REQUEST FOR A SPECIAL PROJECT 2010–2012

MEMBER STATE: Germany ……….

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Other researchers: Dr. Axel Lauer (IPRC, USA) and Dr. Mattia Righi (DLR, Germany)

Project Title:

Impact of anthropogenic emissions on tropospheric chemistry with a special focus on ship emissions

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPDESHIP**	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project. For projects started before 2009, please state 2009 as the start year.)	2009	
Would you accept support for 1 year only, if necessary?	YES ☐	NO **X**

Computer resources required for 2010-2012: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2012.)	**2010**	**2011**	**2012**
High Performance Computing Facility (units)	400,000	400,000	400,000
Data storage capacity (total archive volume) (gigabytes)	4000	4000	4000

An electronic copy of this form ***must be sent*** *via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): 28 May 2009

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

Principal Investigator: Dr. Veronika Eyring Dr. Benedikt Steil

Project Title: **Impact of anthropogenic emissions on tropospheric chemistry with a special focus on ship emissions**

Extended abstract

Emissions from international shipping contribute significantly to the total budget of anthropogenic emissions and have been recognized as a growing problem by both policymakers and scientists. Already today shipping contributes with around 2.7% to all anthropogenic CO_2 emissions, with around 15% to nitrogen oxide (NO_x) emissions and with around 8% to sulphur dioxide (SO_2) emissions (*Eyring et al.*, 2005a, see Figure 1). If no control measure were taken beyond International Maritime Organization (IMO) regulations that existed in 2005, NO_x emissions were predicted to further increase to values of today's emissions from road transport and SO_2 emissions were predicted to double until 2050, with subsequent consequences on tropospheric ozone, air quality in harbour cities and acidification (*Eyring et al.*, 2005b). The aim of the Helmholtz-University Young Investigators Group SeaKLIM and the ECMWF Special Project SPDESHIP is to quantify the impact of gaseous and particulate ship emissions on the chemical composition of the atmosphere and on climate, now and in the future. Detailed atmospheric studies on the impact of ship emissions will help policymakers to develop appropriate monitoring and reduction strategies. Clear information is also needed to allow the industry to incorporate, with greater confidence, environmental considerations into their design and development work.

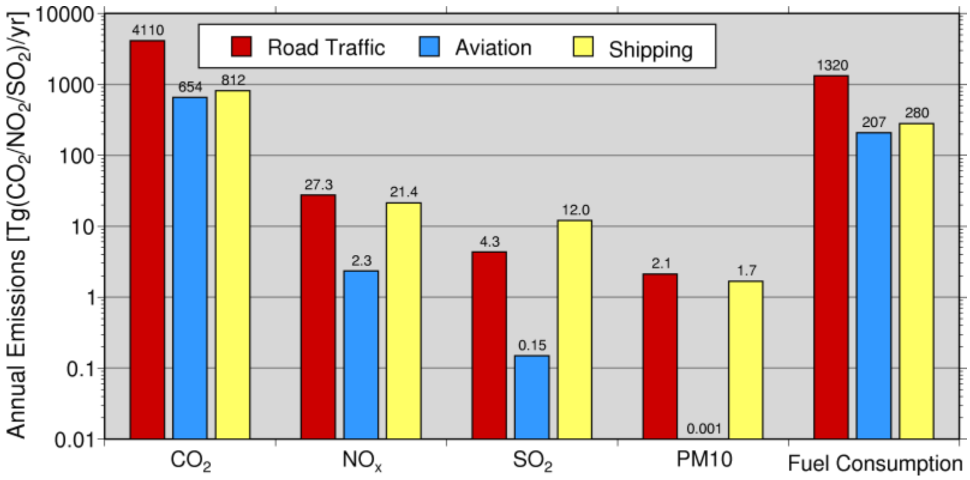

Figure 1. Transport-related annual emissions of CO_2, NO_x, SO_2 and PM_{10} and the fuel consumption in Tg (1 Tg = 1 × 10^{12} g = Mt) estimated for the year 2000. Modified from Figure 3 of *Eyring et al.* (2005a).

A variety of important results have been achieved in the first phase of SeaKLIM (2004-2007) under the Special Project 'SPDESHIP'. One of the major findings was that the potential of particle emissions or their precursors from shipping to modify the microphysical and optical properties of clouds (the so-called "indirect aerosol effect") is significant (*Lauer et al.*, 2007). The additional aerosol particles brighten the clouds above the oceans, which then are able to reflect more sunlight back into space. The model results indicate that the cooling due to altered clouds far outweighs the warming effects from greenhouse gases such as CO_2 or ozone from shipping, overall causing a negative radiative forcing today (see Figure 2). The indirect aerosol effect of ships on climate is found to be far larger than previously estimated contributing up to 39% to the total indirect effect of anthropogenic aerosols. This contribution is high because ship emissions are released in regions with frequent low marine clouds in an otherwise clean environment and the potential impact of particulate matter on the radiation budget is larger over the dark ocean surface than over polluted regions over land. The main reason for the high impact on clouds is the high average sulphur content in maritime fuels. However, uncertainties in the model results are high, so for the 2010-2012 period of SPDESHIP these studies are planned to be continued and extended to reduce uncertainties in the quantification of the indirect aerosol effect in global modelling studies and satellite data analyses.

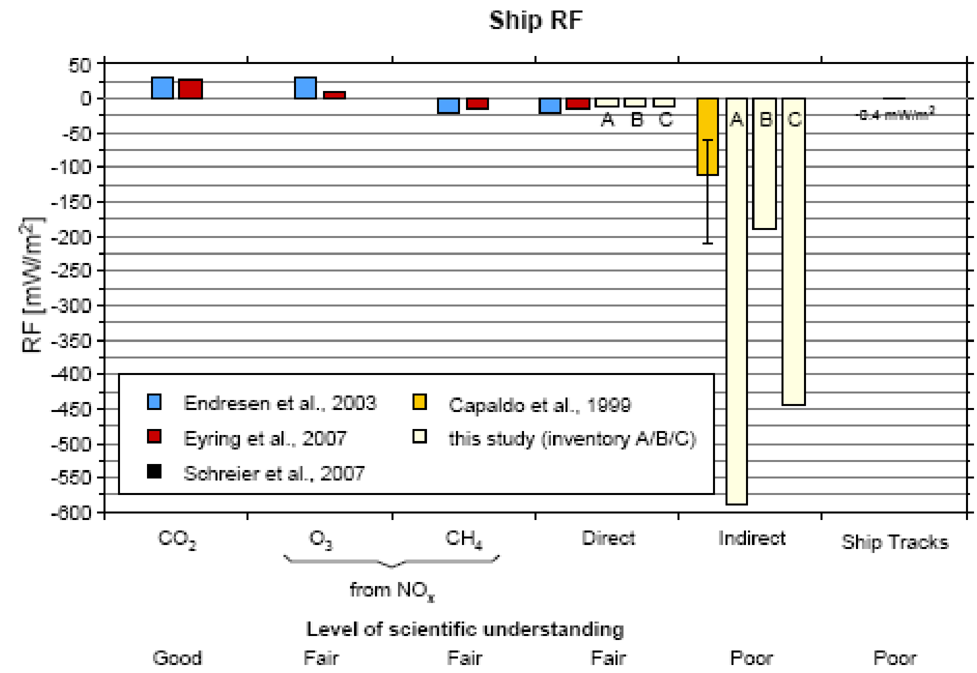

Figure 2. Annual mean radiative forcing (RF) due to emissions from international shipping in mW/m^2. Values for CO_2, O_3, CH_4, and sulfate (direct aerosol effect) are taken from different modeling studies. The indirect aerosol effect displayed with the orange bar includes the first indirect effect of sulfate aerosols and organic matter only. The error bar depicts the range spanned by additional sensitivity studies. The estimated direct and indirect aerosol effect calculated for various emission inventories (yellow bars A, B, and C) also includes changes due to black carbon, particulate organic matter, ammonium, nitrate, and H_2O from shipping in addition to sulfate and refers to the changes in all-sky shortwave radiation fluxes and net cloud forcing at the top of the atmosphere (from *Lauer et al.*, 2007).

At a local and regional-scale, ocean-going ships impact human health through the formation and transport of ground-level ozone, sulphur emissions and particulate matter (*Corbett et al.*, 2007). In harbour cities, ship emissions are in many cases a dominant source of urban pollution. Furthermore, emissions of NO_x, CO, VOCs, particles and sulphur (and their derivative species) from ships may be transported in the atmosphere over several hundreds of kilometres, and thus can contribute to air quality problems on land, even if they are emitted at sea (*Eyring et al.*, 2007). This pathway is especially relevant for deposition of sulphur and nitrogen compounds, which cause acidification / eutrophication of natural ecosystems and freshwater bodies and threaten biodiversity through excessive nitrogen input. Therefore, control of NO_x, SO_2 and particle emissions will have beneficial impacts on air quality, acidification and eutrophication. In recent work (*Corbett et al.*, 2007) we have demonstrated that PM emissions from ocean-going ships could cause approximately 60,000 premature mortalities annually from cardiopulmonary disease and lung cancer. This value is expected to increase by 40% by 2012. However, current efforts to reduce sulphur and other pollutants from shipping may modify this.

Emissions from ships in international trade are regulated by the IMO under Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). The Marine Environment Protection Committee (MEPC) of IMO has recently approved proposed amendments to the MARPOL Annex VI regulations to reduce harmful emissions from ships. The changes will focus on a progressive reduction in SO_x emissions from ships, with the maximum allowed fuel sulphur content reduced initially from the current 4.5% (45,000 ppm S) to 3.5% (35,000 ppm S) in

2012 and then progressively to 0.5% (5,000 ppm S) by 2020. In addition, the sulphur limits in Emission Control Areas (ECA) will be reduced from the current level of 1.5% (15,000 ppm S) to 1% (10,000 ppm S) in 2010 and further reduced to 0.1% (1,000 ppm S) in 2015. In our new SPDESHIP/SeaKLIM work we assessed the impact of a 2012 "*No Control*" scenario with three emissions control scenarios on aerosol burdens and the Earth's radiation budget (*Lauer et al.*, 2009) and a related paper evaluated potential health benefits from reducing ship emissions (*Winebrake et al.*, 2009).

We will further investigate the impacts of ocean-going ships in SPDESHIP under various policy scenarios. We will also study, how climate impacts of particulate and gaseous emissions from large diesel engines changes when fuels from renewable sources are used.

Justification of the computer resources requested

We are planning to perform several simulations with our global aerosol climate model ECHAM5/MESSy1-MADE (*Lauer et al.*, 2007) to study the climate and health impacts of ship emissions for various scenarios as outlined above. Since ship exhaust gases contribute to the worldwide pollution of air and sea, ships are facing an increasing number of rules and regulations as well as voluntary appeals from international, national and local legislators. Merchant ships in international traffic are subject to IMO regulations. MEPC of IMO unanimously adopted amendments to the MARPOL Annex VI regulations to reduce harmful emissions from ships, when it met for its 58th session at IMO's London headquarters in October 2008. Two sets of emission and fuel quality requirements are defined by Annex VI: (1) global requirements, and (2) more stringent requirements applicable to ships in ECAs. An Emission Control Area can be designated for SO_x and PM, or NO_x, or all three types of emissions from ships, subject to a proposal from a Party to Annex VI. Existing SO_x Emission Control Areas in Europe include the Baltic Sea (adopted: 1997 / entered into force: 2005) and the North Sea (2005/2006). Several other national and international regulations are currently discussed by the EU and the IMO.

In order to study the consequences of the various proposed regulations on climate and human health, we are planning to run our model for various policy scenarios. These studies are urgently required to give guidance on the most promising option for future regulations. The integration of science-based and policy-focused research continues to provide important insight and context to the policy dialogue. We would like to run additional sensitivity studies with our model for updated present-day conditions and different possible future policy emission scenarios for 2012 and beyond. The results will be a follow-up work on the studies published in *Corbett et al.* (2007), *Lauer et al*. (2007; 2008) and *Winebrake et al.* (2009).

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