Global land-ocean linkage: direct inputs of water and associated nutrients to coastal zones via submarine groundwater discharge (SGD)

H.H. Dürr, L.P.H. van Beek, C.P. Slomp, H. Middelkoop, M. Bierkens and S. Loos
Faculty of Geosciences, Utrecht University, The Netherlands; e-mail: h.durr@geo.uu.nl

Introduction
Under many climate and aquifer conditions, continental groundwater contributes freshwater and associated nutrients as baseflow to river flow, but also as submarine groundwater discharge (SGD) directly to the coastal zone (Church 1996). At the global scale, near-shore coastal water bodies are generally said to be nitrogen (N)-limited (Howarth and Marino 2006). Inputs from river water are mainly at or slightly below Redfield ratio (N/P~16) (Seitzinger et al. 2005). As phosphorus (P) is mostly efficiently retained in agricultural areas, box modelling has shown that nutrient inputs via SGD have the potential to significantly affect coastal zone nutrient cycling at the global scale (Slomp and van Cappellen 2004) that can lead to increased eutrophication or hypoxia. Most studies focus on the nutrient flux to the coastal zone by SGD have focused on local to regional scales (mainly in the U.S. and Europe), concentrating on areas of high total SGD including recycled fluxes from the saltwater / freshwater mixing zone. While at local scales, the effects of this recycling in the coastal zone require further study. It is important to understand short-term changes in nutrient availability, at the global scale, quantification of the yet poorly constrained net fluxes of freshwater and nutrients discharged via this transport path to the oceans is crucial.

Main aim: we present the first steps towards spatially-explicit estimates of nutrient inputs to the coastal zone via freshwater SGD:

(1) using baseflow estimates from a global hydrological model, combined with (2) assessments of nutrient concentrations in coastal groundwater bodies.

Proximal coastal ocean

• Various direct pathways of coastal groundwater and associated nutrients to the coastal ocean;
• Next steps should now include

Local groundwater discharge

• LOICZ coastal zone highlighted
• Some SGD sites for nutrients shown

Caution:
• Very local phenomena not detected
• Total GW flow in coastal cells, not SGD
• Coastal groundwater discharge not yet considered
• Effect of residence time in GW on nutrient concentrations not yet considered

Mean annual total discharge: model vs. observations

Model results

Residence time of groundwater

Long residence times:
• Low temperature / high rainfall / high drainage density

• High temperature / low rainfall / low drainage density

Some examples of data sets used or derived for the global baseflow equation

Local groundwater discharge

• Drainage distance / aquifer width

Next step: full calibration
• 290 rivers usable for base flow calibration
• Calibration on low flows that are exceeded 92% of the time (8% lowest flows)

Nutrient SGD: controls

Next steps, including GW nutrient data

1) Coastal ribbon definition for SGD:

- distance to water divide at coast

Water extraction:
• country based from IGARAC / TNO
• linked to water use / population data
• water diversion by canals not yet considered (but no global data available)

2) Groundwater abstraction

Problem:
• what is a stream?
• every catchment that has a cumulated upstream area > xx km²
• testing possible

3) Groundwater quality data

• IGARAC / TNO - country-wide data
• USGS, EEA: large DB available for other places: link to_income (GDP) and data from selected studies on some coastal GW sites

Ex: USGS

Groundwater NO₃ data

• Ex: USGS

Groundwater quality data

Combine with land-use and population data

Rural population & Land use

→ Potential hotspots with potentially elevated N input

• Nutrients

• Agricultural land use and population

• Urban population

• Other

– LOICZ coastal zone highlighted
– Some SGD sites for nutrients shown

References

– Groundwater abstraction and saltwater intrusion sites

Holdridge climate data

• J.Hydrol., 295, 54-68.
• J.Hydrol., 295, 54-68.
• J.Hydrol., 295, 54-68.
• J.Hydrol., 295, 54-68.
• J.Hydrol., 295, 54-68.
• J.Hydrol., 295, 54-68.
• J.Hydrol., 295, 54-68.