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# Coseismic hydrogeologic response to the 2019 Ridgecrest Earthquake in the fault system at Devils Hole, Nevada


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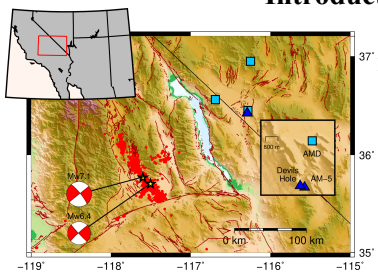
## Abstract


Hydrogeologic responses to earthquakes, either statically or dynamically, are well-documented. Such responses provide information about physical properties of subsurface material and structure. Devils Hole, a fluid-filled fault cavern located in Death Valley National Park (Nevada), is documented as one of the most sensitive water levels in the world to far-field earthquakes. In July 2019, the Mw6.4 and 7.1 Ridgecrest, California earthquakes occurred less than 150 km from Devils Hole. In this study, we analyze water level response data to the earthquakes at both Devils Hole (DH) and an adjacent shallow monitoring well (AM-5). The water level at Devils Hole is connected to a fractured carbonate rock aquifer while the AM-5 well is completed in the Valley Fill Aquifer unit, which is a subunit of the Basin Fill Aquifer. Coseismic groundwater decline of about 0.3 ft is observed at Devils Hole through July 2020. A static strain change due to the fault dislocation does not explain the coseismic water drop, suggesting other mechanisms need to take into account. In comparison to previous major California earthquakes (e.g. the Mw7.3 Landers and the Mw7.1 Hector Mine), groundwater response from Ridgecrest Earthquake shows a gradual recovery lasting about 118 days. We estimate the hydraulic diffusivity *D* during both coseismic and postseismic phases, given a nearly identical D~0.1 $m^2/s$. The pressure drop was about $1.8 \times 10^3$Pa. No coseismic water level offset was identified at AM-5. This might indicate strong heterogeneity in hydrogeologic properties between the fault-zone system at Devils Hole and the AM-5 monitoring well. Analysis of the tidal response of both water levels shows positive phase shifts (leading) of about 12 to 15 degrees, suggesting possible vertical leakage of the aquifers. Temporal fluctuations in phase shift might indicate variations in degrees of leakage in the fault-system. A significant drop of phase shift is observed after the Ridgecrest Earthquake at the AM-5 well. On the contrary, no significant change in phase shift was observed at Devils Hole. We suspect the difference in groundwater observatory setting between the fractured carbonate rock aquifer and the Valley Fill aquifer is producing the heterogeneous hydrogeologic response to earthquakes observed in the Devils Hole region.

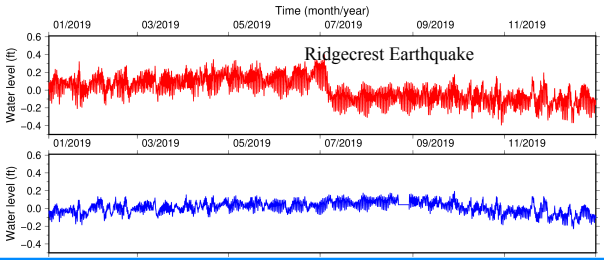

## Introduction



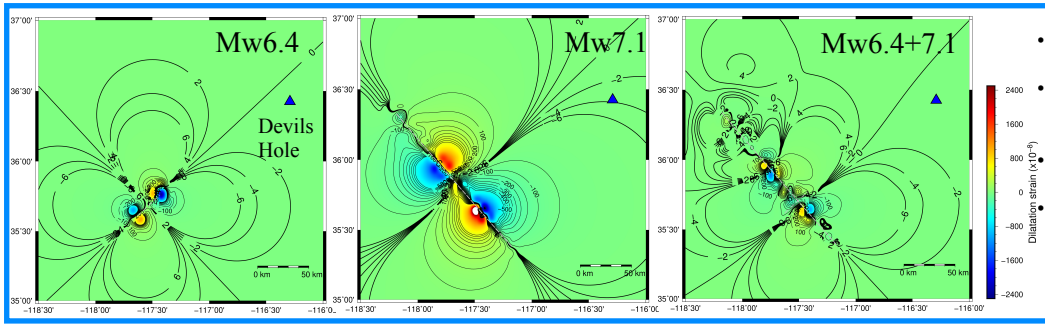

**Devils Hole:** Fluid-filled fault zone

- One of the most sensitive place of hydrologic responses to far-field earthquakes (Weingarten and Ge, 2014).
- Fault-zone surface station (Devils Hole station) and AM-5 well (depth ~ 200ft).
- Continuous groundwater level observation (sampling rate: 15min/p, 1mim/p during earthquakes)

**Red:** Devils Hole
**Blue:** AM-5 well

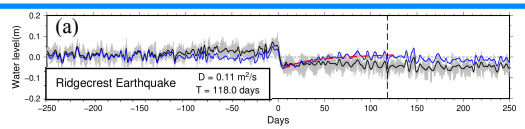


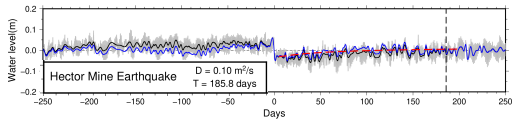

## Static volumetric strain change due to dislocation

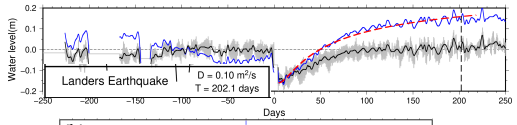



- Volumetric strain change was obtained from Coulomb3 (Toda et al., 2011)
- Fault model of Mw 6.4: homogeneous slip model with source information inferred from GCMT solution
- Fault model of Mw 7.1: USGS finite fault inversion
- Similar result from three cases showing Devils Hole is located in the contraction zone, with strain value ~ $10^{-8}$

## Coseismic and postseismic groundwater level

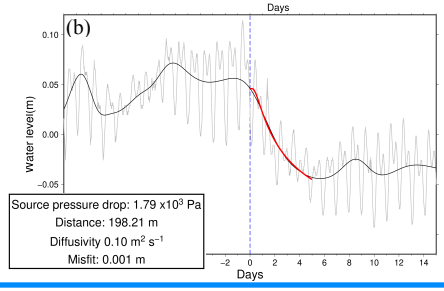



(a) Postseismic analysis for three major earthquakes.
Thin gray: original data
Thin black: after HHT (high modes removed)
Thin blue: after HHT (high modes + Seasonal trend removed)
Dashed red: nonlinear fitting of Eq(1)

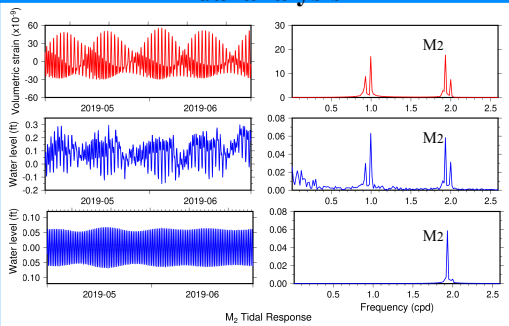
(b) coseismic analysis (5 days since Mw6.4)
Gray thin: original data
Black thin: after HHT (high modes removed)
Red thin: nonlinear fitting of Eq(1)

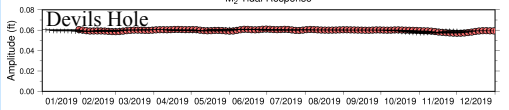


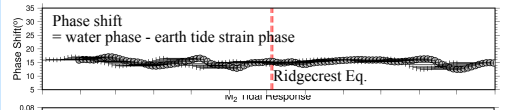

$$h = h_0 - \frac{p}{\rho g} erfc \frac{x}{\sqrt{4Dt}}$$

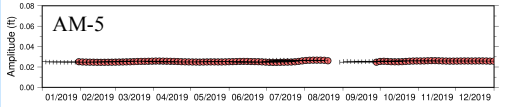
Eq(1): solution for the diffusion Equation
*h*: water level; *h₀*: preseismic level;
*p*: pressure drop; *x*: source distance;
*D*: diffusivity

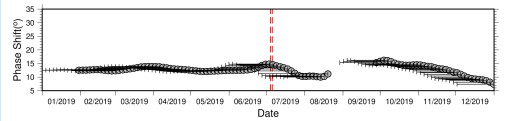
## Tidal analysis





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