Study of black carbon impact on the broadband and spectral snow albedo in Poland

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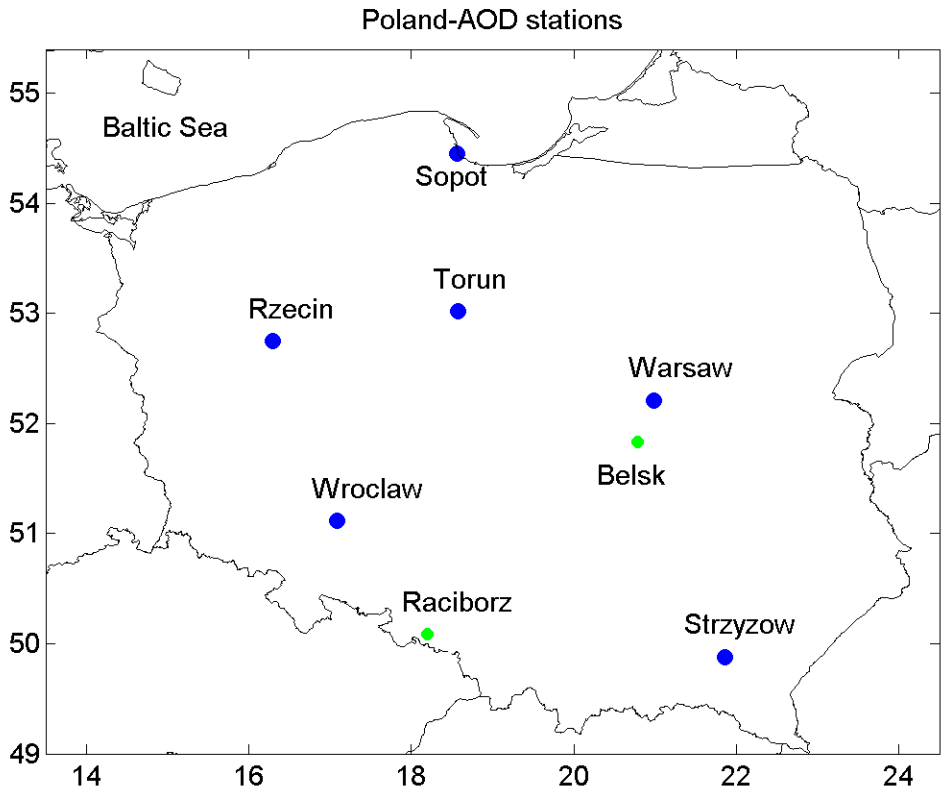
Research tasks

- Developing of the methodology for estimation of BC deposition rate (eddy covariance technique and gradient method)
- Estimation of BC impact on snow albedo (modeling and experimental study)
- Estimation of radiative forcing BC due to reduction of snow albedo as well as for BC suspended in the atmosphere over the snow surface

Poland-AOD network

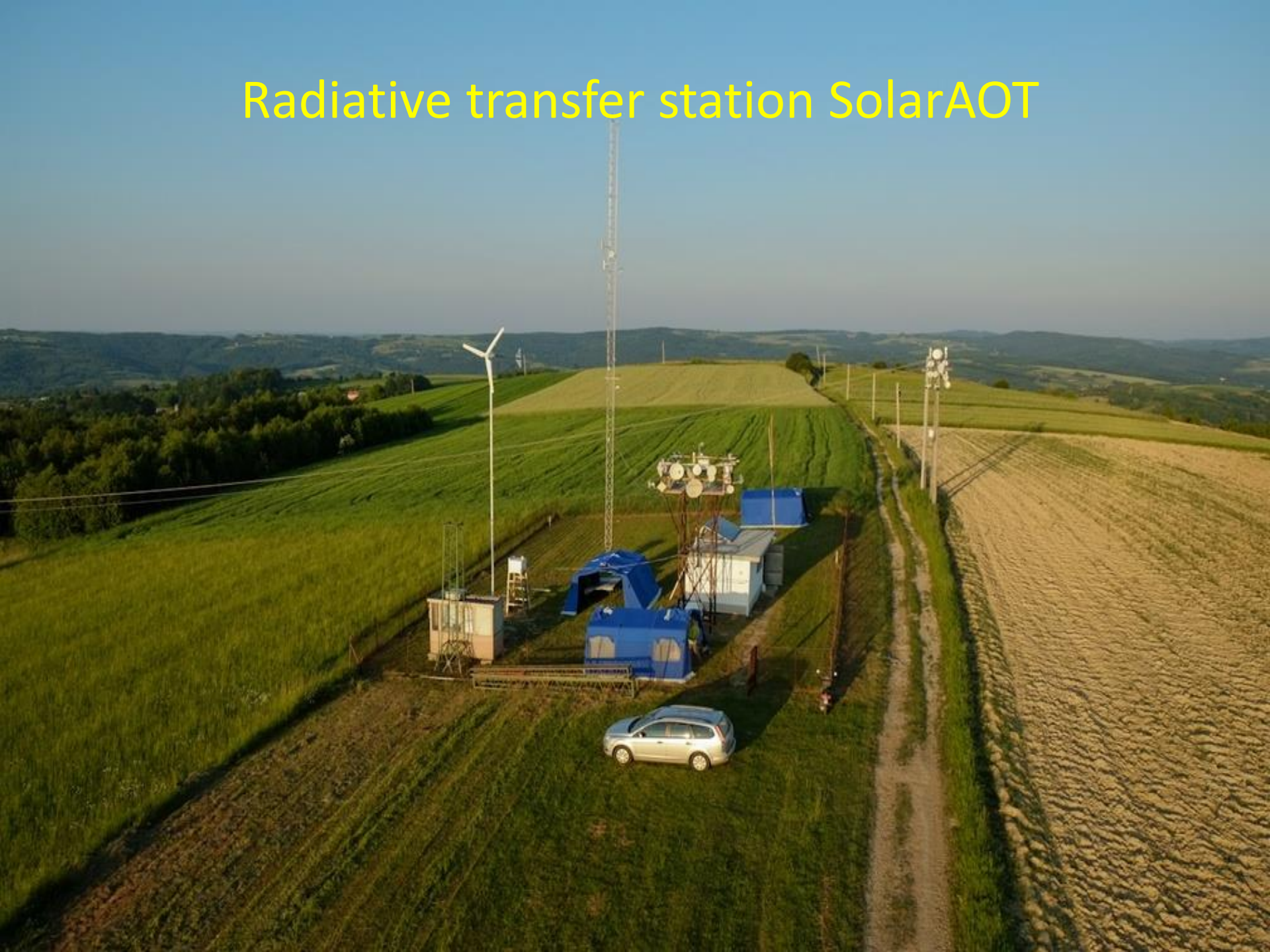
www.polandaod.pl



Equipment

Equipment	Wavelength	Wa-wa	Sopot	Strzyżów	Toruń	Rzecin
Sun photometer Microtops II	380-1020 nm	+	+	-	+	+
Shadowband Radiometer MFR-7	415, 500, 610, 675, 870 oraz 940 nm	+	+	+	-	-
CIMEL	340, 380, 440, 500, 675, 870, 936, 1020, 1640 nm	-	-	+	-	+
Pyranometer	300-4000 nm	+	+	+	+	+
Pyrheliometer	300-4000 nm	+	-	-	+	-
Pyrgeometer	4000-50000 nm	+	-	+	-	-
Albedometer	285 to 2800 nm	-	-	+	-	+
Net radiometer	300-2800 nm oraz 4500 42000 nm	+	-	-	-	+
UW Radiometer	315-400 nm	-	-	-	+	
Sun shine		-	-	-	+	
Sun Spectrometer	350-1050 nm	+	-	+	-	-
Sun Tracker	STR22/Solys2	+	-	+	+	-
Ceilometer CHM15K	1064 nm	-	+	+	-	-
Lidar Raymetrics	532 nm	-	+	-	-	-
Raman lidar + NARL'a	355, 387, 407, 532, 607, 1064 nm	+	-	-	-	-
Aethelometer AE-31	370, 470, 520, 590, 660, 880, 950 nm	-	+	+	-	-
Nephelometer (Aurora/TSI)	450, 550, 650 nm	-	+	+	-	-
PAX 532 (Photoacoustic Extinctiometer)	532 nm	+	+	-	-	-
PAX 870 (Photoacoustic Extinctiometer)	870 nm	+	-	-	-	-
Micro Aethalometr AE-51	880 nm	+		+	-	-
Weather station	WXT510/WXT520	+	-	+	+	+
Sky camera		+	+	+	+	-
MSG/ SEVIRI		+	+	+	+	+
Eddy covariance		+	+	+	-	-
UAV		+	+	-	-	-

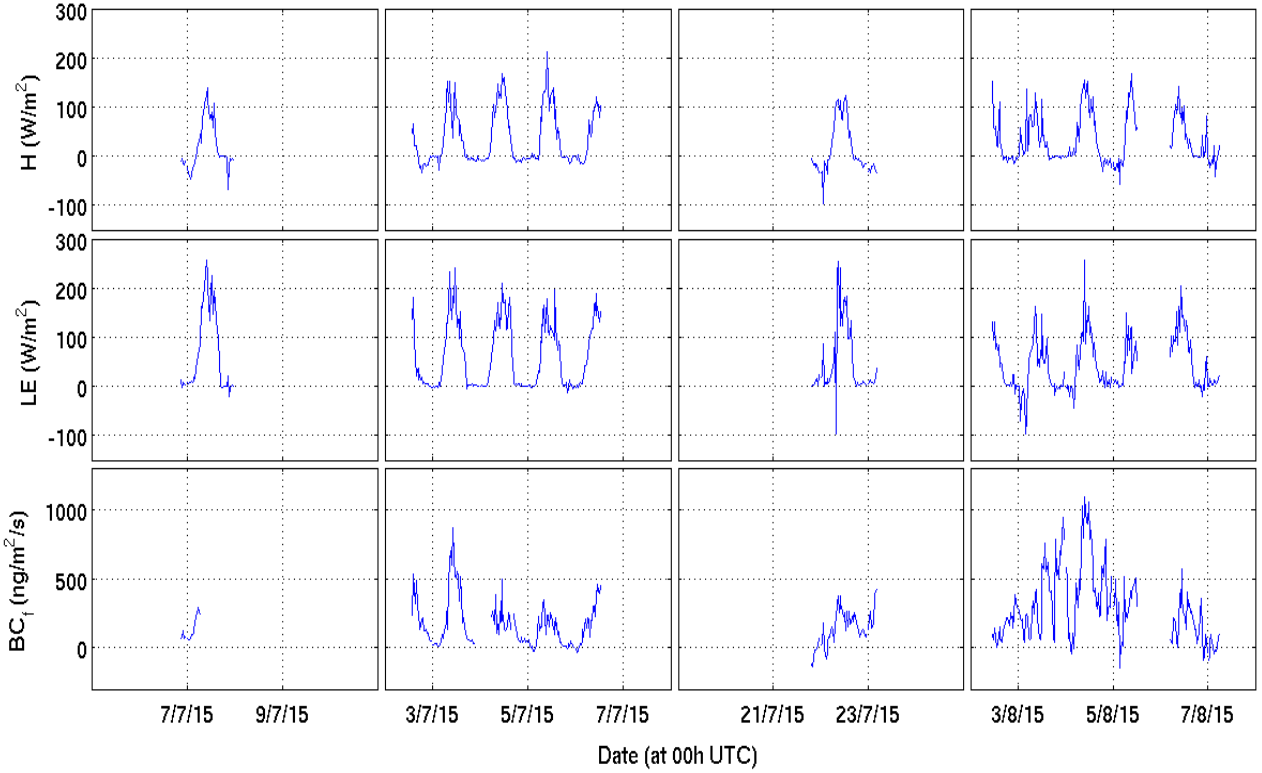
Radiative transfer station SolarAOT



Estimation of the BC flux

- Disjunct eddy covariance method
- Two aethalometer (first measure the BC during updraft and second during downdraft)

Example data



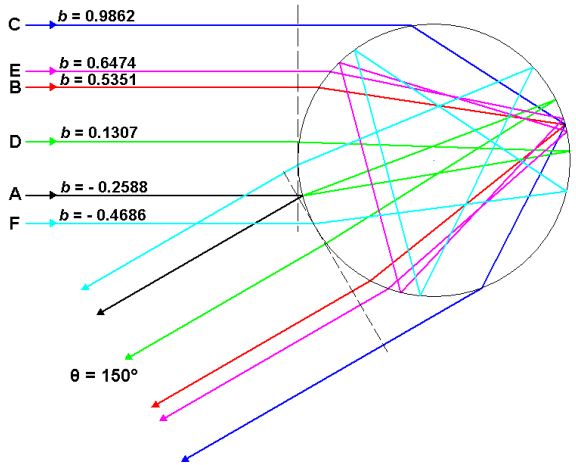
Sensible heat flux (H), latent heat flux (LE) and black carbon flux (BC_f). Time average: 30 min.

Modelling of the snow+BC albedo

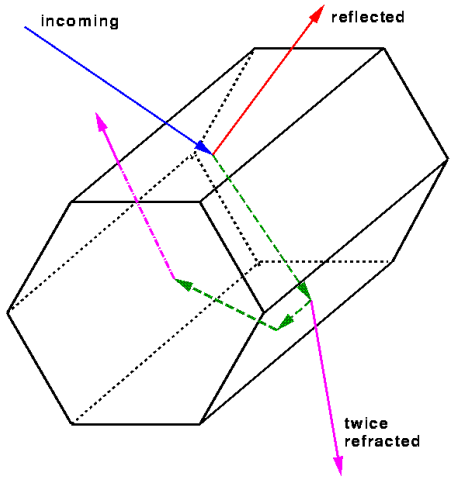
- Geometric methods for calculation spectral single scattering properties of pure snow
- Lorentz-Mie theory of BC properties
- Snow+BC single scattering properties
- Two-stream RTM for estimation snow+BC albedo

Geometric methods

- It can be used for any particles randomly oriented with know refractive index
- Macke, A. and Mueller, J. and Raschke, E , Single scattering properties of atmospheric ice crystals, "J. Atmos. Sci., 1996.
- Input parameters: wavelength, refractive index, particle size, number of photons, maximum number of internal reflection, number of particle orientations
- Output parameters: cross section efficiency for scattering and absorption (for extinction is 2), single scattering albedo, phase function (asymmetry parameter) and Muller matrix elements



Ray-tracing method



Phase function for different ice particles (Macke et al., 1996)

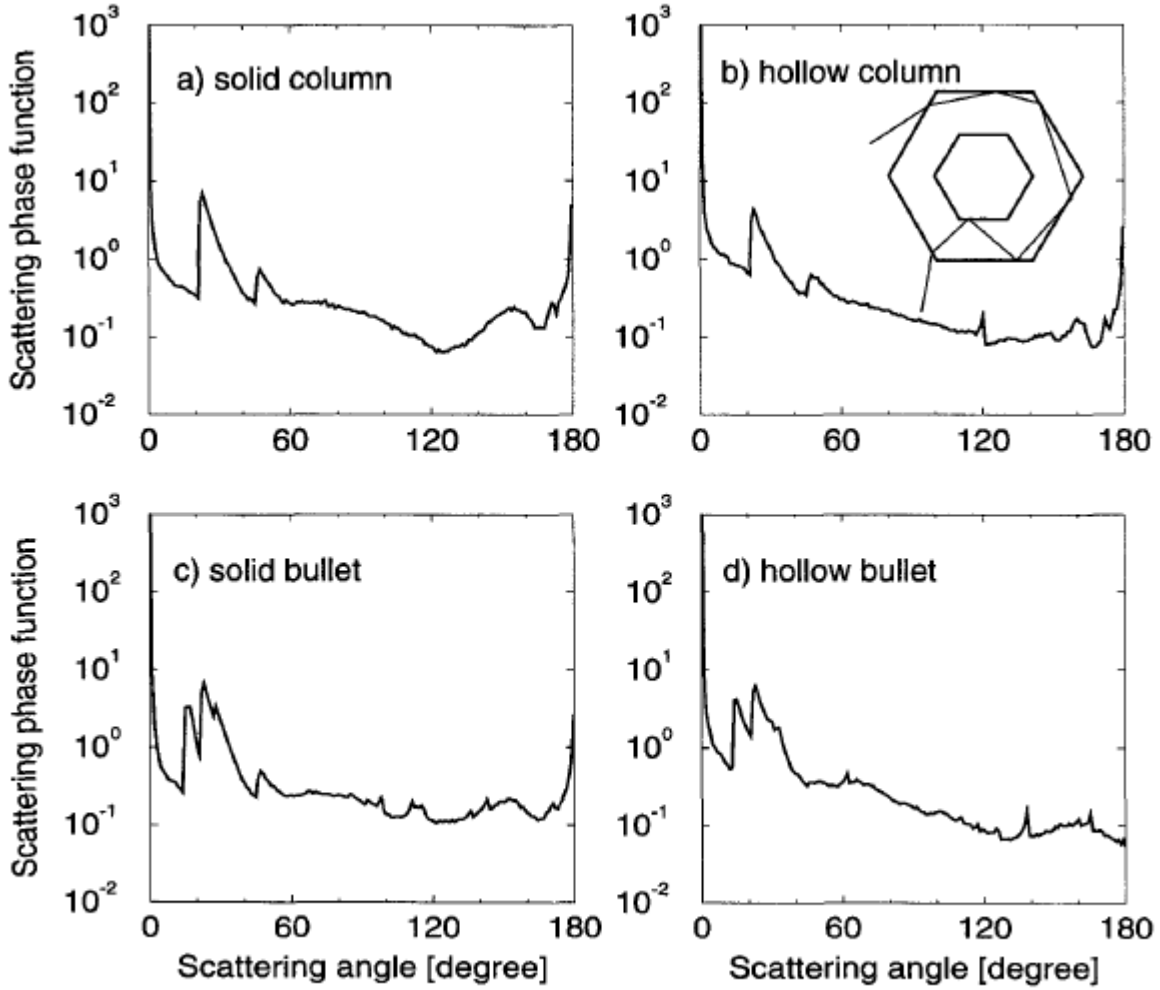
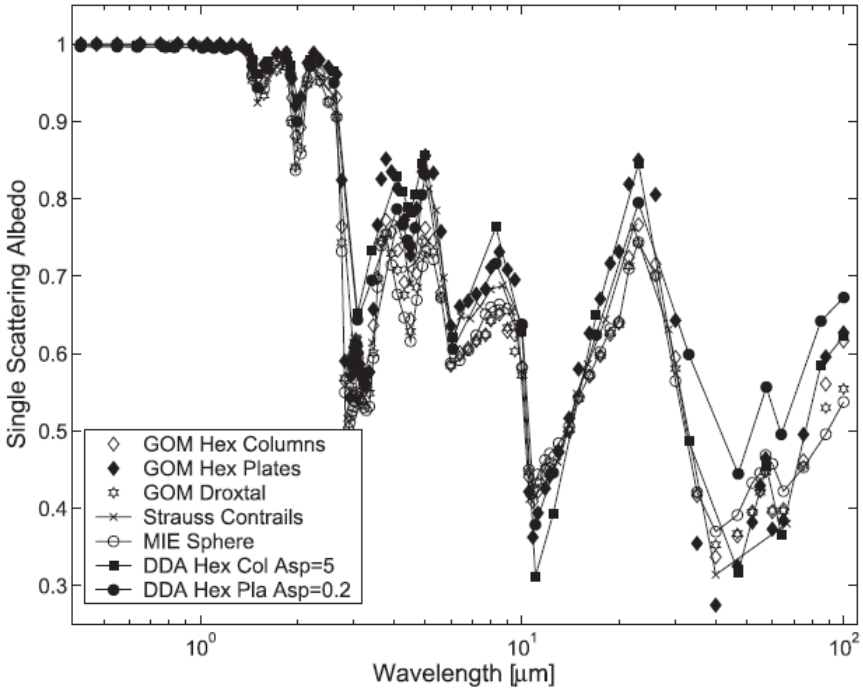
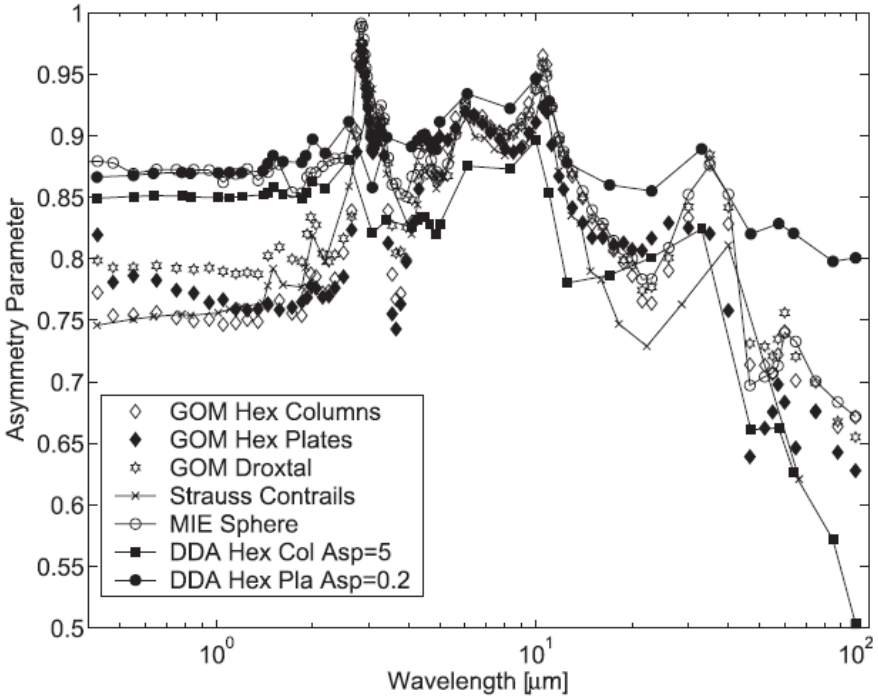


FIG. 3. Scattering phase function for hexagonal symmetric column-like particles. Aspect ratio $L/2a \sim 200\ \mu$m/30 μm.

Single scattering properties





Estimation of BC single-scattering properties

- From Lorenz-Mie theory for uniform spherical particles with know refractive index
- Matlab code for estimation effective cross sextion for extinction , scattering, absorption, asymetry parameter as well as for phase function
- http://www.igf.fuw.edu.pl/~kmark/stacja/kody.php
- Call: [S_1, S_2,Qe,Qs,Qb,g]=mie(X,m+ik,angles)
- Averaging for assumed particle size distribution

Single-scattering properties of snow + BC

- External mixture

$$\sigma_{ext} = \sum_i \sigma_{ext,i} N_{oi} \qquad \omega = \frac{\sum_i \omega_i \sigma_{ext,i} N_{oi}}{\sum_i \sigma_{ext,i} N_{oi}} \qquad i=1,2$$

$$g = \frac{\sum_i \sigma_{ext,i} g_i \omega_i N_{oi}}{\sum_i \sigma_{ext,i} \omega_i N_{oi}} \qquad P(\theta) = \frac{\sum_i P_i(\theta) \sigma_{ext,i} \omega_i N_{oi}}{\sum_i \sigma_{ext,i} \omega_i N_{oi}}$$

$$\tau = \int \sigma_{ext} dz$$

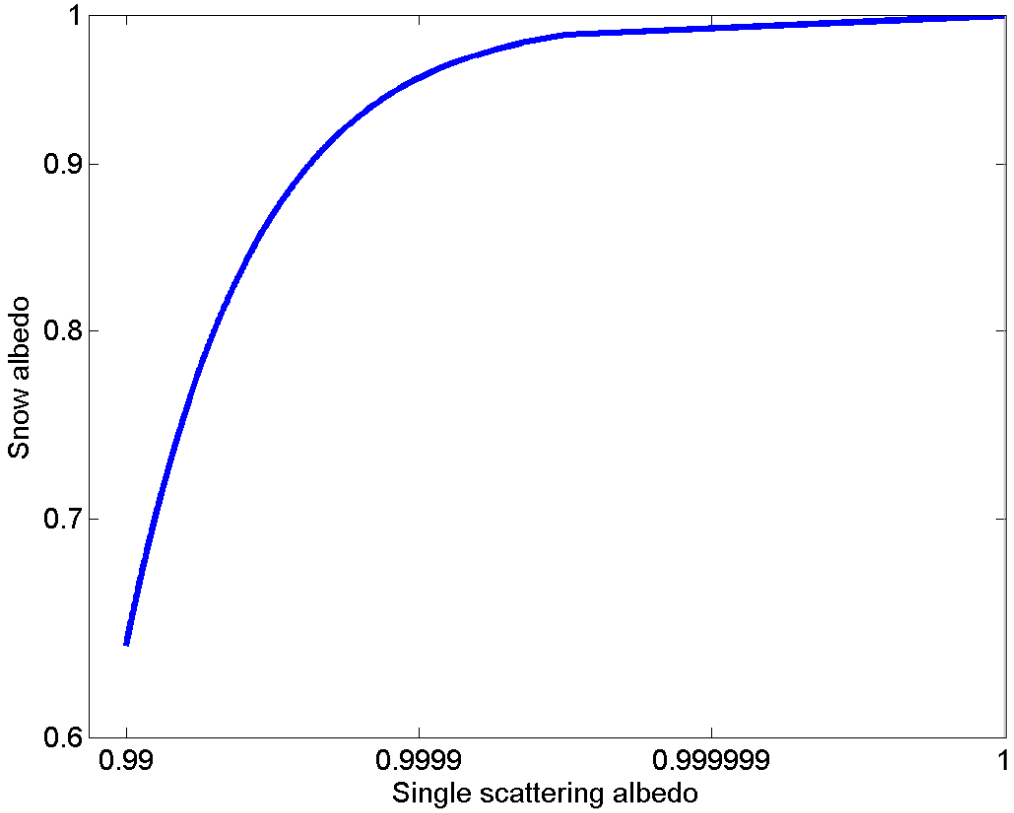
Sensitivity of snow albedo due to single scattering albedo of snow with BC particles

- Two-stream approximation

$$\text{albedo} = r_\infty = \frac{\sqrt{1-\omega g} - \sqrt{1-\omega}}{\sqrt{1-\omega g} + \sqrt{1-\omega}}$$

• large sensitivity of snow albedo for change the mixture single scattering albedo between 0.99 and 0.9999

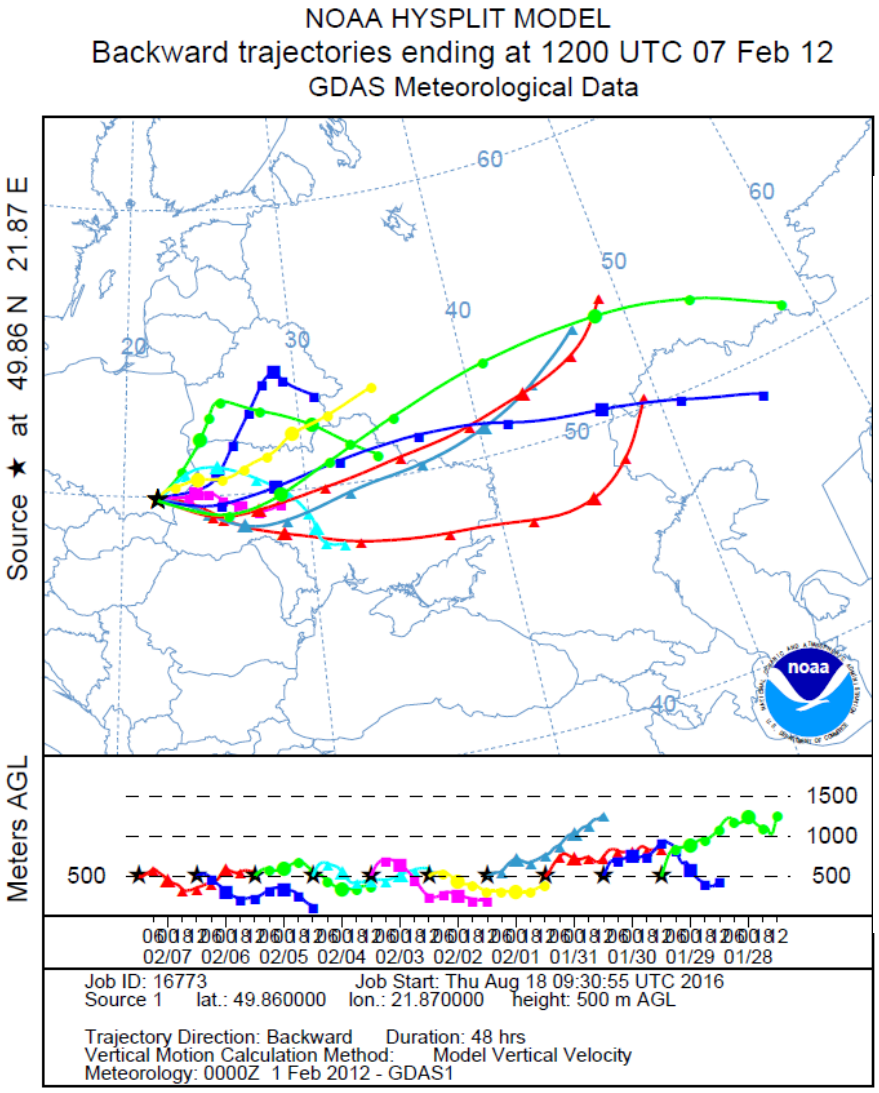
• therefore even for small BC contamination the effect on snow albedo can significant.



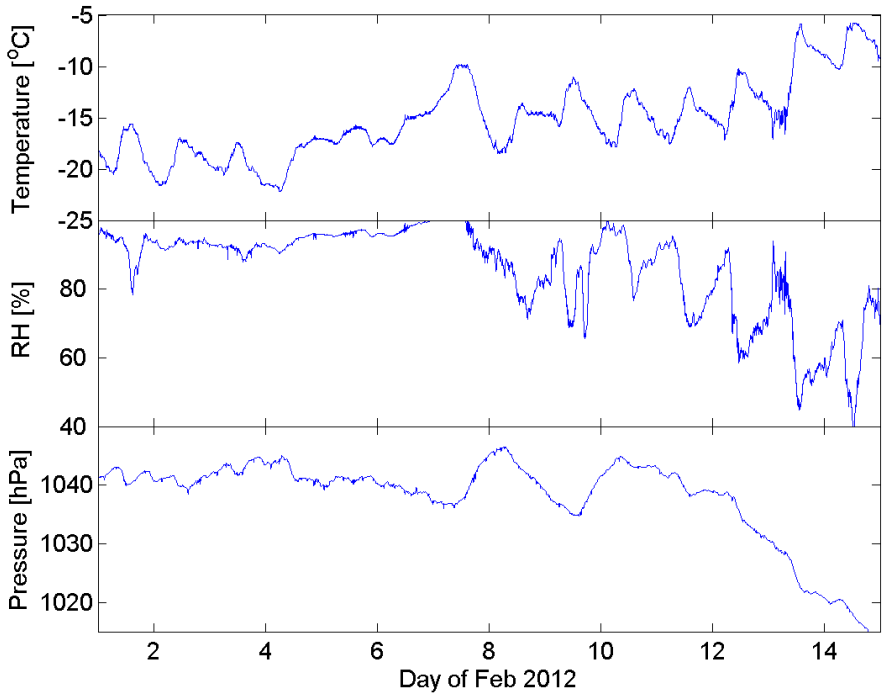
Case study 1-15 Feb 2012

- Intensive smog condition very high BC concentration
- No precipitation between 5 and 15 Feb
- Continental air mass and very low temperature (up to -20 ^{o}C)
- Low wind speed

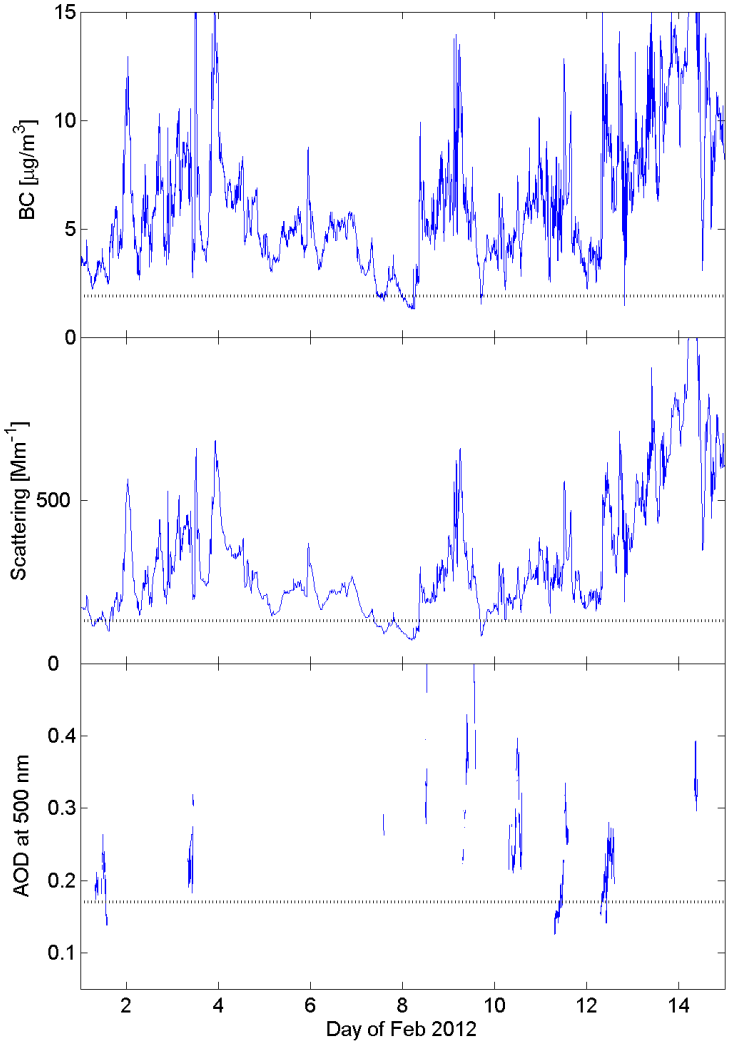
Backtrajectories



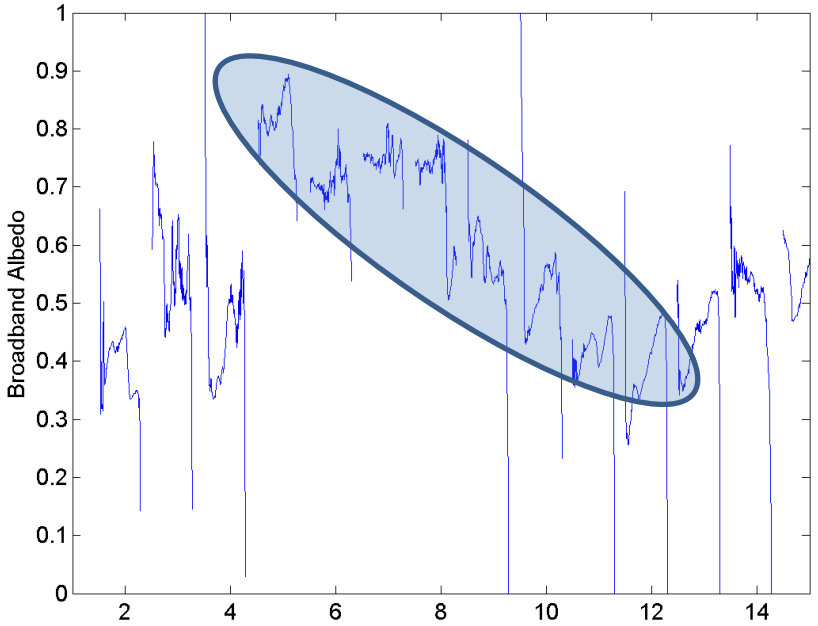
Weather conditions



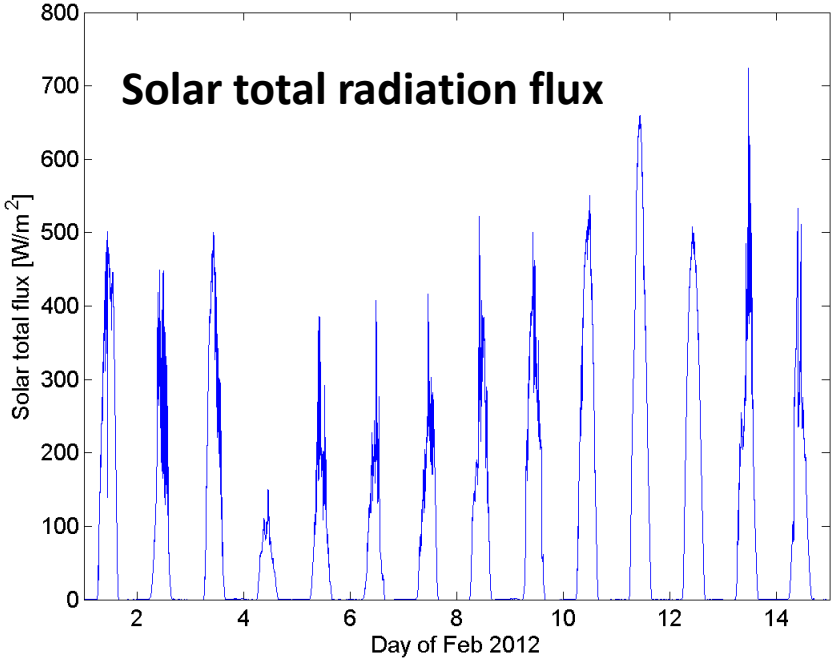
Aerosol condition 3 meters above the surface



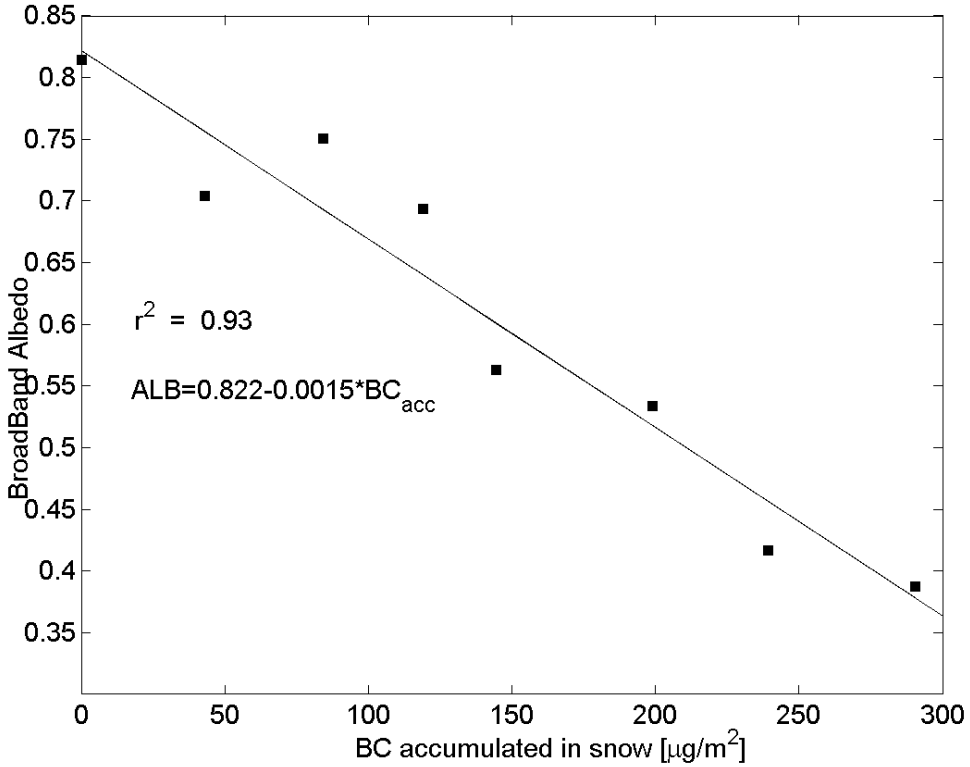
Snow BB albedo



Solar total radiation flux

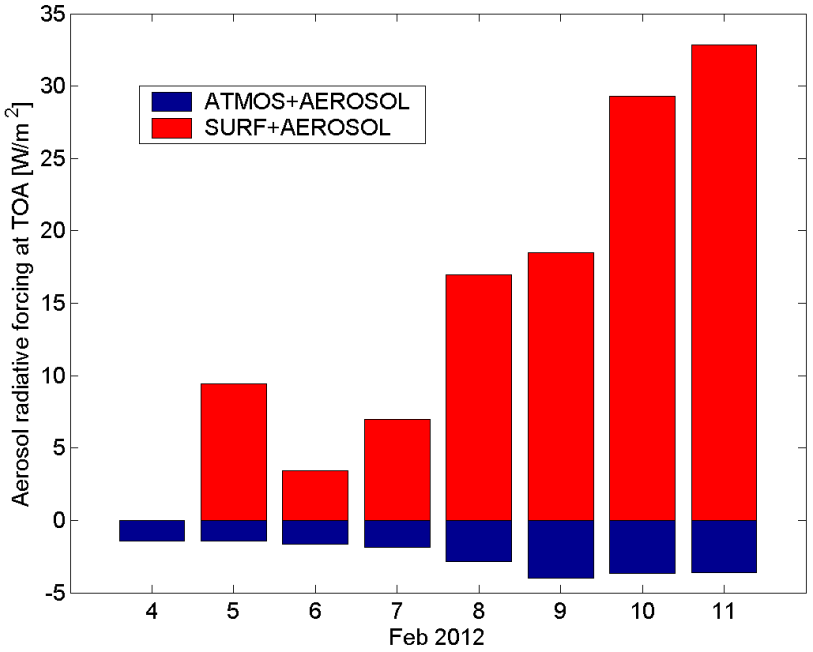


Reduction of mean diurnal BB albedo due to BB deposition into snow

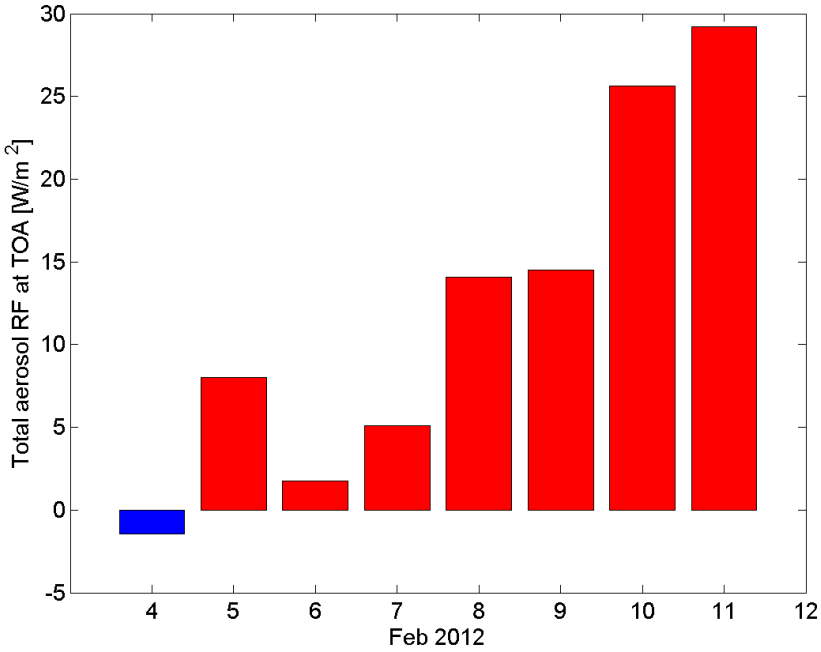


Albedo of fresh pure snow (120 μm) 0.822
Albedo of old pure snow (1000 μm) 0.710

Aerosol radiative forcing

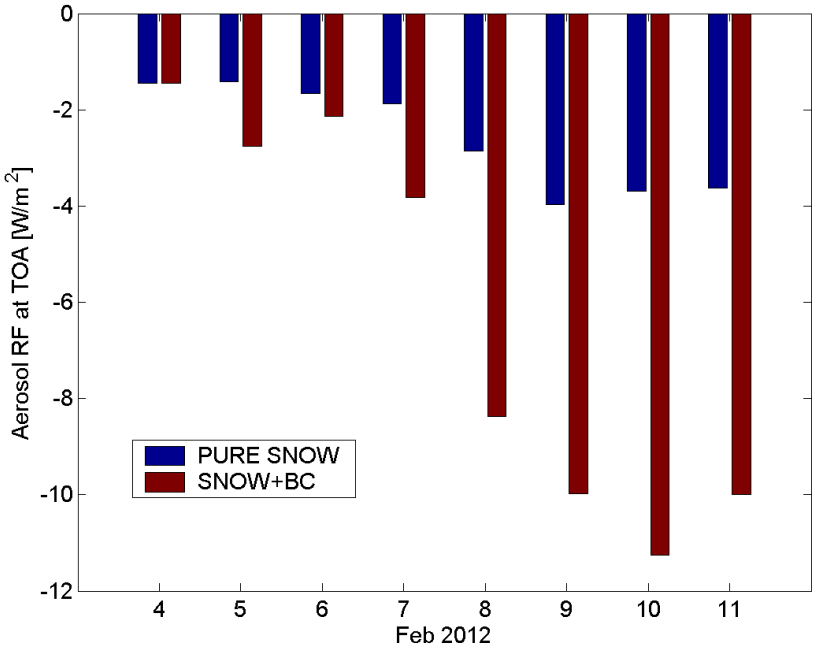


Aerosol radiative forcing at TOA for particles suspended in the atmosphere (blue bars) and BC effect on snow albedo (red bars)

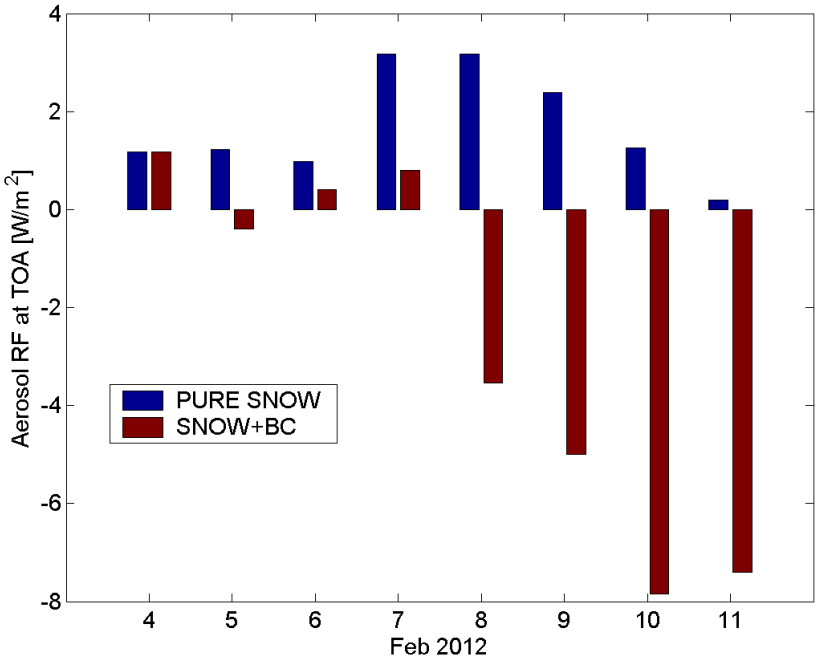


Total aerosol radiative forcing at TOA including particles in the atmosphere and accumulated in the snow

Impact of BC in snow on aerosol radiative forcing in the atmosphere



Aerosol radiative forcing for particle suspended in the atmosphere in case of pure snow albedo and for snow with BC



Aerosol radiative forcing for absorbing (SSA=0.85) particle suspended in the atmosphere in case of pure snow albedo and for snow with BC

Conclusion and future plane

- We found extremely haze event and they impact on radiation budget
- Deposition of BC dramatically change the snow albedo event for rural station
- We found strong positive radiative forcing for BC in snow and negative forcing for aerosol suspended in the atmosphere

Future

- Observation of BC flux close to surface to estimate the BC deposition
- Spectral albedo measurements to estimate the BC effect on the snow albedo
- However, during last 3 years the snow cover in Poland was rather marginal so this kind measurements were occasional

Acknowledgments

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