In the context of climate change, the geological storage of carbon dioxide (CO_2) is considered as a transitional technology to reduce anthropogenic greenhouse gas emissions. Safe and reliable geological storage requires a thorough understanding of the storage reservoir and its induced spatiotemporal changes. Geoelectrical monitoring techniques are highly sensitive to compositional changes of the pore fluid and offer opportunities for spatiotemporal imaging of fluid displacement processes. Although well established in near-surface geophysics, the application of geoelectrical techniques to CO_2 storage monitoring is relatively new and entails specific practical and methodological challenges. This thesis investigates the optimal locations of electrodes along the borehole trajectories, borehole related imaging artifacts, and the integration with data sets from other monitoring techniques by means of a process-based hydrogeophysical modeling and inversion framework with an application to the pilot site for CO_2 storage at Ketzin, Germany.

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