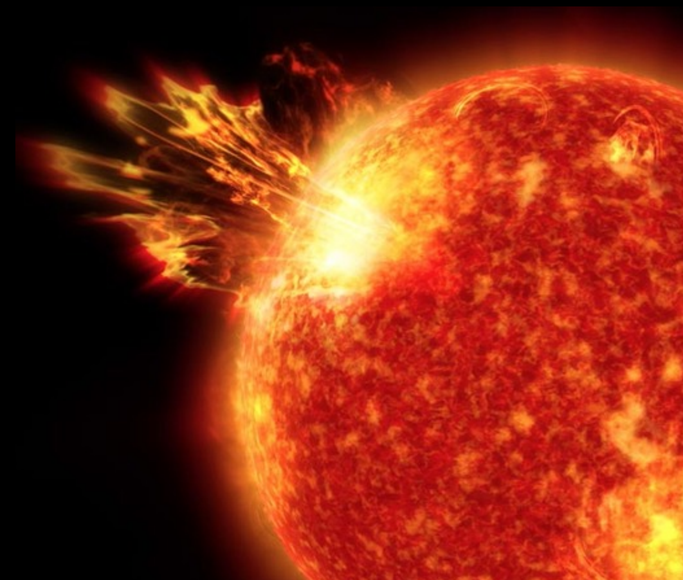
Solar Superstorms: Planning for an Internet Apocalypse

Sangeetha Abdu Jyothi

University of California, Irvine & VMware Research



Impacts of an Internet outage?

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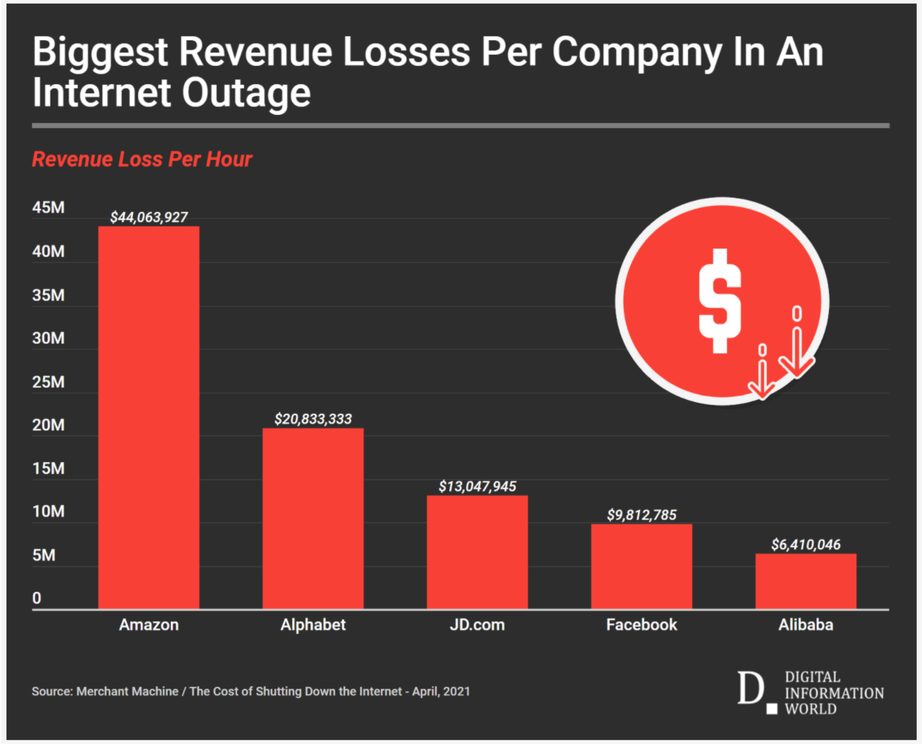
Businesses



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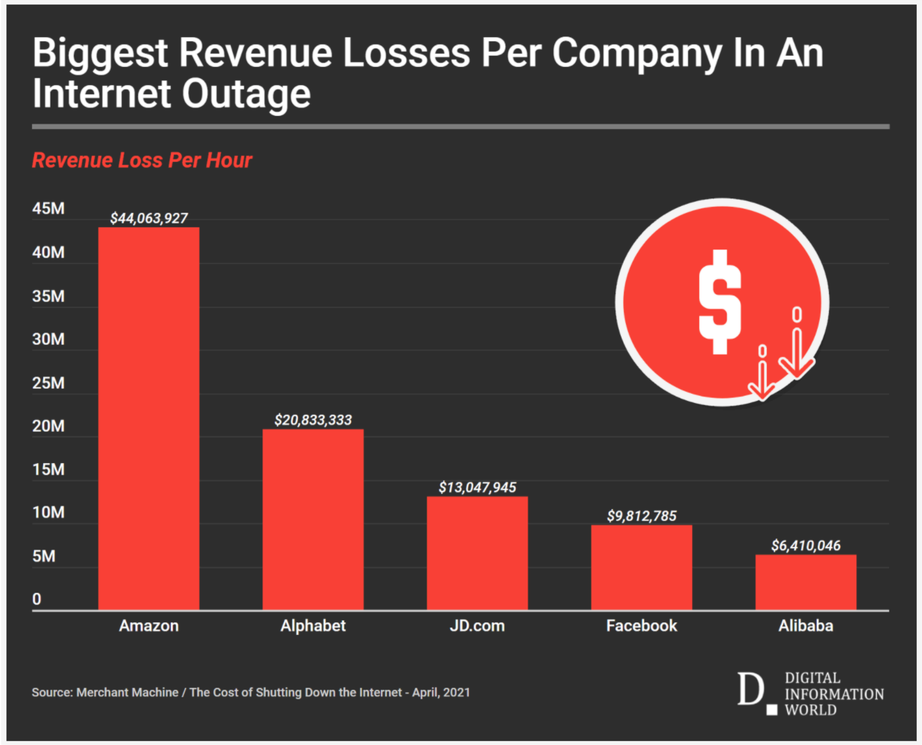
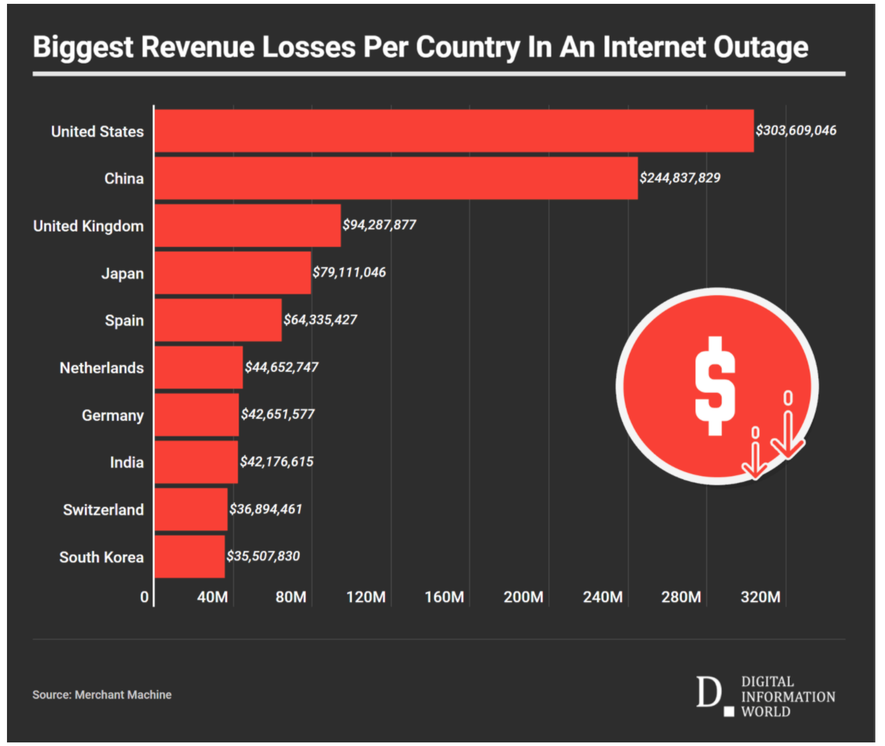


Countries



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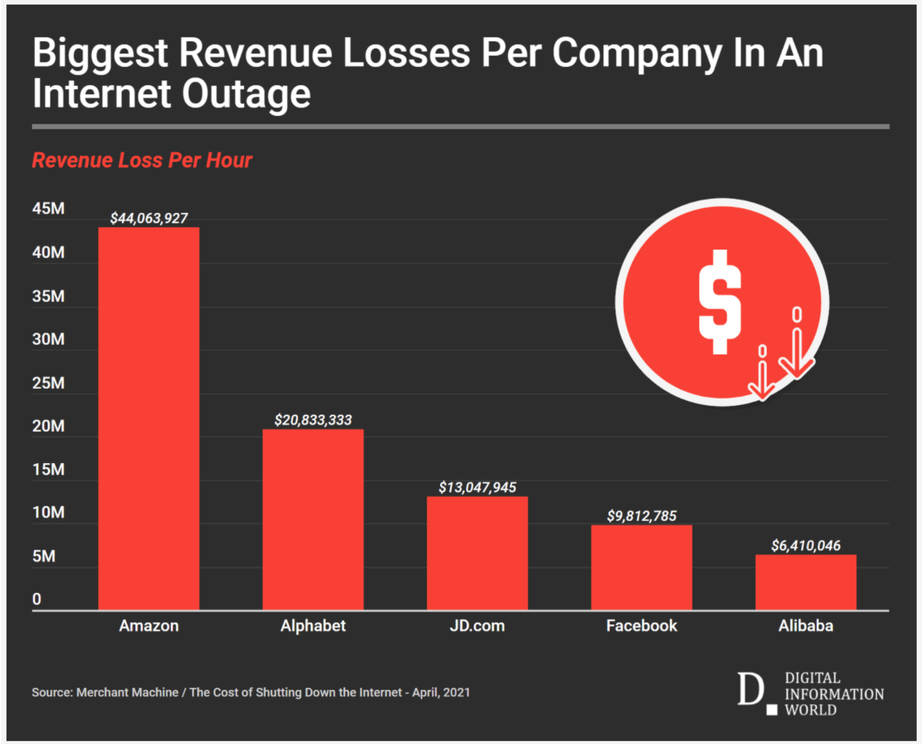

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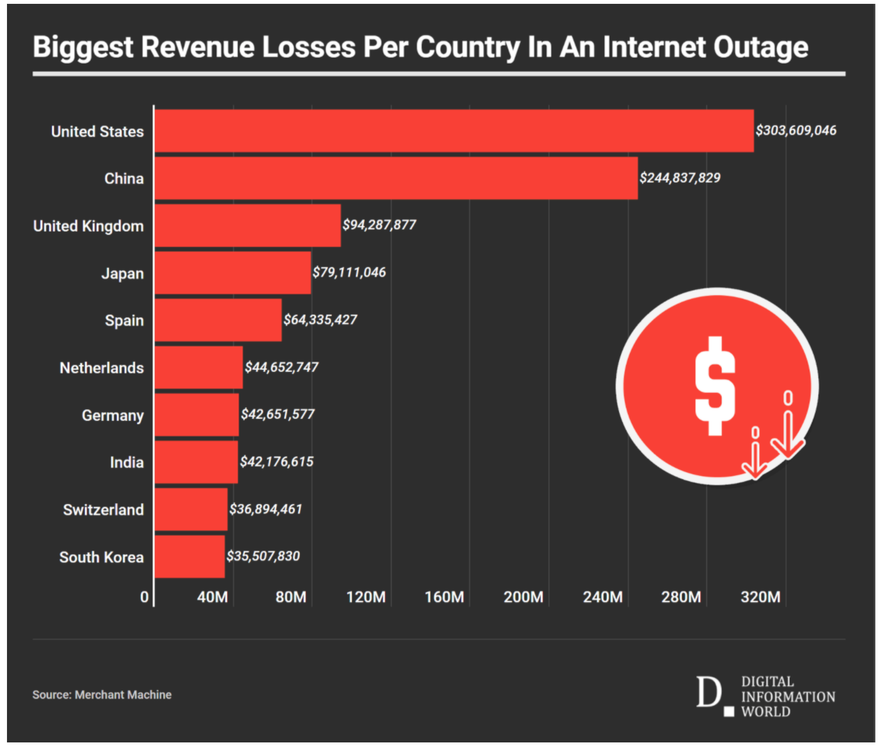
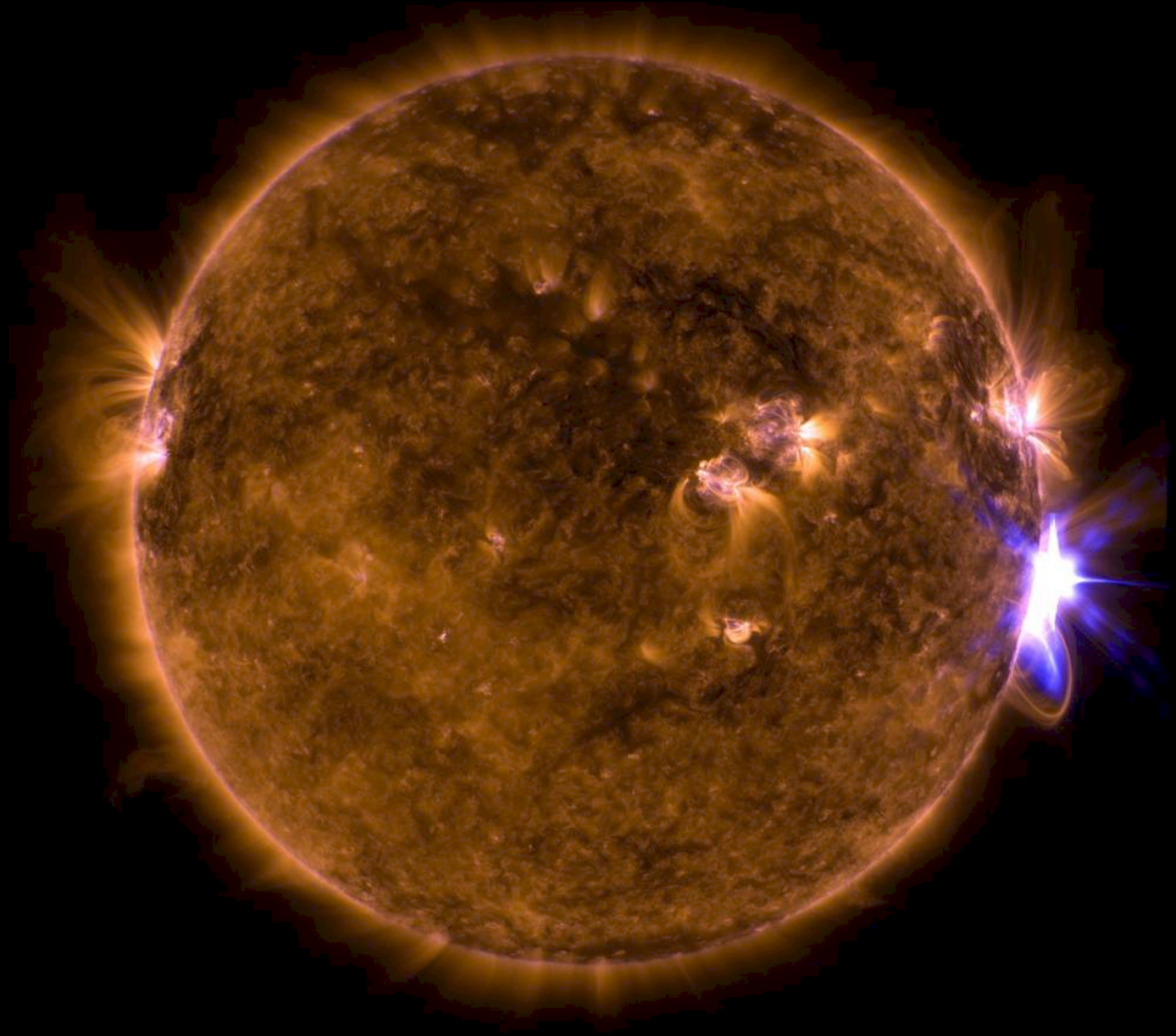


What if we have an Internet outage lasting **weeks or months across the globe?**

Solar Superstorms

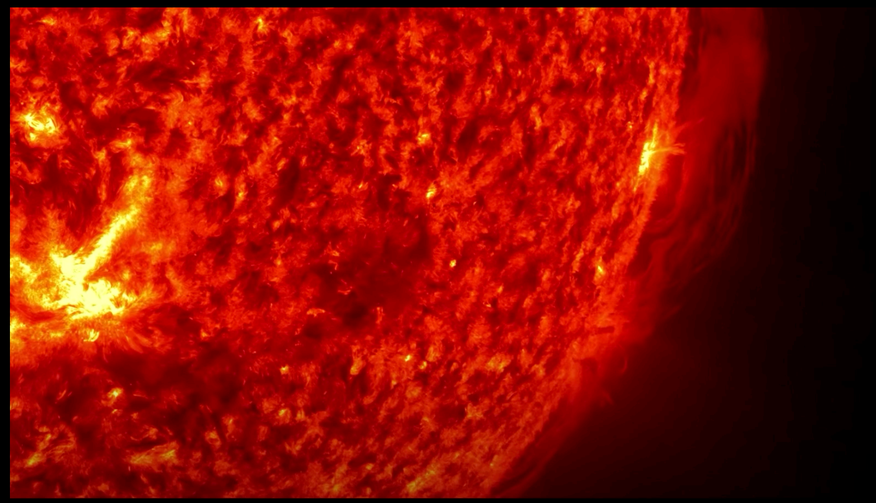


Credits: NASA/SDO/Goddard

Solar Flares and Coronal Mass Ejections (CMEs)

Solar Flare

Coronal Mass Ejection



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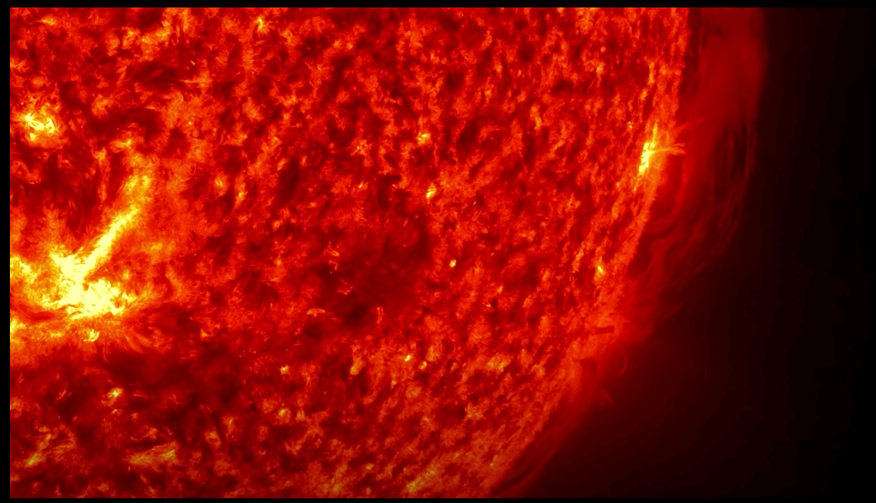

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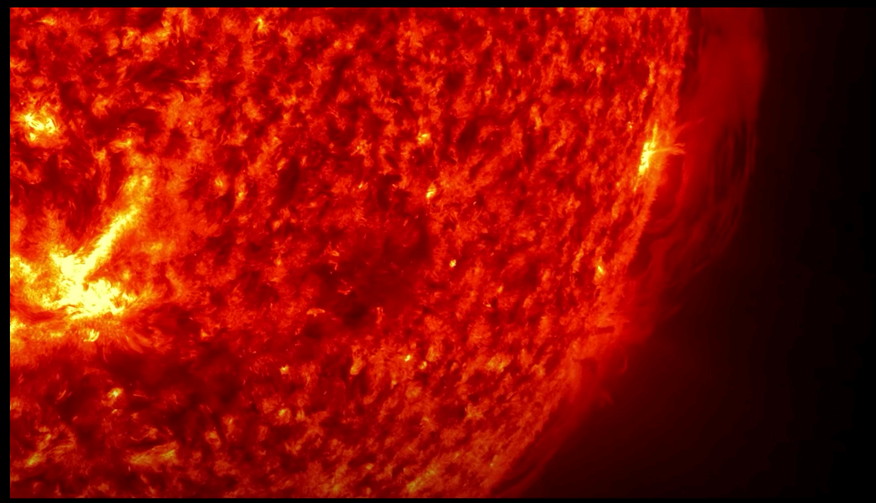

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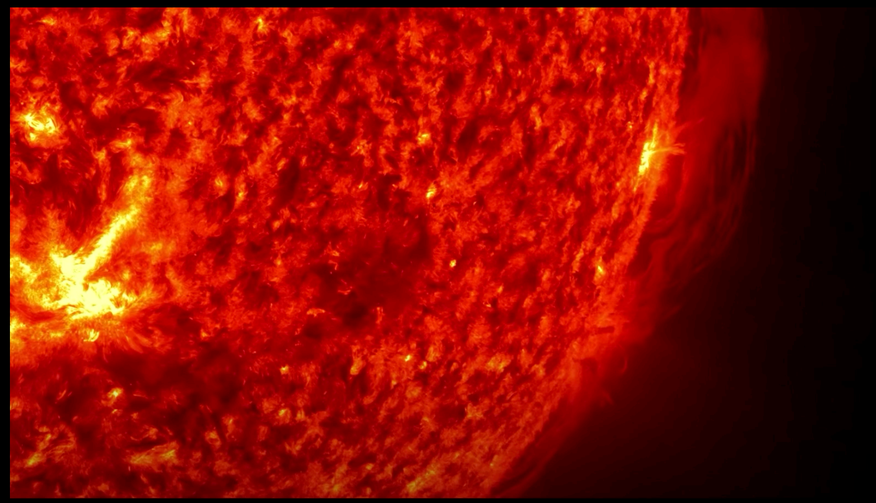

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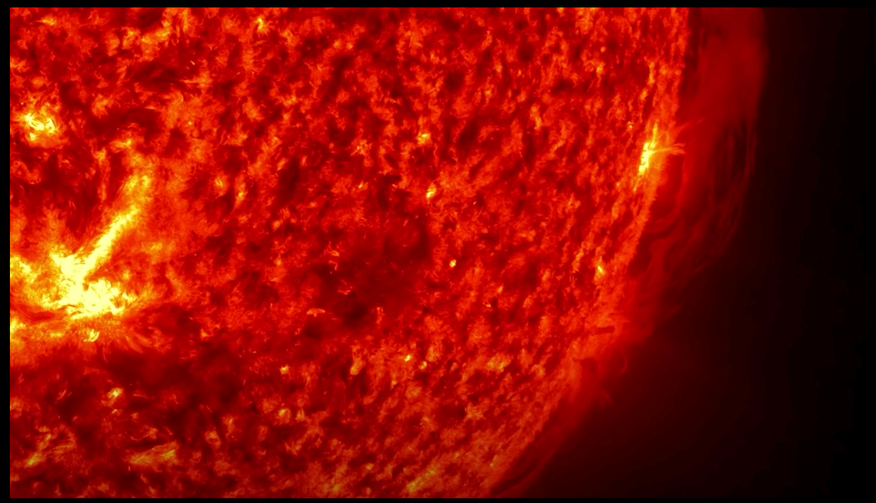

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Solar Flares and Coronal Mass Ejections (CMEs)

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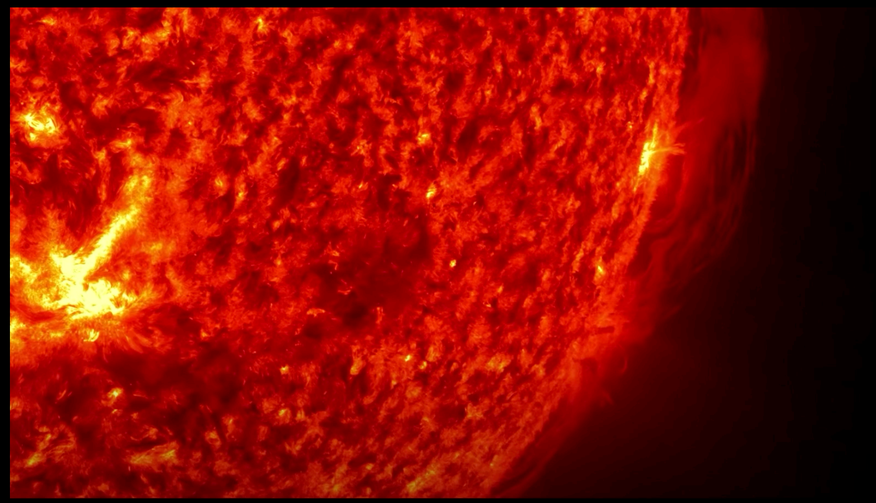

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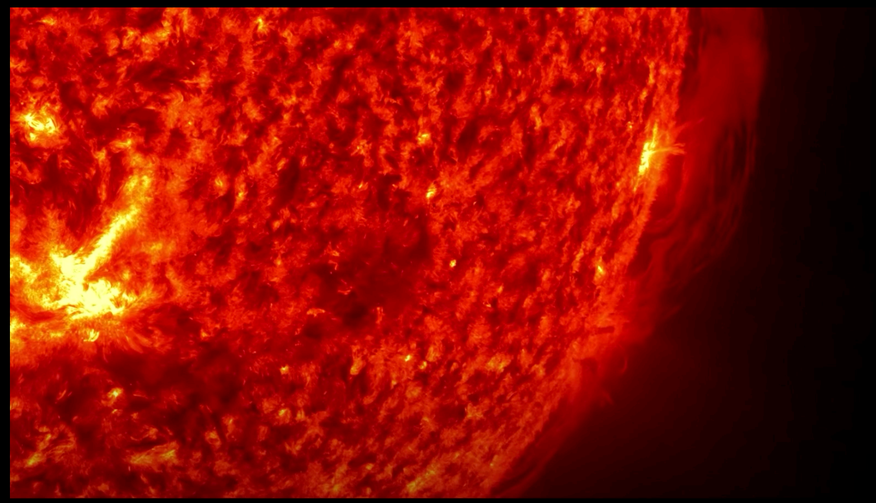

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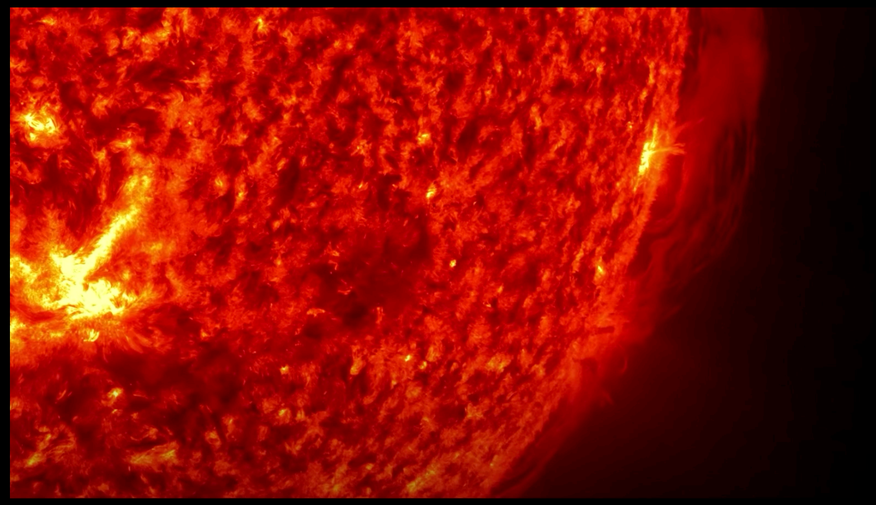

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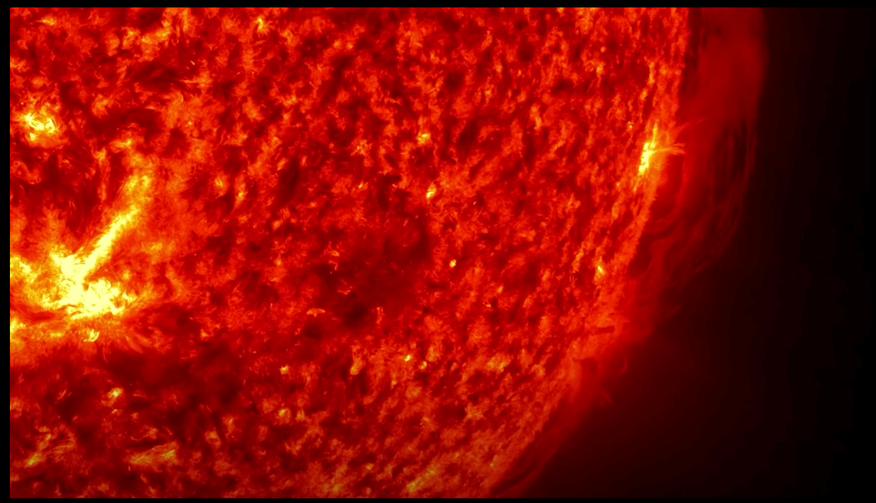

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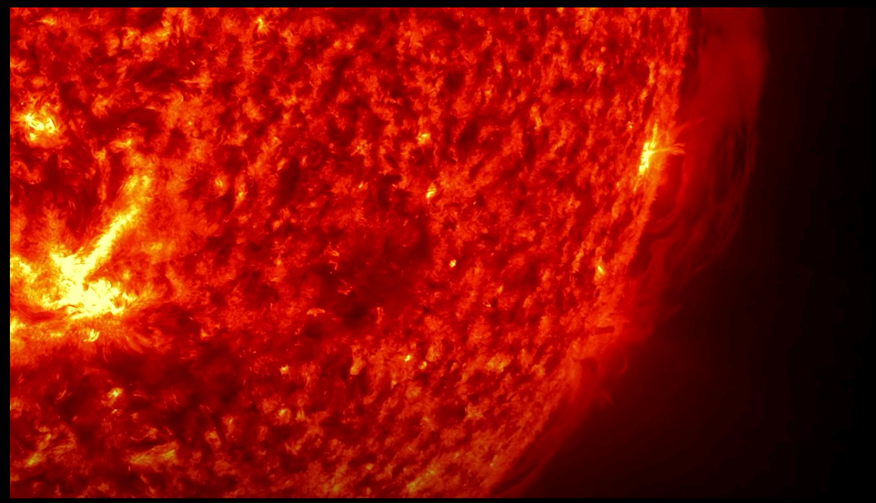

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- Both solar flares and CMEs often originate near sunspots

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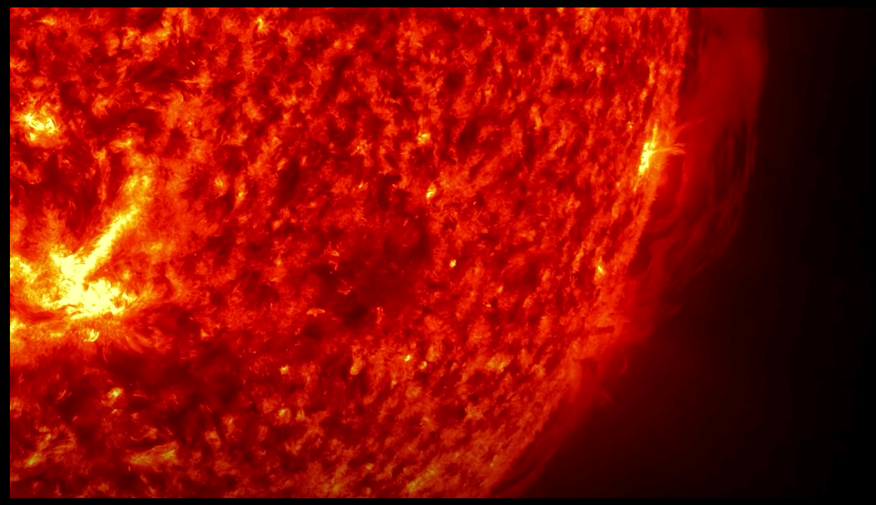

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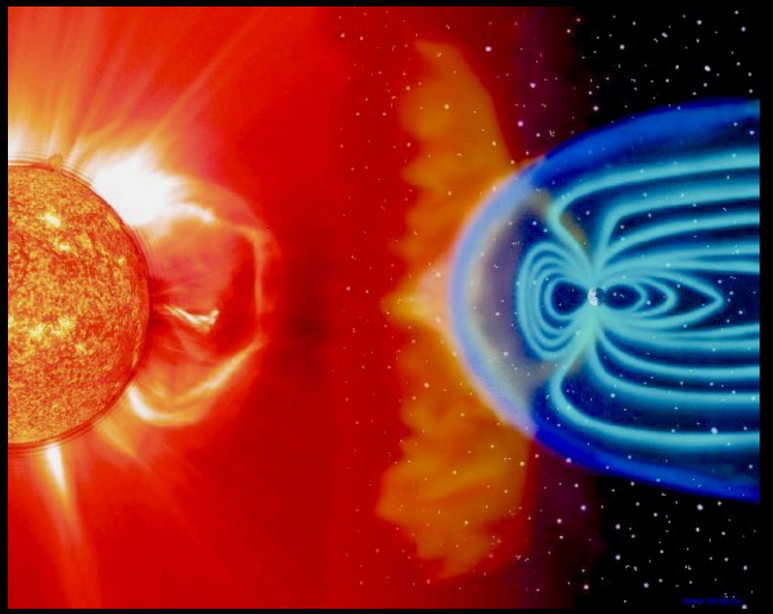
How do CMEs affect us?



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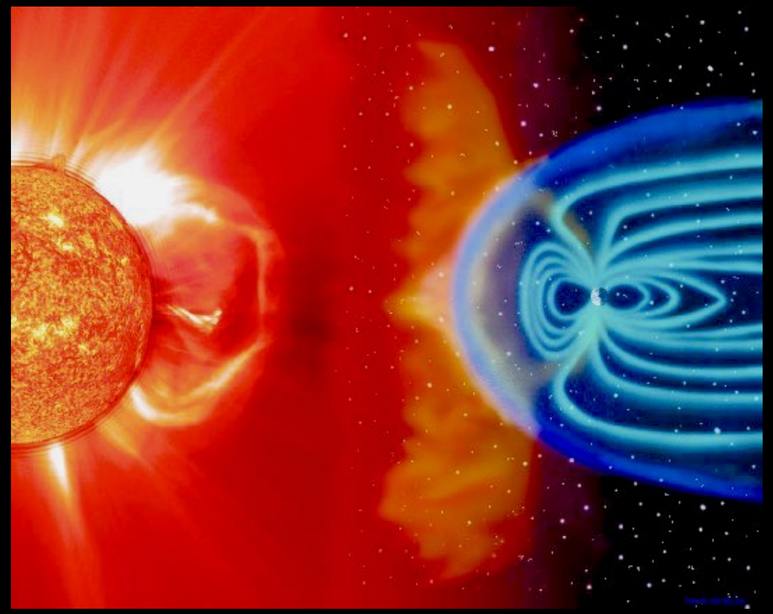
How do CMEs affect us?

- The magnetized emissions are highly directional



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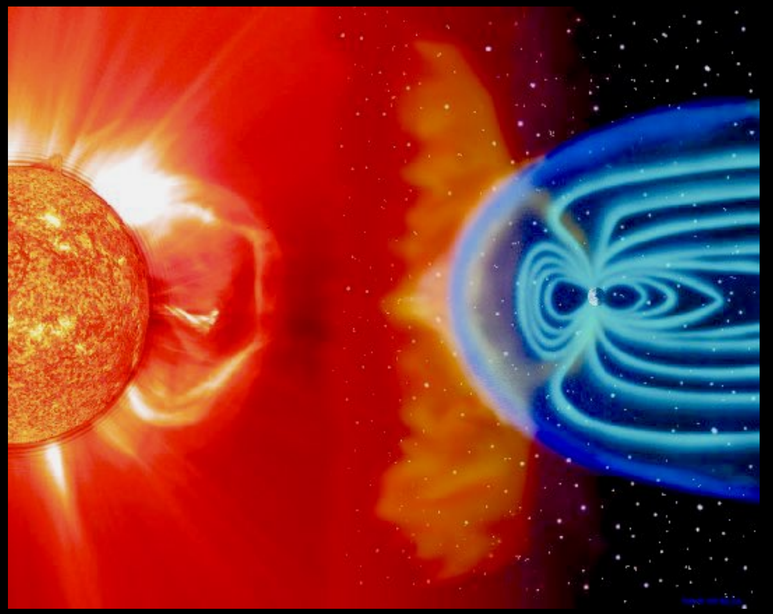

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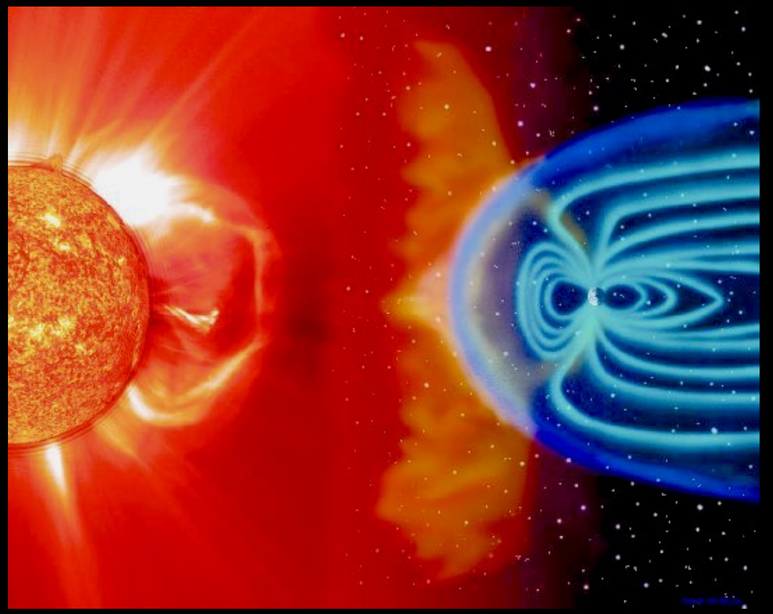

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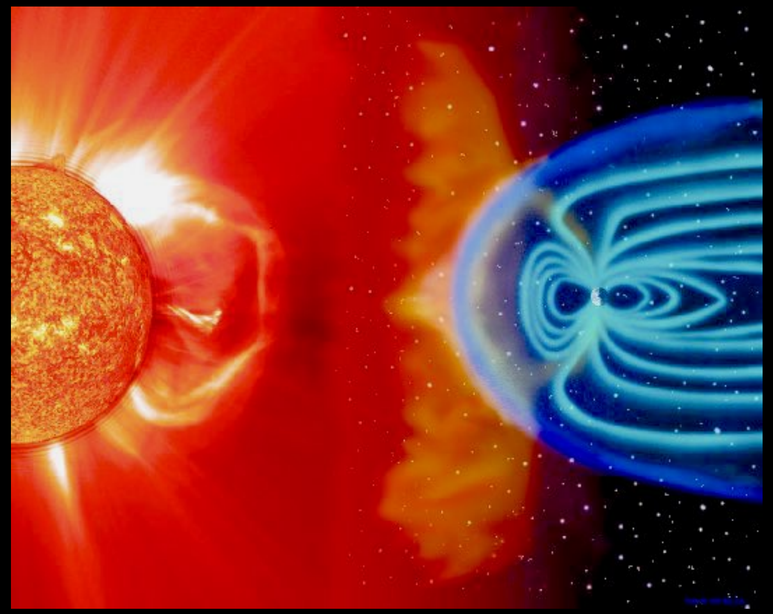
- Geomagnetically Induced Currents (GIC) can enter long cables like Internet cables and power grid and cause significant damage



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Characteristics of GIC

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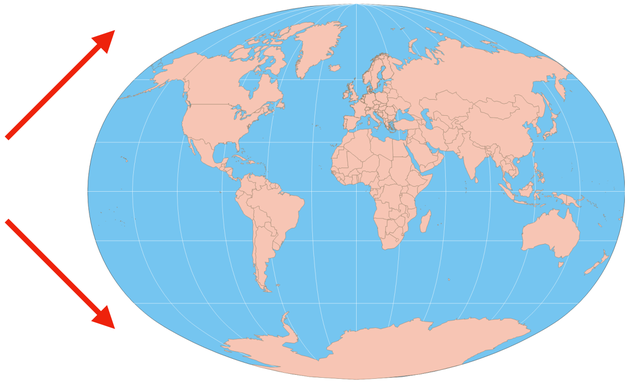

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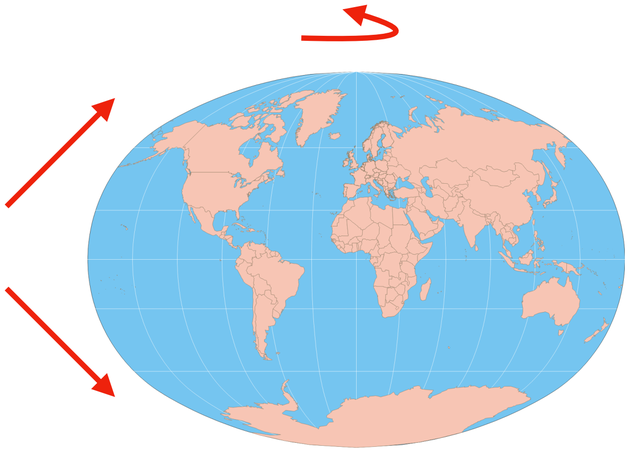

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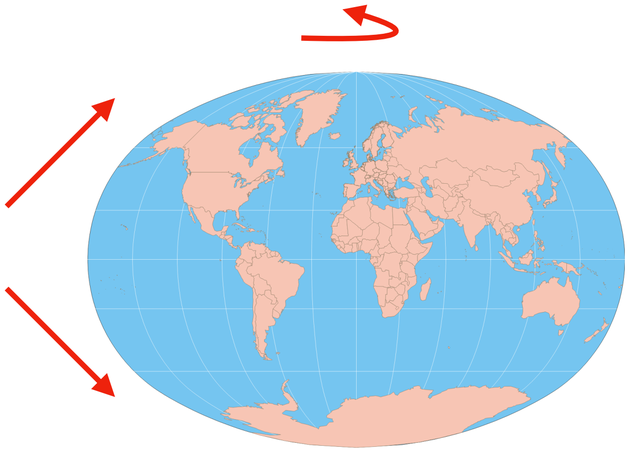

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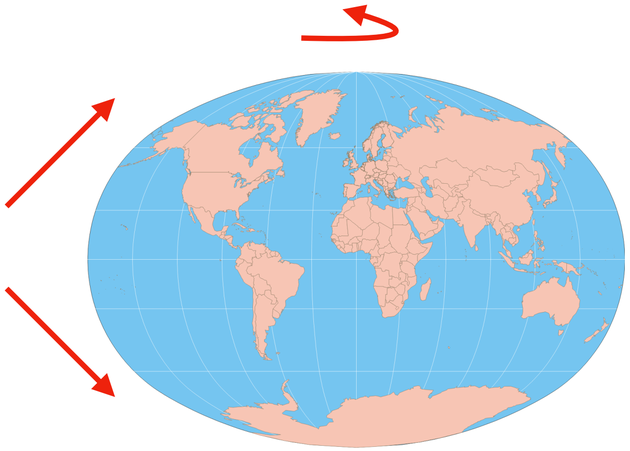
- Conductors along different orientations on earth are at equal risk



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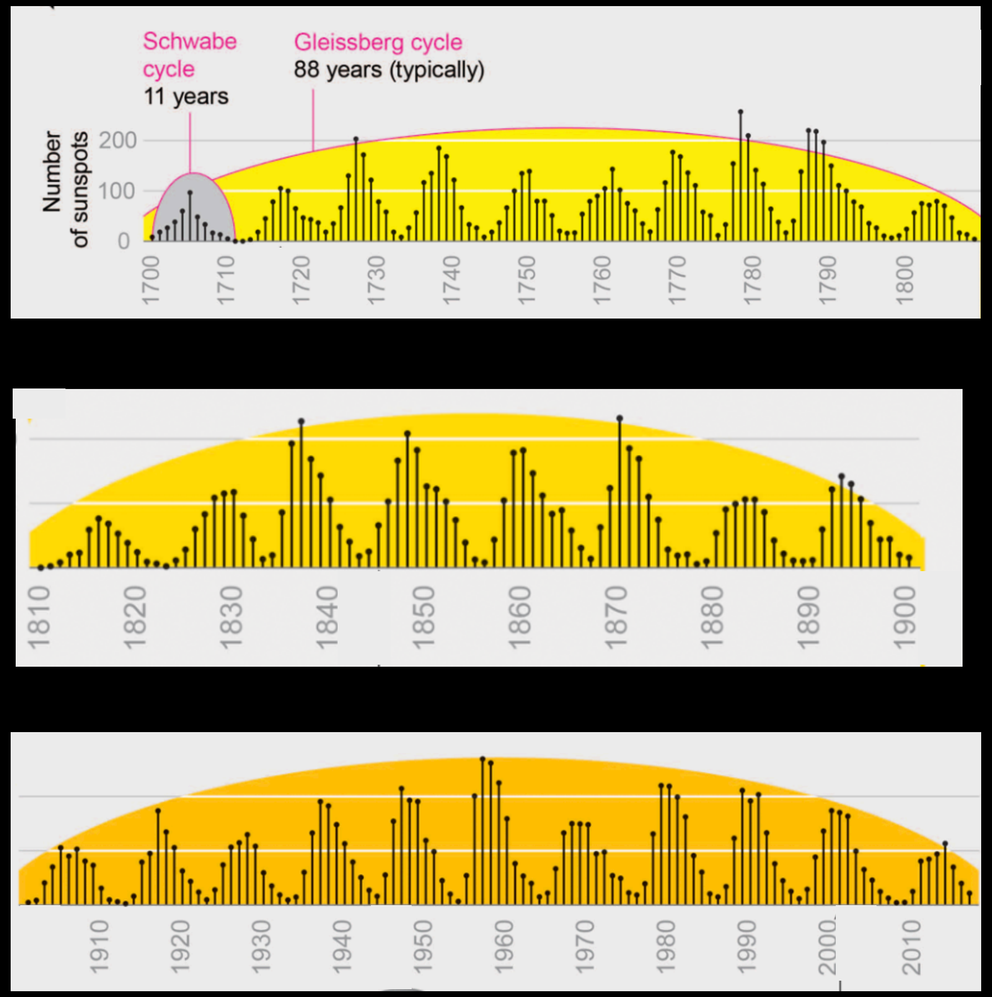

Credits: Katie Peek; Sources: SILSO data, Royal Observatory of Belgium, Brussels

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- Previous solar superstorms happened in 1859 (Carrington event) and 1921
- The estimates for probability of occurrence ranges from 1.6% to 12% per decade
- The risk is not uniform because solar activity goes through cycles
- Modern technological advancement coincided with a period of weak solar activity.

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Data Centers

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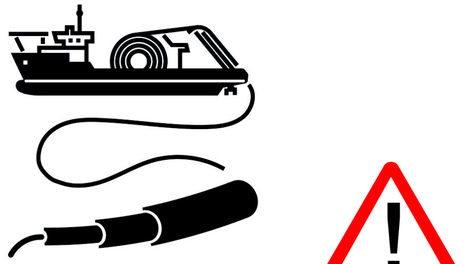

Long Distance Cables

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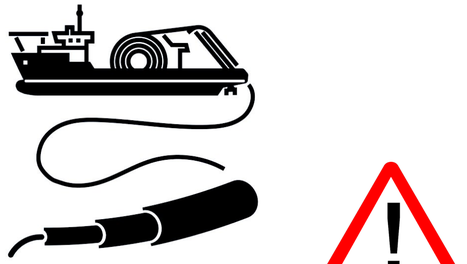

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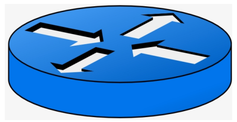

Internet Routers

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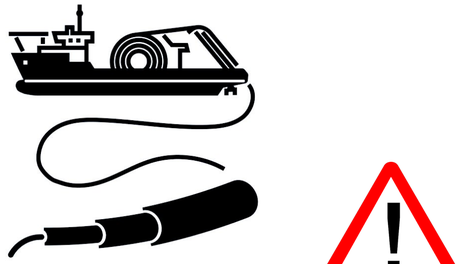

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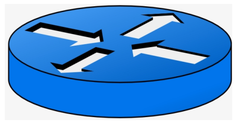

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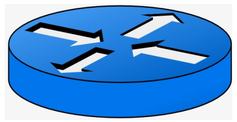

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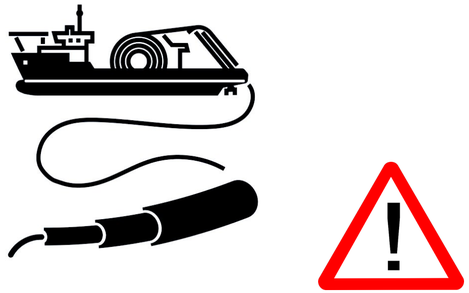

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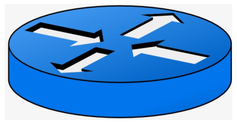

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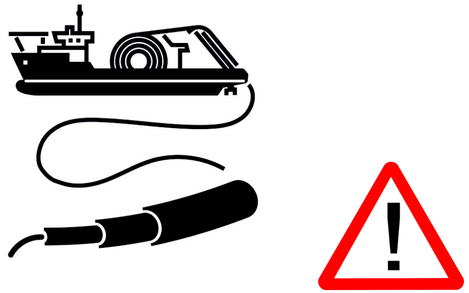

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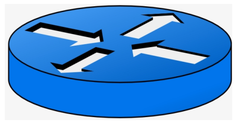

Internet Routers

Personal Devices

Analyzing the Impact on Internet Components

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Datasets

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- Global submarine cable map

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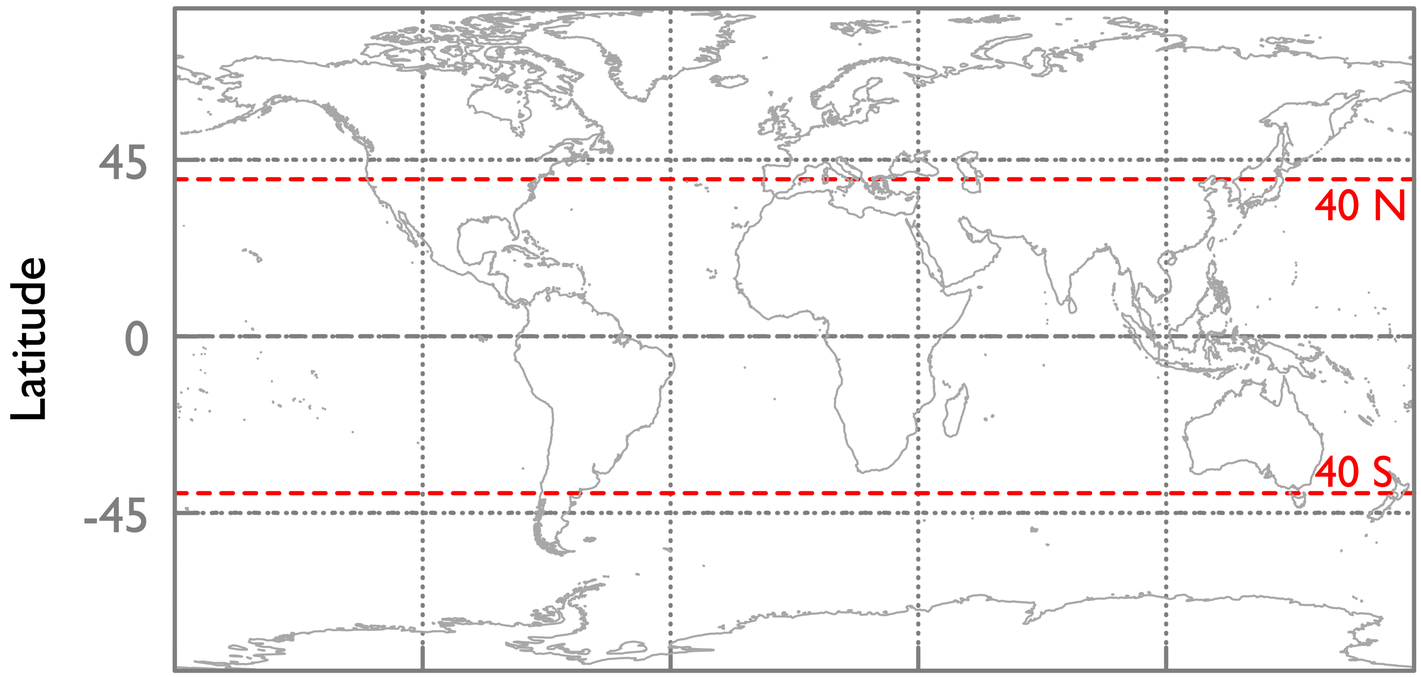

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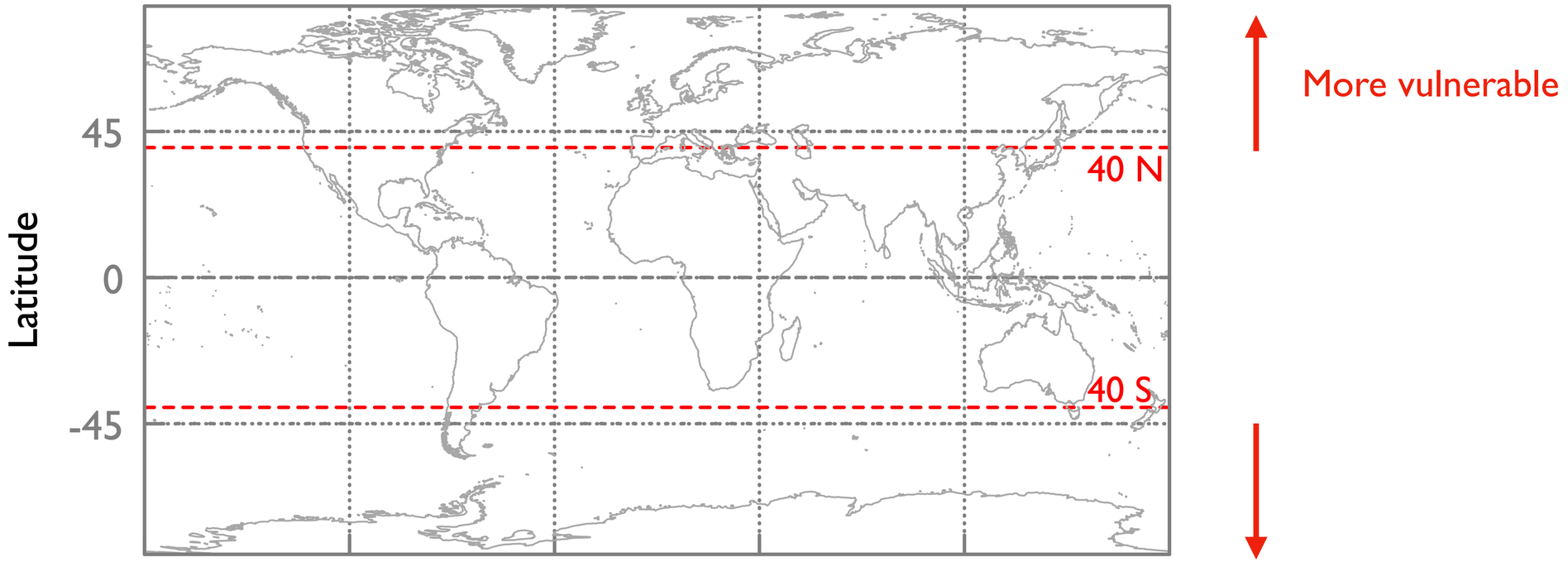

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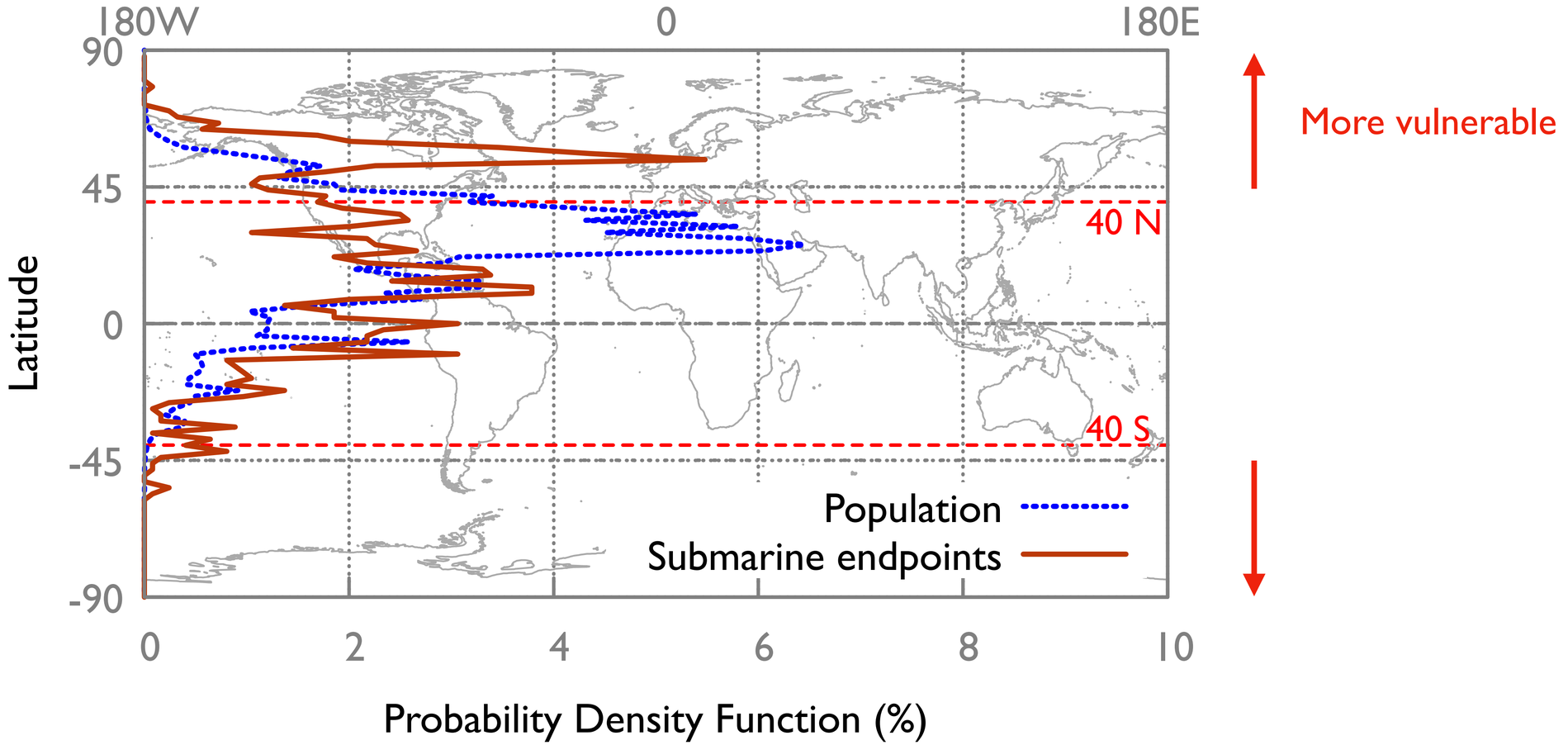

Distribution of Internet Infrastructure Components

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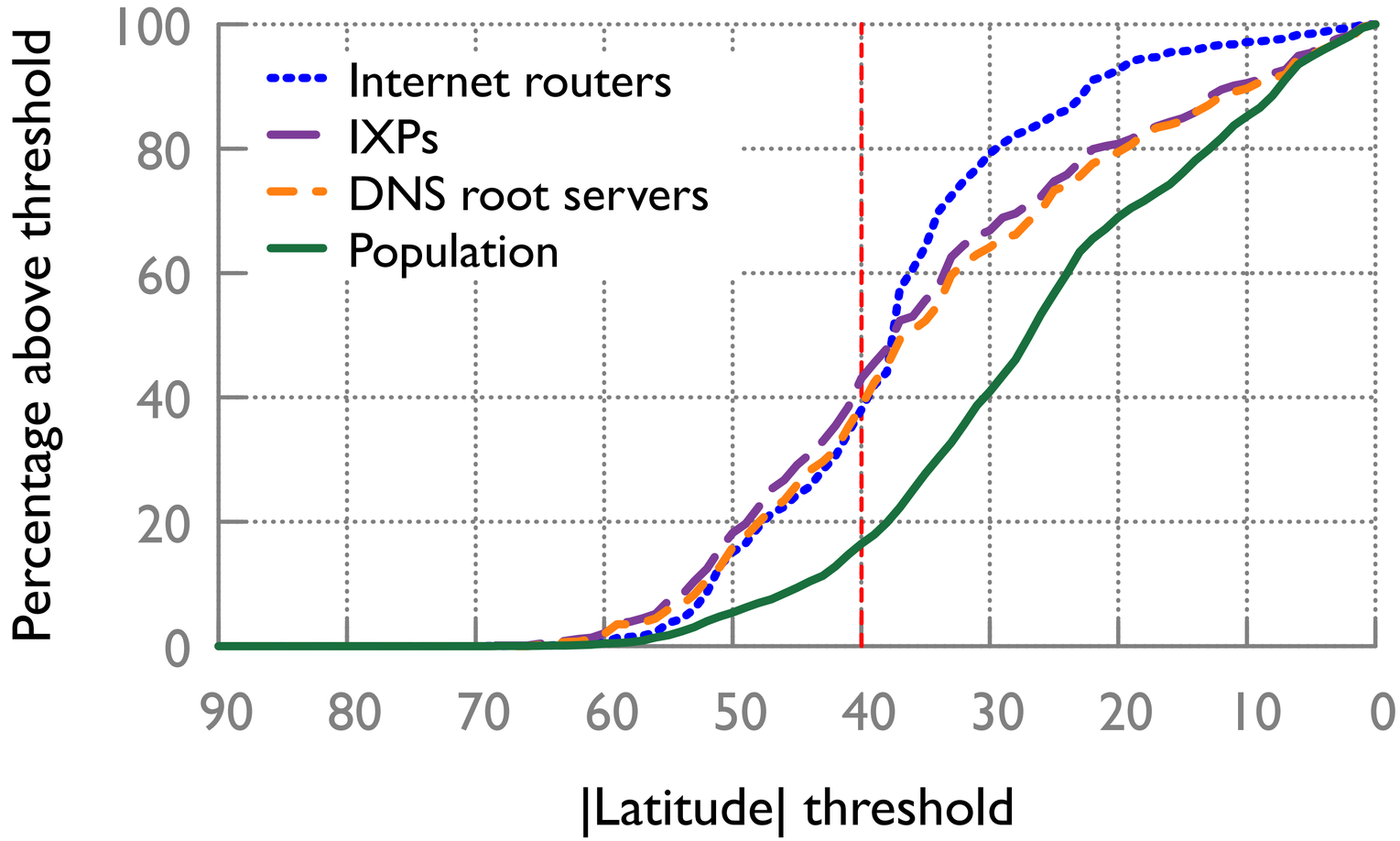

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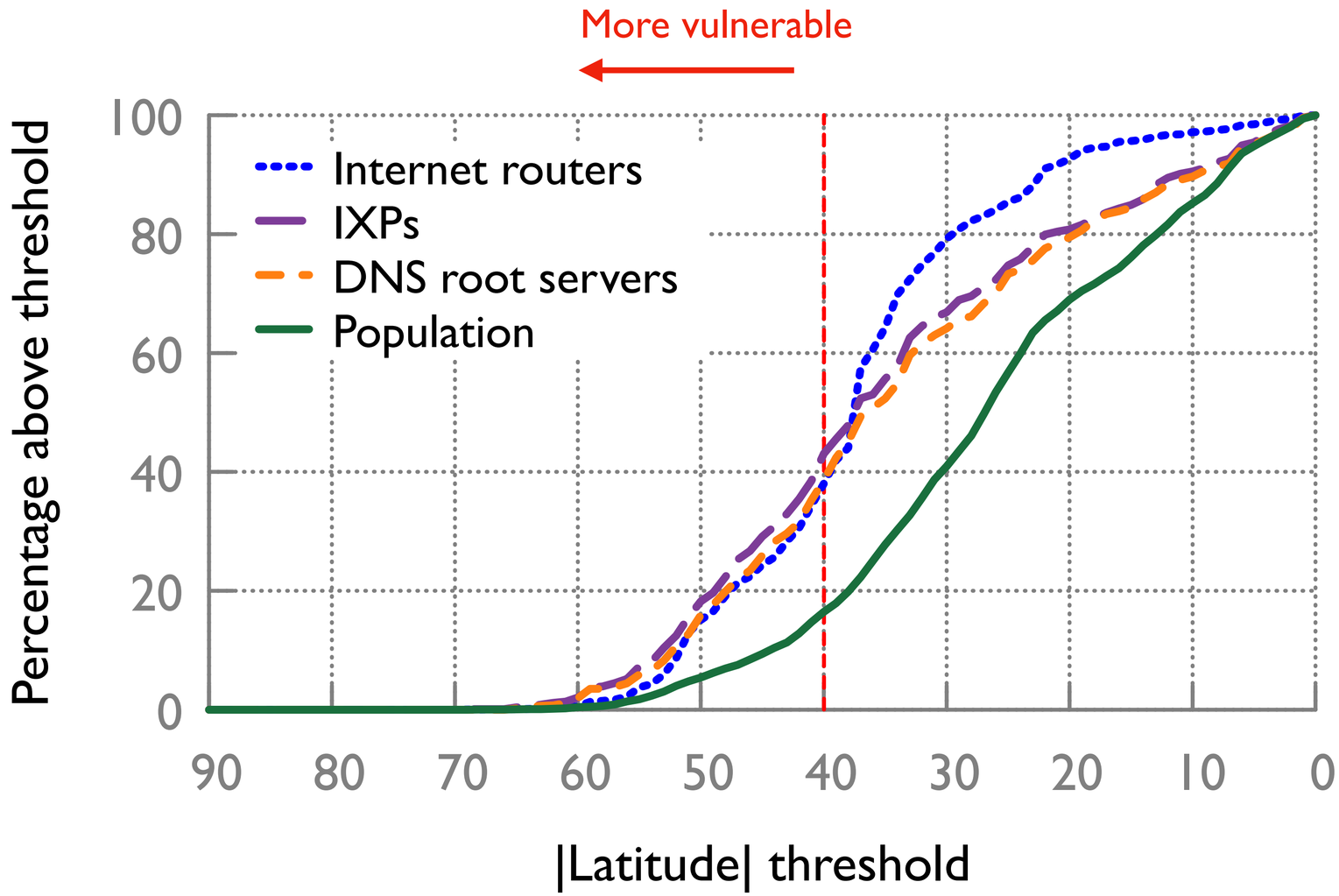

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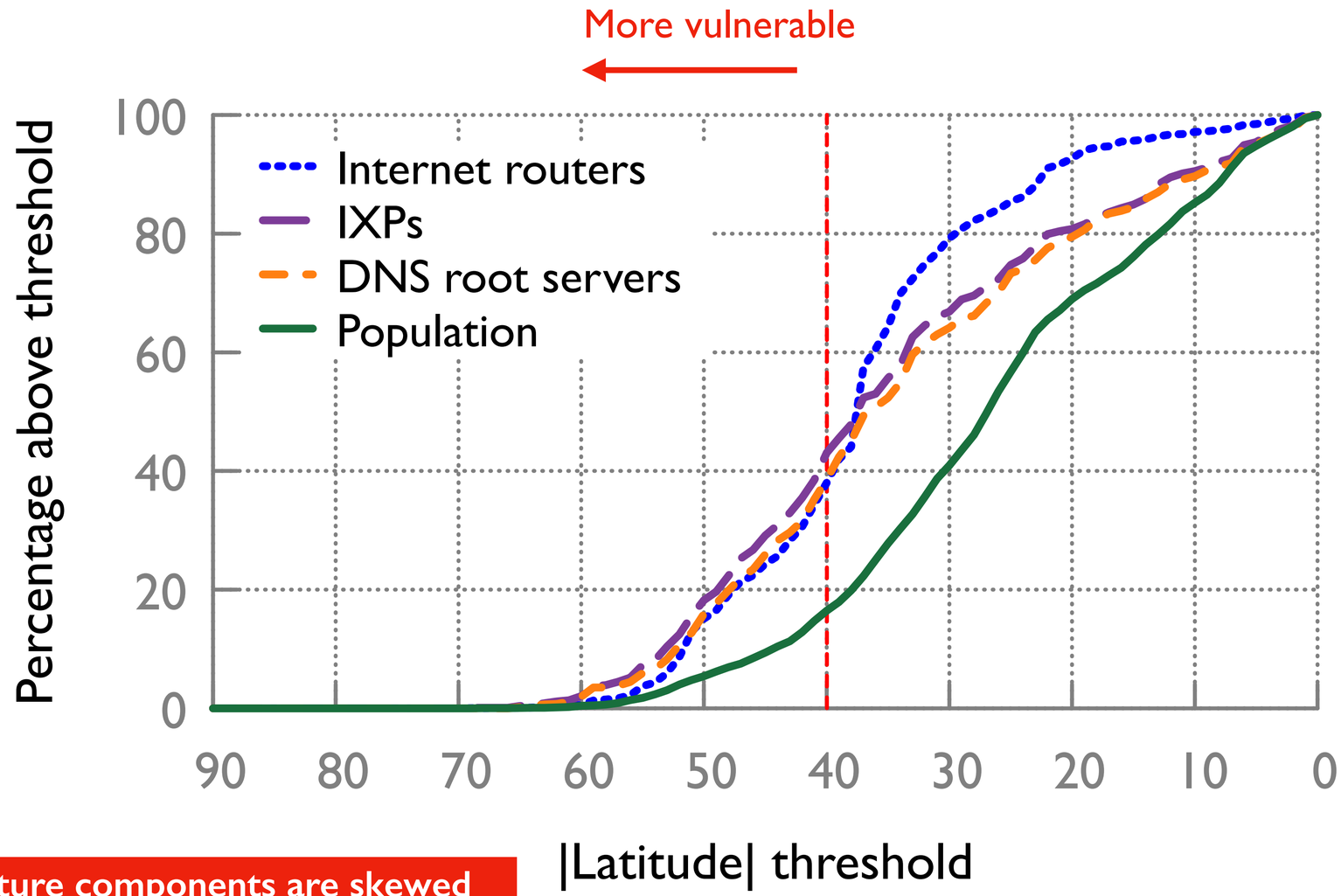
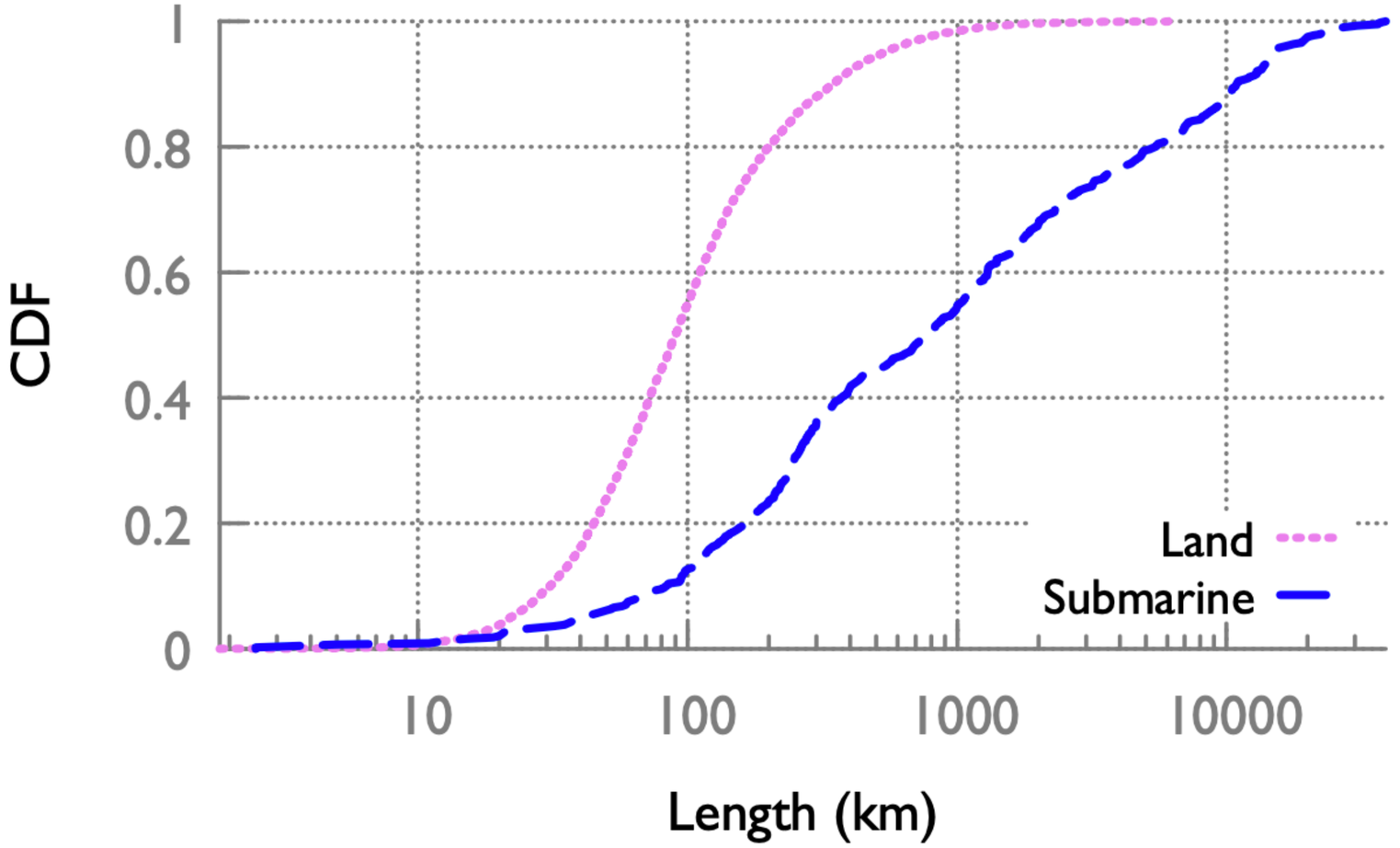


Internet infrastructure components are skewed towards more vulnerable regions

Cable Length Analysis



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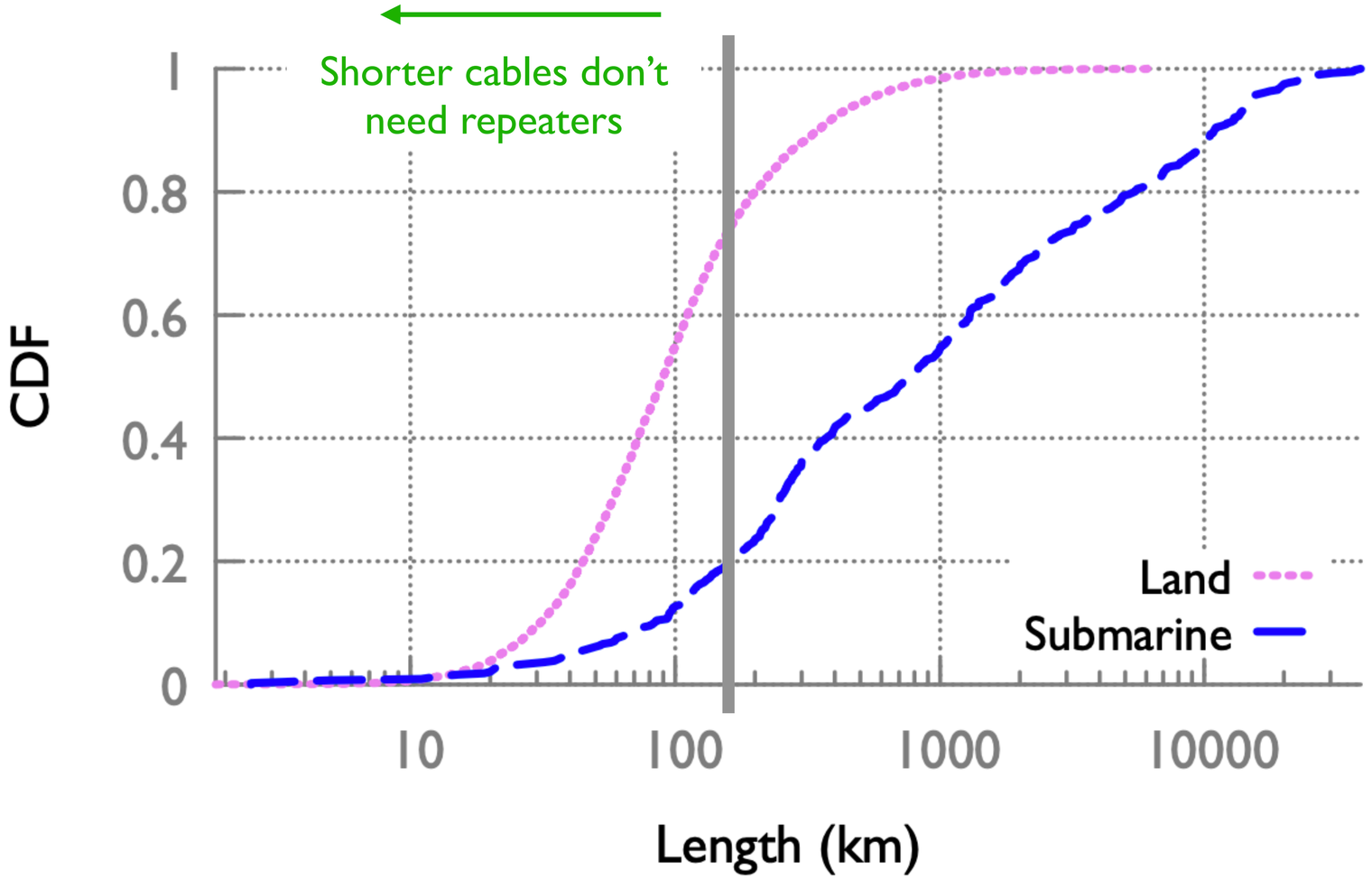

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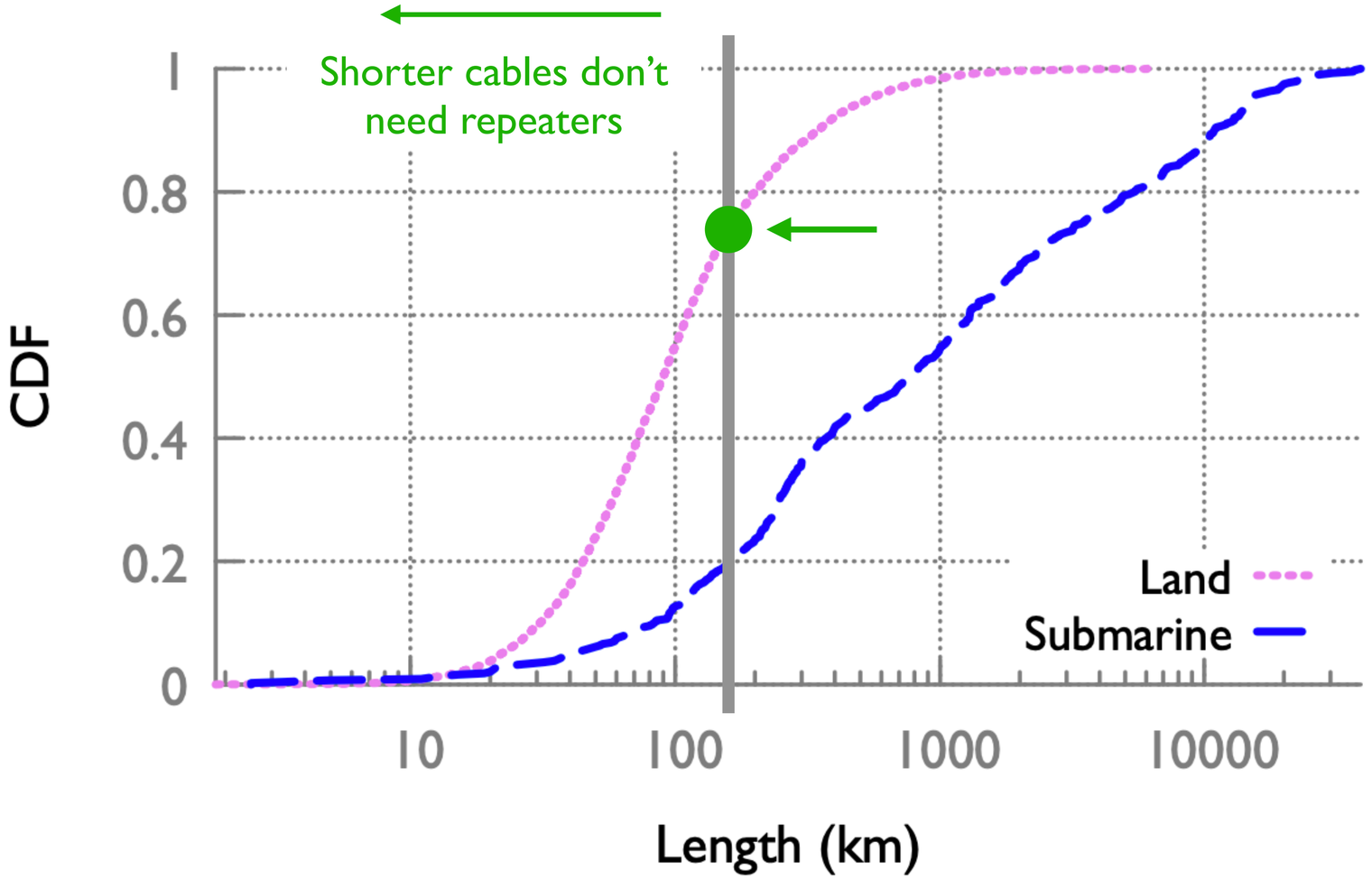

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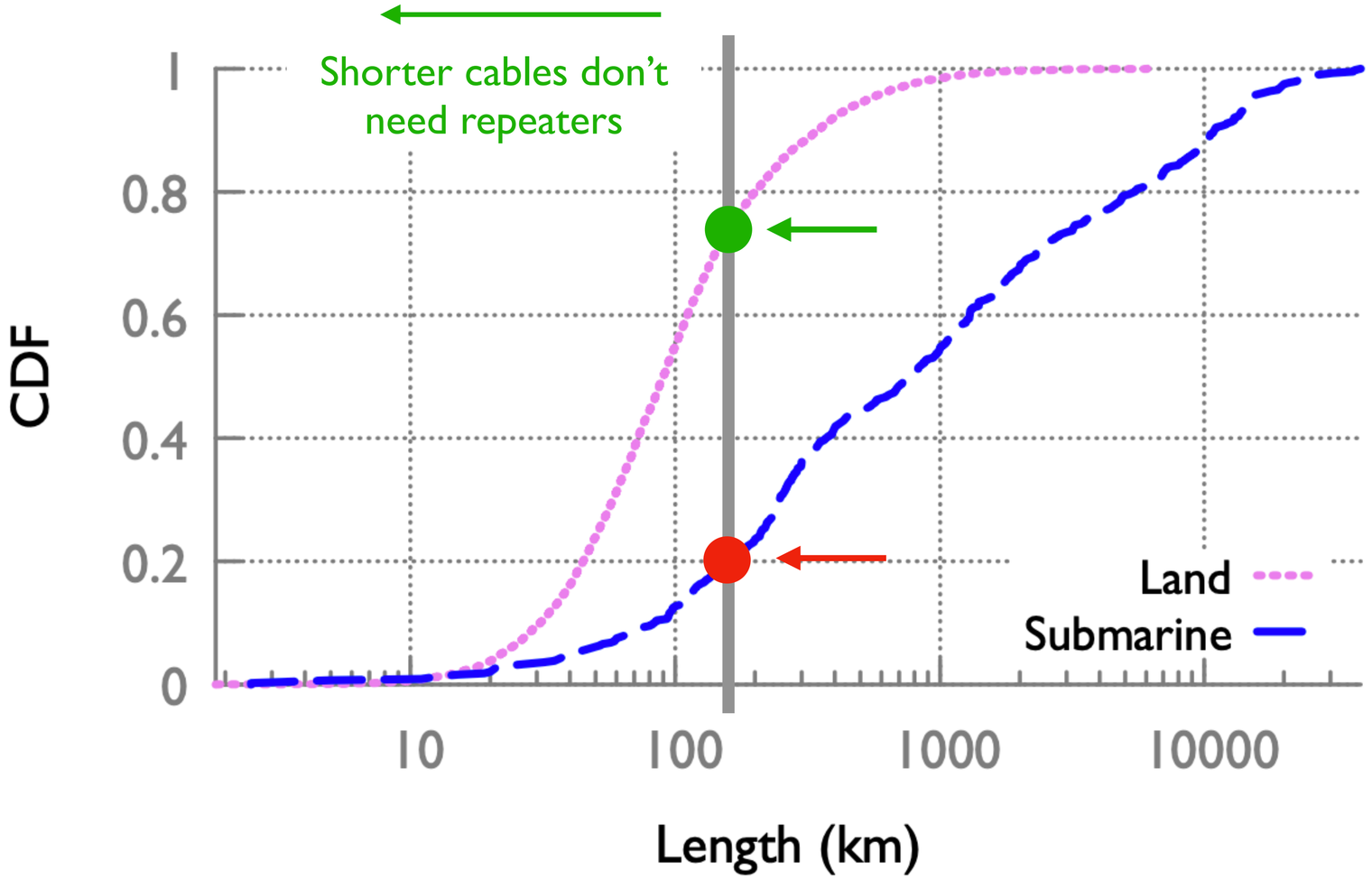

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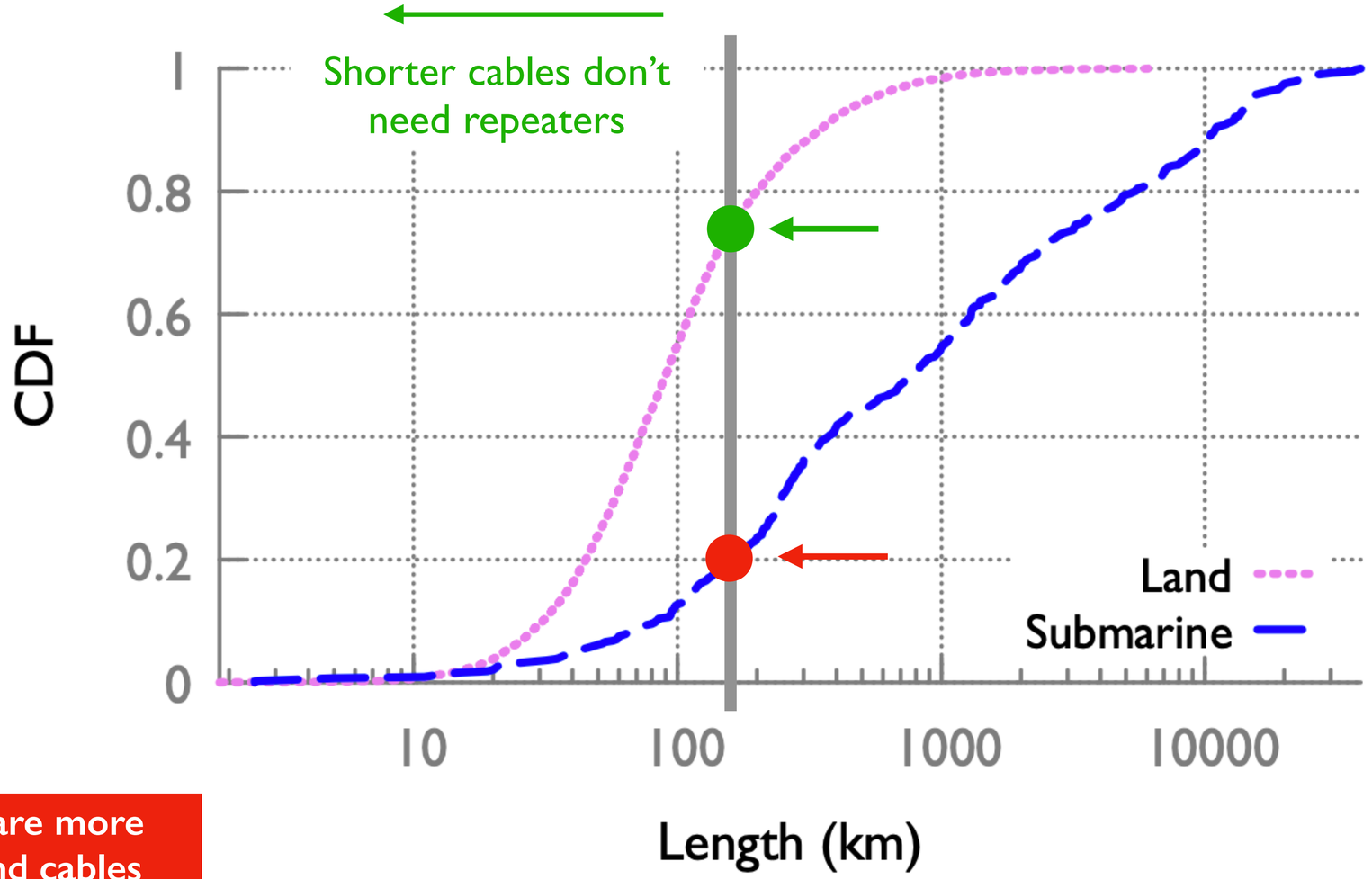


Submarine cables are more vulnerable than land cables

Country-Level Connectivity Analysis

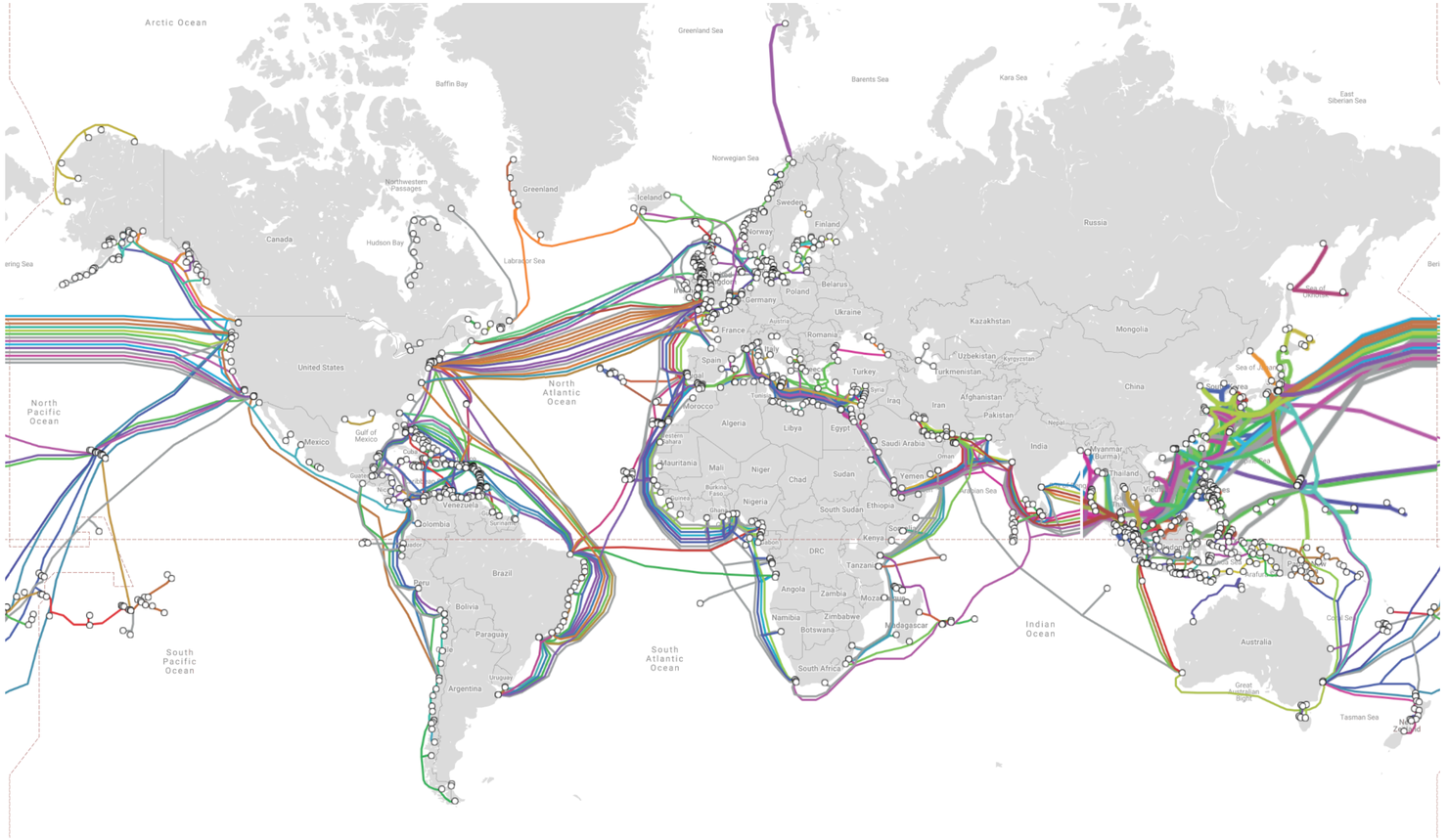
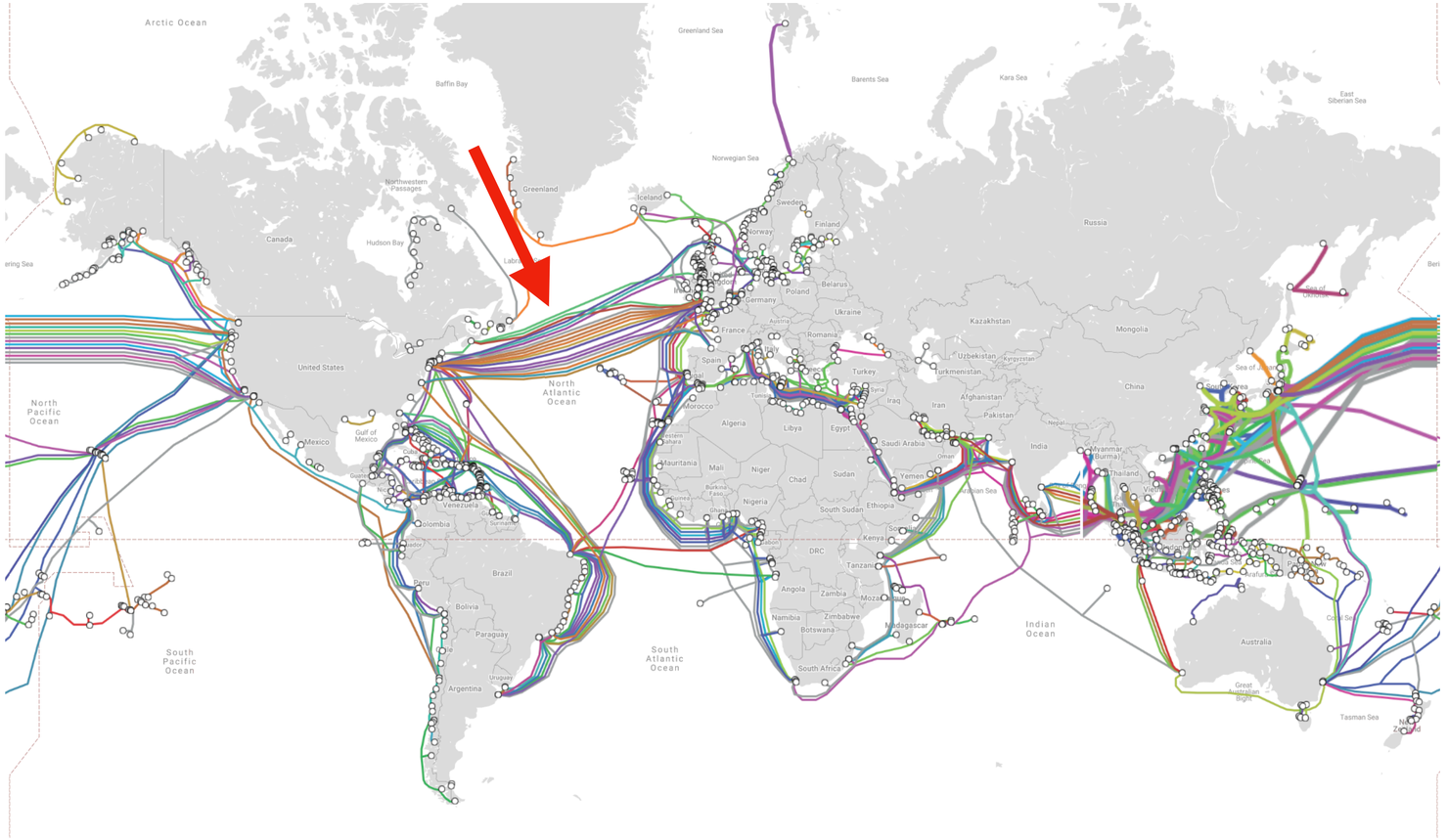


Image Credits: www.submarinecablemap.com

Country-Level Connectivity Analysis

- The US faces a higher risk of losing connectivity to Europe during a solar superstorm.



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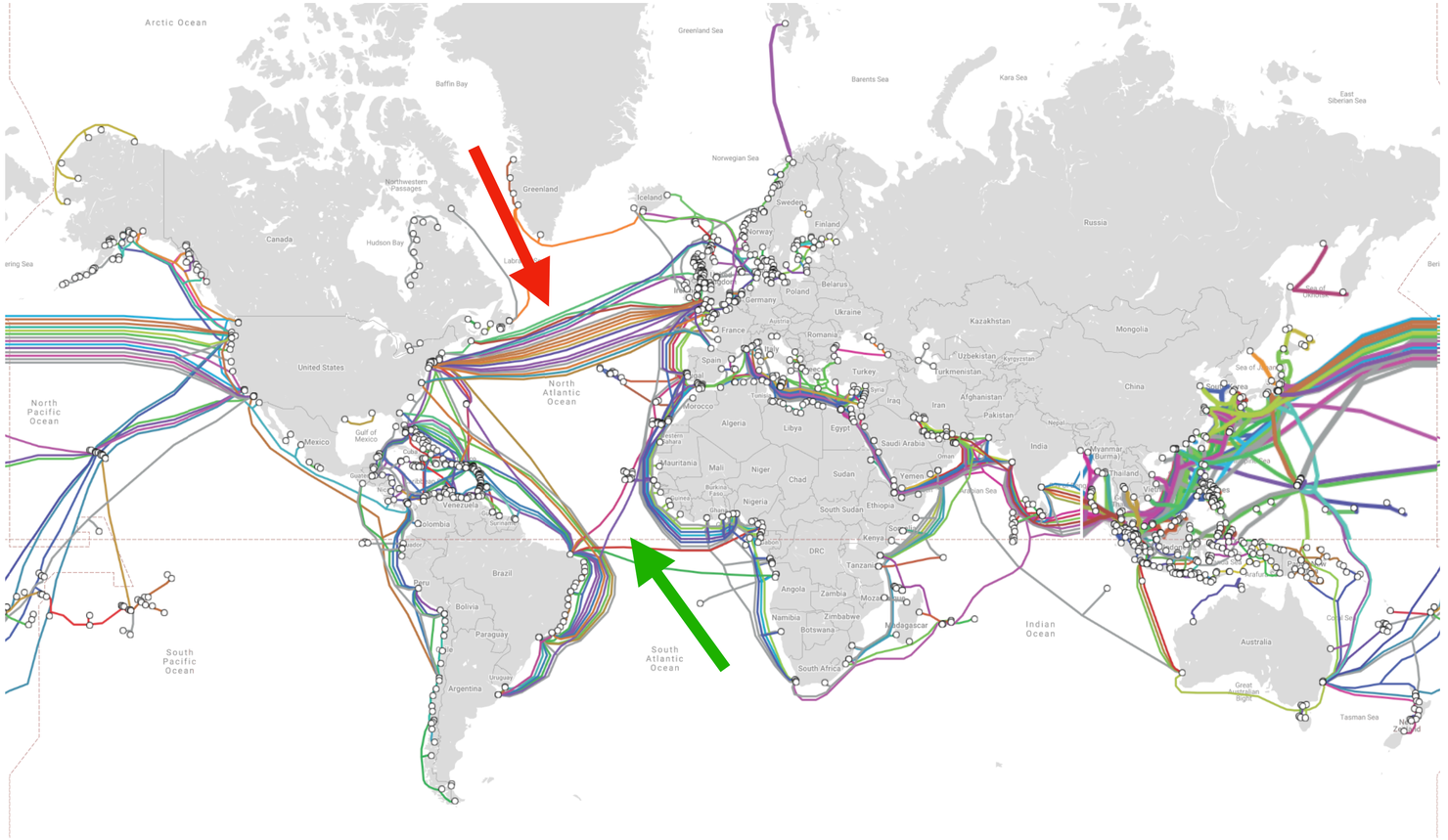
- The US faces a higher risk of losing connectivity to Europe during a solar superstorm.

- The cables between Brazil and Europe are less vulnerable.



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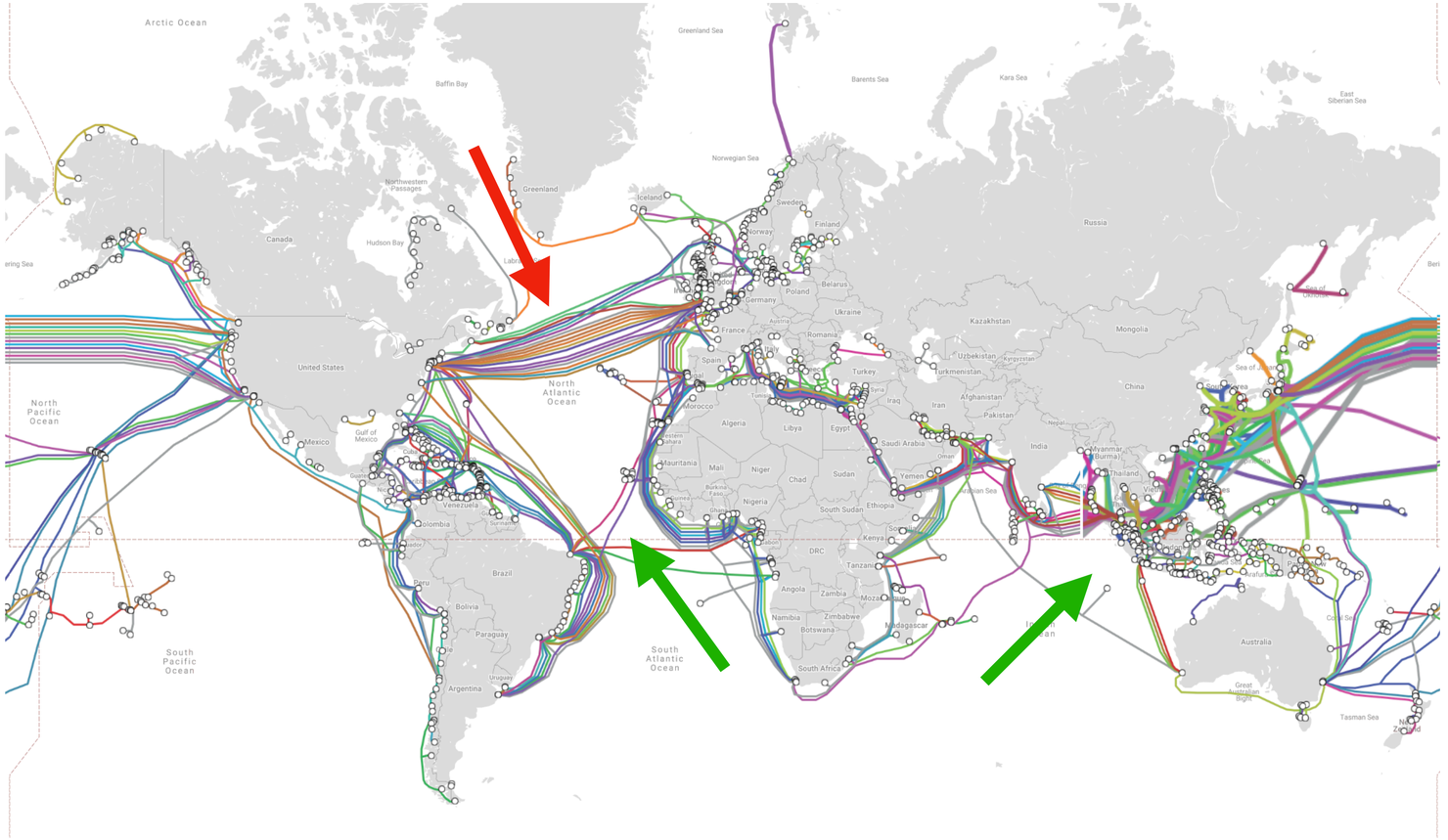
Country-Level Connectivity Analysis

- The US faces a higher risk of losing connectivity to Europe during a solar superstorm.
- The cables between Brazil and Europe are less vulnerable.
- In Asia, Singapore has a higher chance of retaining connectivity to neighboring countries even under severe storms



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Public Data Center Locations

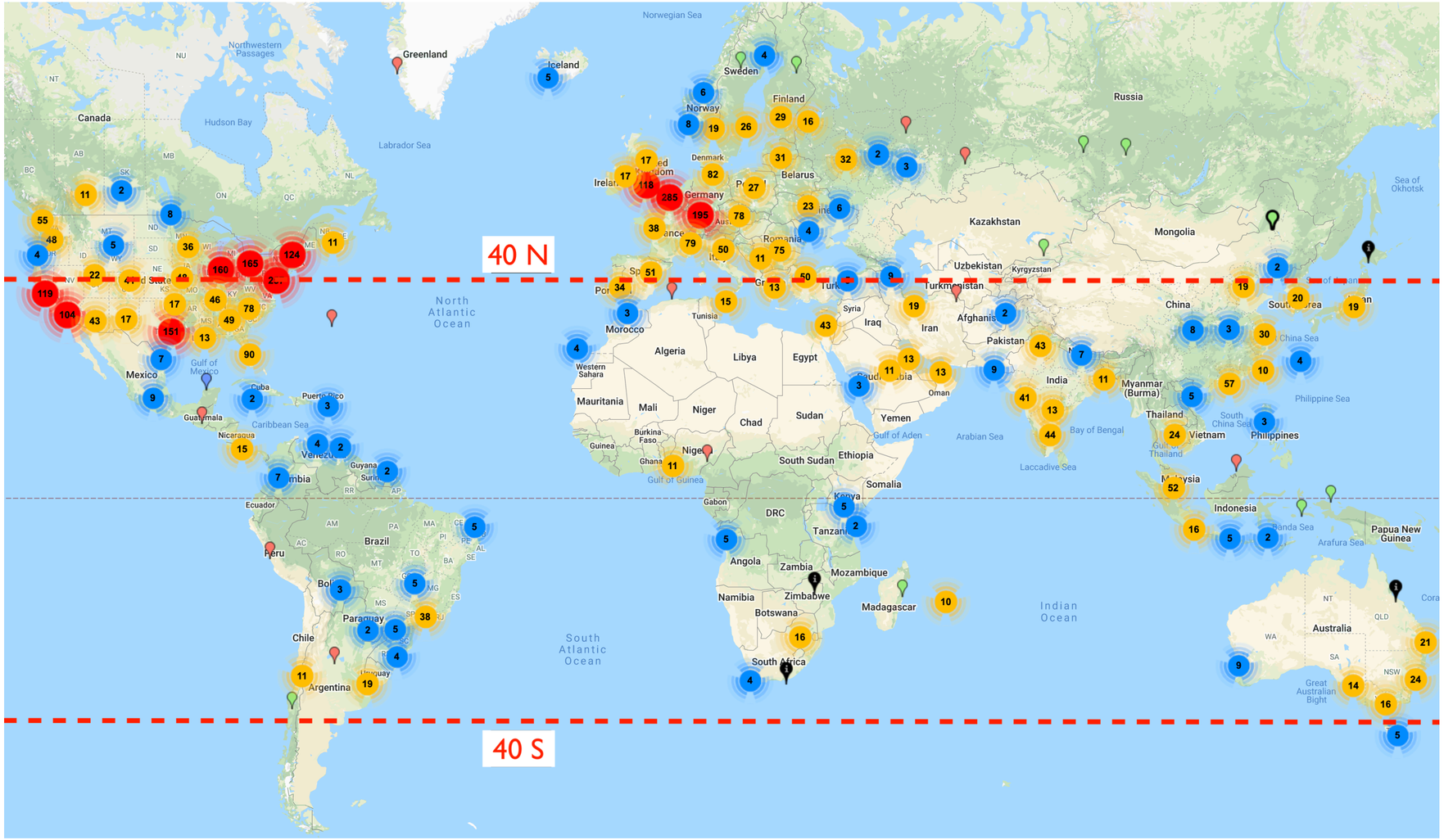

Image: https://www.datacentermap.com/

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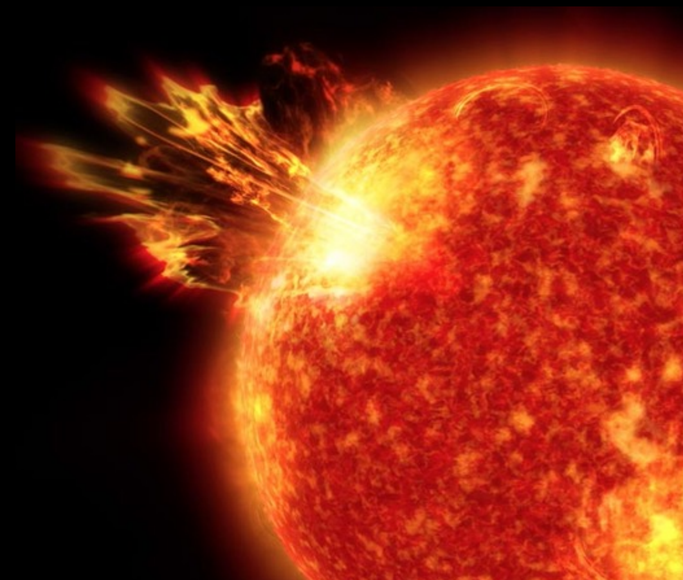
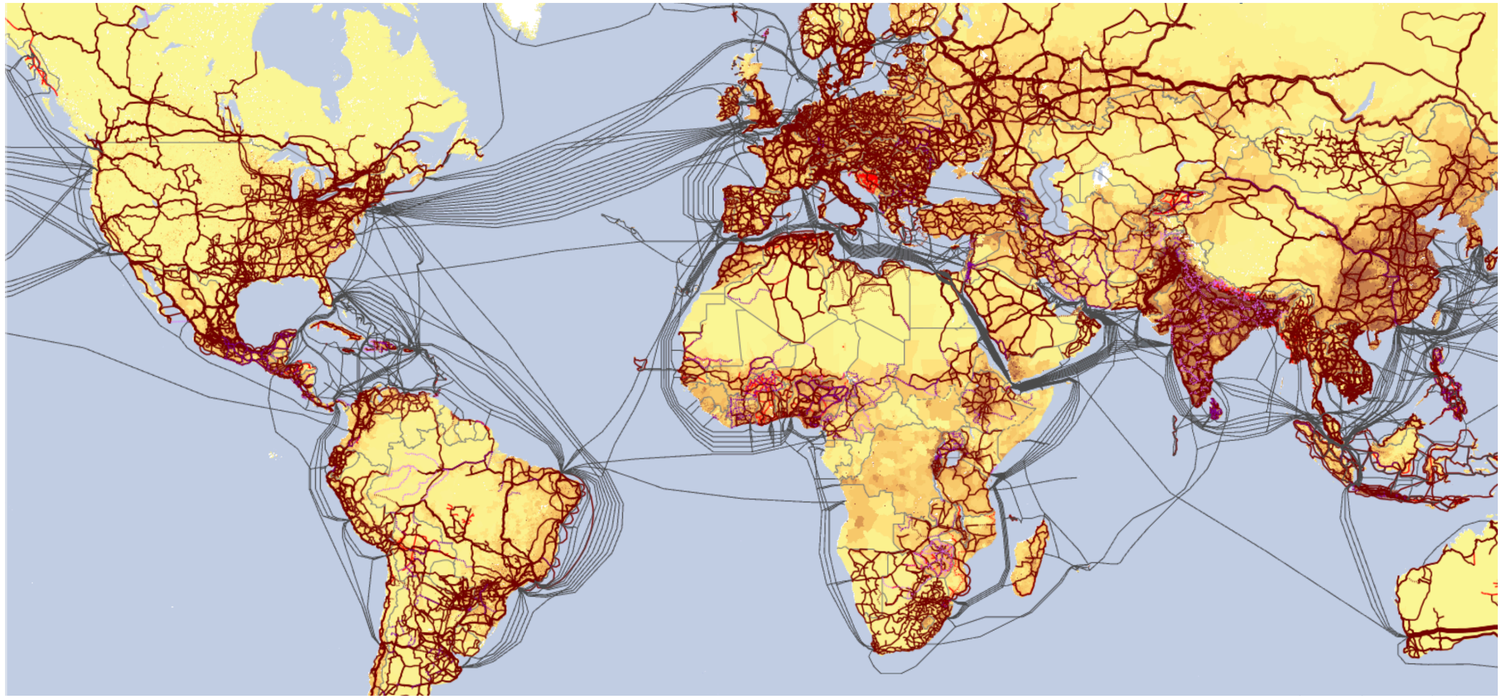
- DNS root servers are highly distributed and hence not vulnerable.
- A large fraction of Autonomous Systems (ASes) have a presence in vulnerable regions
- The vast majority of ASes have a small spread

Ongoing/Future Work



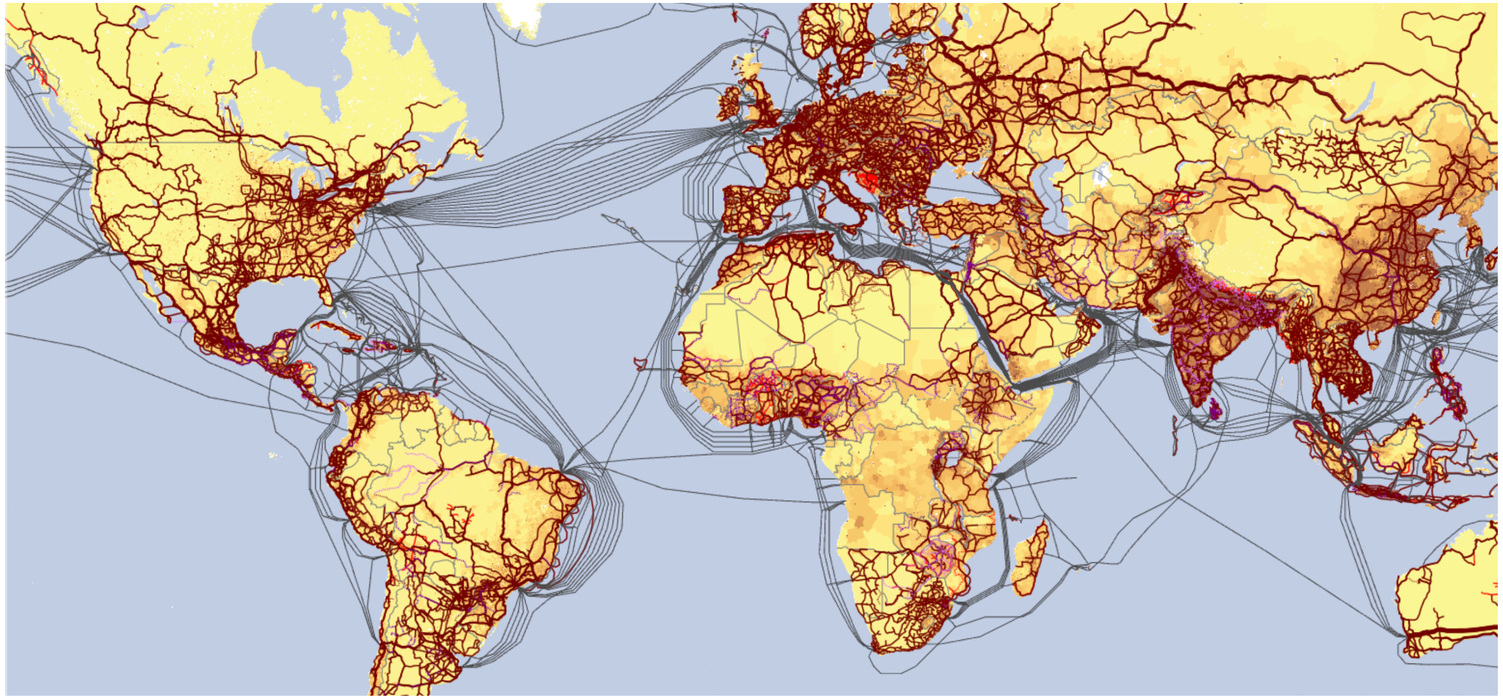
1. End-to-End Analysis of the Risk



Credits: https://www.itu.int/itu-d/tnd-map-public/

1. End-to-End Analysis of the Risk

- End-to-end analysis across land and submarine cables



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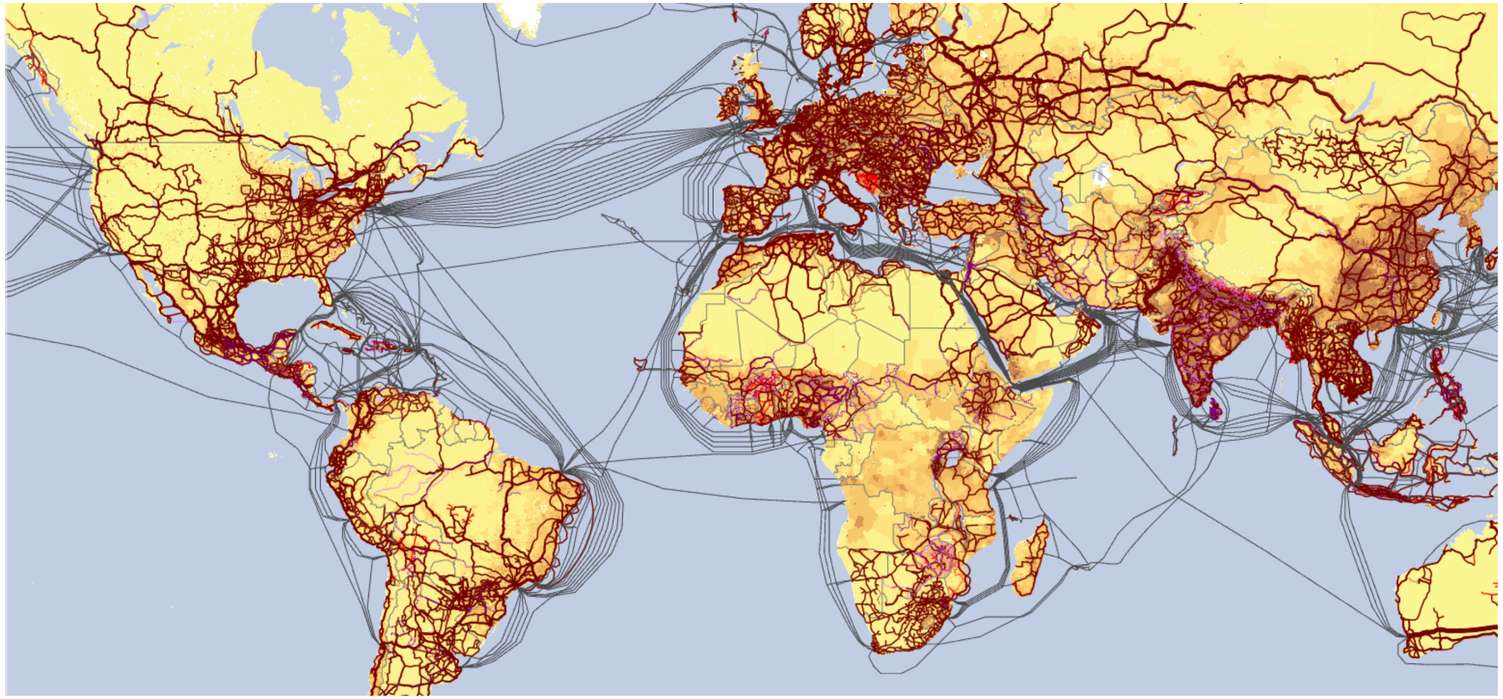

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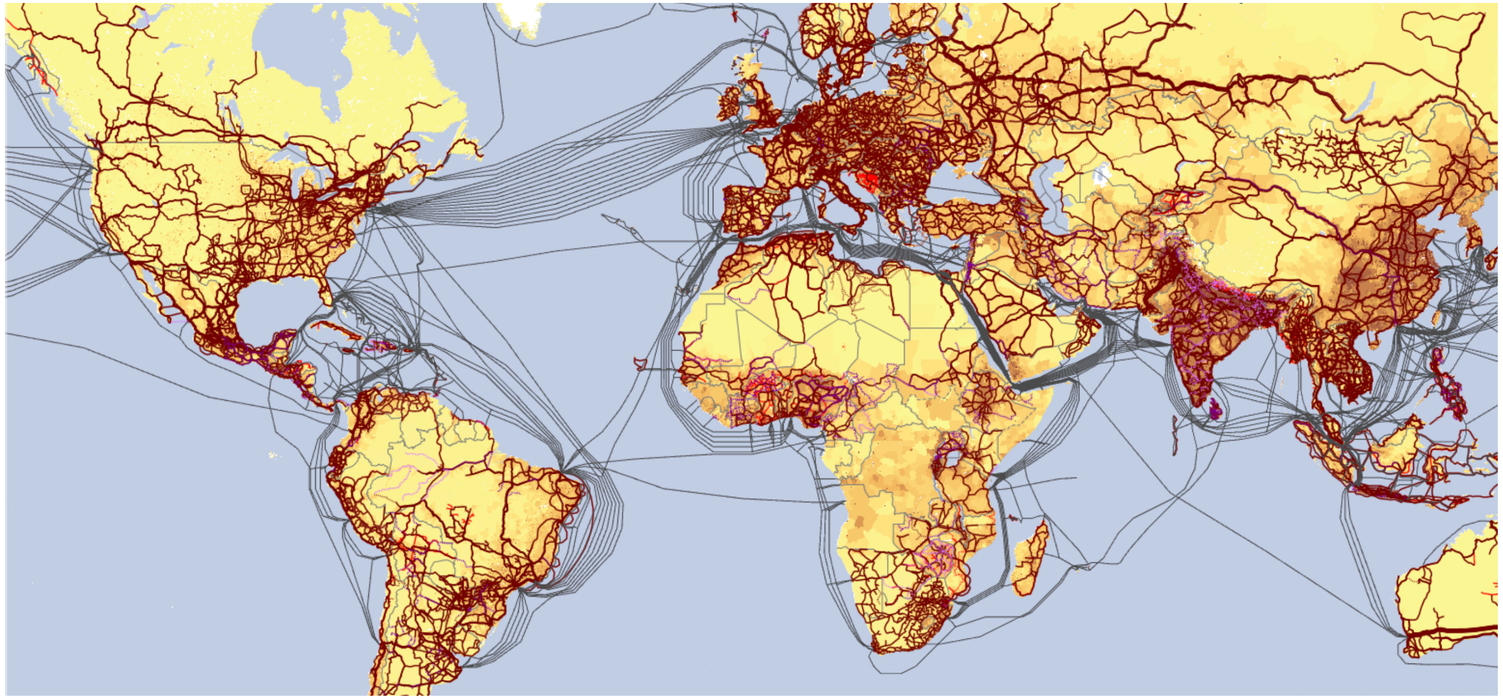

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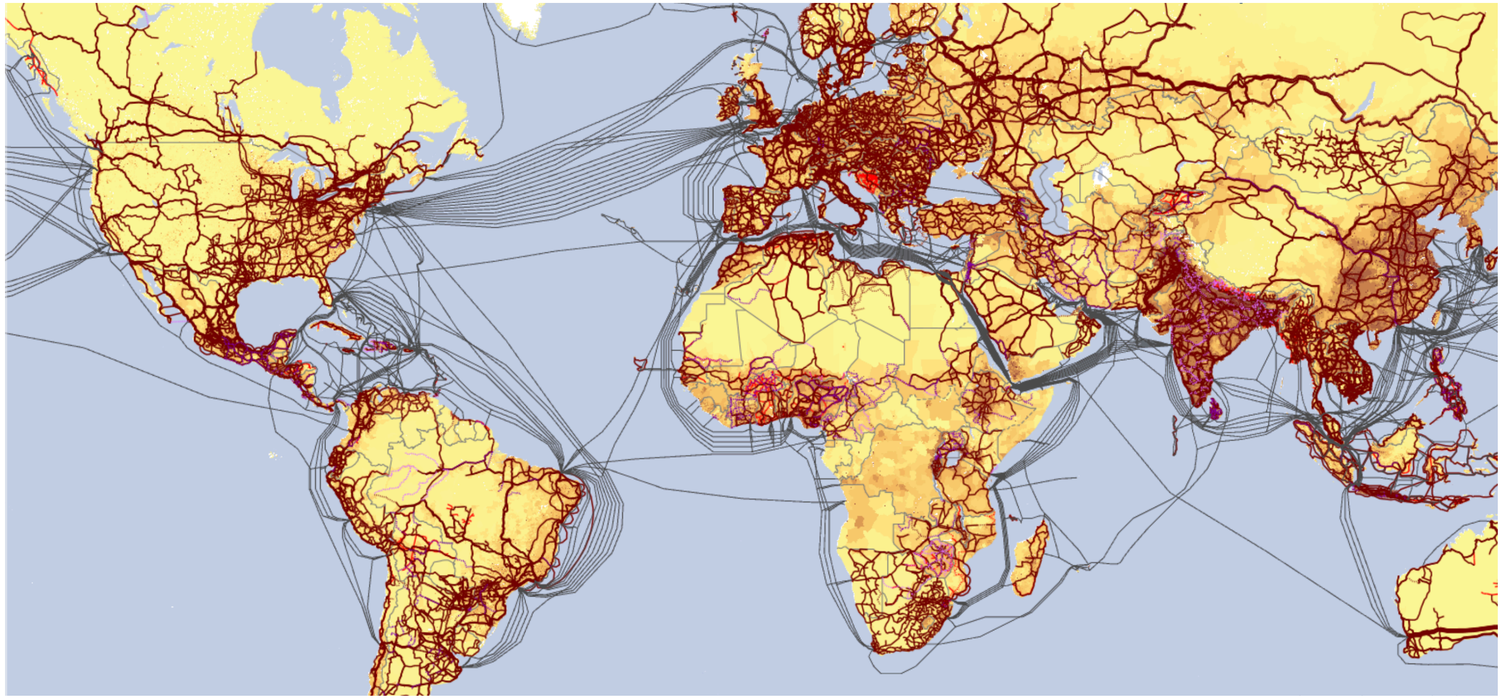

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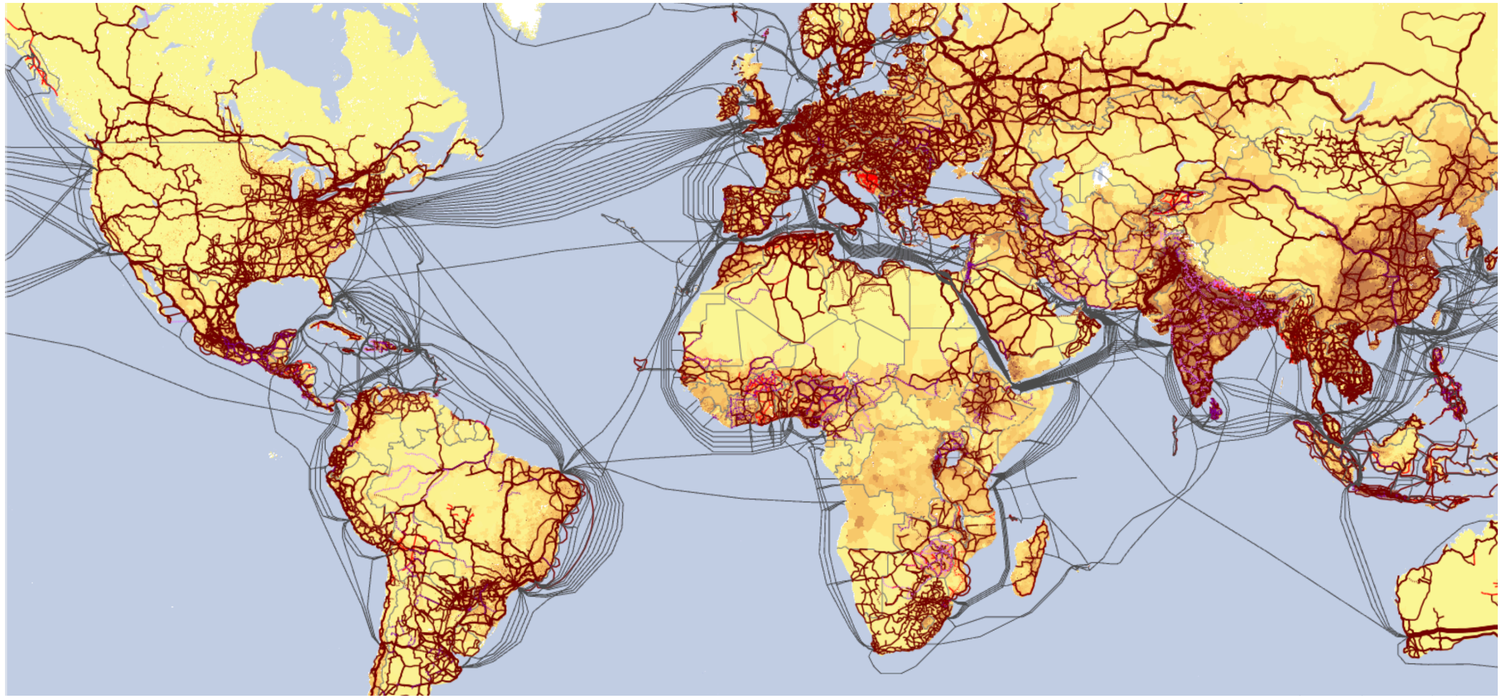

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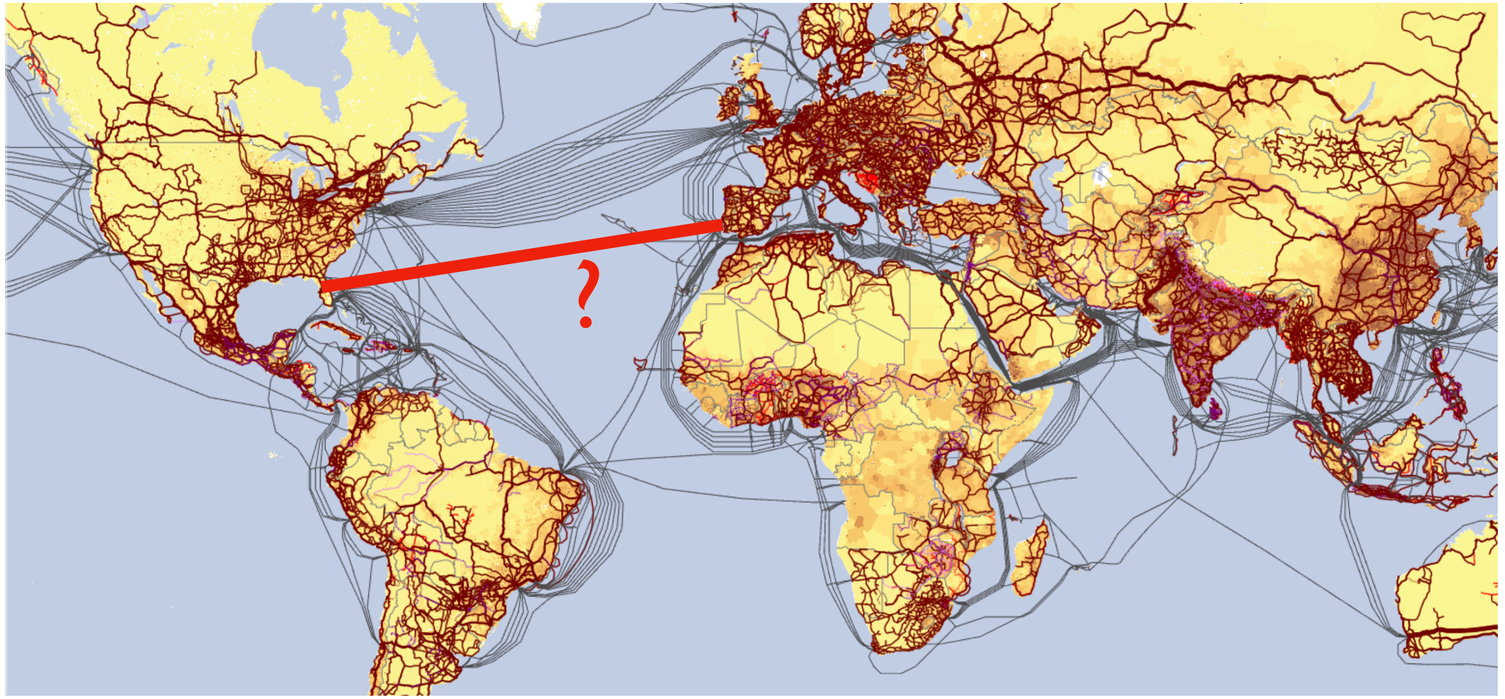
- Infrastructure expansion



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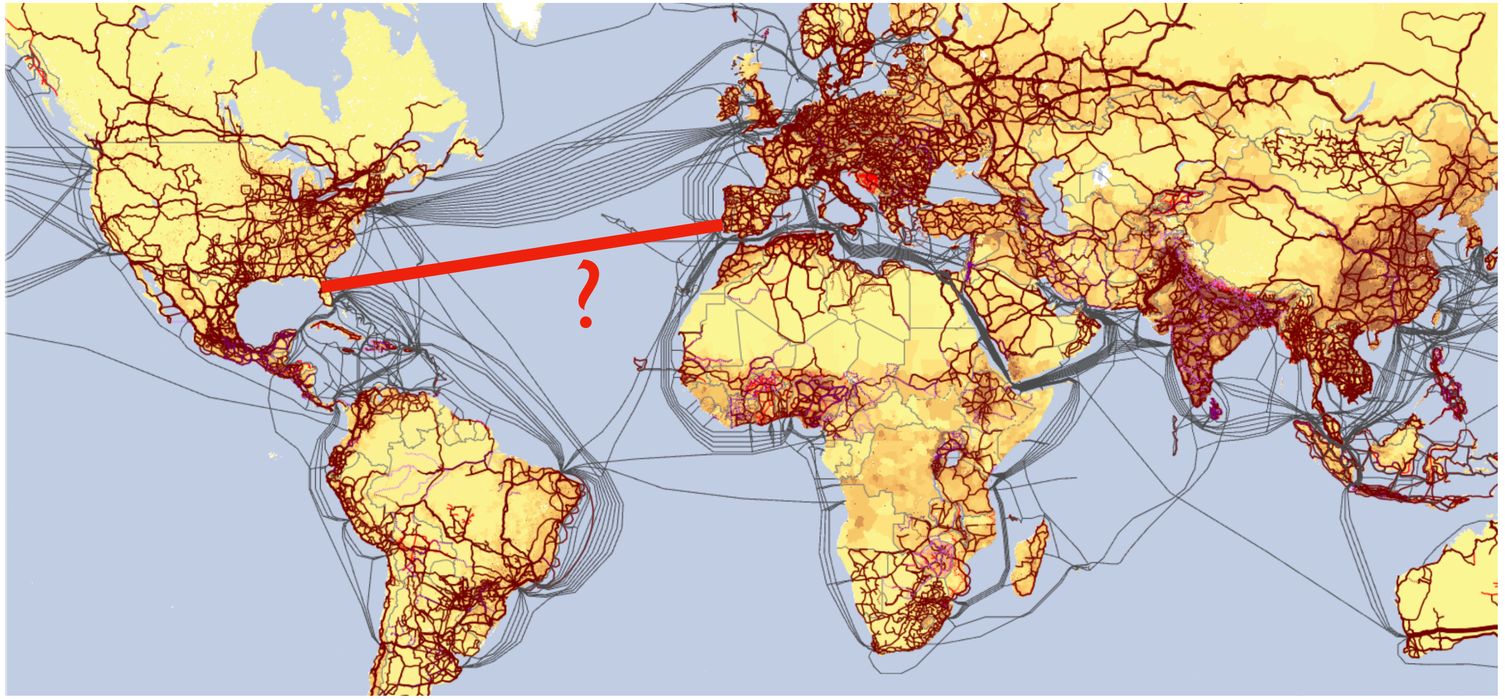

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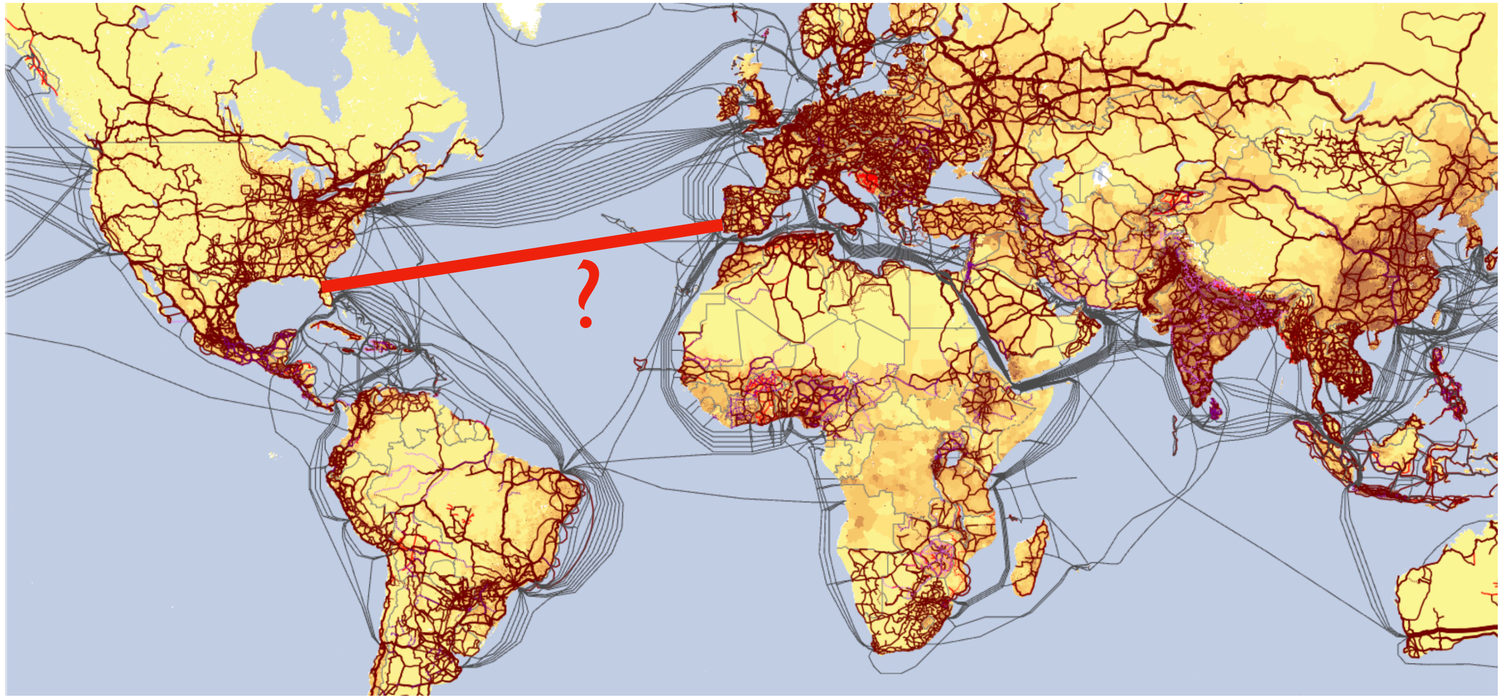

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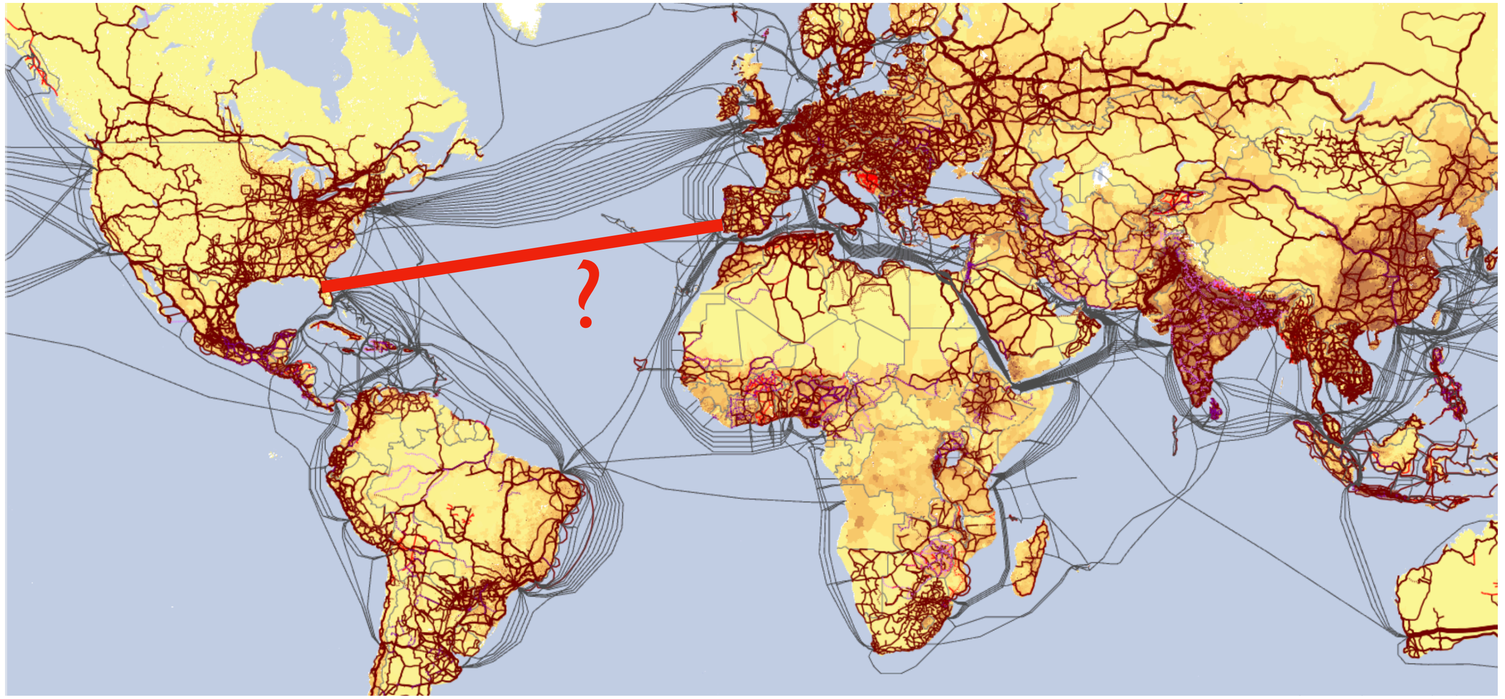

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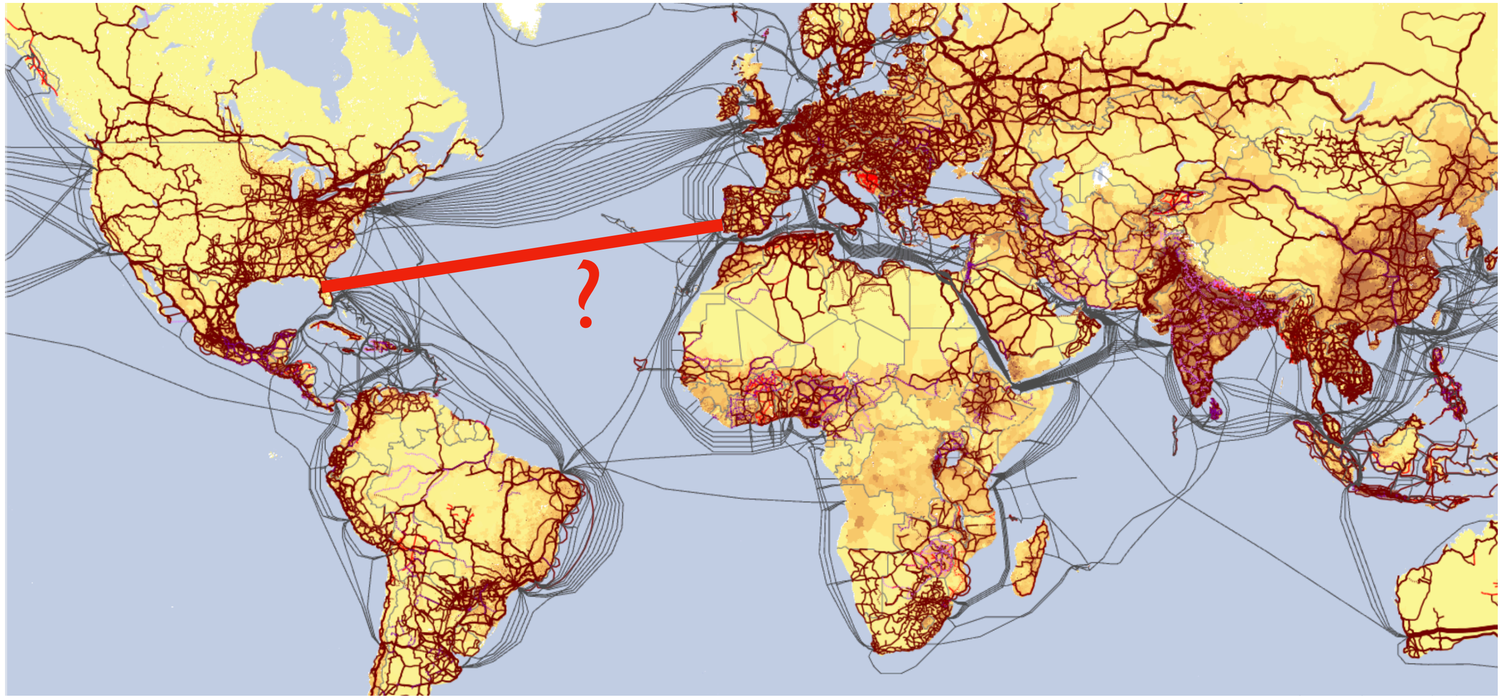

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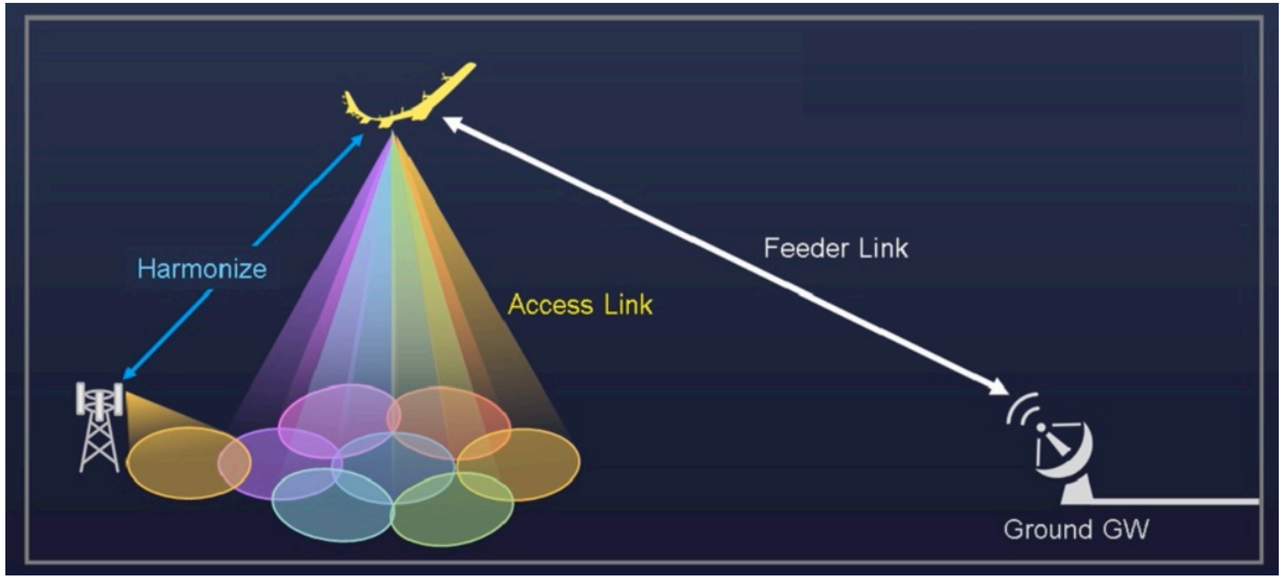
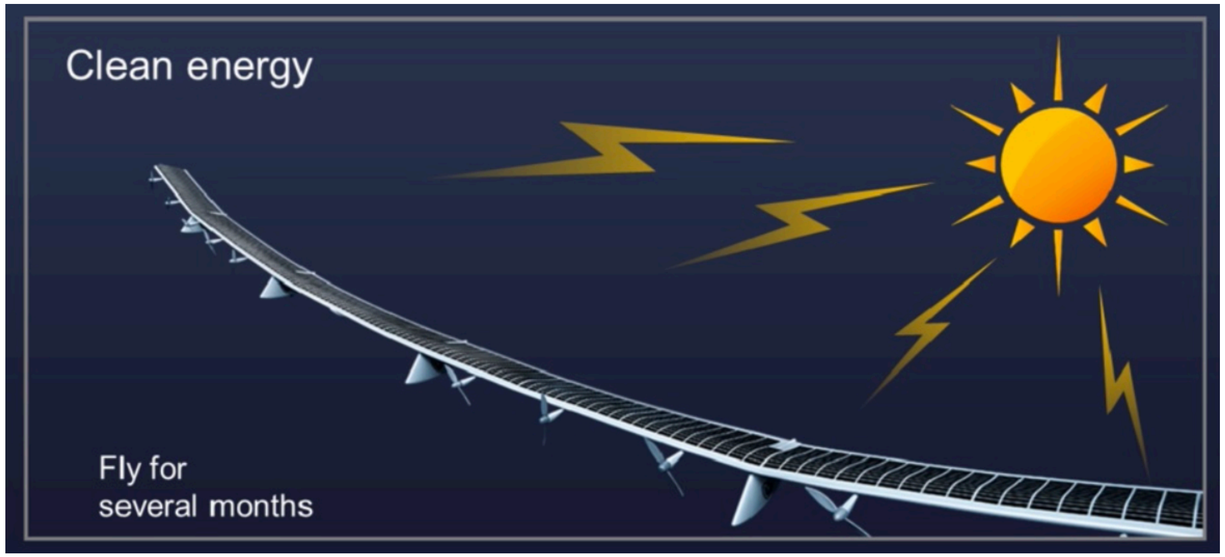
3. Reconnecting a Partitioned Internet

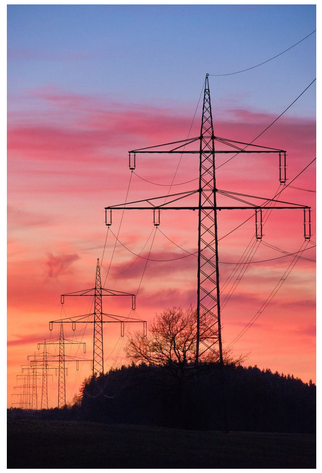




We need alternative solutions such as High Altitude Platform Stations (HAPS) that rely on renewable energy

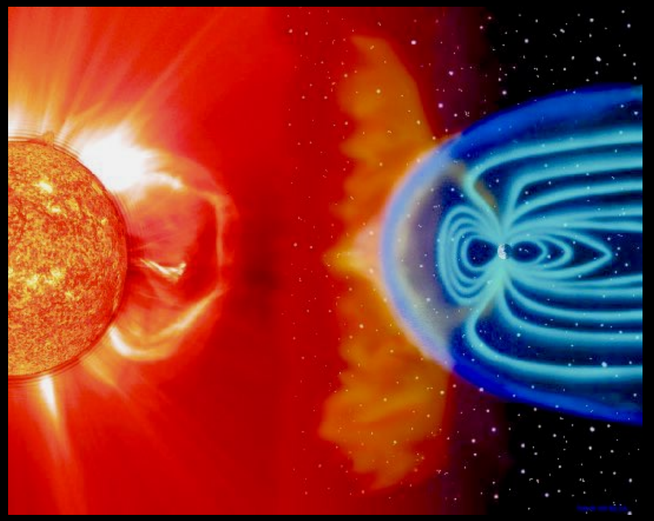
Credits: https://www.connectivity.technology/2020/10/hapsmobile-and-loon-deliver-4g-from.html

4. Interdependence with Power Grids



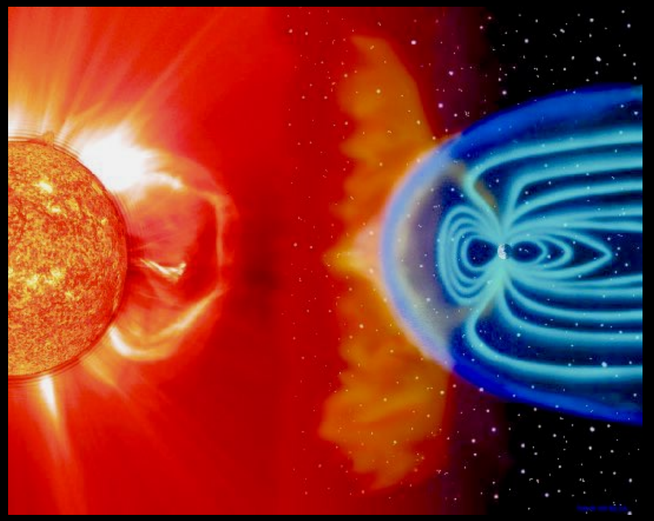
Power grids and the Internet are inter-dependent networks that are both vulnerable to CMEs

Summary



Summary

- Space weather poses a risk to the Internet infrastructure



Summary

- Space weather poses a risk to the Internet infrastructure

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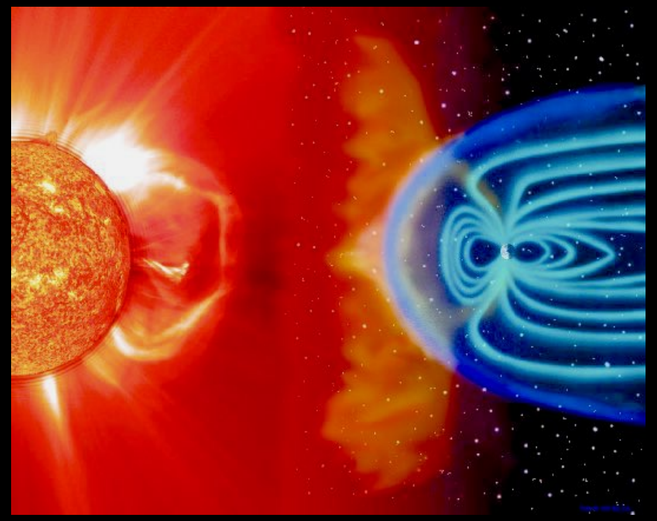

Summary

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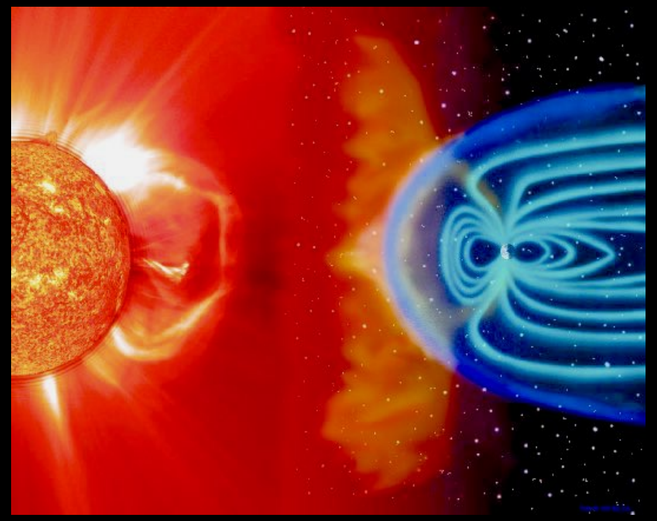

Summary

- Space weather poses a risk to the Internet infrastructure
- The Internet infrastructure has not been stress tested under strong solar events.
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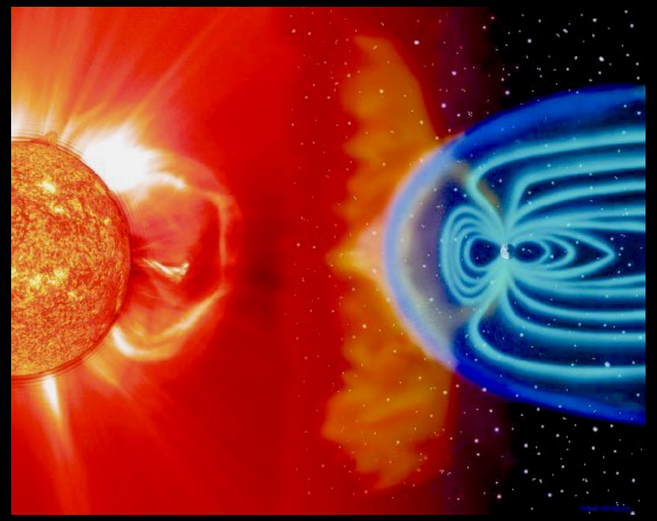
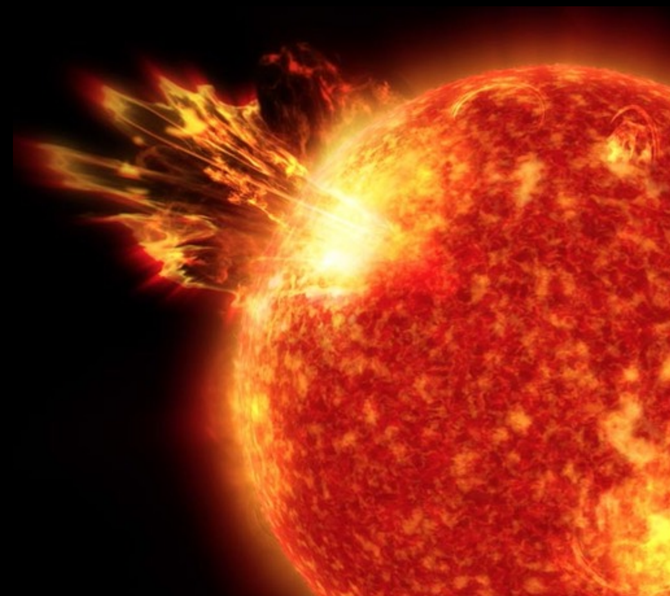
- We need to work towards better understanding and improving the resilience of the global Internet infrastructure.



Thank You!