



Building a global groundwater model from scratch - pitfalls and perspectives

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State of the art: Global scale gradient based groundwater models

Steady state:

- Fan et al. 2013
- de Graaf et al. 2015 PCR-GLOBWB

Transient:

- Graaf et al. 2016 -> “HESS discussion”
- Vergnes et al 2012/14 -> “global ready”

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Building a groundwater model

Motivation and design



Motivation

Currently WaterGAP only storage based:

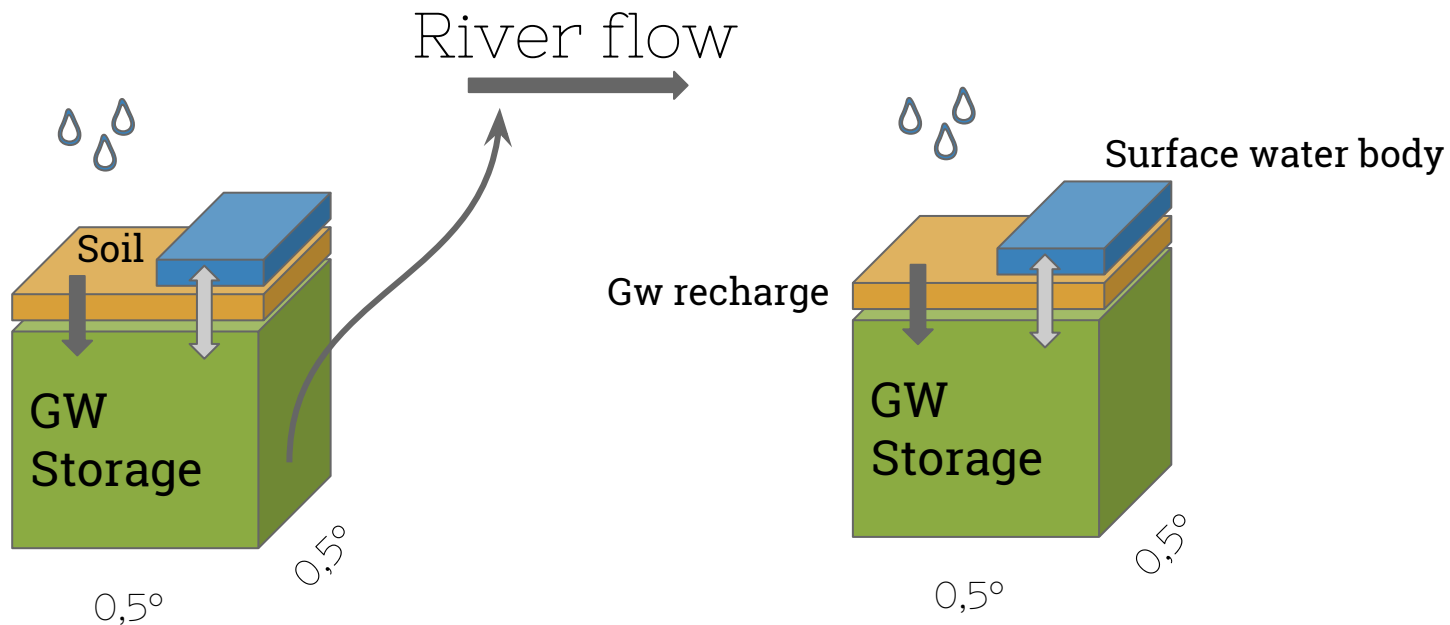
- Missing head information
- No lateral flow

WaterGAP with gradient model:

- **Head-based surface water body interaction**
- **Capillary rise**



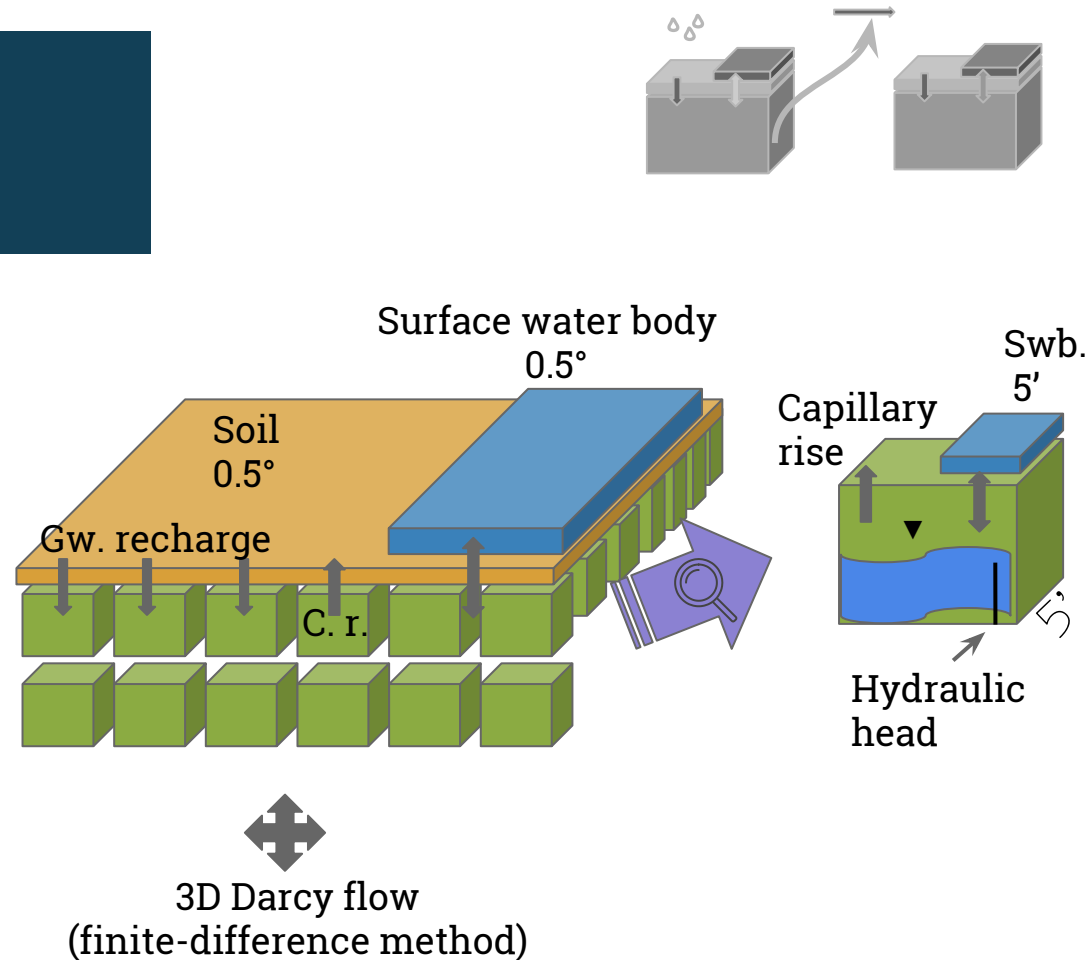
WaterGAP - Current state





WaterGAP - New model

- Recharge from runoff calculated by waterGAP
- Re/Dis-charge from surface water based on head
- Simplified capillary rise (No Richards equation)
- Multi layer groundwater model (2 layers)



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Code architecture

Extensibility and modularity



Design principles of the global groundwater model

- Flexible → Support multiple scenarios
- Extensible → Ready to future development
- Reusable → Usable in other hydrological models

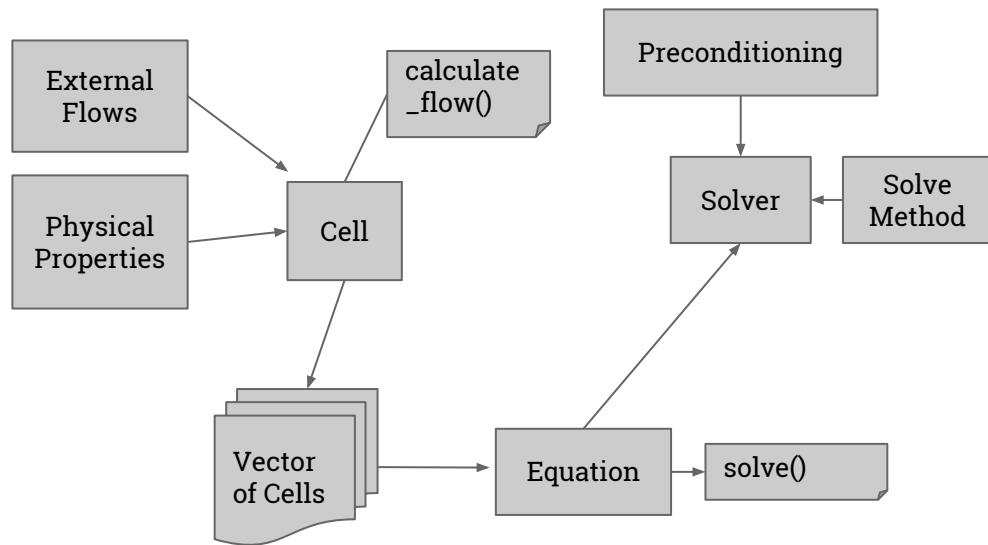
→ Object Oriented Design

- Fast



Object oriented design

- Highly modular
- External flows similar to modflow
- Support for different solve approaches
 - Currently similar to Modflow PCR (Conjugate Gradient Method)
 - Planned newton formulation (as in Modflow NWT)





Performance

- Fast and reliable computation
- Small models as fast as modflow
- 100% parallelized
- Able to benefit from GPU acceleration [build in]



http://www.fujitsu.com/de/Images/W-intel-xeon-phi_tcm20-395006.png

- Small memory footprint (sparse matrix computation)
- Able to handle irregular cells (geographic lat/lon)



Availability

- Open source
 - After completed development and evaluation with WaterGAP

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Data

Resources, cooperation and model coupling



Model Coupling

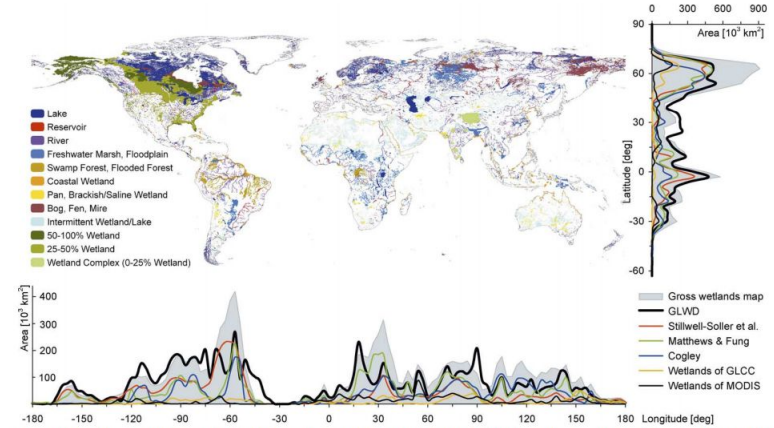
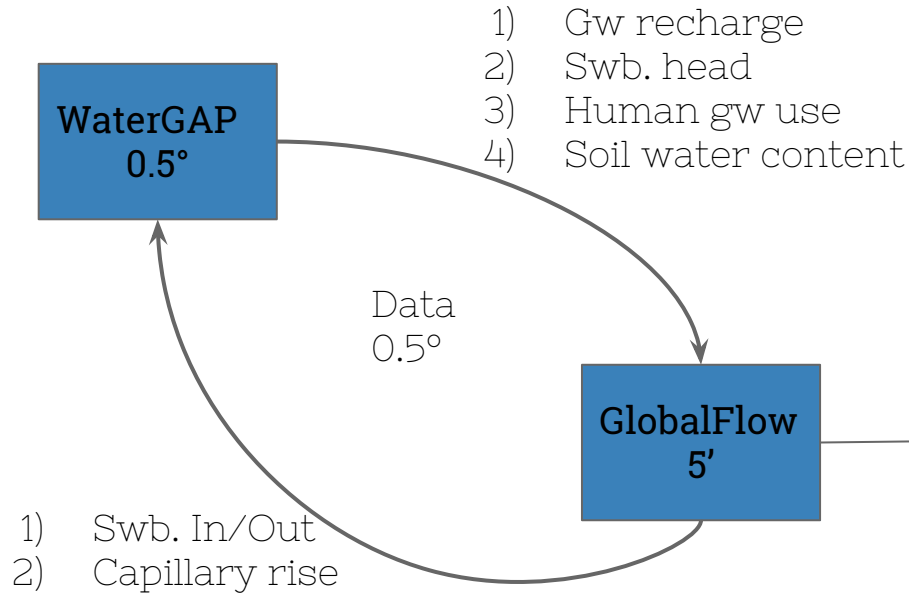
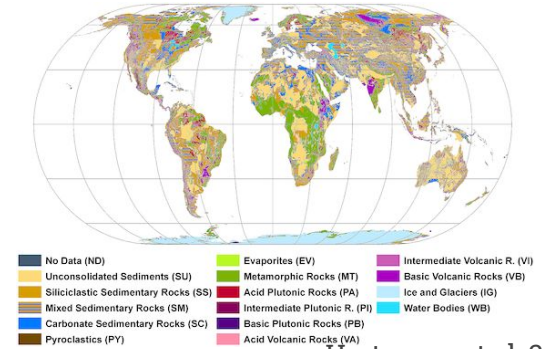


Fig. 5. Global wetlands map GLWD-3, with latitudinal and longitudinal distributions of global wetland areas. Area values are aggregated in steps of 3°. The three fractional wetland classes of GLWD-3 were calculated at their class centers (75, 37.5, and 12.5%). For data description and references see text and Table 1.

Lehner, B. and Döll, P., 2005



Data and Collaboration



Hartmann et al. 2012

- Cooperation with Ying Fan Reinfelder and Gonzalo Miguez-Macho
 - Steady-state as initial head condition
- Conductivity derived from lithology map of Hartmann et al. 2012 based on Gleeson et al. 2014
- Lakes and Wetlands on 5' resolution from GLWD (Lehner and Döll, 2005)
 - As % of cell area



Pitfalls

- How to deal with mountains?
 - Deep head drops in steady state simulations
 - Swb. interaction in mountainous regions?
- Set head of swb. in 5' gridcell and 0.5°
 - Individual and aggregated
- Initial condition?
 - Currently Fan et al. steady state as initial
- River conductance?
- Derive conductance values
 - Sediment difference between fine and coarse not available everywhere -> mean value not plausible
 - Huge difference in neighbouring K
- Need for additional GW-discharge (non-gradient based) to swb

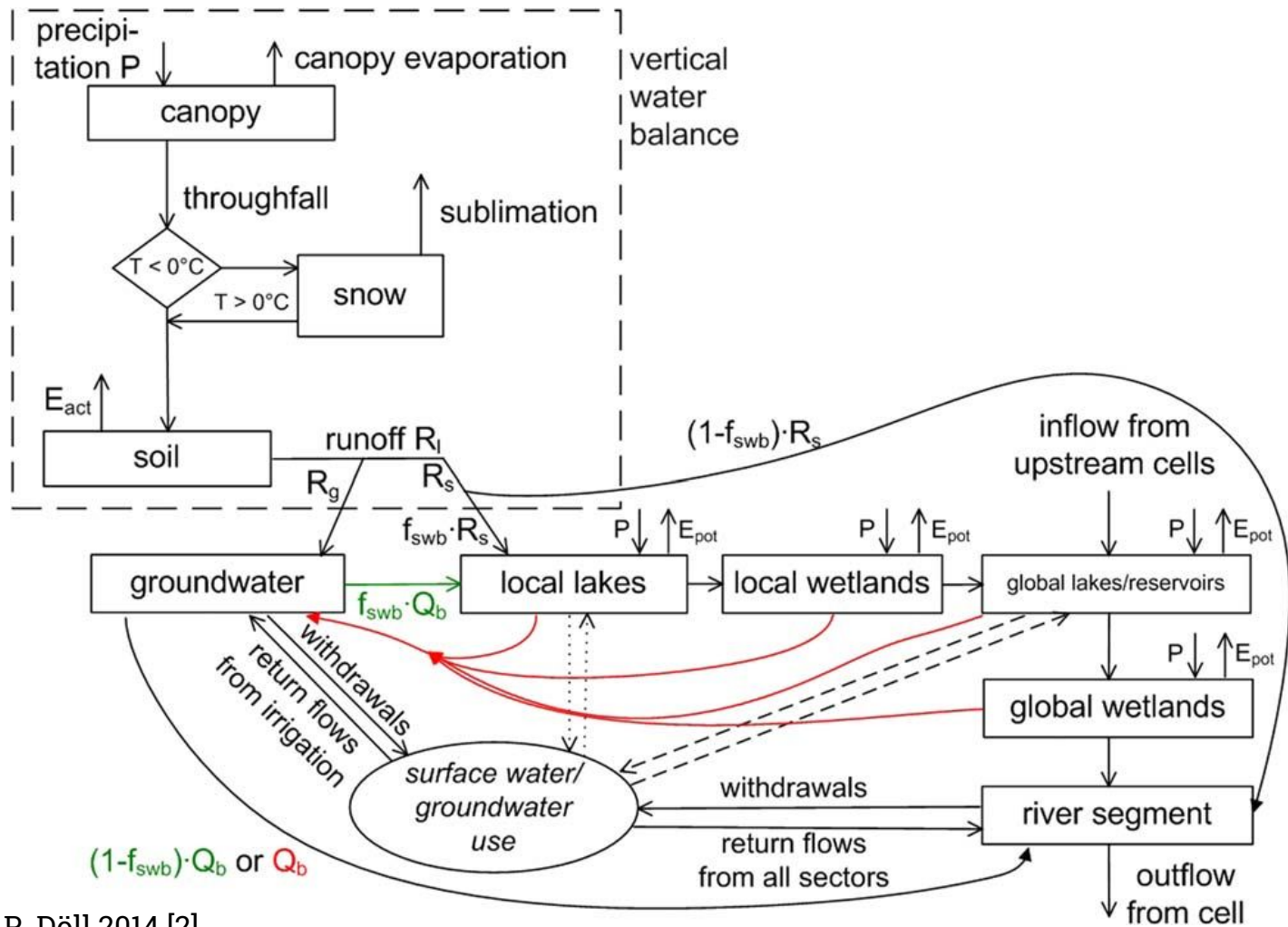
THANK YOU FOR YOUR ATTENTION!

Questions?

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