Given its importance for the transport of goods on a global scale, there is a growing interest on the sustainability of the shipping industry. It has long been recognised that shipping is a very carbon-efficient transport medium, but there is an increasing focus on its broader environmental consequences. The Science for a better future of the Baltic Sea region (BONUS) and the Sustainable Shipping and Environment of the Baltic Sea region (SHEBA) project addresses a wide range of environmental impacts of shipping in the Baltic Sea including air pollution, marine pollution, underwater noise and climate change as well as the socio-economic consequences of these impacts. SOLAS and SHEBA joined forces to organise a two-day conference “Shipping and the Environment - From Regional to Global Perspectives”, which was held at the University of Gothenburg’s conference centre on 24-25 October 2017, and attracted 117 participants from 15 countries. The conference was followed by a SOLAS workshop on “Shipping” on 26 October 2017. These two closely linked events provided a unique opportunity to review the latest research across a
broad interdisciplinary perspective, and to discuss priorities for future work. The conference programme was divided into five sessions with wide interdisciplinary coverage: Atmospheric processes; Assessments of integrated effects on environment and climate; Marine processes; Noise; and Socioeconomic aspects and policies. Each session included both oral and poster presentations. The oral presentations were followed by a panel discussion between researchers and stakeholders. A joint special issue in the journals Atmospheric Chemistry and Physics, and Ocean Science will provide a platform for disseminating the new research presented at the conference.

Several participants noted with pleasure that this was the first international conference addressing the environmental consequences of shipping from a wide range of perspectives. Some interest was expressed in developing a regular series of conferences from this initiative.

Twenty-two participants then took part in the SOLAS workshop (Figure 1) that was held immediately after the conference. This workshop was the third event in an initiative to develop shipping emissions and their consequences as a component of the SOLAS research programme. This initiative started with a discussion session at the 2015 SOLAS Open Science Conference in Kiel, Germany, which was followed by a breakout group on shipping at the 2016 SOLAS Science and Society workshop held in Brussels, Belgium. The aim of the third SOLAS workshop was to develop an outline for SOLAS research on shipping, and to identify a core group that will lead the coming work. Tom Bell, Christa Marandino and Anna Rutgersson have formed this core group and will lead this initiative in moving forward. The “Shipping” workshop resulted in a common framework for considering the various types of ship emissions (i.e. atmospheric, ballast water, grey/black water, scrubber water, noise, and emissions from ship hulls as part of anti-fouling strategies) and how current and future regulations could potentially impact these emissions. The framework reflected how different
regulations could influence ship emissions and have both intended and unintended consequences. These consequences are important at an environmental and a societal level and directly link the science of ocean-atmosphere interaction with stakeholders, economists and policy makers.

It was recognised that the common framework could provide a contribution to the Knowledge Action Network “Oceans” within Future Earth, and would be eligible to apply for funding that may become available through the Belmont Forum.

Link to the event website:

The outcomes of the session contribute to the Cross-Cutting Theme ‘Science and Society’ of the SOLAS 2015-2025: Science Plan and Organisation.

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Josefine Maas studied Climate Physics in Kiel, Germany, and started her PhD at GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Germany, in 2016. Her research focuses on the increase of anthropogenic volatile halocarbons from oxidative water treatment in shipping and industry. Her work contributes to the Emmy-Noether project: A new threat to the stratospheric ozone layer from Anthropogenic Very Short-lived Halocarbons (AVeSH).

**Anthropogenic halocarbons from ballast water treatment**

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In the course of the new International Maritime Organization (IMO) Ballast Water Convention (IMO, 2004), entry into force since September 2017, ships have to treat ballast water (BW) in order to prevent invasion of harmful aquatic species and organisms. The volume of BW discharged each year is highly uncertain and estimates assume a global BW discharge of 3-5 x 10⁹ m³/yr (David, 2015, Globallast IMO, 2015). It is expected that about 50% of the BW treatment systems (BWTS) use chemical disinfection, e.g. chlorination. Chlorination is a widely used disinfection method in industry and is known to produce a variety of halogenated compounds as disinfection by-products (Werschkun et al., 2012). The most abundant compound measured in BW after chemical treatment is bromoform with an average concentration of ~900 nmol/L (Figure 2). Once the bromoform is discharged and emitted into the atmosphere it has a strong ozone depletion potential and can alter the radiative balance and oxidising capacity of the atmosphere (Tegtmeier et al., 2012). Especially in the tropics, a region with dense ship traffic and biggest harbours, bromoform can reach the ozone layer in the stratosphere through deep convection. To assess the bromoform concentration from BW discharge in the ocean, pathways of treated BW are simulated with Lagrangian trajectories. Particles are continuously released at a source region and passively advected with the high-resolution velocity field from Nucleus for European Modelling of the Ocean alias (NEMO)-ORCA12. Source region for the BW spread experiments are major ports and surroundings in Southeast Asia because of the high density of large har-

![Figure 2: Bromoform concentration measured after BW treatment [nmol/L]. Blue, purple and green: samples measured at GEOMAR, Germany, from two chlorination BWTS (blue and purple) and one UV system (green). Red and yellow: concentrations in seawater (red) and brackish water (yellow) from the IMO Marine Environment Protection Committee (MEPC) Reports for BWTS approval.](image-url)
bours and the low latitudes. The simulations at Singapore harbour reveal major pathways of the anthropogenic halocarbons and the resulting ocean surface concentration with an average of ~10 pmol/L after a runtime of one year (Figure 3). Maximum bromoform concentrations of ~30 pmol/L are found in the Strait of Malacca. These values are locally of similar amplitude as shelf water concentrations from databases which lie around 40 pmol/L (Ziska et al., 2013). Oceanic degradation processes (Hense and Quack, 2009), as well as an interactive sea-to-air flux with a steady atmospheric surface concentration of bromoform (Ziska et al., 2013) are taken into account. Concentrations and emissions decrease when the plume is stronger diluted further in the open ocean. Therefore, regional and coastal processes play an important role in the modelling of BW spread. Regional areas with high oceanic surface concentrations provide a strong gradient at the air-sea interface, which can result in very high flux rates into the atmosphere. Further trajectory modelling studies will be done for different harbours and industrial sites in the tropics and shall be compared to bromoform measurements in these areas.

**References**


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Observation of atmospheric derived trace metals into the marine coastal environment, Cornwall, United Kingdom.

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The delivery of trace elements to the ocean can regulate the uptake of carbon in some marine ecosystems and, in turn, the atmospheric concentration of carbon dioxide (Maher et al., 2010). Trace elements, such as iron (Fe), are essential micronutrients which are involved in the biological functions of many enzymes in phytoplankton (Morel et al., 2003), whereas some trace metals, such as copper (Cu) and lead (Pb) can be toxic to some ecosystems (Payton et al., 2009).

Figure 4 outlines the mode of transport of trace metals to the ocean. The project focuses on the wet and dry deposition of trace metals via aerosol particles at Penlee Point Atmospheric Observatory (PPAO). PPAO is situated in an inlet to Plymouth Sound, United Kingdom, which is a busy shipping route, and is of particular interest as it has a high amount of anthropogenically derived trace element emissions from ships, ferries, and city traffic. Typical southwesterly winds tend to bring relatively clean background Atlantic air towards the site. In contrast, winds from the southeast are often more contaminated by exhaust plumes from passing ships and shipping lanes (Yang et al. 2016) (see top right-hand corner of Figure 5 for the different wind directions at PPAO). The impact of such ac-

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tivities would subsequently be detectable in the trace element concentrations (e.g. vanadium (V) and nickel (Ni)) of the aerosol samples collected. The PPAO is in close proximity to the Western Channel Observatory, enabling better understanding of the ocean-atmosphere coupling.

My project involved collecting weekly aerosol samples (February 2015 to August 2016) and rain sampling (October 2015 to November 2016) at PPAO. One batch of filter samples was leached with ultra high pressure water (18.2 mΩcm), resulting in the formation of soluble or potentially bioavailable fractions. Another batch of duplicate samples was completely digested by using hydrofluoric/nitric acid (based on Morton et al., 2010). Both aerosol fractions and rain samples were analysed using Inductively coupled plasma mass spectrometry to determine the concentrations of trace elements, such as aluminium (Al), V, chromium (Cr), manganese (Mn), Fe, cobalt (Co), Ni, Cu and zinc (Zn) etc.; whilst inductively coupled plasma optical emission spectrometry was used to determine sodium (Na), magnesium (Mg), etc., in order to remove the influence of sea spray on the trace metal concentrations. The main aim of this study was to observe the impact of both local activities, such as shipping traffic, and long-range dust transport on trace element concentrations in the aerosol samples collected and their solubility in the surface ocean in the coastal environment.

Figure 5 shows an example of a typical one-year observation of soluble and total Fe concentration in aerosol samples at PPAO.
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