Visual exploration and analysis of time series earthquake data

XSEDE ESRT project

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Research motivation

Earthquake hazard estimation is an important problem. It requires long term past records of earthquakes at all scales (magnitude, space, time)

Problem: We neither have, nor could gather such data from the field

Solution: Develop synthetic method based on first principals to generate such records that could bridge this critical gap of missing data

RSQSim visualization : Amit Chourasia, SDSC

RSQsim

Generates synthetic quakes at all scales i.e. magnitude, space and time

Computation

- Code runs on O(1K) cores with O(100K) elements
- Future needs: O(1M) elements
- Memory usage scales as N_{elem}^{2}

Scaling and optimization work by Dmitry Pekurovsky (SDSC)

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Output data

Event (12 variables): csv file

Fault geometry (11 variables): csv file

Event action (8 variables + index) : binary files

The data is spread over 11 files (2 ASCII, 9 binary)

Sample data catalog	
Size	2.4 GB
Files	2 ascii, 9 binary files
Catalog time duration	From 50k to 90k years (40k years)
Number of events	5,970,621
Event variables	12
Number of fault patches	260,051
Fault patch variables	11
Number of event actions	19,127,461
Event action variables	8

Early data exploration

- Number of events per year (frequency)
- Max magnitude for each year (maxM)

~ 40,000 records with year, frequency and maxM

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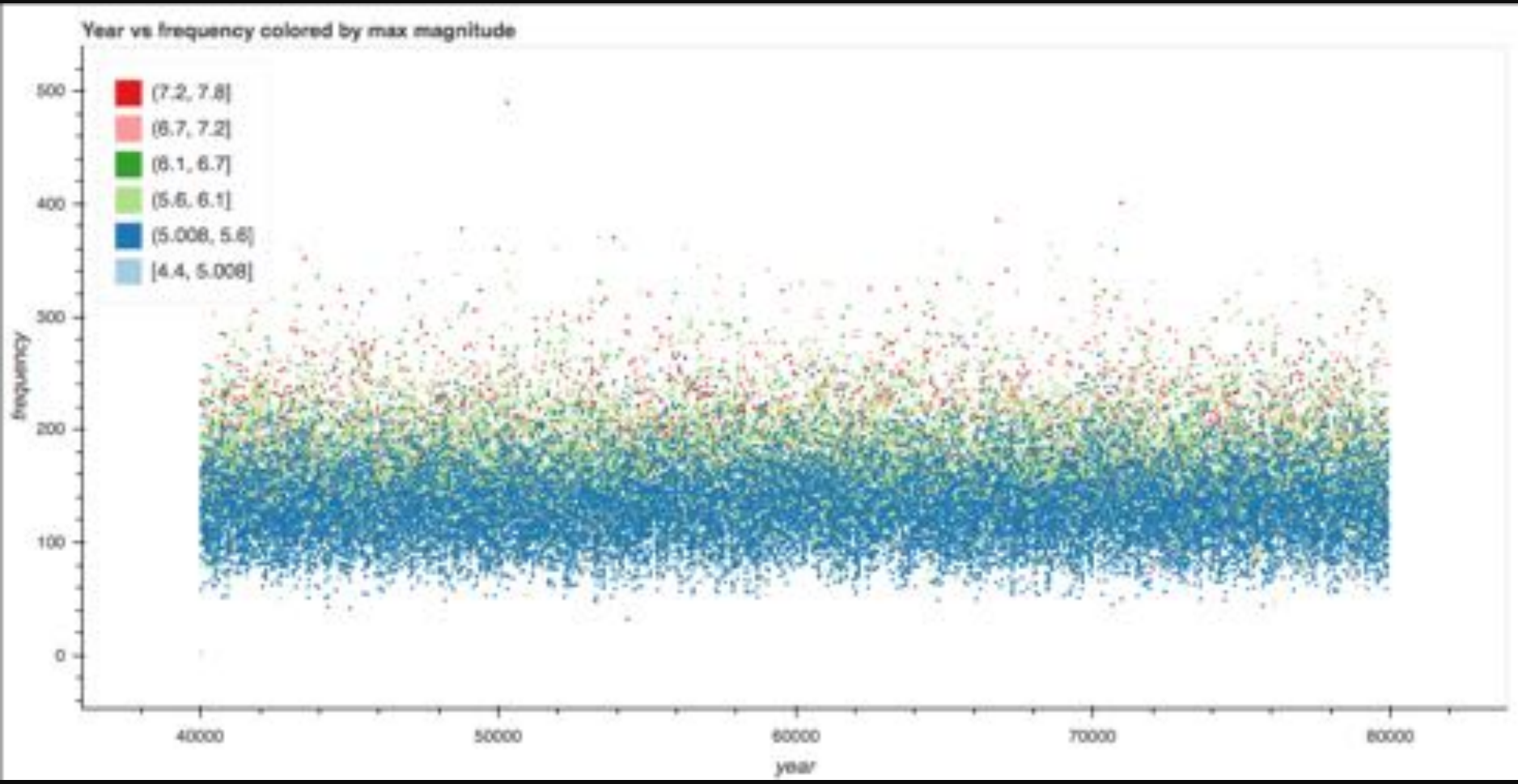

<500 events per year

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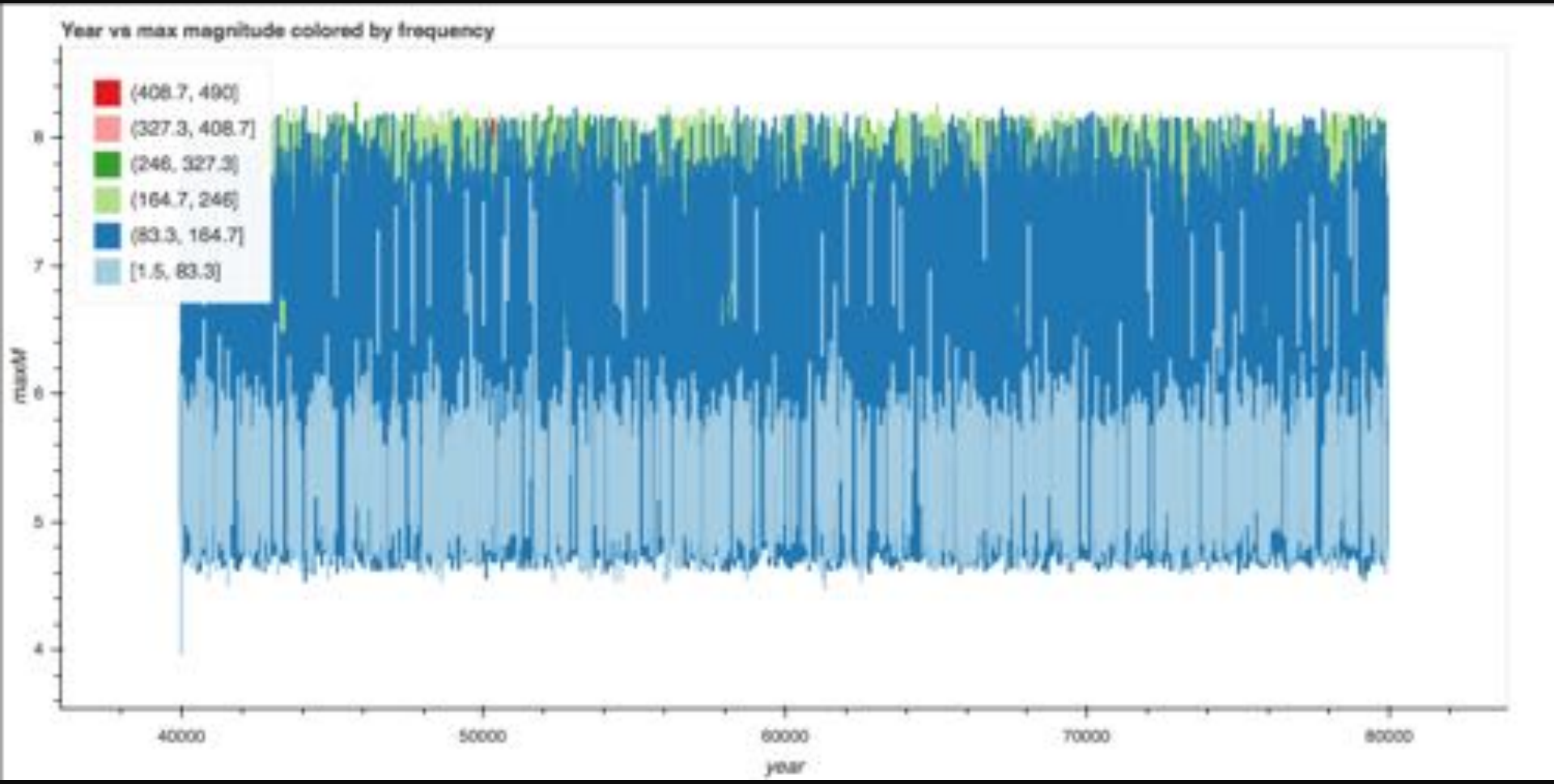

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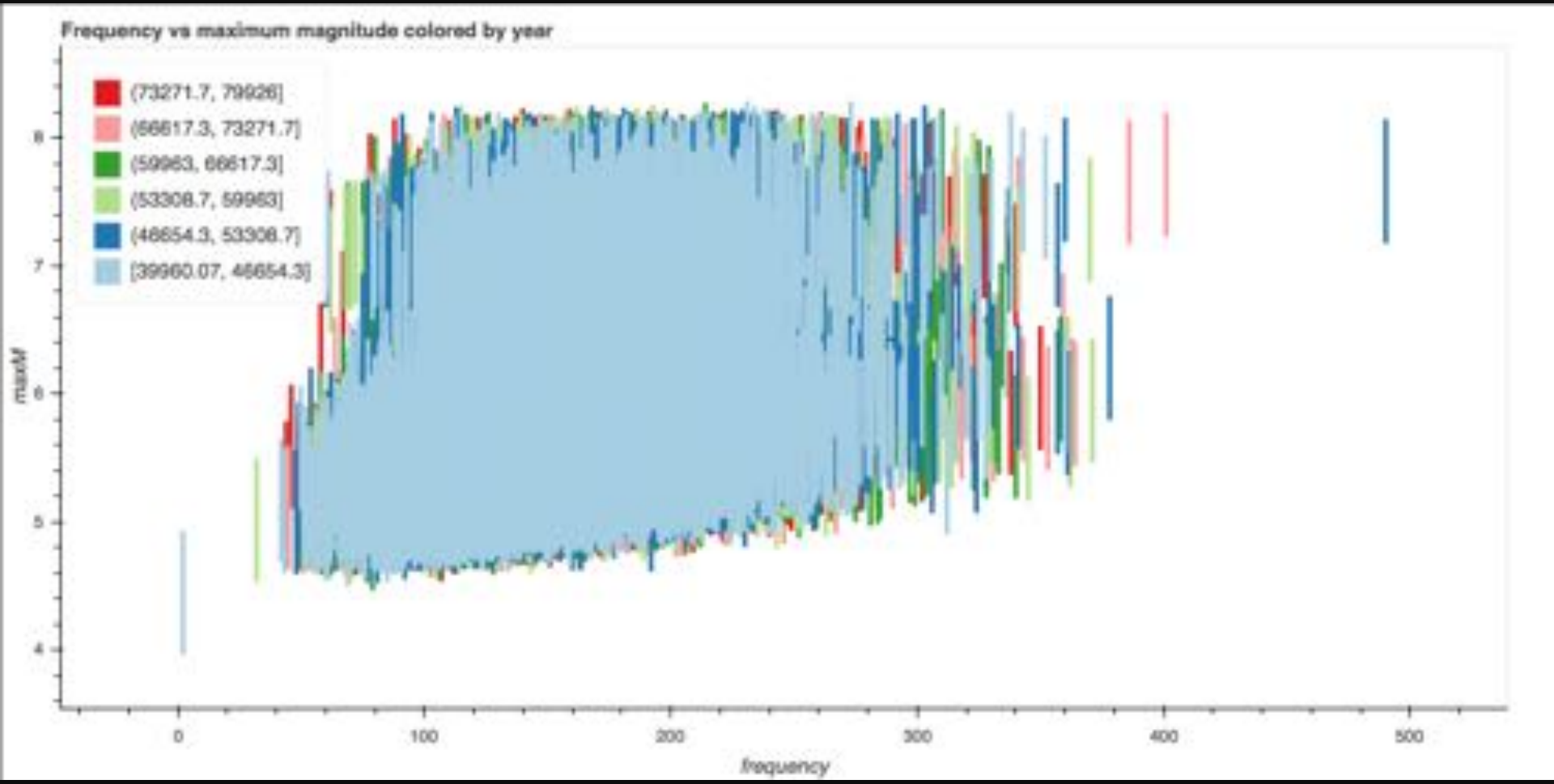

RSQSim visualization : Amit Chourasia, SDSC

Project initiation

- Scientist has a custom 3D interactive vis application
  Lacks geographic context
  Lacks multiuser capability
- Develop an interactive visualization in 2D with richer geographic context, ideally usable from a web browser

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Challenges

Data marshaling

- Normalize index to 1 based
- Normalize variable names
- Translate 3D data to 2D
  (triangle patches stored with vertex + 3D rotations)
  (rectangle patches stored with center + length, width + 3D rotations)
- Add geographic projections from UTM to EPSG 4236
- Consider using raw data vs database

Visualization

- What to display?
- How to display? Which visualization idioms to use?
- Can it work in a web browser?

Visualization goal: Support geographic exploration

- Show an event
- Show fault patches affected by the event
- Interactive

Implementation

Developed a web app using the following

- Python
  - Flask framework : server/client brokering
  - Folium : map plotting
- JavaScript
  - Leaflet : mapping
  - C3JS : time series plots
  - noUISliderJS : mobile friendly sliders
- HTML

Implementation Phase 1

- Build an app with raw data
- Data wrangling

  Format switched from ASCII to binary

  Need to also support rectangular patch elements stored with different scheme

Problems

Slow start up 20 min (pickling brought it to 2min)

Considerable memory use

Painful development/debugging

Implementation Phase 2

- Transform data to database
  - Which database to use?
  - Develop database schema?
  - Verify data translation to database
  - Verify and validate geographic projection transformations

- Retool application to use database
  - Switch search patterns to queries
  - Slow query performance

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Implementation Phase 3

- Develop user interface

  Select event by ID (~ 6M)

  Select event by time (40,000 years at second granularity)

  Other filters

- Link map display with time series
- UI needs to be mobile friendly

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Visualization design

Show selected event with ID: 1419930

Show fault patches affected by selected event (595affected)

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Show trail before/after events (± 5 events connected by a line)

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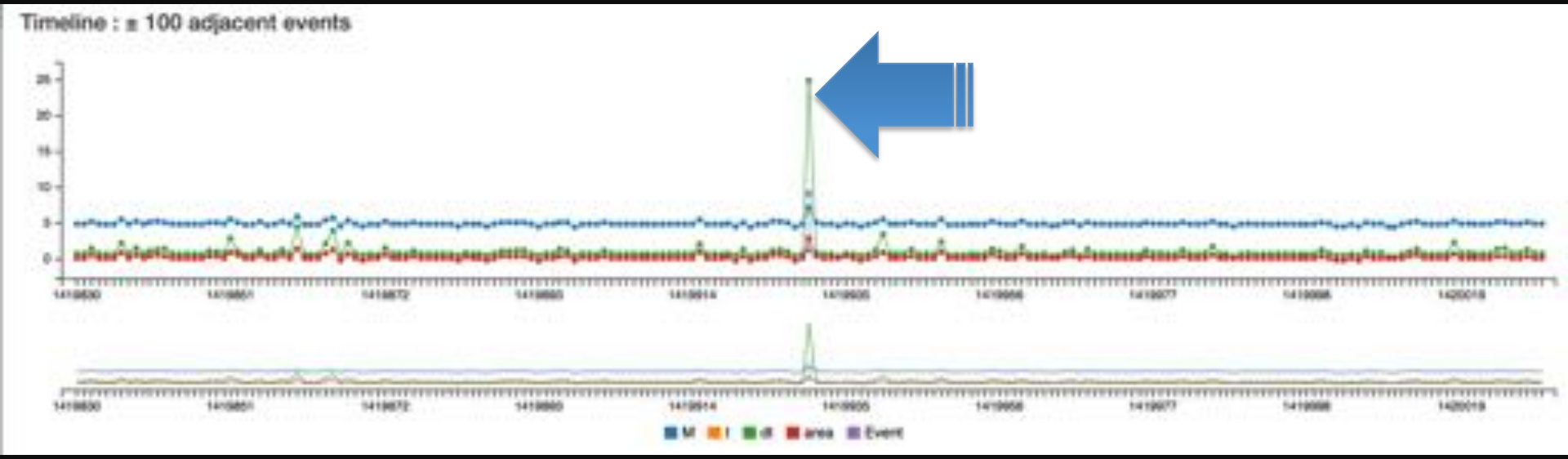
Show time series adjacent to selected event (± 100 events)



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Interaction

- Selection
  - Event
  - Time
- Filters
  - Magnitude
  - Number of patches
  - Trail events
- Map
  - Layers
  - Markers pop-ups
- Time series
  - Linked with map
  - Enable constraints

Demo: http://vis.sdsc.edu:5555

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Analysis

Calculate mean recurrence interval for all fault sub sections (~2600)

- With nucleation only: 1,785 sec
- With participation: 12,613 sec
- Verify and validate calculations

Benchmark hardware

MacPro workstation
2x 2.26 Ghz Quad Core Intel Xeon processor
16 GB memory

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Conclusions

- Transformed data to a database
  - Normalized data with mixed index in raw data
  - Easier data management/sharing, only one file
  - Scalable, as data does not need to be loaded into memory
  - Fast and easy querying

- Developed interactive visualization web application
  - Enables quake exploration in rich geographic context for a large catalog
  - Can support multiple concurrent users

- Provided sample scientific analysis script
  - Mean recurrence interval with nucleation and with nucleation and participation

ESRT project deliverables

- Translation script to create SQLite database from raw data
- Web based visualization application
- Analysis script and other query examples
- Documentation

Potential for research team

- Use less code for analysis (no parsing needed)
- Maintain less error prone code for analysis (queries simplify manual filtering)
- Write output data to SQLite database from simulation instead of ascii+binary files
- Scientists will need to learn to write SQL queries

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Technical lessons learned

Gained familiarity with

- Database schema design
- SQLite database
- Benchmarking and optimizing database queries
- Python modules and framework

  Found a bug in Folium with geojson data
- JavaScript libraries

  Found a bug in popular heatmapjs plugin for Leaflet
- Developing web based graphical user interface

Future possibilities

RSQSim gateway

- Data service
  Allow web based querying
  Allow download of filtered data

- Light visualizations
  Allow spatial filtering
  Add heatmap

Publication

Chourasia, A., Richards-Dinger, K. B., Dieterich, J. H., and Cui, Y. Visual exploration and analysis of time series earthquake data. To be presented at the PEARC 17 conference, New Orleans, LA, Jul 10, 2017

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