Ship Plumes

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Ship Plumes have been suggested as a SOLAS research topic for some time. The first SOLAS Ship Plumes discussion session was held in Barcelona in 2009. That session focused to a very large extent on the atmospheric science questions associated with Ship Plumes, with only limited interest from the marine science community. As a result, the Barcelona initiative did not gain momentum as an integrated SOLAS activity. In contrast, at the Kiel SOLAS Ship Plumes discussion session we had a fairly even division of research interests between atmospheric and marine sciences among the 30 participants.

Ship plumes are an important part of the environmental footprint of shipping. Emission regulations, which are most advanced for sulphur and nitrogen oxides, SO_X and NO_X, have been entirely driven by concerns about air quality and human health but are still very lax in comparison with the regulation of terrestrial emissions of these gases.

The meeting first reviewed the composition of ship plumes. In addition to CO_2 this includes SO_X and NO_X, NH_X, CO, metals, organic compounds, and particulates. Almost all these materials have a limited residence time in the atmosphere, and are therefore deposited relatively close to the source, usually within some hundreds of kilometres. Among the metals, Fe is of particular interest since it acts as a micronutrient in the marine environment: a recent study has suggested that shipping may become the major source of Fe to surface ocean waters by the end of the century. Organic compounds and particulate materials are mainly of concern for human health: PAH emissions are a concern, and also small (< 2.5 μm) particles that penetrate deep into the lungs. The emission of black carbon may have significant effects at high latitudes, where it reduces albedo following deposition to ice surfaces. This implies that the anticipated opening of Arctic shipping routes as the sea ice retreats may lead to a positive feedback through black carbon deposition on the ice.

The fate of the materials discharged in Ship Plumes depends on both transport processes in the atmosphere, and also transformation reactions. These, together with information on the emission sources (i.e. ships) determine the extent to which these materials are deposited to the sea surface, or transported to the terrestrial atmosphere. Marine and coastal atmospheric circulation systems will have a strong impact on the deposition, atmospheric dispersion and transport. Specific features of the marine atmosphere need to be considered.

A closely related topic, that should be included in a Ship Plumes study, is the use of wet scrubbers that remove SO_X in a stream of seawater: in the simplest (open-loop) scrubbers, the effluent is discharged back to the surface water. These scrubbers are currently being installed within sulphur emission control areas (SECA), which encompass some northern hemisphere coastal waters. In these areas, the maximum allowed sulphur content of marine fuel was reduced from 1% to 0.1% in January 2015. Since this change results in a doubling of fuel costs, it has become attractive to use scrubbers so that cheap, high-sulphur fuel can be used without breaching the limits on SO_X emission. However, little is known about the chemical composition of the effluent and its consequences for the marine environment.

During the meeting, all participants introduced themselves and provided a short summary of their research interests, which covered a broad range of atmospheric and marine science. A list of participants, together with email addresses and research interests, has been compiled. There was broad agreement that development of an integrated research programme on Ship Plumes would not only be scientifically exciting, but would also have significant societal implications: SOLAS science can play an important role in providing the scientific basis for future regulations. This led to a discussion of the need to develop collaboration with researchers in areas such as economics, law and social sciences,

and also of the need to engage the attention of the public at large, approaches that fit well within the Future Earth concept. However, it was concluded that the first priority is to identify the scientific questions and challenges, as a basis for developing wider collaborations.

Possible specific regions of interest were also considered. It was pointed out that the Arctic could be an important study area. Climate change is expected to lead to an opening of Arctic shipping routes, bringing a significant change in the distribution of Ship Plumes. The retreat of sea ice is already changing the Arctic environment: understanding the consequences of adding Ship Plumes with their cocktail of nutrients such as N and Fe, together with toxicants and black carbon, presents both an exciting scientific challenge and a question of substantial societal relevance. Other regions of relevance are shipping hot-spots regions (strongly trafficked regions in the vicinity of large harbours) and the protection regions (SECA…), where changes in the emission patterns are expected.

On a show of hands, 23 participants expressed strong interest in attending a workshop to further develop the basis for an integrated programme on Ship Plumes within SOLAS. Such a workshop would need additional invited participants to cover areas of expertise not represented at the meeting (e.g. ship traffic analysis, marine engineering).