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AEROCOM Supersites experiment

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with thanks to WDCA contributors, especially John Ogren, Uwe Kaminski, Margerete Fricke, Chris Wehrli, J-P Putaud, S. dos Santos, G. Zibordi , Stefan Kinne & the AEROCOM community &
Elisabetta Vignati & Matthias Karl

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- **Introduction to WDCA**
- **Using *in-situ* observations of aerosol physical properties to understand aerosol models.**
- **Observed relationship between RH & Aerosol optical properties**
- **BC, E. Vignati & M. Karl model results (tomorrow?)**

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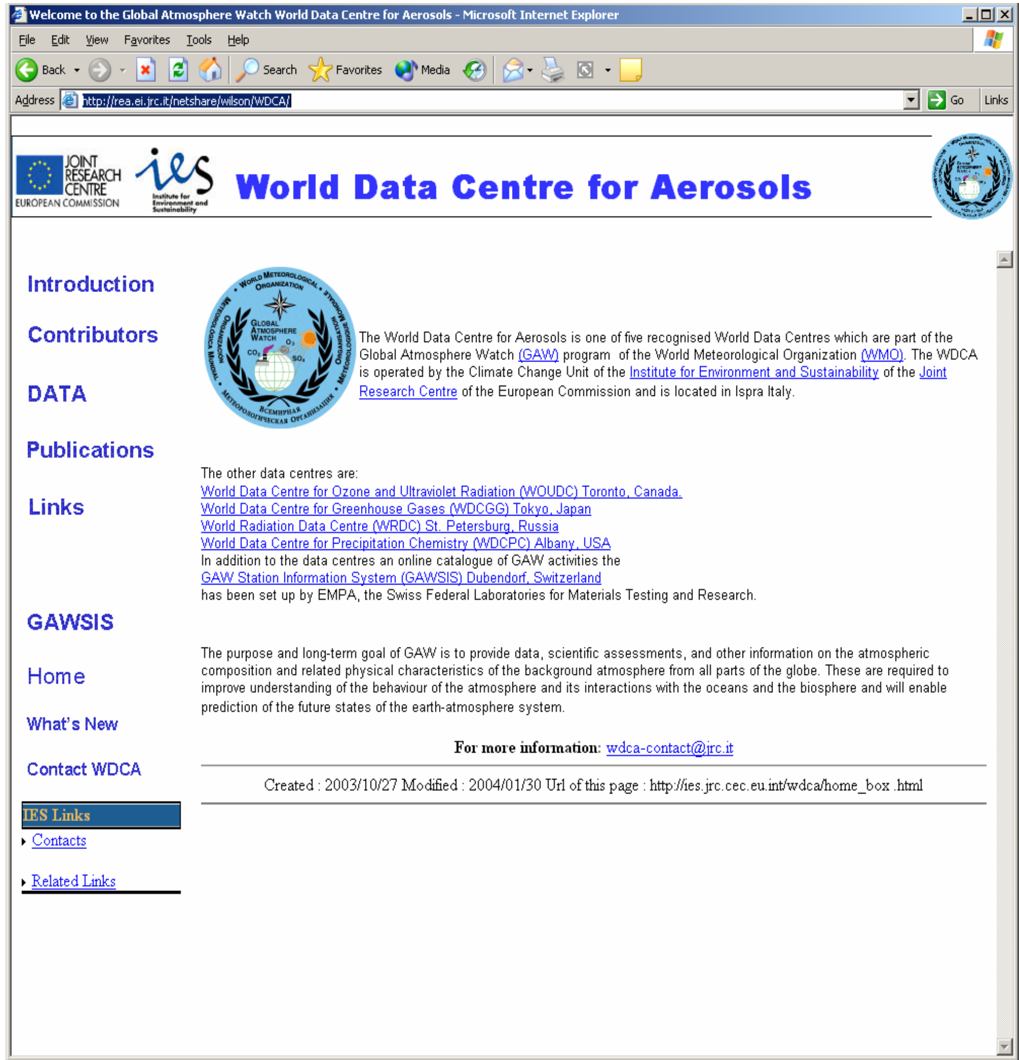
http://wdca.jrc.it/



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The GAW Aerosol program

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The SAG Aerosol recommends that the GAW aerosol program include:

- **for regional stations any one, or more of the following:**
    - *optical depth*
    - *mass (preferably in two size fractions)*
    - *major chemical components in two size fractions*
    - *light scattering coefficient*
- **for global stations as many as possible of the following:**
    - *optical depth*
    - *mass in two size fractions*
    - *major chemical components in two size fractions*
    - *light scattering & hemispheric backscattering coefficients at various wavelength*
    - *light absorption coefficient*
    - *aerosol number concentration*
    - *cloud condensation nuclei number concentration at 0.5% supersaturation*
    - *diffuse, global and direct solar radiation*
- **intermittently:**
    - *aerosol size distribution; detailed size fractionated chemical composition; dependence of aerosol properties on relative humidity; CCN spectra at various supersaturations; LIDAR measurements and other altitude profiles.*

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Organisations that have contributed data to WDCA

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PMOD/WRC	Physikalisch-Meteorologische Observatorium Davos / World Radiation Centre, Switzerland
ESRL	NOAA Earth System Research Laboratory (ex CMDL)
MSC	Meterological Service of Canada
DWD HOP	Deutscher Wetterdienst, Hohenpeissenberg Meteorological Observatory
DWD LIN	Deutscher Wetterdienst, Lindenberg Meteorological Observatory
JMA	Japanese Meterological Agency
NILU	Norwegian Institute for Air Research
PSI	Paul Scherrer Insititute, Switzerland
NUI,G	National University of Ireland, Galway
UM-RSMAS	University of Miami, Rosenstiel School of Marine and Atmopheric Sciences
CHMI	Czech Hydrometeorological Institute
FMI	Finnish Meteorological Institute, Air Quality Research
MDE	Ecole de Mines de Douai, France
UBA	Umweltbundesamt, Langen, Germany
EPA	Irish Environmental Protection Agency, Ireland
JRC	Joint Research Centre, Ispra, Italy
IfT	Institute for Tropospheric Research, Leipzig
BAM	Australian Bureau of Meteorology

IMPROVE	Interagency Monitoring of Protected Visual Environments, USA
UH-SOEST	University of Hawaii, Department of Oceanography
NERI	National Environmental Research Institute, Denmark
UJF	University Joseph Fourier, France
FMI	Finnish Meteorological Institute
CSIRO	Commonwealth Scientific and Industrial Research Organisation, Australia
AWI	Alfred Wegener Institute, Bremerhaven, Germany
RIVM	Netherlands National Institute of Public Health and Environmental Protection,
IMGW	Polish Institute of Meteorology and Water Management
SHMI	Slovak Hydrometeorological Institute
DGCEA	Direccion General de Calidad y Evaluacion Ambiental del Ministerio de Medio Ambiente, Spain
IVL	Swedish Environmental Institute
EMPA	Swiss Federal Laboratories for Materials Testing and Research
LHMA	Latvian Hydrometeorological Agency
AEA Tech	AEA Technology, National Environmental Technology Centre, UK

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	Data Class	AOD	LScat	Labs	CN	Size dist	PM Chem	PM	CCN
Alert	1		2004	1989-2006(a)	2004		1992-2005		
Ny Alesund	1/3	2003-2005	*-2006*	*-2006*	*-2006*	2001-2004*(-2006)*	1989-2004 *(-2006)*		
Point Barrow	2		1976-2006	1988-2006	1976-2006		*1997-2003*		
Pallas	1/3		2000-2005 *(-2006)*	*(-2006)*	1996-2004*(-2006)*	2001-2004*(-2006)*	*(-2006)*		
Mace Head	1/3	2001-2005	2000-2002 *(-2006)*	1989-2002 *(2006)*	1991-4, 2000-2005*(-2006)*	*2002-2006*	1992-1994 *(-2006)*		
Hohenpeissenberg	1	1993-2005	1999-2005 *(-2006)*	*-2006*	1995-2005 *(-2006)*	2001-2005 *(-2006)*	1997-2002 *(-2006)*		
Zugspitze	1	2003-2004							
Jungfraujoch	1/3	1999-2005	1995-2006	1995-2006	1995-2006	*1997-1998*	1995, 1999-2001 *(-2006)*		
Mount Waliguan		(b)							
Izana	1	2001-2005					1992-1995		
Minamitorishima	1	2003-2004							
Assekrem									
Mauna Loa	2	2000-2005	1975-2006	1990-2006	1975-2006		1992-1995		
Mount Kenya									
Bukit Kototabang									
Arembepe									
American Samoa	2		1977-1991		1977-2006				
Cape Point							1992-1996		
Amsterdam Island									
Lauder									
Cape Grim	1				2003		1983-1996		
Ushuaia									
Neumayer	1		2003-2006		1993-2006				
South Pole	2		1979-2006	1987-2006	1974-2006				

global station/key parameter

1 = narsto by originator

2 = narsto by WDCA

3 = narsto by CREATE

NARSTO format at WDCA

GAWSIS but not WDCA

neither GAWSIS nor WDCA

EUSAAR to process at NILU

(a) submitted as BC (ng.m-2)

(b) broad band pyriheliometer

1 = narsto by originator

2 = narsto by WDCA

3 = narsto by CREATE

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$SSA = \frac{b_{sp}}{b_{sitp}}$

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Integration of Physical Chemical Aerosol Properties

Why?

outcome of AEROCOM optical properties & forcing evaluations: comparison with AOD permits model tuning as it leaves a lot of degrees of freedom.

How?

In a comparison with *in-situ* chemical & optical properties the only variables are *aerosol mass* & extinction efficiencies for the component species. Concurrent *Scattering* and *Absorption* observations from c20 sites globally with consistent methods (humidity control) => data set where the uncertainties can be evaluated & at most of these AOD &or chemical composition are available.

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Local closure check on aerosol mass fields and optical model will inform any comparison with column AOD

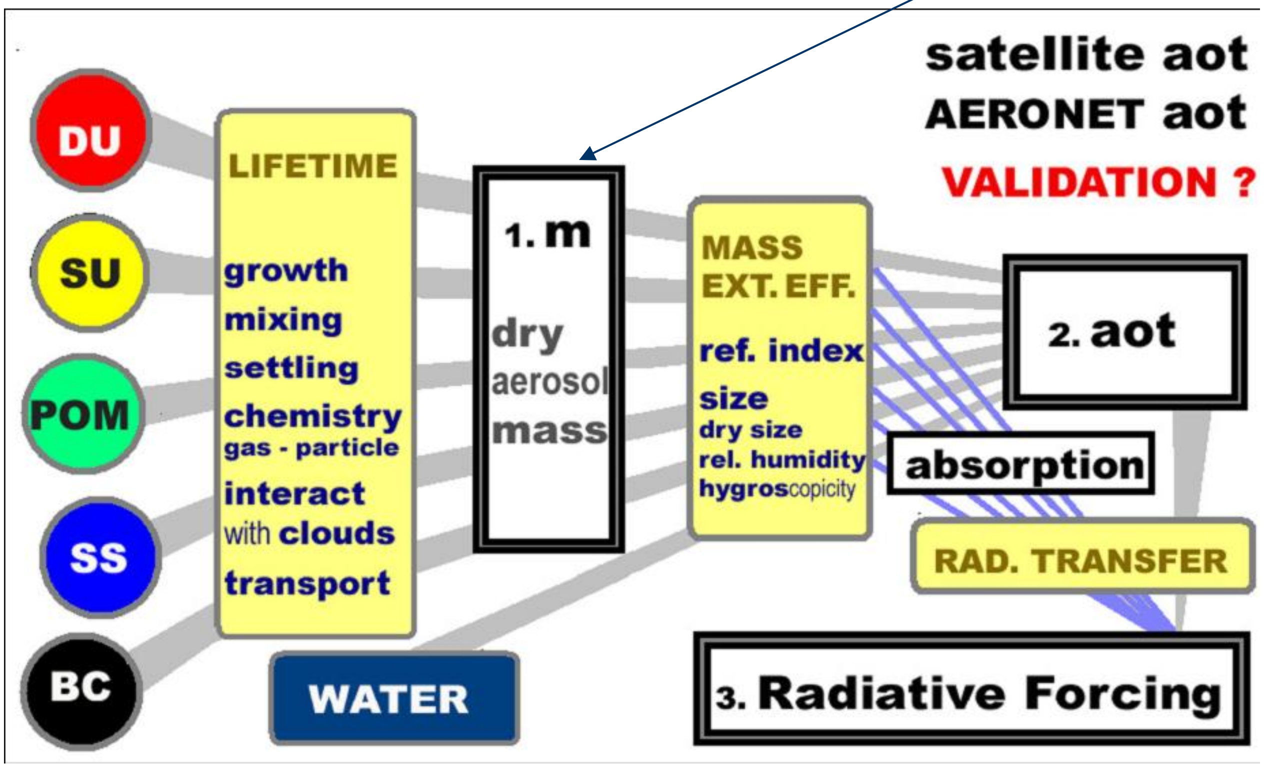

Fig 2 from Kinne et al., 2006 - AEROCOM optical properties

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AEROCOM Optical Properties (Kinne et al., 2006)

“At 0.11 to 0.14, simulated aot values are at the lower end of global averages suggested by remote sensing from ground (AERONET ca. 0.135) and space (satellite composite ca. 0.15). More detailed comparisons, however, reveal that larger differences in regional distribution and significant differences in compositional mixture remain. ***Of particular concern are large model diversities for contributions by dust and carbonaceous aerosol, because they lead to significant uncertainty in aerosol absorption (aab)”.***

Table 4.

MAX/MIN DUST = 11 (1.4)
MAX/MIN BC = 6.6 (1.8)
MAX/MIN WATER = 7.1 (3.1) – 9 models
WATER 28 – 79% of total (AOT)

Why Dry Extinction and SSA ?

$$b_{extp} = b_{scap} + b_{absp}$$

$$\omega_0 = b_{scap}/b_{extp}$$

•Malm et al (1997) & others have shown that the differences in refractive index and scattering and absorption efficiencies from using external vs internal aerosol mixing models c 10%.

$$\textit{i.e. } b_{extp} = \Sigma\, \alpha_{scai}\, m_i + \alpha_{absi}\, m_i$$

Where α_{si} and α_{si} are the specific scattering and absorption efficiencies for aerosol species i.

Water soluble aerosol species have varying patterns of hygroscopic growth – changes both scattering (*aerosol water is a scatterer*) and absorption (*'magnifying' effect of increasing scattering material*).

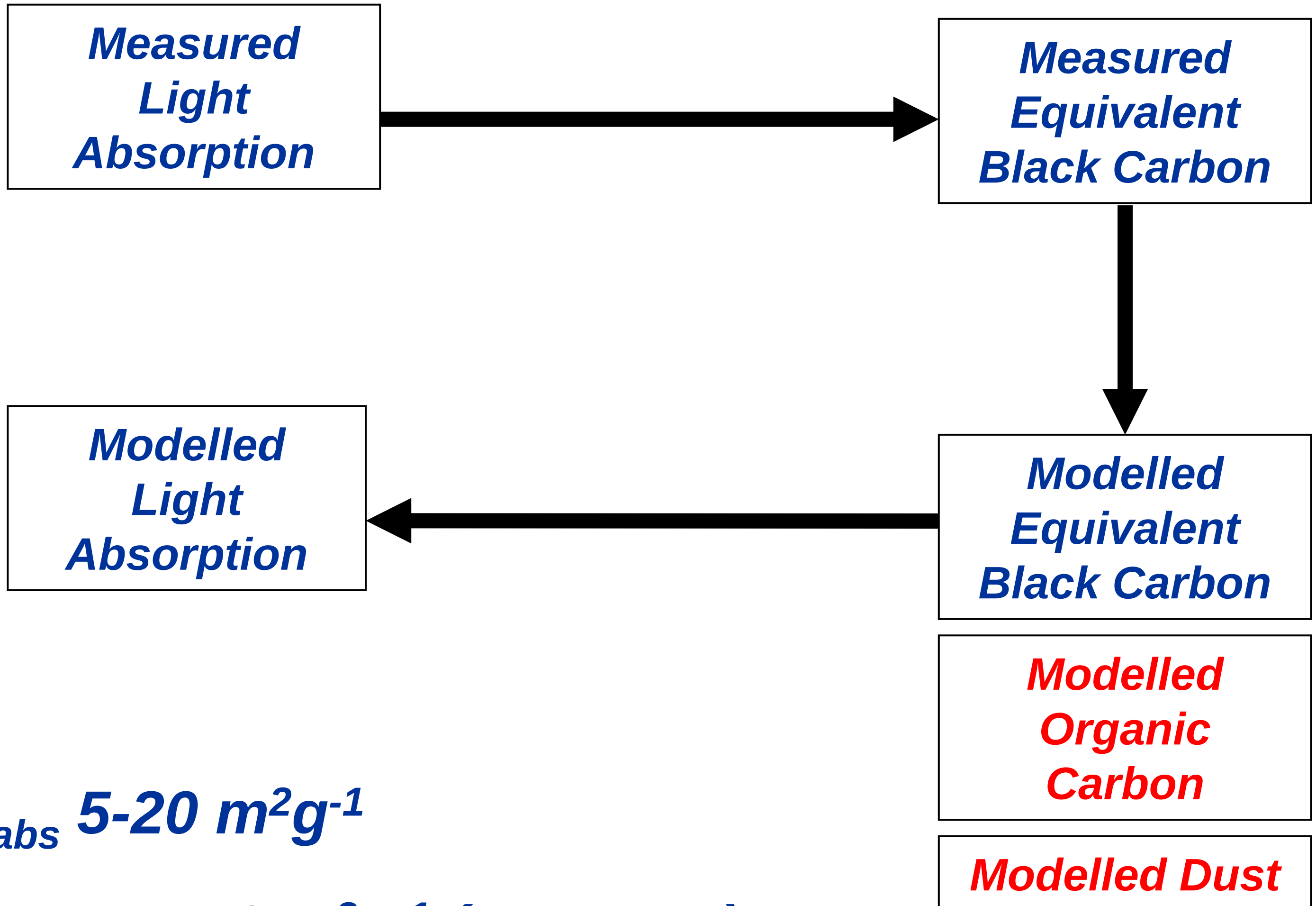
Why Dry Extinction and SSA pt II ?

Dry avoids water vapour effects in the model, for in-situ comparison & treatment of water in the models is very variable & uncertain.

Dry reduces the scattering response in absorption measurements (2% of scattering signal, Bond et al, 1999) – reduces the uncertainties in the measurements.

Currently in calculating extinction, use BC models that are 'validated/constrained' by comparison with optical Equiv. BC data (specific absorption coeff.). In calculating the BC contribution to specific extinction other optical properties likely to be assumed –> systematic & variable bias effectively a function of instrument calibration. If instead absorption measurements are only compared to calculated absorption, single use of specific absorption coeff. in the model calculation.

Systematic and Variable Bias



σ_{abs} **5-20 m²g⁻¹**

σ_{absBCm} **4-10 m^2g^{-1} (aerocom)**

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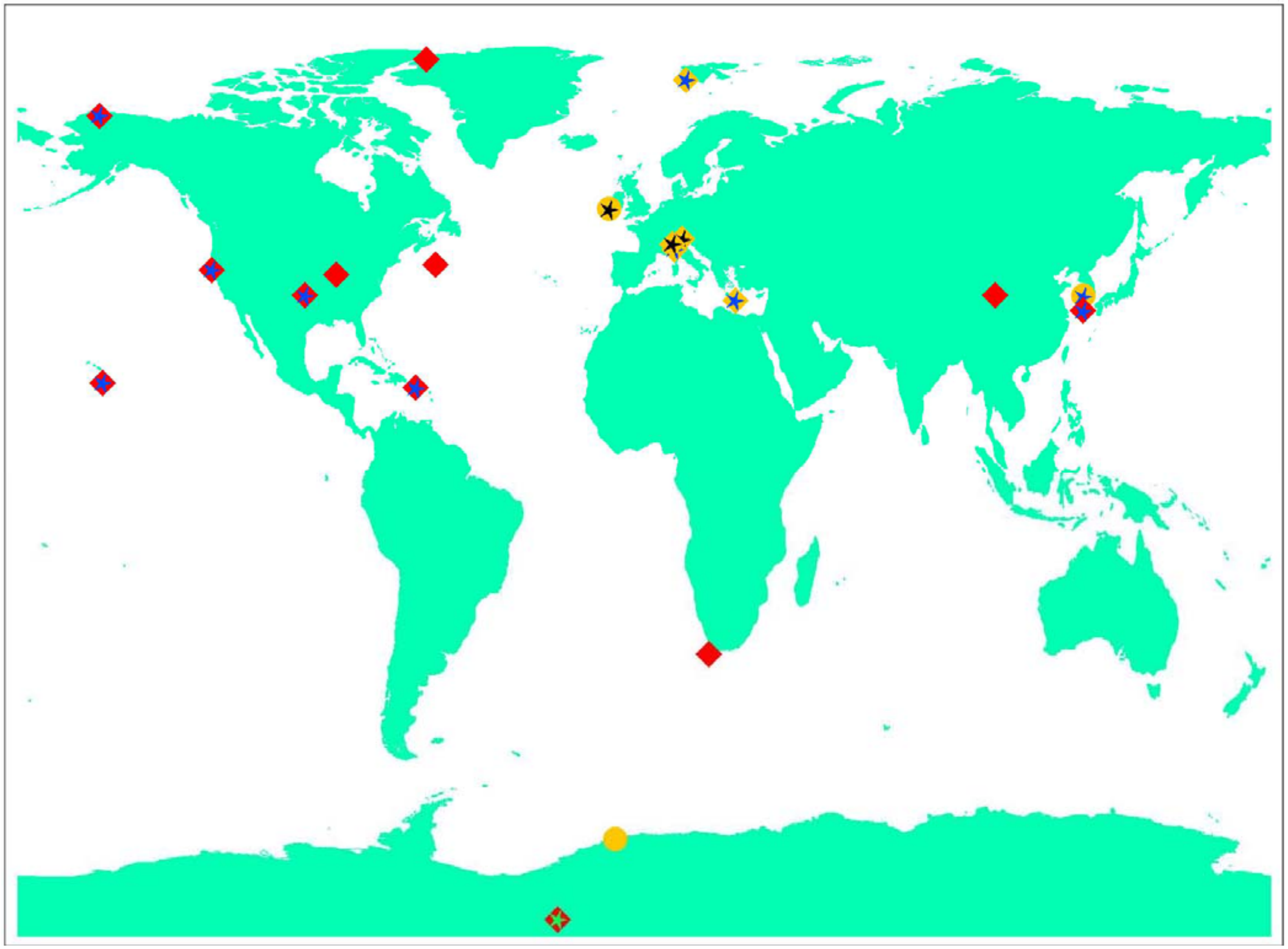
‘dry’ aerosol extinction coefficient sites



CMDL pack (TSI3563+PSAP@ controlled humidity) – *in-situ* 550nm extinction co-efficient @ STP ♦

3563/903 Neph + narrowband absorption – *in-situ* 550nm extinction co-efficient @STP feasible - ♦

3563/903 Neph + broadband absorption – uncertain *in-situ* extinction “co-efficient“- ●

CIMEL Sunphotometer co-located ✡

PFR Sunphotometer co-located ✡

SP01A Sunphotometer co-located ✡

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Station Details

Region	Station	AOD	Light Scattering (nm)	Light Absorption (nm)	RH
Arctic	Alert (to end 2005)		450, 550, 700 (3563)	550 (PSAP)	<40%
Arctic	Ny Alesund	CIMEL, PFR, BSRN	450, 550, 700 (3563)	450, 550, 700 (CUSTOM)	Ambient
Arctic	Point Barrow	CIMEL, SPO1A, BSRN	450, 550, 700 (3563)	550 (PSAP)	<40%
Europe	Mace Head	PFR	450, 550, 700 (3563)	broadband (AE-9)	<45%
Europe	Hohenpeissenberg	PFR	450, 550, 700 (3563)	532 (MAAP), & Broadband AE-10)	<45%
Europe	Finokalia	CIMEL (Heraklion)	530 (903)	550 (PSAP)	Unknown
Europe	Ispra	CIMEL	450, 550, 700 (3563)	370, 450, 571, 615, 660, 880, 950 (AE-31)	Ambient
Americas	Bondville	BSRN	450, 550, 700 (3563)	550 (PSAP)	<40%
Americas	Lamont SGP	CIMEL, BSRN	450, 550, 700 (3563)	550 (PSAP)	<40%
Americas	Sable Island (to 2000)		450, 550, 700 (3563)	550 (PSAP)	<40%
Americas	Trinidad Head	CIMEL, BSRN?	450, 550, 700 (3563)	550 (PSAP)	<40%
Americas	Cape San Juan	CIMEL	450, 550, 700 (3563)	550 (PSAP)	<40%
Asia	Anmyeon-do	CIMEL	450, 550, 700 (3563)	broadband ?	Unknown
Asia	Kosan (2000-2001)	CIMEL	450, 550, 700 (3563)	550 (PSAP)	<40%
Africa	Cape Point (2006+)		450, 550, 700 (3563)	550 (PSAP)	<40%
Antarctic	S. Pole	SPO1A, BSRN	450, 550, 700 (3563)	none	<40%
Antarctic	Neumayer	BSRN	450, 550, 700 (3563)	broadband	Unknown
F. Trop	Jungfraujoch	PFR	450, 550, 700 (3563)	370, 450, 571, 615, 660, 880, 950 (AE-31)	T=25 C
F. Trop	Mount Waliguan		450, 550, 700 (3563)	550 (PSAP)	<40%
F. Trop	Mauna Loa	CIMEL	450, 550, 700 (3563)	550 (PSAP)	<40%

PFR = 368, 412, 500, 862 nm, SP01A = 412,500,675, 862 nm,

CIMEL = 1020, 870, 675, 440, 936, 500, 340, 380 nm
RED = data set collected & being processed, blue = negotiating

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CMDL Data Summary (Delene & Ogren, 2002)

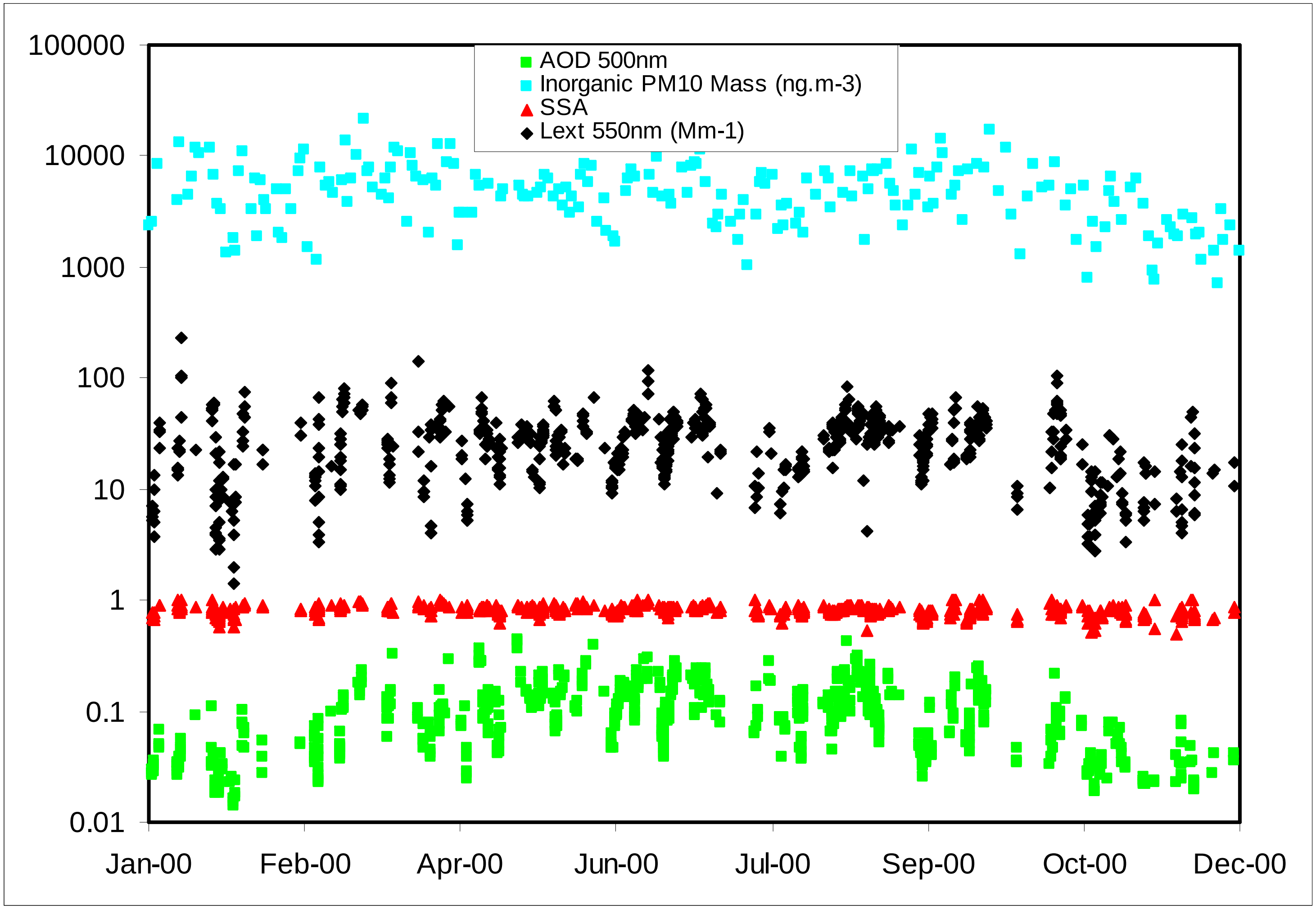
Station	Pm10 σ_{ap} (Mm^{-1})	Pm10 σ_{sp} (Mm^{-1})	Pm10 σ_{extp} (Mm^{-1})	ω_p
Point Barrow	**0.39 ± 0.41**	**9.76 ± 5.20**	**10.2 ± 5.41**	**0.965 ± 0.023**
Bondville	**4.66 ± 2.27**	**57.7 ± 17.7**	**62.4 ± 18.8**	**0.924 ± 0.028**
Lamont SGP	**2.46 ± 1.09**	**46.9 ± 16.9**	**49.4 ± 17.4**	**0.947 ± 0.025**
Sable Island	**1.88 ± 0.73**	**39.9 ± 7.2**	**41.8 ± 7.56**	**0.956 ± 0.015**
Hohenpeissenberg	***4.82***	***23.02***	***28.47***	***0.765***
Hohenpeissenberg AOD times only	***4.91***	***23.56***	***28.47***	***0.800***

Station	Pm1 σ_{ap} (Mm^{-1})	Pm1 σ_{sp} (Mm^{-1})	Pm1 σ_{extp} (Mm^{-1})	ω_p
Point Barrow	**0.36 ± 0.38**	**6.17 ± 3.61**	**6.53 ± 3.8**	**0.954 ± 0.023**
Bondville	**3.94 ± 1.80**	**48.7 ± 14.7**	**52.6 ± 15.6**	**0.924 ± 0.028**
Lamont SGP	**2.08 ± 0.98**	**37.5 ± 12.7**	**39.6 ± 13.2**	**0.944 ± 0.025**
Sable Island	**1.51± 0.66**	**13.6 ± 7.2**	**15.1 ± 7.53**	**0.897 ± 0.031**

Monthly average dry optical properties at 4 CMDL sites for the period 1997-2000 (94-2000 Sable Island, 96-2000 Bondville).

Estimated calibration uncertainties for Scattering 7%, Absorption 20%.

Hohenpeissenberg *In-situ* inorg. Chem mass, extinction, SSA and column AOD



Based on data from Kaminski, Fricke & Werhli

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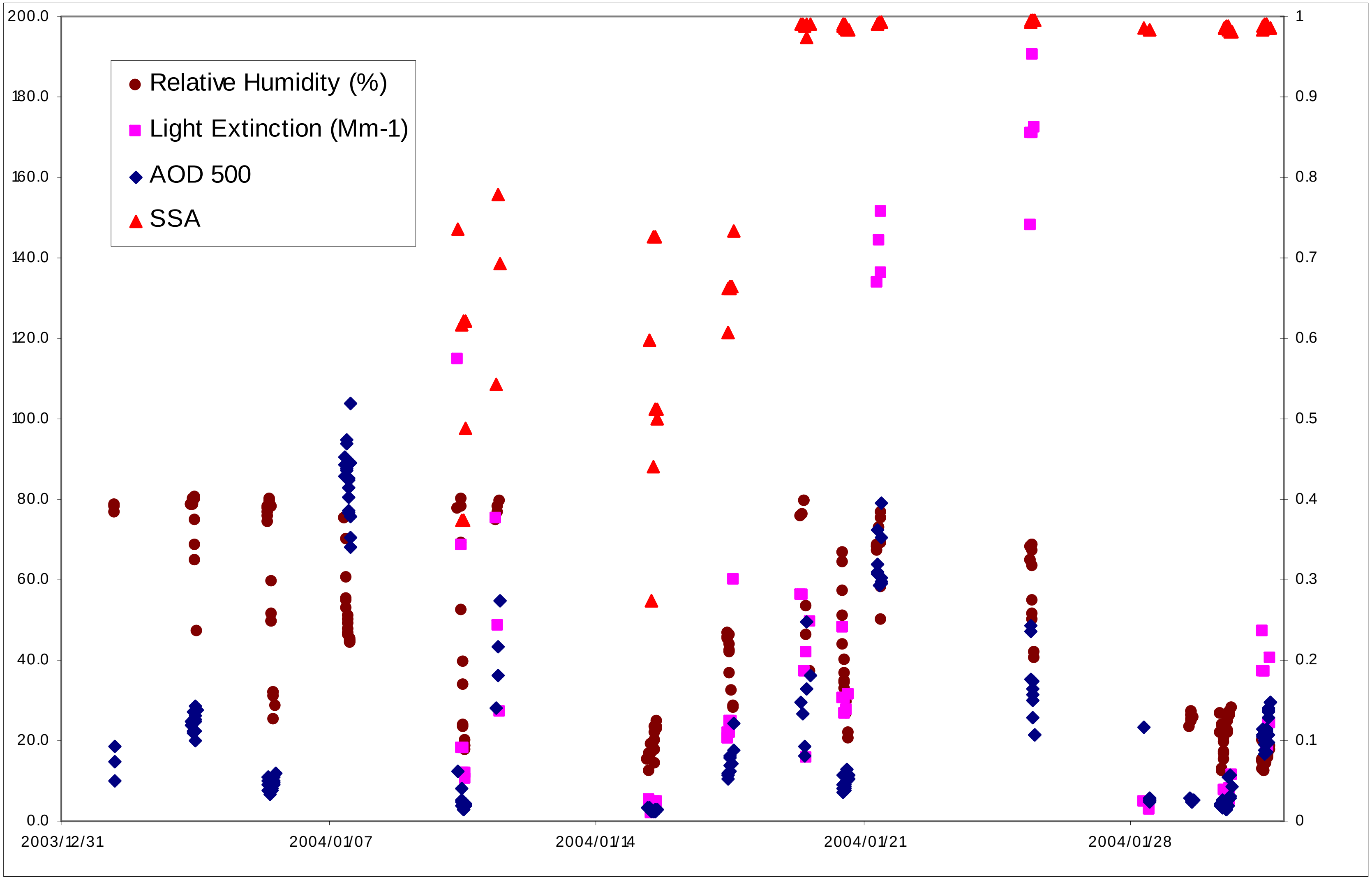
Ispra *In-situ* RH, extinction, SSA and column AOD



Data from Putaud & dos Santos, Zibordi & Suri.

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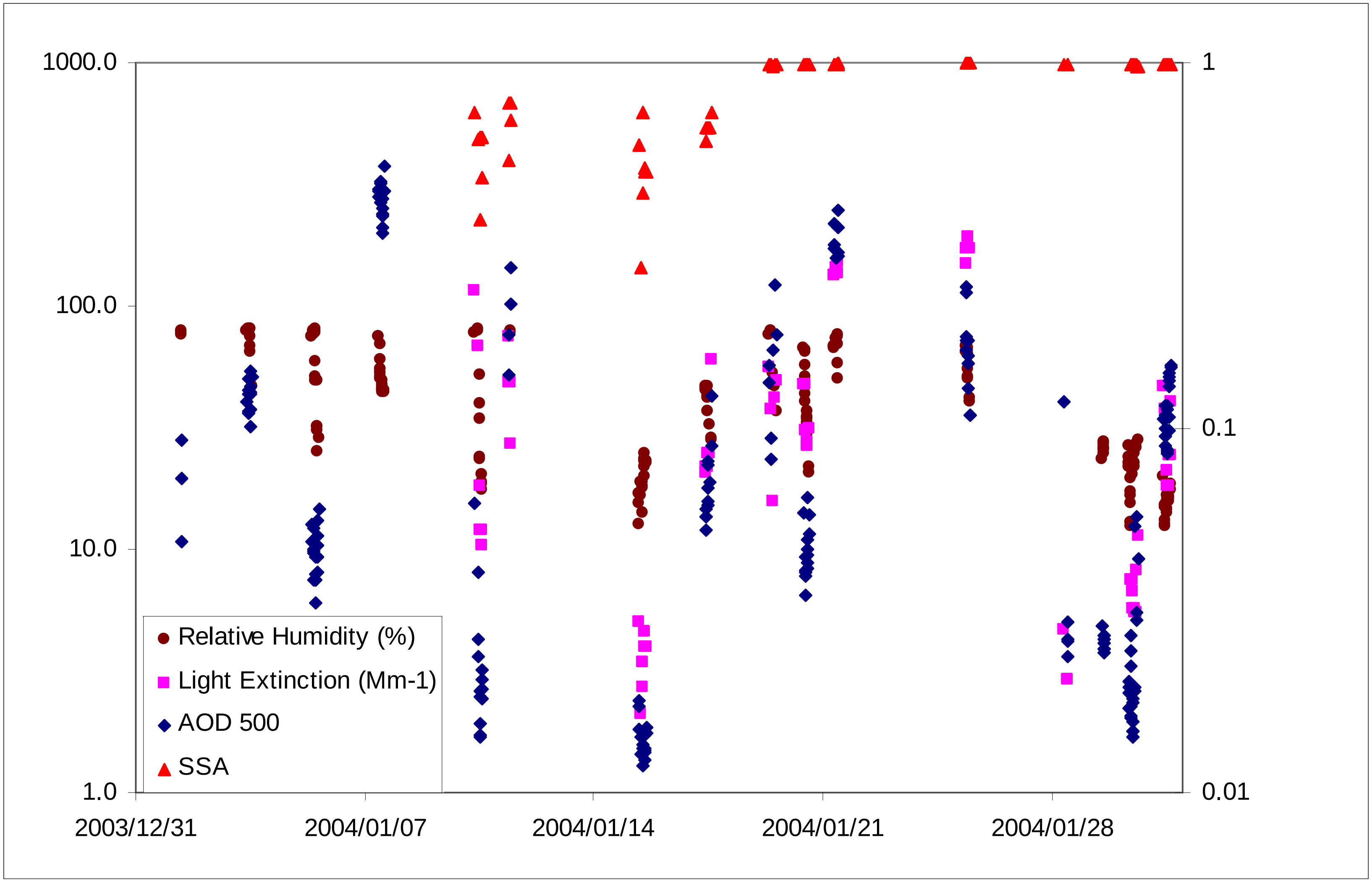
Ispra *In-situ* RH, extinction, SSA and column AOD



Data from Putaud & dos Santos, Zibordi & Suri.

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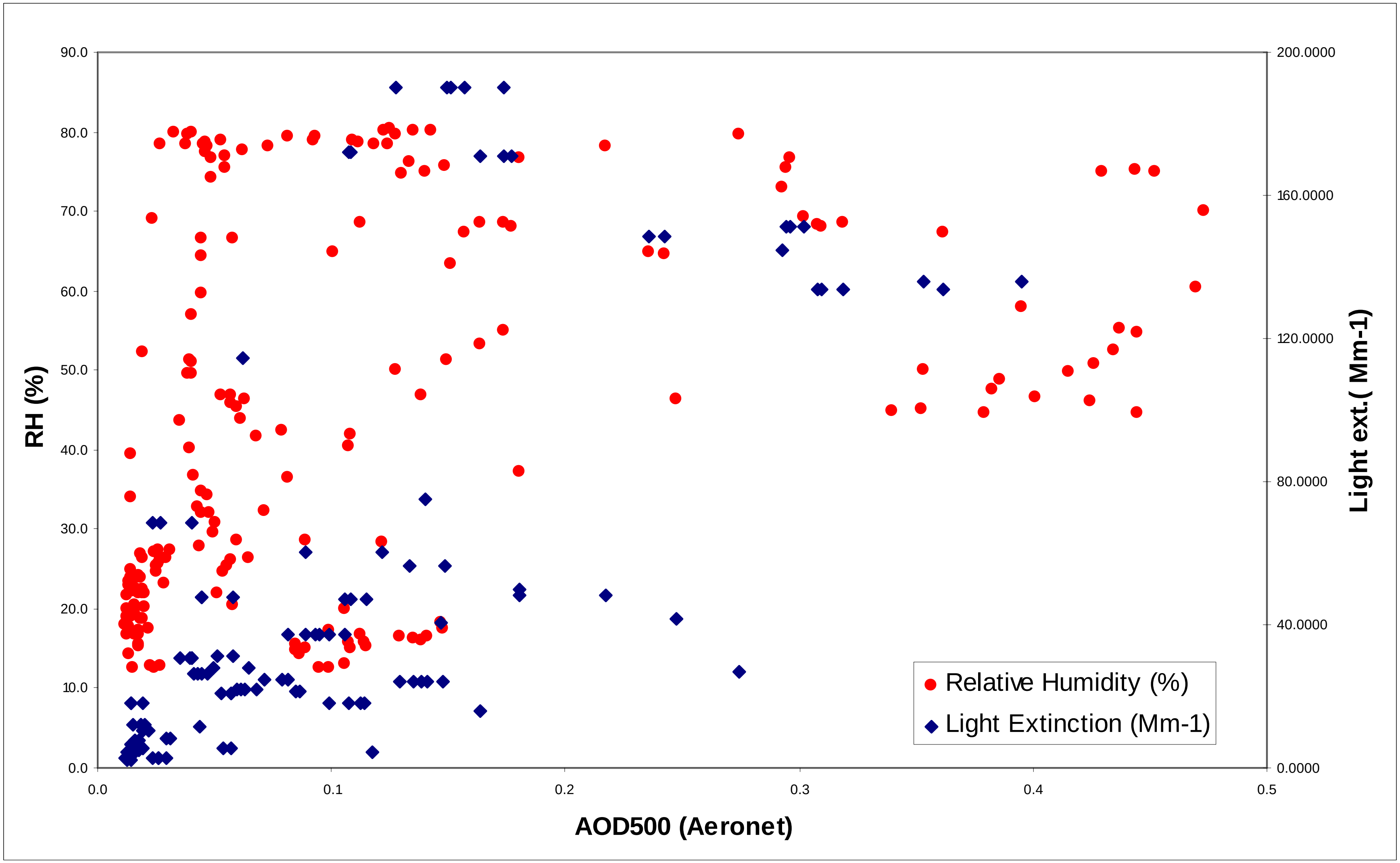
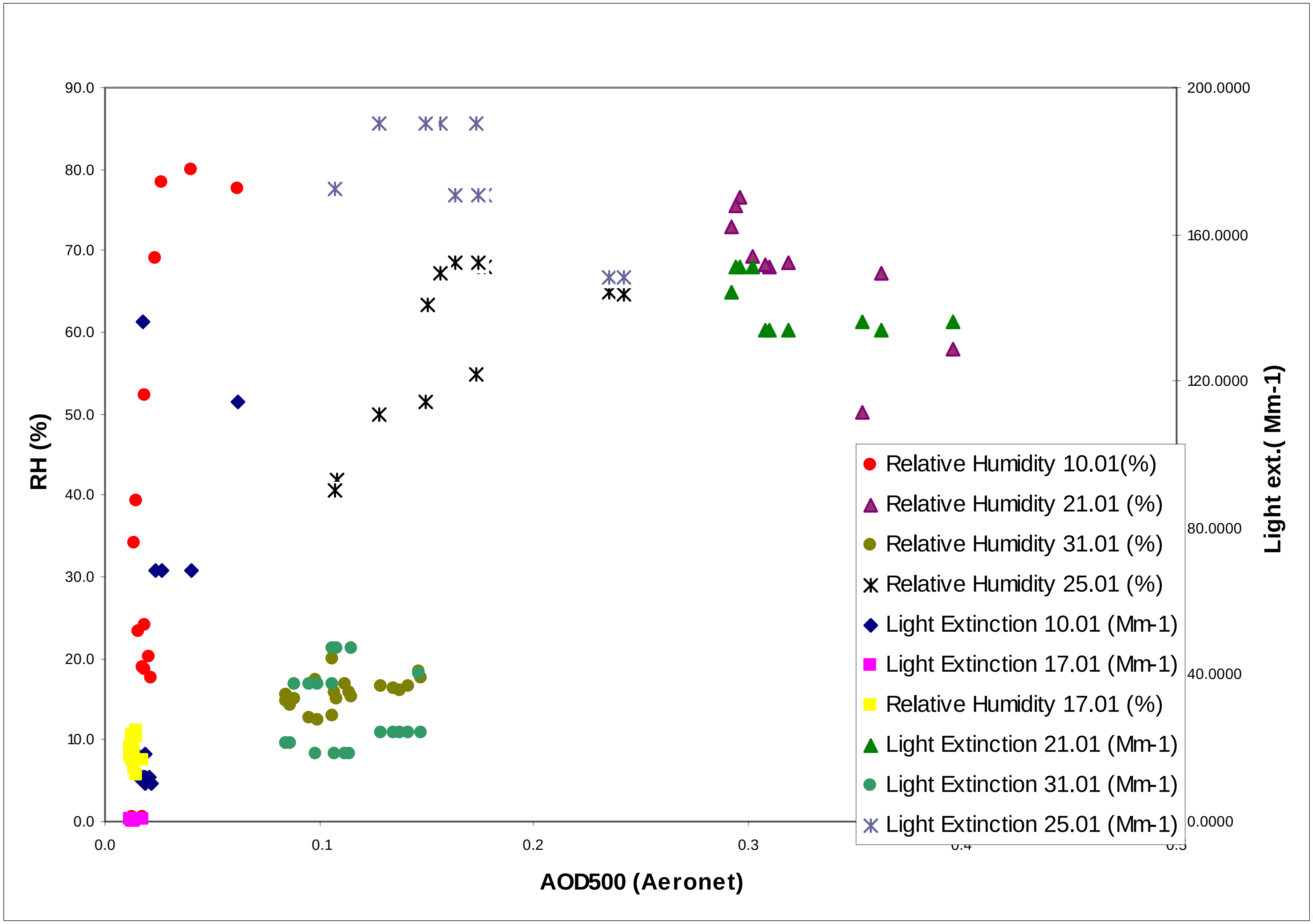
Ispra *In-situ* RH & extinction, vs column AOD



Data from Putaud & dos Santos, Zibordi & Suri.

Ispra *In-situ* RH & extinction, vs column AOD



Data from Putaud & dos Santos, Zibordi & Suri.
Ambient aerosol inlet 'heating' to c25c.

Issues for Experiment

- Model inter-comparisons such as AEROCOM have demonstrated the need for 'integrating' i.e. multi-parameter *in-situ* aerosol data sets for closure studies
- Observations of aerosol optical properties in controlled, known humidity conditions give the models a realistic test of their aerosol fields in the absence of model water vapour.
- Such observations are available at c20 (17 NH) sites the majority of which also have AOD & or aerosol composition observations.
- What year(s) 2004-6?
- What time resolution? – less than 24 h, AOD mainly morning measurements, however large RH changes from >30%% during morning common.
- Subjectively it appears that changing RH during a day correlates with changes in RH, but over a month no consistent correlation between changing RH and AOD emerges => sunset-sunrise or 06-12h local probably good enough.
- Correlation between RH & extinction coeff. strong in Ispra observations even at low temperatures.

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TM5 model set-up

- 25 vertical hybrid sigma-p layer, resolution of **6°x4**
- BC treatment:
  - **BULK:**
    - mass
    - considered accum. mode for removal processes (mass mean radius = 0.14 μm)
    - cloud-free atmosphere: hydrophobic
    - in cloud: 30% interstitial, 70% behaves as hygroscopic

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– **DYNA:**

- size resolved BC, mass and number in: insoluble Aitken; soluble Aitken, accumulation and coarse modes
- aerosol dynamics in the microphysical aerosol model M7 (Vignati et al., 2004): nucleation, coagulation, condensation of H_2SO_4
- in-cloud processing of accumulation and coarse modes

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- **BC GLOBAL EMISSIONS:**
- fossil & bio fuel = 4.67 TgC/y (Bond et al., 2004);
- biomass burning = 3.52 TgC/y (van der Werf et al., 2004)

- **RUN YEAR: 2002 MODEL OUTPUT:** monthly mean

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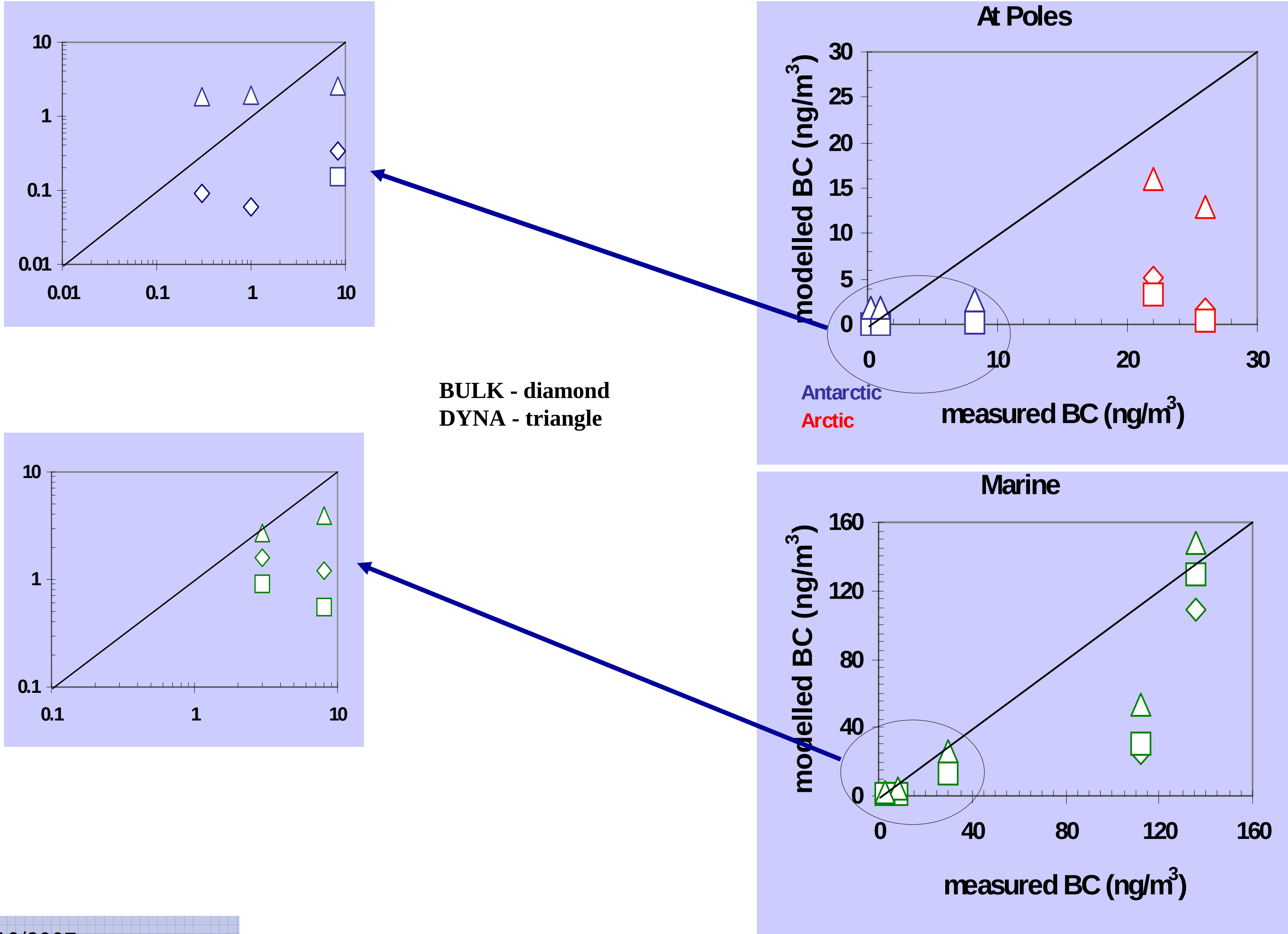
BC at marine and remote sites



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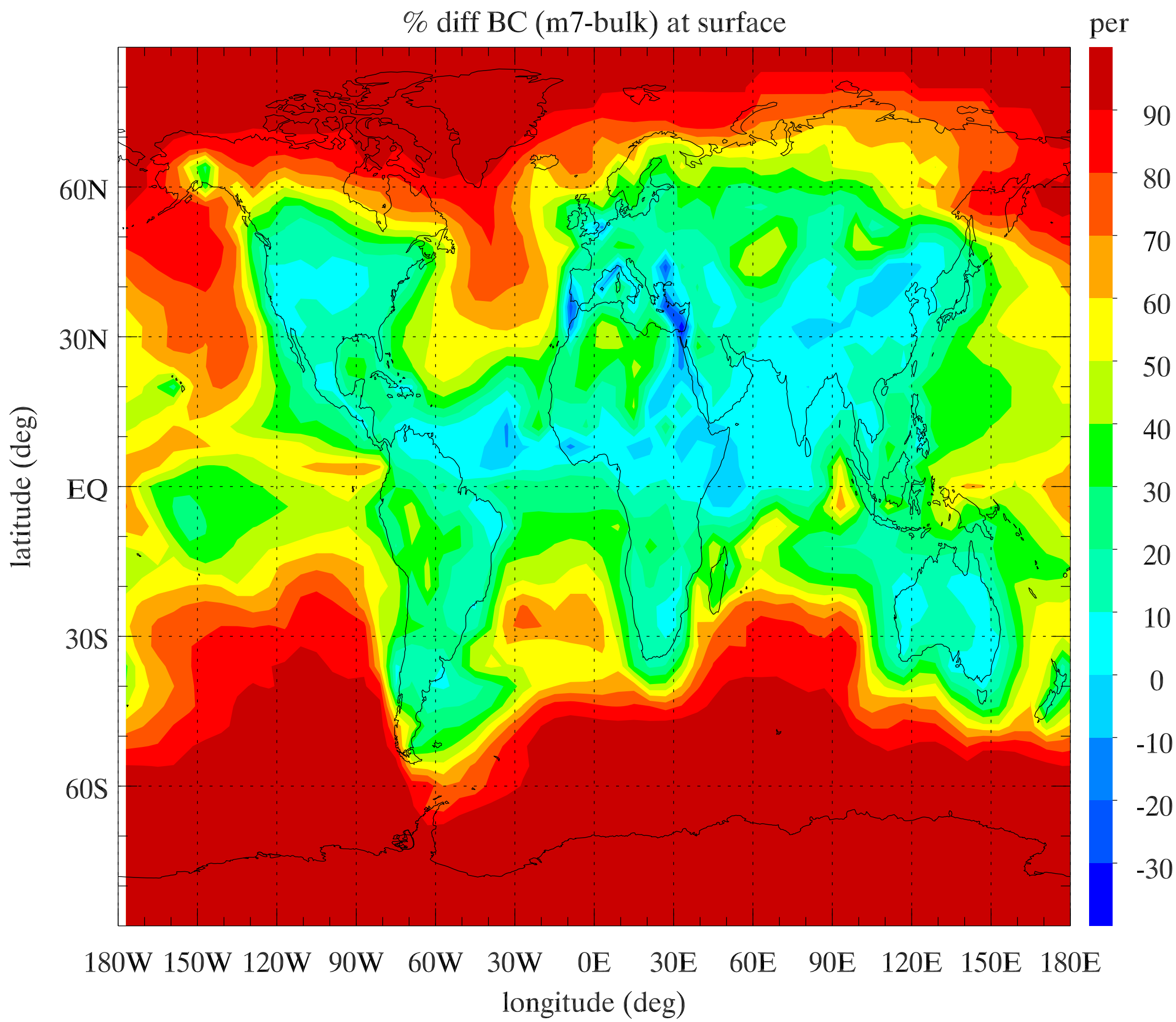
% diff BC (m7-bulk) at surface
per
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
60N
30N
EQ
30S
60S
latitude (deg)
180W 150W 120W 90W 60W 30W 0E 30E 60E 90E 120E 150E 180E
longitude (deg)

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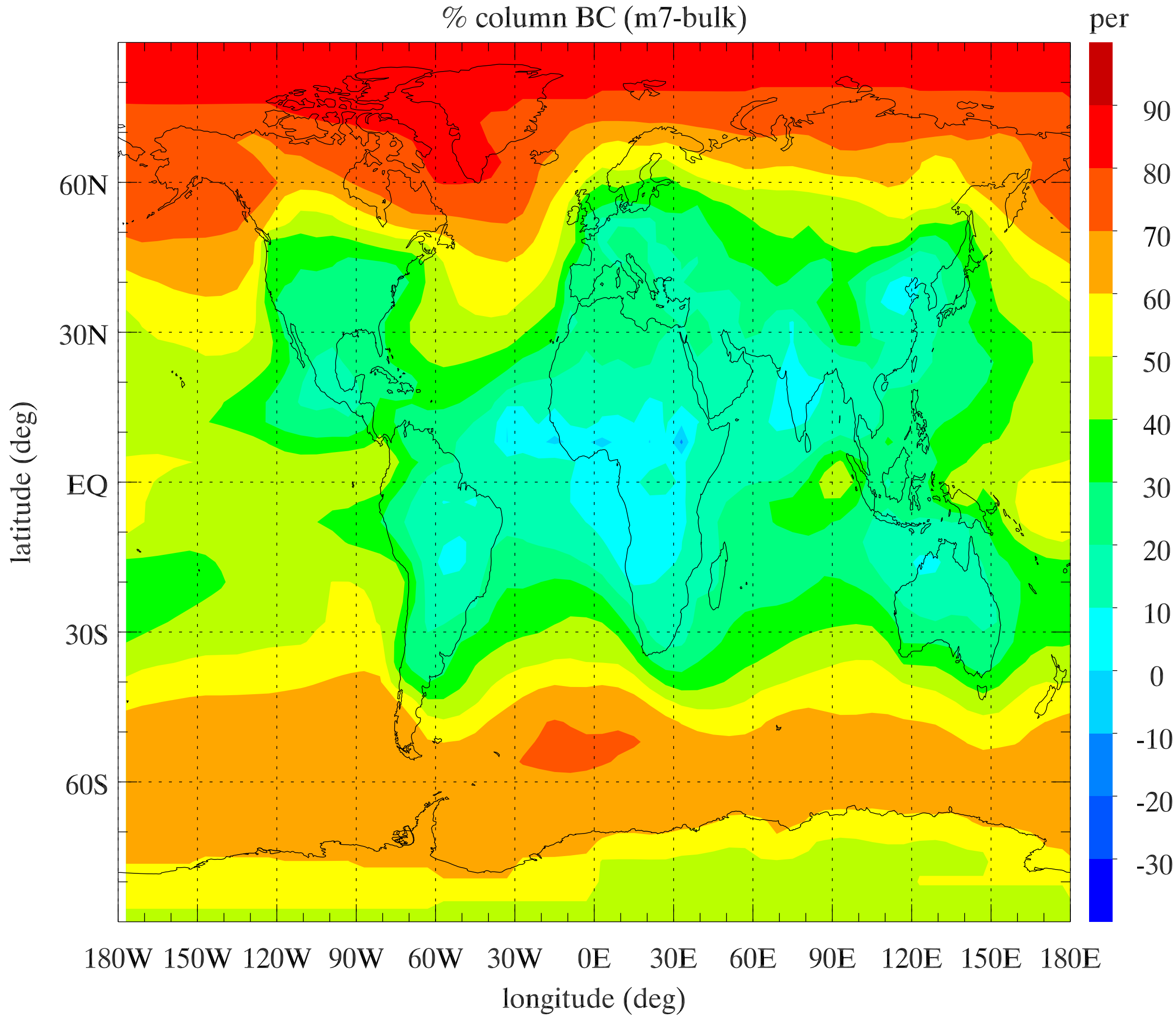

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