bm0531: Zyklieren organischer Stoffe im Ozean und Erdsystem

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Introduction

• **Project**: since July 2009, 30-60 kCPUh per year, externally funded (EU project FP7 #226534 ArcRisk)

• Application of a comprehensive global multicompartment chemistry-transport model (MPI-MCTM) to study the transport pathways of persistent organic pollutants (POPs) into the Arctic.

•**The model**: MPI-MCTM [1-3] = coupled atmosphere-ocean general circulation model (ECHAM5-MPIOM) + 2D vegetation, soil, ice, snow

•Substances studied here: *p,p'*-dichloro-phenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs, congeners 28, 101, 153, and 180).

Methods –

1. Multicompartment model MPI-MCTM

Atmosphere : 3D global circulation model ECHAM5 plus aerosol model HAM [3]

Ocean/sea ice : 3D global ocean circulation model MPIOM [4] including sea ice and bio-geochemistry model HAMOCC [5]

Soil and vegetation: 2D single layers partitioning in soil, volatilisation, degradation [1])

PFOA degradation rates in soil, vegetation, and ocean are set to zero.

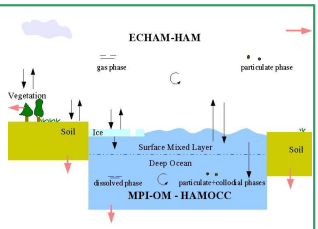

Fig. 1: Multicompartmental model world, schematic overview. Red arrows denote sinks of a compartment, black arrows exchange processes.

Methods - 3. Model experiment

The period 1950-2050 was simulated under the A1B climate scenario of the IPCC (4th assessment report) with spatial resolutions of 3.75° (T31) in the atmosphere and ~3° (GR30) in the ocean. 10 yr time slices were run with higher resolution (T63, GR15)

DDT was simulated according to application in agriculture for 1950-1990, and usage in health programs for 1991-2020. For 2021-2050 primary DDT sources were set to zero .

Methods - 2. Emissions

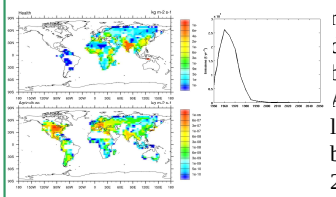

Fig. 2: DDT emission spatial (T31, accumulated) and temporal distributions.

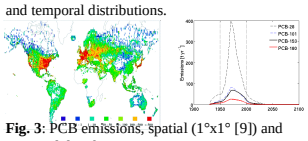

Fig. 3: PCB emissions, spatial (1°x1° [9]) and temporal distributions.

DDT: Annual usage in agriculture reported to FAO, gridded using crop distribution as the surrogate distribution [1] (Fig. 2, lower, 1980).

Annual usage in health programmes linearly interpolated for 1990-2020 based on estimates for 2000 and 2010 [7], gridded using population density [8] as surrogate (Fig. 2, upper, 2000).

Identical primary emissions were input to study the PCBs, namely those of PCB153. These were taken from Breivik et al. [9] (Fig. 3).

Results – 1. Exposure of the Arctic environment

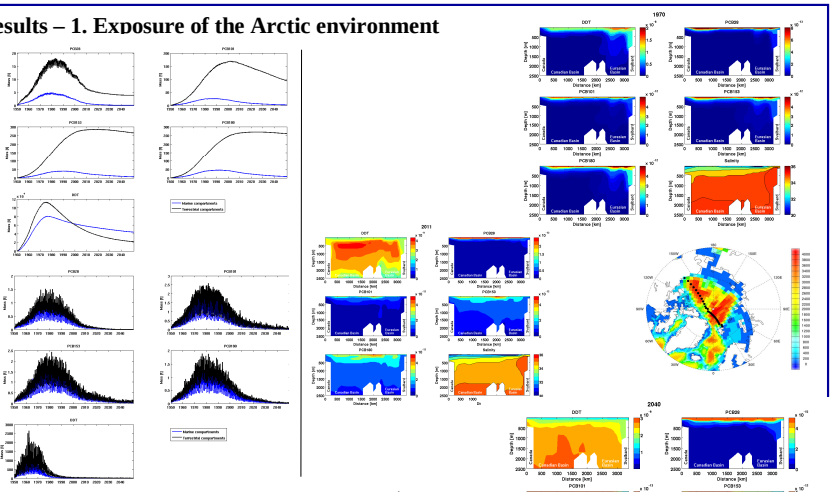

Fig. 4: Exposure of the terrestrial and marine Arctic environment (left) and deposition from the atmosphere to surface compartments (right).

The terrestrial Arctic (> 65 °N) environment is much stronger polluted by PCBs than the marine environment in all years, 1950-2050 (Fig. 4). In contrast the oceanic burden exceeds the terrestrial burden in the case of DDT from 1990 on. For PCB28, 101, and DDT the exposure follows the deposition pattern with a delay of years to decades. PCB153 and 180 accumulate strongly in the terrestrial environment.

Surface ocean concentrations in 2000 compared to deposition patterns reveal oceanic transport, as deposition maxima

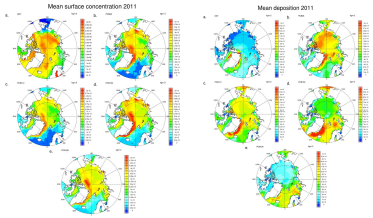

Fig. 5: Mean depositions (left) and surface ocean concentrations (right) in 2011.

Fig. 6: Pollutant concentrations in 1970,2011, and 2049. Vertical transsects crossing the Cental Arctic ocan..

do not coincide with surface concentration maxima (Fig. 5).

The vertical stratification in the Arctic ocean is different among the PCBs and DDT. PCB28 and 101 show maxima at the surface throughout the entire 100 years. In contrast, PCB 153, 180 and DDT develop maxima at 500-3000m depth of the Canadian Basin indicating penetration of Atlantic water.

Highest contamination potentials with regard to emissions are found for the heavier PCBs (Tab.1).

	DDT180	PCB28	PCB101	PCB153	PCB
eACP[10]	4.32	3.07	11.35	14.68	13.02
eACP[50]	2.28	0.59	8.32	13.38	12.71

Tab. 1: Arctic contamination potential after 10 years (eACP[10]) and 50 years (eACP[50]).

Results – 2. Fluxes to the Arctic with ocean currents

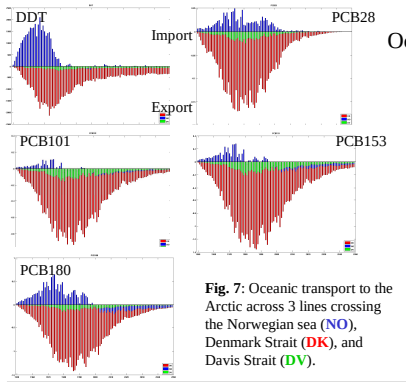

Fig. 7: Oceanic transport to the Arctic across 3 lines crossing the Norwegian sea (**NO**), Denmark Strait (**DK**), and Davis Strait (**DV**).

Ocean currents are net exporting resulting from import via the Norwegian Sea and large exports via the Denmark Strait (East Greenland Current) and Davis Strait (Canadian Archipelago). Outflow via the Denmark strait is highest due to a local deposition maximum (Fig. 7).

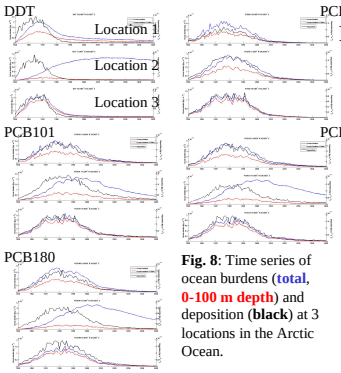

Fig. 8: Time series of ocean burdens (**total**, **0-100 m depth**) and deposition (**black**) at 3 locations in the Arctic Ocean.

In shelf regions of the Arctic ocean (locations 1,3) most of the pollutants are stored in the uppermost 100 m of the water column and the burden closely follows the deposition pattern. Deeper ocean regions such as the Canadian Basin (loc. 2) accumulate the heavier PCBs (congeners 101, 153, 180) and DDT, while PCB28 shows a similar distribution as in the shelf regions.

Conclusions

- The temporal evolution of the pollutant burdens is very different according to region (sea) and depth of the Arctic Ocean, as well as substance. While the shallow shelf regions closely follow the emissions' and deposition pattern, the Beaufort Sea and other parts accumulate the contaminants.
- Atmospheric transports contribute more to accumulation in the Arctic, and are substance-selective, too [10-11]
- Temporal trends of concentrations in the deep sea can be bimodal despite emissions peaking only once in history [12]

Acknowledgements

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