What actually influences air pollution over the Indian Ocean?

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Scientists from the Max Planck Institute for Chemistry detect substantial pollution of the atmosphere during periods between summer or winter monsoons

Using a combination of satellite observations and computer modelling, researchers of the Max Planck Institute for Chemistry have studied **nitrogen oxides pollution over the Indian Ocean**. They showed that the central Indian Ocean in the southern hemisphere is not always as pristine as found earlier during the winter monsoon period, but is polluted during the monsoon transition periods by pollution plumes from Africa and Southeast Asia. Generally, the most polluted region is the Bay of Bengal, which is influenced by Indian and south-east Asian outflow during most of the year and China during part of the year (Geophysical Research Letters, 30 April 2004 and 11 August 2004).

Current knowledge of atmospheric chemistry over the Indian Ocean is still limited due to the scarcity of long-term observations covering all seasons. The region is dynamically and chemically active because of the strong tropical sunlight, high humidity and the increasing anthropogenic emissions. The Indian Ocean Experiment (INDOEX) was an international field campaign during the winter monsoon period in 1999 to study how air pollution affects climate processes over the tropical Indian Ocean. Satellite pictures showed a thick haze - one of the now well-known "Atmospheric Brown Clouds" - which spreads thousands of kilometers south of India during this period. The results contrasted the highly polluted northern hemisphere with the more pristine air of the

southern hemisphere (Fig. 1a).

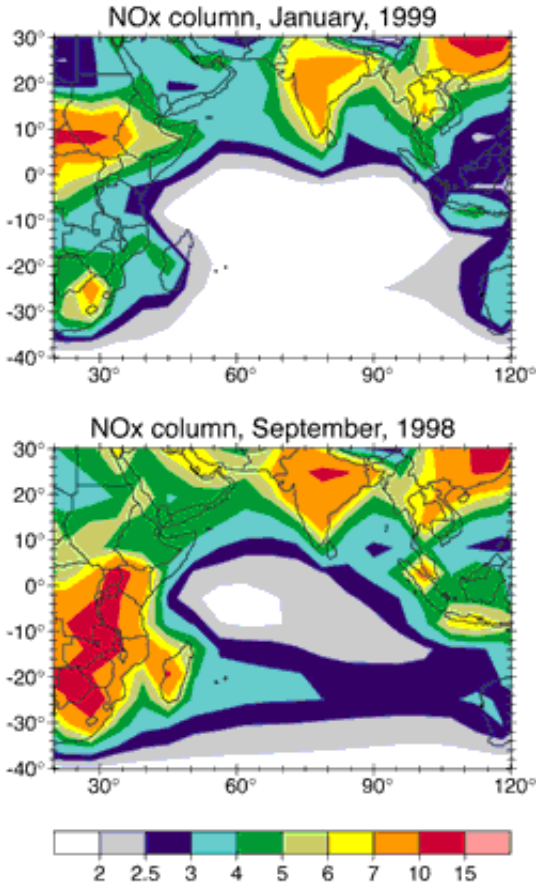

Fig. 1: Calculated tropospheric nitrogen oxide column (in 1014 molecules / cm2) from the computer model for (a) January 1999, during INDOEX and (b) September 1998, during the monsoon transition period. Image: Max Planck Institute for Chemistry

Research on southern Asian pollution at the Max Planck Institute for Chemistry since then has focused on other periods of the year. The field campaign MINOS (Mediterranean Intensive Oxidants Study), led by the institute during the summer of 2001, showed that the same monsoon storms which produce the torrential rains also lift insoluble gases like

carbon monoxide into the upper troposphere, where they are then transported towards the Mediterranean. The junior research group of the Department of Atmospheric Chemistry has developed the technique of "chemical weather forecasting", that is, predicting the day-to-day changes in the concentrations of gases like ozone and carbon monoxide. These forecasts indicated on which days the "plume" of pollution would be within reach of a research aircraft stationed on Crete. On three occasions, these forecasts guided the aircraft into air which was far more polluted than normal for such altitudes over the Mediterranean Sea, and which clearly carried the signature of southern Asian emissions. This teamwork demonstrated the existence of a previously undocumented pathway for intercontinental pollution transport.

Researchers of the junior research group now report new results on this topic in two current papers in the journal Geophysical Research Letters. Using a combination of satellite data from 1996-2000 and global model simulations, they focused on nitrogen oxide pollution during the periods between the summer and winter monsoons - the monsoon transition periods. Nitrogen oxide (NOx = NO + NO2) is an important component of tropospheric chemistry, which catalyzes ozone production and influences hydroxyl radicals, the "detergent" of the atmosphere. The main maritime NOx sources are long-range transport of continental emissions, lightning and ships. The new data show pronounced, semi-regular plumes of nitrogen oxide pollution extending all the way across the central Indian Ocean, mainly in the middle troposphere, originating from Africa in the west and from southeast Asia (Indonesia and other countries) in the east (Fig. 1b). "Our results suggest that the central Indian Ocean is not always as pristine as found during the winter monsoon", says Mark Lawrence, the leader of the junior research group. "It is especially interesting that during this period, pollution levels are even greater south of 10oS than in the northern Indian Ocean, the opposite of the situation encountered during INDOEX".

The research of the group has also taken a more general view of how emissions from the surrounding continental regions influence NOx pollution over the Indian Ocean. This work shows that feedbacks in atmospheric chemistry can result in downwind regions being highly insensitive to upwind emissions: that is, a 50% reduction in global emissions of NOx - from all sources - might only lead to a 15% reduction in NOx levels over parts of the Indian Ocean - and vice versa for increases in NOx emissions. The results show that the influence of Indian emissions on the central Indian Ocean is limited to the winter monsoon period only, and is nevertheless quite weak - a 10% change in Indian NOx emissions only leads to a 3% change in northern Indian Ocean NOx levels. This is in contrast to the strong effect of the Indian outflow on aerosols and long-lived gases like carbon monoxide and is due to the short lifetime of NOx (about a day on average) and the feedback mentioned above. Generally, the strongest influence on central Indian Ocean NOx chemistry throughout the year is from south-east Asia. African emissions are important especially at higher altitudes. The most polluted region is the Bay of Bengal, which is more strongly influenced by continental emissions than the Arabian Sea (which was the focus of INDOEX), with the pollution originating mainly from Indian and south-east Asian outflow during most of the year and China during part of the year. These results strongly encourage future field campaigns, especially during the monsoon transition periods, to further explore the extent of air pollution in this region.

Original work:

T. Kunhikrishnan, Mark G. Lawrence, Rolf von Kuhlmann, A. Richter, A. Ladstätter-Weißenmayer, and J. P. Burrows
Semiannual NO2 plumes during the monsoon transition periods over the central Indian Ocean
Geophysical Research Letters, 31, L08110, doi 10.1029/2003GL019269, 2004

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Sensitivity of NOx over the Indian Ocean to emissions from the surrounding continents and nonlinearities in atmospheric chemistry responses
Geophysical Research Letters, 31, doi 10.1029/2004GL020210, 2004

Source: Max Planck Society