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Subsidence in the Mekong Delta, Vietnam: Impact of groundwater extraction

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Introduction

Land subsidence rates of ~1-4 cm yr⁻¹ are measured in the low-lying Vietnamese Mekong Delta (Fig. 1). These relatively high subsidence rates are attributed to groundwater extraction. On daily basis over two million m³ of groundwater is extracted from the upper 500 m of the multi-aquifer subsurface. As a result, hydraulic heads in aquifers are dropping, on average 0.3-0.7 m yr⁻¹.

Land subsidence increases flood risk, and, on the longer term, threatens the delta with drowning. To evaluate the impact of future land subsidence, we need to go from measurements to predictions. Here we present our approach to assess the subsidence potential of the multi-aquifer subsurface of the Mekong delta due to groundwater extraction under different groundwater management scenarios.

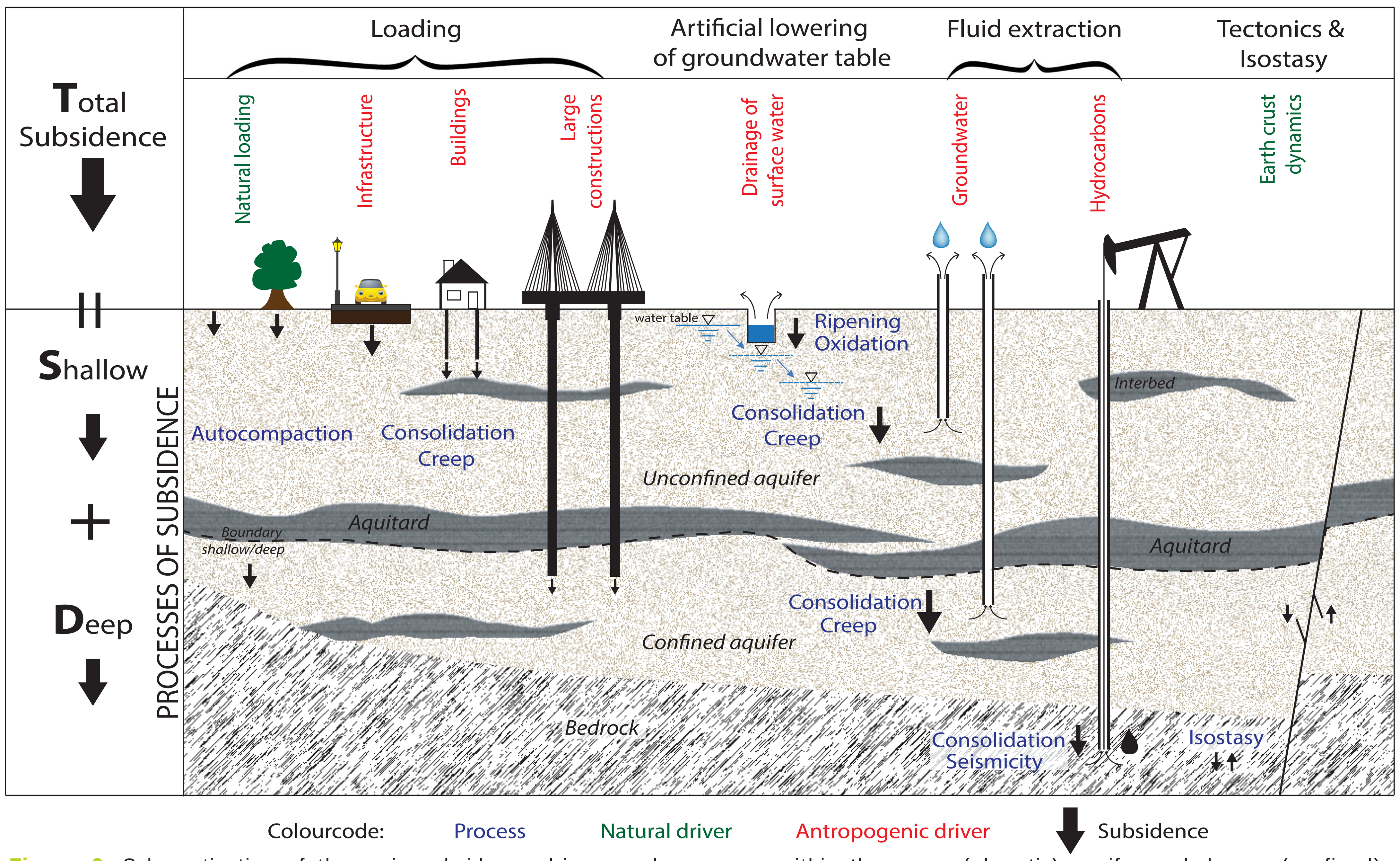

Figure 2. Schematization of the main subsidence drivers and processes within the upper (phreatic) aquifer and deeper (confined) aquifer(s). Both natural and anthropogenic drivers are distinguished. The subsidence balance equation is given on the left side, being the total sum of all shallow and deep subsidence rates.

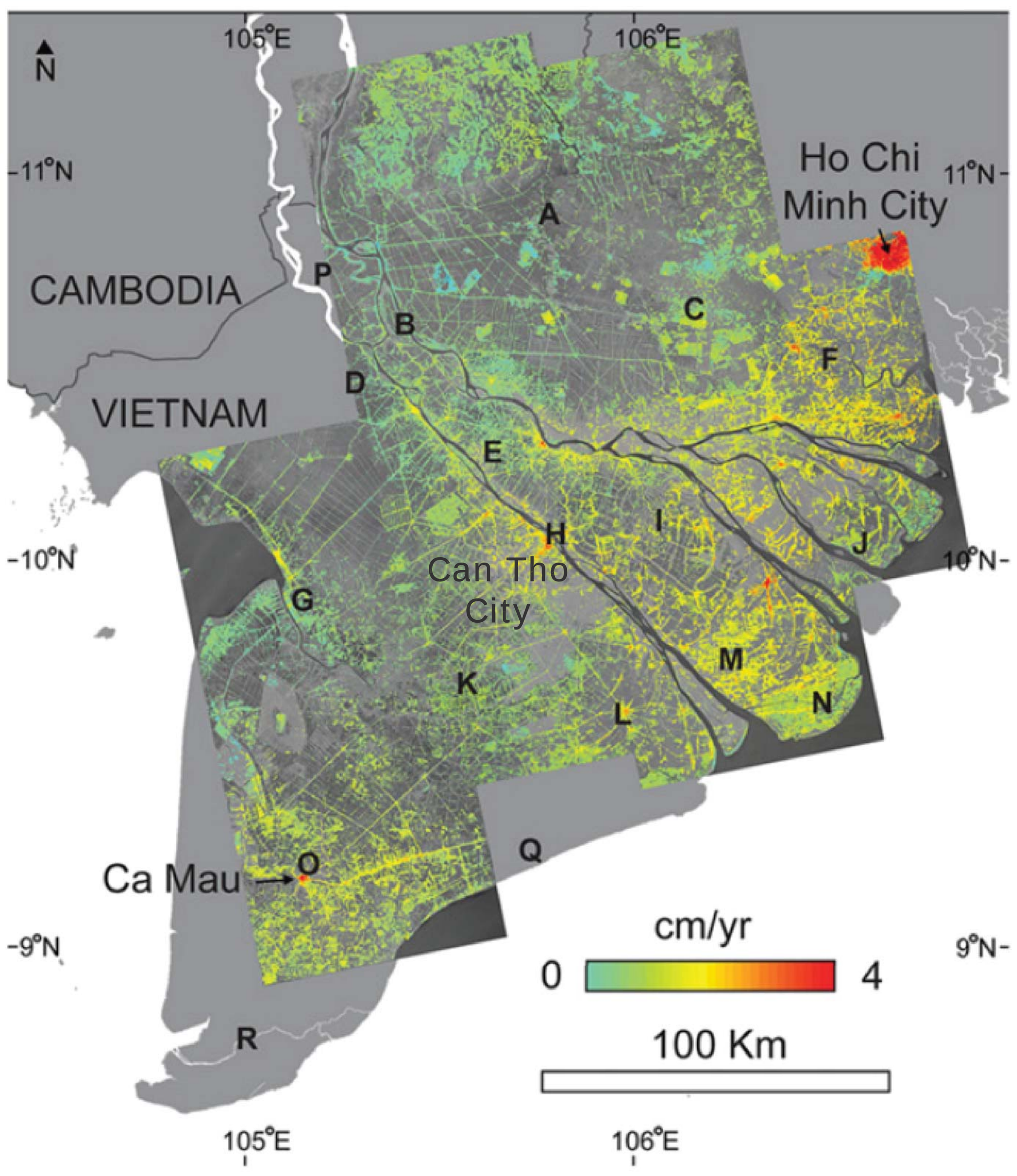

Figure 1. Satellite based (InSAR) subsidence rates measured between 2006-2010 for the Mekong Delta. Data © JAXA, METI 2011 (Erban et al., 2014).

From monitoring to predicting

Total measured subsidence at the earth surface is the sum of subsidence resulting from all natural and human-induced drivers, the subsidence balance (Fig. 2). We distinguish between shallow and deep drivers and processes of subsidence.
To determine the contribution of groundwater extraction, and to go from measuring to predicting subsidence, the cumulative signal needs to be unraveled. We develop a 3D geohydrogical model to model hydrology and calculate subsidence to evaluate the impact of groundwater extraction.

Available data

Lithological borehole descriptions

Hydraulic head and extraction well data

Physical and chemical sediment properties

Geological and geohydrological cross-sections

1: Standard penetration test 2: Logging while drilling 3: Vertical electronical sounding

+

Additions to existing models

Conceptual models of delta evolution

Lithostratigraphical analysis

Palaeogeographical analysis (Depositional environments & sediment preservation)

3D lithological interpolation

→

Outcomes

3D lithological subsurface model

Better understanding aquifer - aquitard architecture / properties

Improved distribution of sediment properties

↓

Improved geo-hydrological model

→

Gain

Hydrological model with subsidence module:

1. Unravel the subsidence balance

↓

Identify subsidence drivers and develop mitigation strategies

2. Evaluate future groundwater management scenario's

↓

Supporting decision-making towards sustainable groundwater management

Figure 3. Workflow of the approach to develop the 3D lithological subsurface model and construct an improved geo-hydrological model to enable subsidence modeling.

Results

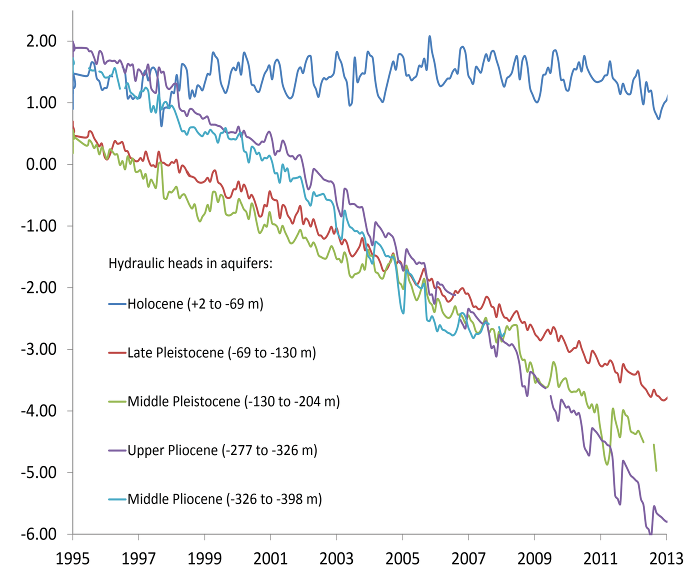

Figure 4. Measured hydraulic head time series from monitoring wells near Can Tho city, central Mekong delta. Filter depths between brackets.

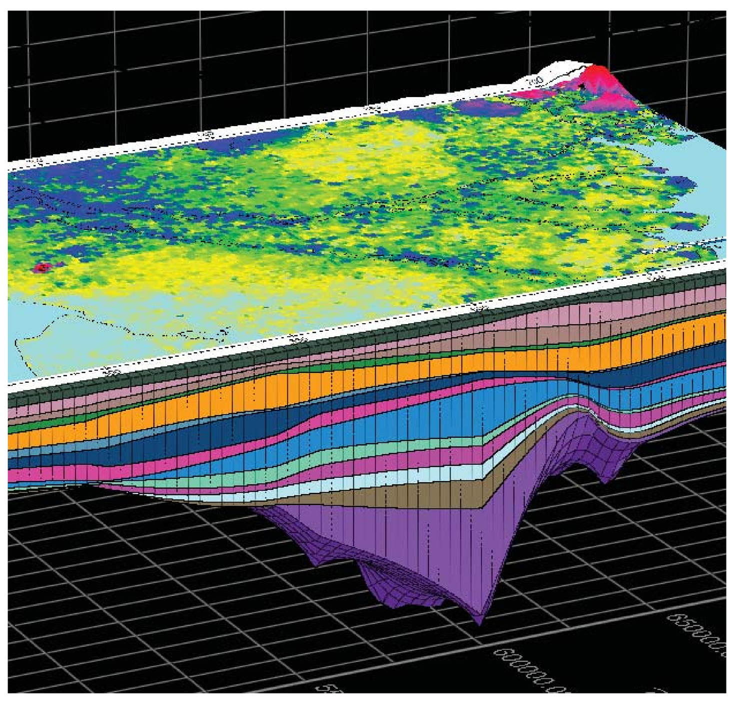

Figure 5. Visualisation of the 3D geo-hydrological model in iMOD (MODFLOW shell by Deltares) showing the DEM and subsurface architecture.

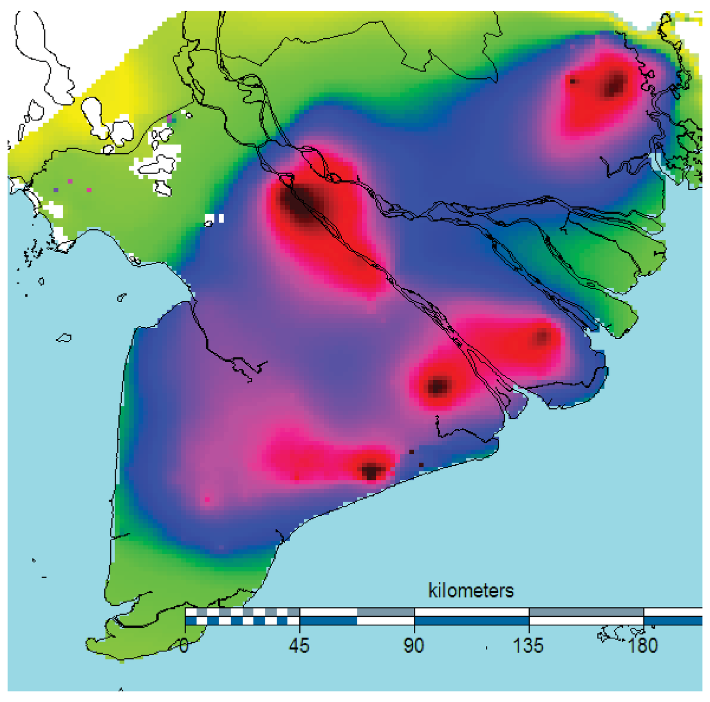

Figure 6. Spatial variability of hydraulic head decline of the Middle Pleistocene aquifer after a 25-year model run (1990-2015)*.

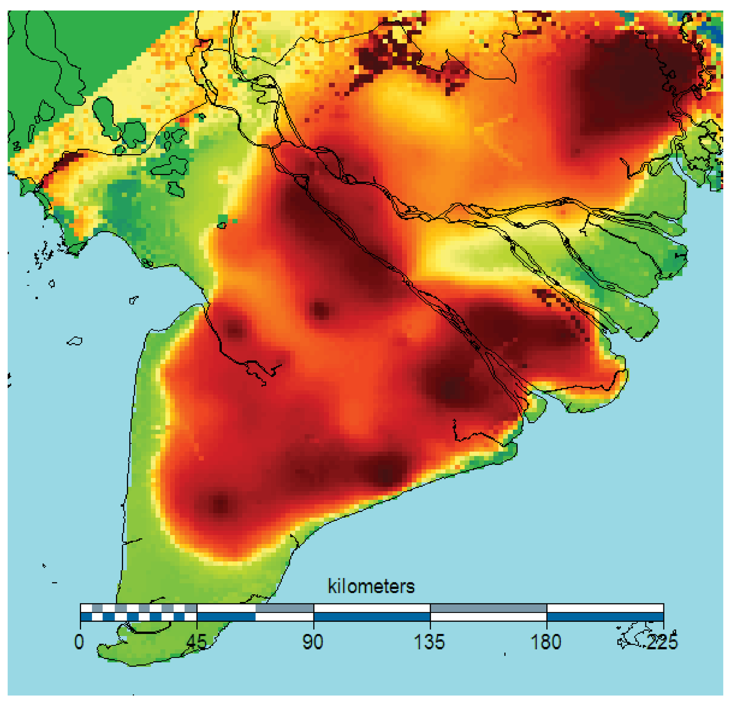

Figure 7. Total calculated subsidence for all layers (1990-2015) modeled using the coupled SUB-Cr module in iMOD (NEN-Bjerrum method)*.

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References

Erban, L. E., Gorelick, S. M., & Zebker, H. A. (2014). Groundwater extraction, land subsidence, and sea-level rise in the Mekong Delta, Vietnam. Environmental Research Letters, 9(8), 1–6.

* The results depicted are preliminary model outputs before model calibration.

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