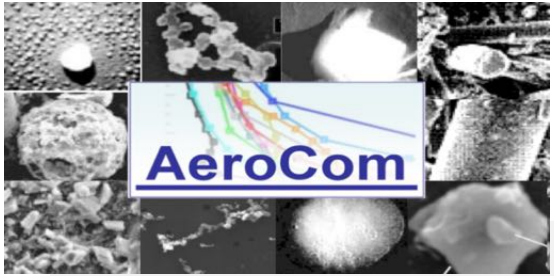

AeroCom - Aerosol model intercomparison overview …with an emphasis on dust

Michael Schulz
Norwegian Meteorological Institute

Meteorologisk institutt

AeroCom =
Aerosol comparisons of models and observations

AeroCom is an open international initiative of scientists interested in the advancement of the understanding of global aerosol properties and aerosol impacts on climate, weather, and air quality. **A central goal is to more strongly tie and constrain modeling efforts to observational data from satellite, ground-based, and aircraft observations.**

A major element for exchanges between data and modeling groups are annual meetings of AeroCom together with the satellite data oriented initiative AeroSAT.

In addition to the comparisons among models and between models and data, **AeroCom initiates and coordinates model experiments to target particular research topics, leading to joint research papers of synthesizing character**. **A common database is maintained at the Norwegian Meteorological Institute to facilitate joint scientific exploration**.

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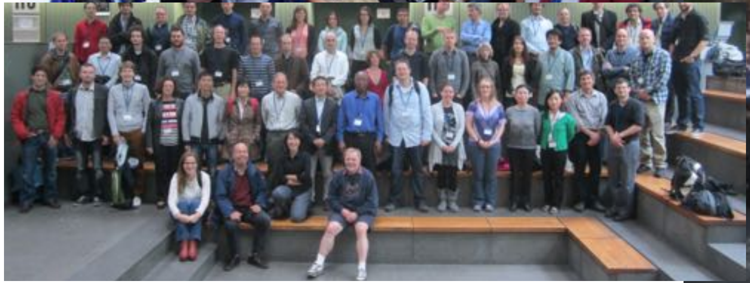
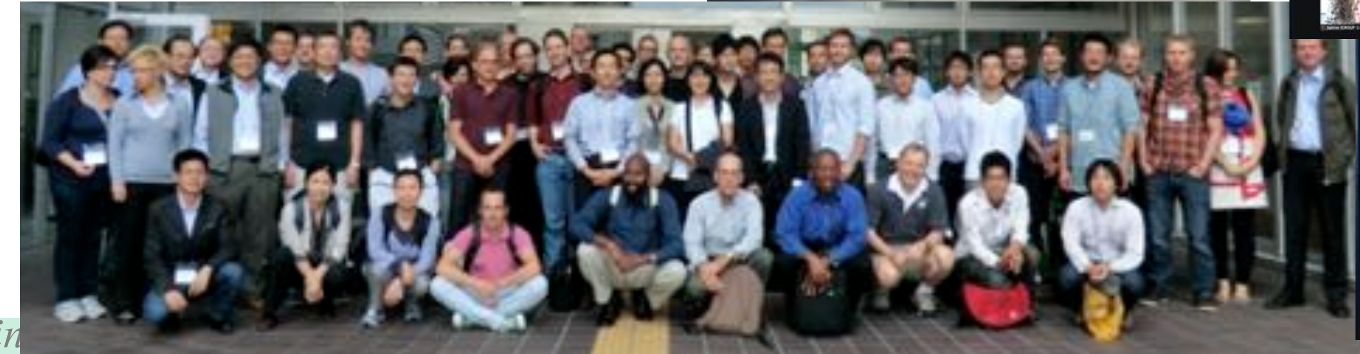
ICOS
DYNAMICUM


外国专家大厦
FOREIGN EXPERTS BUILDING


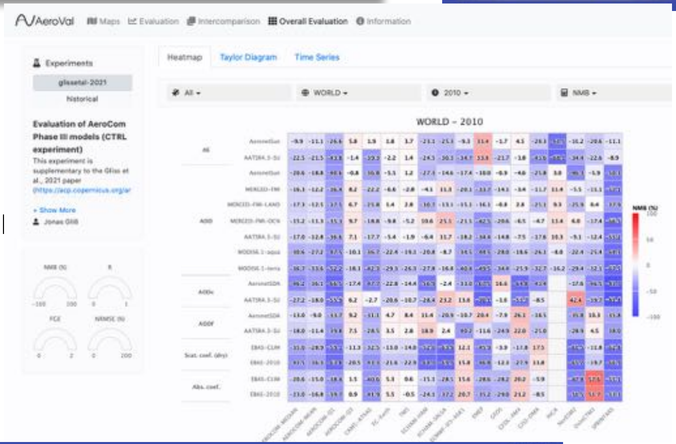

青木一真 Kazuma_...
Xiaohua

37° N
Rob


AeroCom infrastructure

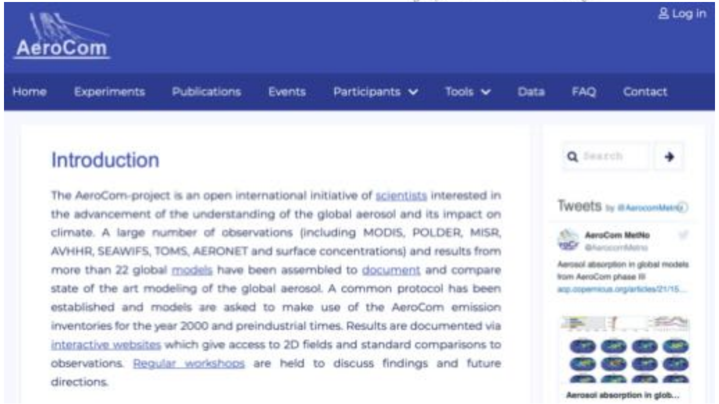
- AeroCom database and AeroCom user server
  (50 TB of model data, 300 registered users)

- New AeroCom aeroval web interface
  showing e.g. 2019 control Gliss et al ACP 2021, historical simulatio
  https://aeroval.met.no/evaluation.php?project=aerocom



- aerocom.met.no website

- Email list, annual meetings, joint publications, SSC



Recent joint Publications AeroCom 2019/2020/2021

Google scholar search on "aerocom aerosol" + (2019+2020+2021) => 1240 items

AeroCom

AeroCom models

Sand et al. Aerosol absorption in global models from AeroCom Phase III, ACP, 2021
Su et al. Understanding top-of-atmosphere flux bias in the AeroCom phase III models: A clear-sky perspective, James, 2021
Brown et al. Biomass burning aerosols in most climate models are too absorbing. Nat Comm 2021
Schutgens et al. AEROCOM and AEROSAT AAOD and SSA study – Part 1: Evaluation and intercomparison of satellite measurements , ACP 2021
Gliss et al. Multi-model evaluation of aerosol optical properties in the AeroCom phase III Control experiment, ACP, 2021
Schutgens et al. An AeroCom/AeroSat study: Intercomparison of Satellite AOD Datasets for Aerosol Model Evaluation, ACP, 2020
Myhre et al. Cloudy-sky contributions to the direct aerosol effect, ACP, 2020
Burgos et al. A global model–measurement evaluation of particle light scattering coefficients at elevated relative humidity , ACP, 2020
Laj et al, Global analysis of climate-relevant aerosol properties retrieved from Global Atmosphere Watch (GAW) near-surface observatories AMT 2020
Kim et al, Asian and Trans-Pacific Dust: A Multimodel and Multiremote Sensing Observation Analysis, JGR Atm, 2019

Aerocom & CMIP6 models

Mortier et al. Evaluation of climate model aerosol trends with ground-based observations over the last two decades – AeroCom + CMIP6 analysis , ACP, 2020
Gryspeerdt et al. Surprising similarities in model and observational aerosol radiative forcing estimates,ACP 2020
Bellouin et al. Bounding Global Aerosol Radiative Forcing of Climate Change Rev Geo Phys, 2020

CMIP6 models

Smith et al. Energy budget constraints on the time history of aerosol forcing and climate sensitivity. JGR, 2021
Smith et al. Effective radiative forcing and adjustments in CMIP6 models , ACP, 2020
Thornhill et al. Climate-driven chemistry and aerosol feedbacks in CMIP6 Earth system models , ACP, 2020
Thornhill et al. Effective Radiative forcing from emissions of reactive gases and aerosols – a multimodel comparison , ACP, 2020
Moseid et al. Bias in CMIP6 models compared to observed regional dimming and brightening trends (1961–2014), ACP, 2020
Allen et al. Climate and air quality impacts due to mitigation of non-methane near-term climate forcers , ACP, 2020
Zanis et al. Fast responses on pre-industrial climate from present-day aerosols in a CMIP6 multi-model study , ACP, 2020
Wilcox et al. Accelerated increases in global and Asian summer monsoon precipitation from future aerosol reductions, ACP, 2020
Turnock et al. Historical and future changes in air pollutants from CMIP6 models , ACP, 2020

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Acknowledgment

AeroCom SSC: Stefan Kinne, Mian Chin, Kostas Tsigaridis, Bjørn Samset, Gunnar Myhre, Duncan Watson-Parris, Yves Balkanski, Michael Schulz

WG leads: Wenying Su, Nick Schutgens, Betsy Andrews, Gunnar Myhre, Paul Ginoux, Dongchul Kim, Hongbin Yu, Mian Chin, Duncan Watson-Parris, Huisheng Bian, Florent Malavelle, Daniel Partridge, Maria Sand, Lindsay Lee, Xiaohua Pan

Website, Web interface, AeroCom user server, email list, AeroCom database, pyaerocom
Anna Benedictow, Augustin Mortier, Jan Griesfeller, Jonas Gliss

Some recent results on dust…

Comparison to AOD and coarse mode AOD Aeronet
Inspection of trends
Absorption optical depth due to dust
Process uncertainty in dust cycle
Size distribution of dust revisit
Climate-dust feedback

AeroCom control
Gliss et al 2021

https://aeroval.met.no/overall.php?project=aerocom

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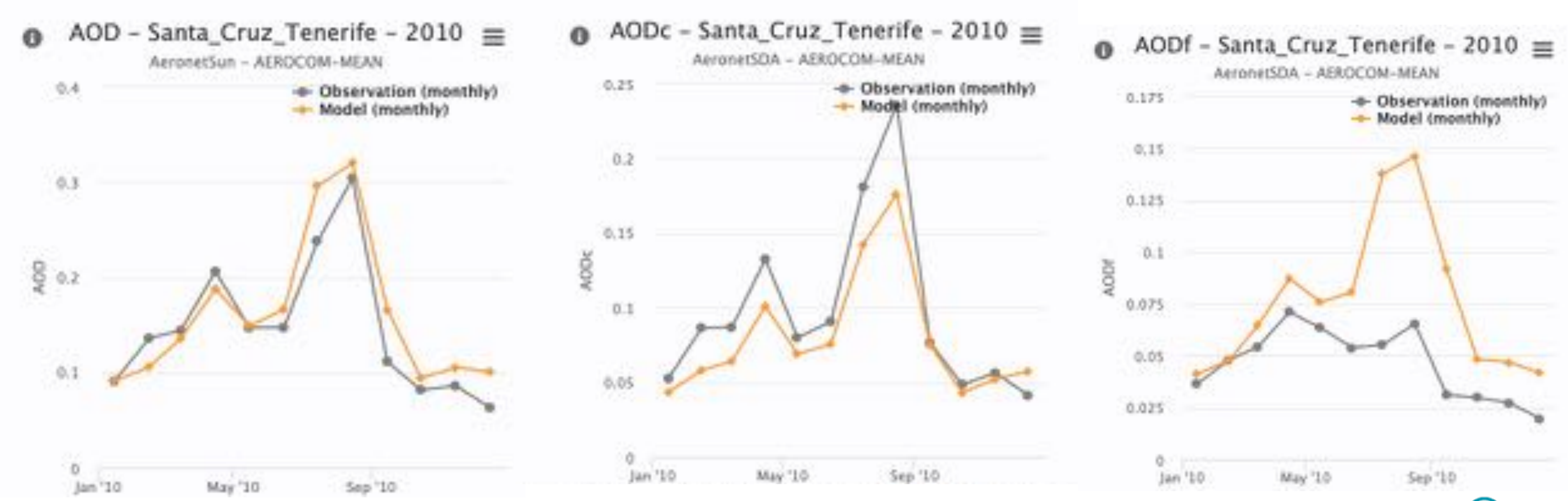
AOD total, coarse, fine in Tenerife

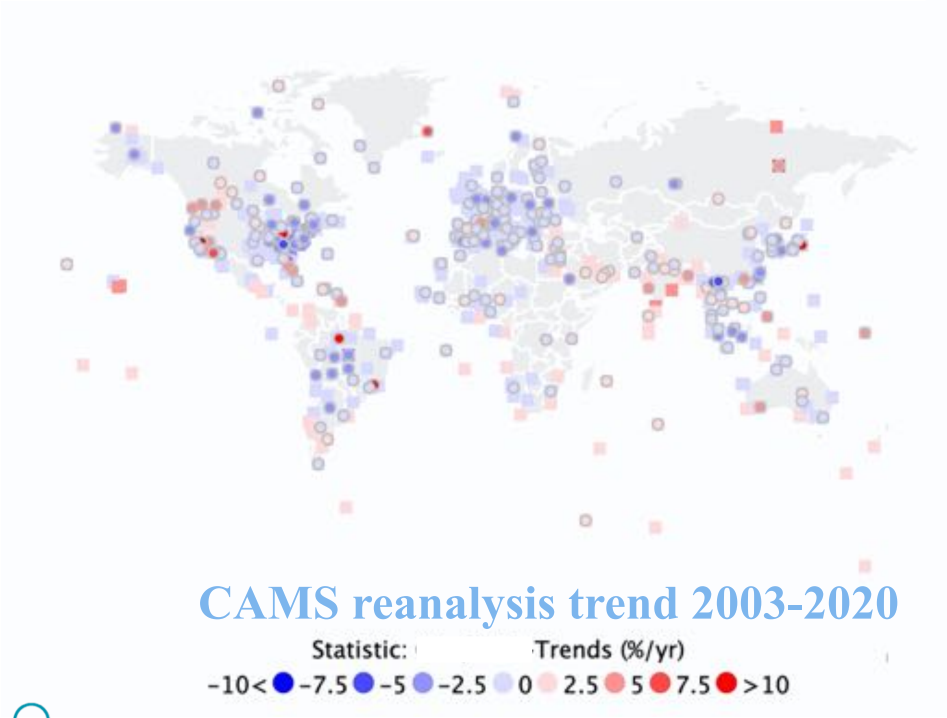


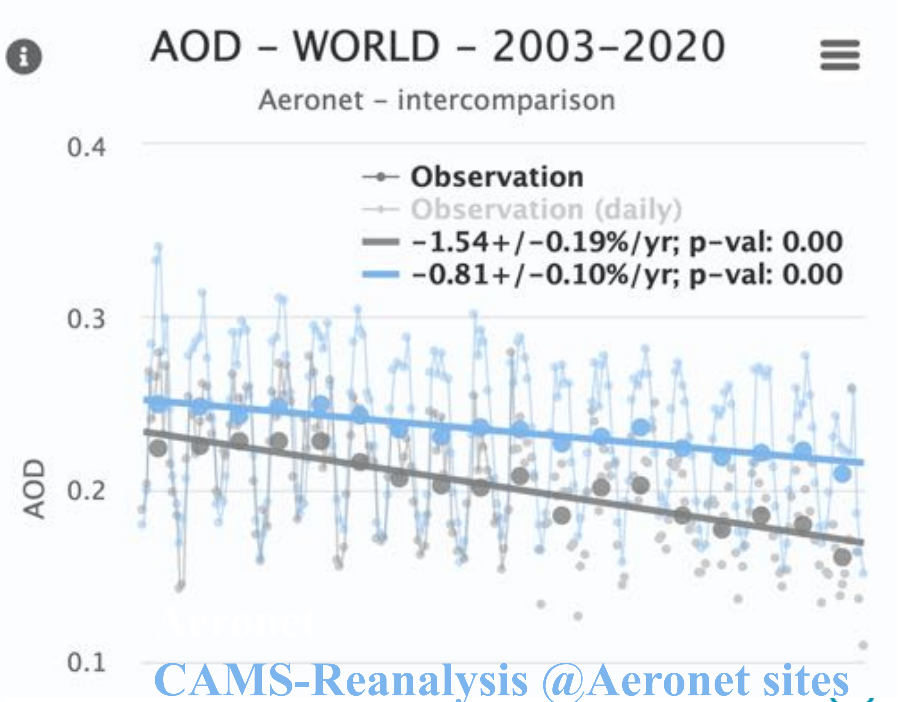
AeoCom mean versus Aeronet (from aeroval.met.no interface)

AeroCom control historical trend evaluation last decades since 2000

https://aeroval.met.no/overall.php?project=aerocom

From aeroval Aerocom web interface to model evaluation of trends (work in progress)





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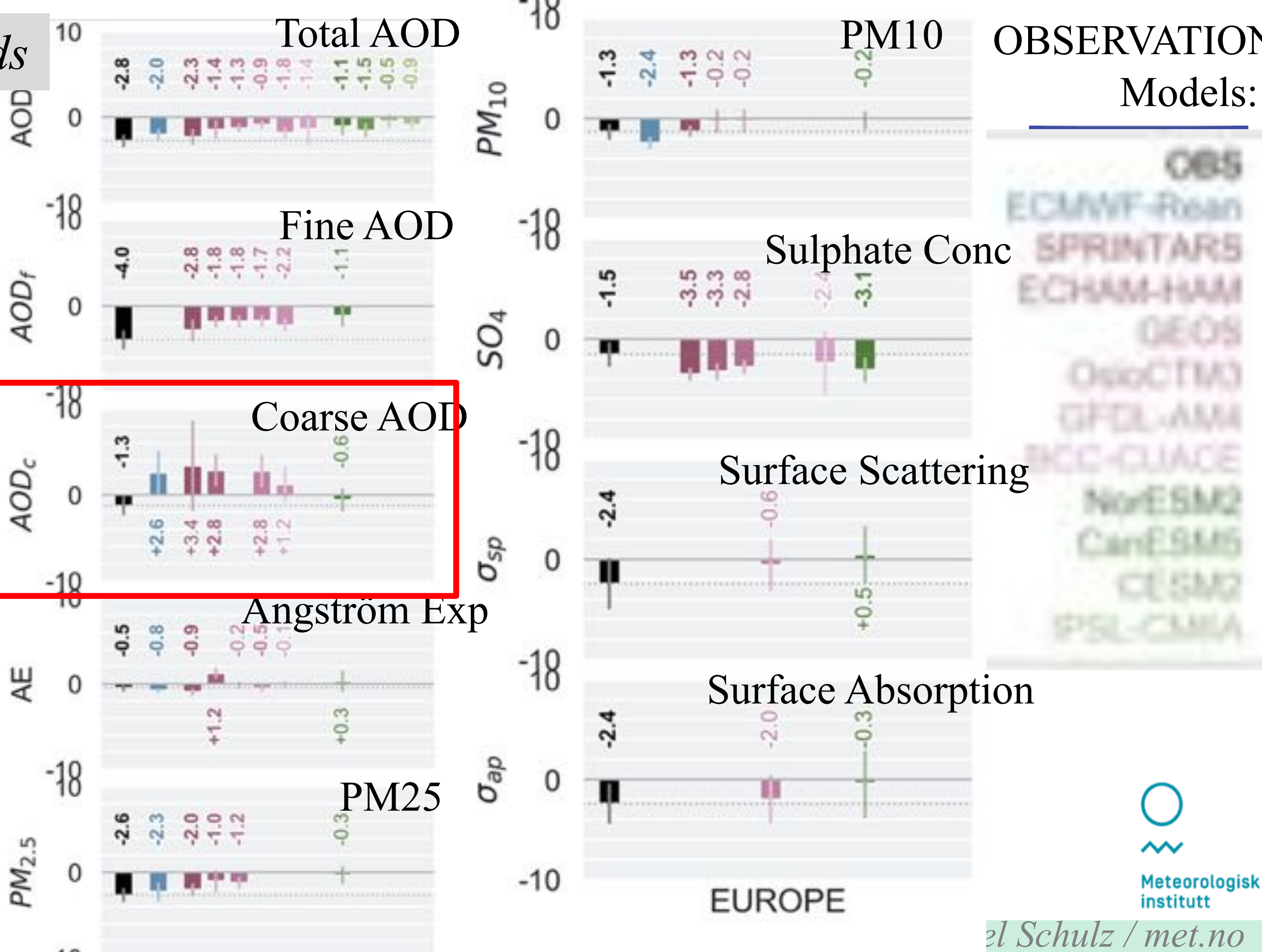
Recent aerosol trends

European trends 2000-2014 in Reanalysis & AeroCom & CMIP6 and Observations

[%/y]



Mortier et al. ACP 2020

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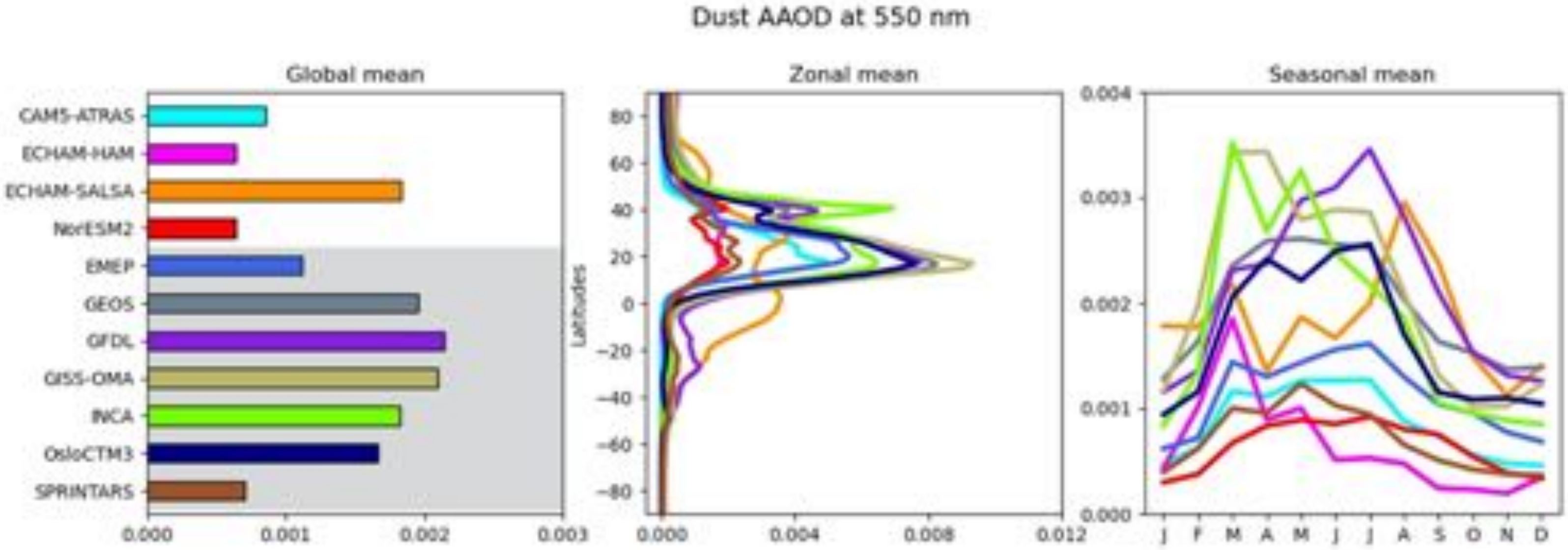
Dust absorption optical depth



Atmos. Chem. Phys., 21, 15929–15947, 2021
https://doi.org/10.5194/acp-21-15929-2021

Atmospheric Chemistry and Physics
Open Access
EGU

Aerosol absorption in global models from AeroCom phase III

Maria Sand[1], Bjørn H. Samset[1], Gunnar Myhre[1], Jonas Gliß[2], Susanne E. Bauer[3,4], Huisheng Bian[5,6], Mian Chin[6], Ramiro Checa-Garcia[7], Paul Ginoux[8], Zak Kipling[9], Alf Kirkevåg[2], Harri Kokkola[10], Philippe Le Sager[11], Marianne T. Lund[1], Hitoshi Matsui[12], Twan van Noije[11], Dirk J. L. Olivié[2], Samuel Remy[13], Michael Schulz[2], Philip Stier[14], Camilla W. Stjern[1], Toshihiko Takemura[15], Kostas Tsigaridis[4,3], Svetlana G. Tsyro[2], and Duncan Watson-Parris[14]

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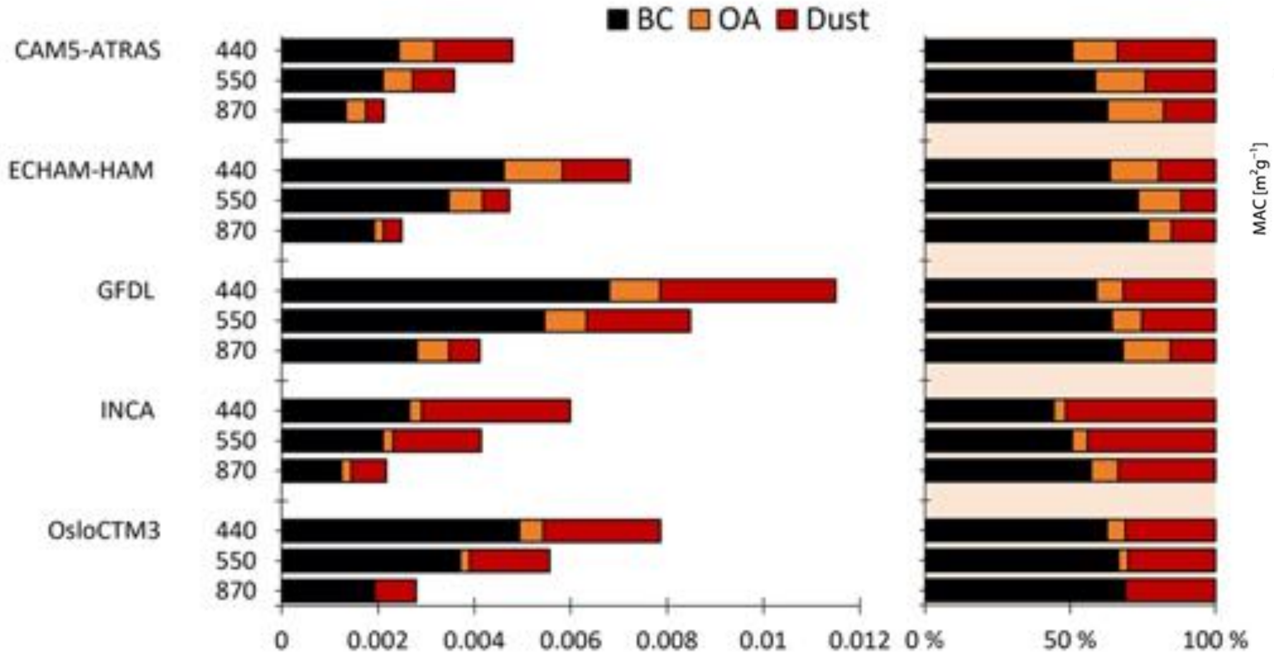
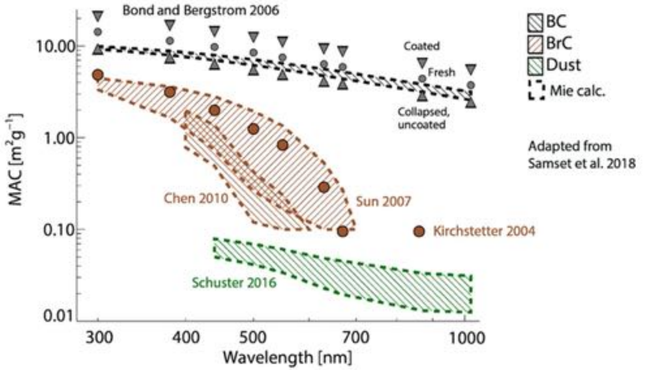
Role dust absorption for total aerosol absorption





Global mean AAOD at λ = 440, 550, and 870 nm for each model split into BC (black), OA (orange), and dust (red)

Sand et al. ACP 2021

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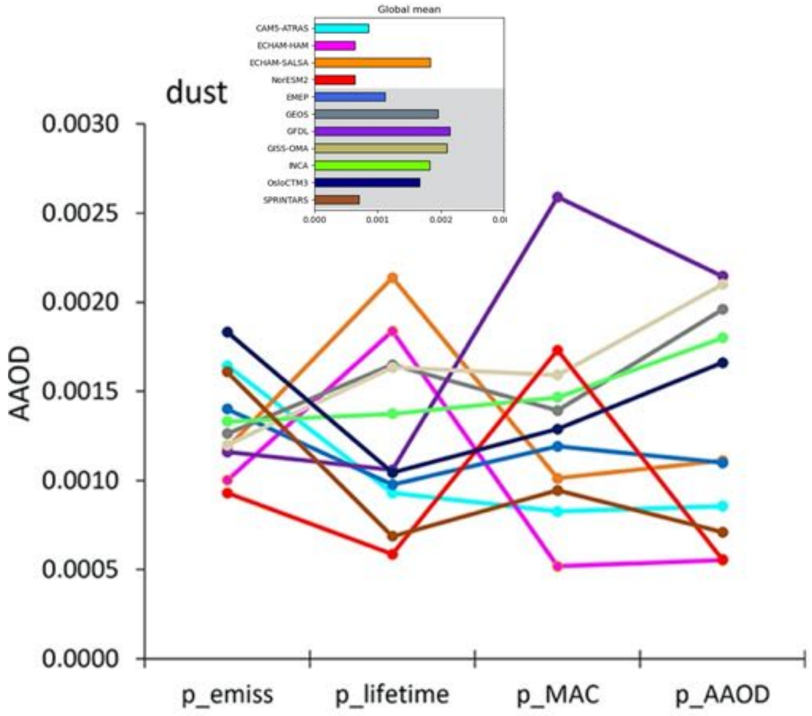
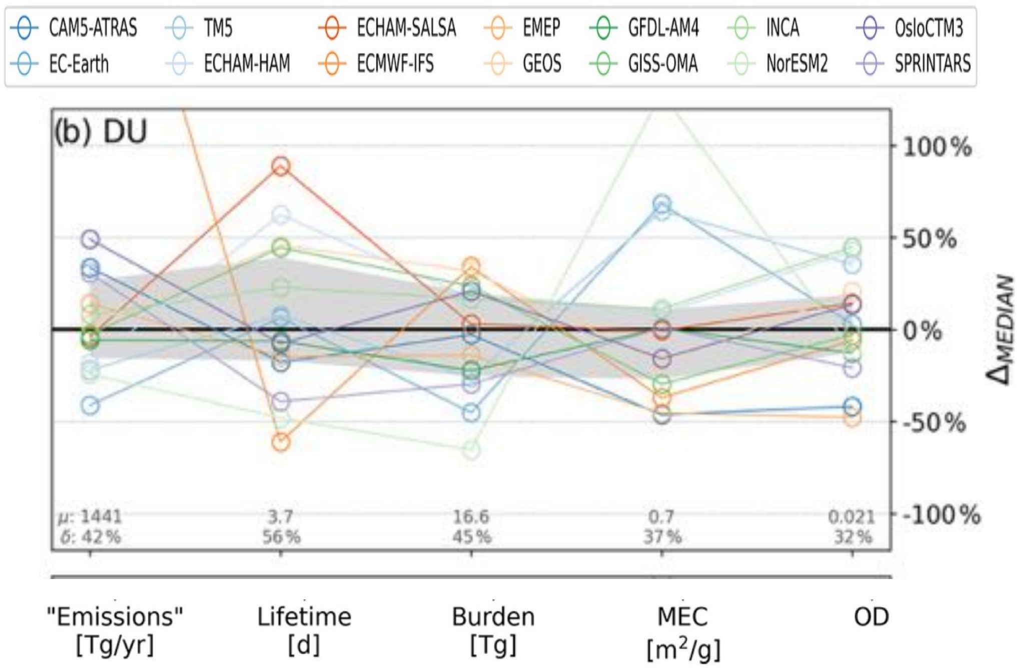
Partial sensitivities / Impact on Dust AAOD , AOD



Sand et al. ACP 2021



Gliss et al. ACP 2021

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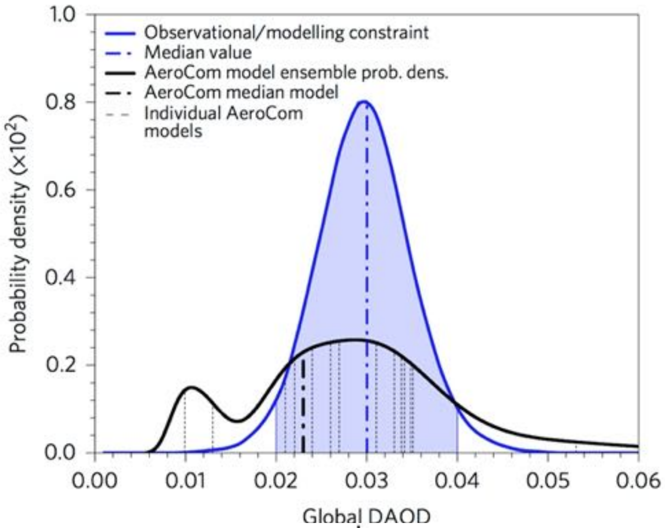
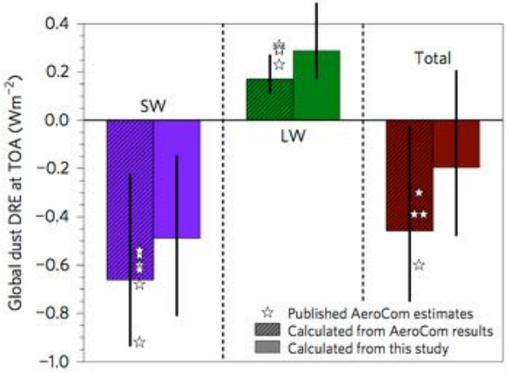
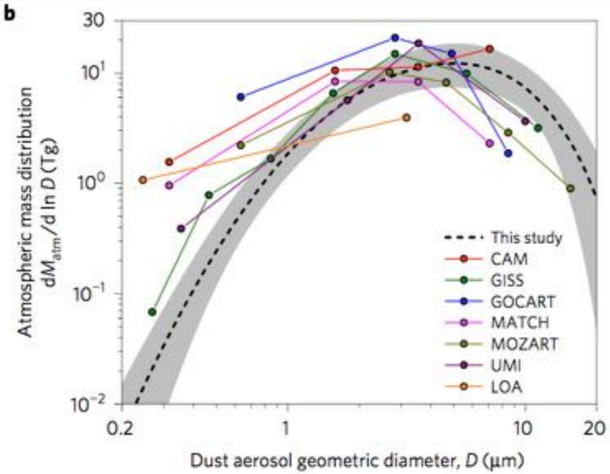
Recommendations for modelling…







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Constraints suggest that AeroCom models

- ***emit too fine dust***
- ***underestimate extinction, assuming sphericity***
- ***underestimate Dust AOD***

=> More dust absorption, more LW, less SW, less net radiative effect

nature geoscience ARTICLES
PUBLISHED ONLINE: 13 MARCH 2017 | DOI: 10.1038/NGEO2912

Smaller desert dust cooling effect estimated from analysis of dust size and abundance

Jasper F. Kok[1]*, David A. Ridley[2], Qing Zhou[3], Ron L. Miller[4], Chun Zhao[5], Colette L. Heald[2,6], Daniel S. Ward[7], Samuel Albani[8] and Karsten Haustein[9]

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Dust feedback in a changed climate? AerChemMIP

ERFdust

Dust Emissions under 4xCO2

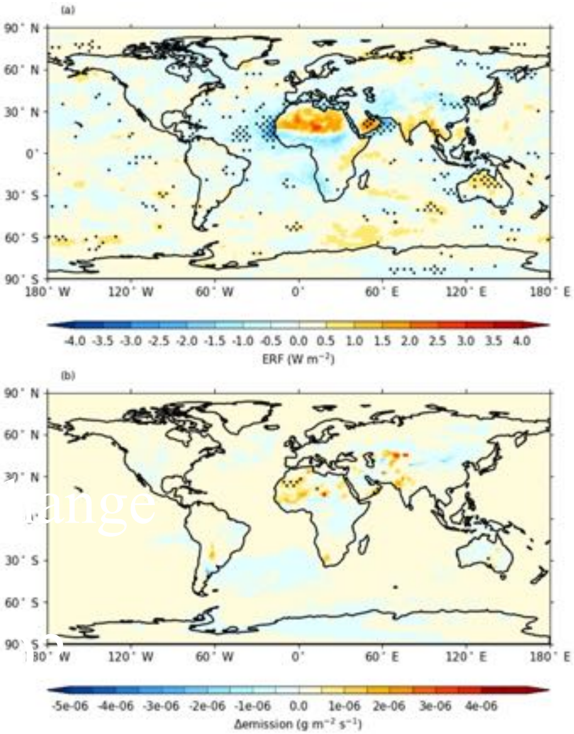
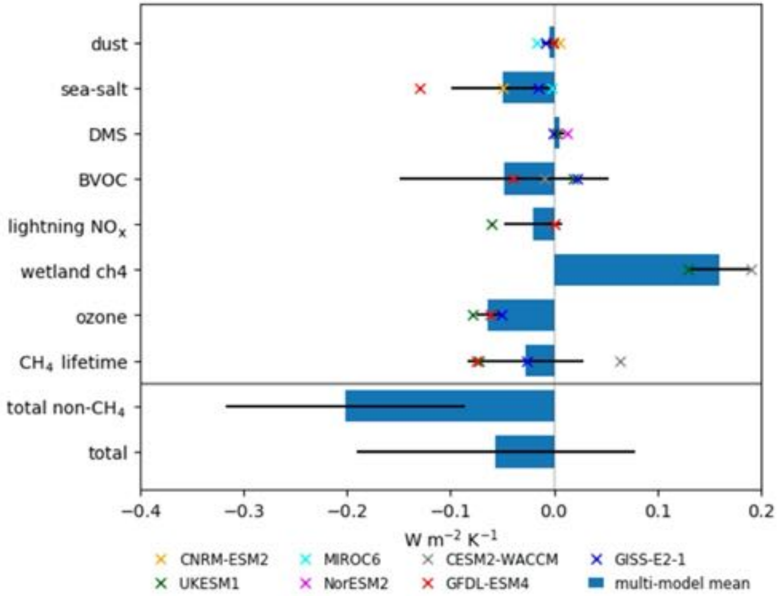


Figure 1. Multi-model mean **(a)** ERF from *piClim-2xdust* vs. *piClim-control*, **(b)** change in dust emissions for *abrupt-4xCO2* vs. *piControl*. Stippling shows areas where the mean changes by more than the standard deviation across models.



Thornhill et al. ACP 2021

How to better constrain the simulated aerosol effect on climate and air quality ?

AeroCom

Study sensitivity to process uncertainty

PPE+emulators
AeroCom WGs
Individual model studies
AeroCom aerosol module
Transport Tracers

Constrain models to range of observed parameter values

Commission on constraining aerosol properties
TAO group
Model recommendations

Score with observations

Representation error
Trend understanding
Reference:
Aerocom Median / Re-analysis
Observational benchmarks
cis-tools / pyaerocom
Multi-model papers

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Selected current activities

Dust source attribution experiment
Trans-Atlantic dust experiment
Commission on constraining aerosol properties
Code exchange and generalised aerosol-chemistry interface

Dust Source Attribution experiment DUSA

Assessment of dust source attribution to the global land and ocean regions

(Aerocom3-DUSA Experiment Update)

October 11, 2021, Aerocom workshop

Dongchul Kim[1], Mian Chin[2], Greg Schuster[3], Toshihiko Takemura[4], Paolo Tuccella[5], Paul Ginoux[6], Yang She[7], Xiaohong Liu[7], Hitoshi Matsui[8], and Kostas Tsigaridis[9,10]

[1]GESTAR/NASA Goddard Space Flight Center, Greenbelt, MD, United States
[2]NASA Goddard Space Flight Center, Greenbelt, MD, United States
[3]NASA Langley Research Center, Hampton, VA, United States
[4]Research Institute for Applied Mechanics, Kyushu University, Fukuoka, Japan
[5]University of L'Aquila, L'Aquila, Italy
[6]NOAA, Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey, USA
[7]Texas A&M University, College Station, TX, United States
[8]Nagoya University, Nagoya, Japan
[9]Center for Climate Systems Research, Columbia University, New York, NY, USA
[10]NASA Goddard Institute for Space Studies, New York, NY, USA

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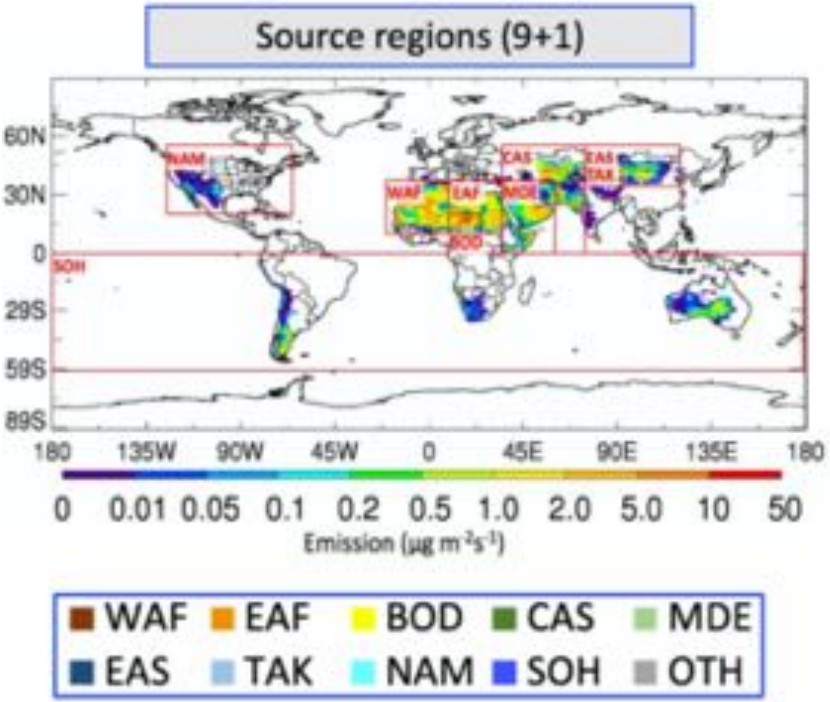
DUSA source regions



- Source regions (9+1)
- Receptor regions (14 = L7+O7)
- Participating models (6):
  - GEOS, SPRINTARS, GEOS-chem
  - GFDL, CAMS, CESM2 (new 2021!)
- Period: 4 years (2009-2012)
- Models also provide DOD 10um (separate talk, October 14, 11 UTC)

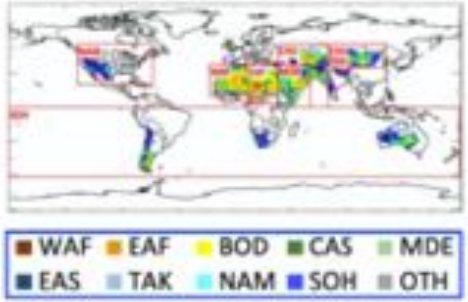
Courtesy Dongchul Kim

DUSA global budgets

AeroCom

Source contribution in global scale (annual)

	Unit	GEOS	SPRINTARS	GEOS-chem	GFDL	CESM2	CAM5
EMI	$Tg\ yr^{-1}$	1417	2278	1130	1578	2826	4311
LOAD	$Tg\ yr^{-1}$	20.8	22.7	21.9	28.7	61.9	67.0
DEP	$Tg\ yr^{-1}$	1418	2084	1132	1595	2929	4531
DOD	none	0.025	0.017	0.012	0.022	0.034	0.027
PM2.5	$\mu g m^{-3}$	1.6	1.0	2.1	3.6	0.9	5.2



EMI

GEOS SPRINTARS GEOS-chem GFDL CESM2 CAM5

Courtesy Dongchul Kim

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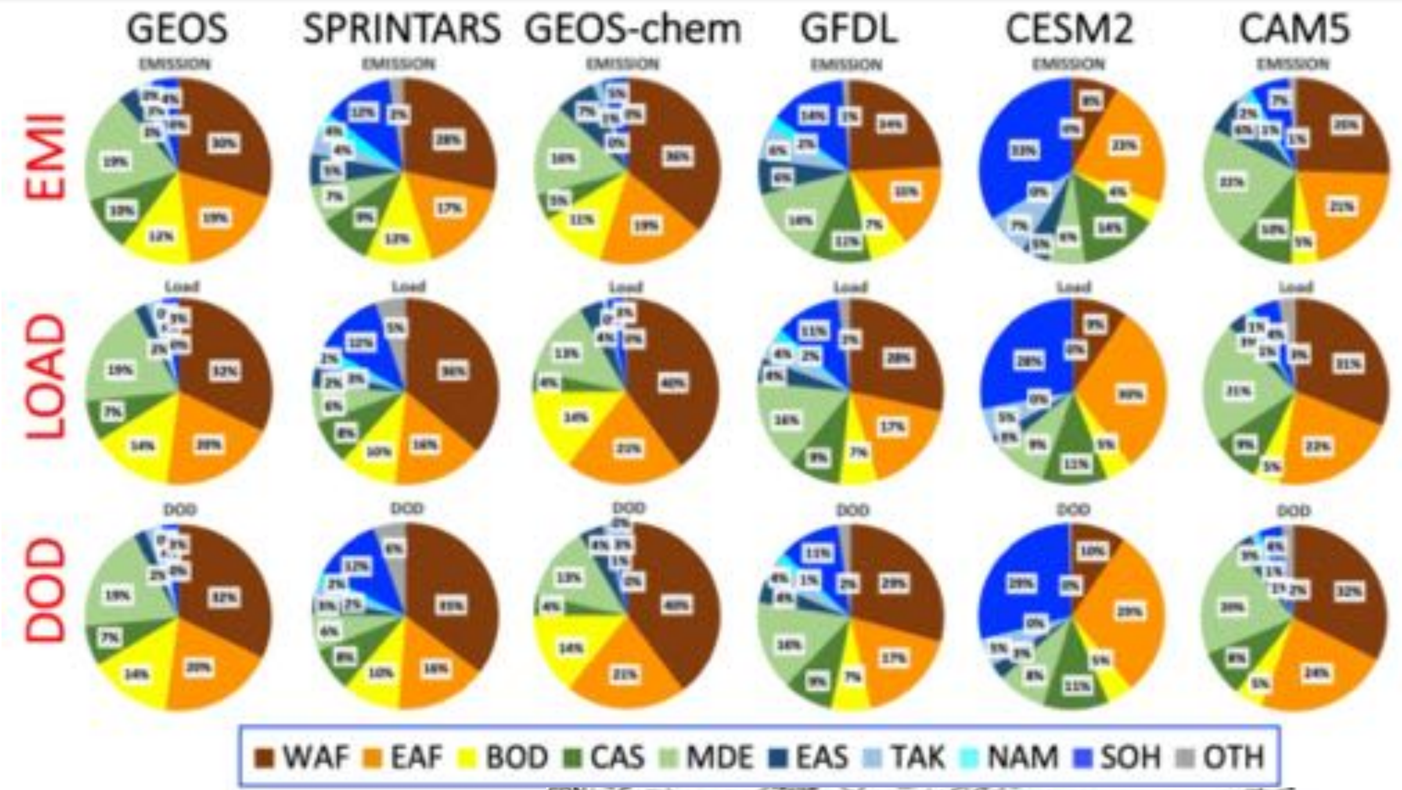
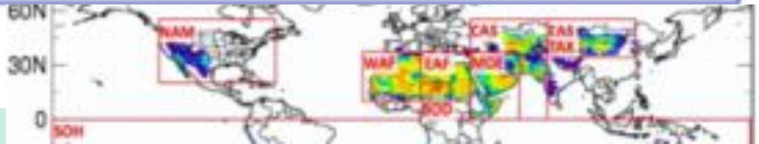
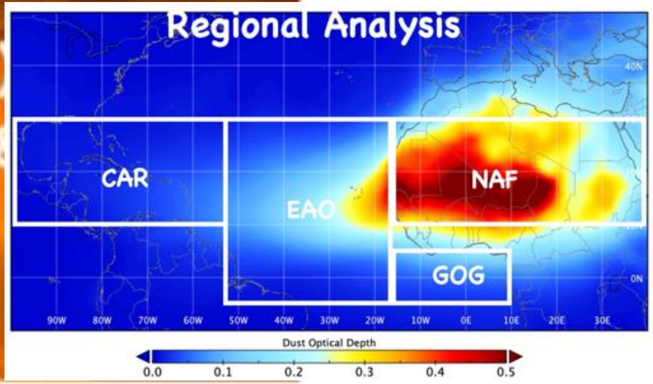
DUSA source contribution to emission, load, DOD





Courtesy Dongchul Kim

Trans Atlantic Dust Experiment (TADD)



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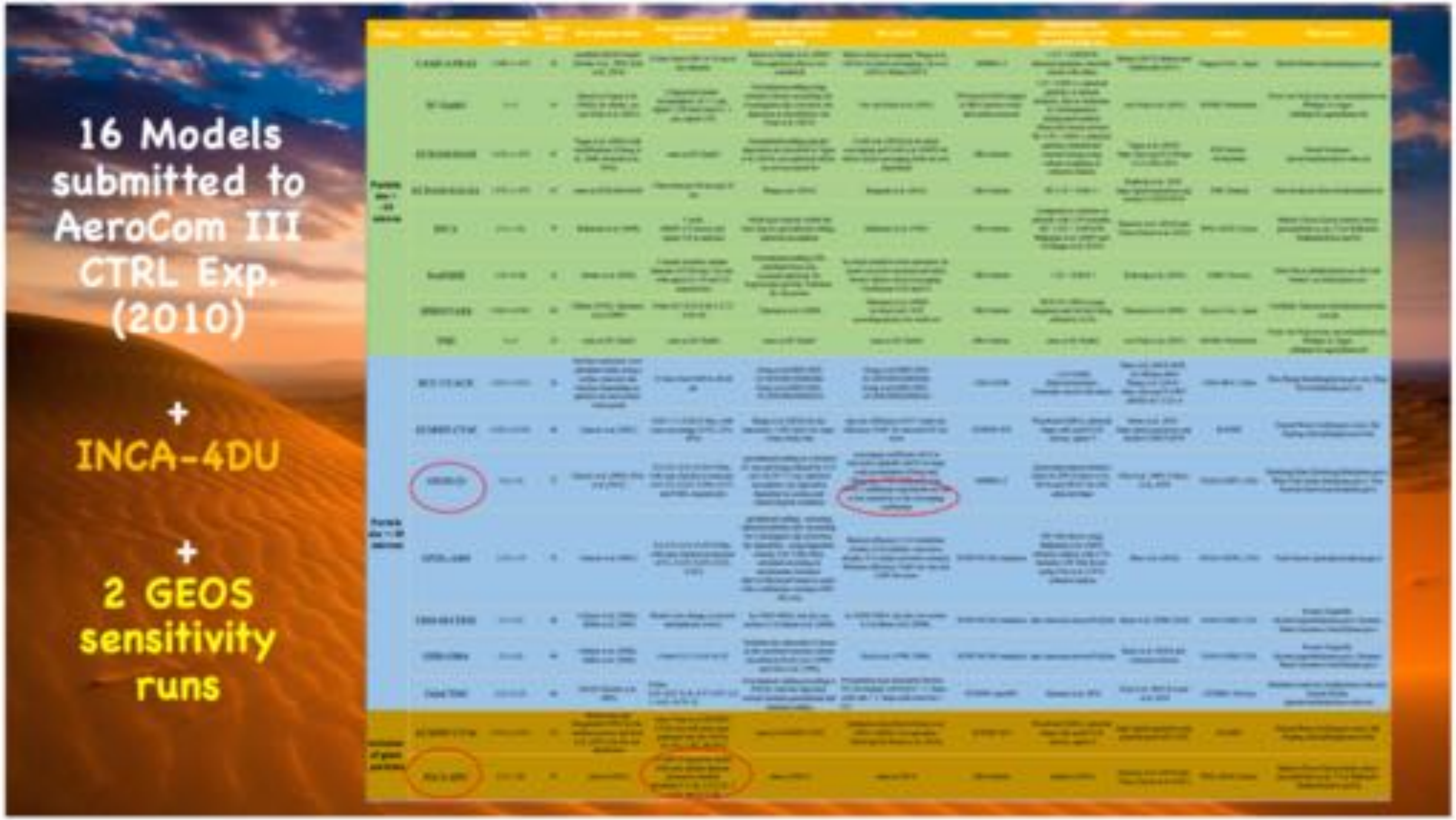
TADD



Courtesy: Hongbin Yu

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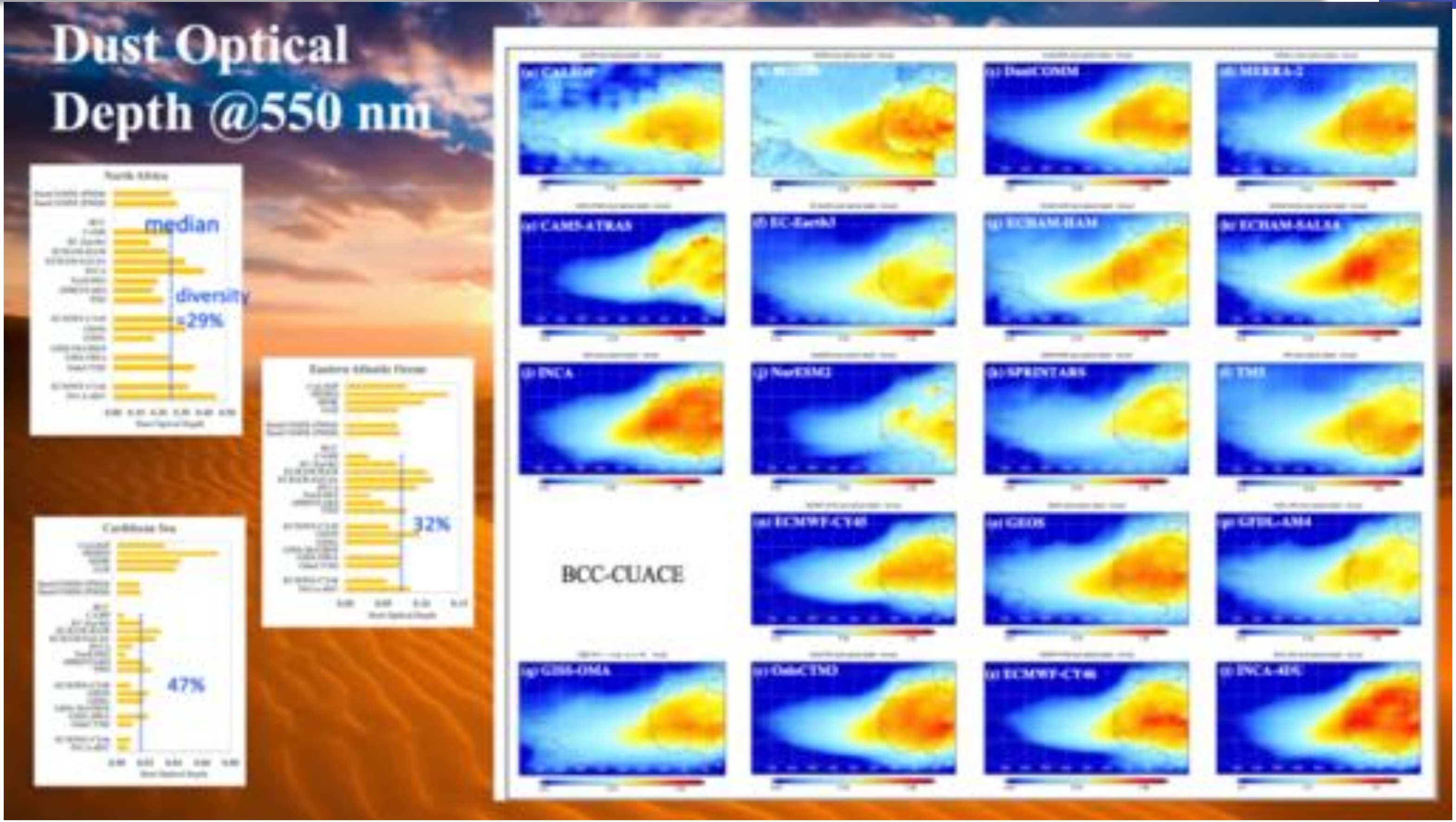
TADD



Courtesy: Hongbin Yu

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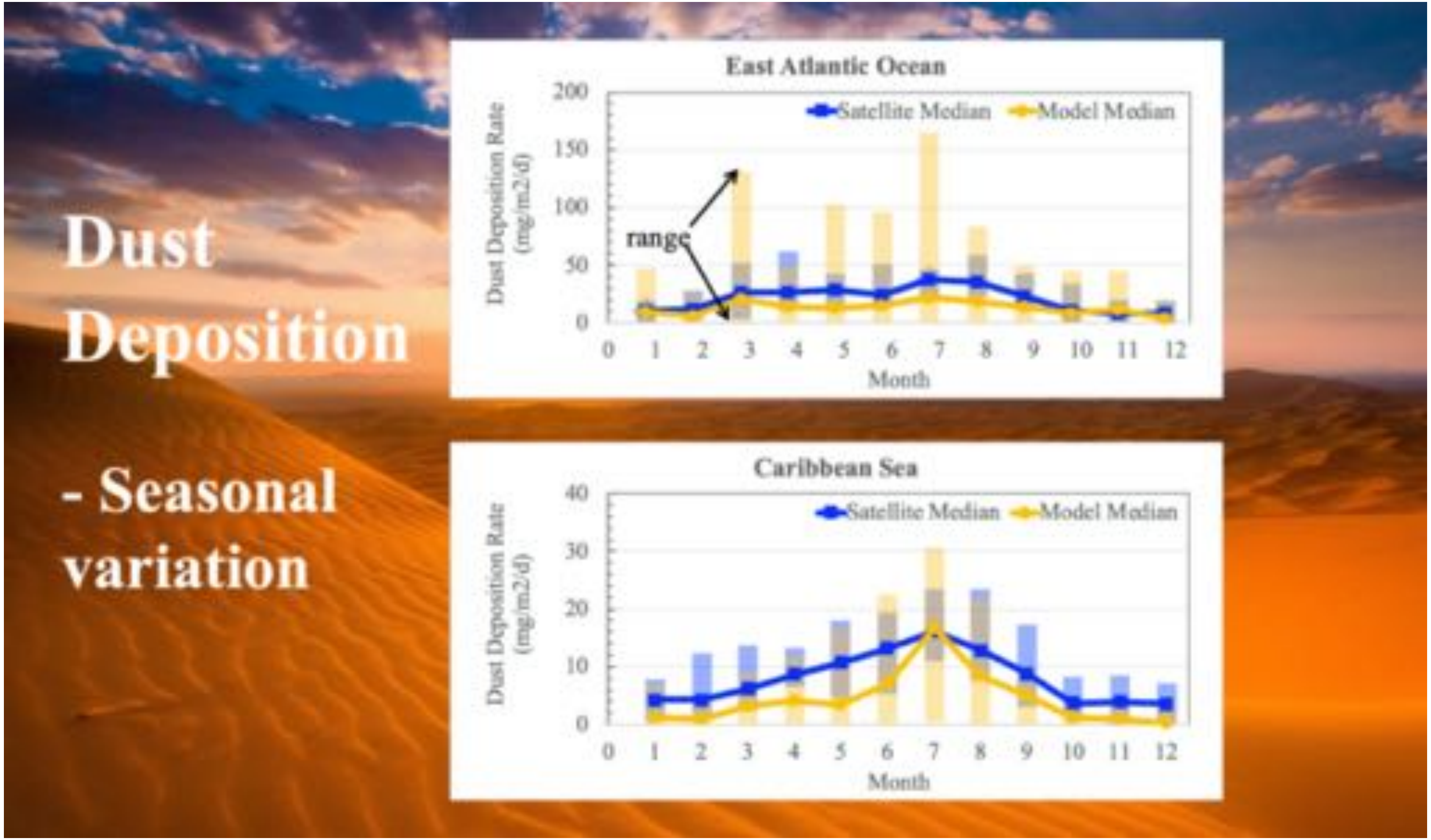
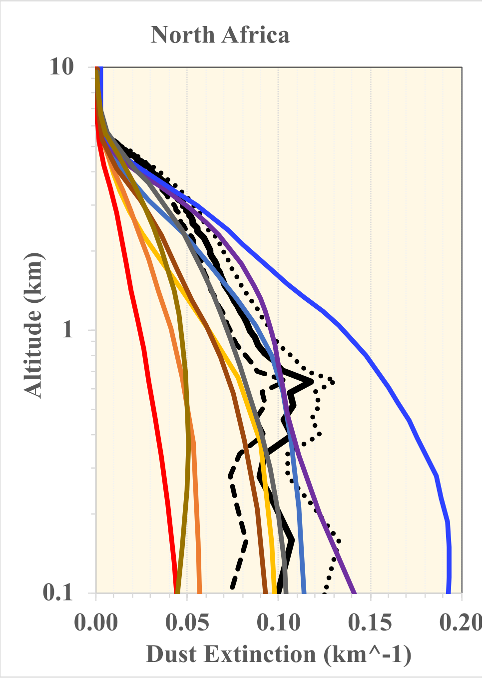
TADD

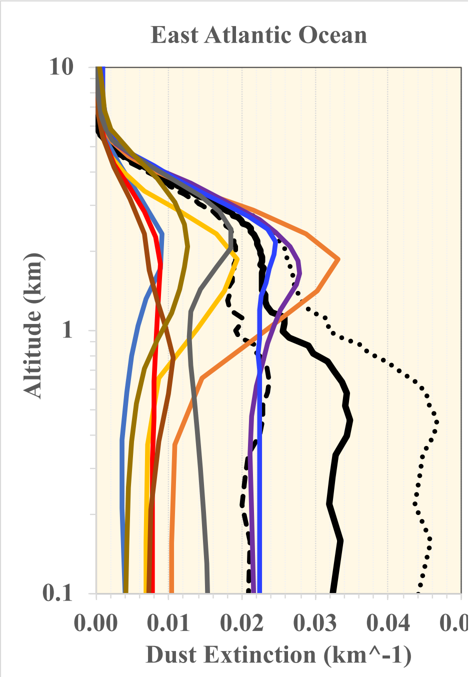


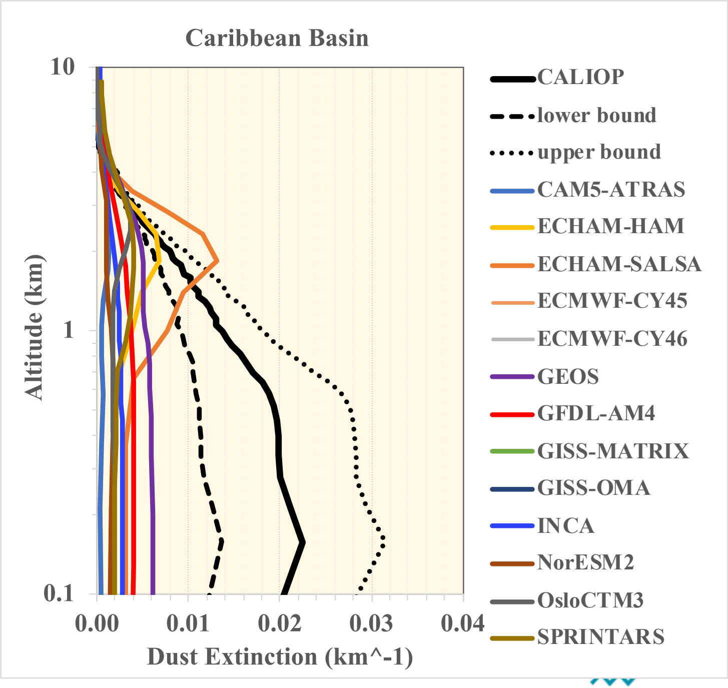
Courtesy: Hongbin Yu

TADD comparison to CALIOP profiles

North Africa | **E. Atlantic** | **Caribbean Basin**







Courtesy: Hongbin and Qianquin / NASA Goddard

TADD

The global dust cycle: Evolving from AP1 to AP3

AeroCom Phase (AP)		Emissions (Tg/yr)	Deposition (Tg/yr)	f_wet	Lifetime (d)	Mass Loading (Tg)	MEE (m2/g)	DOD
AP1 *Huneeus et al. (2011)*	Median	1628	1627	0.35	4.05	19.8	0.69	0.030
	Diversity	61%	59%	44%	37%	39%	49%	38%
AP3	Median	1437	1434	0.45	3.71	16.6	0.74	0.022
	Diversity	139%	141%	52%	50%	47%	46%	24%
AP3 – excluding ECMWF-CY46 & INCA-4DU	Median	1397	1379	0.46	3.97	15.4	0.74	0.022
	Diversity	30%	33%	42%	42%	32%	41%	24%

AP3 models have much larger spread in emissions, deposition than AP1 models, simply due to the inclusion of super coarse/giant particles in two models (ECMWF-CY46 and INCA-4DU).

Courtesy: Hongbin Yu

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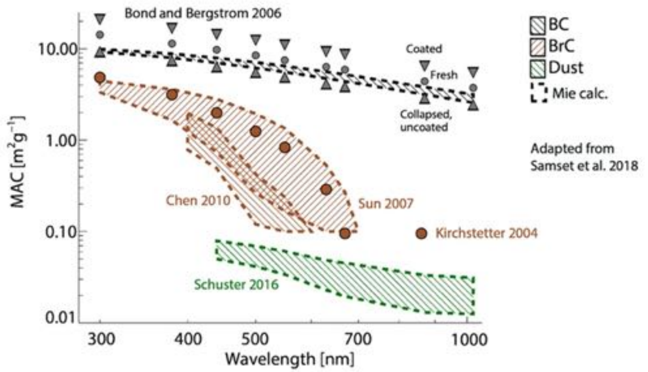
Commission on Constraining Aerosol Properties

Yves Balkanski, Lucia Mona, Betsy Andrews, Nicolas Bellouin, Ken Carslaw, Mian Chin, Peter Colarco,
Ed Gryspeerdt, Paola Formenti, Stefan Kinne, Gerrit de Leew, Claudia Di Biagio, Roy Grainger,
Ralph Kahn, Pekka Kolmonen, Rob Levy, Tero Mielonen, Thanos Nenes, Thomas Popp, Adam Povey,
Claire Ryder, Andrew Sayer, Lauren Schmeisser, Michel Schulz, Greg Schuster, Nick Schutgens,



- Setting up bounds and means on useful global aerosol property, to be revised annually.
- What should models and satellite retrievals be able to simulate/retrieve in relation to global aerosol loads and optical properties?
- What should be recommended to modellers/satellite scientists to test and document?
- Bounds and means on these properties and on aerosol radiative effects could suggest strategies for future observations

Aerosol codes available for inspection

CESM-MAM3+MAM7 / *??* / https://github.com/ESCOMP/CAM

EMEP / *Simpson 2012* / https://github.com/metno/emep-ctm

NorESM/CAM6NOR & aerotab / *Seland 2020* / https://github.com/NorESMhub/NorESM

GFDL AM4 / *Zhao 2018* / https://github.com/NOAA-GFDL/AM4

GISS OMA/MATRIX / / ??

IPSL-CM5A2 / *Sepulchre 2020* / svn checkout ?

GOCART/GEOS / ?? / on request)

ECHAM6-HAMMOZ / *Tegen 2019* / available under ECHAM licence agreement

ECHAM-SALSA / *Kokkola 2018* / under ECHAM license

EC-EARTH3/TM5 / *von Noije in prep* / restricted acces to consortium

IFS-ECMWF / *Remy 2019* / access granted for European MET services

GLOMAP/UKESM / ?? / ?

E3SM-MAM4 / *Wang 2020* / https://e3sm.org/model/ github available to collaborators

CNRM-ESM2-1 / *Seferian 2019* / ?

CAM5-ATRAS / *Matsui 2017* / ?

Code exchange / Common aerosol interface

AeroCom

Planned and upcoming:
Virtual workshop on developing a general set of requirements for aerosol/chemistry interfaces within weather/climate models
Wednesday Feb 16 from 12-3pm Eastern US Time

Contact mahowald@cornell.edu, alma@ucar.edu

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Thanks for the attention

aerocom.met.no

michael.schulz@met.no