Aerosols observations onboard ships at surface and in the atmospheric column

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Aerosols observations at surface and in the atmospheric column

OUTLINE

- My connections to measurements on ships
- In-situ measurements for studying processes
  - new particle formation and growth in the MBL
  - transport of aerosols from various source regions
- Column measurements such as AOD measured with sun photometers or layer structures with LIDARs provide information to be combined with data from satellites
  - LIDARs
  - Drones
  - helicopters
- All of these should be combined with transport modeling
- Sampling

My connections to measurements on ships

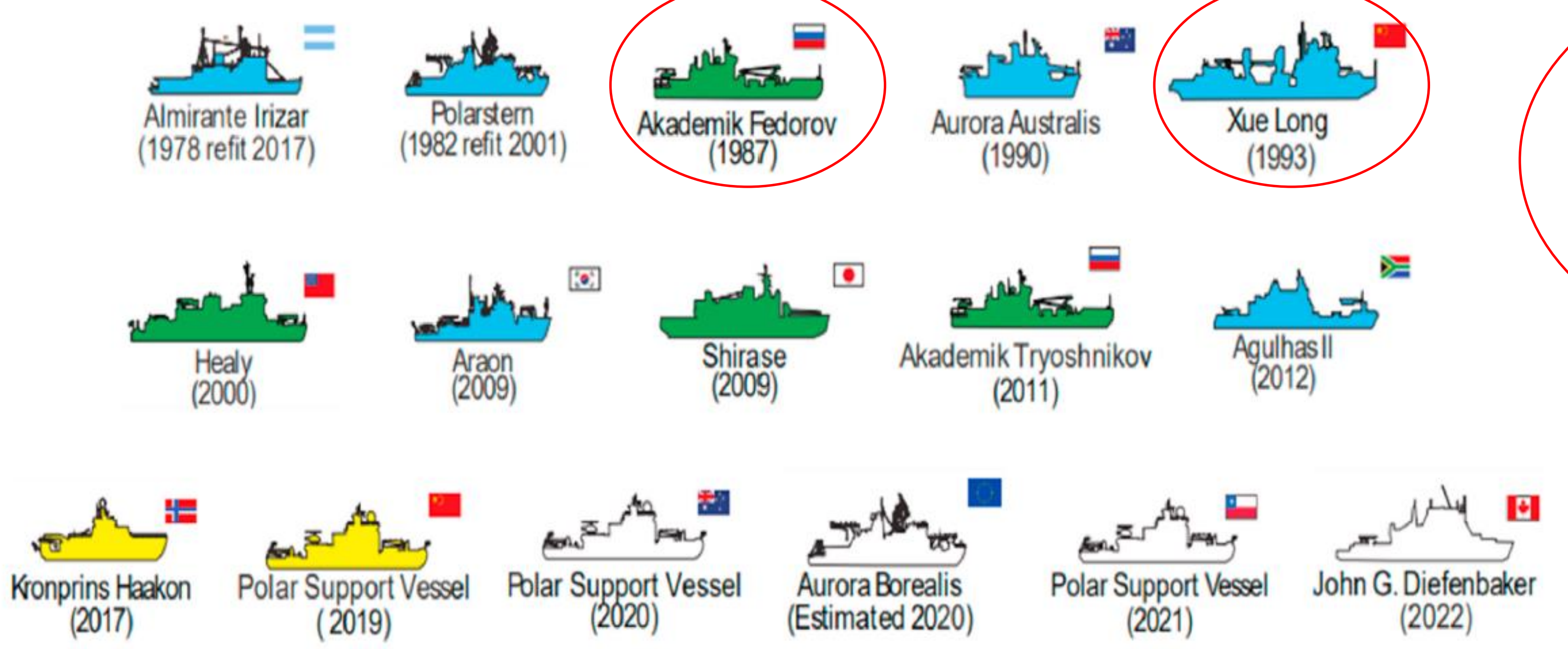


Fig. 4. Sourced from the major icebreaker chart. Adapted from USCG (2017). White: Planned, Yellow: Under construction, Blue: 10,000–20,000 HP, Green: 20, 000–45,000 HP. . (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Ron Brown, NOAA, USA

Aerosol research on ships, what to study?

- ❑ Aerosol sources
  - Biogenic
    - ❑ primary
    - ❑ secondary
  - ❑ Anthropogenic
  - ❑ Continental
  - ❑ Shipping

- ❑ The climate effects of all them
  - ❑ Scattering, absorption, contributions to CCN
  - ❑ Vertical distribution
  - ❑ Seasonal cycles
  - ....

In-situ measurements for studying processes

- new particle formation and growth in the MBL

To cite this article: David S. Covert, Alfred Wiedensohler, Pasi Aalto, Jost Heintzenberg, Peter H. Mcmurry & Caroline Leck (1996) Aerosol number size distributions from 3 to 500 nm diameter in the arctic marine boundary layer during summer and autumn, Tellus B: Chemical and Physical Meteorology, 48:2, 197-212, DOI: 10.3402/tellusb.v48i2.15886

ABSTRACT

Aerosol physics measurements made onboard the Swedish icebreaker *Oden* in the late Summer and early Autumn of 1991 during the International Arctic Ocean Expedition (IAOE-91) have provided the first data on the size distribution of particles in the Arctic marine boundary layer (MBL) that cover both the number and mass modes of the size range from 3 to 500 nm diameter. These measurements were made in conjunction with atmospheric gas and condensed phase chemistry measurements in an effort to understand a part of the ocean-atmosphere sulfur cycle.

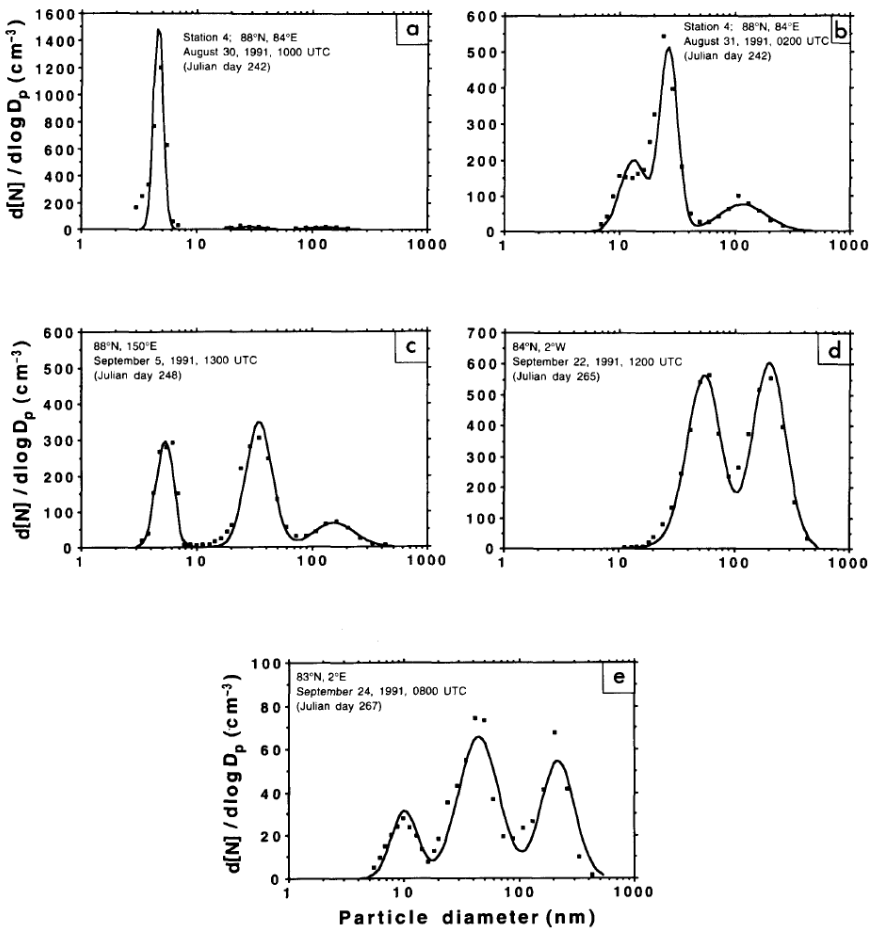


Fig. 2. Particle number size distributions, $d[N]/d\log D_p$; examples of the measured one hour average data and the log normal fits to the modes of the data. Squares are measured data, solid lines are the fitted log normal modes determined by DistFit™. (a) Station 4 (88°N, 84°E), August 30, 1991 at 1000 UTC. As an example of a dominant ultrafine mode. (b) Station 4 (88°N, 84°E), August 31, 1991 at 0200 UTC. Trajectories were from Spitsbergen. Aitken and ultrafine modes are minimally separated. (c) (88°N, 150°E), September 5, 1991 at 1300 UTC. Three widely separated and distinct modes were present. (d) (84°N, 2°W), September 22, 1991 at 1200 UTC. Aerosol concentrations were relatively high and trajectories were from the Kola Peninsula. (e) (83°N, 2°E), September 24, 1991 at 0800 UTC. Typical trimodal distribution from the Arctic MBL.

Aerosol research on ships, what to study

- Aerosol sources
  - Biogenic: primary, secondary

Antarctic sea ice region as a source of biogenic organic nitrogen in aerosols

Manuel Dall'Osto[1], Jurgita Ovadnevaite[2], Marco Paglione[3], David C. S. Beddows[4], Darius Ceburnis[2], Charlotte Cree[5], Pau Cortés[1], Marina Zamanillo[1], Sdena O. Nunes[1], Gonzalo L. Pérez[6], Eva Ortega-Retuerta[1], Mikhail Emelianov[1], Dolors Vaqué[1], Cèlia Marrasé[1], Marta Estrada[1], M. Montserrat Sala[1], Montserrat Vidal[7], Mark F. Fitzsimons[5], Rachael Beale[8], Ruth Airs[8], Matteo Rinaldi[3], Stefano Decesari[3], Maria Cristina Facchini[3], Roy M. Harrison[4,9], Colin O'Dowd[2] & Rafel Simó[1]

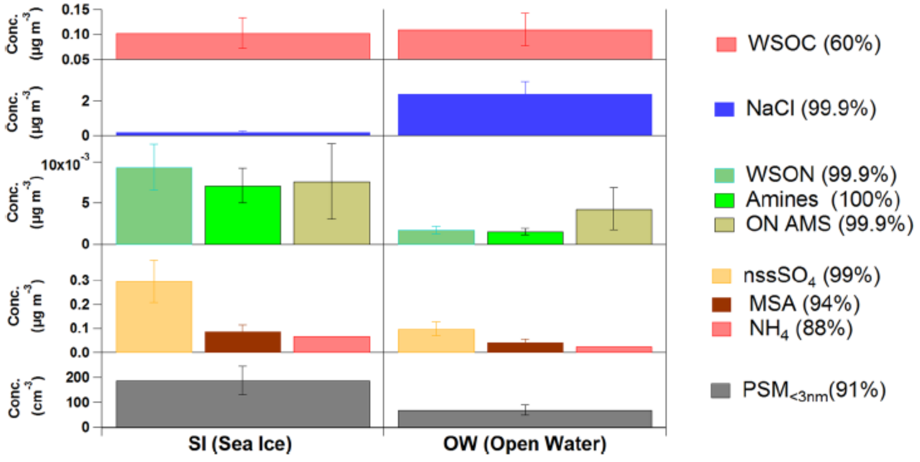


Figure 1. Characteristics of collected aerosols according to their origin. Average and standard deviations are

SCIENTIFIC REPORTS | 7: 6047 | DOI:10.1038/s41598-017-06188-x

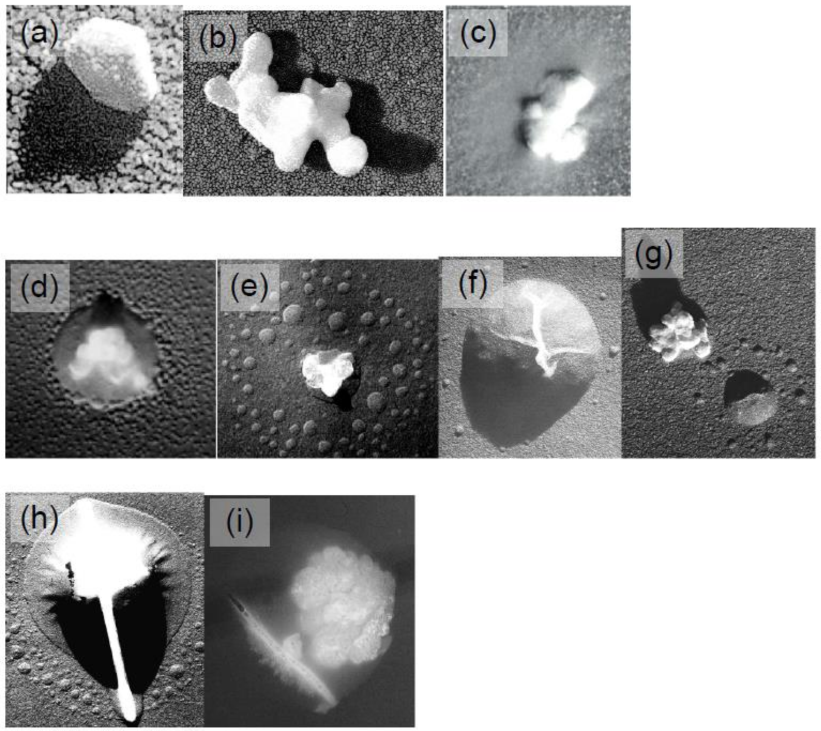


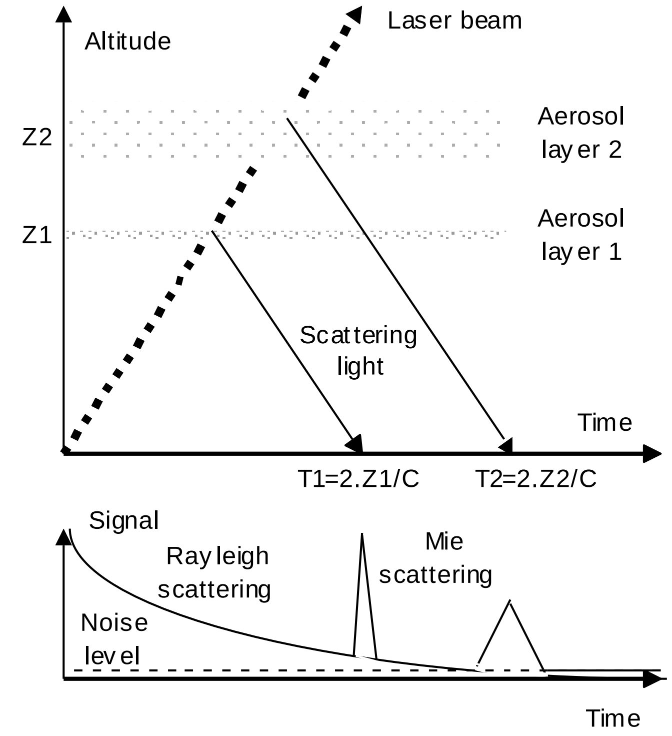
Figure 10. Examples of the changing nature of the high Arctic particles in different modal diameters: **(a–c)** sub-Aitken mode, **(a)** penta-hexagonal structure, crystalline and hydrophobic in nature assumed to be a colloidal building block of a polymer gel, **(b)** small polymer gel-aggregate slightly covered with hydrophilic mucus, **(c)** same as in b but with more mucus remaining promoting its hydrophilic properties, **(d–g)** Aitken to small accumulation mode, **(d)** particle with a high sulfuric acid content with a gel-aggregate inclusion embedded in a film of high organic content, **(e)** gel-aggregate with satellites, indicating the presence of organics and acids, **(f)** particle containing mainly ammonium sulfate and methane sulfonate, **(g)** external mixture of a gel-aggregate and similar particle as of **(f)**, and **(h–i)** large accumulation mode, **(h)** sea-salt particle with an organic content. The rod through its centre is assumed to be a bacterium. The particle has an acquired coating of sulfuric acid, **(i)** a gel-aggregate containing a bacterium attached to a small aggregate possibly detached from the larger one. The particles' bubble-like shape indicates a possible recent injection to the atmosphere at the air–sea interface.

Atmos. Chem. Phys., 15, 2545–2568, 2015

Column measurements such as AOD measured with sun photometers or layer structures with LIDARs provide information to be combined with data from satellites.

- ❑ LIDARs

Lidar (Light Detection And Ranging) [9664]



S. Bohlmann et al.: Aerosol profiling over the Atlantic Ocean

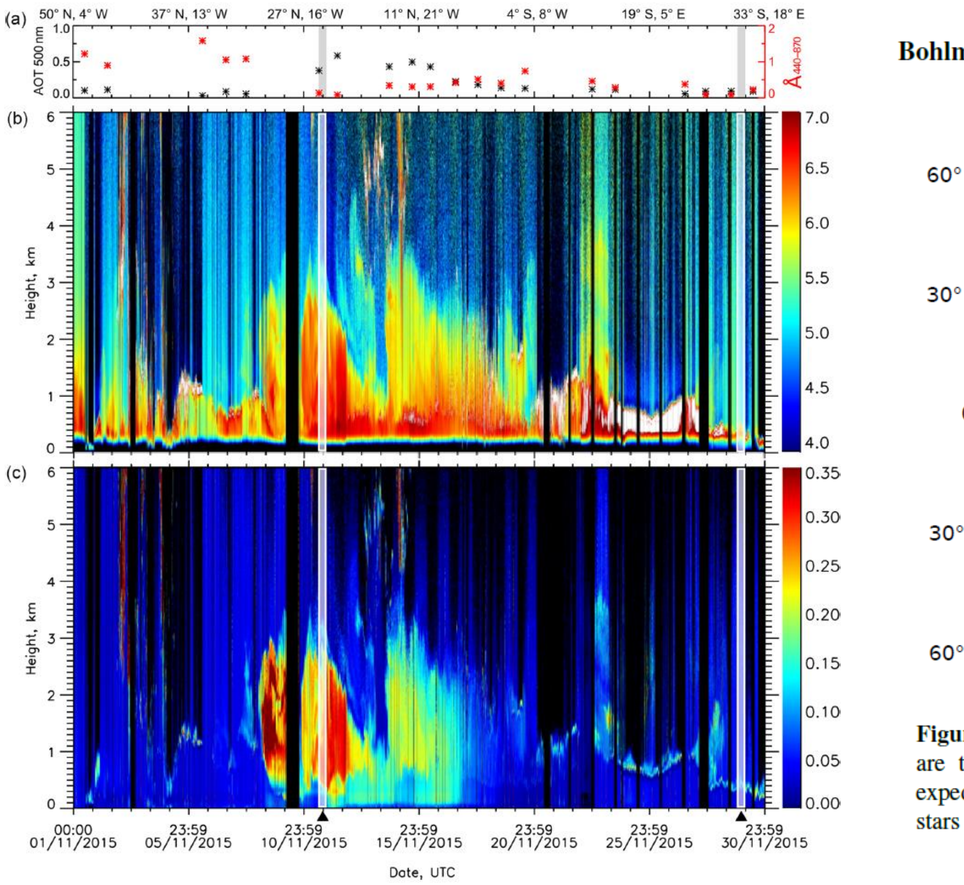


Figure 2. Observational overview of the autumn cruise PS95 from Bremerhaven to Cape Town. Time series of the 500 nm daily mean AOT and daily mean 440–870 nm Ångström exponent derived with Microtops sun-photometer measurements (**a**), height–time display of the 1064 nm range-corrected lidar signal (**b**), and the volume depolarisation ratio at 532 nm (**c**). White bars mark the case studies discussed in Sect. 3.2.

Bohlmann et al.: Aerosol profiling over the Atlantic Ocean

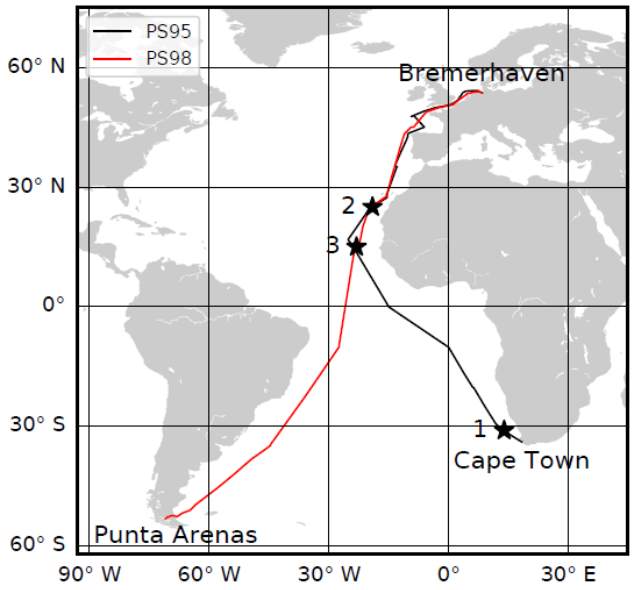


Figure 1. RV *Polarstern* cruises with Polly^{XT} aboard. Cruise tracks are taken from the Pangaea database (https://www.pangaea.de/expeditions/cr.php/Polarstern, last access: 24 February 2017). Black stars mark the location of the case studies presented in Sect. 3.2.

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MARITIME AEROSOL NETWORK (MAN)

The Maritime Aerosol Network (MAN) component of AERONET provides ship-borne aerosol optical depth measurements from the Microtops II sun photometers. These data provide an alternative to observations from islands as well as establish validation points for satellite and aerosol transport models. Since 2004, these instruments have been deployed periodically on ships of opportunity and research vessels to monitor aerosol properties over the World Oceans.

Microtops instruments currently in the network have five channels but they may have one of two configurations: 340, 440, 675, 870, 936nm or 440, 500, 675, 870, and 936nm. In addition, the instrument has built-in temperature and pressure sensors as well as the ability to log accurate time and geographical position using a GPS. The Microtops instruments are calibrated at the NASA Goddard Space Flight Center (GSFC) calibration facility via a transfer calibration procedure between the Microtops and the master Cimel sun photometer at GSFC, which has a calibration traceable to a Langley calibration of a Cimel sun photometer on Mauna Loa, Hawaii. In general, the estimated uncertainty of the aerosol optical depth in each channel does not exceed plus or minus 0.02, which is slightly higher than the uncertainty of AERONET field (not master) instruments.

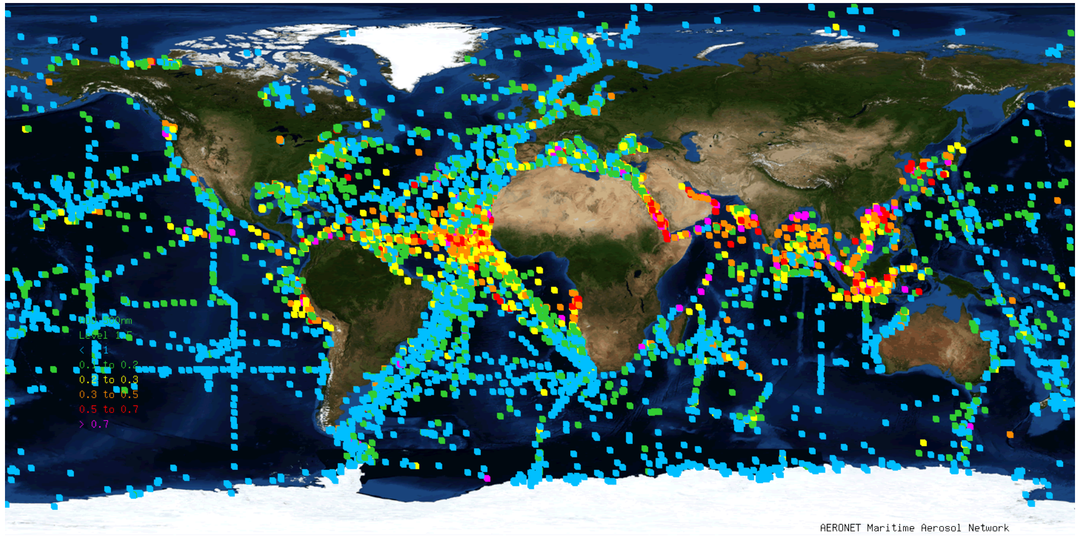
Additional information on data processing and quality may be found by choosing the "Data" link in the left column.

MAN Publication Reference:

Smirnov, A., B. N. Holben, I. Slutsker, D. M. Giles, C. R. McClain, T. F. Eck, S. M. Sakerin, A. Macke, P. Croot, G. Zibordi, P. K. Quinn, J. Sciare, S. Kinne, M. Harvey, T. J. Smyth, S. Piketh, T. Zielinski, A. Proshutinsky, J. I. Goes, N. B. Nelson, P. Larouche, V. F. Radionov, P. Goloub, K. Krishna Moorthy, R. Matarrese, E. J. Robertson, and F. Jourdin (2009), **Maritime Aerosol Network as a component of Aerosol Robotic Network**, *J. Geophys. Res.*, 114, D06204, doi:10.1029/2008JD011257.

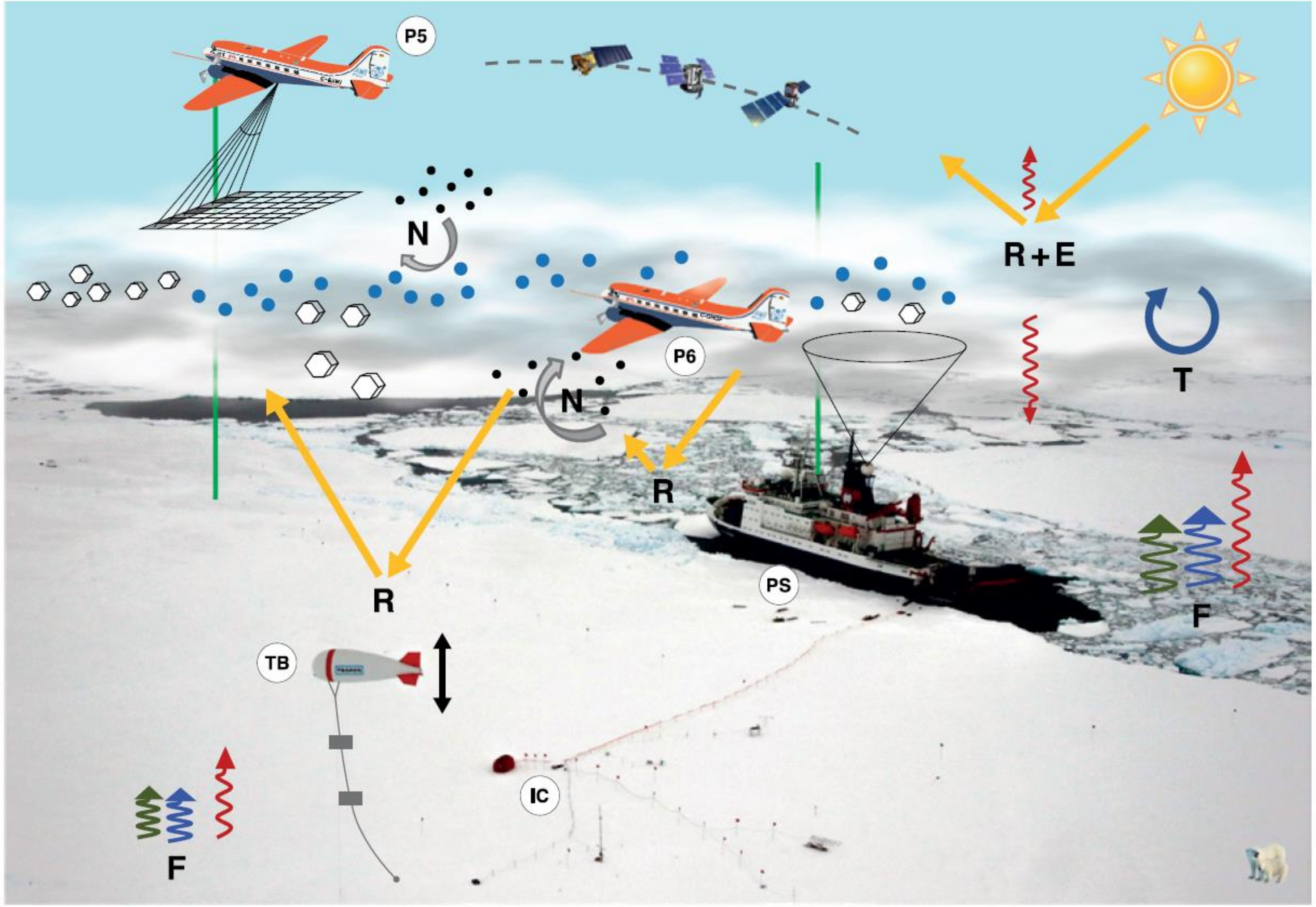
+ Download All MAN Data

CRUISES



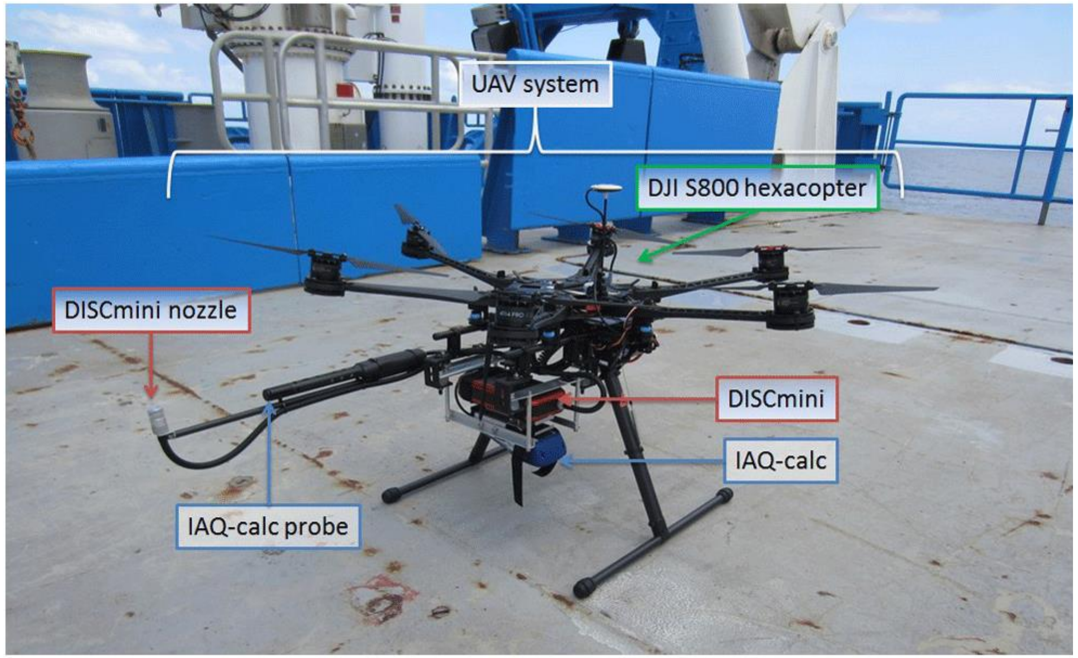
Wendisch et al., The Arctic cloud puzzle: Using ACLOUD/PASCAL multi-platform observations to unravel the role of clouds and aerosol particles in Arctic amplification, B. Am. Meteorol. Soc., https://doi.org/10.1175/BAMS-D-18-0072.1

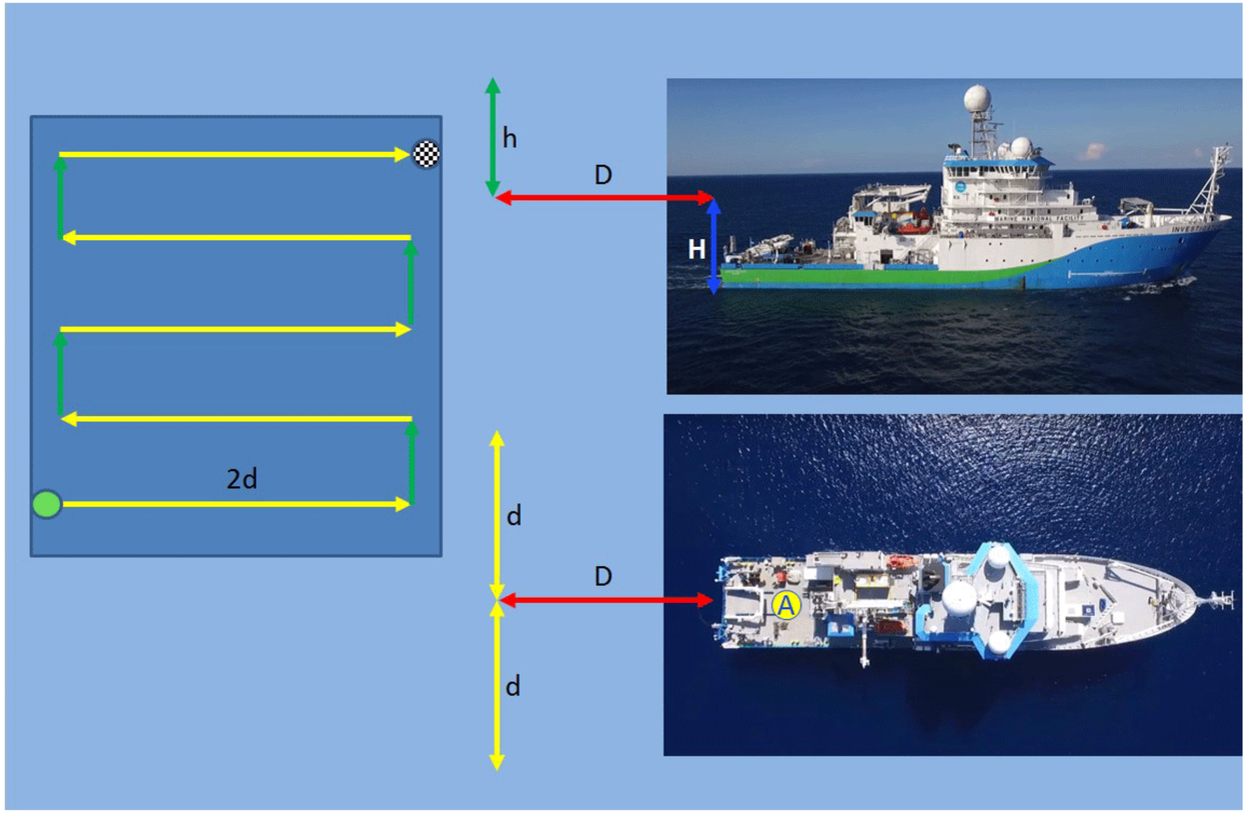
Fig. 1 (top). Multiplatform measurement setup during the ACLOUD/PASCAL campaigns. Observations were performed from the ground using R/V *Polarstern* (PS) and an ice floe camp (IC) close to R/V *Polarstern*, including a tethered balloon (TB). Two aircraft were used: Polar 5 (P5) and Polar 6 (P6). Collocated underflights of satellites were carried out. The two green vertical lines indicate the lidar, the pixel field below P5 the imaging spectrometers, and the vertical cone from PS the radar. The A-train satellite constellation is indicated by the dashed line with the three schematics of *Aqua*, *CloudSat*, and *CALIPSO* at the top of the figure.



Drones operated from ships

Villa, T. F., Brown, R. A., Jayaratne, E. R., Gonzalez, L. F., Morawska, L., and Ristovski, Z. D.: Characterization of the particle emission from a ship operating at sea using an unmanned aerial vehicle, Atmos. Meas. Tech., 12, 691–702, https://doi.org/10.5194/amt-12-691-2019, 2019.





Column measurements such as AOD measured with sun photometers or layer structures with LIDARs provide information to be combined with data from satellites.

- ❑ helicopters

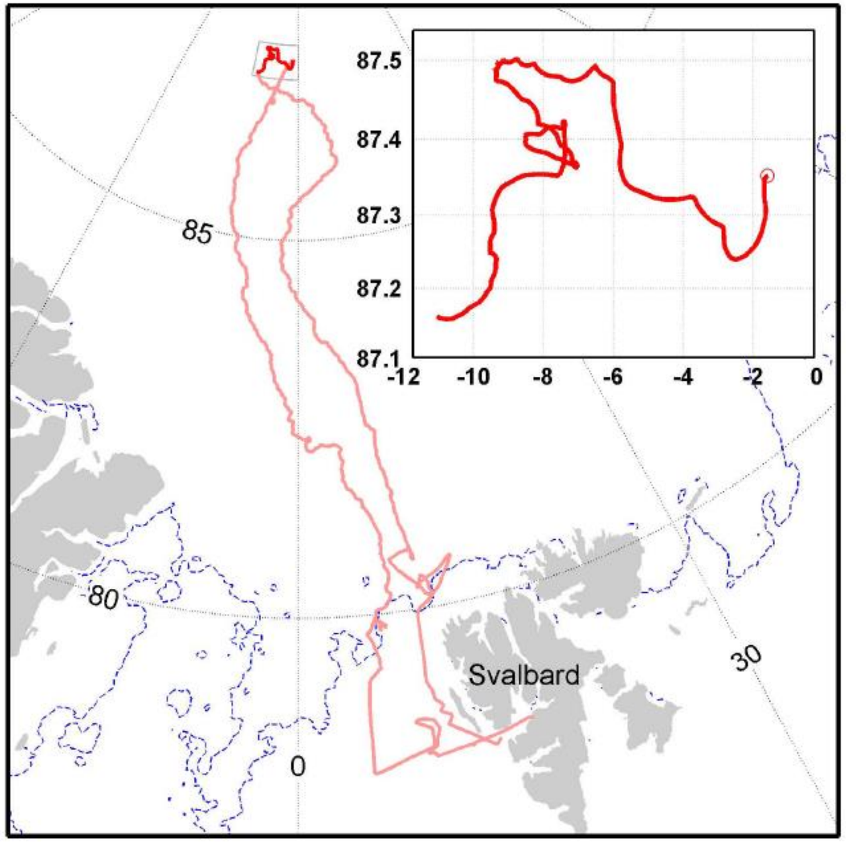


Fig. 2. The ASCOS 2008 expedition helicopter with instrument and air inlet locations.

Column measurements such as AOD measured with sun photometers or layer structures with LIDARs provide information to be combined with data from satellites.

- ❑ helicopters

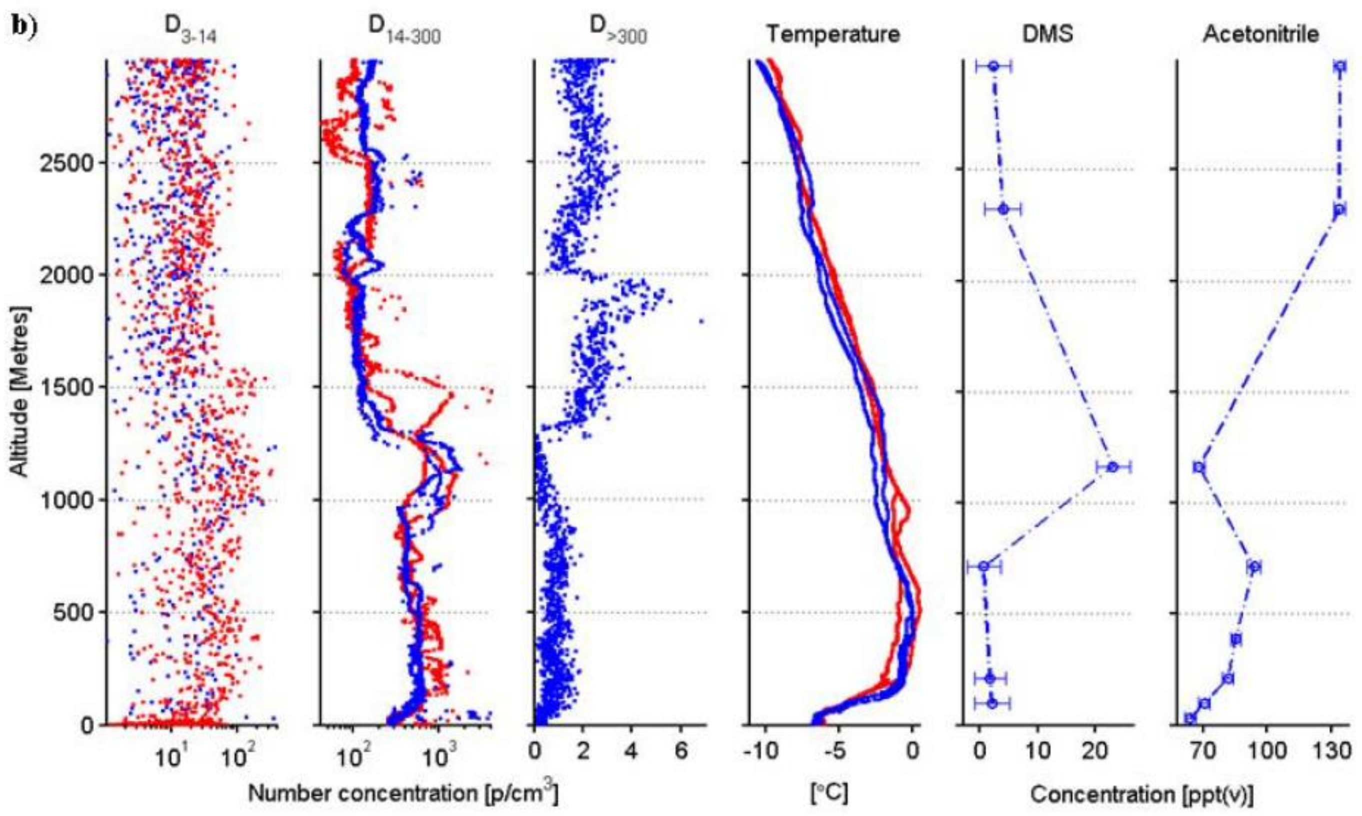


Fig. 9b. Vertical profiles of aerosol particle number concentration, temperature, and dimethyl sulphide (DMS) and acetonitrile concentrations (error bars give the 95 % confidence interval) during ASCOS 2008 expedition helicopter flights, Period 2: 23:17–23:57 UTC, 21 August (DoY 234) 2008 (red); 07:26–08:03 UTC, 22 August (DoY 235) 2008 (blue).

Atmos. Chem. Phys., 13, 12405–12431, 2013 **www.atmos-chem-phys.net/13/12405/2013/**

Combined with transport modeling

Easiest approach: backtrajectories

Potential Source Contribution Functions

Virkkula et al.: Atlantic aerosol chemistry

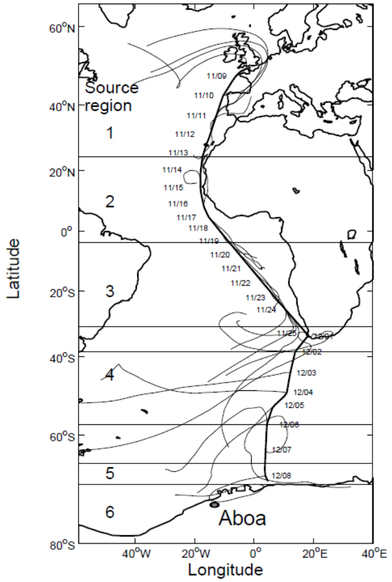


Fig. 1. Ship route, source region limits, and 5-day backtrajectories arriving at 500 m above sea level.

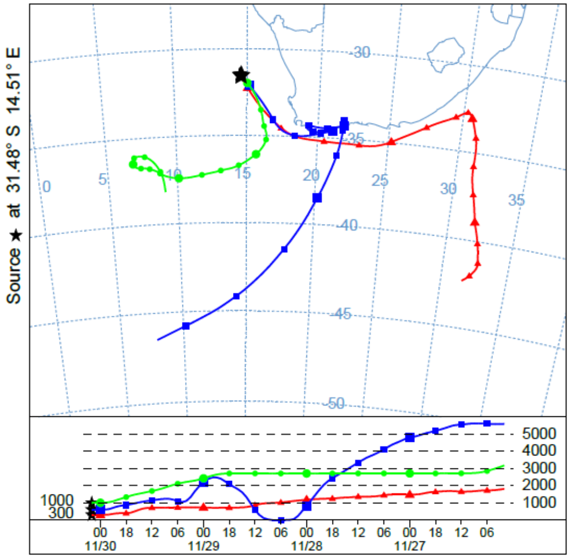


Figure 6. NOAA HYSPLIT backward trajectories for 4 days ending at the position of RV *Polarstern* (31.48° S, 14.51° E; marked by the black star) on 30 November 2015, 02:00 UTC, at 300, 600, and 1000 m a.g.l.

Bohlmann et al.: Aerosol profiling over the Atlantic Ocean

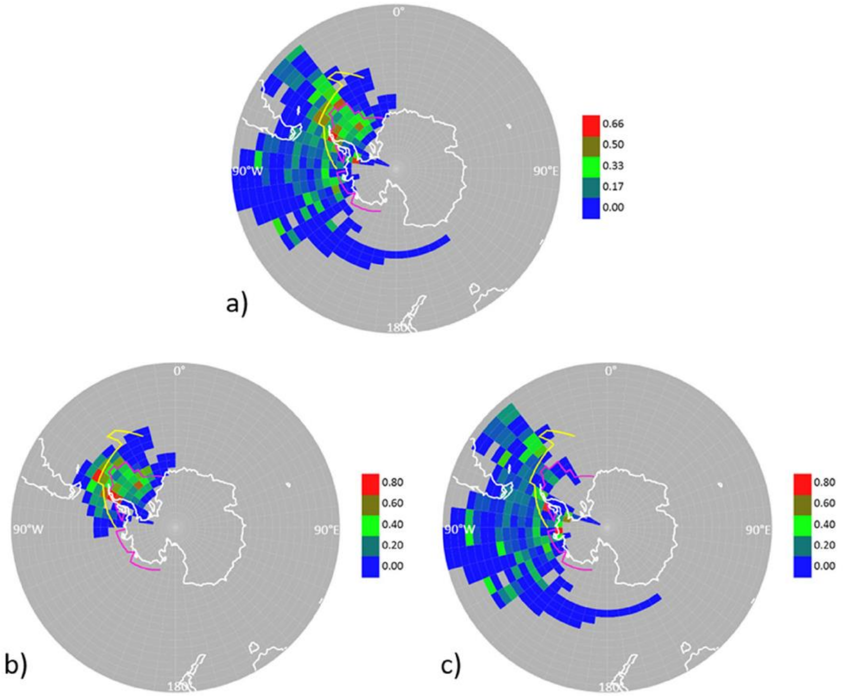


Figure 2. Apportioning of the origin of organic nitrogen in aerosols by Probability Source Contribution Function (PSCF) analysis. Continuous aerosol mass spectrometry data were combined with air-mass back trajectory analysis to quantify the probability of pixels to be the source of high ON concentrations in aerosols (defined as above the 3rd quartile). (**a**) Throughout the entire PEGASO cruise; (**b**) for the first half of the cruise, 8–21 January; (**c**) for the second half of the cruise, 22–31 January. Colour scale indicates PSCF weighting factors. The pink line indicates sea ice extent in January-February 2015. The yellow line indicates the approximate location of the Southern Boundary of the Antarctic Circumpolar Current (SBACC) within the 19–90° W sector, which defines the extent of major Weddell Sea ice influence on the contiguous ocean. This plot was created using the R software (R Development Core Team, R i386 3.3.2; www.r-project.org).

Dall'Osto et al. SCIENTIFIC REPORTS | 7: 6047 | DOI:10.1038/s41598-017-06188-x

Or footprints with FLEXPART

Sampling issues

- The ship contaminates your samples very easily
- Never place your inlet behind the smoke stack
- Also other holes, ventilation etc. contaminate
- Seaspray makes your sample lines wet. Install inlet as high as possible
- If possible, get an inlet that turns into the wind
- Dry the sample air

Examples of sample inlets on some ships

NOAA Ship *Ronald Brown*

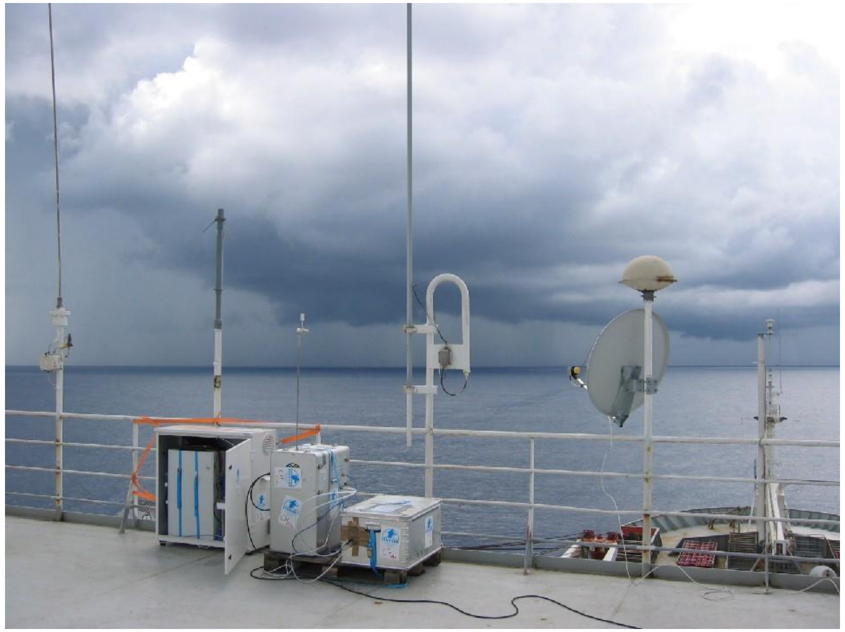
Inlet turning according to wind

Akademik Fedorov

On the roof above the bridge

Bremerhaven

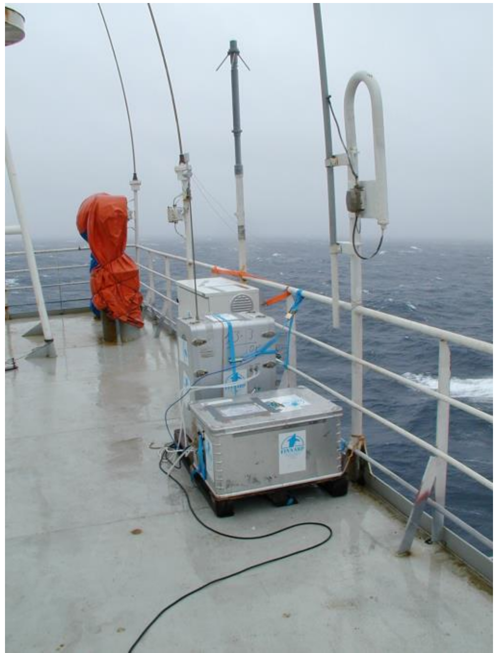
Akademik Fedorov, On the roof above the bridge

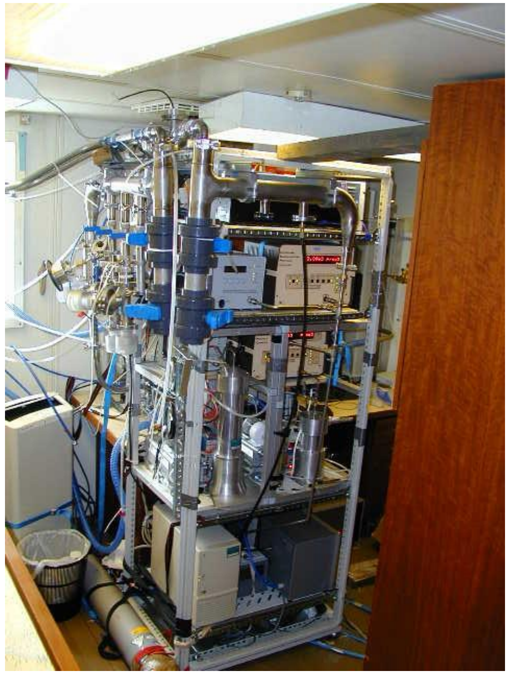


Inlets high
above the sea

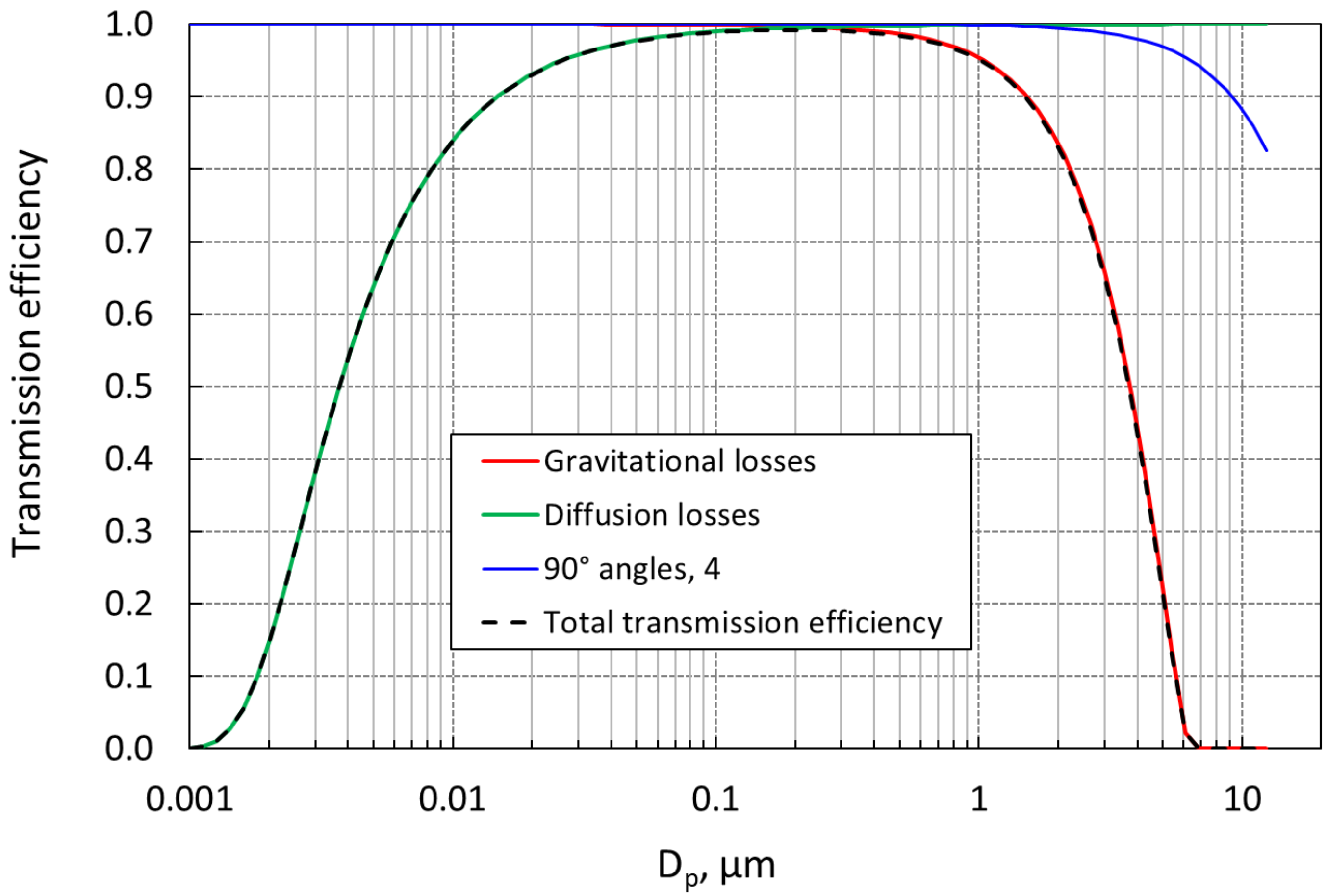
For nanometer-size particles (Air Ion Spectrometer measurements) as short inlet as possible

For larger particles longer sampling lines





Calculate size-dependent transmission efficiency of the sampling lines

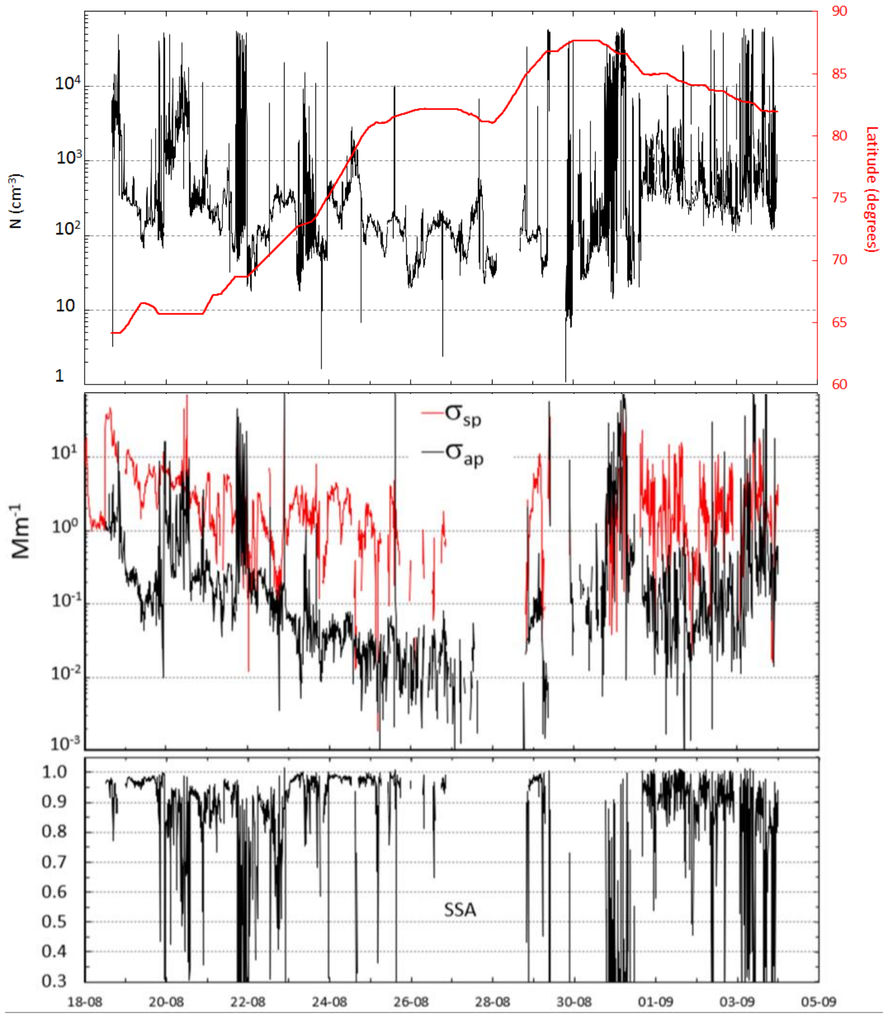


https://therealandrewmaynard.com/2020/05/27/the-aerosol-calculator/

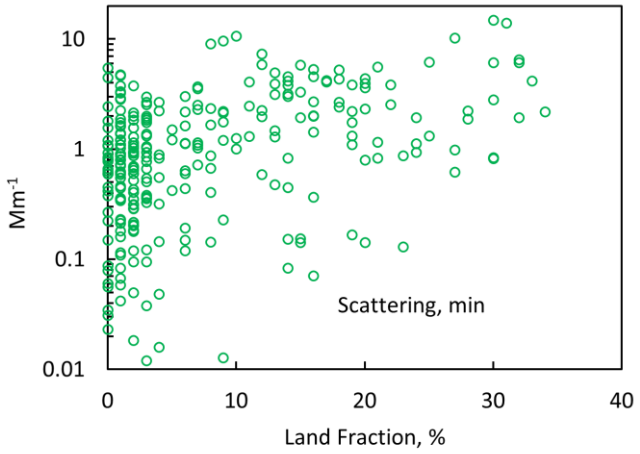
The Aerosol Calculator, created by Paul Baron, is an essential tool for anyone working in aerosol science

Figure 2. The research vessel Xue Long a Reykjavik harbour on 18 August 2012. The insert on the left shows the instrument rack, the insert on the right the inlet; the arrows show their locations on the bridge.

Good data before the ship enters the ice



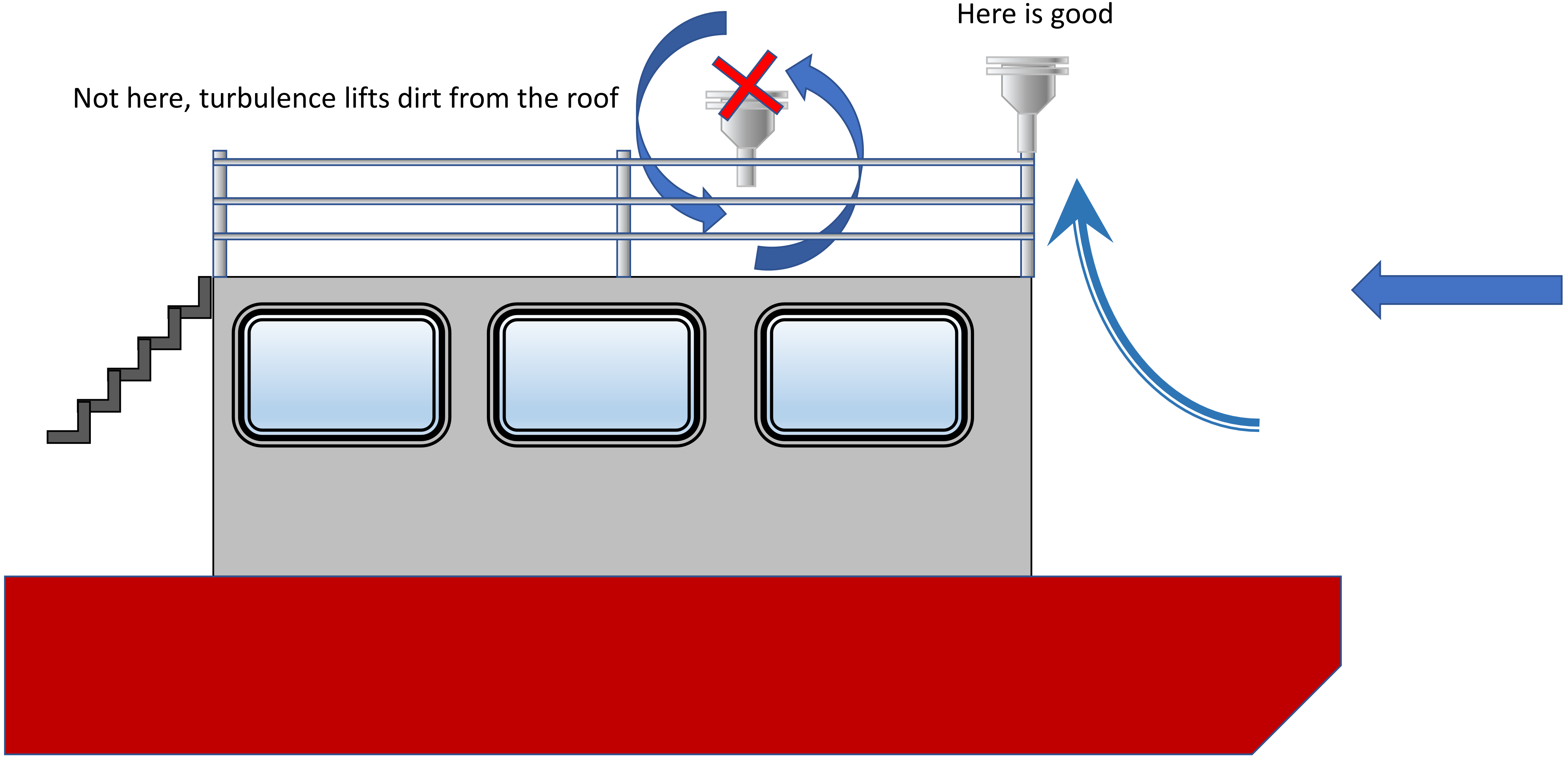
Cruising route of CHINARE 2012



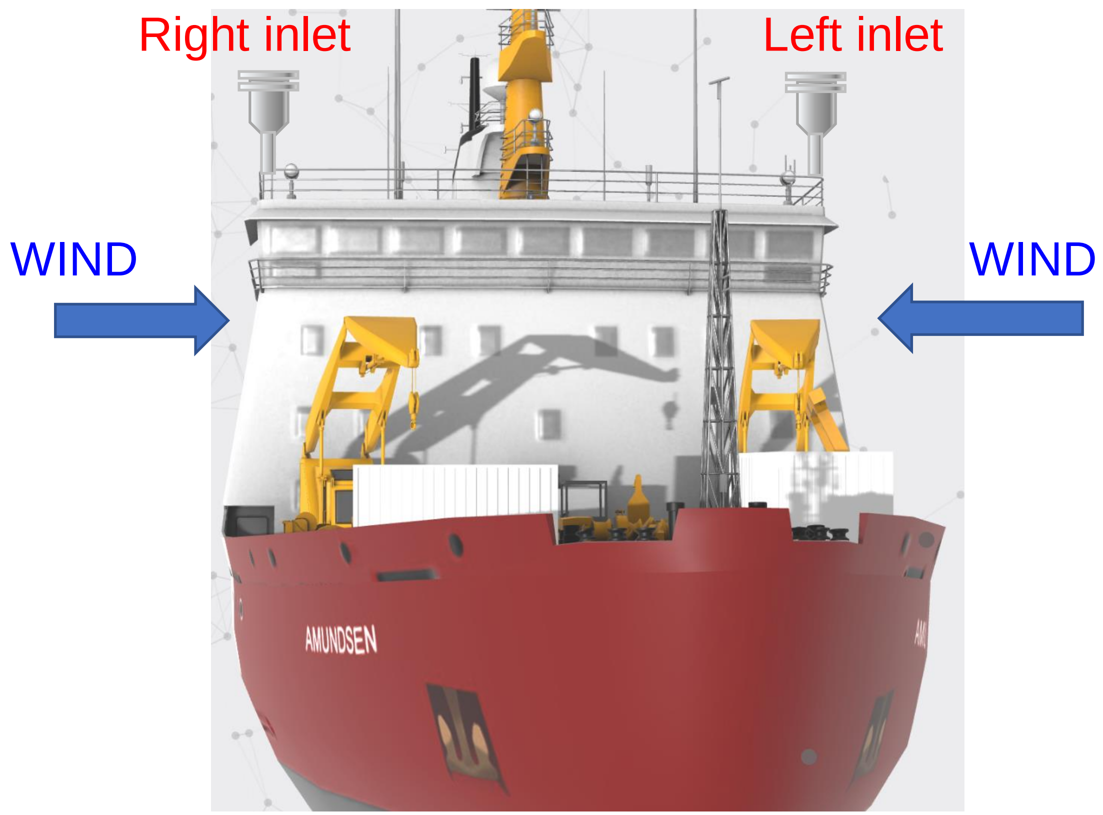
What to get out of the data?

- Filter data
  Maybe it could be assumed that during each hour the lowest 5% not contaminated
- Backtrajectories, footprints
- Effect of fraction of time spent over
  - ice
  - open sea
  - land

Inlet installation suggestions

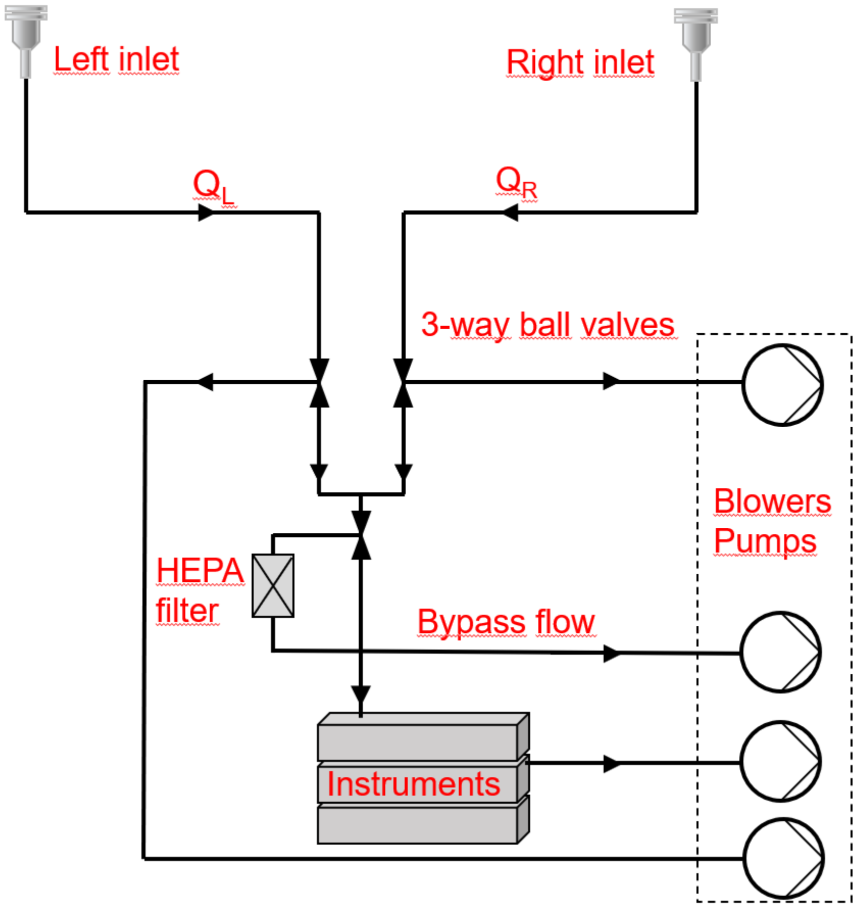


Suggestion for a sample flow setup



https://amundsenscience.ulaval.ca/#explorez

- Two equal-sized inlets
- Both flows continuously on
- Ball valves select the cleaner side
- Ball valves because they avoid pressure drops and particle losses
- HEPA filter for simultaneous zeroing and used when contaminated air comes from both inlets



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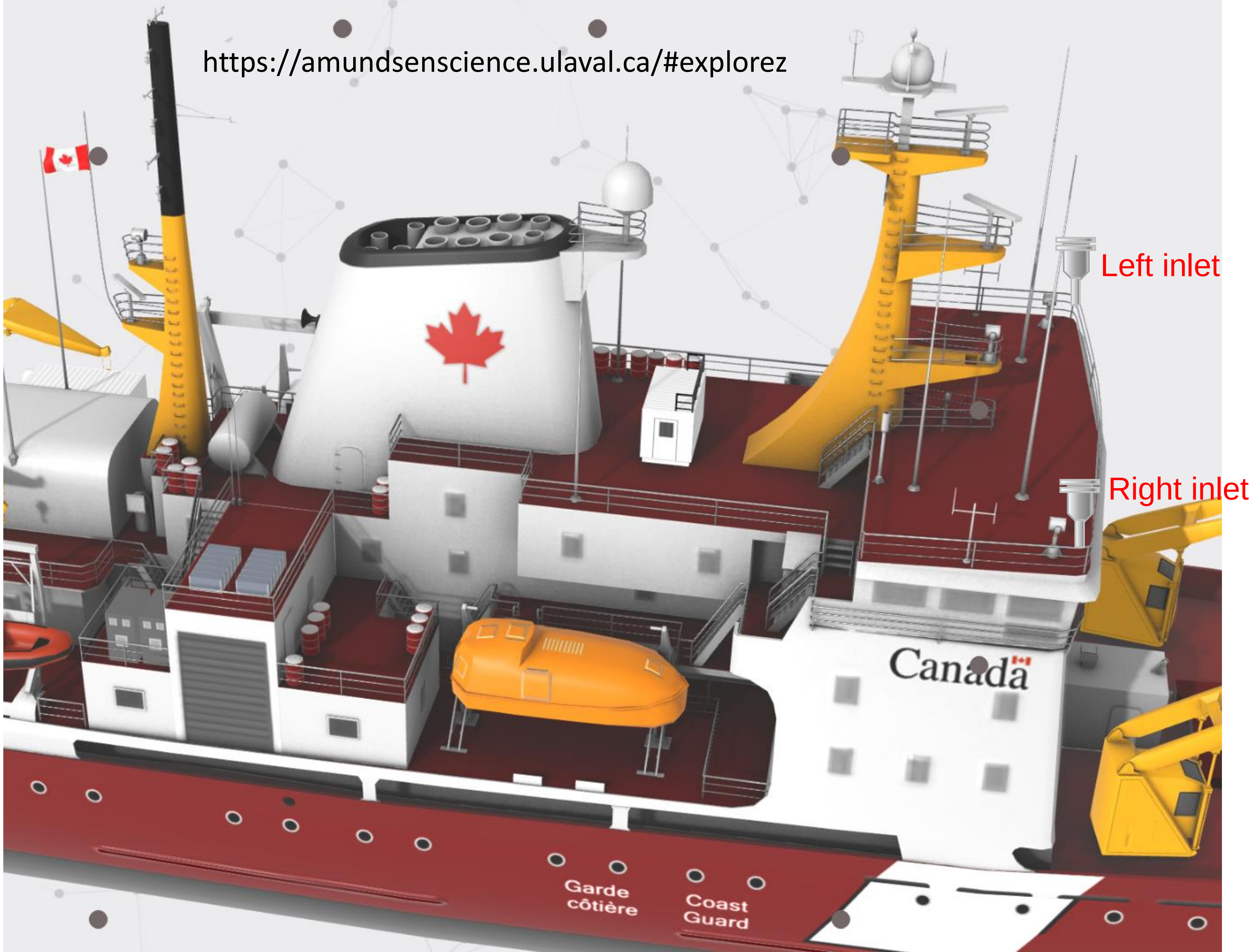
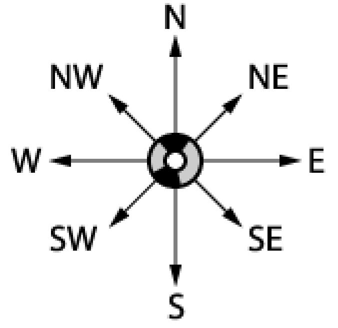
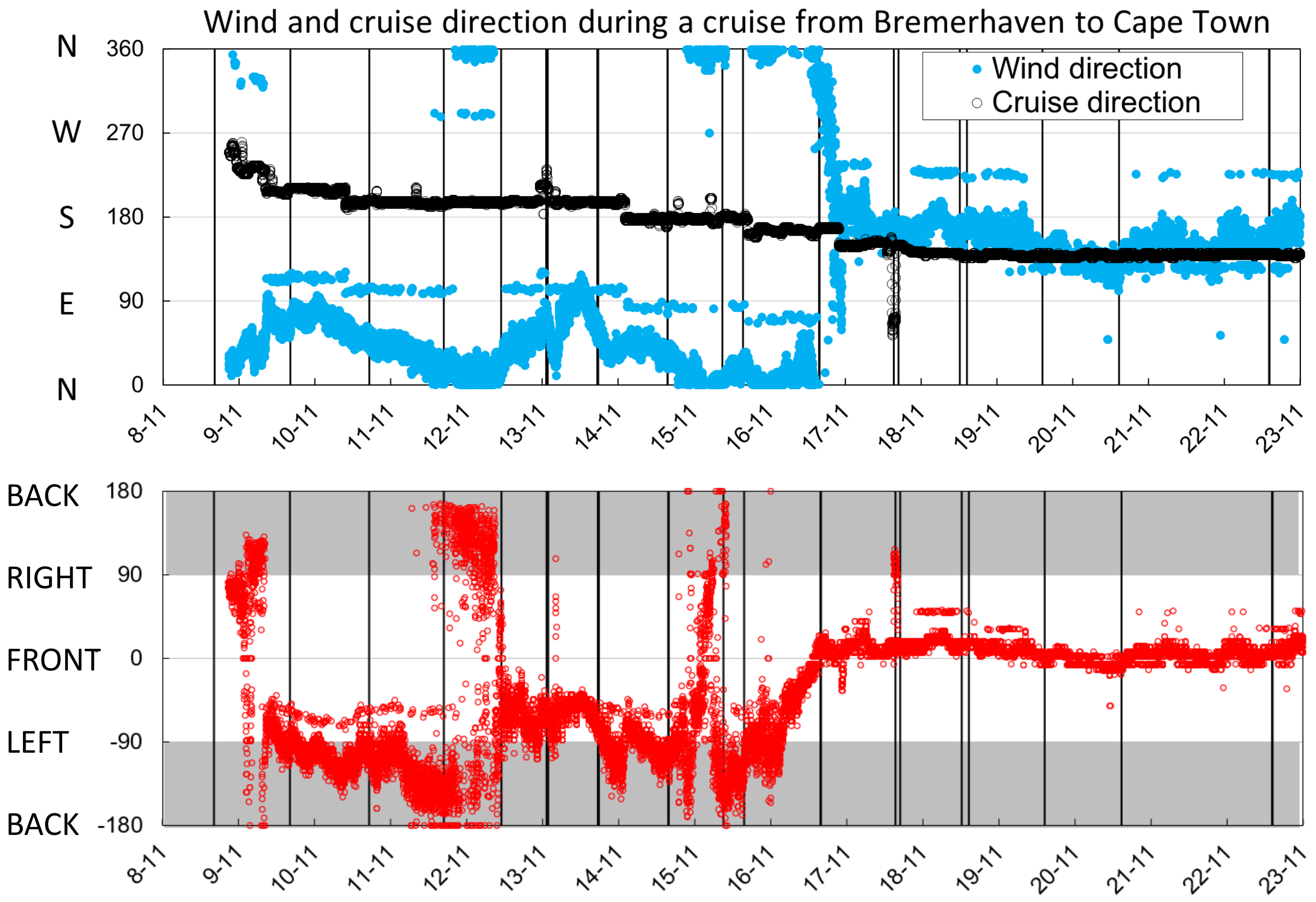
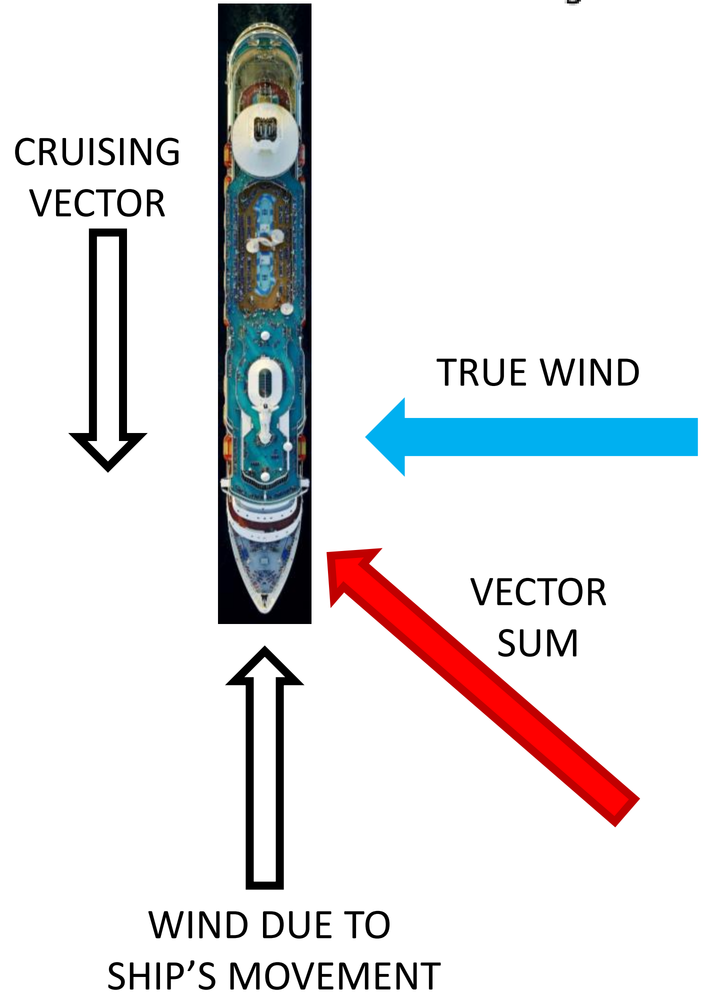


Calculate **vector sum** of true wind and wind due to the ship's movement to see, whether samples have been contaminated







Thanks for listening me!