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Dynamics and hydrodynamic mixing of reactive solutes at stable fresh-salt interfaces

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In coastal zones with saline groundwater, but also in semi-arid regions, fresh groundwater lenses may form due to infiltration of rain water. The thickness of both the lens and the mixing zone, determines fresh water availability for plant growth. Due to recharge variation, the thickness of the lens and the mixing zone are not constant, which may adversely affect agricultural and natural vegetation if saline water reaches the root zone during the growing season. A similar situation is found in situations where groundwater is not saline, but has a different chemical signature than rainwater-affected groundwater. Then also, vegetation patches and botanic biodiversity may depend sensitively on the depth of the interface between different types of groundwater. In this presentation, we study the response of thin lenses and their mixing zone to variation of recharge. The recharge is varied using sinusoids with a range of amplitudes and frequencies. We vary lens properties by varying the Rayleigh number and Mass flux ratio of saline and fresh water, as these dominate on the thickness of thin lenses and their mixing zone. Numerical results show a linear relation between the normalised lens volume and the main lens and recharge characteristics, enabling an empirical approximation of the variation of lens thickness. Increase of the recharge amplitude causes increase and the increase of recharge frequency causes a decrease in the variation of lens thickness. The average lens thickness is not significantly influenced by these variations in recharge, contrary to the mixing zone thickness. The mixing zone thickness is compared to that of a Fickian mixing regime. A simple relation between the travelled distance of the centre of the mixing zone position due to variations in recharge and the mixing zone thickness is shown to be valid for both a sinusoidal recharge variation and actual records of irregularly varying daily recharge data. Starting from a step response function, convolution can be used to determine the effect of variable recharge in time. For a sinusoidal curve, we can determine delay of lens movement compared to the recharge curve as well as the lens amplitude, derived from the convolution integral. Together the proposed equations provide us with a first order approximation of lens characteristics using basic lens and recharge parameters without the use of numerical models. This enables the assessment of the vulnerability of any thin fresh water lens on saline, upward seeping groundwater to salinity stress in the root zone.