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Deltares

WP2.1 - Integrated and scalable high-resolution surface-groundwater modelling considering variable density flow

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Research objective

Develop seamlessly scalable (between regional and local scale) Integrated Groundwater-Surface water Models (IGSMs) that consider groundwater flow and salinity transport. We will use these models for:

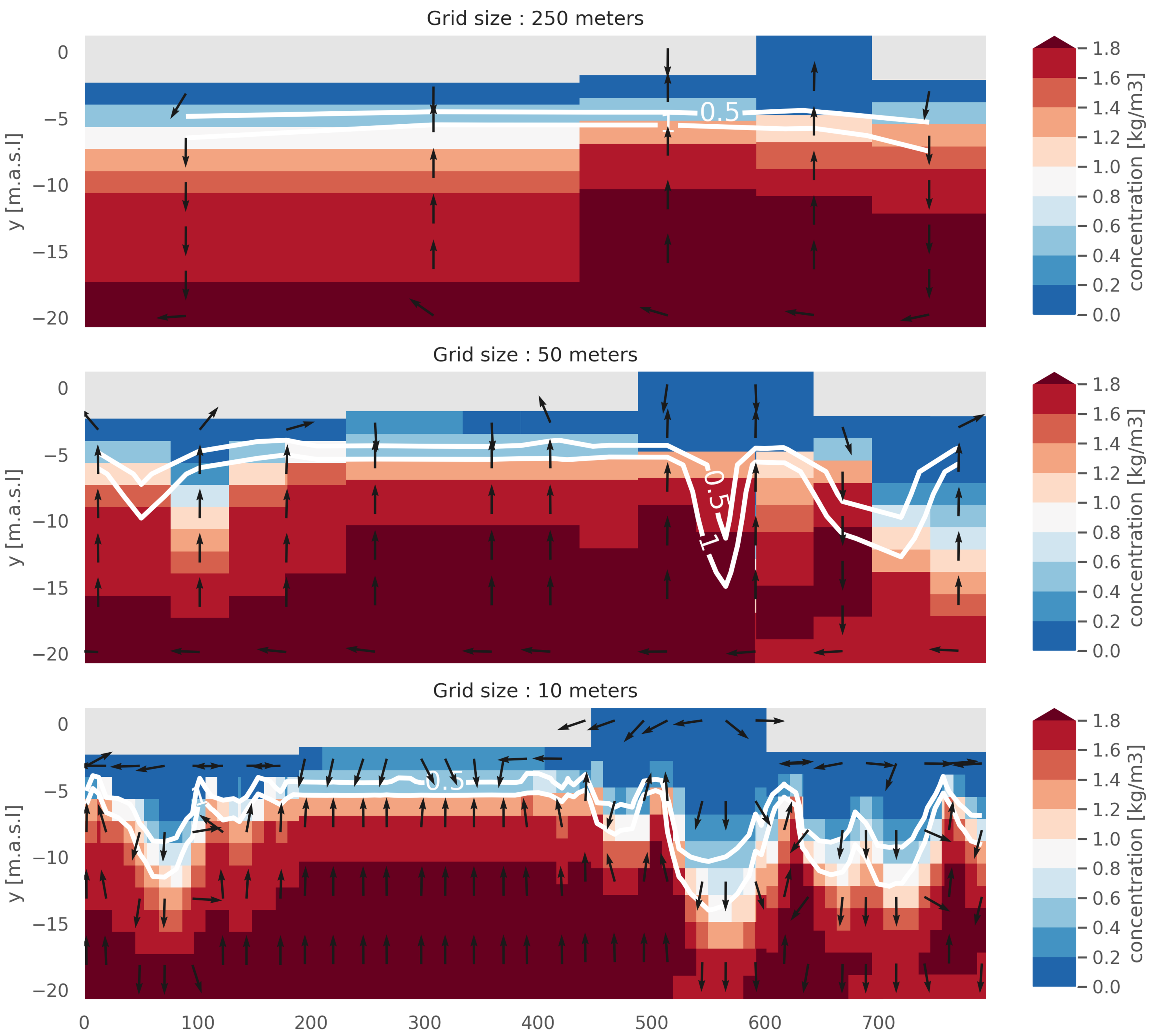
- Calculating the current and future groundwater head and groundwater salinity distribution under different climate (e.g., sea level rise) and anthropogenic pathways.
- Test water storage and distribution measures aimed at achieving local to regional water self-sufficiency.

As a first step, we are working on the effects of grid resolution on modelled groundwater salinity and salt fluxes to surface water. To do this we explore **(a)** how the groundwater salinity distribution is affected by varying grid sizes and **(b)** how salt loads and fluxes to the surface vary with grid size. All this while constrained by runtimes and computing power **(c)**.

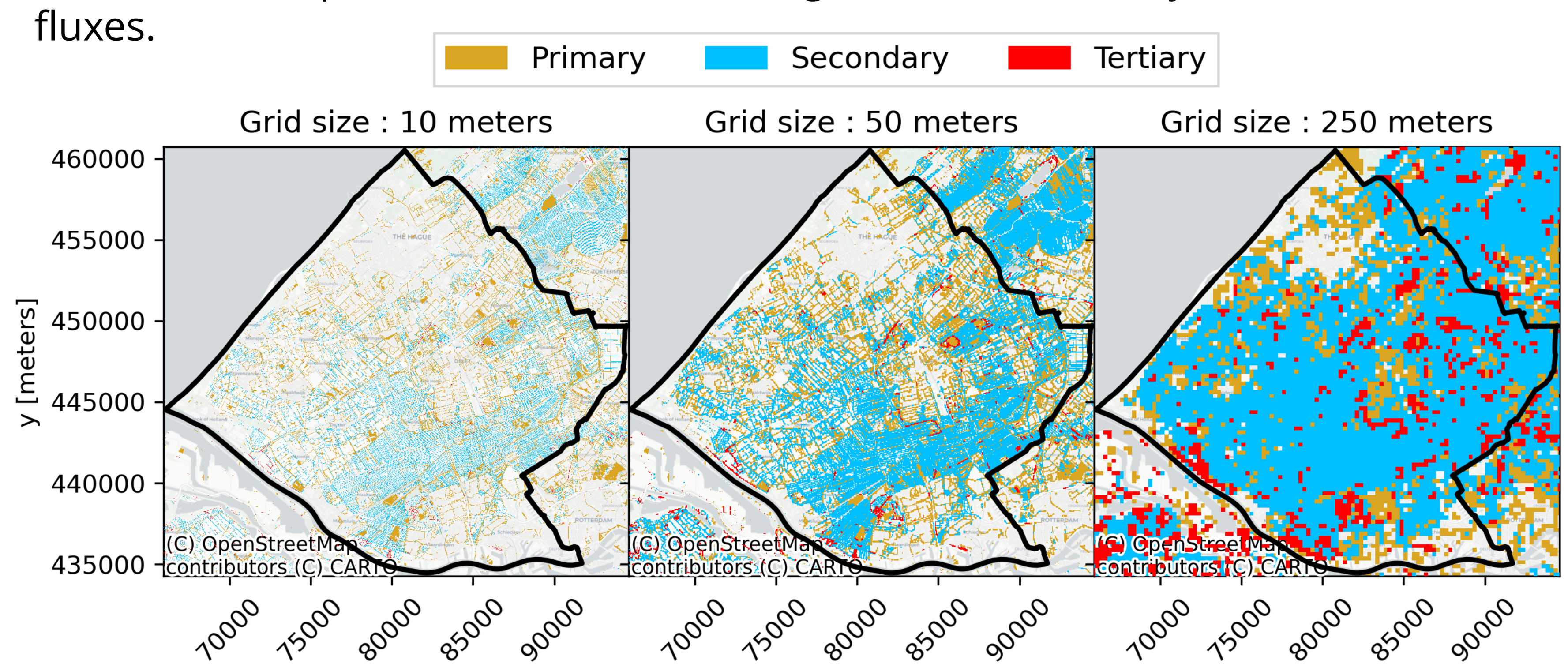
Simplified groundwater models (no pumping, no temporal variations) of the Water Board of Delfland were run at varying grid sizes in the Dutch supercomputer Snellius and analyzed. Apart from varying the grid size, we also recalculate the parameter that controls the exchange between surface water and groundwater (conductance). We use two methods for this, the standard MODFLOW way and a more complex formula from De Lange(1999) that tries to account for overlap of features within a cell.

Results

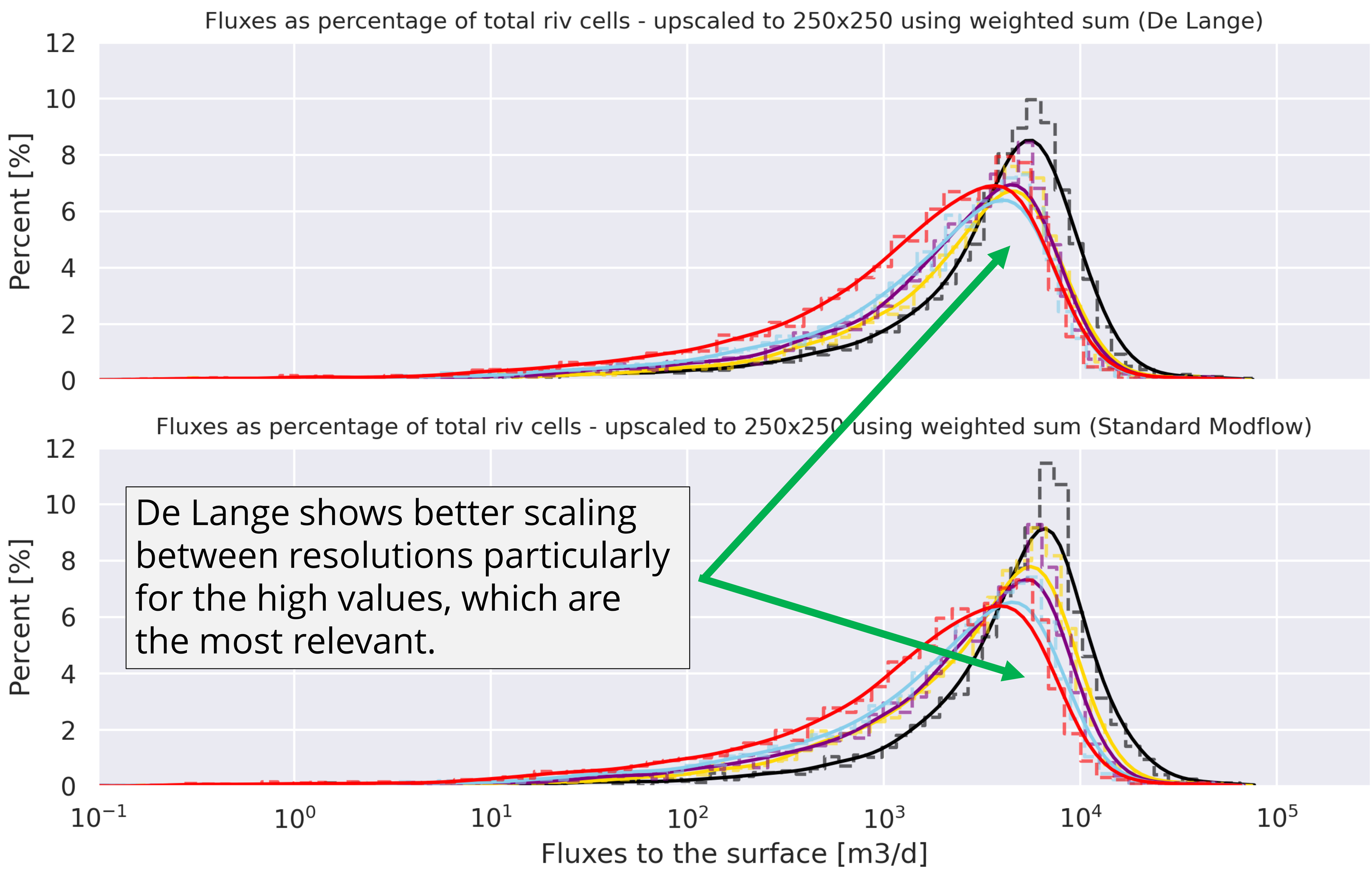
(a) Cross sections of the upper sections of the model show us processes that would otherwise would not be distinguishable like upconing and downconing. The figure below shows the groundwater salinity distribution for a random cross section at varying grid resolutions. The white lines show iso-chlorine concentrations at 0.5 and 1 kg/m3, the black arrows show the flow directions. The “interface” lines at coarse resolutions are practically horizontal, while at fine resolutions there are much greater spatial variations.



There is clear overlaps in the surface water network (rivers, canals, ditches), when we discretize it at varying grid resolutions. This is clear from seeing that at coarse resolutions there is barely any area not covered by the surface water network. With this research we are trying to understand the effects this may have over the spatial distributions of the groundwater salinity, salt loads and fluxes.



(b) To model surface-groundwater interactions we use what we call Boundary Conditions (BCs). The two main ones are Rivers (identified as the primary, secondary and tertiary systems) and Drains (pipe drainage, small ditches and overland flow). Our results suggest that with smaller grid sizes the river system contributes less mass to the surface while drainage features increase their contribution with finer grid sizes.
The source of this difference seems to be the flow scaling across resolutions for the river systems (Reminder: we scaled the conductance of the river system using two methods).



(c) This test suggests that large high-resolution models are yet far from practical application because of (1) computing power required; (2) runtimes; (3) memory usage. Since the models used are simplified versions, higher complexity still needs to be added which further suggest that for resource efficiency, the 25m-50m grid size is the highest resolution for a regional setting. We intend to improve our models in the future by adding more components like pumping while maintaining the resolution.

Grid size [m]	Cell Number	Run time [hours]	Cores*	Memory usage* [GB]
10	289,768,050	59.00	256	1010
25	46,412,457	8.25	96	57
50	11,644,776	2.73	32	14
100	2,932,566	1.07	32	5
250	475,410	0.33	32	3

*For reference, an average computer has 4 cores and 16gb memory of RAM

Take-home message

- Modelling groundwater salt-related processes is incredibly data and computationally intensive. We are still in the process of understanding how all the variables interact with each other to conclude on scalability.
- So far, our main results regard:
  - Having a tool that allows us to clip and create a model for any area of the Netherlands at any given resolution, albeit simplified.
  - Horizontal spatial scalability, we have a good understanding of the software limitations, how big of an area we can cover and at what resolution.

Future plans

- Finish first publication.
- Add complexity to the models created (Pumping, seasonality).
- Test the effect of temporal scaling on calculated salt loads to the surface.
- Apply the knowledge gained so far in a practical case in one of the Aqua Connect case studies (eg: Zuid-Holland).

AquaConnect