Studies of the impact of aerosol optical properties on climate change processes

T. Zielinski, A. Ponczkowska, P. Makuch, J. Kowalczyk,
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OTEM, CLUJ 2010

Where do I come from

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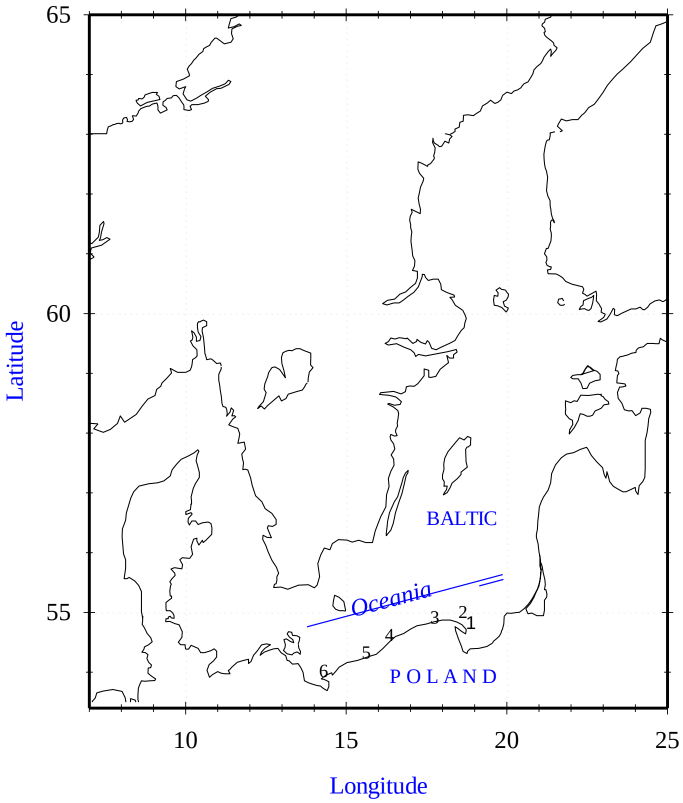
Research vessel *OCEANIA*

Measuring stations in the Baltic



Duck, NC, USA

ACCENT - Access to infrastructures

- **S**tudies **O**f **A**erosol **P**roperties – SOAP 2006

- Access to field stations:

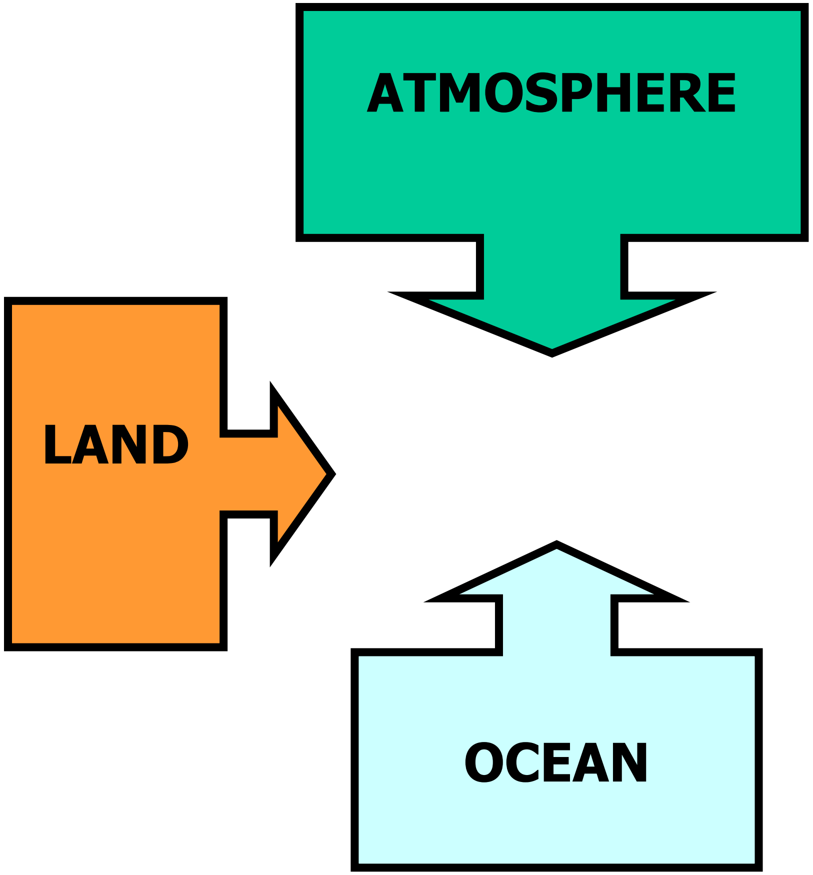
  - Finokalia sampling station Crete (35º 20'N, 25º 40'E)

  - Dates:

  27 July – 10 August 2006

Instrumentation (*Oceania*/Svalbard)

Instrument	**Parameters observed**	**Location**	**Operated since**
Lidar LB 10 (532 nm)	Aerosol profiles	r.v. Oceania/Svalbard	2009
Microtops II sunphotometers	AOD	r.v. Oceania/Svalbard	2001
Microtops II ozonometer	Ozone profiles	r.v. Oceania/Svalbard	2001
PMS laser particle counter CSASP-100	Coarse aerosol size distribution and concentration	r.v. Oceania/Svalbard	1993
TSI Condensation Particle Counter	Fine mode aerosol concentration	r.v. Oceania/Svalbard	2007
TSI laser counter	Aerosol size distribution and concentration	r.v. Oceania/Svalbard	2010
TSI nephelometer	Aerosol light scattering	r.v. Oceania/Svalbard	2010
GILL acoustic anemometer	Wind speed pulsations	r.v. Oceania/Svalbard	2007
Meteo-station	Meteorological parameters	r.v. Oceania/Svalbard	1993
Eppley Precision spectral Pyranometers	Solar radiation fluxes	r.v. Oceania/Svalbard	1993
Kipp&Zonen net radiation meter	Upward and downward radiation fluxes	r.v. Oceania/Svalbard	2000



meet at the coastal zone!

Source: www.nioz.nl/loicz

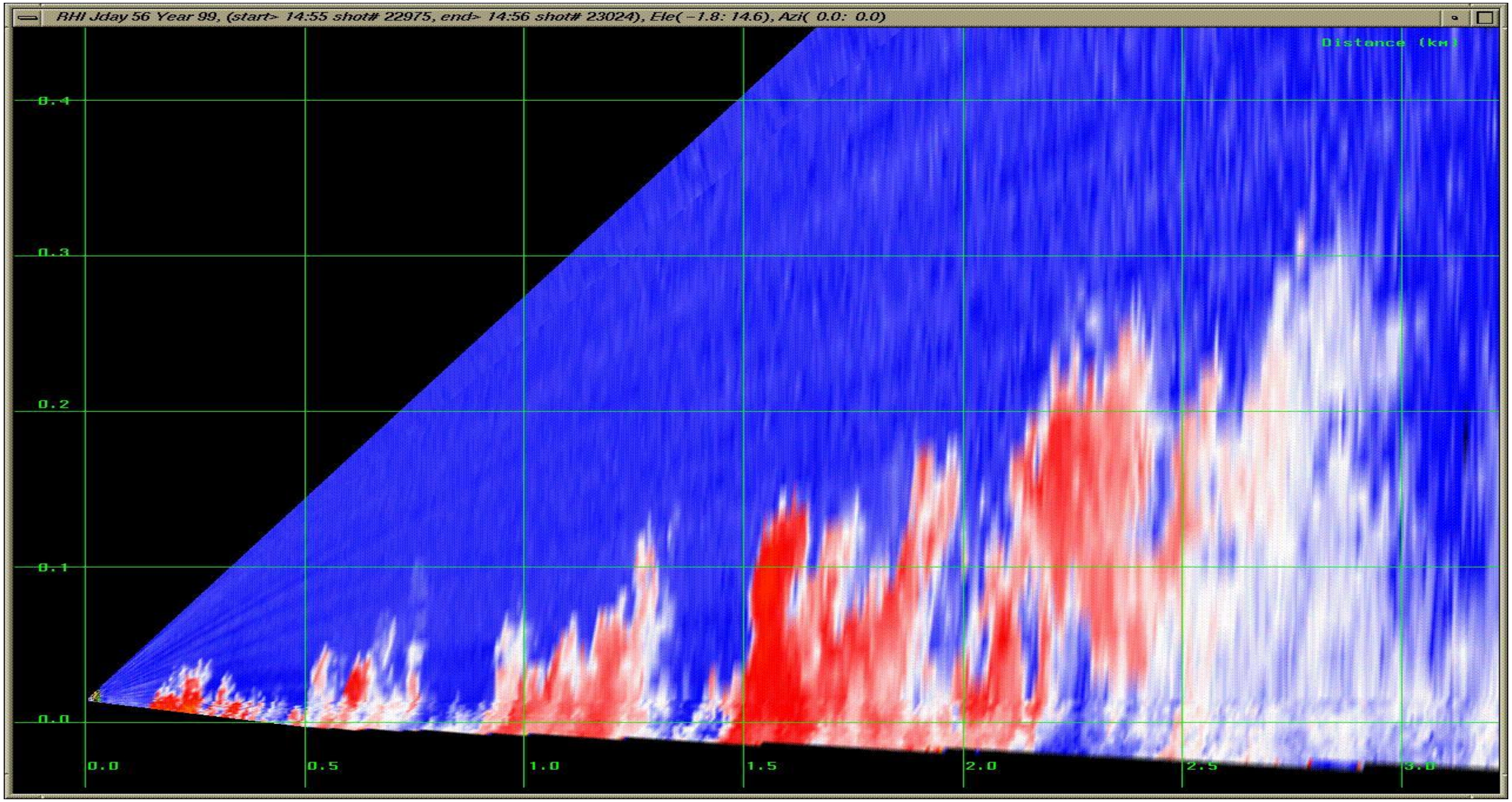
Description of experiments

Season of measurements in 1993-2003	Eastern station				Western station			
	Number of experi-ments	Number of measu-ring days	Number of onshore wind days	Number of offshore wind days	Number of experi-ments	Number of measu-ring days	Number of onshore wind days	Number of offshore wind days
Winter (February, March)	1	11	2	7	1	2	2	0
Spring (late March, April, May, early June)	6	42	26	16	5	31	18	13
Summer (June, August, early September)	2	12	4	6	2	9	4	5
Fall (September, October, November)	6	37	12	29	5	41	10	31
Total	15	102	44	58	13	83	34	49

Description of the campaigns

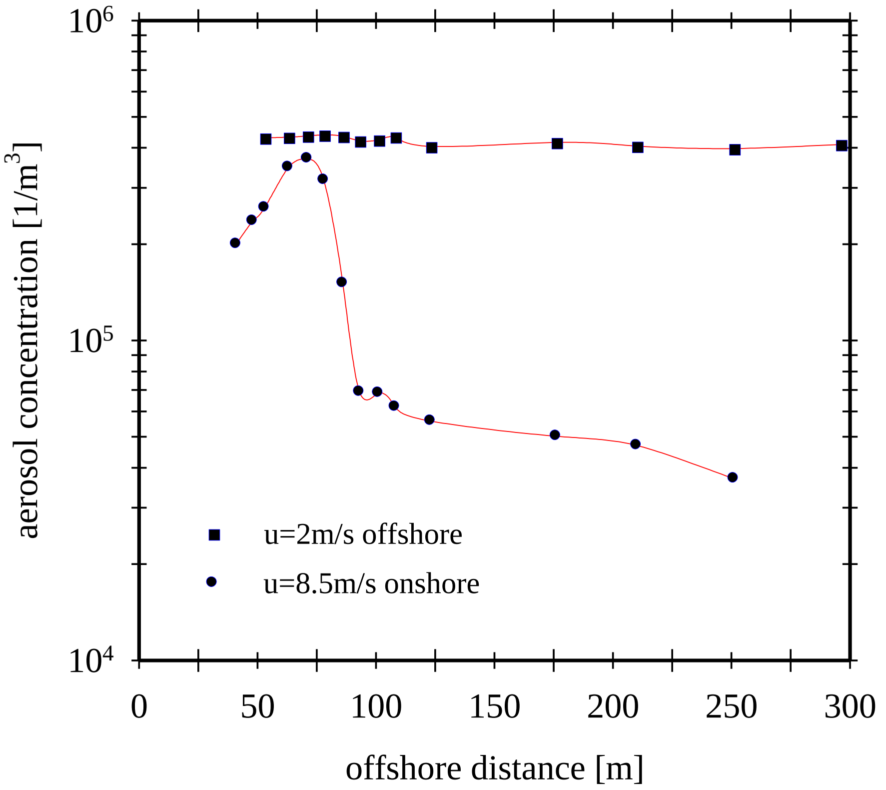
- Application of the FLS-12 lidar system for obtaining the horizontal and vertical profiles of aerosol concentration and size distributions as well as optical properties
- The useful part of the optical path is between 60 and 2000 m and altitudes up to 600 m can be sounded.
- Simultaneous measurements using Microtops sunphotometers, the lidar system and Hires A and Hires B
- Full meteorological coverage
- Measurements during and beside the overpasses

Aerosol cloud in the coastal zone at an offshore wind speed of 5 m/s

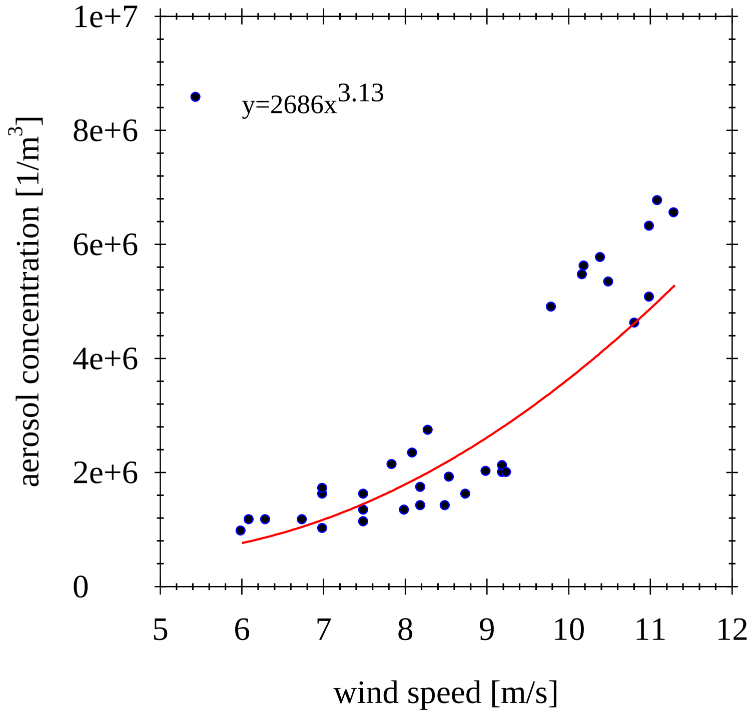


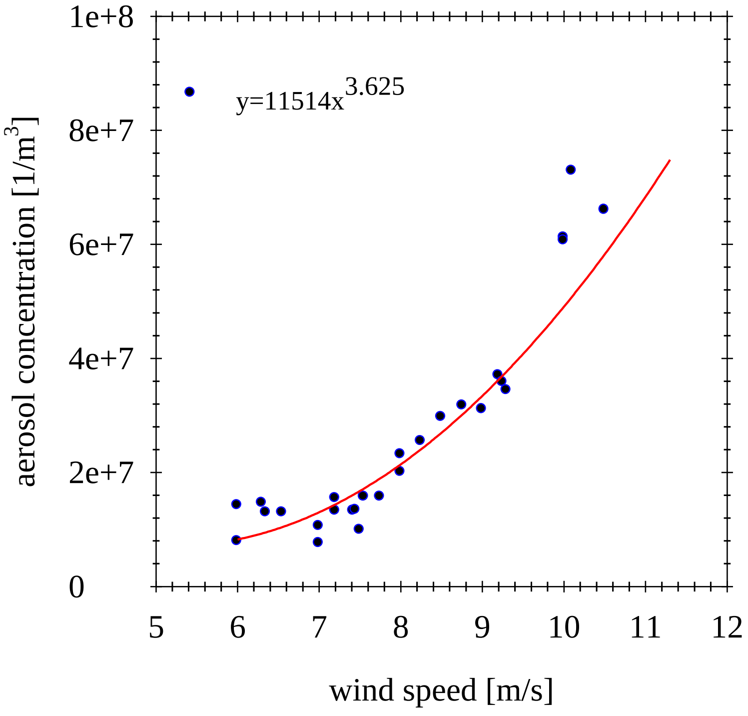
RHI Jday 56 Year 99, (start> 14:55 shot# 22975, end> 14:56 shot# 23024), Ele(-1.8: 14.6), Azi(0.0: 0.0)

Variations of aerosol concentration with offshore distance in the Baltic Sea

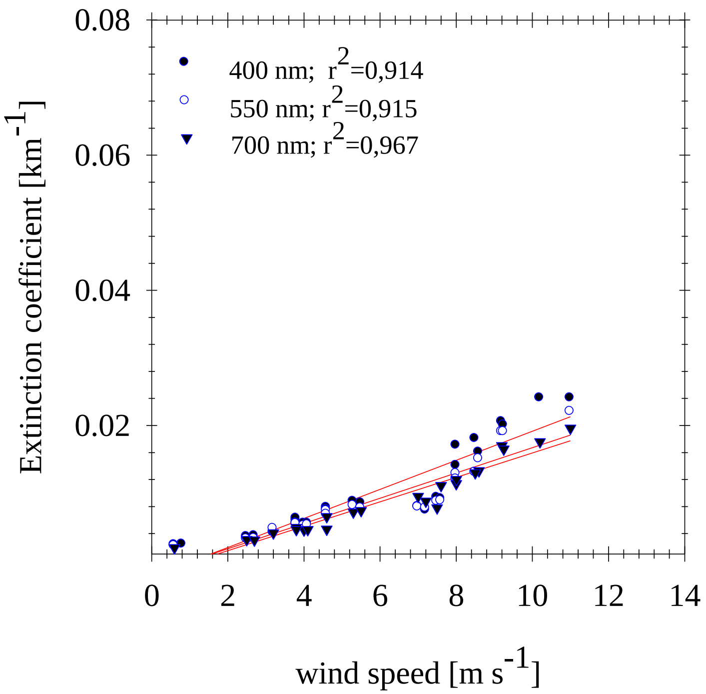


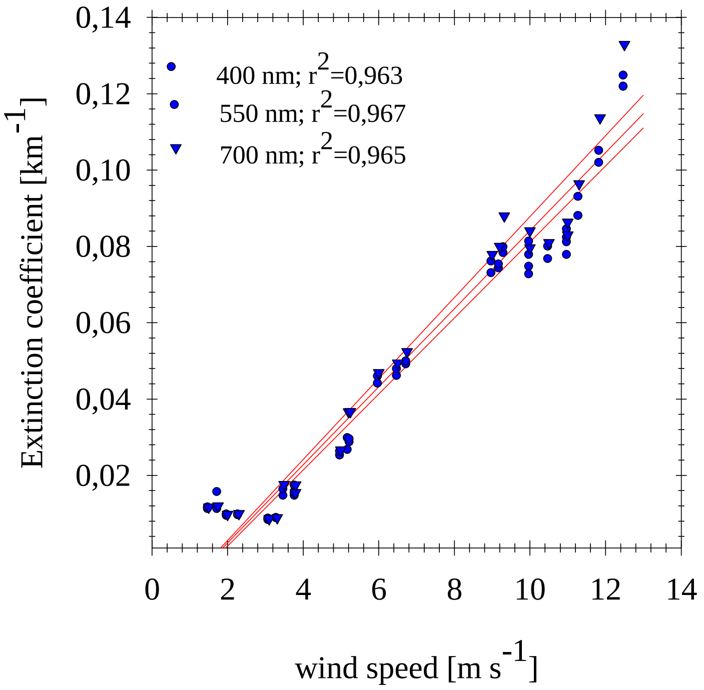
Lidar-obtained marine aerosol concentration for two station types



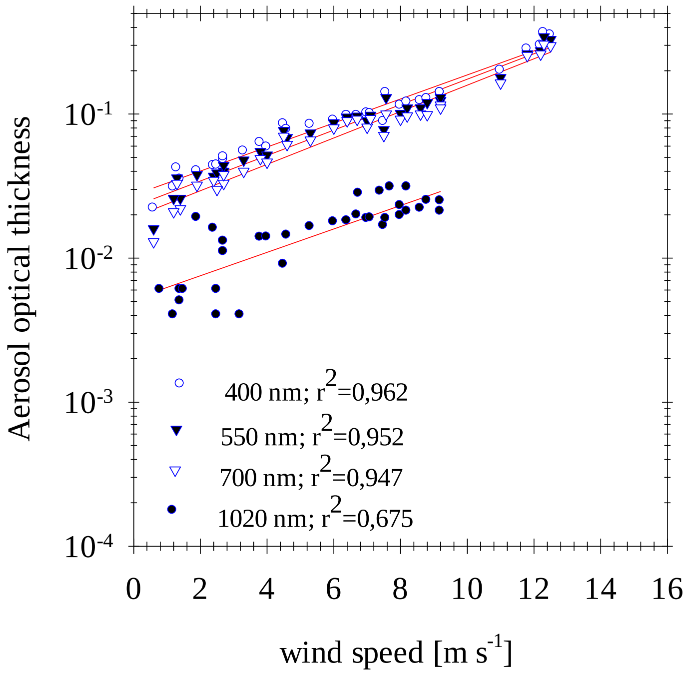


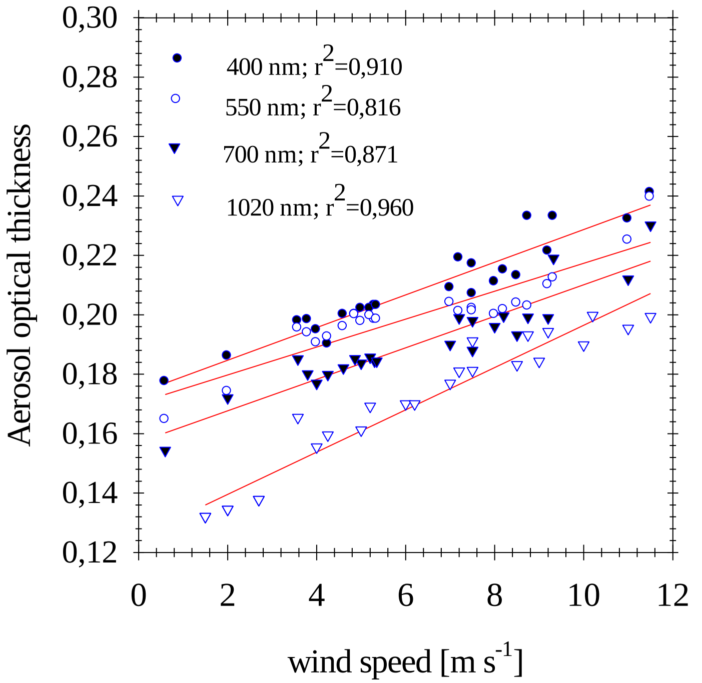
Variations of marine aerosol extinction with wind speed at both types of stations



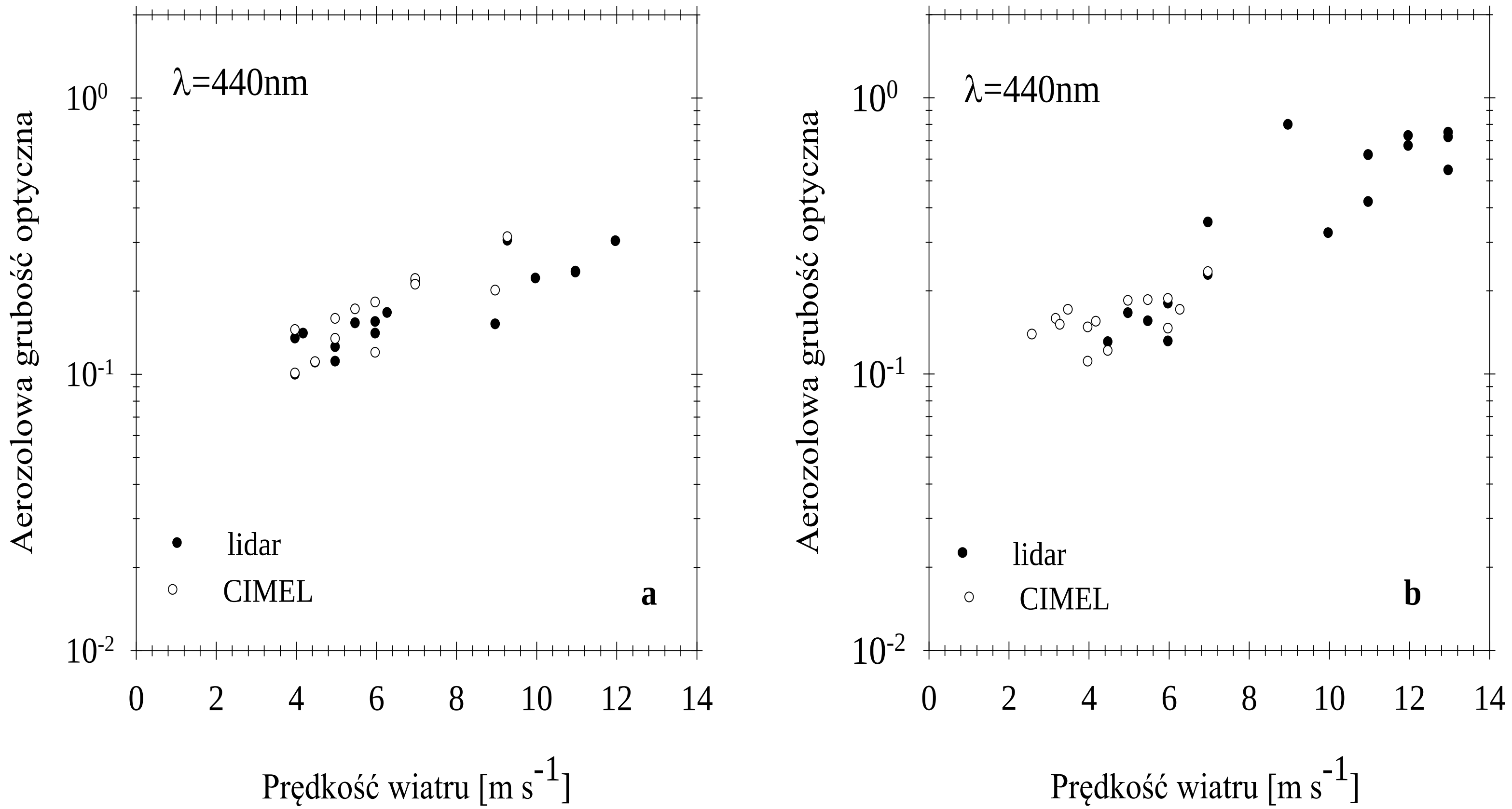


Variations of AOT with wind speed at both types of stations





AOT in the coastal area



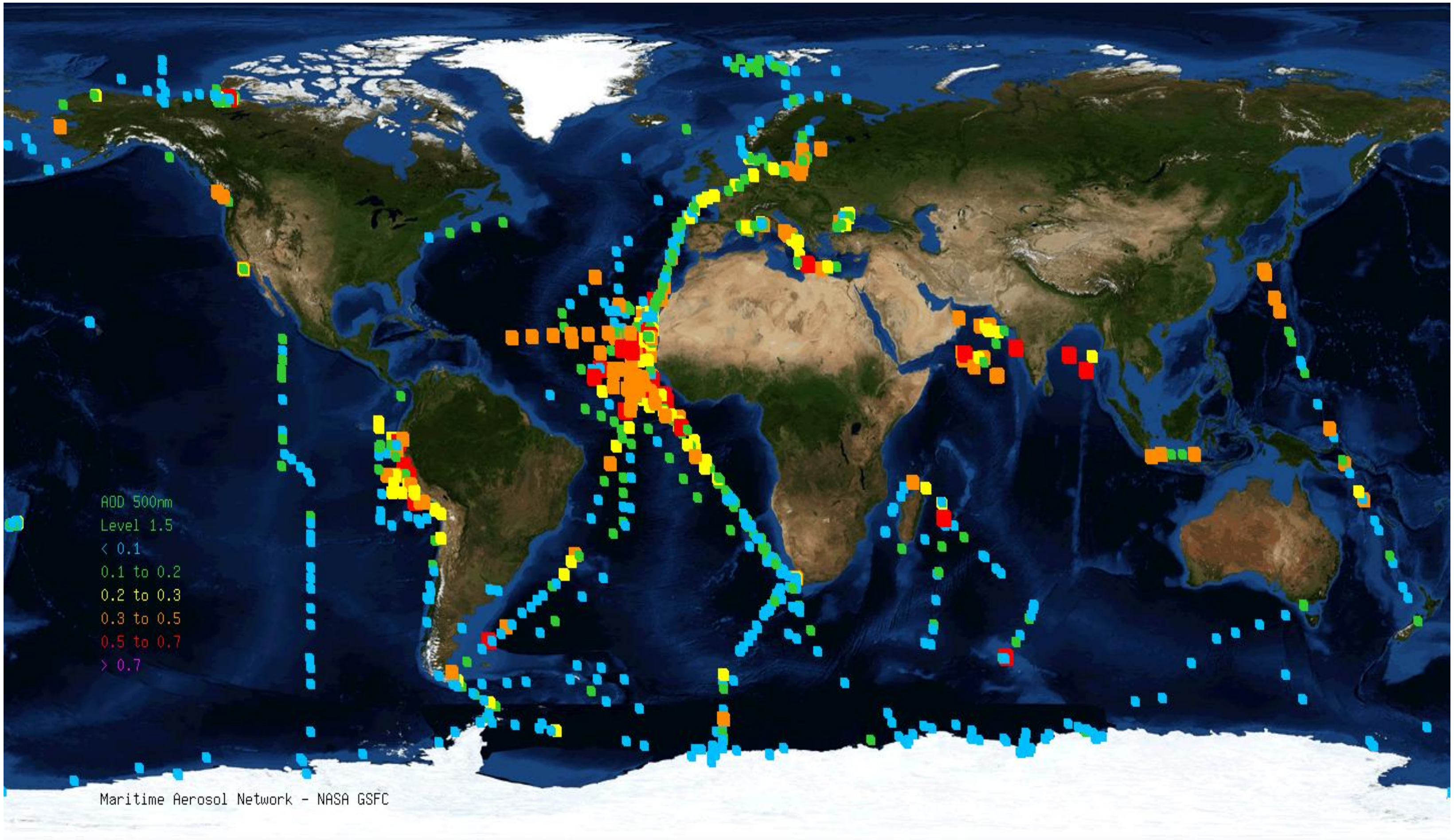
Extinction coefficient - comparison

Author	Air mass type	Extinction coefficient [km^{-1}] λ = 550 nm	Area/model	Description
Gathman, 1983	**Continental**	**0.370**	**NAM - Navy Aerosol Model**	**h = 4 m a.s.l.** **RH = 80%** **$v = 8\ m\ s^{-1}$**
d'Almeida and Koepke, 1991	**Continental** **Marine**	**0.167** **0.078**	**Global Aerosol Model**	**Entire atmos. column** **RH = 80%**
Gathman and Jensen, 1995	**Continental** **Marine**	**0.58** **0.04**	**Coastal station Katwijk aan Zee, Holland**	**h = 2 m a.s.l.**
Gathman and Smith, 1997	**Marine**	**0.32**	**San Diego Bay, USA**	**h = 4 m a.s.l.** **RH = 80%** **$v = 1,8\ m\ s^{-1}$**
Gathman and Smith, 1997	**Marine**	**0.103**	**San Diego Bay, USA**	**h = 8 m a.s.l.** **RH = 80%** **$v = 1,8\ m\ s^{-1}$**
Hess et al.., 1998	**Continental** **Urban** **Marine**	**0.151** **0.353** **0.090**	**Model OPAC-Optical Properties of Aerosols and Clouds**	**Atmos. column** **$h \in [0; 2000\ m]$** **RH = 80%**

Extinction coefficient - comparison

Author	Air mass type	Extinction coefficient [km^{-1}] λ = 550 nm	Area/model	Description
Jensen et al., 2001	Marine	0.6	Monterey Bay, USA	h = 4 m a.s.l. RH = 80%
Jensen et al., 2001	Marine	0.1	Monterey Bay, USA	h = 10 m a.s.l. RH = 80%
Zieliński, 2006	Continental (lidar) Marine (lidar)	0.077 0.0096	Southern Baltic (Eastern station)	h = 4 m a.s.l. RH = 80% v = 7,5-9 m s^{-1}
Zieliński, 2006	Continental (lidar) Marine (lidar)	0.0098 0.0068	Southern Baltic (Eastern station)	h = 30 m a.s.l. RH = 80% v = 7,5-9 m s^{-1}
Zieliński, 2006	Marine (spring) Continental (fall)	0.006-0.008 0.027-0.047	Southern Baltic (Eastern station)	h = 4 m a.s.l. RH = 80% v = 3,8-4,8 m s^{-1} v = 4,8-6,0 m s^{-1}
Zieliński, 2006	Marine (spring) Continental (fall)	0.075-0.078 0.105-0.113	Southern Baltic (Western station)	h = 4 m a.s.l. RH = 80% v = 4,1-4,3 m s^{-1} v = 3,6-4,2 m s^{-1}

Maritime Aerosol Network



Work

Work

Microtops II sunphotometer

Optical channels	340 ± 0.3 nm, 2 nm FWHM* 380 ± 0.4 nm, 4 nm FWHM 440 ± 1.5 nm, 10 nm FWHM 500 ± 1.5 nm, 10 nm FWHM 675 ± 1.5 nm, 10 nm FWHM
Resolution	$0.01\ W\ m^{-2}$
Dynamic range	>300000
Viewing angle	2.5°
Precision	1-2%
Non linearity	max. 0.002%

Radiative forcing

Aerosol radiative forcing at an arbitrary place in atmosphere

$$\Delta F = F^{net}_{aerosol} - F^{net}_{clean}$$

$$F^{net} = F\downarrow - F\uparrow$$

where: F↓ and F↑ radiation fluxes [W/m^2] at a fixed altitude a.s.l.

Source: Satheesh and Ramanathan (2001)

Aerosol radiative forcing

$$\Delta F \cong -1/2 f \times T_i^2 (1-A) \times (1-R)^2 \beta \times \nu$$

No multiple scattering and absorption.

where:
f – solar constant,
T_i – transmission through the part of atmosphere over the aerosol layer,
A – average cloud coverage,
R – reflection from Earth surface,
β - upward scattering coeff. for entire sloar ardiation spectrum,
ν - averaged optical thickness

Source: Charlson et al. (1991)

Climate change uncertainty

- Climate change „sensitivity”

$$\Delta T = a\Delta F$$

where:

ΔT – global, averaged temperature change

ΔF – global, averaged radiation forcing

a – climate „sensitivity”

- In climate models clouds are the greatest source of uncertainity
- In retrospective studies lack of knowledge on aerosol radiative forcing

Data

Level 1.5 - Cloud and pointing error screening criteria:

- Within a series, the minimum aerosol optical depth for each point is identified at each wavelength (τai). The following criteria are examined for cloud and pointing errors:
- If the difference (τai - τai min) for each spectral channel is less than the maximum of { τai min *0.05, 0.02}, then the point within a series is considered cloud and pointing error free.

If the above screening removes all but one point from a series, then an additional criterion below is applied to the spectral channels:

- If the Angstrom parameter computed using all available channels between 440 and 870 nm is greater than -0.1, then the point is considered cloud and pointing error free.

Level 2.0 - Quality Assurance Criteria:

- Final post-deployment calibration values are applied to the data set.
- Spectral channels are evaluated for filter degradation, other possible instrumental problems, or data anomalies.
- Aerosol optical depth data are inspected for possible cloud contaminated outliers.

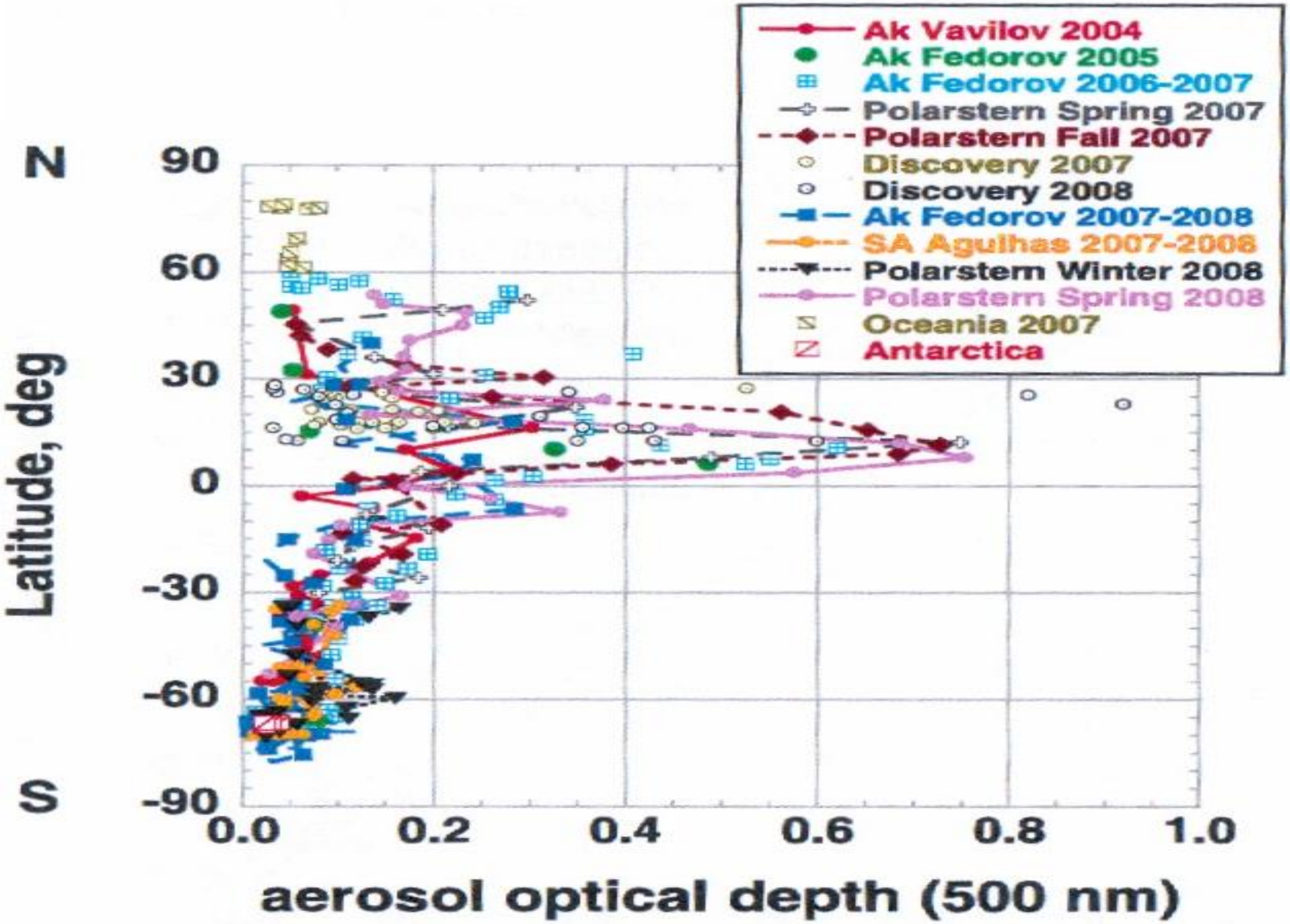
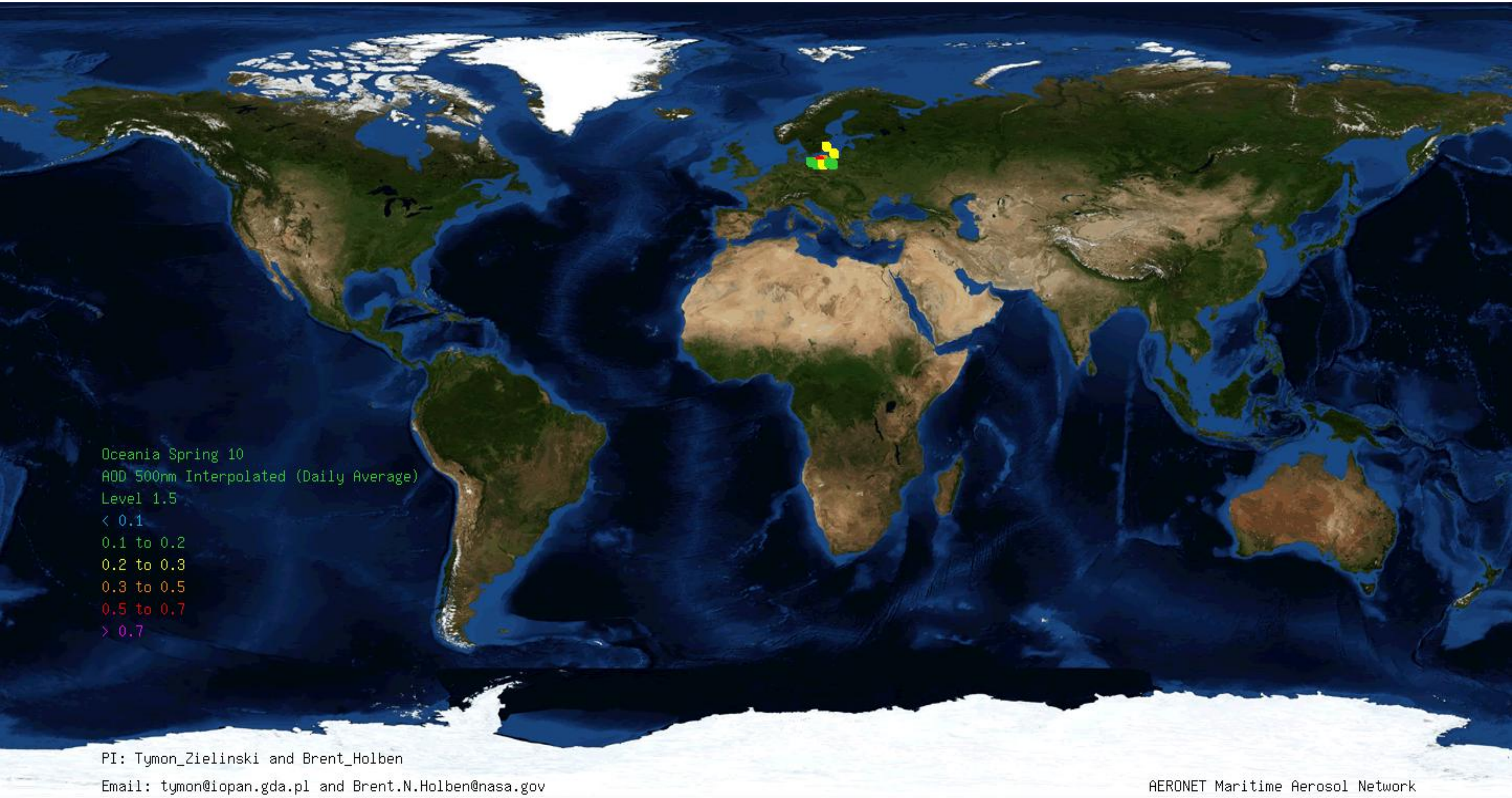


Figure 7. Latitudinal dependence of aerosol optical depth in the Atlantic Ocean. Seasons in the legend correspond to meteorological seasons for Northern Hemisphere.

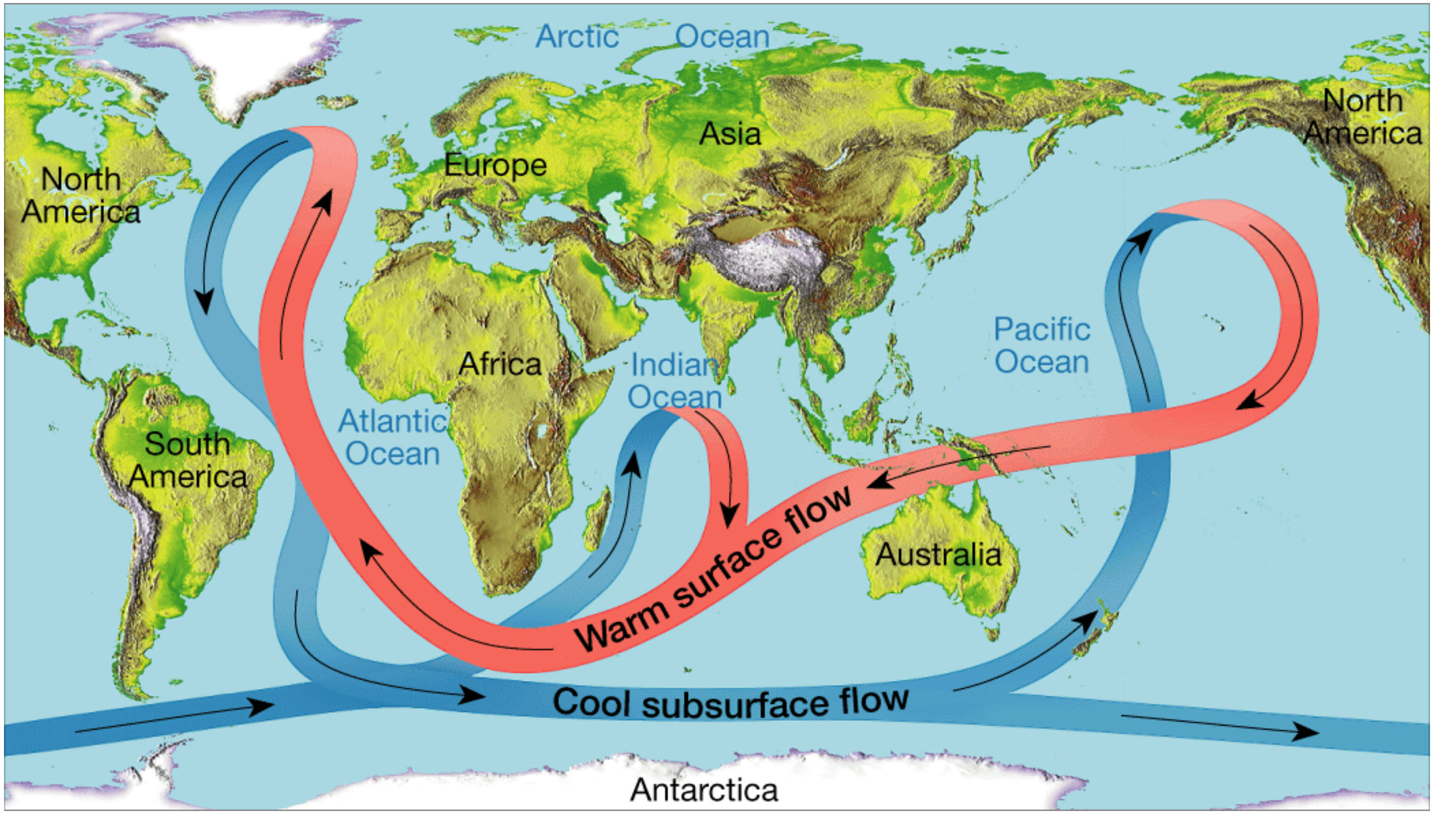
Maritime Aerosol Network



PI: Tymon_Zielinski and Brent_Holben

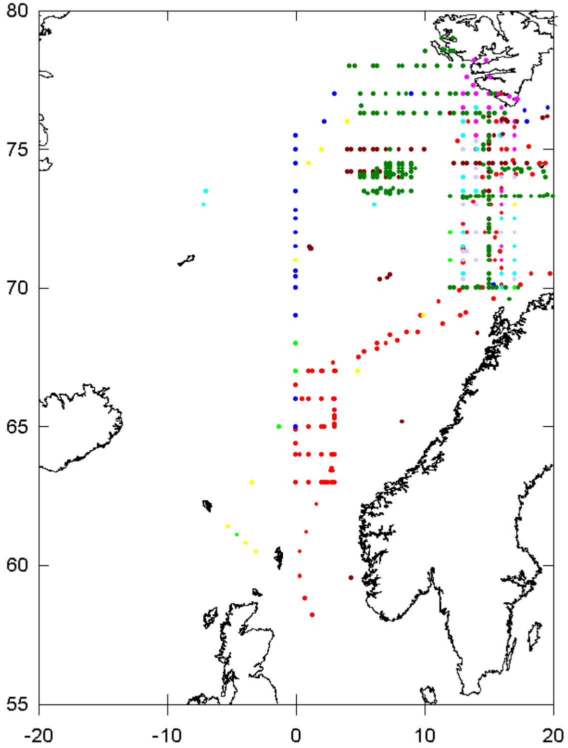
Email: tymon@iopan.gda.pl and Brent.N.Holben@nasa.gov

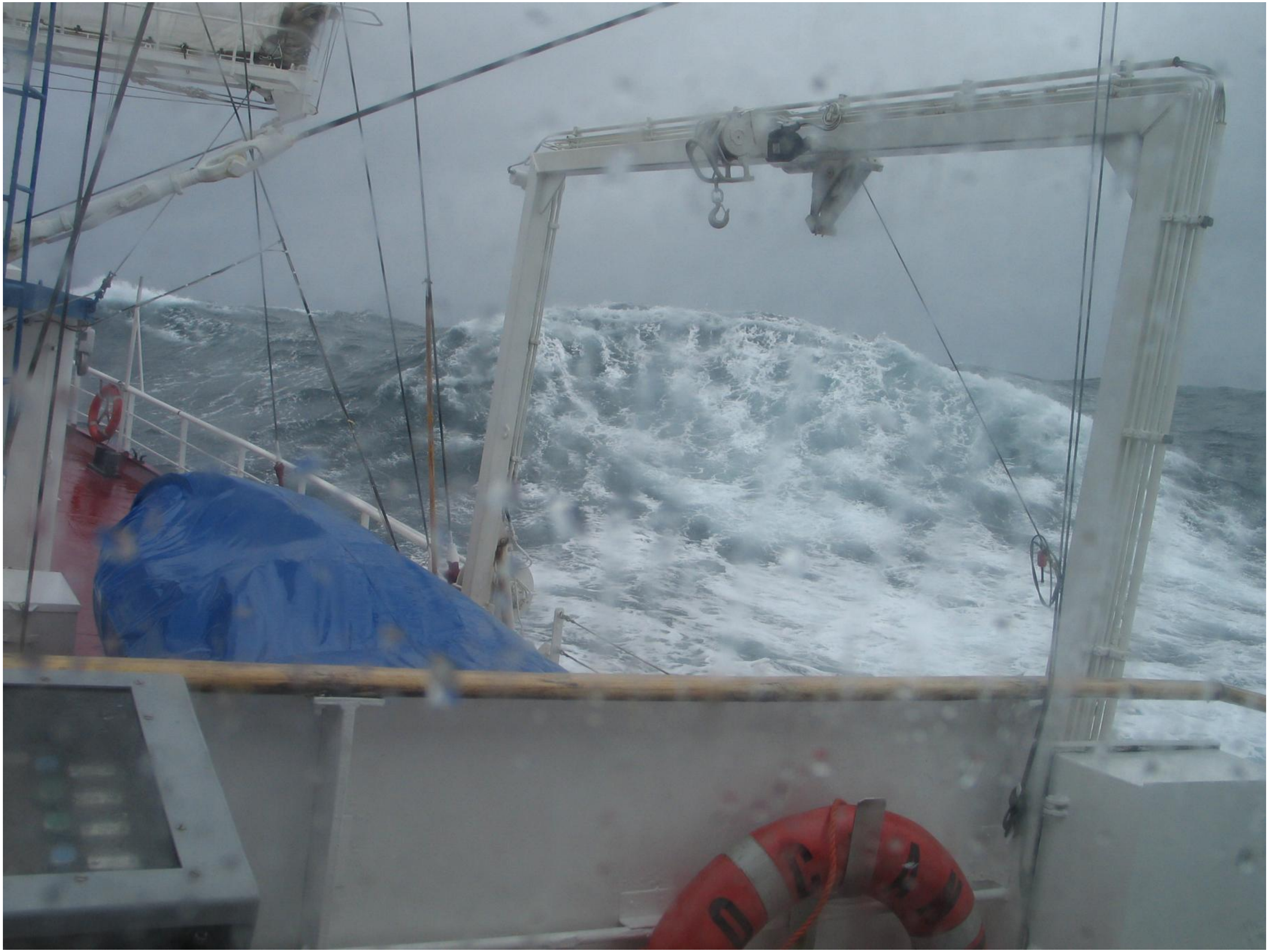
Ocean conveyor belt



Source: Prentice Hall

Our presence in the Arctic 1990-2010





Specifics of the Arctic studies

- High ground albedo (multiplescattering between ground and atmosphere)

- Low sun elevation above the horizon

- Polar day and night

- Low air temperature (low absolute water vapor content)

- **Objectives:**

Determination of the vertical structure of the chemical, physical, and optical properties of Arctic aerosol particles, including solar radiative closure between observed and calculated aerosol properties (direct climate effect)

Lidar measurements near Spitsbergen

DATE	STAT.	TIME (local)	NUMBER OF SHOTS (6)	COLOR	POWER	LAT.	LONG.
2.07.2002	01	11:33	1(4)	BLUE	450		
	01	11:41	1(4)	GREEN	400		
	O4	15:39	1(4)	GREEN			
	O4	15:46	1(4)	BLUE			
3.07.2002	K3	12:34	1	BLUE	470	75.00	18.00
	K3	12:46	1	GREEN	460		
	K14	16:51	1	GREEN	400		
7.07.2002	N-8	12:27	1(8)	BLUE	320	76.30	6.00
	N-8	12:40	1(8)	GREEN	370		

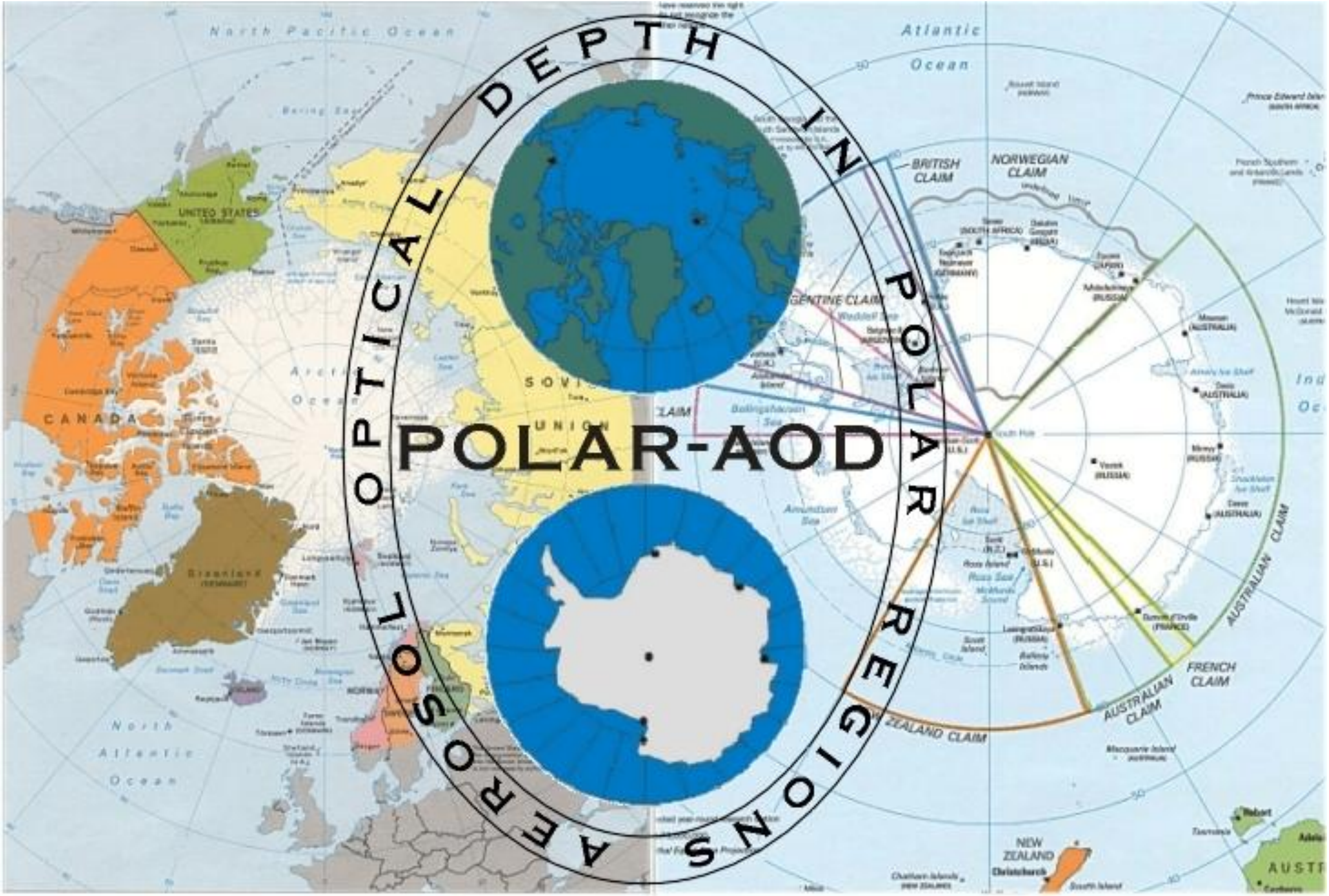
Lidar measurements near Spitsbergen

DATE	STAT.	TIME (local)	NUMBER OF SHOTS (6)	COLOR	POWER	LAT.	LONG.
9.07.2002	S7	8:59	1	BLUE		77.495	9.53
	S7	9:08	1	GREEN			
	S4	12:53	1	GREEN	260	77.55	11.02
	S4	13:07	1	BLUE	300		
	S4	13:28	1	BLUE			
	S4	13:42	1	GREEN			
	S3	15:05	1	GREEN		78.02	12.00
	S3	15:15	1	BLUE			
	S2	17:09	1	BLUE		78.07	12.55
	S2	17:19	1	GREEN			

Arctic Study of Tropospheric Aerosol, Clouds and Radiation – ASTAR 2004-2007

AWI Bremerhaven/Potsdam, Germany
NIPR Tokyo, Japan
ITM/MISU Stockholm, Sweden
DLR-IPA Oberpfaffenhofen, Germany
LaMP Clermont-Ferrand, France
IFT Leipzig, Germany
KNMI de Bilt, The Netherlands
NILU Kjeller, Norway

DLR Flight Operation,Germany
FMI Helsinki, Finnland
IOPAN Sopot, Poland
Norsk Polarinstitutt, Norway
IUP Bremen, Germany
CNR Bologna, Italy
Hokkaido University Sapporo, Japan
Nagoya University, Japan
NASA LaRC Hampton, USA
NOAA Boulder, USA



POLAR-AOD

AEROSOL OPTICAL DEPTH IN POLAR REGIONS

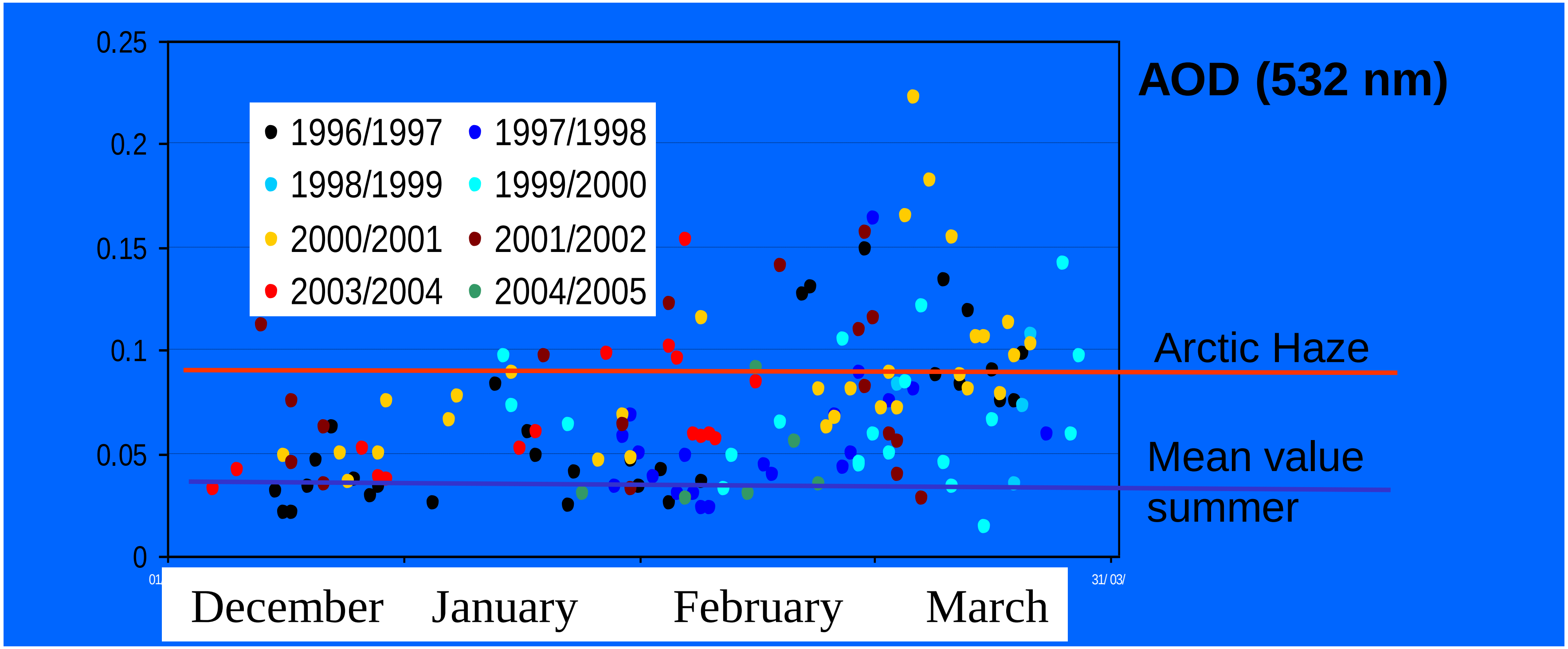
POLAR-AOD participating institutions

- Institute of Atmospheric Sciences and Climate (ISAC), CNR, Bologna, Italy
- Alfred Wegener Institute of Polar and Marine Research, Bremerhaven/Potsdam, Germany
- Global Monitoring Division (GMD), NOAA, Boulder, USA
- Atmospheric Environment Services, Downsview, Ontario, Canada
- Arctic and Antarctic Research Institute, St. Petersburg, Russia
- Institute of Environmental Physics / Remote Sensing, University of Bremen, Germany
- Norwegian Institute for Air Research (NILU), Tromsø, Norway
- PMOD/WRC, Davos, Switzerland
- Finnish Meteorological Institute, Helsinki, Finland
- Dept. of Meteorology, Stockholm University, Stockholm, Sweden
- Grupo de Óptica Atmosférica, Universidad de Valladolid, Spain
- ALOMAR/Andoya Rocket Range, Norway
- Institute of Oceanology, Polish Academy of Sciences, Sopot, Poland
- National Institute of Polar Research (NIPR), Tokyo, Japan

Microtops II sunphotometer

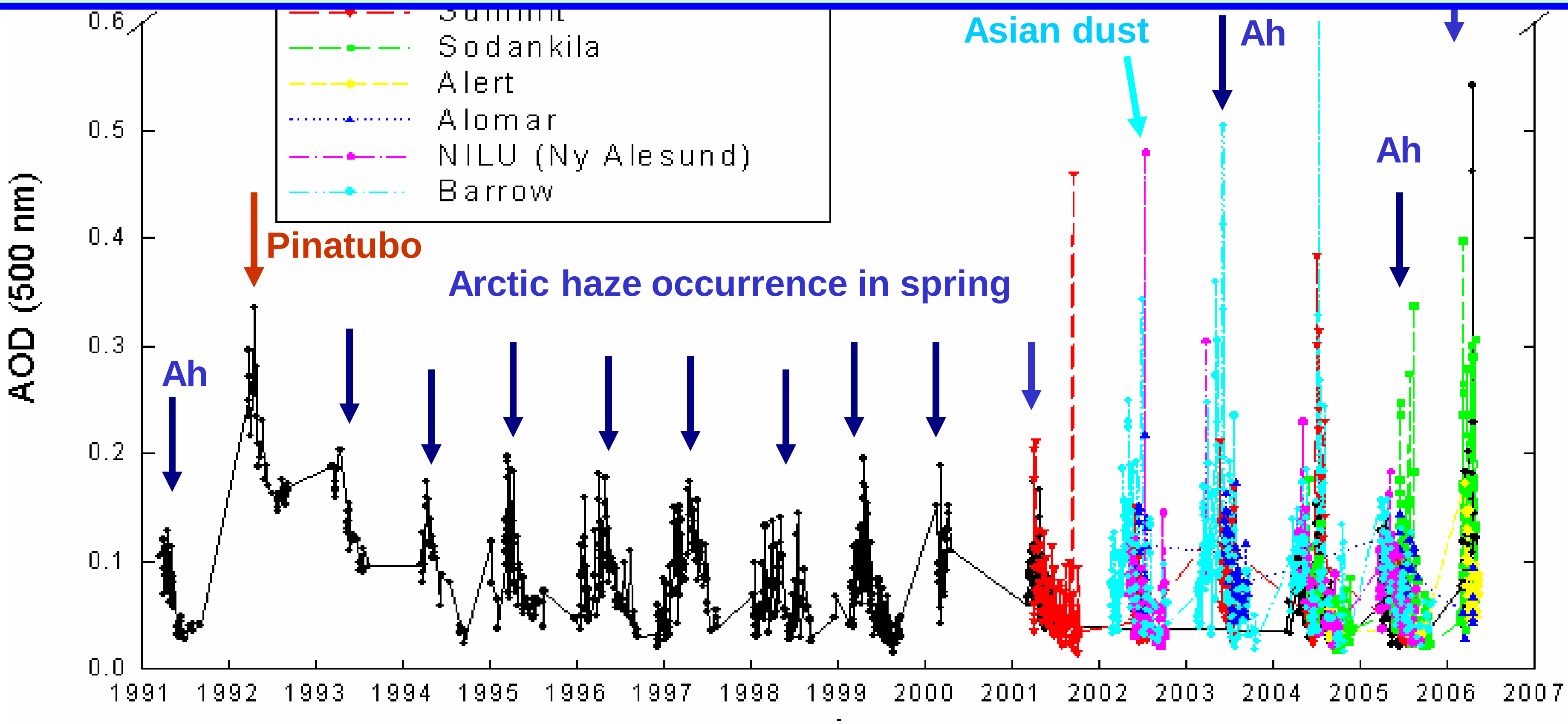
Seasonal variations in aerosol radiative parameters at the Arctic stations in the Svalbard region

From the Ny Ålesund (AWIPEV) measurements performed from 1996 to 2005, a set of daily mean values of *AOD(500 nm)* performed for Arctic haze conditions on the winter and spring days were determined, yielding an average value of about 0.09, compared to an average summer value of less than 0.04.

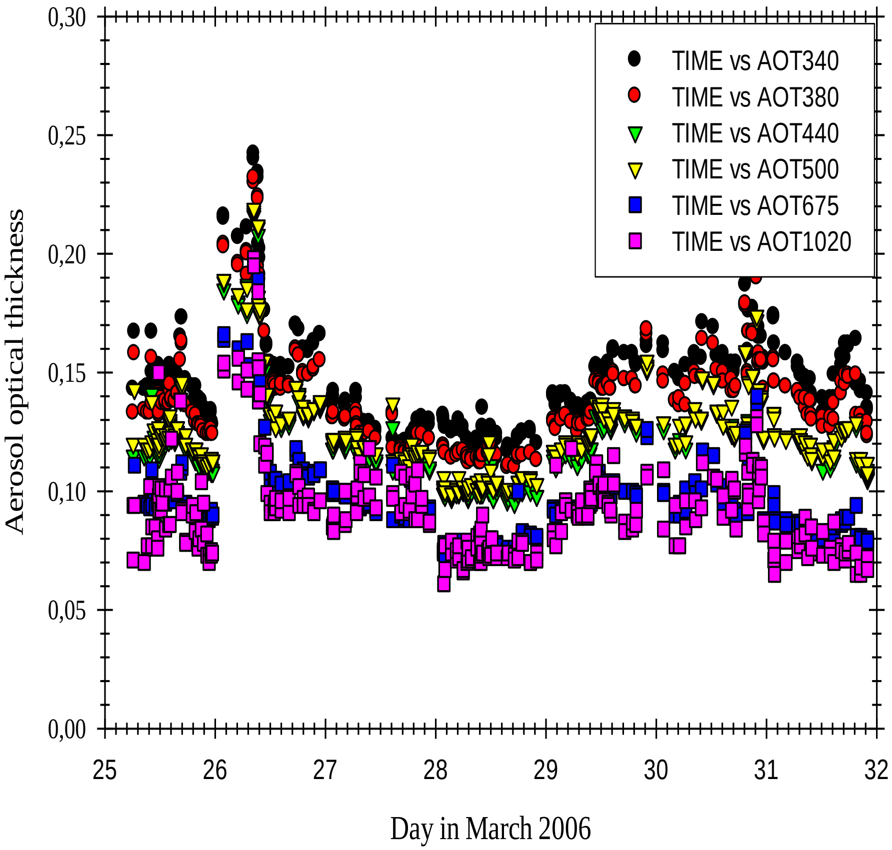


Source: Tomassi et al. 2nd International Conference on Global Warming and the Next Ice Age
Santa Fe, New Mexico, July 17 – 19, 2006

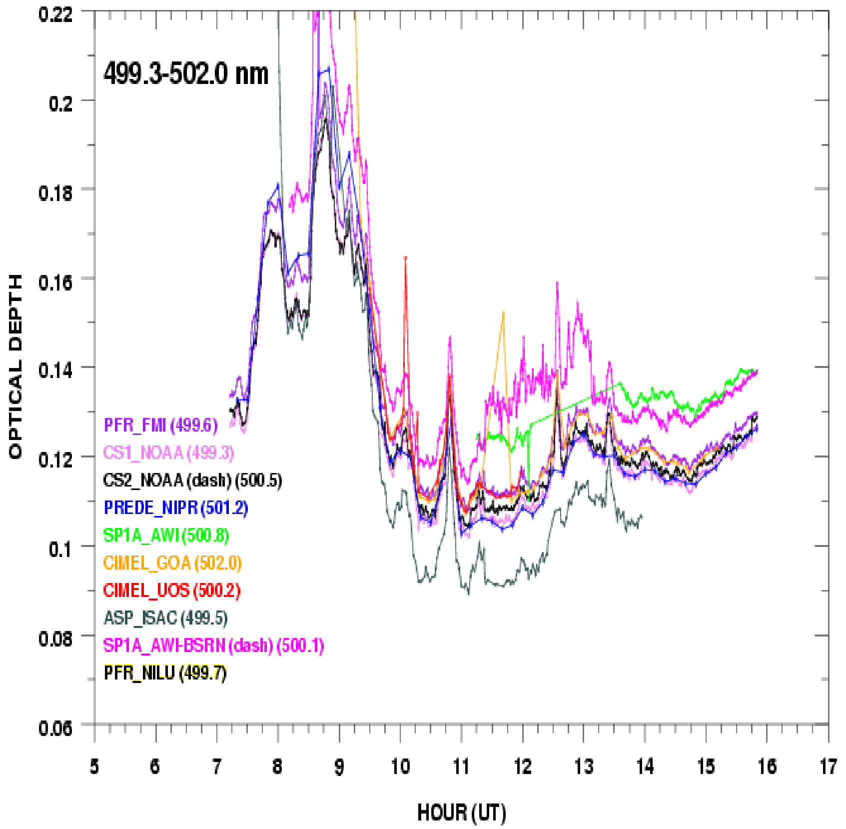
The time patterns of the daily mean values of *AOD(500 nm)* give not only a measure of the changes in the columnar aerosol extinction features due to the Pinatubo eruption in 1991 but also offer evidence for the marked seasonal changes in *AOD*, due the presence of Arctic haze in the spring months, and other important transport episodes (Asian dust in April 2002, and boreal smokes in summer 2004).



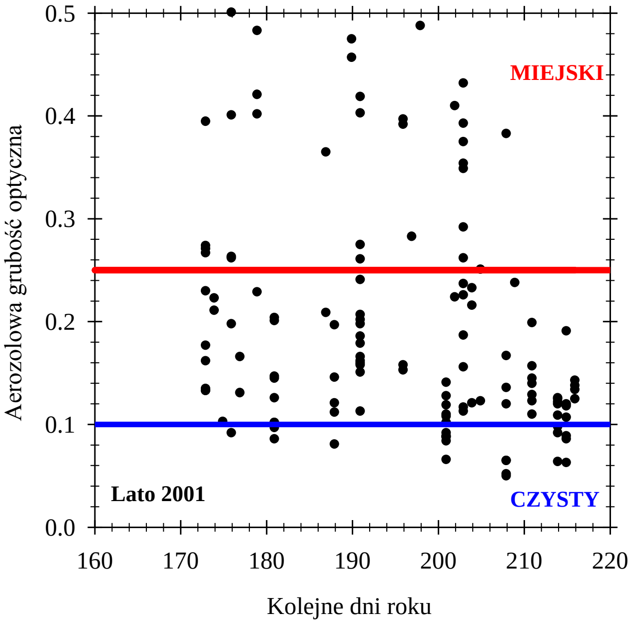
AOT in March 2006

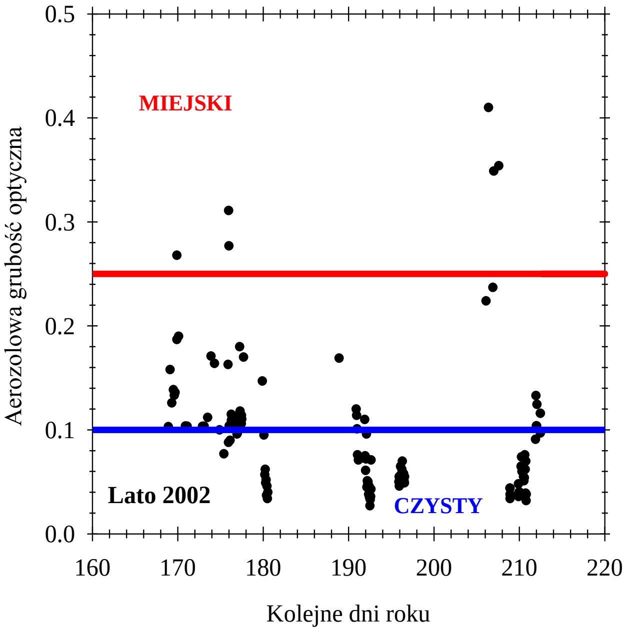


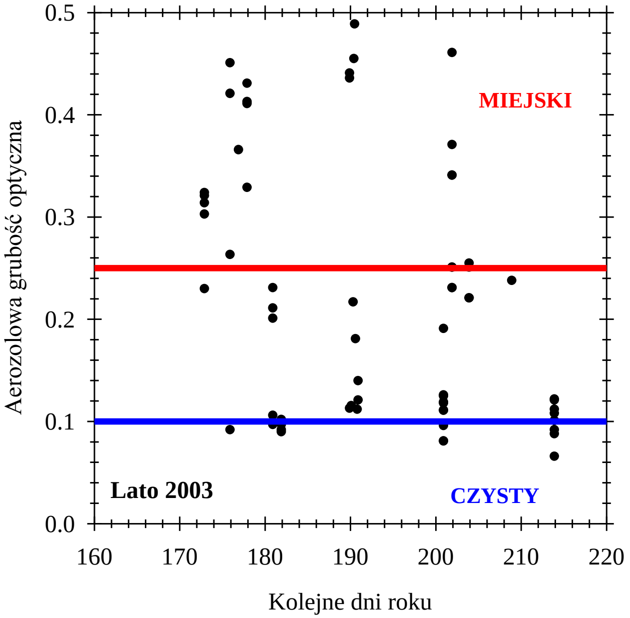
NY-ALESUND INTERCOMPARISON 26 MARCH 2006



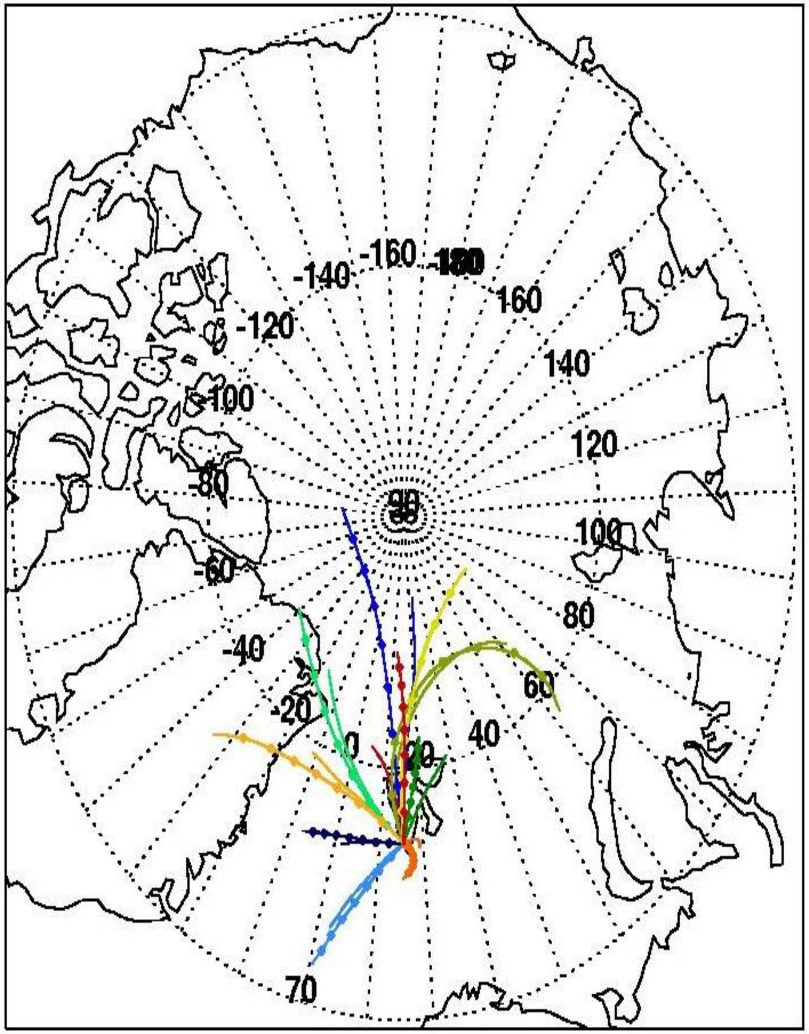
Aerosol optical thickness
in the Svalbard region

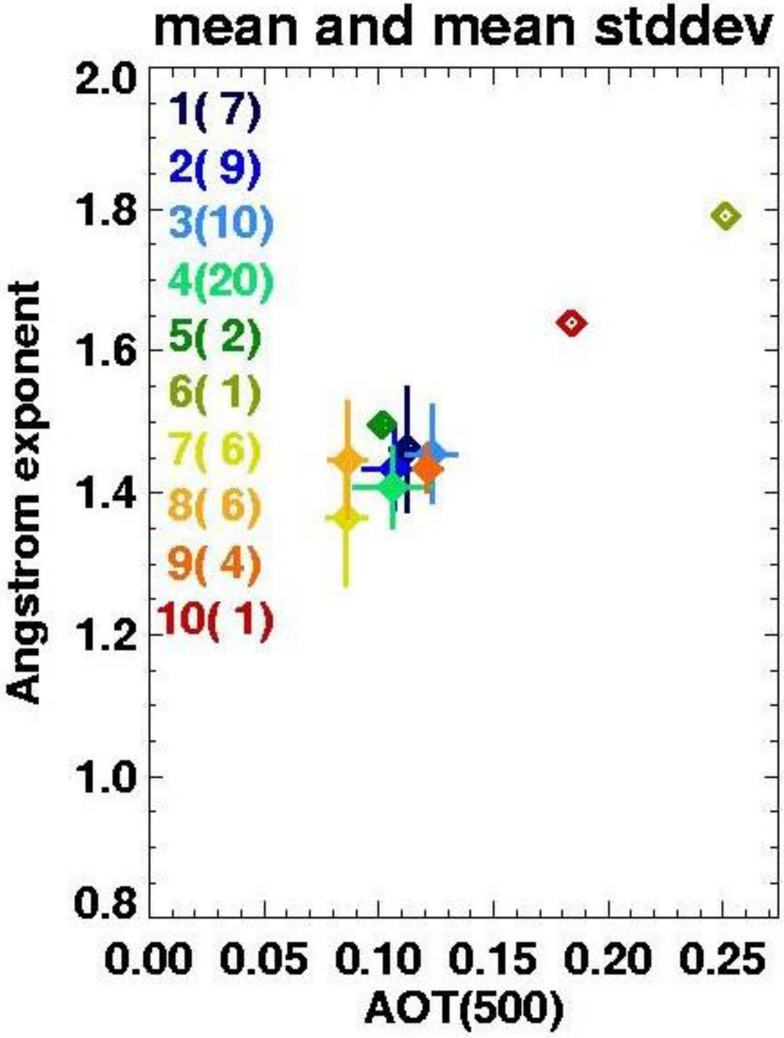




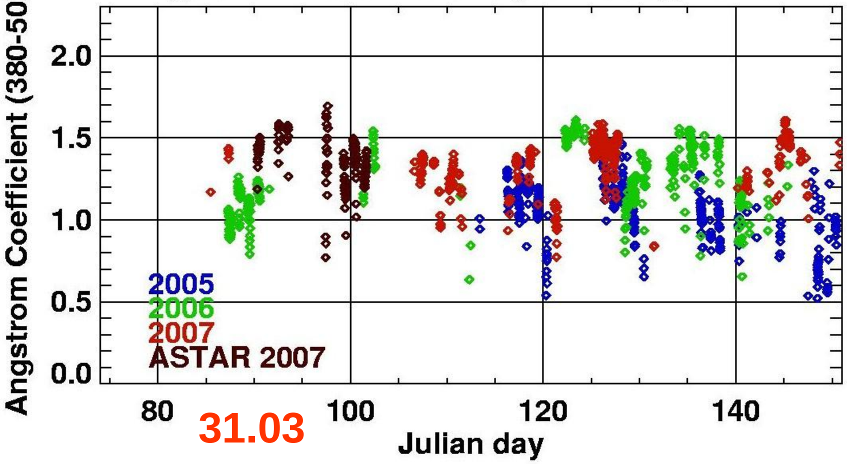


AOT/Angstroem exponent



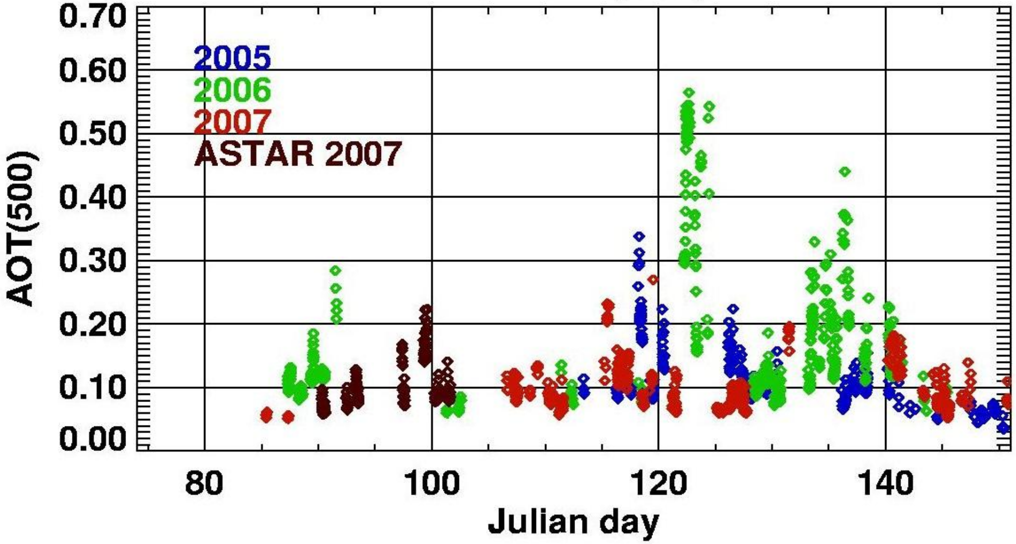


Angstrom Coefficient (380-500), var<0.4

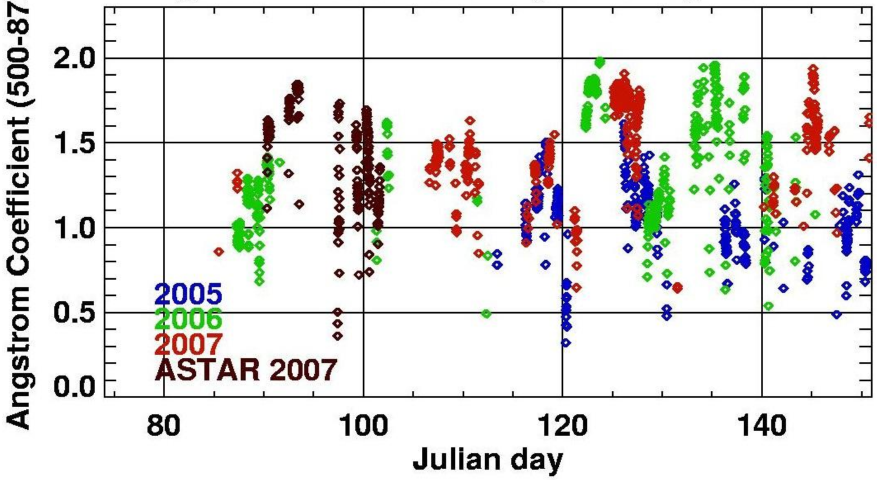


31.03

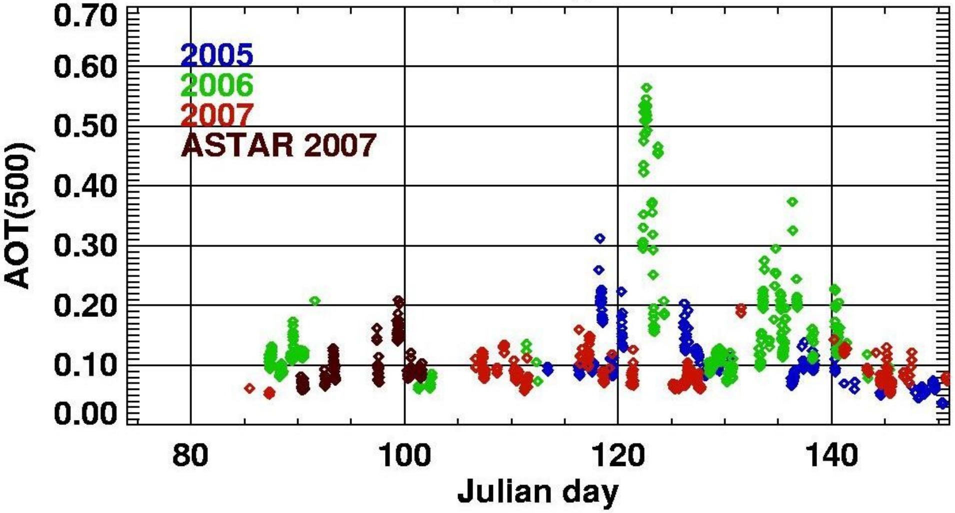
AOTe-fit(500)



Angstrom Coefficient (500-870), var<0.4



AOTe-fit(500), var<0.4



Acknowledgements

- University of Warsaw, Poland
- Alfred Wegener Institute, Germany
- DLR-Berlin, Germany
- SPAWAR Systems, San Diego, USA
- Navy Research Laboratory, Washington, D.C.
- Office of Naval Research, USA
- ALOMAR Laboratory, Norway
- Unviersity of Valladolid, Spain

Some recent publications

- Aerosols in Polar regions: A historical review on the basis of optical depth and in-situ observations, **Journal of Geophysical Research**, Vol. 112, D16205, doi:10.1029/2007JD008432, C. Tomasi, V. Vitale, A. Lupi, C. Di Carmine, M. Campanelli, A. Herber, R. Treffeisen, R. S. Stone, E. Andrews, S. Sharma, V. Radionov, W. von Hoyningen-Huene, K. Stebel, G. Hansen, C. L. Myhre, C. Wehrli, V. Aaltonen, H. Lihavainen, A. Virkkula, R. Hillamo, J. Ström, C. Toledano, V. Cachorro, P. Ortiz, A. de Frutos, S. Blindheim, M. Frioud, M. Gausa, **T. Zielinski, T. Petelski**, M. Shiobara, **2007**.

- Lidar-based Studies of Aerosol Optical Properties Over Coastal Areas, **Sensors**, 7, 3347-3365, **T. Zielinski**, B. Pflug, **2007.**

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- Aerosol optical depth measured at different coastal boundary layers and it links with synoptic-scale features, **Remote Sensing**, 1, doi:10.3390/sensors90rs1030557, **A. Ponczkowska, T. Zielinski, T. Petelski**, K. Markowicz, G. Chourdakis, G. Georgoussis, **2009**.

- Cluster analysis of the impact of air back trajectories on aerosol optical properties at Hornsund, Spitsbergen, **Atmospheric Chemistry and Physics**, 10, (3), 877 – 893, **A. Rozwadowska, T. Zielinski, T. Petelski**, P. Sobolewski, **2010**.