Subgrid hydrology in NOAH-MP

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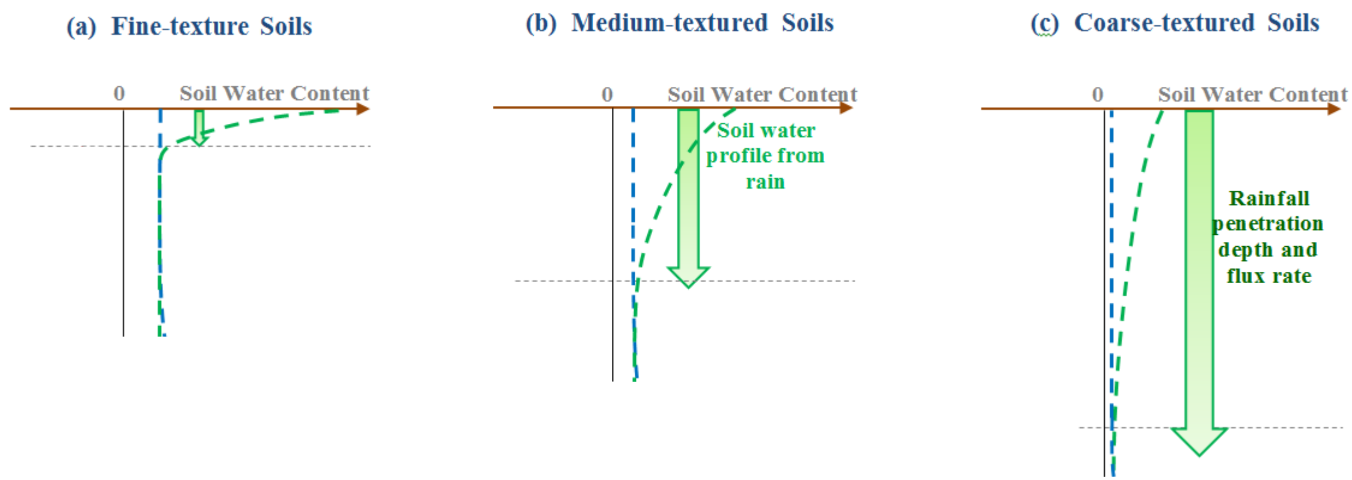
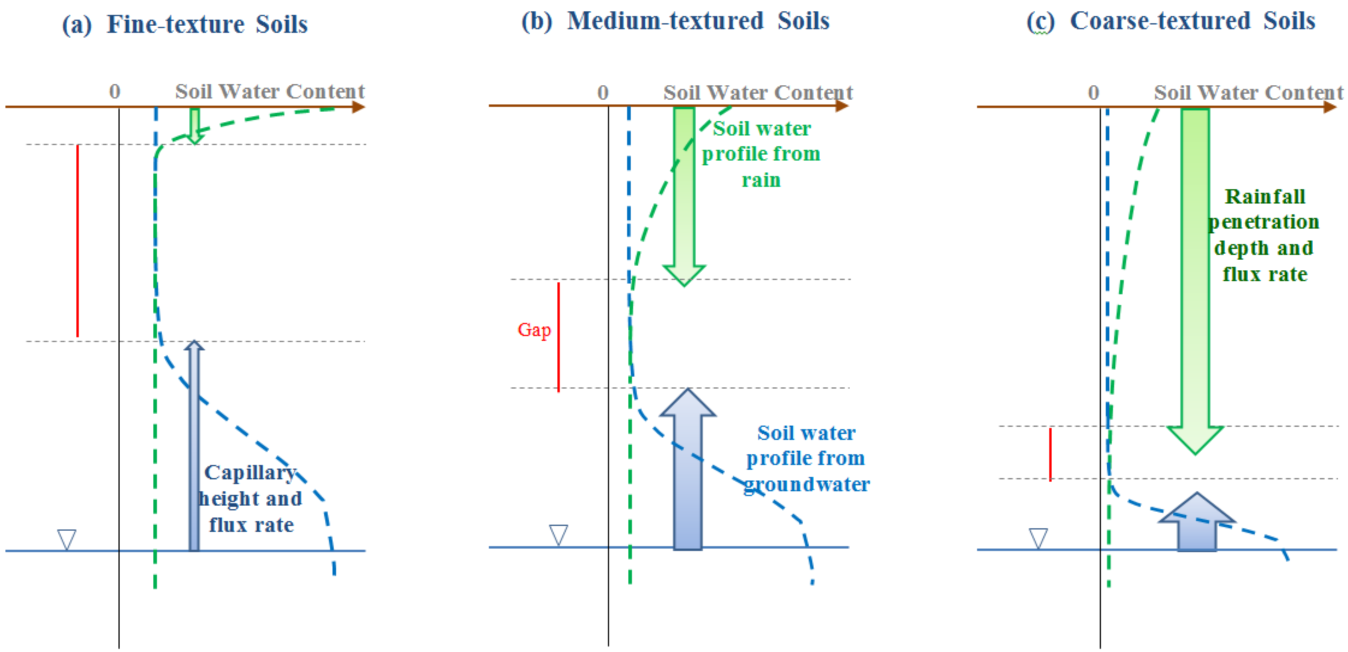
Soil moisture profiles determined by water sources from above

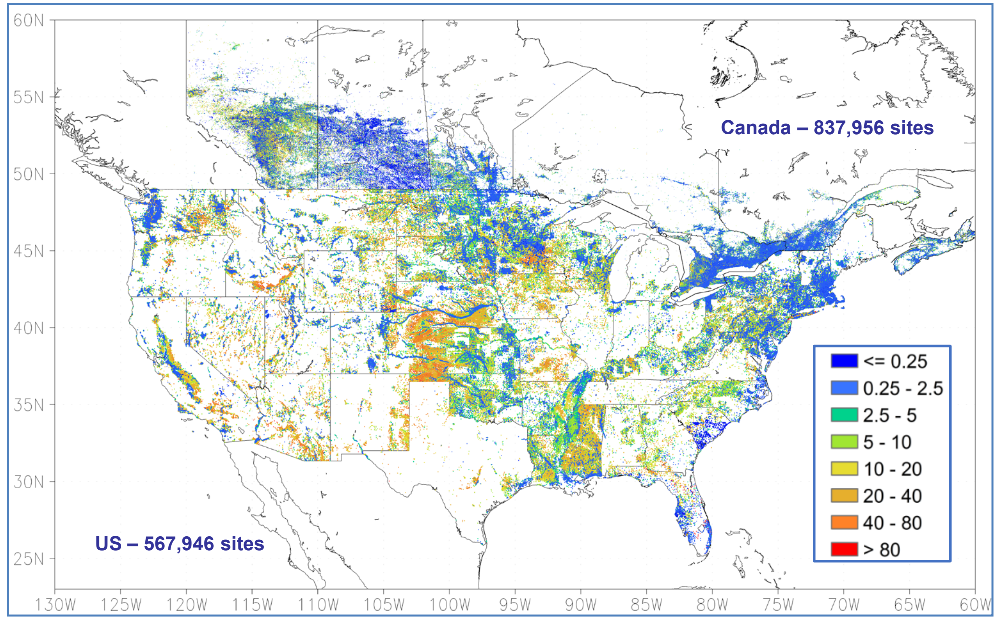


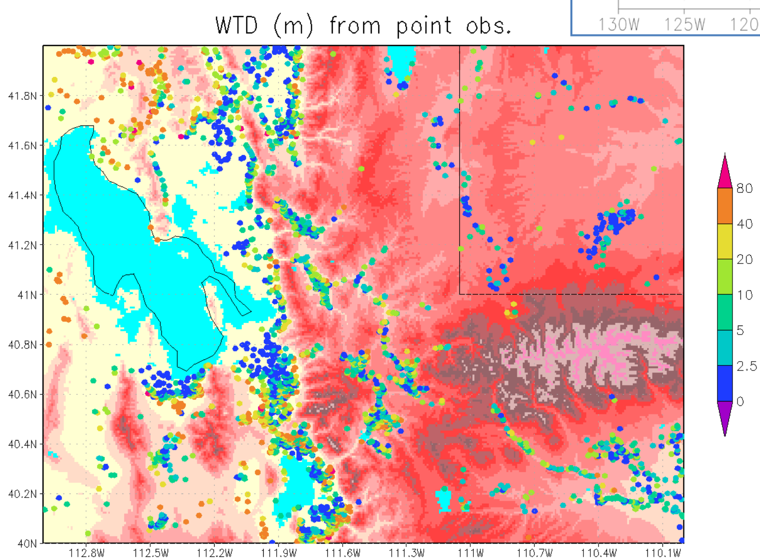
Soil moisture profiles determined by water sources from above and below



→ ***A shallow water table confounds it***

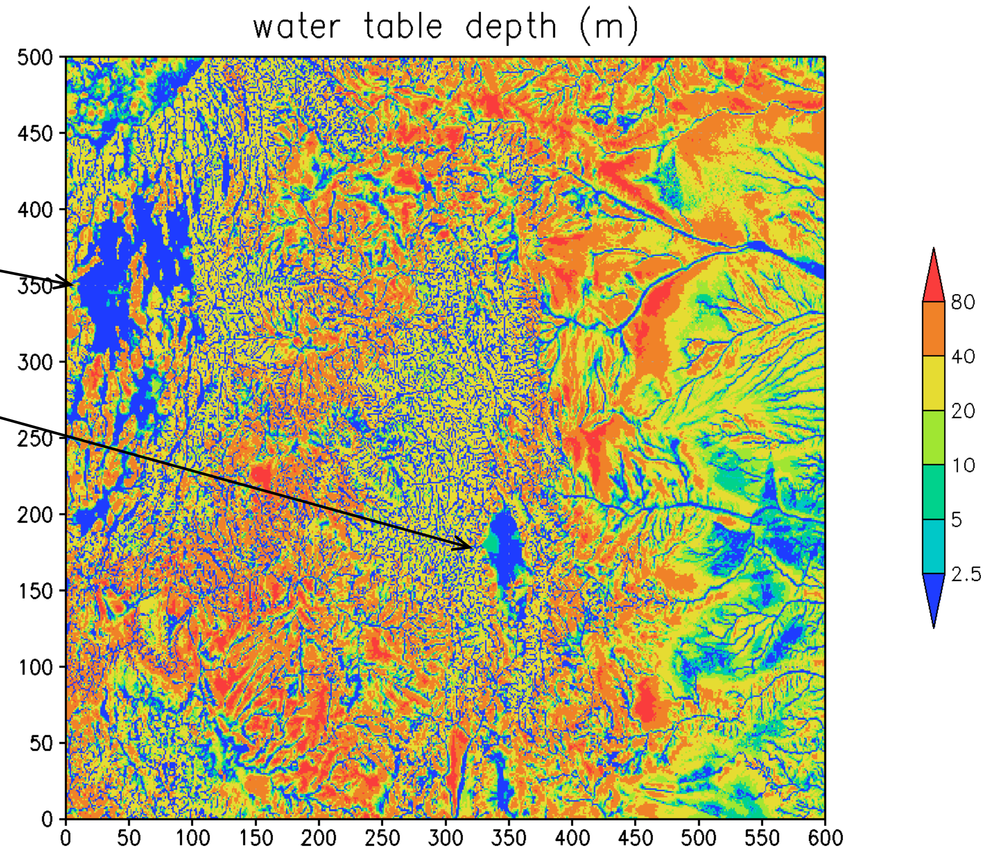
Water table depth (m) observations



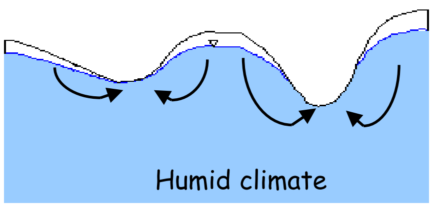


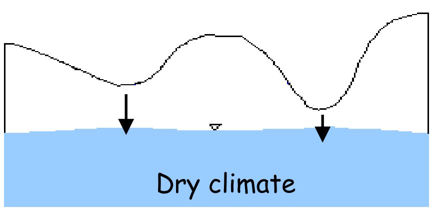
Shallow water tables linked to soil moisture and affecting land-air fluxes are found in humid as well as dry climates.

Shallow water table depths are found in valleys (strong groundwater convergence) or flat areas with poor drainage and groundwater lateral convergence, even in arid climates (e.g. Great Salt Lake desert, San Luis Valley)



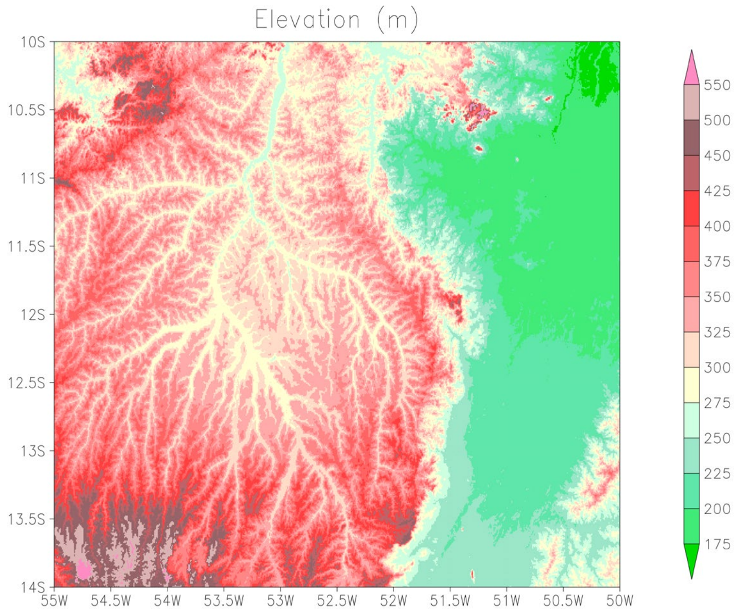
The water table is deeper under hilltops, especially if the recharge is low and transmissivity high.



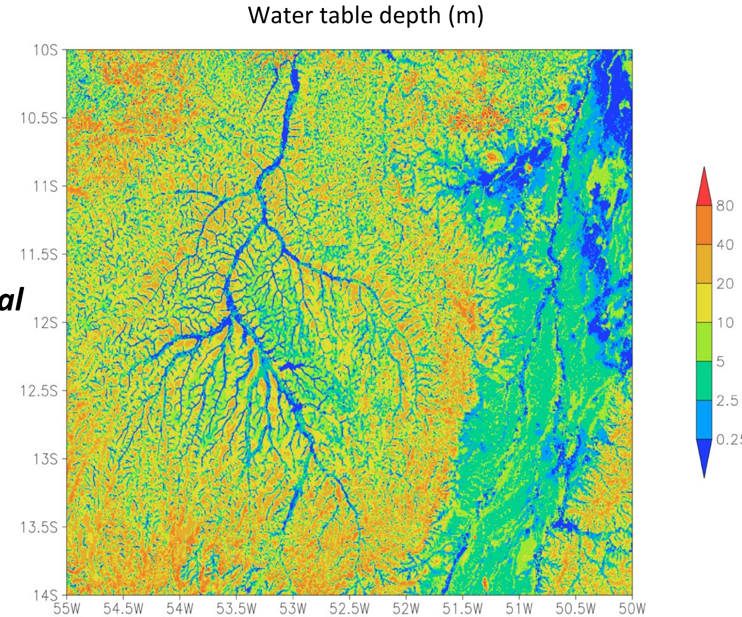


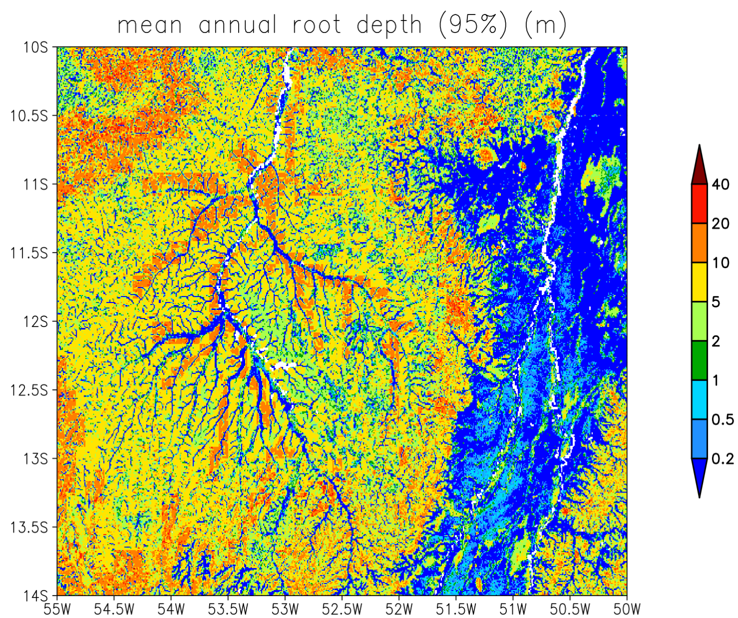
The water table depth pattern at smaller scales depends primarily on topography. Lateral groundwater flow redistributes recharge horizontally

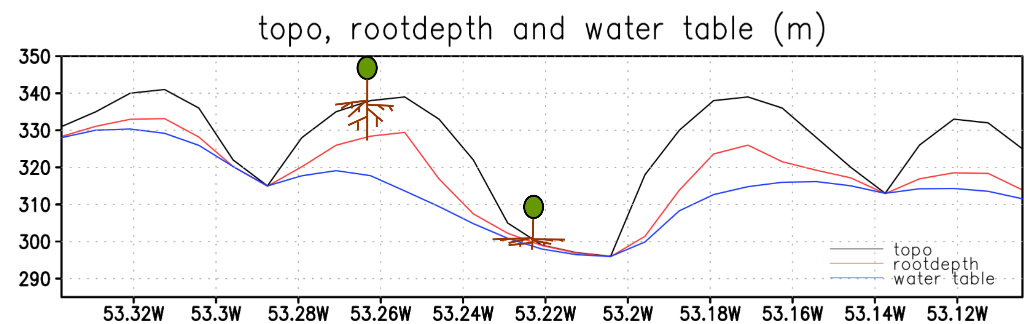
Fan et al, 2007, JGR



Fine-Scale Spatial Variability







How do we represent all these fine scale hydrology in a model WITHOUT superhigh resolution?

The importance of resolution

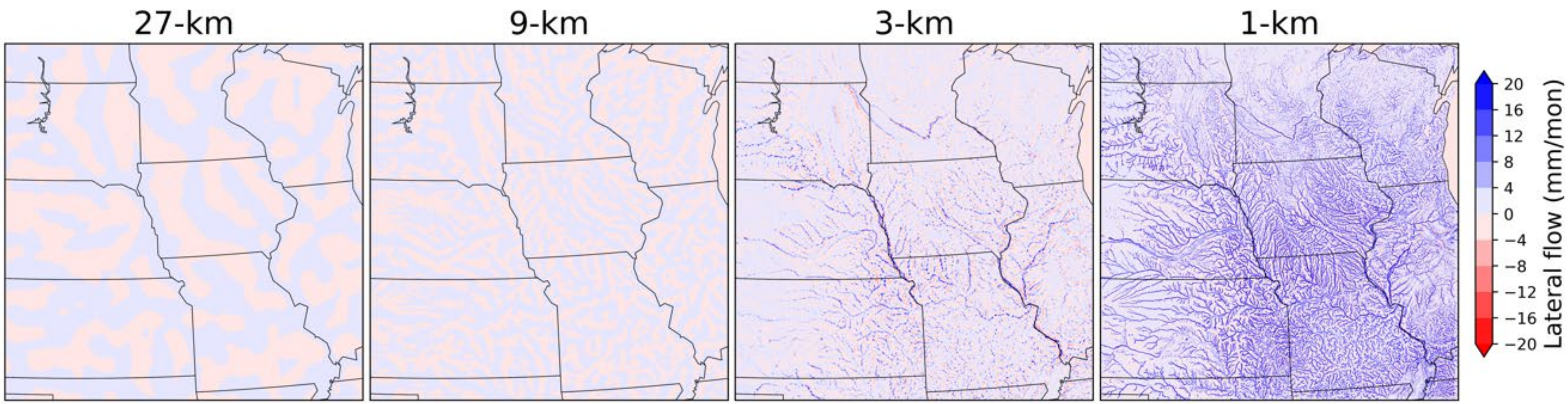
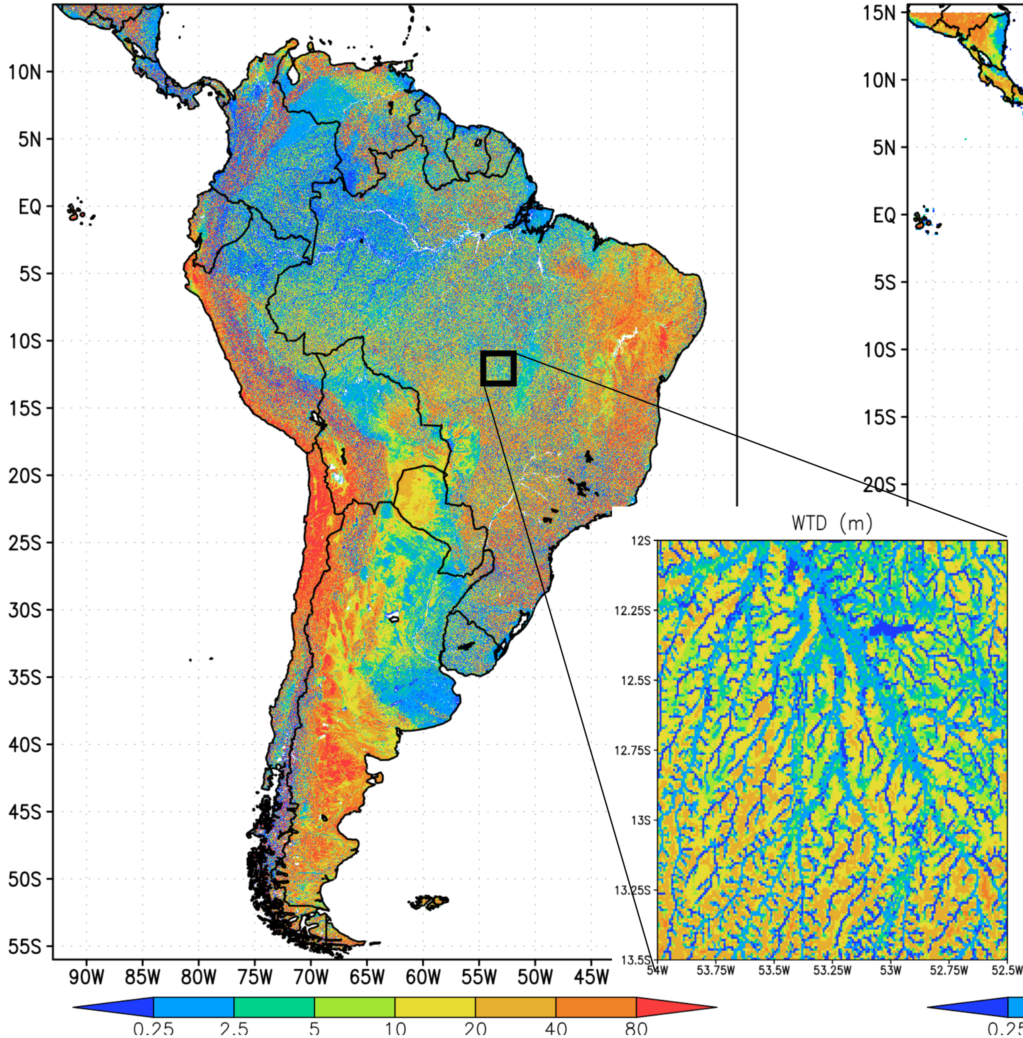


Figure S1. Spatial distribution of monthly accumulated groundwater lateral flow (mm/month) for 2012 July and for WRF-GW simulations with 27-, 9-, 3-, and 1-km grid spacing. Red indicates water leaving the grid box and blue indicates receiving water from surrounding grids.

Barlage, M., Chen, F., Rasmussen, R., Zhang, Z., & Miguez-Macho, G. (2021). The importance of scale-dependent groundwater processes in land-atmosphere interactions over the central United States. *Geophysical Research Letters*, 48, e2020GL092171. https://doi.org/10.1029/2020GL092171

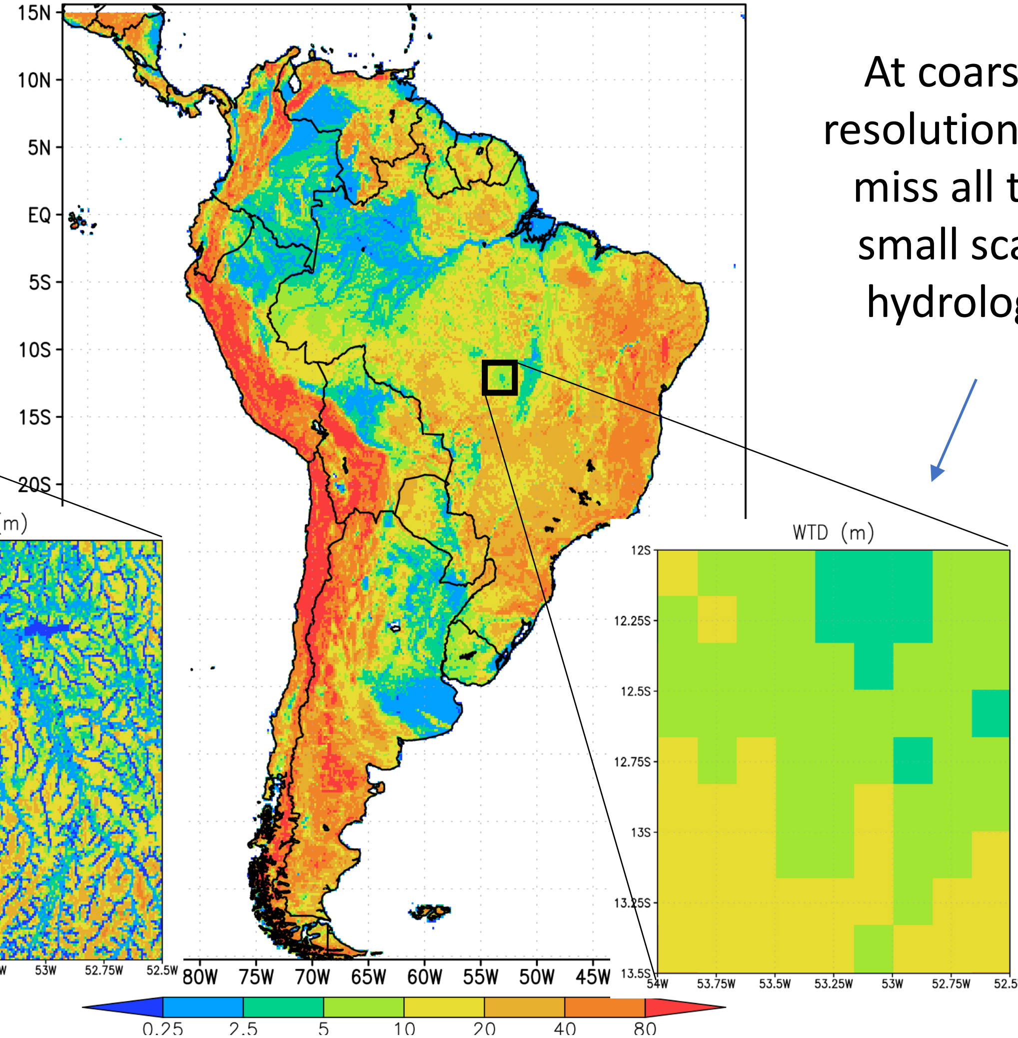
30 arc sec resolution

Water Table Depth (m)



10 min resolution

Water Table Depth (m)



At coarser resolution, we miss all the small scale hydrology

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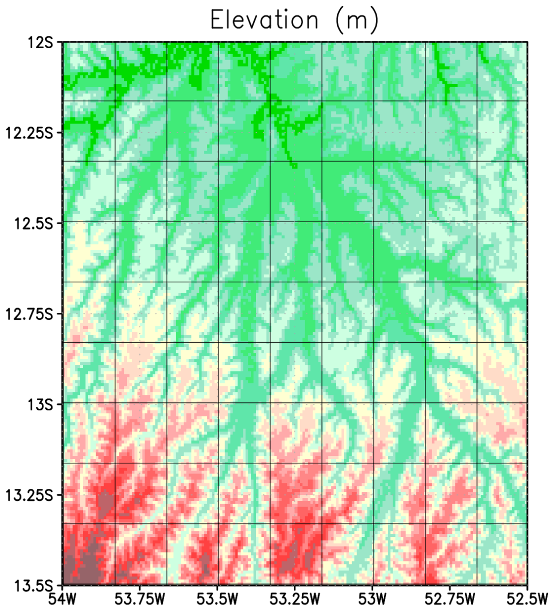
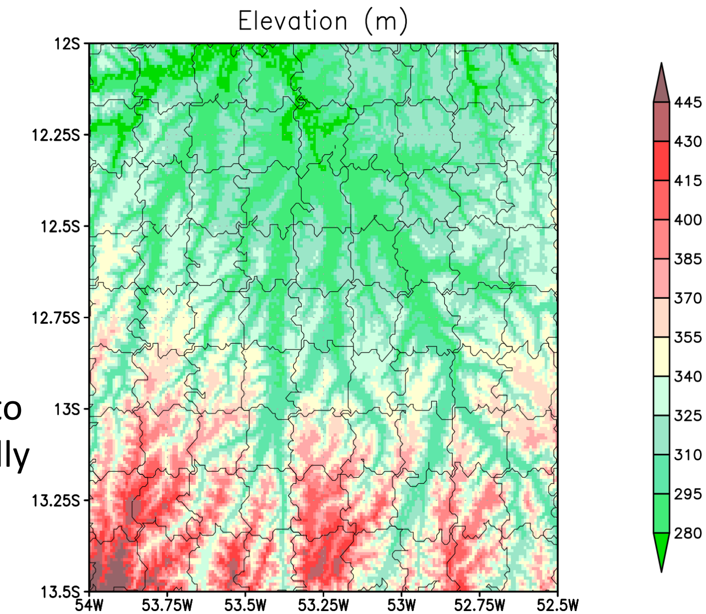
First, change the view of land to be more hydrologically meaningful



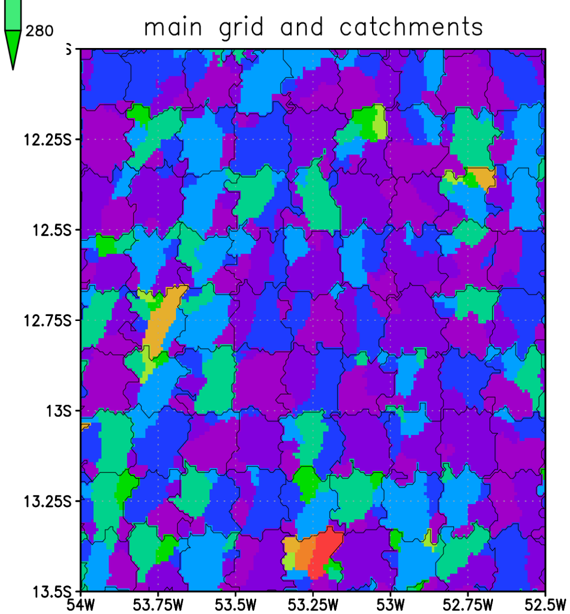
10 min res grid (~ 20km)

Change from square grid cells to more hydrologically meaningful boundaries



Grid cells have now irregular shapes, as they are composed of catchments (not many, in this example, up to 6, usually less)

There are the same number of cells as if they were square, and approximately at the same positions and with the same area



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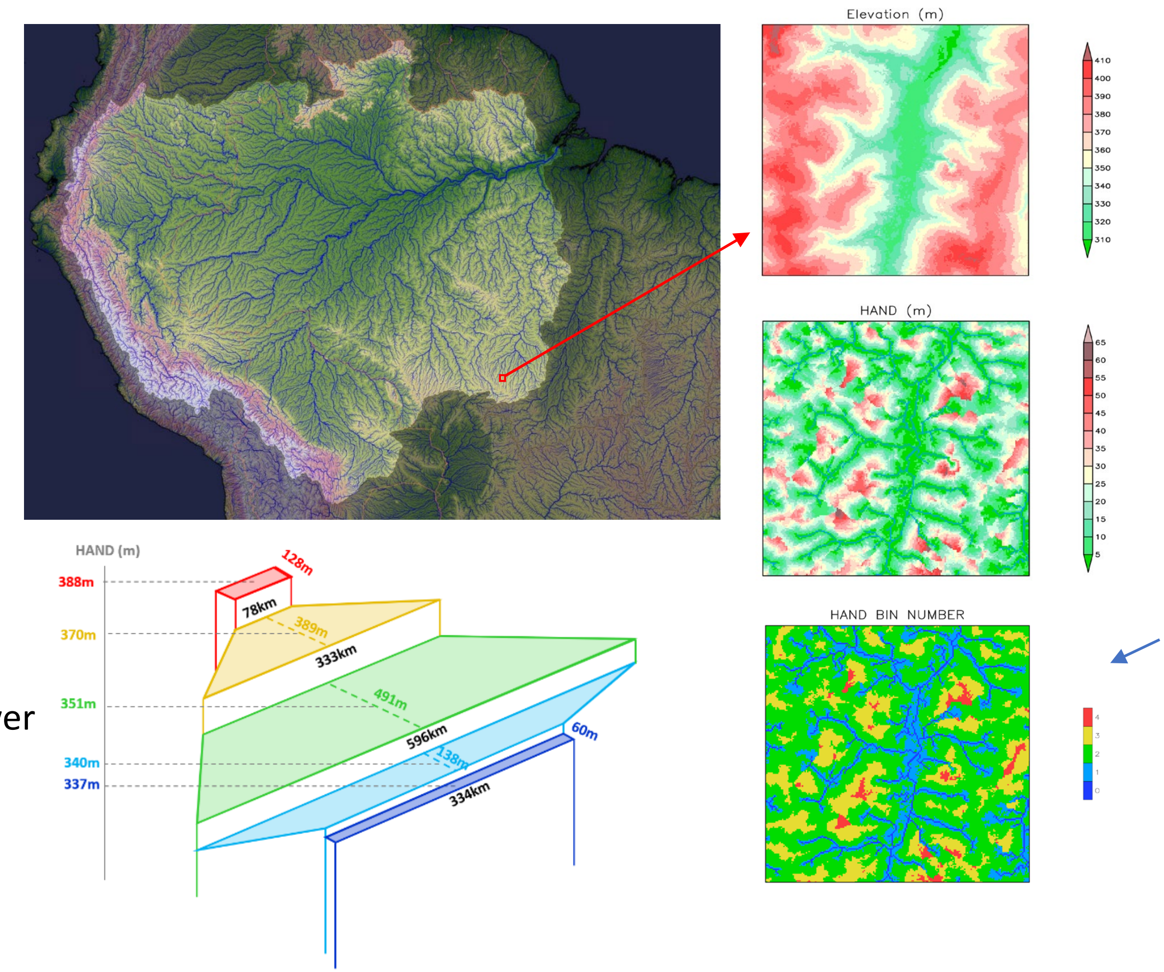
Then, subdivide catchments into elevation zones from rivers or groundwater discharge points



Each catchment within each cell is divided into bins, according to distance from groundwater discharge points

In this example, there are 5 bins, from 0 being riparian zones to 4, being hilltops

Groundwater lateral flow is computed from upper to lower bins

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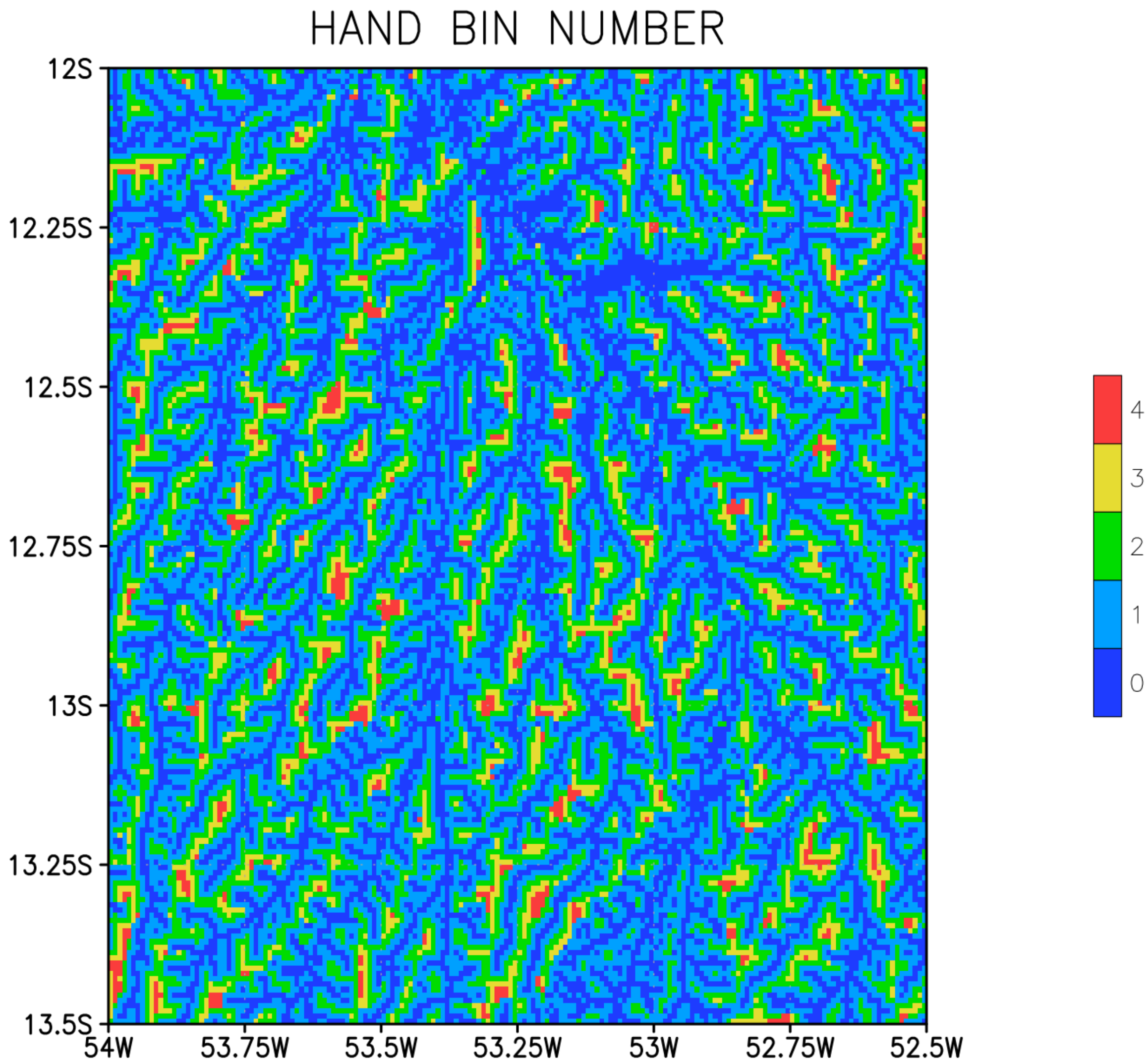

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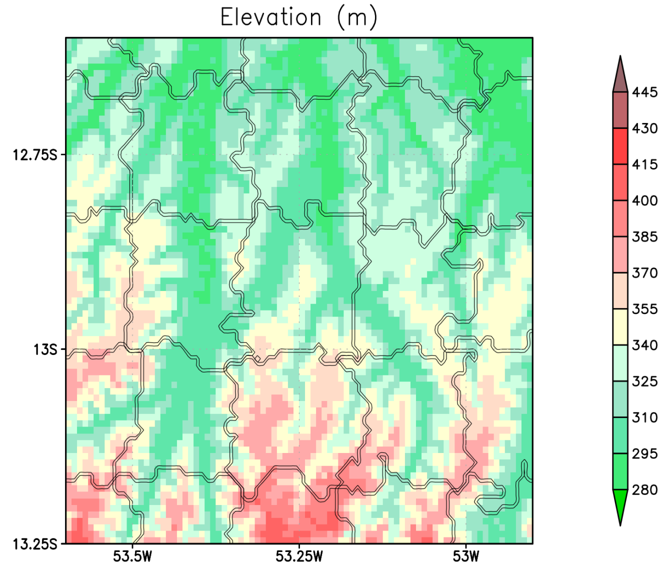
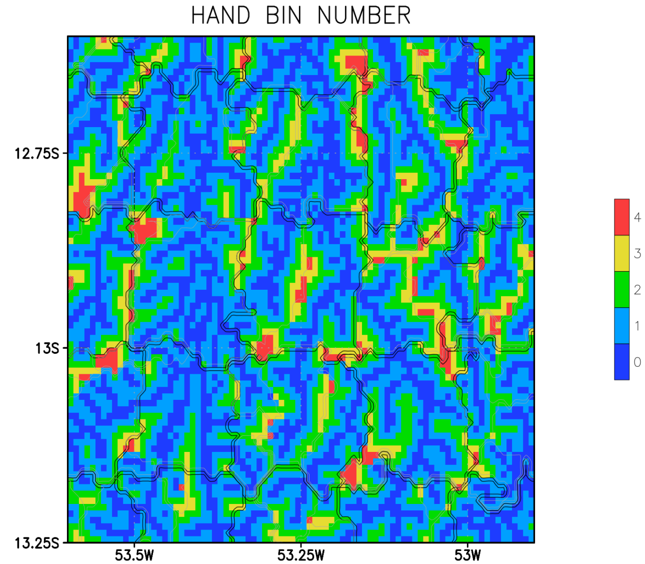
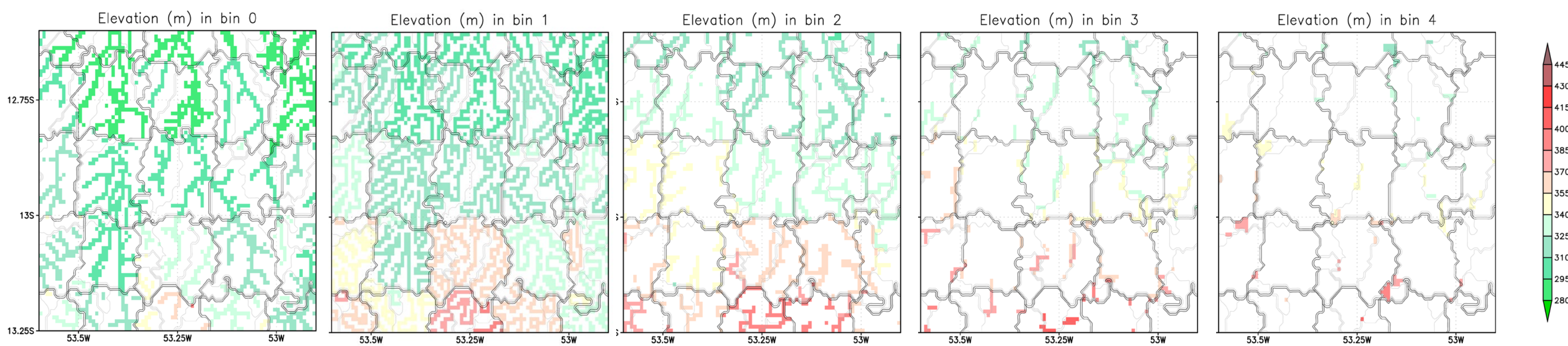
High resolution topography





Each bin within each catchment has one value of elevation, water table depth, soil texture, vegetation, etc.



The elevation of each bin in each catchment is obtained as the average of the elevation of the pixels of the high resolution grid used to distribute the land in bins

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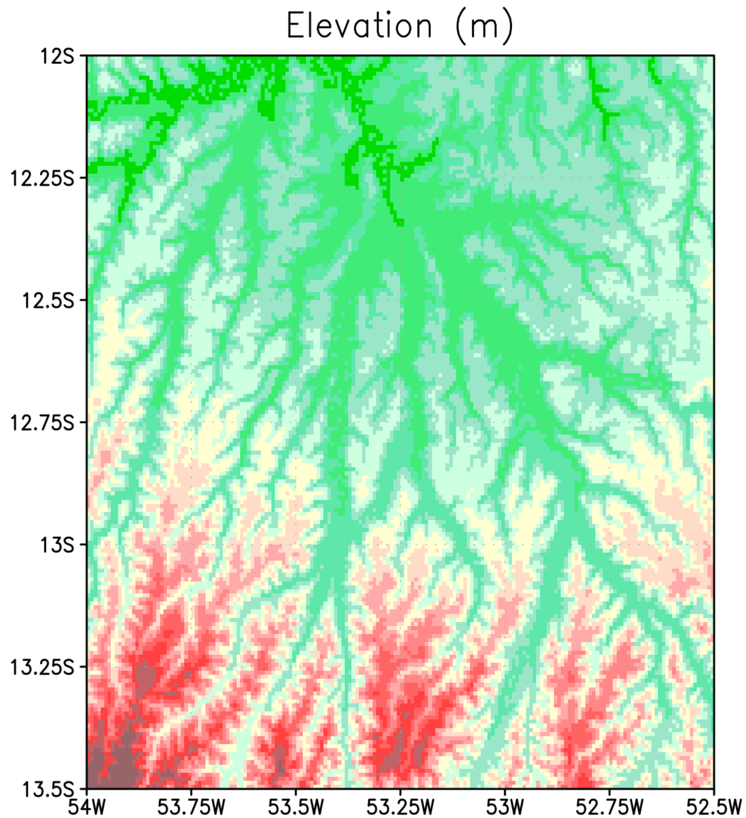
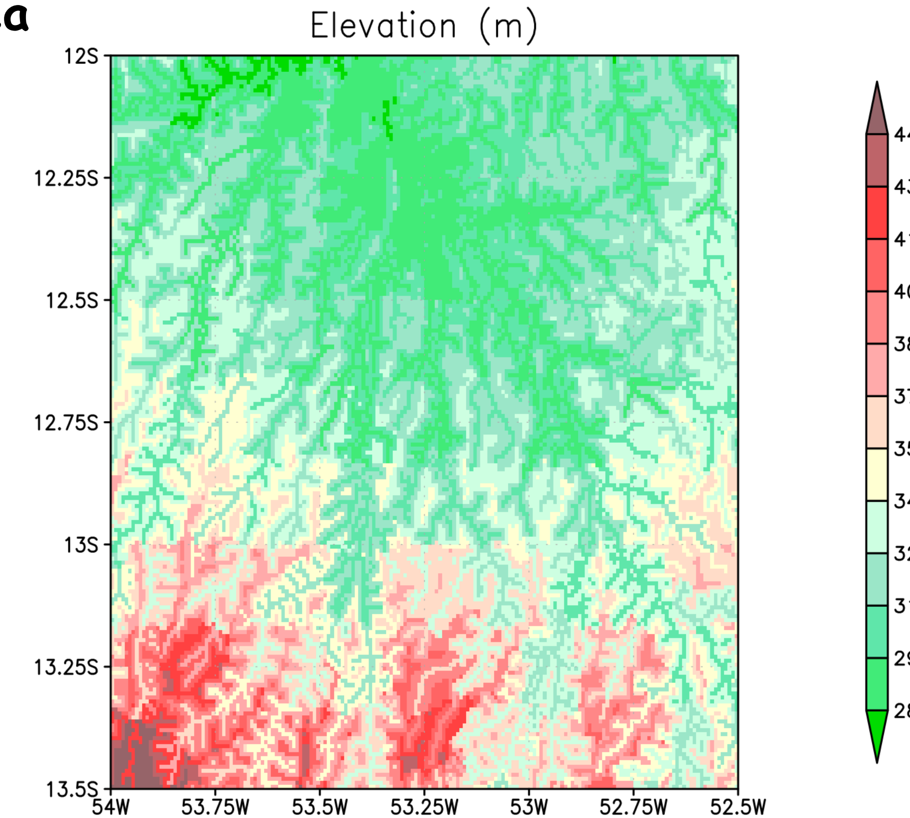
We reduce by more than one order of magnitude the number of points while retaining the essentials of the high-resolution hydrological setup of the area

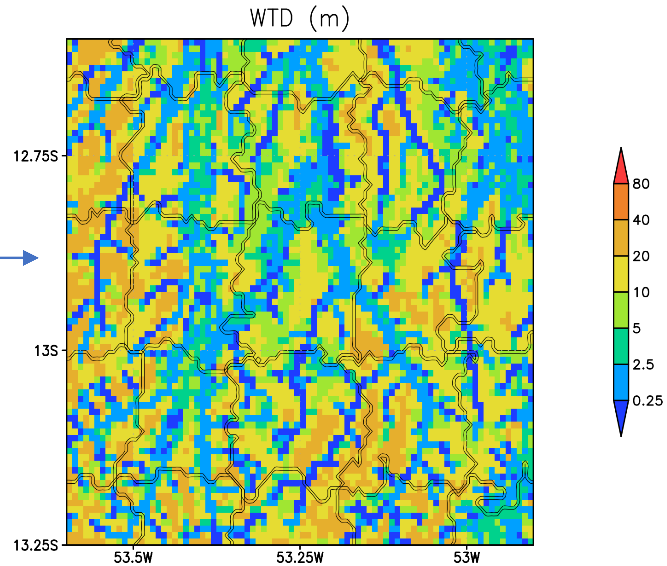


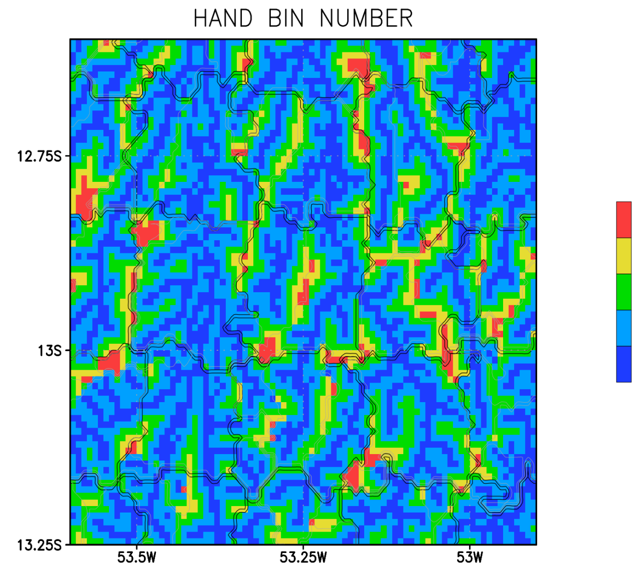


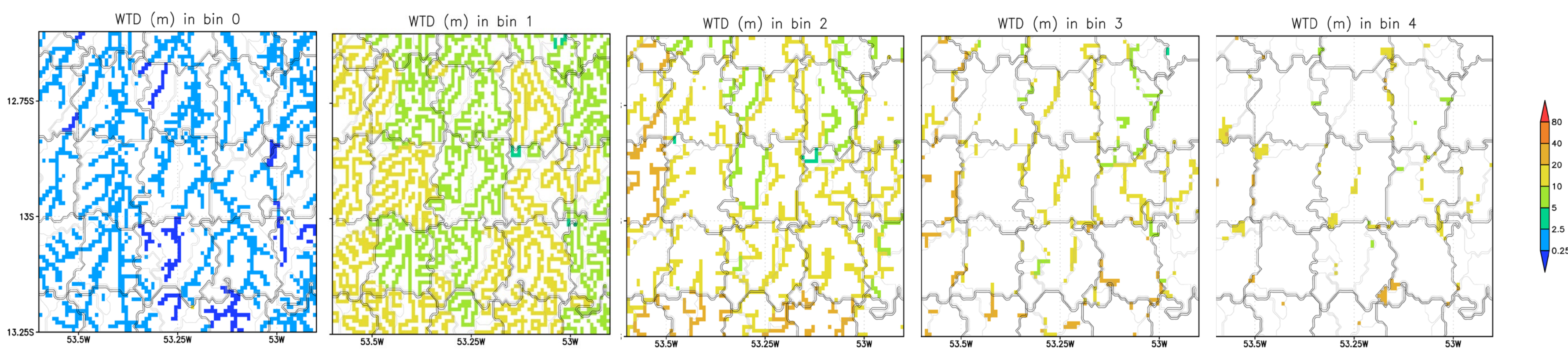
We go from a grid of 30´´ ~ 1km resolution of 120 x 120 = 14400 points per square degree

To a grid of 10min ~ 20km resolution with 6 x 6 = 36 cells per square degree. Each cell has several catchments (up to 6 in this example, so there are less than 36 x 6 =216 per square degree), and within each catchment there are 5 bins. In total we have up to 1080 “points” (in reality, much less) per square degree.

High resolution water table depth







Bin 0 represents riparian and floodplain zones, where the water table is shallow

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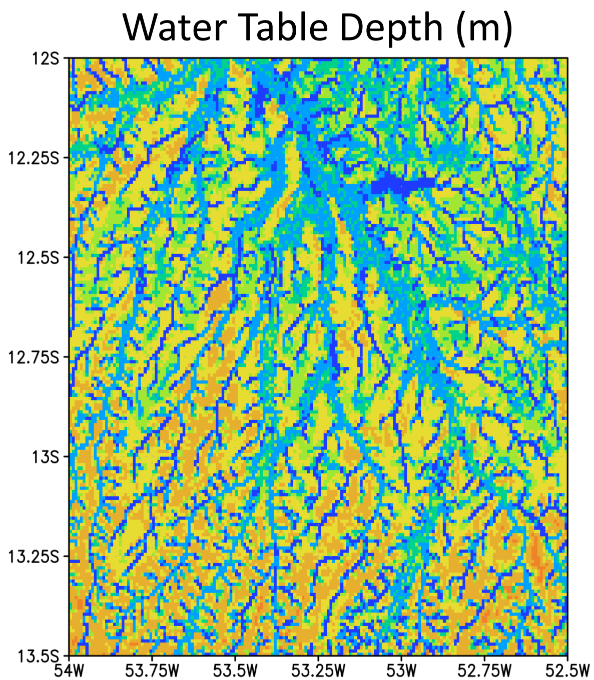
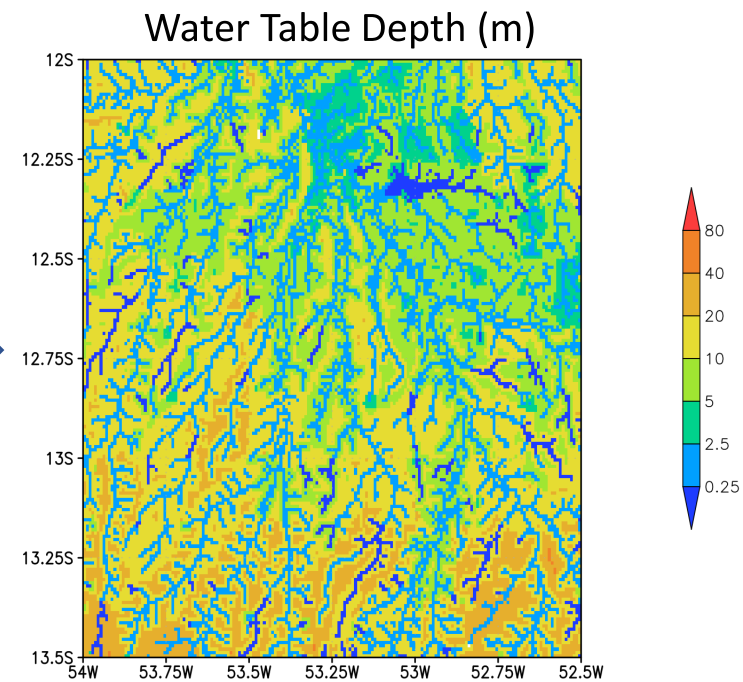
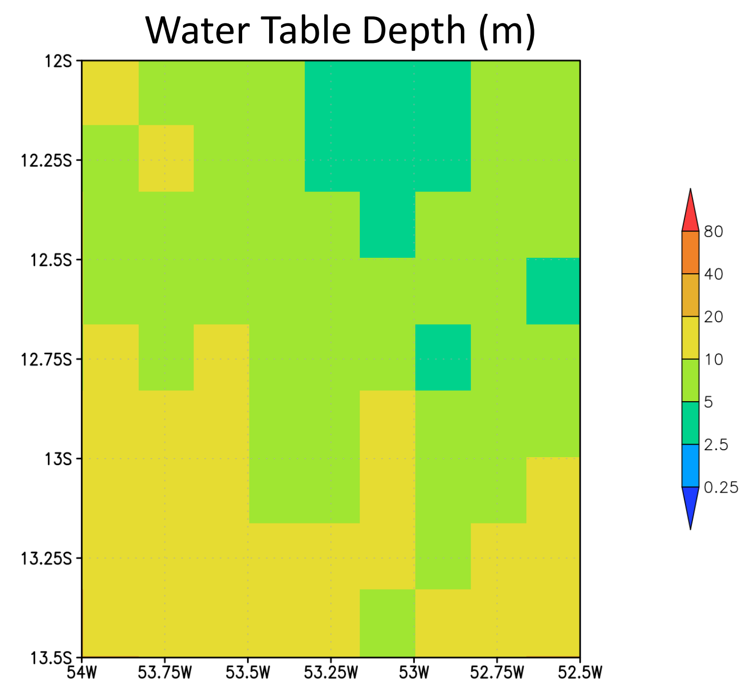


High resolution
30” grid



“Coarse resolution” (10min) with catchments and HAND bins



Coarse resolution (10min), simply aggregating from 30”

The high-resolution water table table pattern is retained, and it is maintained during the simulation by groundwater lateral flow from upper to lower bins (hillslope) and from cell to cell (regional).

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Conclusion

Dividing the land surface into hydrologically meaningful grids allows us to represent groundwater processes that are important for soil moisture and vegetation and hence for land-air fluxes of water, energy and carbon, without excessive computational cost.