Distributed Systems and Natural Disasters

BitTorrent as a Global Witness

Zachary Bischof, John Otto, Fabián Bustamante

Northwestern University

Distributed Systems in the Wild

- Distributed systems are becoming fully integrated into our daily lives

- Pervasive distributed systems provide a vantage point for monitoring our networked society
  - *Can they act as witnesses of natural and man-made phenomena*

BitTorrent as a Witness

- Why BitTorrent?
  - One of the most popular distributed systems
    - Over 100 million users
  - Users around the globe

- When a group of users that share some trait leave BitTorrent, it could be due to a common event

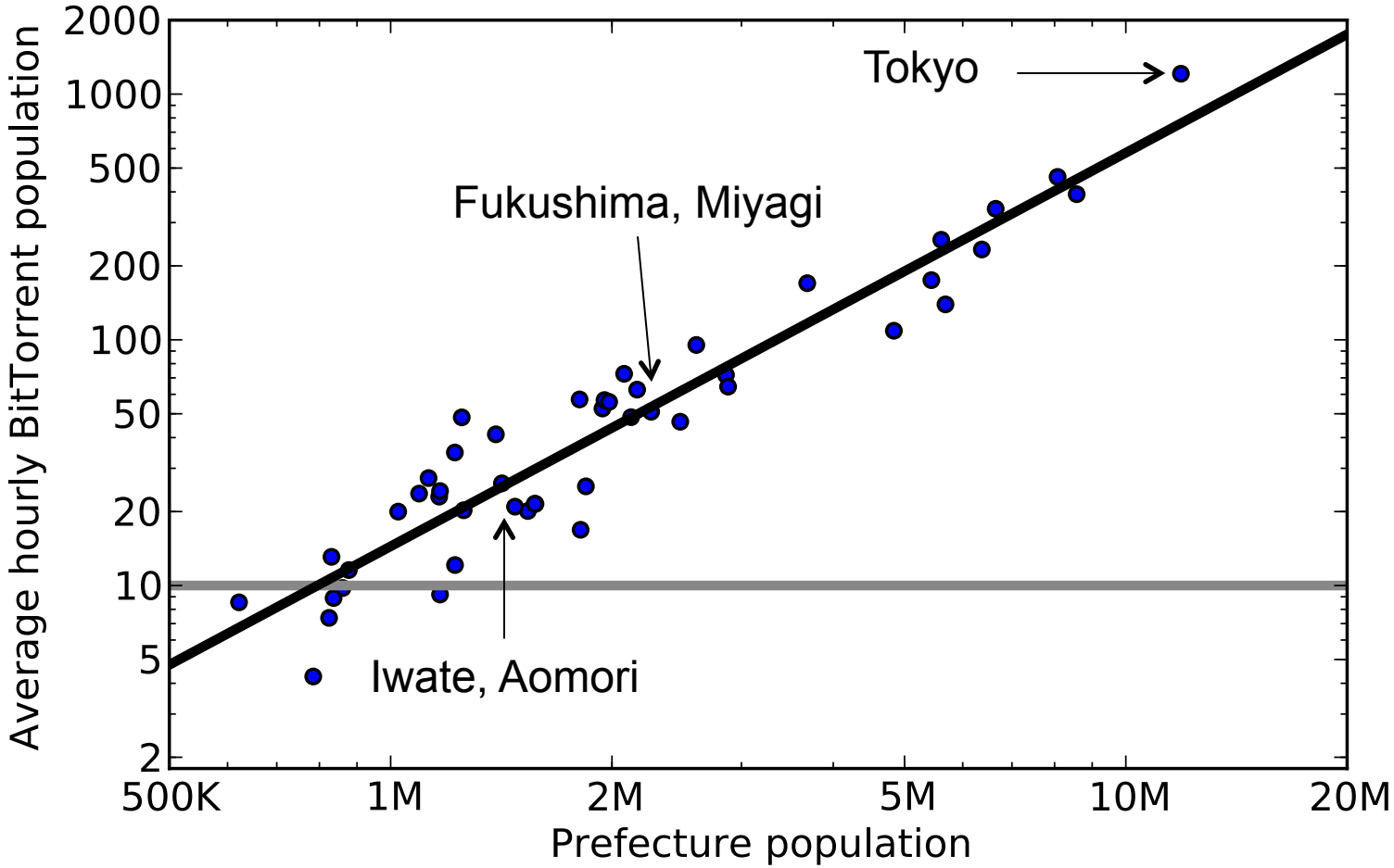
Disaster Impact on BitTorrent Population

- Look for relationship between disaster intensity and effects on BitTorrent population

- Snapshots of BitTorrent usage
  - Data collected by Ono – client extension for Vuze
  - List of connected peers

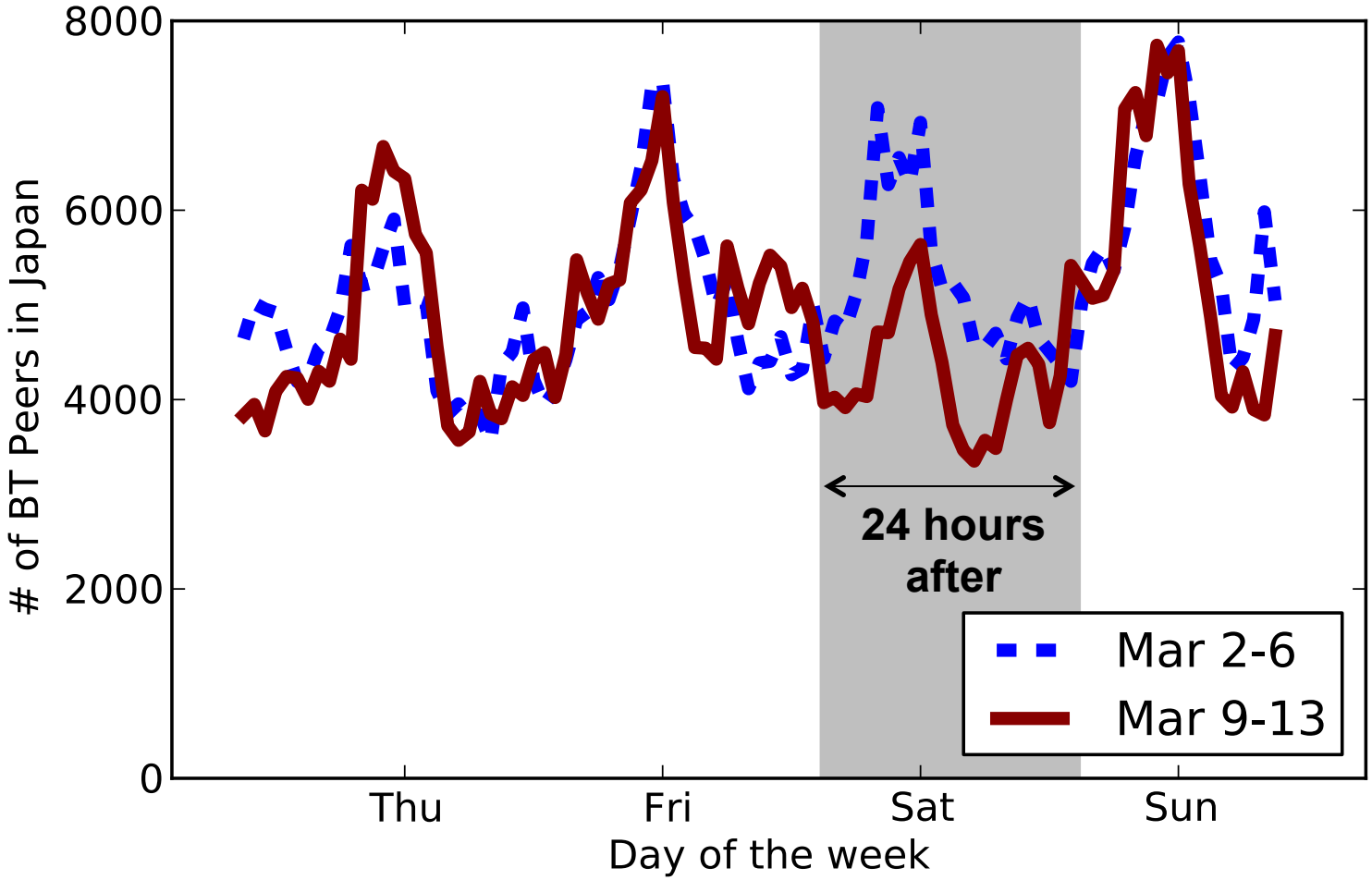
- Datasets on the disaster
  - Tsunami data (148 locations) Japan Meteorological Agency
    - Intensity measured by maximum water level
  - Earthquake data (1,218 locations) JPL, NASA
    - Intensity measured by ground displacement

BitTorrent Usage in Japan



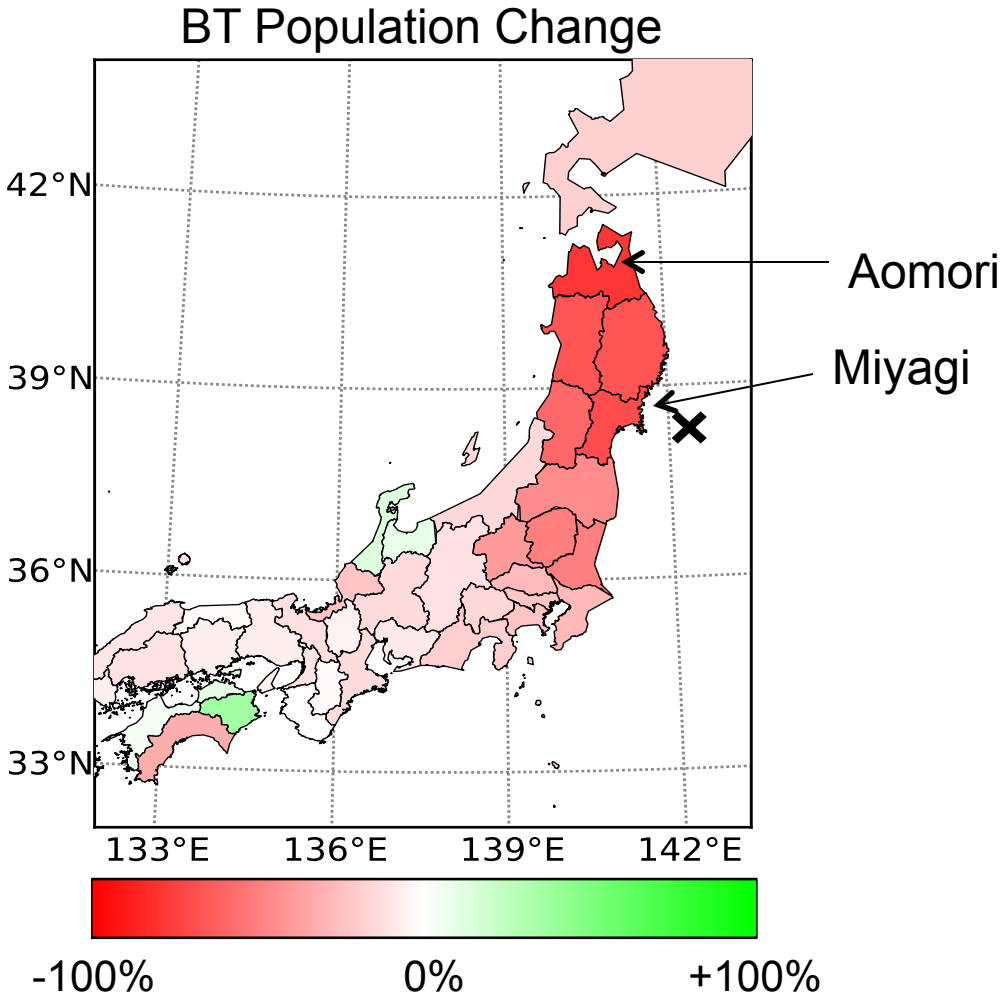
- Strong correlation ($r = 0.90$) between prefecture population and number of BT users

Japan – Country-wide BT Population



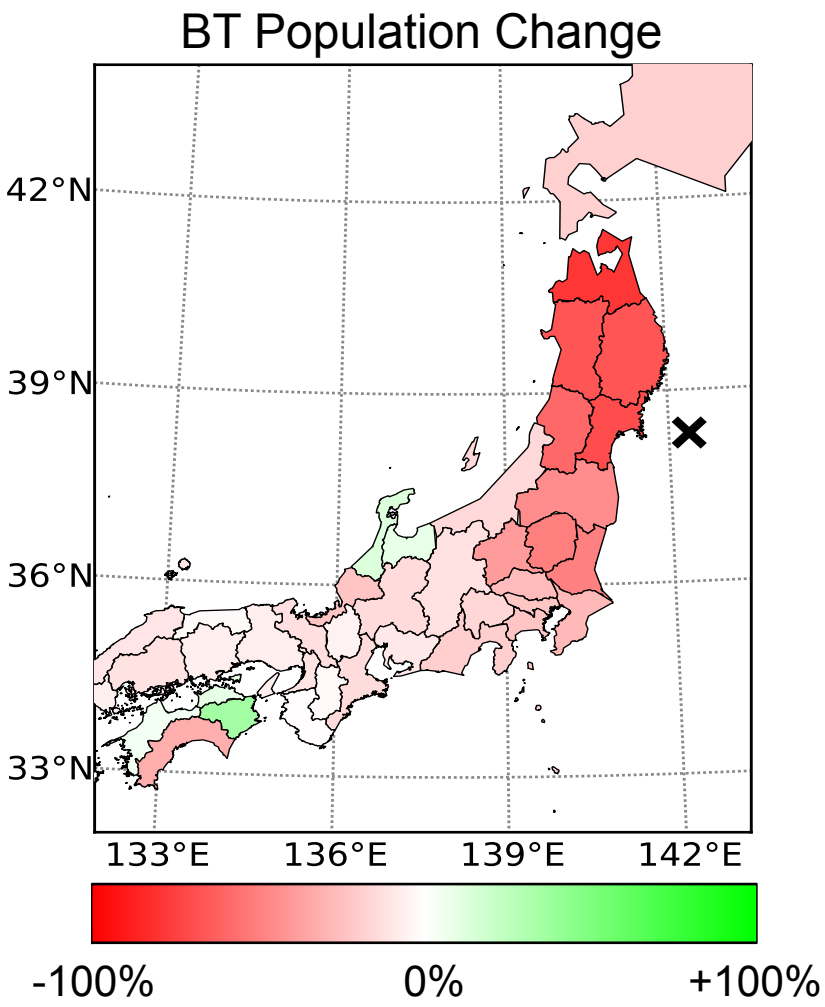
- BT user population affected by disaster
- Eventually, the user population recovers

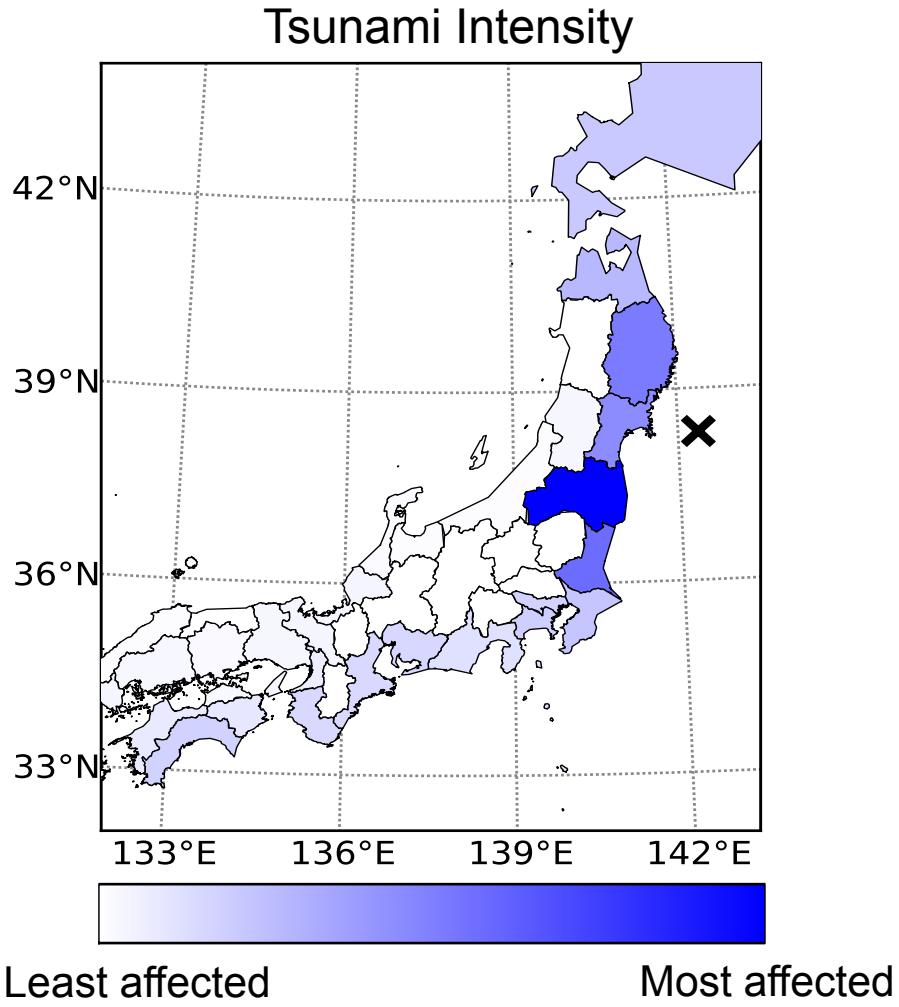
Geographic Changes in BT Population



- Prefectures with the largest drops are concentrated in the Tohoku region

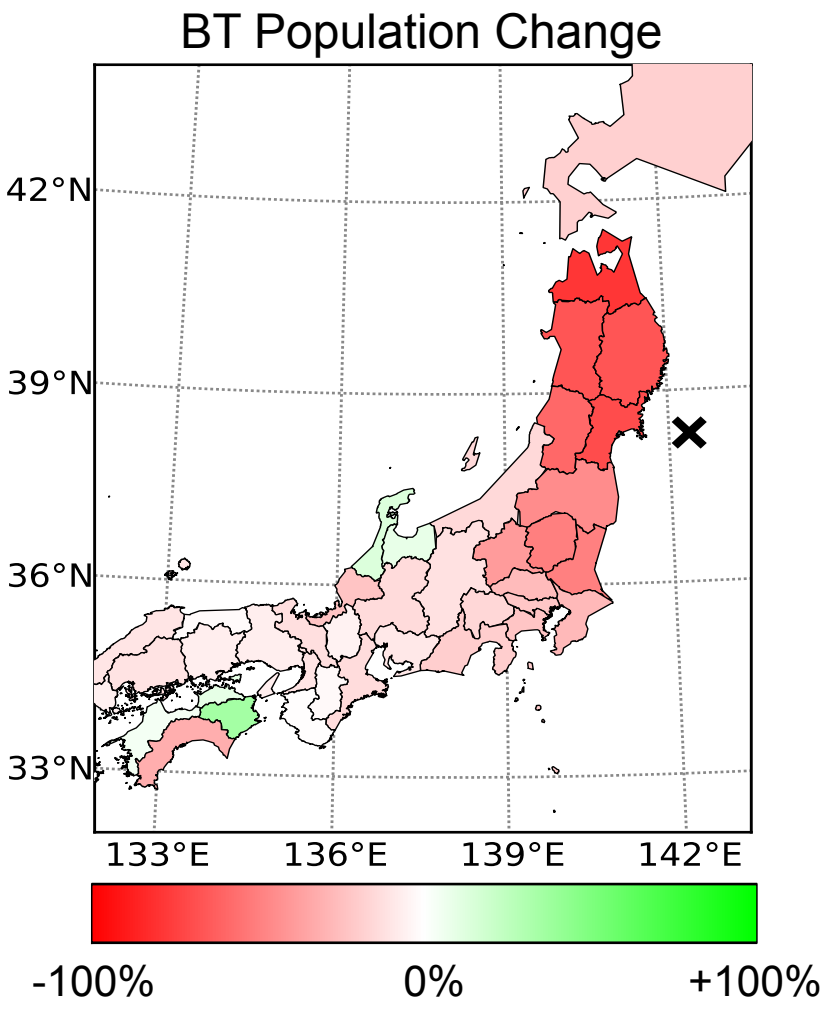
Compared with Tsunami Intensity

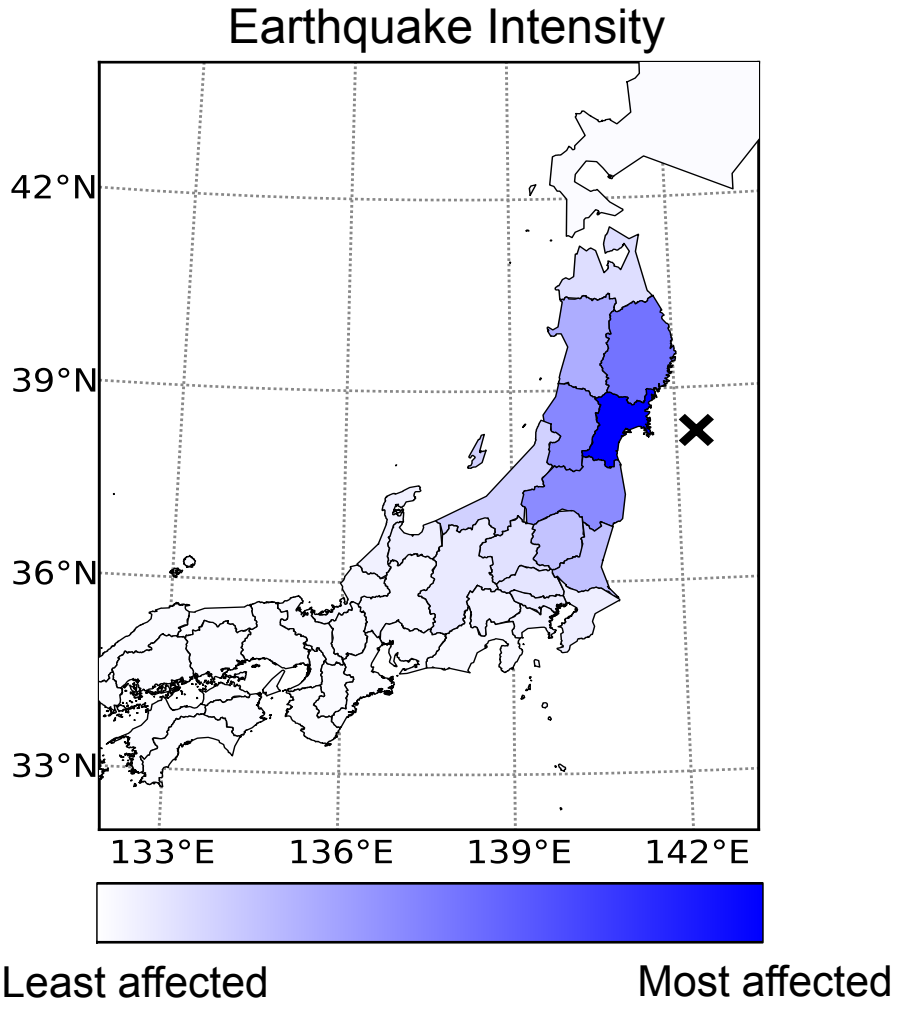




- Significant correlation between BT change and tsunami intensity (*r = -0.62)*

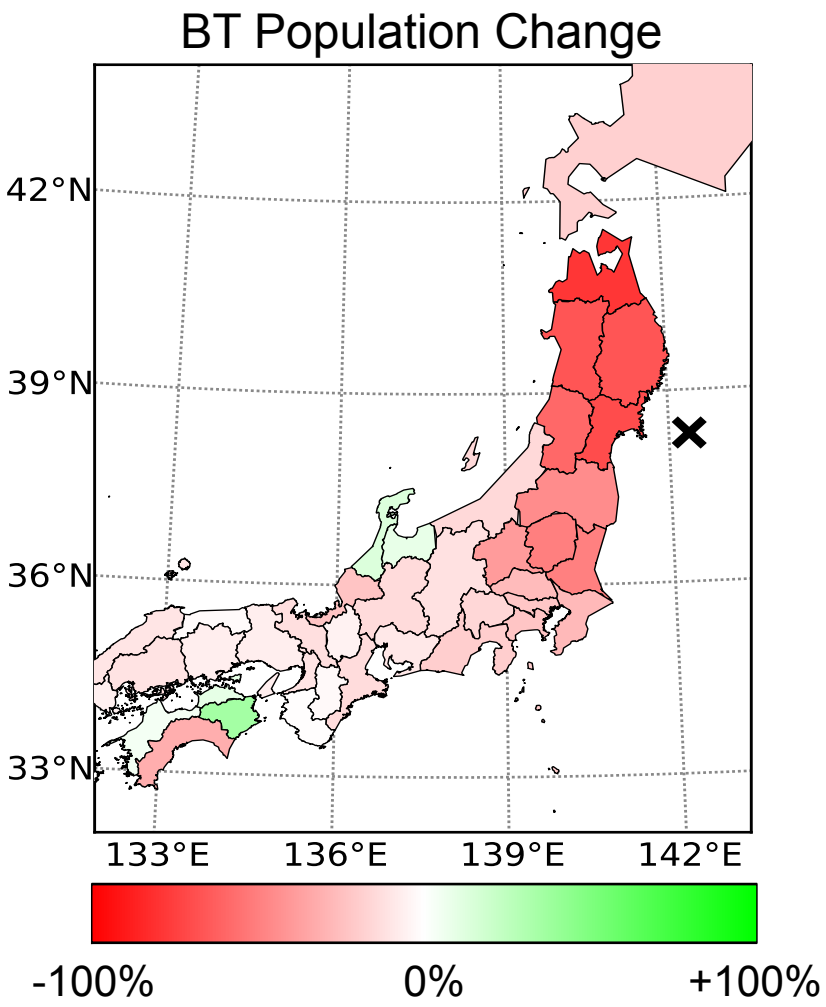
Compared with Earthquake Intensity

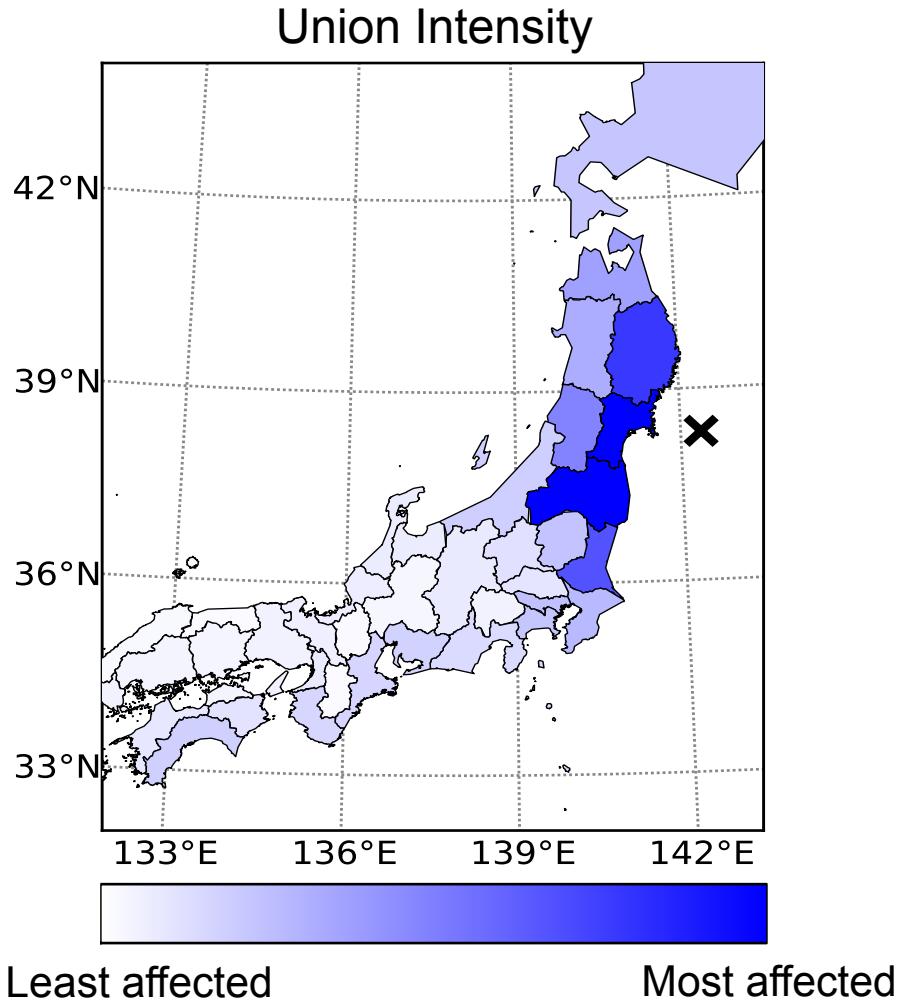




- Strong correlation between BT change and log of earthquake intensity ($r = -0.81$)

Compared with Earthquake and Tsunami





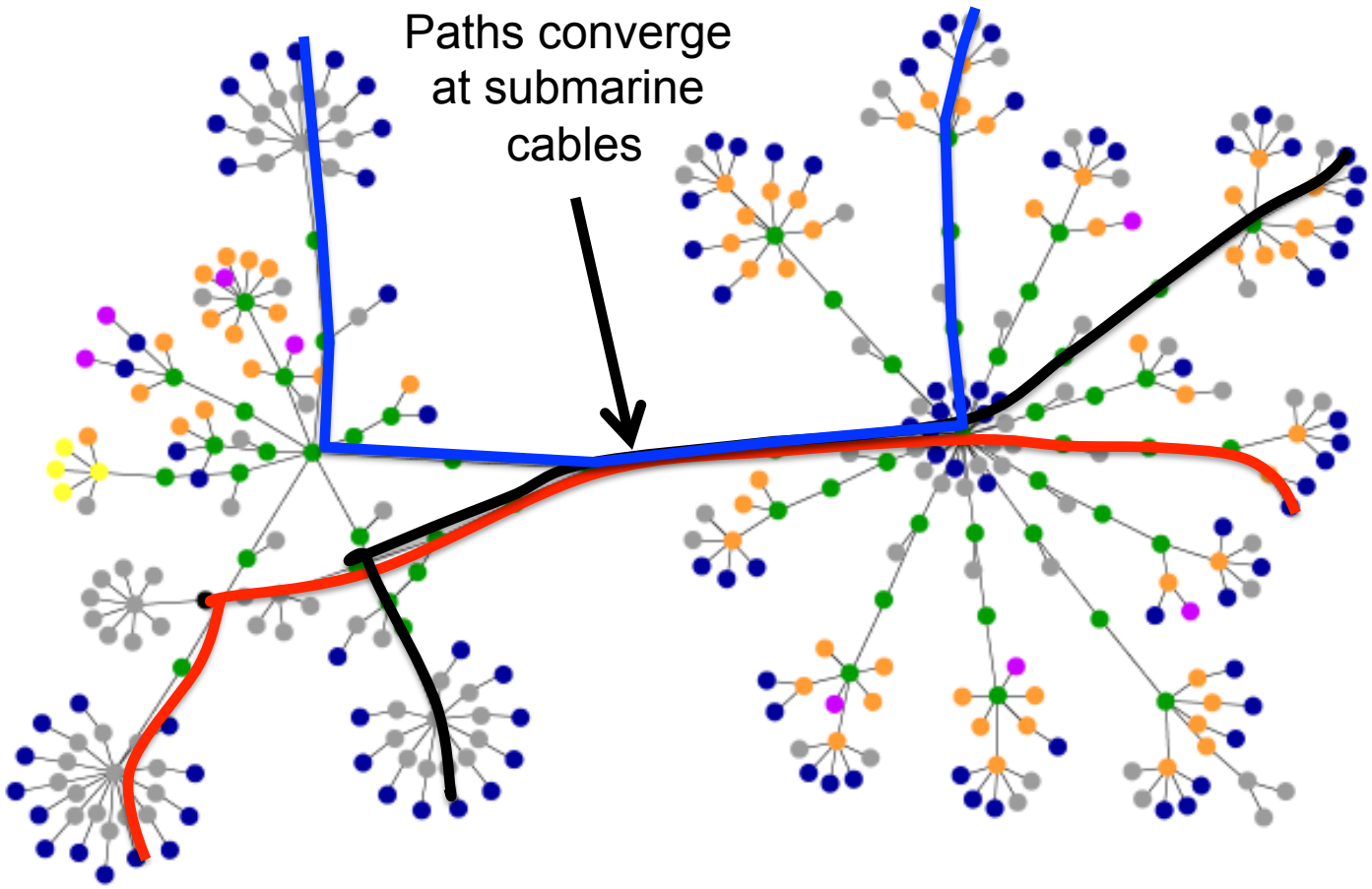
$$p = [1 - (1 - a) * (1 - b)]$$

Disaster Impact on the Network

- Reports of damage to submarine cables due to earthquake and tsunami
- *Can we identify how the disaster affected the underlying network and routing?*
- Using traceroute measurements to detect changes in the underlying network
  - E.g. Links disappearing, changes in routing, …

Identifying Submarine Cables

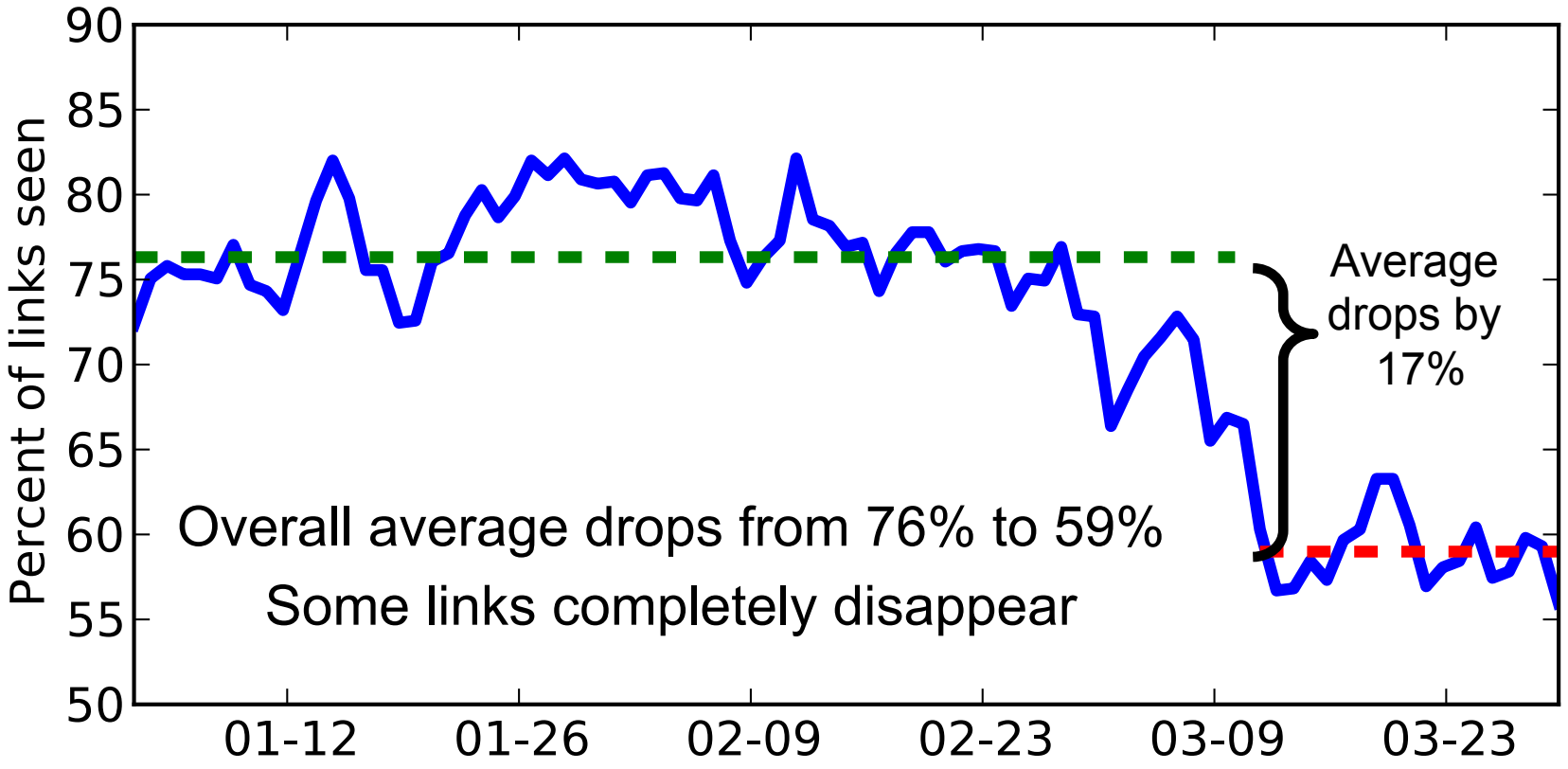
- Assume that routes through Japan converge at submarine cables (few alternate routes)



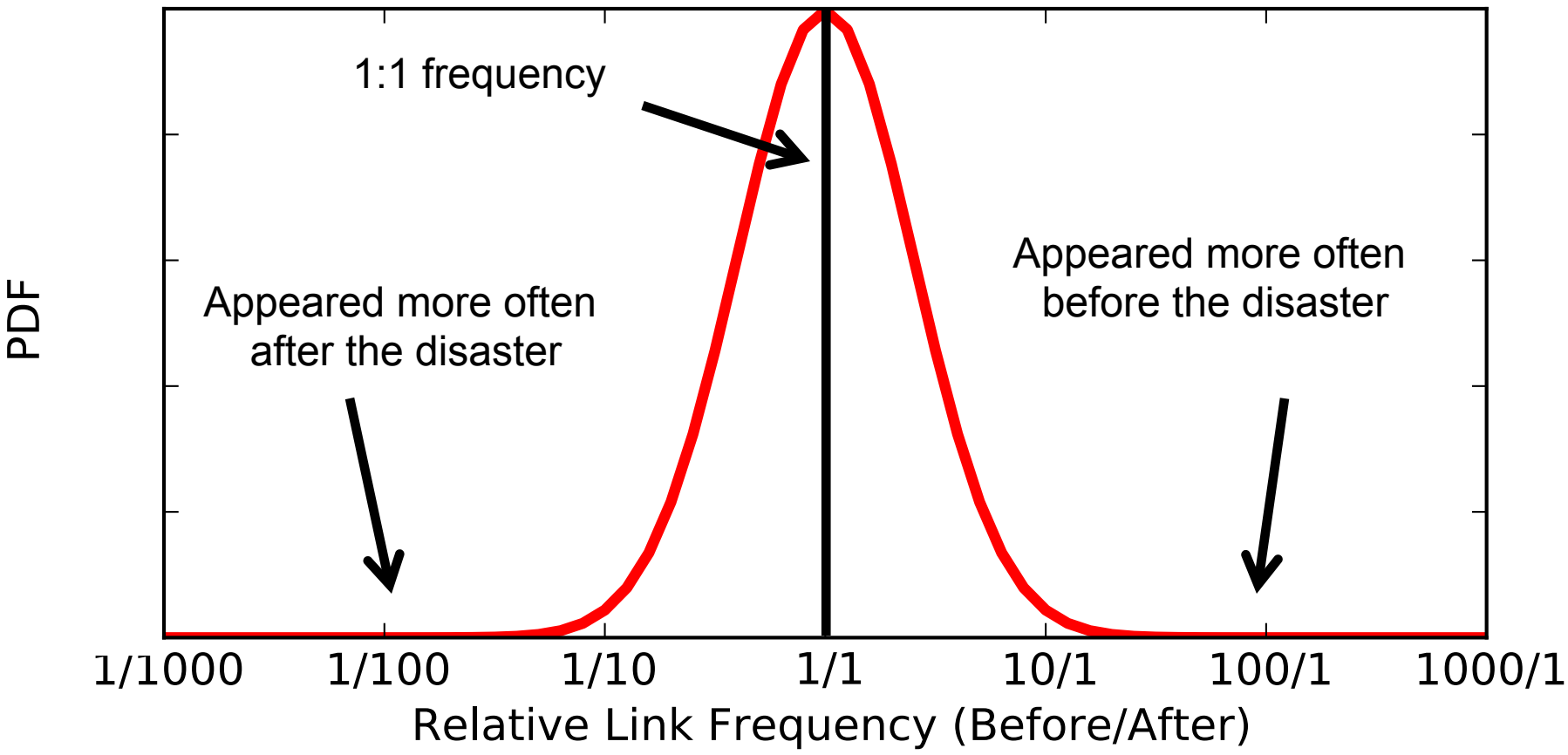
Identifying Submarine Cables

- Assume that routes through Japan converge at submarine cables (few alternate routes)
  - Identify IP links that appear frequently in traceroutes
  - Select the top 1% most “popular” IP links
- Submarine cables have a significant propagation delay
  - Identify links with consistently long delay
  - Select the top 10% in latency (>87 ms)

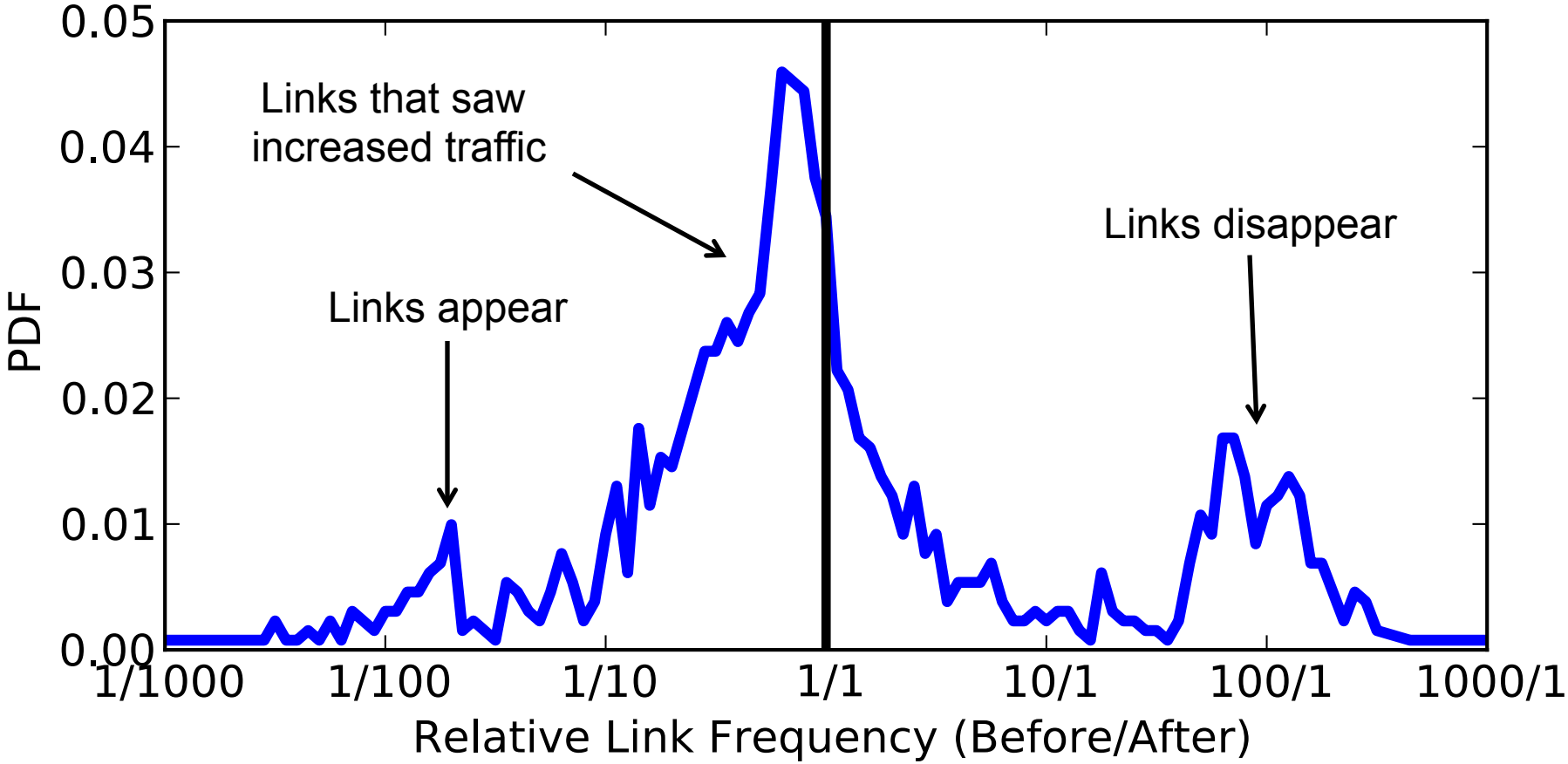
Effect on Submarine Links



Expected Normal Distribution



Disaster's Impact on Links Used



- Able to identify links appearing, links disappearing, and links handling more traffic

Changes in Link Popularity

ASN	ISP	% Disappearing	% Increased by x10	% Appearing
2516	KDDI	15.3%	6.8%	0.6%
2914	NTT	26.7%	13.8%	3.9%
10026	Pacnet	8.3%	11.1%	8.3%
2497	IIJ	13.9%	27.7%	23.1%

- Press reported damage to cables in the networks of KDDI, NTT, and Pacnet

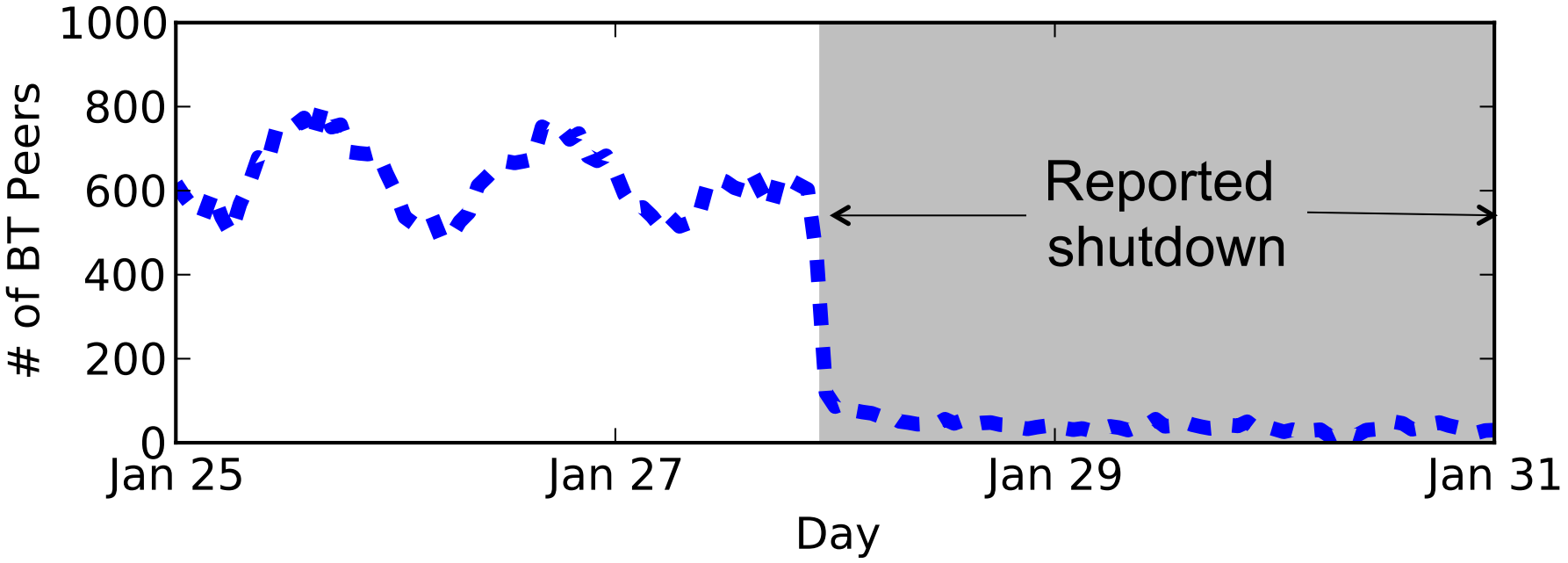
Distributed Systems and Disasters

- Leveraging distributed systems allows us to see the impact of natural disasters on our networked society

- *Can we see the effects of other man-made phenomena?*

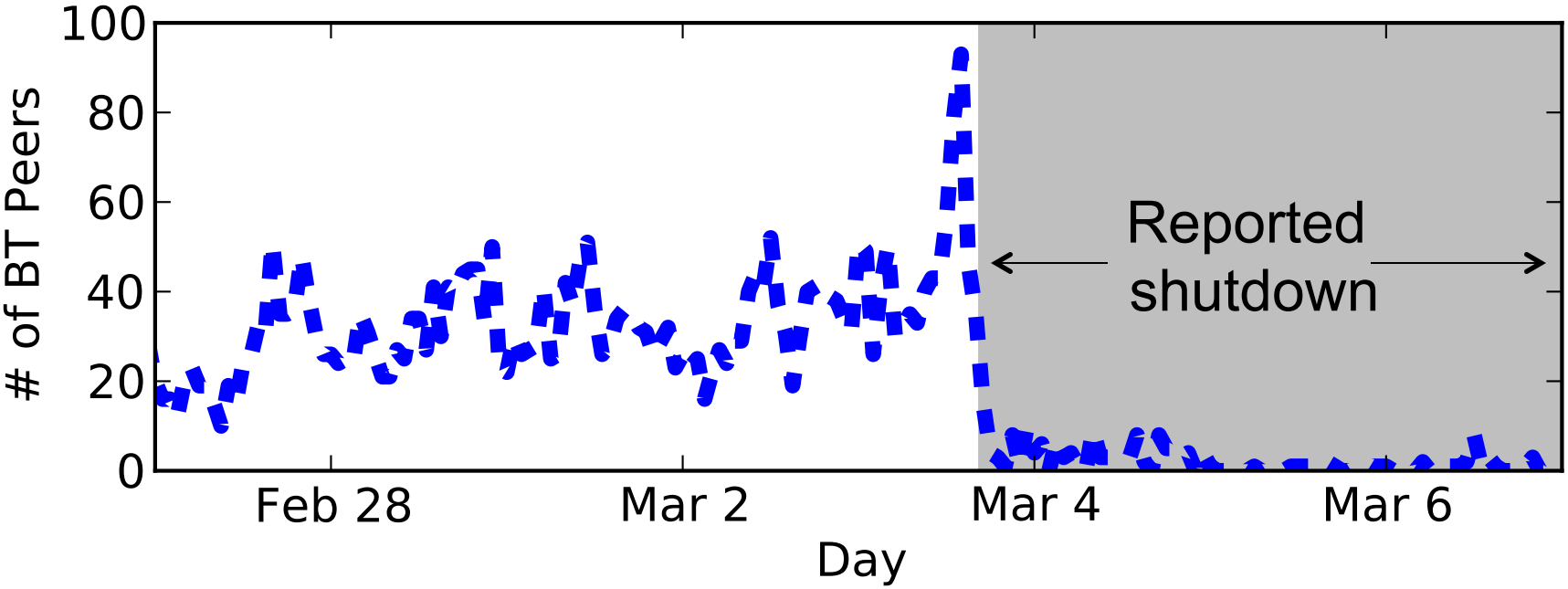
Political Unrest in Egpyt

- On January 27th, at about 22:30 UTC, Internet access in Egypt was shut off
  - [BGPmon, renesys]



Political Unrest in Libya

- On March 3rd, by about 16:30 UTC, Libyan networks were unreachable
  - [Google, renesys]



Questions Worth Exploring

- Other applications/systems?
- Different systems with different or complementary views
- What can we expect to capture and what can we not?
- How to combine the view of networked systems with information from other sources?
- Other network-level metrics?
- Beyond observation – distributed systems doubling as early emergency notification systems?