Numerical modeling of nutrient transport in the Ise Bay basin

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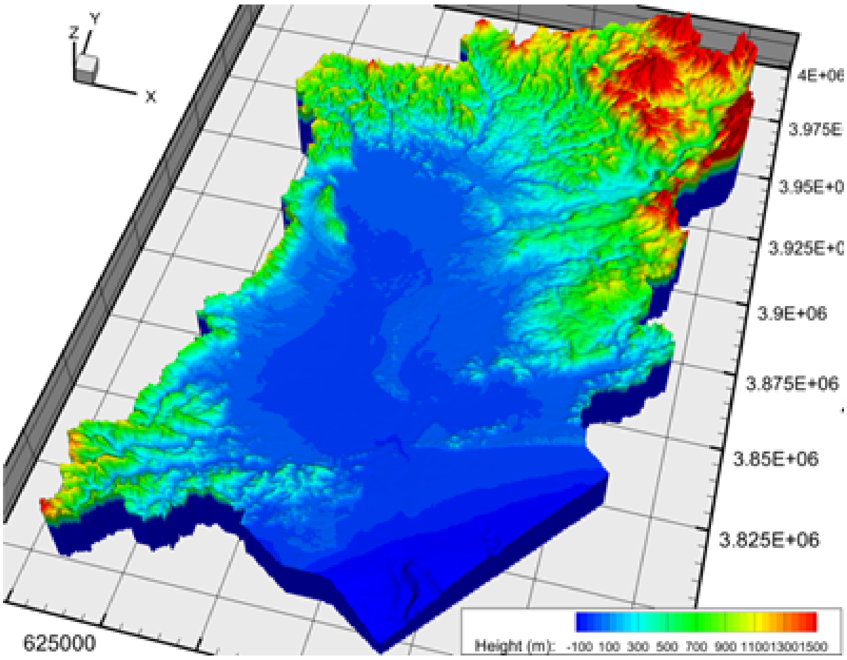
Eutrophication is the main cause of the occurrence of red tides in semi-enclosed coastal areas. Studies performing numerical simulations have reproduced the complicated phenomena that caused problems in bays including mid-layer oxygen depletion and the occurrence of discolored tides. The nutrient inflow conditions used in such simulations reflect measured values as closely as possible, however, they are often not temporally and spatially considered in detail. There are limitations on the available measurement data, making accurate simulations difficult to realize. Furthermore, nutrients are transported not only from the surface water but also from the groundwater, and the actual temporal and spatial transport mechanisms are not always understood. The inflow of nutrients in groundwater largely depends on factors such as the geological characteristics of the coastal area, groundwater utilization, and nutrient load in the basin. Models of nutrient transport at watershed scales can therefore be useful tools for elucidating complex mass-transfer phenomena in coastal areas. In this study, we developed a nutrient transport model for marine numerical simulations to track nutrient behavior in Ise Bay by focusing on the actual long-term circumstances of nutrient load and groundwater use in the basin, thereby enabling more accurate reproduction of nutrient load conditions in terrestrial areas.

To calculate the nutrient flow from land to sea in the Ise Bay basin, we constructed a basin model that reflects the hydrological processes and the water usage occurring on the land surfaces, including basin-scale hydrogeological structures. In particular, we incorporated groundwater pumping and nutrient loading processes into models to simulate changes in groundwater levels and nitrogen concentrations from the 1970s until present. During that time, the groundwater level showed a large temporary decrease, from which it gradually recovered, and the initially extremely low nitrogen concentration tended to gradually increase. The constructed model was validated via matching of multiple historical data, including measured river flow, groundwater levels, and water quality factors such as ammonia nitrogen and nitrate nitrogen. The simulation was conducted using the geofluid simulator of GETFLOWS.

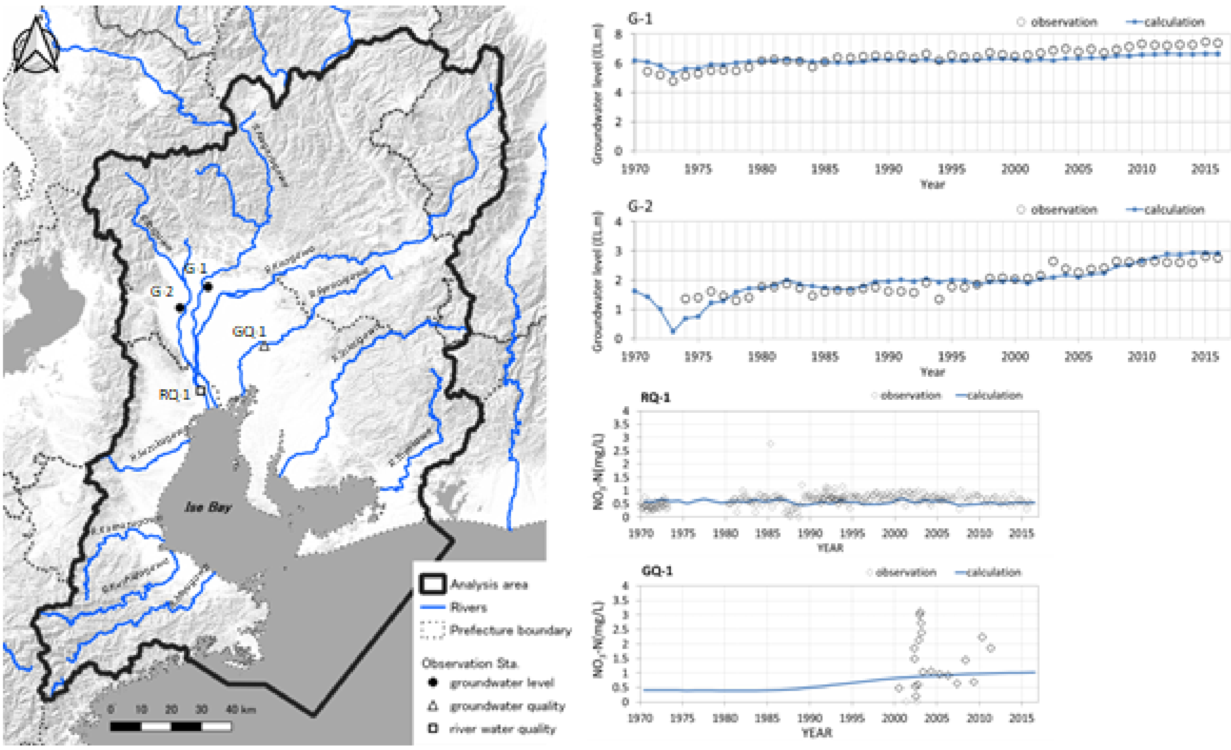
The simulation of groundwater levels was successfully reproduced the trend of gradual groundwater level recovery from the 1970s to the 2010s. Furthermore, the simulated ammonium and nitrate nitrogen concentrations in rivers were well-reproduced when compared with measured data. Consequently, we considered that the estimated nutrient loads in the basin using statistical data are temporally and spatially consistent with the actual situation. Regarding observed groundwater concentrations, while responses to seasonal changes have not yet been verified, reproductions of change over time were generally consistent.

The results show that the fluctuation patterns of nitrate nitrogen inflowing from land to sea are highly affected by annual changes in precipitation and are particularly dependent on surface-ground water components. However, there are indications that while groundwater components show small year-round fluctuations, they comprise up to 10% of inflowing surface water. Therefore, we suggest that the nutrient influx should be considered not only from surface water but also from groundwater when evaluating nutrient behavior in semi-enclosed coastal areas. This will lead to a better understanding of marine nutrient transport and more accurate predictions of the effects of countermeasures.

Keywords: Ise Bay, Watershed water cycle, Basin-scale modeling, Nutrient transport, GETFLOWS



Constructed 3D model of Ise Bay basin



The reproduction state of simulation model with observation data

