Since 2001 Hermann Bange has been working as a chemical oceanographer in the Marine Biogeochemistry Research Division of IFM-GEOMAR in Kiel. Currently he is coordinating the German SOPRAN project. His research interests include the oceanic emissions and pathways of trace gases such as nitrous oxide, methane and dimethyl sulfide. He is interested in the distributions of short-lived intermediates of the marine nitrogen cycle such as hydroxylamine and hydrazine. Hermann participated in several cruises to the North and Baltic Seas, the Aegean Sea, the Arabian Sea and the tropical North Atlantic Ocean.

Enhancement of oceanic nitrous oxide emissions by storms

Hermann W Bange[1], H Naik[2] and SWA Naqvi[2,3] , [1]IFM-GEOMAR, Kiel, Germany, [2]National Institute of Oceanography, Goa, India, [3]Max-Planck-Institut für Marine Mikrobiologie, Bremen, Germany Contact: hbange@ifm-geomar.de

The world's oceans (including the coastal zones) account for about one-third of the global nitrous oxide (N_2O) emissions to the atmosphere (IPCC, 2007). In the tropical ocean containing pronounced oxygen minimum zones (OMZs) – such as those found in the Arabian Sea and the eastern tropical North Pacific (ETNP) – maximum accumulation of up to 80 nmol L^{-1} of dissolved N_2O generally occurs at water depths of 50-150 m (Bange, 2008) For comparison: typical N_2O concentrations in the surface mixed-layer are 5-10 nmol L^{-1} (Bange, 2008). However, N_2O from this upper-ocean maximum is not ventilated to the atmosphere because of stratification. Weather disturbances such as storms can, nevertheless, deepen the mixed layer considerably, thereby entraining N_2O from the subsurface maximum to the surface layer, where it easily escapes to the atmosphere. This simple scenario of enhanced N_2O emissions from the ocean caused by strong wind events (such as cyclones in the North Indian Ocean and hurricanes in the East Pacific Ocean) has never been demonstrated because scientific ship campaigns usually avoid storms.

In a recent paper, Naik et al. (2008) provide the first evidence for this phenomenon. These authors could obtain data on vertical distribution of N_2O in the central Arabian Sea just before and after a cyclone crossed the region in December 1998, and found a significant enhancement of N_2O concentration in the surface layer along with a decrease in temperature and an enrichment of macronutrients (nitrate and phosphate), all testifying to intense vertical mixing caused by the cyclone. On the basis of their data they calculated that the N_2O inventory in the upper 50 meters increased by about 2.3 Gg N_2O following the cyclone. Assuming that an equal amount would already have escaped to the atmosphere (because of the high wind speeds facilitating vigorous air-sea gas exchange) during and shortly after the cyclone (4-8 days) before the observations were made, we estimate that this single event, which lasted only for 7 days, contributed an extra 1% to the annual Arabian Sea N_2O emissions of about 500 Gg N_2O (Bange et al., 2001). The central Arabian Sea on an average experiences 2 cyclones every year (mean calculated from the 1945-2007 data given at http://weather.unisys.com/hurricane/n_indian/index.html). Thus, the annual contribution of cyclone-triggered N_2O should be at least 4.6 Gg yr^{-1}. The average hurricane frequency in the ETNP is much higher (14 per year, calculated from the 1949-2007 data given at http://weather.unisys.com/hurricane/e_pacific/index.html). In the ETNP comparable N_2O accumulation occurs in the shallow subsurface layer. Assuming a similar efflux of N_2O caused by each cyclone or hurricane, we estimate that a total of about 80 Gg N_2O is released from the Arabian Sea and the ETNP annually as a result of tropical storms. This amounts to about 1.3% of the global open ocean N_2O emissions of 6000 Gg yr_{-1} (IPCC, 2007). This is a very conservative estimate, however, because the effect of storm events on N_2O emissions from adjacent ocean areas such as the coastal upwelling in the Arabian Sea has not been taken into consideration, and Cyclone 08A-98, the data for which have been used here, was of a very moderate intensity (maximum wind speed ~120 km h_{-1} as compared to, for example, 270 km h_{-1} for the super-cyclone Gonu that hit exactly the same area during 27 May - 5 June 2007). Moreover, Patra et al. (2004) used a model to simulate N_2O emissions from the Arabian Sea triggered by a cyclone (03A-98) in June 1998: They estimated that as much as 40 Gg N_2O was released to the atmosphere during this single 7-day event (that was intermediate of 08A-98 and Gonu in intensity – maximum wind 185 km h_{-1}). This corresponds to about 8% of the annual N_2O emissions from the Arabian Sea alone, and about 0.7 % of the annual global open ocean emissions. The global contribution of cyclone-triggered N_2O emissions from the North Indian Ocean should be even larger when including regions such as the Bay of Bengal (where there is also a large build-up of N_2O beneath the strongly stratified surface layer (Naqvi et al., 1994) and cyclones are far more frequent and intense than in the Arabian Sea). Therefore, we conclude that N_2O emissions triggered by strong wind events – cyclones in the North Indian Ocean and hurricanes in the ETNP – contribute significantly to both the regional and global oceanic N_2O fluxes. This contribution must be included in future model scenarios of oceanic N_2O emissions.

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