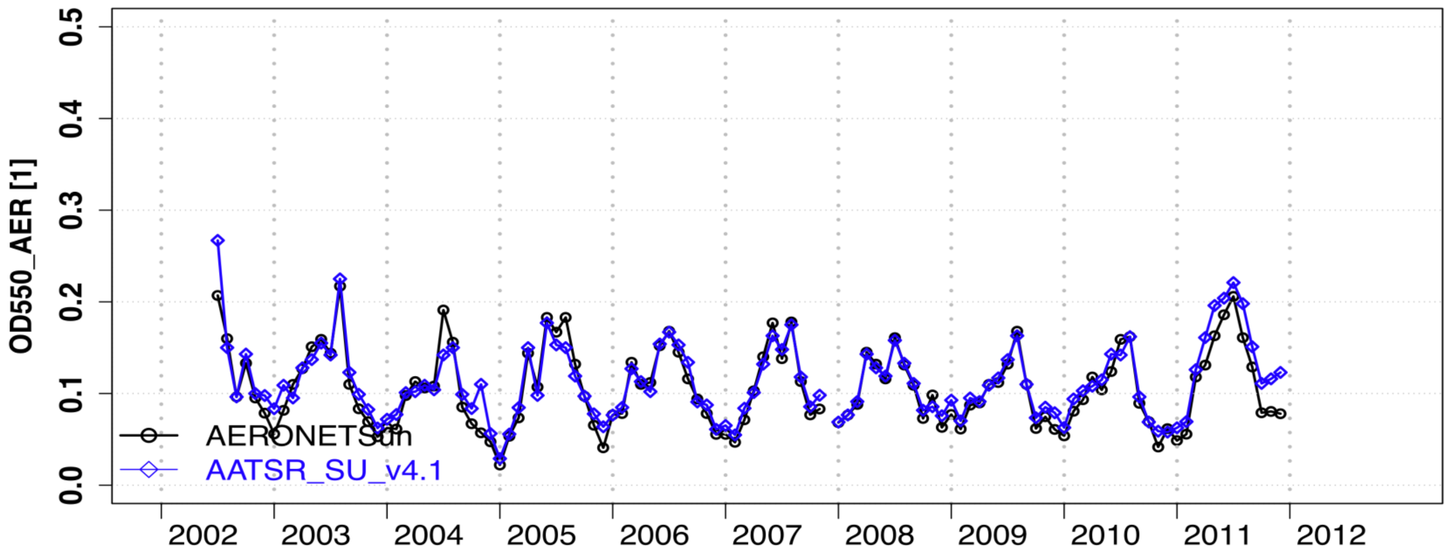


East Asia

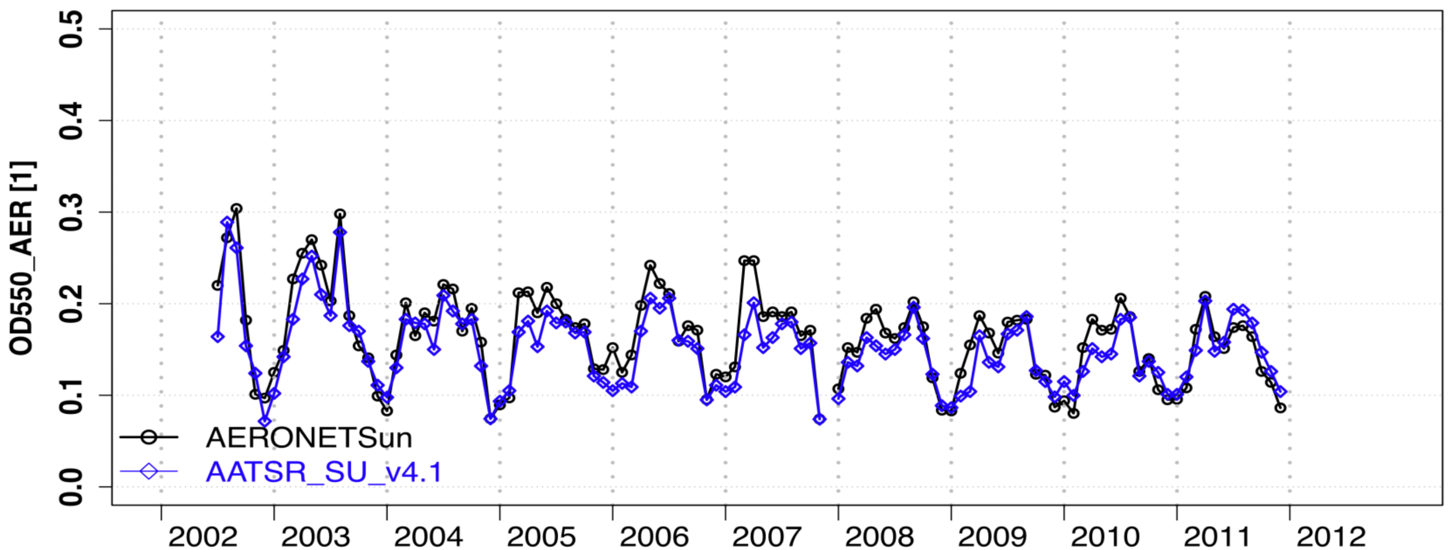


Regional time series

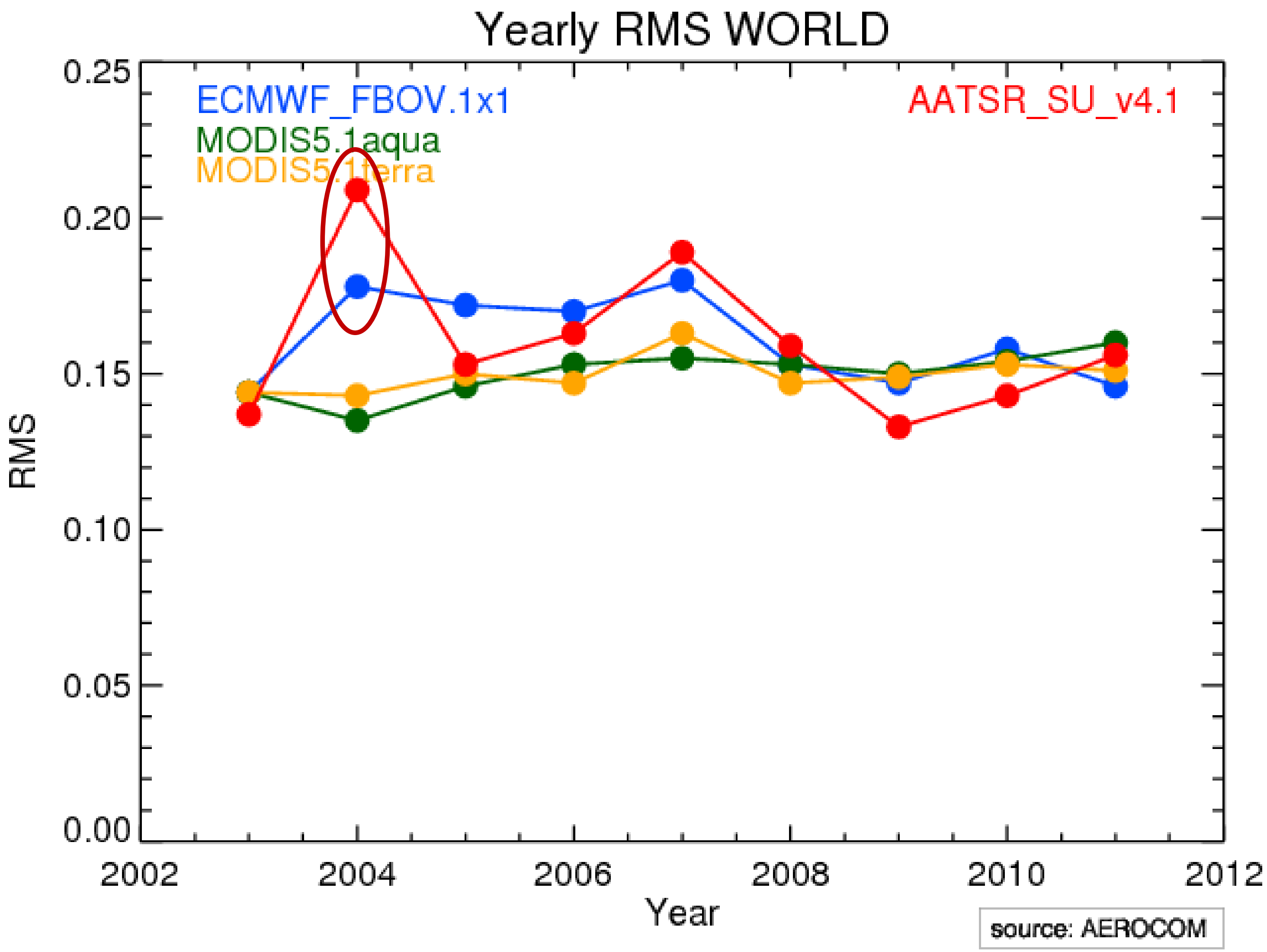
N America



Europe



Stability: RMS



Overall achievements

- Significant algorithm improvement towards GCOS requirements
  - Aerosol optical depth (AATSR; MERIS, PARASOL ocean)
  - Stratospheric extinction (GOMOS)

- AATSR time series 2003 – 2012 consistent with AERONET

- Improved product content and auxiliary information
  - Individual pixel-level uncertainties in products
  - Consistency with Cloud_cci
  - Model simulator for absorbing aerosol index

(Initial) product assessment

- Activity:
  - ECMWF / MACC-II planned data assimilation (early 2014)
  - Inter-comparison to other satellites, models
  - Example aersosol-cloud interaction study at DLR
- Problems
  - Limited length of ECV datasets

Lessons learned (1)

- critical mass of experts / open exchange on problems and solutions highly beneficial; including active involvement of users
- 3 steps meaningful to consolidate discussions into improved datasets
- round robin exercise: statistical significance with four months of global data (in 4 seasons); seasonal + regional analysis needed
- prototype system “near science” ensures flexibility for changing user requirements, algorithm, analysis tools

Lessons learned (2)

- 3 AATSR algorithms performing almost equal -> combination needs further investigation (uncertainty-weighted ensemble, combination over different regions) – requires harmonized uncertainties
- Uncertainties demonstrated but need further consolidation and harmonization
- Aerosol type information (Ångström exponent, mixing fractions, pre-scribed aerosol type, absorption AOD) needs further work - highly relevance for applications (e.g. aerosol-cloud interaction)
- Further work needed on surface treatment (nadir algorithms), cloud clearing
- different AOD algorithms and instruments valuable to show uncertainties

Aerosol_cci products main advantages

- accuracy
  - Very high: PARASOL over ocean and 3 AATSR algorithms
- Coverage
  - ATSR-2 + AATSR enable time series 1995 – 2012
- Information content
  - Very high for PARASOL, good for AATSR
  - Absorption qualitative with absorbing index
  - Vertical with stratospheric product
- General
  - 3 year intensive team dialogue /efforts improved data
  - Significant improvement against baseline algorithms
  - Similar quality to MODIS / MISR over land
  - Pixel level uncertainties / quality indices
- Documentation at Aerosol_cci website

Information + data

Documentation freely available at

http://www.esa-aerosol-cci.org/

Public open data access at

http://www.icare.univ-lille1.fr/archive/index.php?dir=CCI-Aerosols/

(user: cci / password: cci)

with acknowledgement to ESA CCI program

Aerosol_cci Phase 2
Proposed products 2014/15

Parameter	Sensor (Algorithms)	Coverage (planned) - status
AOD, up to 4 wavelengths	ATSR-2 + AATSR (ADV, SU, ORAC)	1995 – 2012
	AATSR / MERIS	2003 - 2012
	PARASOL	1996, 1998, 2006 – 2015 (selected land regions)
	SYNAER	2003 - 2012
Dust AOD	IASI	2006 - 2015
Stratospheric extinction, AOD, size parameter	GOMOS	1984 - 2005
	SAGE-II, ODIN, OSIRIS, GOMOS	2003 – 2012
Sentinel demo datasets	SLSTR AOD TROPOMI AAI	2015

All products contain pixel level uncertainties

AEROSAT
International Satellite Aerosol Science Network

AEROSAT

- unfunded, open, independent, international network of aerosol remote sensing scientists (retrieval experts, validation experts, data centers) and users of satellite data
- close collaboration with related initiatives: AEROCOM (models), ICAP (forecasts) and AERONET (sun photometers)
- Goals
  - promote the use of satellite data
  - achieve open and active exchange of information

AEROSAT goals

- **promote the use of satellite data**
  - as **complementary** to other sources of information
  - to better understand the role of aerosols on climate, climate change, air quality and atmospheric processes
- **achieve open and active exchange of information**
  - retrievals and their strengths and limitations
  - match requirements of users to technical capabilities
  - benefit from the latest technological advances
  - standardization (data formats, data standards)

aero-sat.org

AERO-SAT

International Satellite Aerosol Science Network

Information on the occurrence and properties of atmospheric aerosol is of crucial importance for climate and atmospheric research, numerical weather prediction and air quality monitoring. Satellite retrieval of aerosol properties, together with ground-based in-situ and remote sensing, and atmospheric models, are the essential tools used to provide aerosol information.

The **International Satellite Aerosol Science Network (a.k.a. AERO-SAT)** is an initiative to help strengthen collaboration between different research groups around the world working on satellite aerosol retrieval. The AERO-SAT constituting meeting took place in Hamburg (Germany), on 27 September 2013, in association with the 10th annual AeroCom meeting. The terms of reference, contact points and network participants are provided in the pages below.

AERO-SAT is an unfunded activity intended to be of mutual benefit to the scientific work of the network participants.

Objectives

To:

- Advance satellite aerosol retrieval research and product development by providing a mechanism to promote and facilitate international scientific collaboration.
- Federate the satellite aerosol community to provide a more powerful collective voice towards the ecosystem of international projects, funding agencies and space agencies
- Coordinate scientific activities of mutual benefit (*e.g.* intercomparisons, common definitions, common tools, common formats, etc.)
- Stimulate communication and coordination between producers of satellite information on aerosol properties and the global user community.
- Identify best practice in retrieval development
- Promote the long term continuity of satellite aerosol data set production
- Encourage the open exchange of satellite, model and *in-situ* aerosol data streams, and harmonized access for users
- Help users to understand the strengths and weaknesses of different satellite aerosol products by promoting activities to intercompare data sets

Next Meeting

We aim to hold the next AERO-SAT meeting once again in cooperation with the AeroCom meeting in September 2014 in the USA (tbc).

Terms of Reference
Chairs and Participants
Meetings

Contact

THANK YOU FOR ATTENTION!