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Temporal evolution of transition zone by EC depth profiles (Salento karst coastal aquifer, Southern Italy)

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In coastal aquifers, many factors, including sea-level oscillations, cyclic flow, aquifer geologic structure, hydraulic properties of the aquifer, seawater density, variation in groundwater recharge, and human activities that involve groundwater exploitation influence the 3D spatial distribution of salt content of groundwater. Its changes over time under the natural and human forcing locally reflect on the width and elevation of the mixing (transition) zone, with different response times compared to applied stresses depending on the aquifer size and hydrogeological features at the monitoring sites.

Groundwater depth profiles of EC in coastal aquifers allow identifying the features of the transition zone. Reliable information on the EC vertical distribution comes only from wells reaching saltwater beneath freshwater, with screens along with the entire aquifer thickness and crossing zones of prevalent horizontal flow with negligible vertical components.

The study shows the temporal evolution of transition zones reconstructed from combining periodical EC depth profiles carried out over five decades in a few special deep wells. Such wells pertain to the regional net for groundwater monitoring of the Salento karst coastal aquifer (Southern Italy). The aquifer coincides with the geological basement of the Salento Peninsula, which is a carbonate formation of the Upper Cretaceous–Palaeocene. It comprises layers and banks of fractured and karstified limestone and dolomitic limestone. Gentle folds and normal and strike-slip faults dislocate the basement. Groundwater flows in phreatic conditions with max hydraulic heads around 3 m AMSL and low hydraulic gradients. It may be locally in confined conditions because of low permeability carbonate levels or when the carbonate basement top is below mean sea level. Hydraulic conductivity is highly anisotropic because of the combination of major and minor discontinuities and surface and subsurface karst features, thus conditioning the groundwater flow. Lateral seawater intrusion and saltwater up-coning cause diffuse and progressive groundwater salinization from the 1960s because of over-exploitation.

Starting from an initial well net of deep wells set in the 1970s to monitor groundwater salinization, the number of deep wells changed over time. Some of the oldest wells are no longer operational because of obstruction, while others are more recent. As a consequence, the available EC depth profiles cover, for each well, different periods from 1974 to 2021. The evolution of EC vertical distributions allows recognizing the effects of climate variations (wet periods and droughts) that influence the hydrodynamics of the aquifer and unveiling critical transitions triggered by such

extremes. Data evolution allows clarifying the system's response to long-term exploitation in a more effective and comprehensive way than the only variations in groundwater levels. Because of the regional scale of the flow system, the high natural storage, and high groundwater residence times, this response shows lags compared to disturbances (as exploitation, recharge variability, droughts). The significant storage acts as a buffer, allowing cushioning from their adverse effects. Over time, the transition zone deforms with distinct upward expansion leading, in the most severe cases, to the disappearance of the freshwater of low salinity observed in the wells in the 1970s.