Which earthquakes are the most damaging? An examination of community-collected ‘Did You Feel It’ observations in California, USA

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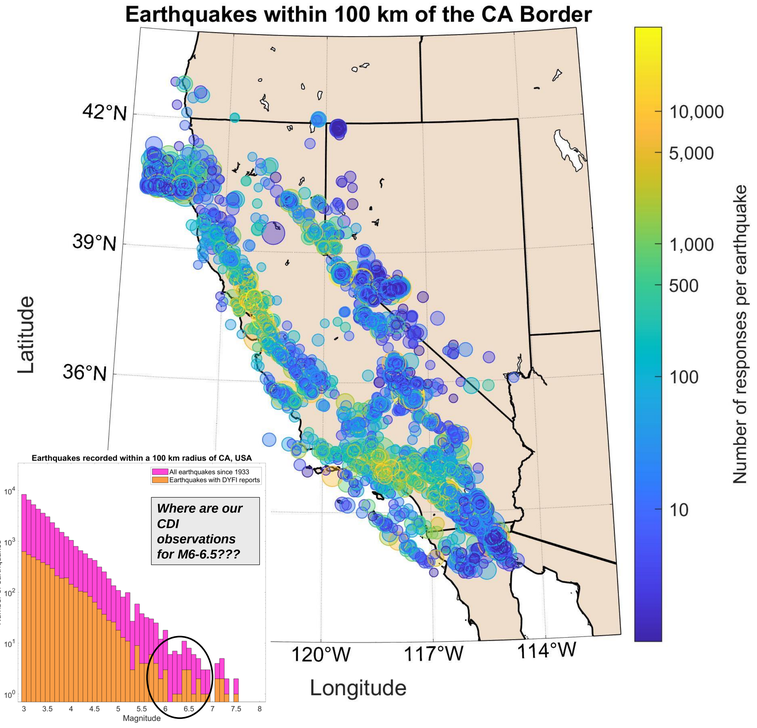
Motivation and Background

- The DYFI project is a compilation of community-sourced reports of shaking experiences translated into shaking intensities using the MMI category definitions. DYFI observations have been used as ground truth for developing ground-motion models like ground-motion-to-intensity conversion equations (GMICEs) used in ShakeMap and ShakeAlert.
- Minson et al. found that most shaking comes from earthquakes that are so small that they were not expected to produce strong shaking; we call them little earthquakes with ambition (Minson et al., 2020).
- If we relate shaking to damage, are little earthquakes also the main source of damage? Do we see this with the reported Did You Feel It (DYFI) intensities?
- While **seismic hazard maps include hazard from little earthquakes** with ambition, **these earthquakes aren't usually a focus** when discussing earthquake hazard with the public.

Methods

- DYFI reports are aggregated into 1 and 10 km geocoded regions. We are **presenting analysis of the 1-km geocoded cell reports.**
- Users can **retroactively** report their earthquake experiences through the DYFI survey; **we have records of DYFI back to the 1933 Long Beach earthquake. We include these historical event reports in our analysis.**
- We choose to **examine DYFI information from M3+ earthquakes in and around California** due to the abundance of seismic activity in and/or near densely-populated areas.
- We gather **all available 1 km aggregated CDI observations from earthquakes within CA and within 100 km of the CA boundary** (matching the UCERF3 boundary for earthquakes that contribute to seismic hazard in CA).
- We apply a **filter to remove responses that are located 600km+** away from the EQ epicenter.
- Over half of the DYFI 1km geocoded data are represented by one respondent. We keep this in mind in our analysis but **decide to keep all data, regardless of number of respondents.**
- We present preliminary analysis of **628,251 DYFI-derived CDI observations from 4,598 unique events.**
- **CDI** or **Community Decimal Intensity**, is a processing product of DYFI surveys that communicates intensity (on a similar scale to the Modified Mercalli Intensity scale).
- The DYFI catalog contains: CDI observation; CDI location (latitude, longitude, UTM location); the number of DYFI reports used for the CDI aggregation; distance between CDI location and earthquake epicenter; and earthquake catalog information
- **97% of the CDI observations are from earthquakes that occurred after 1999**, the year that DYFI released online.
- **61% of the CDI observations are represented by only 1 DYFI report; 2.8% of the CDI observations are represented by 10+ DYFI reports**.

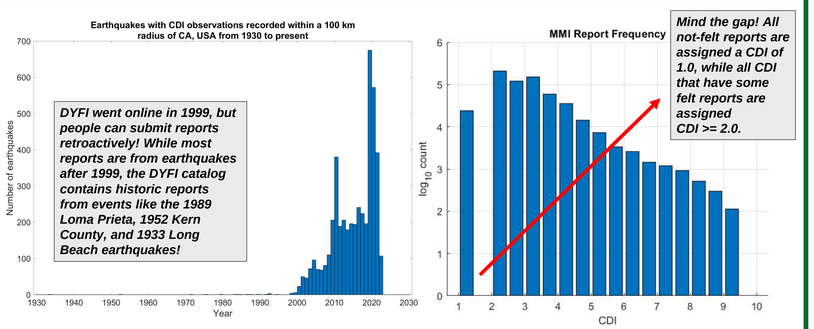
Earthquakes within 100 km of the CA Border



Take away points

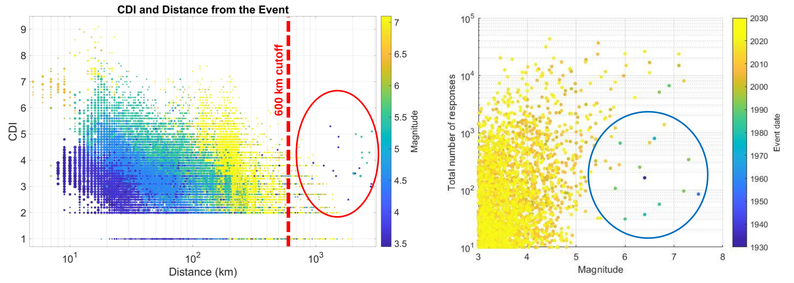
- **We know that the main source of shaking comes from little earthquakes with ambition – but is this true for damage?**
- **We analyze 628,251 Community Decimal Intensity (CDI) observations (similar to the modified Mercalli intensity) from earthquakes within, and 100 km outside of, the state of CA. This DYFI catalog represents a wealth of intensity observations that could be used to update ground-motion modeling relationships.**
- **Observations of potentially-damaging shaking (CDI>5) occur for smaller earthquakes a well as the larger earthquakes, suggesting that we should include communications about the hazard from smaller earthquakes that occur more often than larger events.**

Results

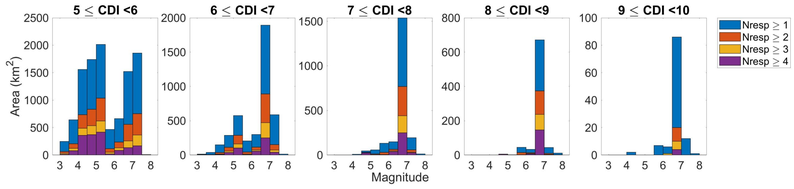


We guide our decisions about data QA/QC by considering the distributions of CDI with distance for the top 10 earthquakes with the most DYFI reports (below). Choosing a distance cutoff of 600 km removes the most obvious outliers (red circle). Further refinements to identify outlier CDIs within 600 km will improve overall data quality.

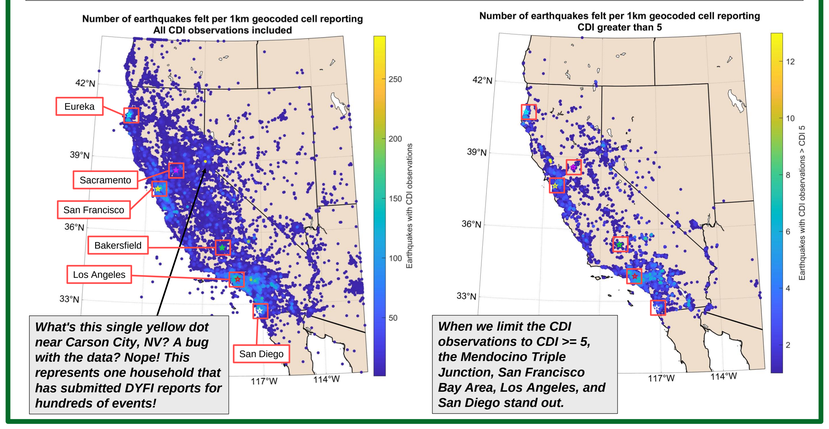
Evaluating the total number of responses per earthquake (below) reveals that smaller-magnitude earthquakes can have a range of total responses, but a majority have lower total responses. Larger magnitude events have higher responses except for historic large events with retroactive DYFI reports (blue circle).



Let’s separate earthquakes by their CDI observation values, and then by magnitude!

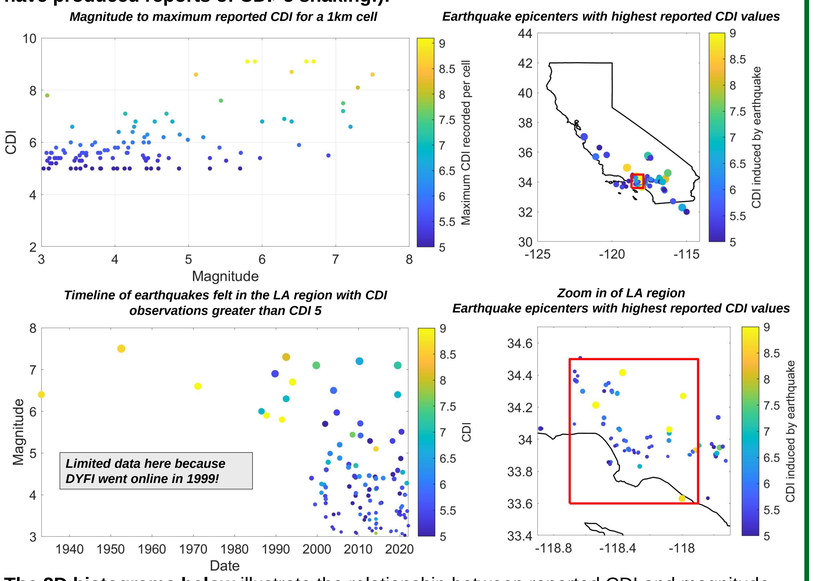


We separate CDI observations into categories and find the number of CDI responses for a given magnitude (above). We show these distributions in terms of area (each 1 km cell of CDI represents 1 km² of area). We also separate the observations by how many DYFI reports contributed to each CDI observation. More than 50% of the CDI observations in our catalog only use 1 DYFI report to determine CDI.

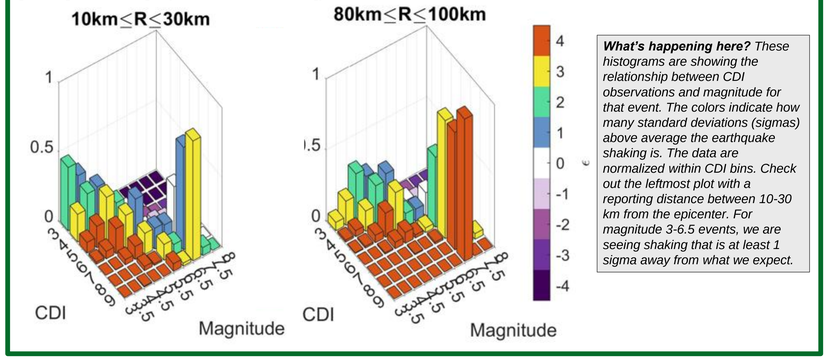


Results continued

Earthquake history through the lens of DYFI: For a hypothetical person living in Los Angeles, San Francisco, etc., what would their experience with damaging shaking look like according to the DYFI observations we have? We evaluate the maximum-reported CDI for each earthquake that produced reports of CDI 5+ shaking within a given region (red box in the maps below). **Here's a look at the Los Angeles area (there are many M<4.5 earthquakes that have produced reports of CDI>5 shaking!):**

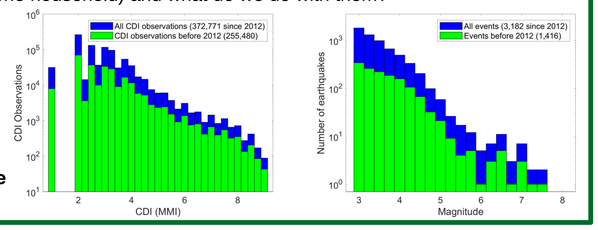


The 2D histograms below illustrate the relationship between reported CDI and magnitude within a given distance range from the earthquake source. **Each bar is colored by the average departure of these CDI values from median-expected MMI determined by ground-motion models** (Boore et al. [2014] GMPE, VS30 of 350 m/s, and Worden et al. [2012] GMICE [Equations 3 and 10]).



Interesting observations and further questions

- **Where are the M6 events** that we see in the earthquake catalog but do not appear to have any DYFI reports?
- U.S. applications of intensity-based ground-motion models like ShakeMap and ShakeAlert rely on the Worden et al. (2012) GMICE. **The DYFI catalog has expanded significantly since the publication of this paper, and we now have 2x more earthquakes and over 370,000 more CDI observations for this region since 2012 (see below).**
- **How can we standardize this dataset** as a common repository for use in efforts to update intensity-based ground-motion models?
- What does the regional analysis of DYFI data (top panel) look like for other areas like San Francisco? Or downtown Los Angeles versus north Los Angeles?
- **Do we need to consider number of respondents** when analyzing these data?
- How do we go about finding ‘quirks' in the dataset (e.g., the CDI location containing several hundred reports from one household) and what do we do with them?
- How do we further analyze and compare these findings in a context of earthquake early warning?
- **How can we quantify CDI observations to find the ‘main’ source of shaking?**



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Acknowledgments

We utilize MATLAB R2021a in the analysis we present. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.
Interested in viewing DYFI data yourself? Check out this link: https://earthquake.usgs.gov/data/dyfi/ or scan the QR code to the right! Data for this project was last accessed June 1, 2022.
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Scan me to view the DYFI catalog!