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Accelerated Nitrogen Cycle in Global River Basins in the Anthropocene

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Background

Rivers transport large amounts of nitrogen (N) from land to sea. River N loading has rapidly increased with the accelerated global biogeochemical N cycle since pre-industrial times, due to the ever-increasing population, food production, fertilizer use, intensification and expansion of agriculture, and wastewater discharge[1].

Meanwhile, human interference in river hydrology, such as construction of dams and reservoirs[2], has increased the water travel time, and thus sediment trapping and biogeochemical retention[3].

However, the N cycle and underlying in-stream mechanisms in global river basins remain unclear, particularly their spatial heterogeneity and temporal changes with the conspiring changes in human activities, climate and other environmental conditions.

Aim

To improve the quantitative understanding of the long-term changes in global river N cycle (sources of N, loading, in-stream retention, and export to coastal waters of different N forms: nitrate, NO_x^-; ammonium, NH_4^+; organic nitrogen, ON) for the period since 1900.

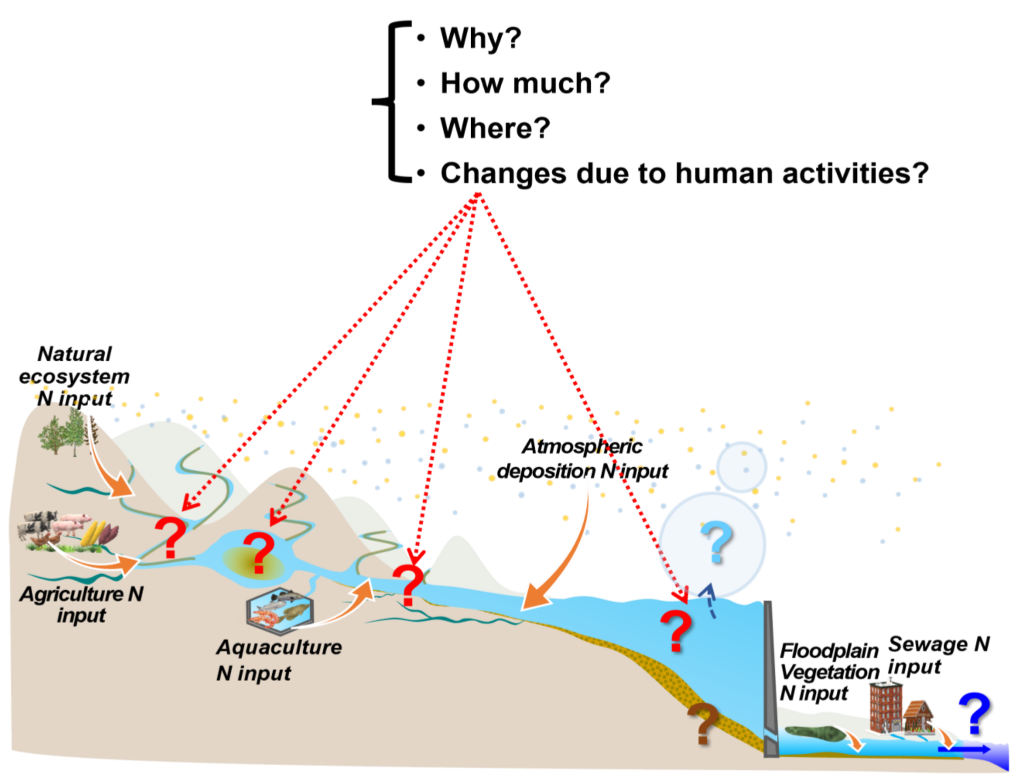

Figure 1. Key research questions.

Modelling approach

We use the 0.5 by 0.5 degree-resolution IMAGE-DGNM (Integrated Model to Assess the Global Environment - Dynamic Global Nutrient Model) with the process-based DISC (Dynamic In-Stream Chemistry) module[4,5] to simulate the long-term changes in the annual N loading, in-stream biogeochemical transformations, and river N export to coastal waters from global river basins during the period 1900-2010.

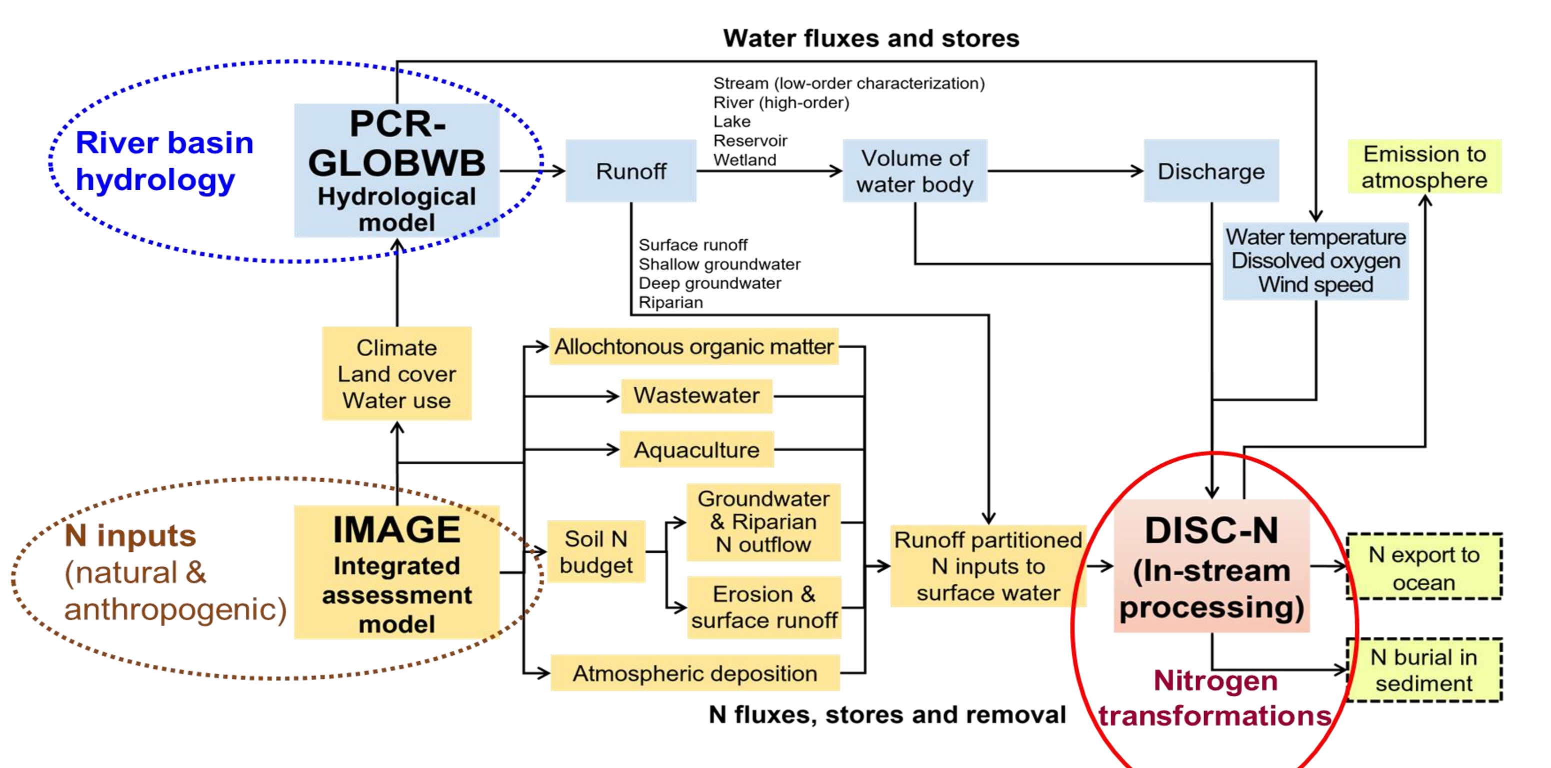

Figure 2. Model scheme of IMAGE-DGNM.

Results

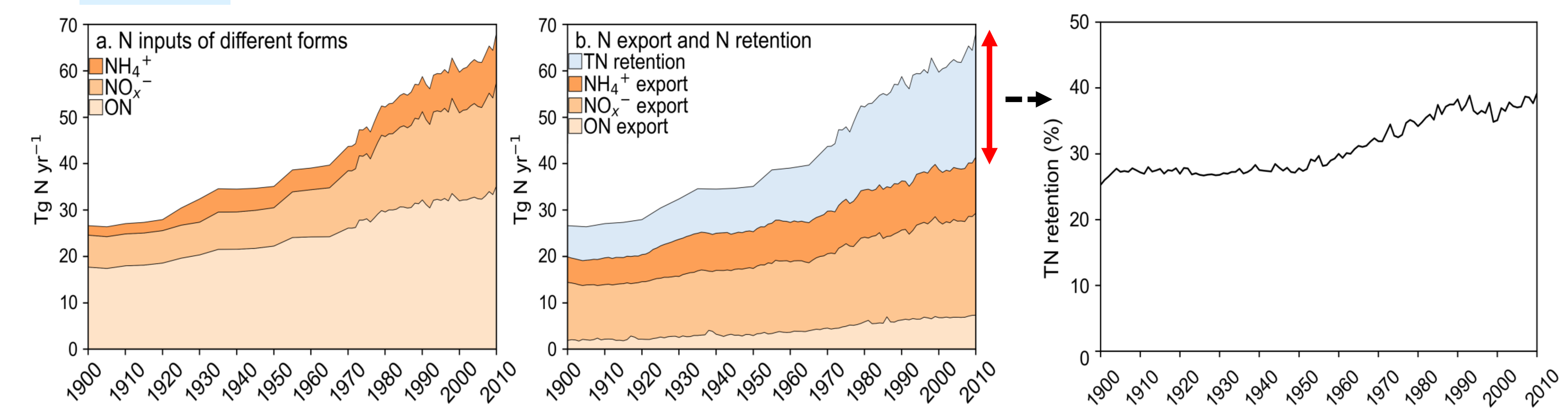

Figure 3. Temporal changes in overall N budget (inputs, export, and retention) in global river basins during 1900-2010.

- During the period 1900-2010, TN inputs, retention and export from global river basins have increased.
- Due to enhanced retention, TN river export increased less rapidly than TN inputs.
- ON dominated TN inputs to river basins, followed by NO_x^- and NH_4^+.
- NO_x^- dominated river TN export to oceans, followed by NH_4^+ and ON.
- Inputs and export of NH_4^+, NO_x^-, and ON increased at different rates.

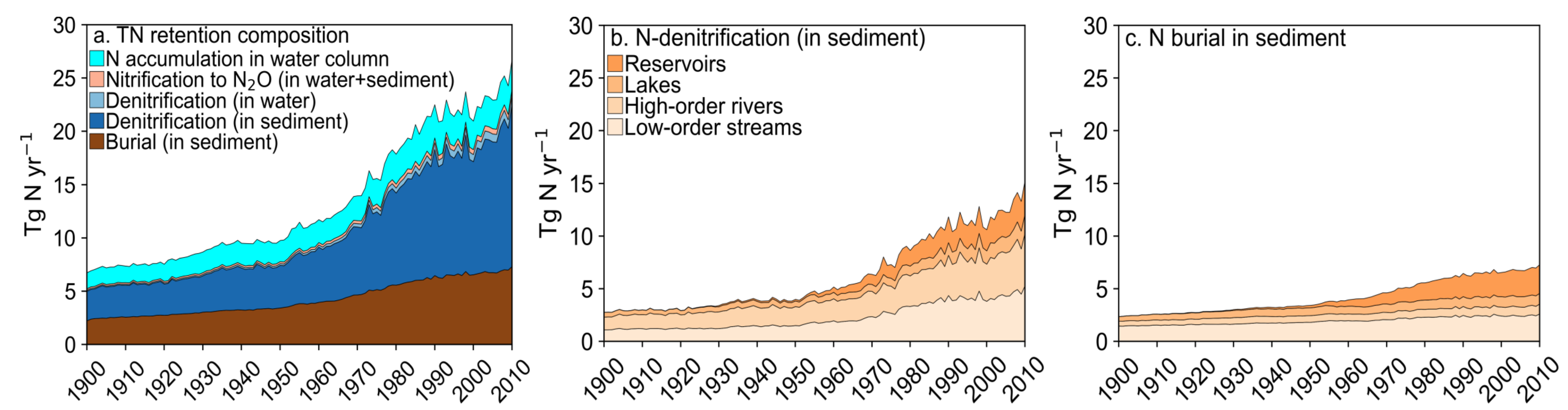

Figure 4. (a) Contributions of different in-stream processes to TN retention in global river basins during 1900-2010 and (b-c) global N flows in different inland waterbodies for the dominant contributing processes: (b) denitrification in sediment and (c) burial in sediment.

- The increase in global in-stream TN retention is mainly due to increasing **denitrification** and **burial** in sediment.
- **Low-order streams** (with both large denitrification and large burial in sediment) are active sites for TN retention.
- **Reservoirs** play an increasingly important role in global in-stream TN retention.

- Between 1900 and 2010, the concentrations of different N forms increased in most inland waters and the regions with high N concentrations substantially increased.
- The most rapid increases in TN concentrations were in eastern and southern Asia, Europe, southern North America, southeastern Oceania, and eastern Africa.
- In 2010, the highest ON and NO_x^- concentrations were in extensive areas with rapid increases in N inputs from agricultural intensification. The highest NH_4^+ concentrations were scattered near big cities and coastal areas with rapid increases in N inputs from point sources.
- N concentrations do not reflect N loading everywhere due to the different importance of in-stream N processes locally. For example:
  - Areas with active in-stream transformation processes do not show high N concentrations despite high N inputs, like natural systems in the tropics and reservoir areas.
  - N concentrations in (semi-)arid areas may be high due to limited water discharge and limited in-stream processes.
  - The concentrations of one N form seem largely influenced by inputs of other N forms, e.g., NH_4^+ produced from mineralization of ON, and NO_x^- produced from oxidation of NH_4^+ (nitrification).

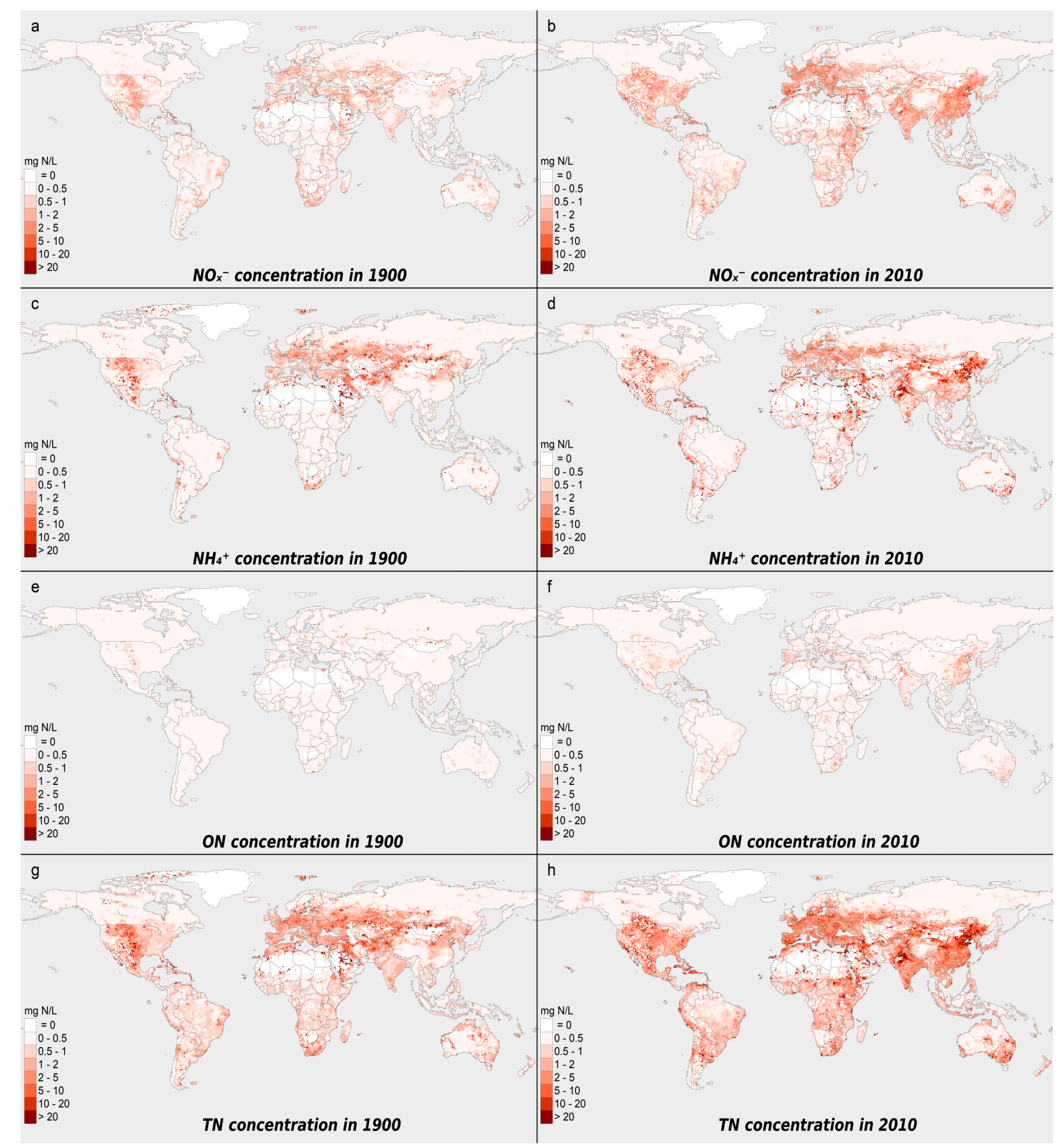

Figure 5. Spatial distributions of the simulated concentrations of multiple N forms in global river basins in 1900 (left) and 2010 (right): (a, b) NO_x^-, (c, d) NH_4^+, (e, f) ON, and (g, h) TN.

Literature

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