Long-range Monitoring of Ship Emissions

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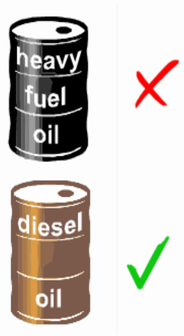
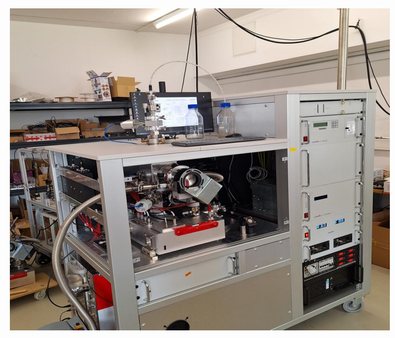
Lohmeyer
Air Quality | Aerodynamics
Climate | Environmental Software

The global maritime cargo transport is an important part of globalization and contributes to the prosperity of society. However, the ecological footprint of this transportation system and the cruise lines is considerable. For this reason, there are already restrictions and regulations in coastal areas, for example in the North and Baltic Seas, which regulate the use of permitted fuels and their emissions. According to the state of the art, monitoring outside port areas, narrow sea passages or canals is hardly possible or involves high operating costs.

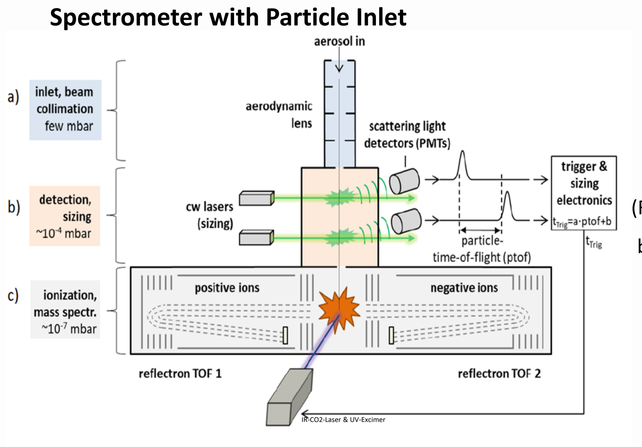


Within the project "SEP-3AP", a system for long-range monitoring of ship emissions was developed based on an aerosol single particle mass spectrometer. This allows to determine the actual chemical composition of individual particles and to detect specific elements such as iron, vanadium and sulphur, enabling conclusions to be drawn about the type of fuel used (heavy fuel oil or marine diesel). To detect possible ships as emission sources, the information on the chemical fingerprint is correlated with meteorological data, i.e. wind direction and wind speed, as well as the current ship positions, in order to specifically identify a particular ship as a possible emission source.



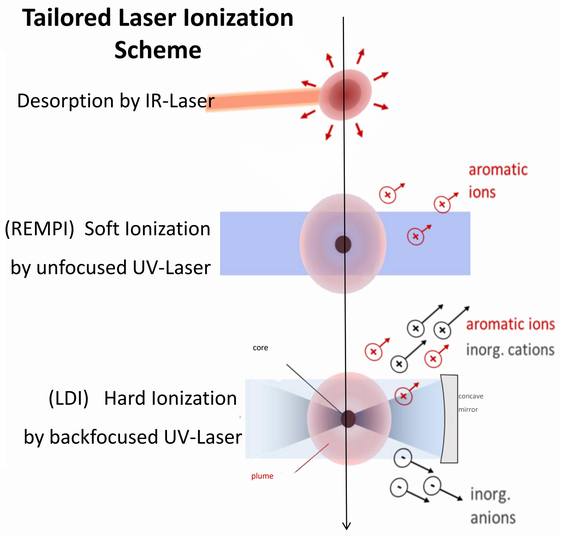
Ship Emission Profile – Advanced Analyzer for Aerosol Particles

Bipolar Time-of-Flight Mass Spectrometer with Particle Inlet

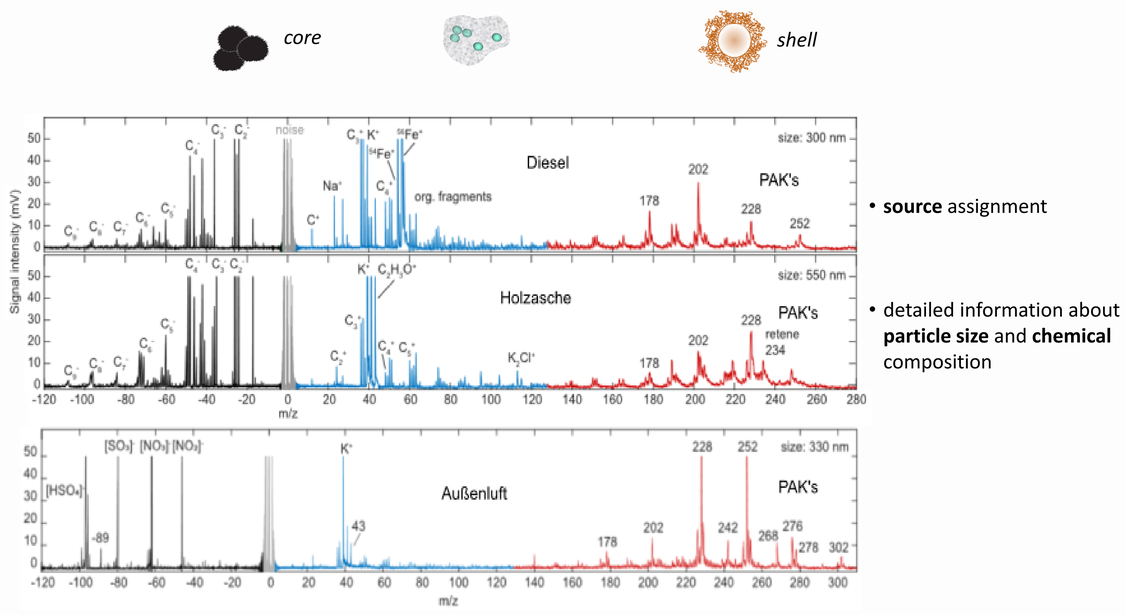


Particle Size Range 200nm – 3.5µm
Duration of Measurement ~ 2ms

Tailored Laser Ionization Scheme



Graphics by J. Passig, UniRostock



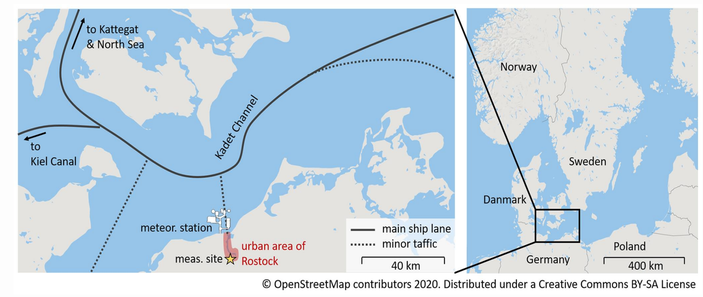
- **source** assignment
- detailed information about **particle size** and **chemical** composition

Schade, J. ,Passig, J. et al., *Anal. Chem.* 2019 **91**, 15 10282-10288

To locate the origin of the emissions, a model for backward trajectories was developed, which is characterized by a high temporal and spatial resolution. Point measurements, for example, are not sufficient for this, as they are not spatially dense enough, so that high-resolution temporal and spatial simulation data of the wind fields from weather forecasts are used. As the forecasts have a certain degree of uncertainty, sets of trajectories are calculated from ensemble forecasts in order to be able to show a possible range of the area of origin. The freely available model forecasts of the German Weather Service (DWD), which have a horizontal resolution of around 2.2 km, are available as spatial input data for the North and Baltic Seas. The data is also available as an ensemble forecast, i.e. several numerical weather forecasts that cover the same period but differ in terms of slightly different initial conditions, boundary conditions and/or physical parameterizations. The ensemble forecasts are used to compute trajectory plots that span a bandwidth of the area of origin of a possible emitter. By evaluating a ship tracking system (AIS data of the ships), the trajectory locations can be compared with the ship positions at any time and possible emitters can be extracted.

Weather forecast from the past (up to 6 h) to the present
DWD Model chain

ICON Global, ICON-EPS	about 13 km resolution, hourly Issue 6-hour update
⇩	
ICON-EU, ICON-EU EPS	about 7 km resolution, hourly Issue 6-hour update
⇩	
ICON-DE, ICON-DE EPS	approx. 2.2 km resolution, hourly Output 3-hour update



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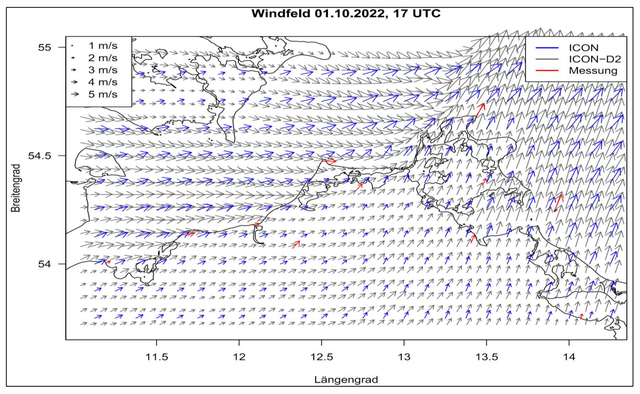
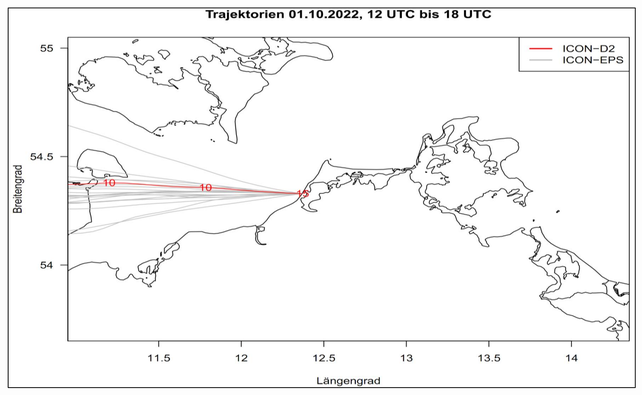
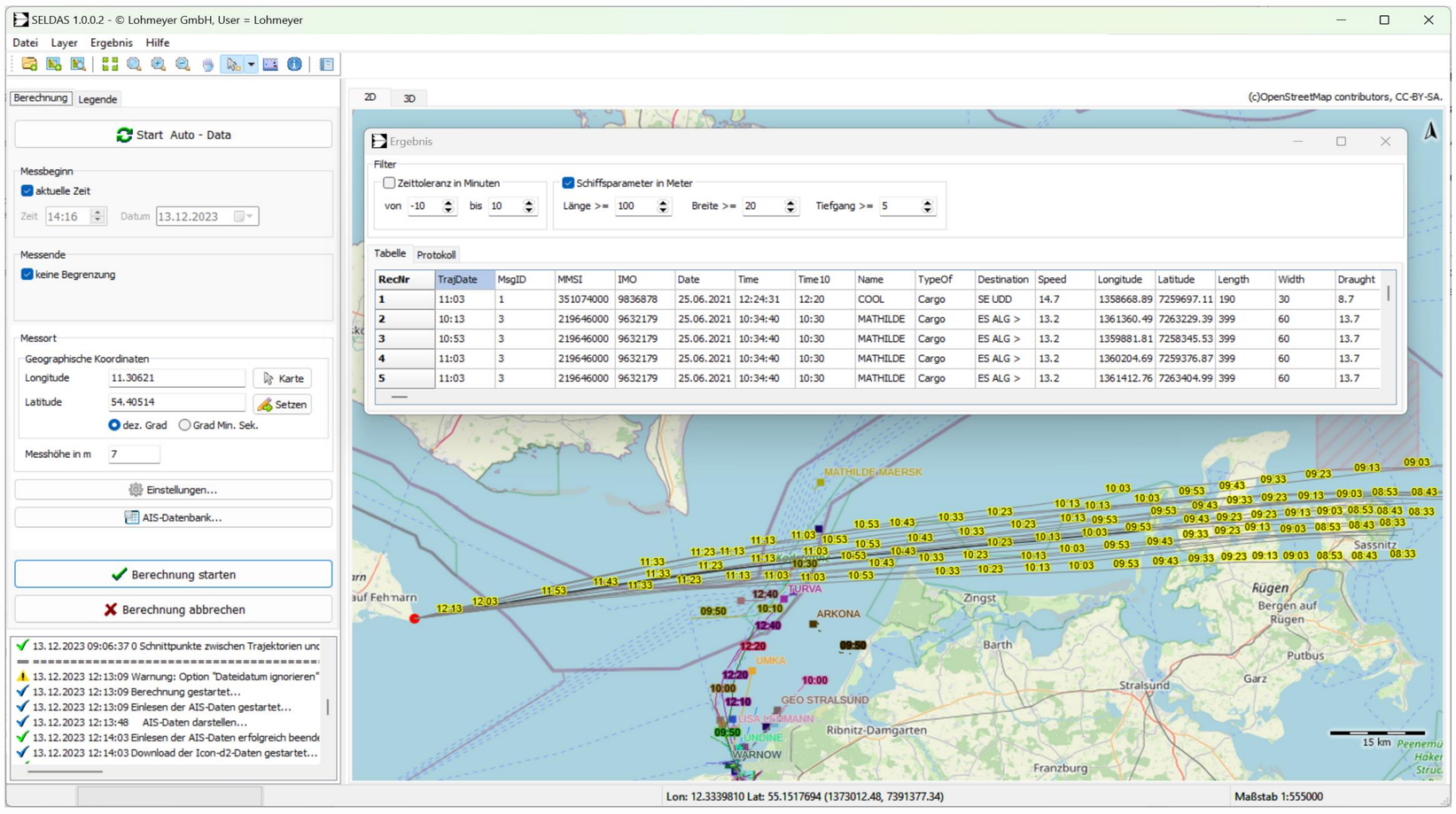
Passig, Schade et al., Atmos. Meas. Tech., 14, 4171–4185, 2021







The software is controlled via a user-friendly program interface named SELDAS (Ship Emission Long Distance Aerosol Surveillance).
To localize ships after a successful detection of air pollutants, the AIS data is automatically read and displayed by the program system when a calculation is started. In the second step, the meteorological data (in this case model forecasts ICON-D2 from the DWD) are read in, processed and the backward trajectories are calculated and also displayed. Subsequently, a geometric intersection of the displayed AIS data and the calculated backward trajectories is performed. The result is a tabular output of all intersections found. Finally, the results table can be restricted by the user using adjustable filter functions. Both the time tolerance and the ship parameters can be changed.

Federal Ministry for Economic Affairs and Climate Action

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