Combined Effects of Geological Heterogeneity and Discharge Events on Groundwater and Surface Water Mixing

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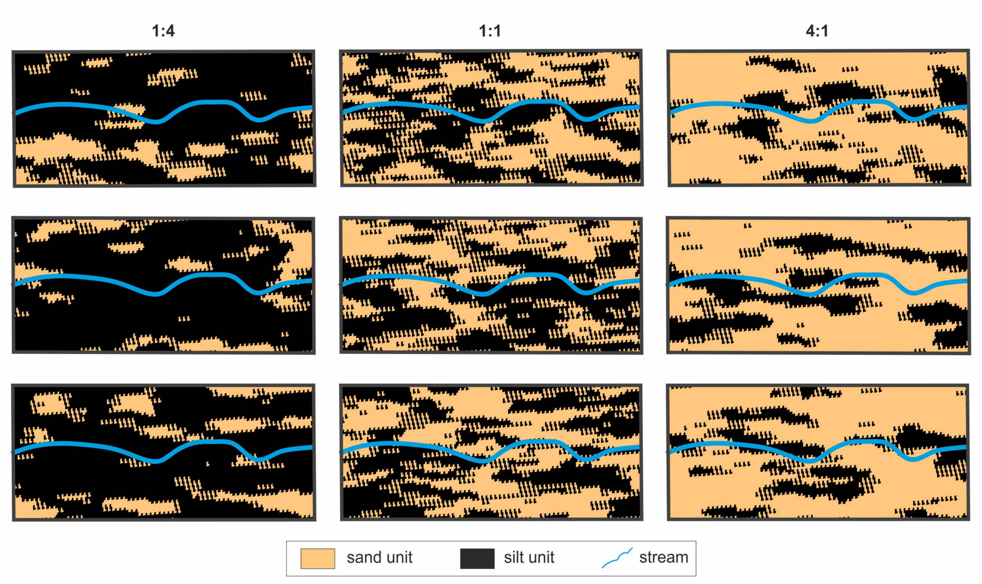
1 Introduction

- Exchange and mixing between stream water (SW) and groundwater (GW) affects water quality in river corridors;
- Complex interaction between hydrological and geological characteristics for SW-GW exchange fluxes (EF);
- How EF and SW-GW mixing development are affected by different discharge events (e.g., maximum peak discharge and total duration) taking place within different geological settings?
- What are the main controlling factors for EF and SW-GW mixing?

2 Methods and Materials

2.1 Geological scenarios

- Markov Chain model and indicator simulation (**TProGS**)
- 30 different bimodal fields with different sand-to-silt ratios (1:4, 1:1, and 4:1)
- Equivalent pure homogeneous models based on geometric mean of hydraulic conductivity (*K*)



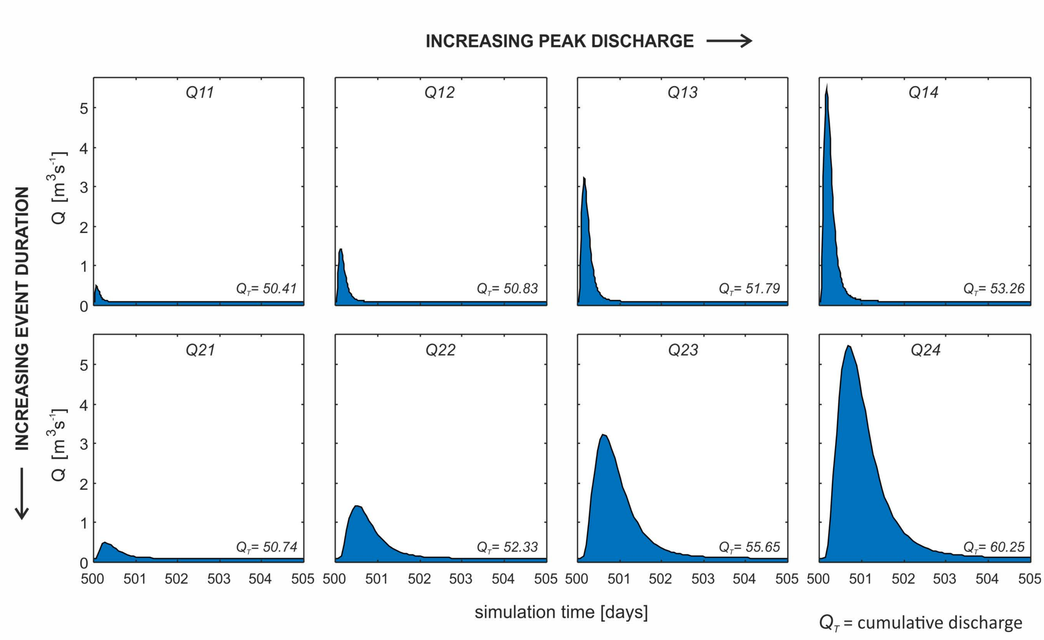
- **Low** and *high* *K* contrast cases:

Sand: **8.0x10^{-3}** or *8.0x10^{-2}* [m/s]
Silt: **5.7x10^{-4}** or *5.7x10^{-5}* [m/s]

Sand-silt ratio	0:1	1:4	1:1	4:1	1:0
Sand fraction	0.0	0.2	0.5	0.8	1.0
Geomean *K* (m/s) (low contrast)	5.7e-4	9.8e-4	2.2e-3	4.9e-3	8.0e-3
Geomean *K* (m/s) (high contrast)	5.7e-5	2.4e-4	2.5e-3	2.1e-2	8.0e-2

2.2 Fully-coupled 3D numerical model

- transient simulations (**HydroGeoSphere**)
- 8 different discharge events: 4 maximum discharge peaks and 2 sets of durations
- Baseflow (BF) conditions for 500 days before and after discharge events
- total of 560 model runs

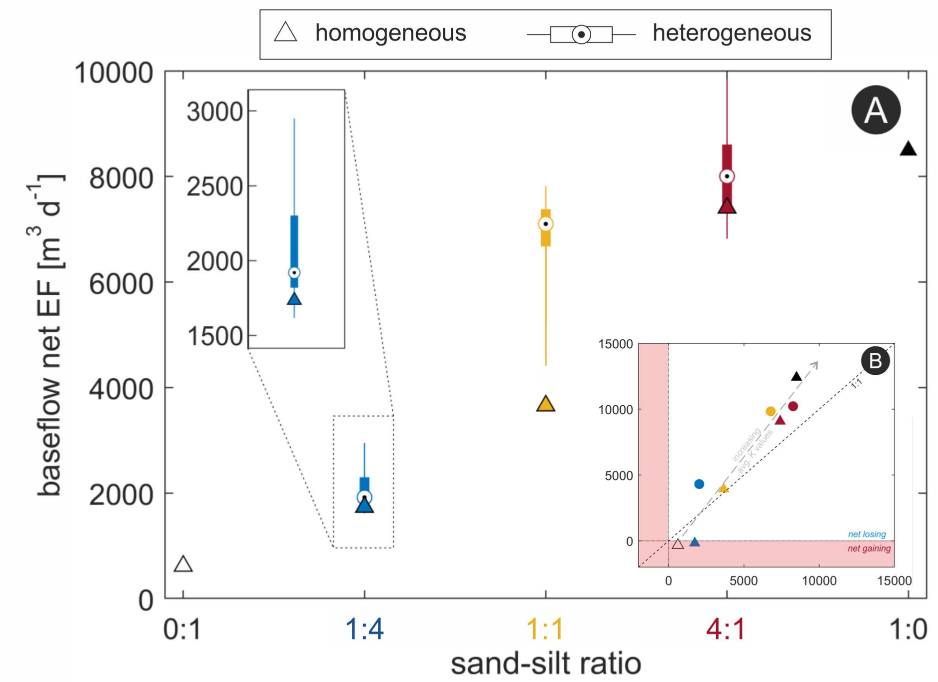


2.3 Mixing analysis

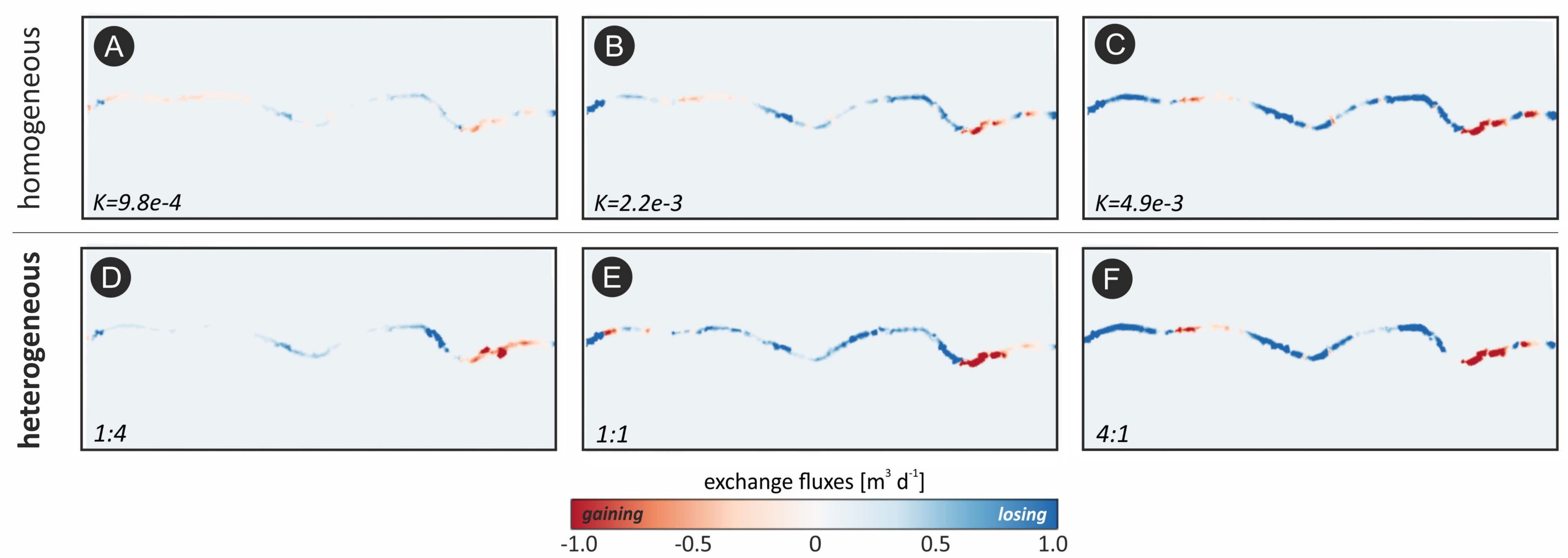
- Hydraulic Mixing Cell method (**HMC** - *Partington et al., 2011*)
- Tracking of infiltrating SW and flowing GW parcels, and their fractions in different times and locations within the subsurface of the model domain

3 Results: SW-GW exchange fluxes

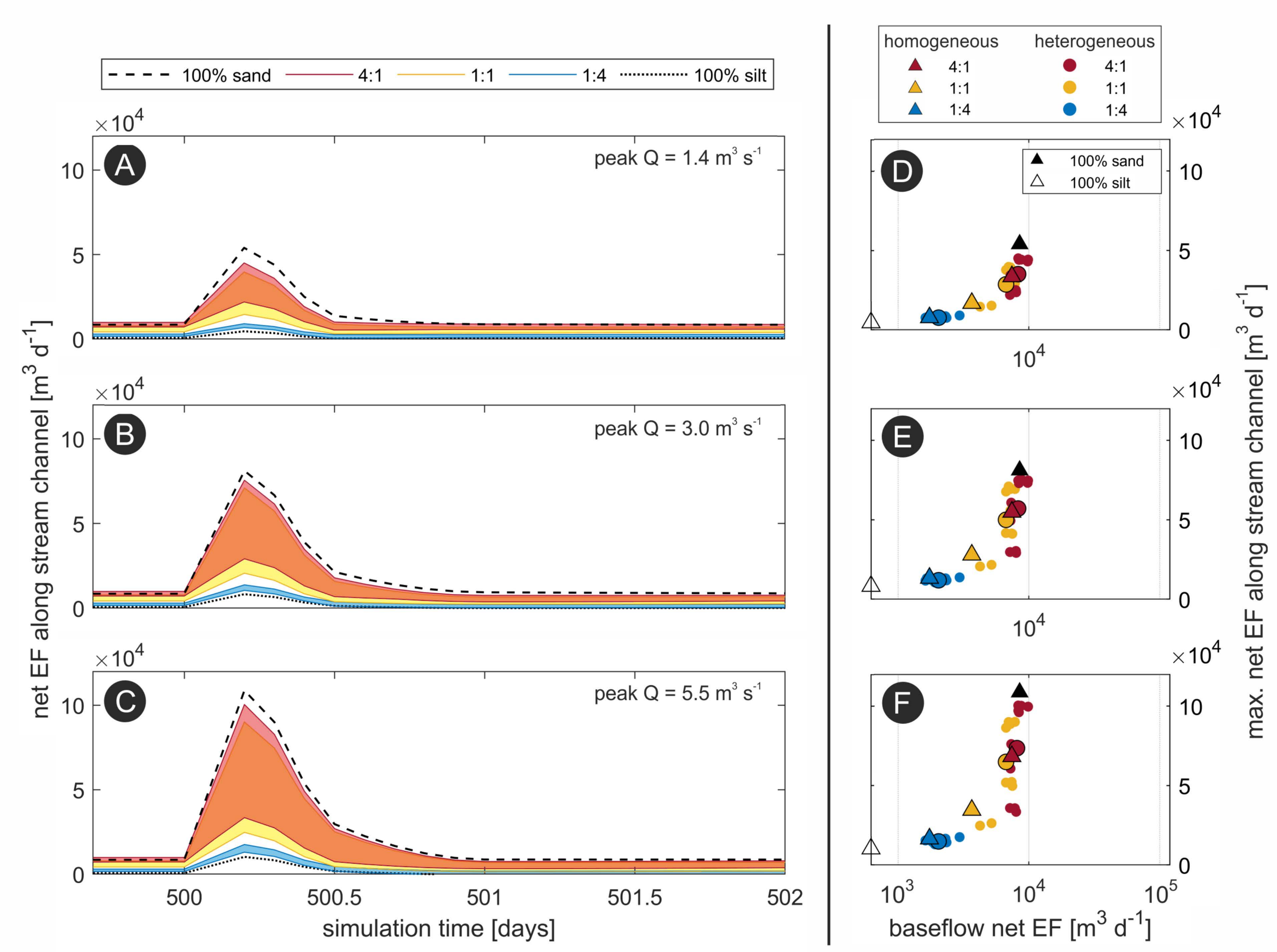
- Positive net EF: general losing conditions in the reach (with limited gaining spots only)
- Generally larger EF magnitudes in heterogeneous models
- EF magnitudes and overall net EF increasing with sand fractions (and *K* contrast)



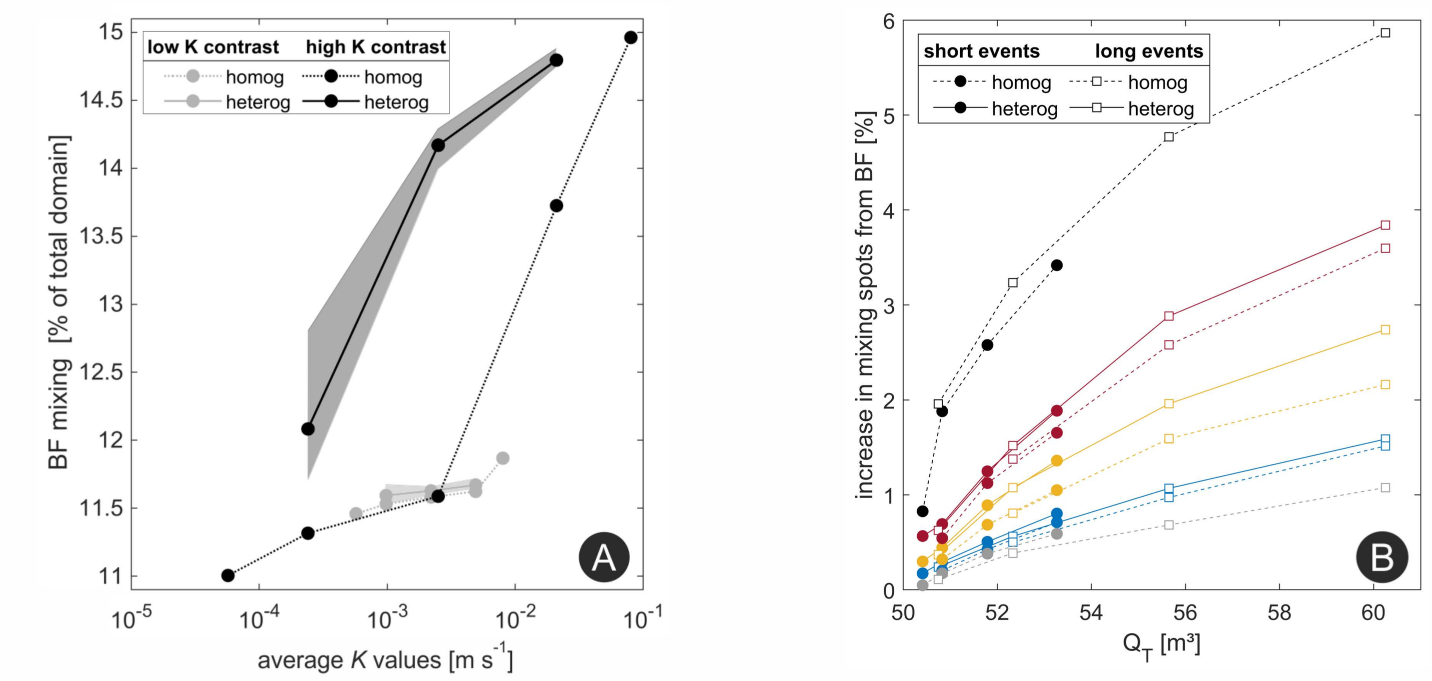
Similar EF patterns between homogeneous and heterogeneous models: subordinate impact of geological heterogeneity



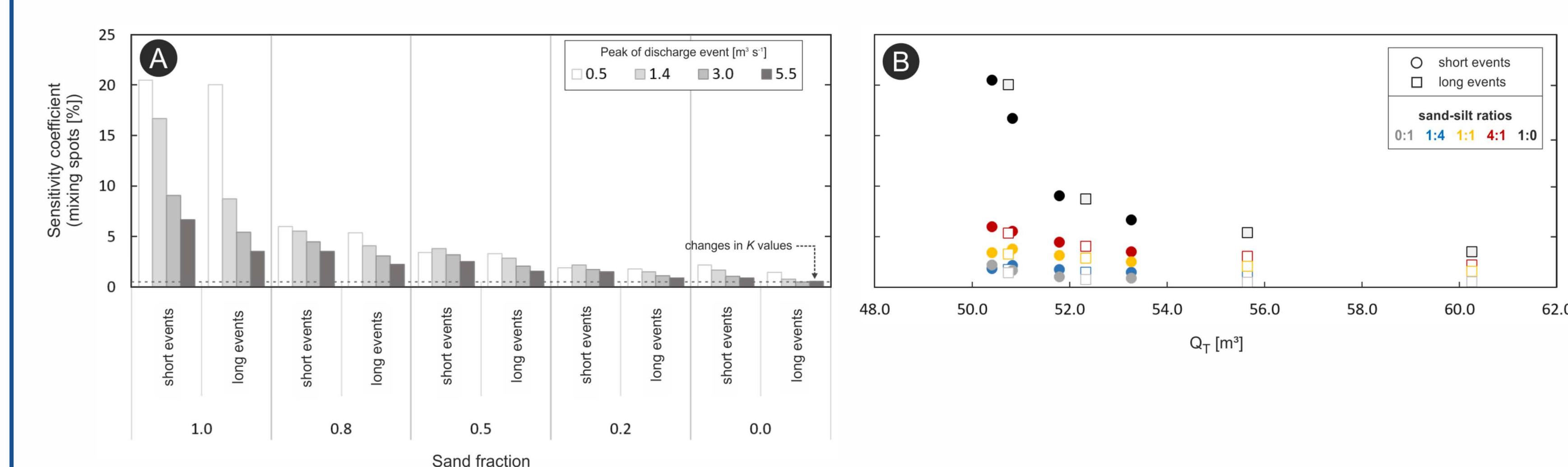
Larger increase of EF magnitudes during discharge events in heterogeneous models with higher mean *K* values in comparison to homogeneous models



4 Results: Riparian SW-GW mixing



- SW-GW mixing increases with mean *K* values (i.e., EF magnitudes)
- Larger mixing for heterogeneous models (and high *K* contrast cases) compared to their equivalent homogeneous models
- Short and more intense events lead to a larger mixing increase than longer events with similar cumulative discharge
- Higher sensitivity coefficients from hydrological variations than from change in *K* values; but sensitivity generally increases with *K* values



5 Conclusions and Outlook

- Modelling suggests a subordinate effect of reach-scale geological heterogeneity for EF patterns - but substantial for EF magnitudes
- Introduction of geological heterogeneity enhances EF and SW-GW mixing potential in comparison to equivalent homogeneous models
- For events presenting similar cumulative discharge values, short and more intense events lead to larger increases in SW-GW mixing

References

Partington D, Brunner P, Simmons CT, Therrien R, Werner AD, Dandy GC, Maier HR. 2011. "**A hydraulic mixing-cell method to quantify the groundwater component of streamflow within spatially distributed fully integrated surface water-groundwater flow models**". Environmental Modelling and Software 26 (7): 886–898 *DOI: 10.1016/j.envsoft.2011.02.007*

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