Shipping and the Climate

An interview with Dr. Veronika Eyring, by Thomas Bührke

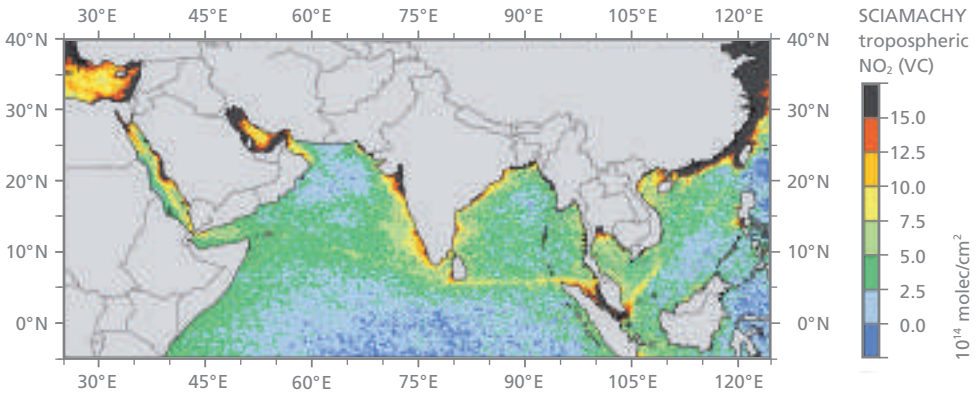
The exhaust gases from factories, cars, and aeroplanes have been scrutinized for quite some time now because they are noticeably changing the Earth's atmosphere and the global climate. Only shipping has remained unnoticed for a long time. A research group at the DLR Institute of Atmospheric Physics in Oberpfaffenhofen led by Dr. Veronika Eyring has now analyzed the emissions caused by ships more thoroughly. The result? While the emitted airborne particles (aerosols) may cause the climate to cool down, they are still polluting the air.

Several fortunate conditions resulted in the foundation of the research group led by Dr. Veronika Eyring. The scientist, who is today a mother of two, gained her PhD in 1999 at the Institute of Environmental Physics (Institut für Umweltphysik – IUP) at the University of Bremen. Her research focus back then was the modeling of the higher atmosphere (stratosphere). A few years later, Horst Köhler, in charge of the promotion of technology at the Augsburg-based company MAN Diesel, started to engage in the analysis of ship emissions, which is a research subject hardly anybody had been concerned with until that point.

In order to be able to compare the global ship emissions with those from aviation, Köhler got in touch with an expert in this area: Prof. Dr. Ulrich Schumann, Director of the DLR Institute for Atmospheric Physics. At DLR, Köhler was met with receptive ears as DLR had already been considering not only analyzing aviation emissions in an isolated manner in future but rather in a comparative form across all other means of transport. The beginning of the joint research project was forged with several workshops at both DLR and MAN.

Dr. Veronika Eyring, who was involved in the analyses right from the outset, recognized the opportunity which arose with an application for funding from the Helmholtz Association for Young Investigators Groups. Relying on a high level of dedication and the support of Professor Schumann, she submitted an application. Former colleagues at the University of Bremen also supported her, especially Professor John Burrows who is a project scientist for the spectrometer SCIAMACHY on board of the European environmental satellite Envisat. Burrows and his team had already had many years of experience with evaluating satellite data as well as with handling global datasets. Satellite data is essential for the task of quantifying climate effects and evaluating model results.

Dr. Veronika Eyring has been leading her own junior research group since 2004. Her research project is SeaKLIM – the influence of shipping emissions on the atmosphere and the climate. Her team is comprised of one post-doc researcher at the DLR Institute for Atmospheric Physics in Ober-



Vertically integrated nitrous oxide concentration (NO_2) from measurements taken by SCIAMACHY (taken from Richter et al., 2004, Copyright American Geophysical Union)

pfaffenhofen as well as two PhD students at the IUP in Bremen and one supervisor on location. "This was an optimal way of combining the expertise of the two institutes. The satellite data is evaluated by the IUP and the DLR institute provides atmospheric models as well as measurement facilities with the research aeroplane Falcon," explains Veronika Eyring.

For the first time, the SCIAMACHY data enabled the SeaKLIM group to determine the contribution of ships to air pollution, which is caused by increasing the concentration of nitrous oxide along shipping routes.

Clouds along shipping routes

The findings of the SeaKLIM group were indeed somewhat surprising. In the year 2000, approximately 800 million tons of carbon dioxide (CO_2) were caused by ship engines, which equates to approximately 2.7 percent of all anthropogenic CO_2 emissions. For nitrous oxides (NO_x), the emissions account for 15 percent and for sulfur dioxide (SO_2) 8 percent. This means that shipping causes as many CO_2 emissions as aviation. The NO_x and SO_2 emissions are even ten times and a hundred times higher respectively. Climate effects thus cannot be excluded.

Shipping contributes to global warming through emissions of the greenhouse gas CO_2. However, the high SO_2 emissions counter this effect. This is because sulfur dioxide and other sulfuric compounds react to sulfuric acid in the atmosphere. Together with water, they lead to the creation of very small sulfuric droplets, so-called aerosols. These function like a reflector and send the sunlight back into space. Additionally, the aerosol creates condensation nuclei on which water vapor can condensate, creating clouds.

In some parts of the world, this process can be studied very precisely. On satellite images, regions along the busy shipping routes are covered with long-stretching low layers of clouds, which are definitely not of natural origin. These so-called "Ship Tracks" are a result of ship emissions.

The analysis of these Ship Tracks is best carried out with the instrument AATSR (Advanced Along Track Scanning Radiometer) onboard the Envisat satellite. It captures images in different spectral ranges. These images especially reveal Ship Tracks in the North Pacific, along the Western Coast of North America and the South African West Coast. Ship Tracks are thus more of a local phenomenon, which is strongly dependant on the seasonal properties of the atmosphere and the oceans.

Ship Tracks, however, only reveal the directly visible consequence of ship emissions. Some of them mix with normal clouds and strengthen them, others dissolve. However, the aerosols still remain in the atmosphere and can change the properties of clouds similar to the way in which condensation trails can change into contrail cirrus which can then no longer be clearly attributed to aeroplane emissions. Contrary to the condensation trails and cirrus clouds in high air layers, the change in cloud properties caused by shipping traffic occurs in the lower troposphere, which is in an altitude of approximately 1,500 meters.

Against global warming

Their effects on the climate have been analyzed using computer models by Dr. Eyring's research group. Even if some of the variables such as the size distribution of the droplets or the total global shipping SO_2 emissions are associated with a degree of uncertainty, all of the model simulations reveal the same result: The sulfur dioxide emissions of shipping traffic cause a "lightening-up" of low maritime clouds which can thus reflect more sunlight back into space than in their natural state. This means that the sulfur emissions of shipping traffic are counteracting global warming.

Even though this effect is restricted to the areas along the main shipping routes, shipping at its global average causes 17 to 39 percent of all anthropogenic changes in the radiation balance through aerosols. Overall, the effect of cooling the climate through clouds weighs stronger than the heat increase caused by the greenhouse gases. However, it would be wrong to draw the conclusion that

the sulfur emissions from ships only have a positive effect on the atmosphere. The climate effect is confronted with massive air pollution at sea borders and ports. Additionally, the sea absorbs the sulfur compounds, which leads to an increase in ocean acidification.

Alternative ship fuels

The aim of the Helmholtz Young Investigators Group SeaKLIM is to continue the analysis and quantification of these effects over the coming years. Veronika Eyring's team is therefore closely cooperating with national and international institutes as well as the industry, especially MAN Diesel. The current emissions from international shipping are being estimated and future emission scenarios are being developed together with experts from the company.

This cooperation has revealed that the globally existing engine performance of freight ships increased by 30 percent between the years 2001 and 2006. Emissions are expected to have grown accordingly at the same rate. This enormous increase has already led to the first countermeasures. For example, only ships whose fuel contains a maximum of 1.5 percent sulfur are allowed in the Baltic Sea. In the North Sea and the English Channel, the same regulations have been effective since 2007. The European Union even wants to ensure that by 2012 only ships whose fuel contains a maximum of 0.1 percent sulfur may dock in EU ports.

Desulfurized fuels or catalytic converters are already technically feasible today but are not used much, mainly due to higher costs. DLR also wants to contribute to resolving this issue through its research. Since mid-2006, the SeaKLIM group has been part of a new project by the name of BIOCLEAN, which is coordinated by Veronika Eyring's colleague Dr. Andreas Petzold at DLR. In cooperation with MAN, the team is planning to research whether bio or regenerative fuels are suitable for use in ship engines and how much pollutant emissions can be reduced this way. A key factor will be incorporating all relevant chemicals, such as CO_2, NO_x, hydrocarbons, SO_2, H_2SO_4, and soot particles, in the studies.

At the same time, technical improvements for ship engines will be investigated. The planned BIOCLEAN work package includes measurements of experimental and complete engines with alternative and regenerative fuels and exhaust gas measurements.

From a theoretical point of view, the research group wants to use computer simulations to analyze the expected climate impact of using alternative fuels. To conclude, transport plays an important role in the progressing globalization process. Forecasts predict the traffic volume will continue to strongly increase in the years to come. The challenges for science, technology, and politics thus remain multifaceted.

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The HelmholtzYoung Investigators Group of Dr. Veronika Eyring unites scientists from the Institute of Environmental Physics at the University of Bremen (IUP) and scientists from the DLR Institute for Atmospheric Physics (DLR-IPA) in Oberpfaffenhofen.

From left to right:
Dr. Heinrich Bovensmann (IUP), Dr. Axel Lauer (DLR-IPA), Dr. Veronika Eyring (DLR-IPA), Mathias Schreier (IUP), and Klaus Franke (IUP)

The "Young Investigators Group" funding instrument was established by the Helmholtz Association in order to promote cooperation between universities and Helmholtz institutes as well as to provide young scientists and researchers with good career opportunities. If after three or four years an independent expert review panel considers the research positive, the group leader receives an unlimited employment contract with their institute. Additionally, the Young Investigators Groups provide training for PhD students and graduate students and provide young postdoc researchers with an opportunity to establish themselves in science and earn a reputation. The groups are funded with an average of 250,000 Euros per year for a maximum of five years.