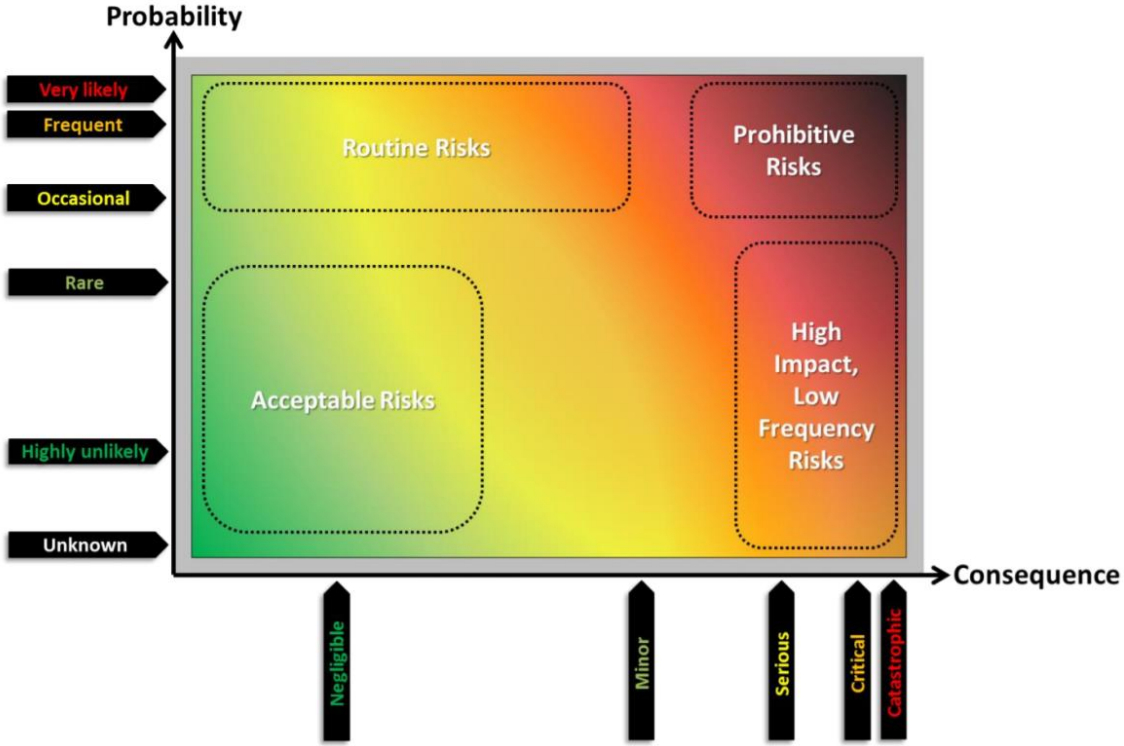
# SURFnet: Surprisingly Vulnerable or Remarkably Resilient?

Jorik Oostenbrink
Fernando Kuipers
LOIS, TU Delft

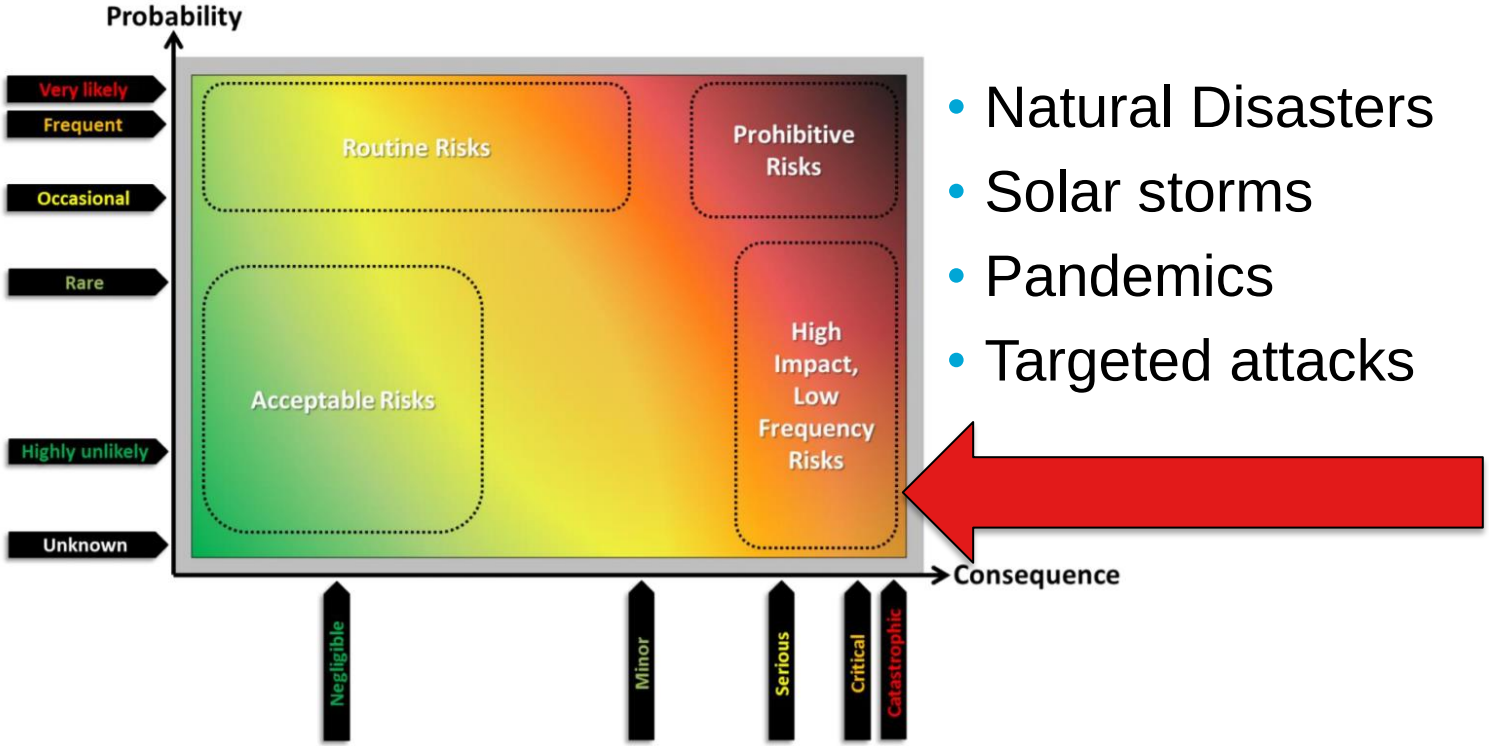
TU Delft

# Risks: Frequency vs Impact




"Resilience of the U.S. electricity system: A multi-hazard perspective", 2016

# Risks: Frequency vs Impact




- Natural Disasters
- Solar storms
- Pandemics
- Targeted attacks

"Resilience of the U.S. electricity system: A multi-hazard perspective", 2016

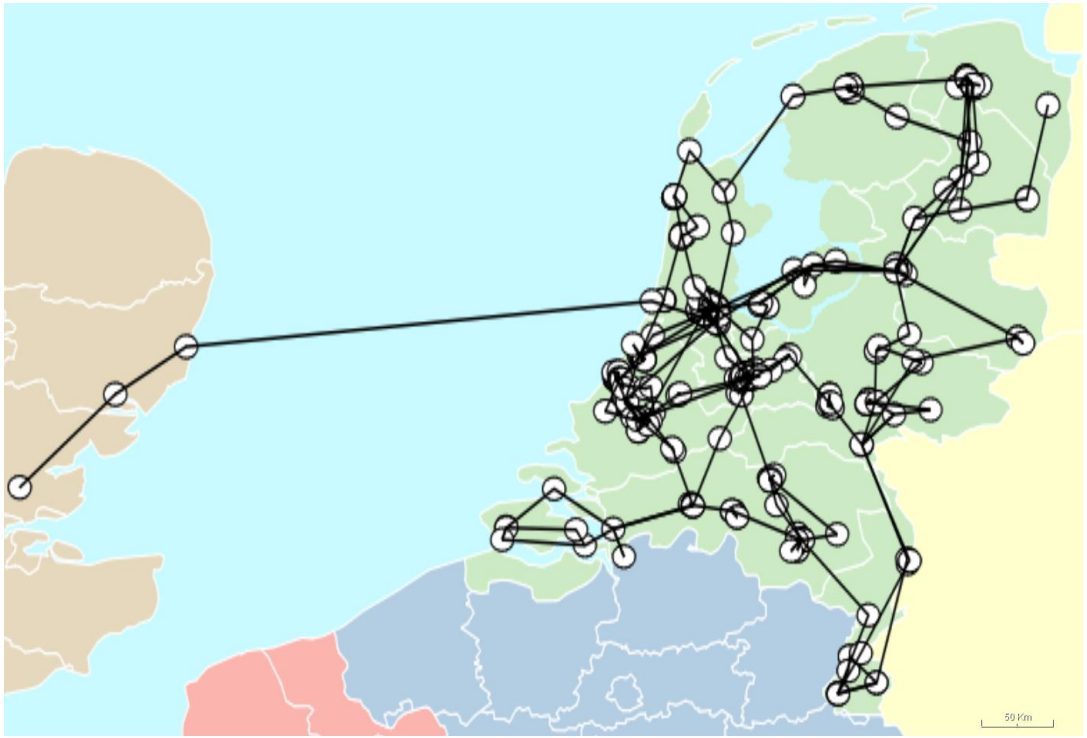
# Sint-Maarten, Hurricane Irma, 2017

- Transmission masts destroyed
  - No emergency masts ready
- No communication means
  - Within local government
  - With residents
- Humanitarian aid delayed

# Project Goals

- Determine the resilience (or vulnerability) of SURFnet to HILF events
- Focus on flooding
  - Pluvial
  - Coastal and river

# SURFnet Graphs

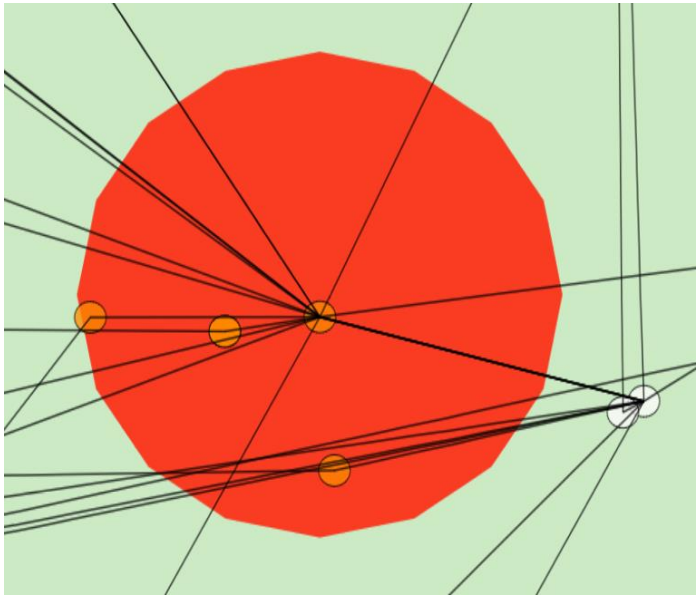



“Complete” network


Core network

# Starting Small

- What happens when all nodes within *x* meters of a chosen node fail?
- Expectation
  - As long as *x* is small, no impact

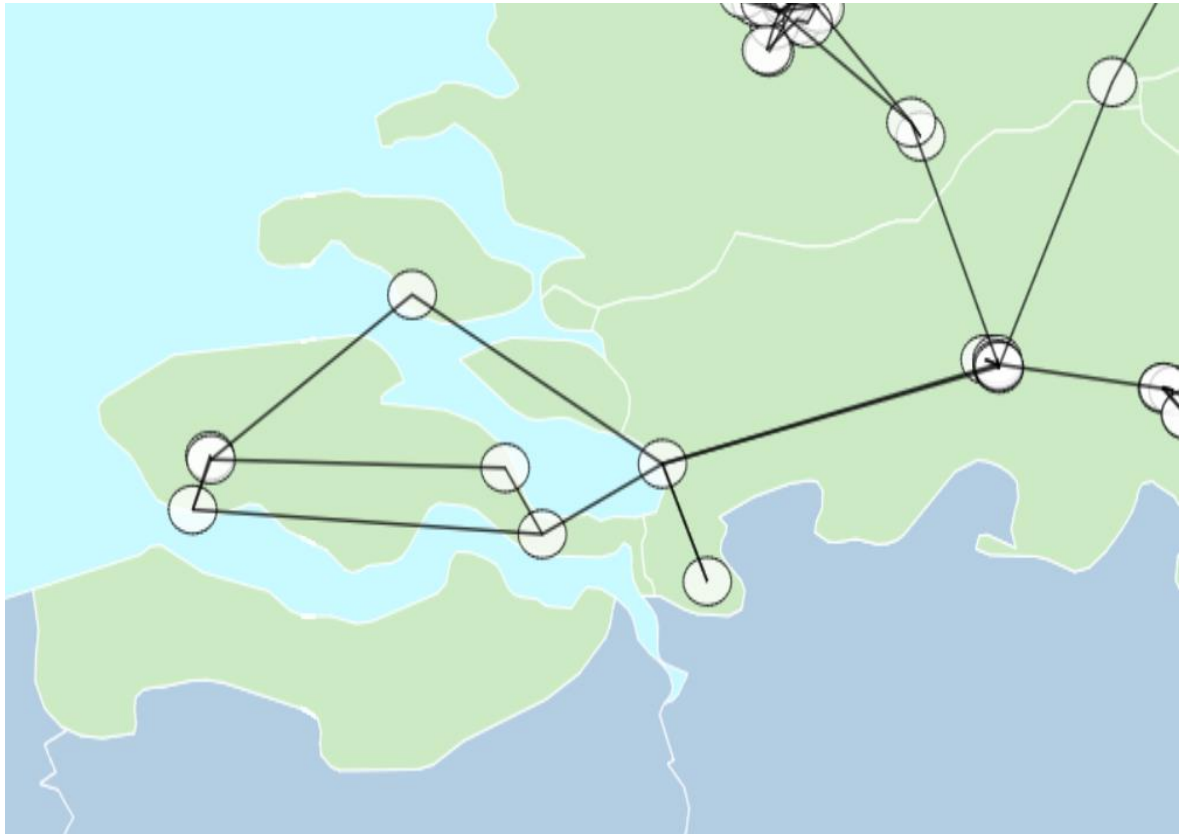


# Results (Complete Network)

- We can disconnect almost 10% of all surviving node pairs with a 500 m radius disk failure!
- 49 (out of 264 locations) vulnerable to 500 m radius disk failures

TU Delft

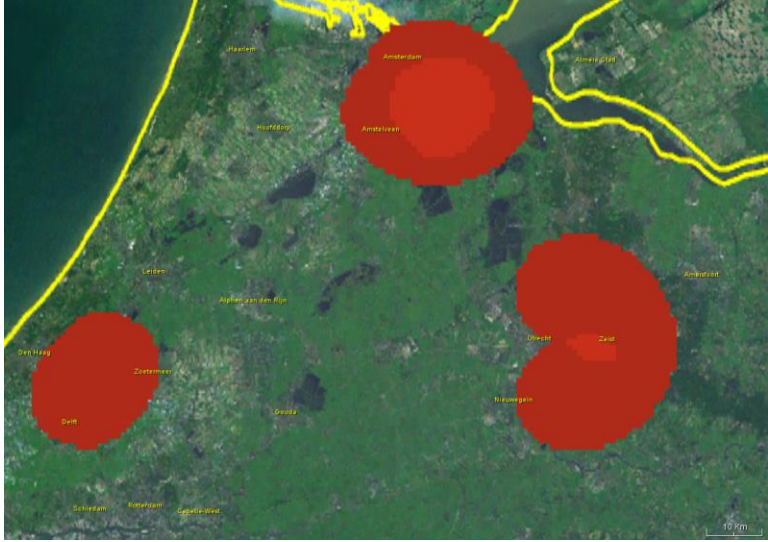
# Single Point of Failures



# Larger Disk Failures

- Study impact of larger disk failures
- Goals
  - (Over)estimate impact “general” HILF events
  - Find vulnerable areas

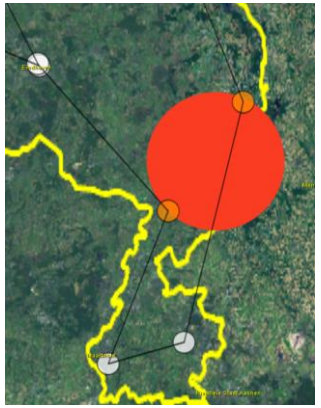
# Overall Results




- Complete network
  - 3 vulnerable areas:
    - The Hague, Amsterdam, and Utrecht
  - <= 25 km radius impact limited to < 21% disconnections

# Overall Results

- Core network
  - No disconnections by ``smaller'' events (<= 10 km radius)
  - Randstad is most vulnerable area
  - Interesting vulnerability in Limburg



# Pluvial Flooding

- Flooding due to extreme precipitation
  - Independent of water bodies
  - Precipitation overwhelms drainage systems
- 10-20% of all land at risk?
- Climate change
  - Extreme precipitation will occur more frequently in the future


# Wateroverlast: natte voeten en zwemmen in het Mediapark

NOS NIEUWS • BINNENLAND • 12-07-2019, 15:45

NOS NIEUWS • REGIONAAL NIEUWS • 02-08-2019, 21:08

# Wateroverlast door plensbuien in Gelderland en Limburg

TU Delft

# Approach

- Keep track of network state over large sequences of simulated weather
  - 2 sets of 15 KNMI climate simulations
  - spanning a total of 2 x 750 years
- Apply threshold on average precipitation over last 2 hours

# Influence of Precipitation Threshold

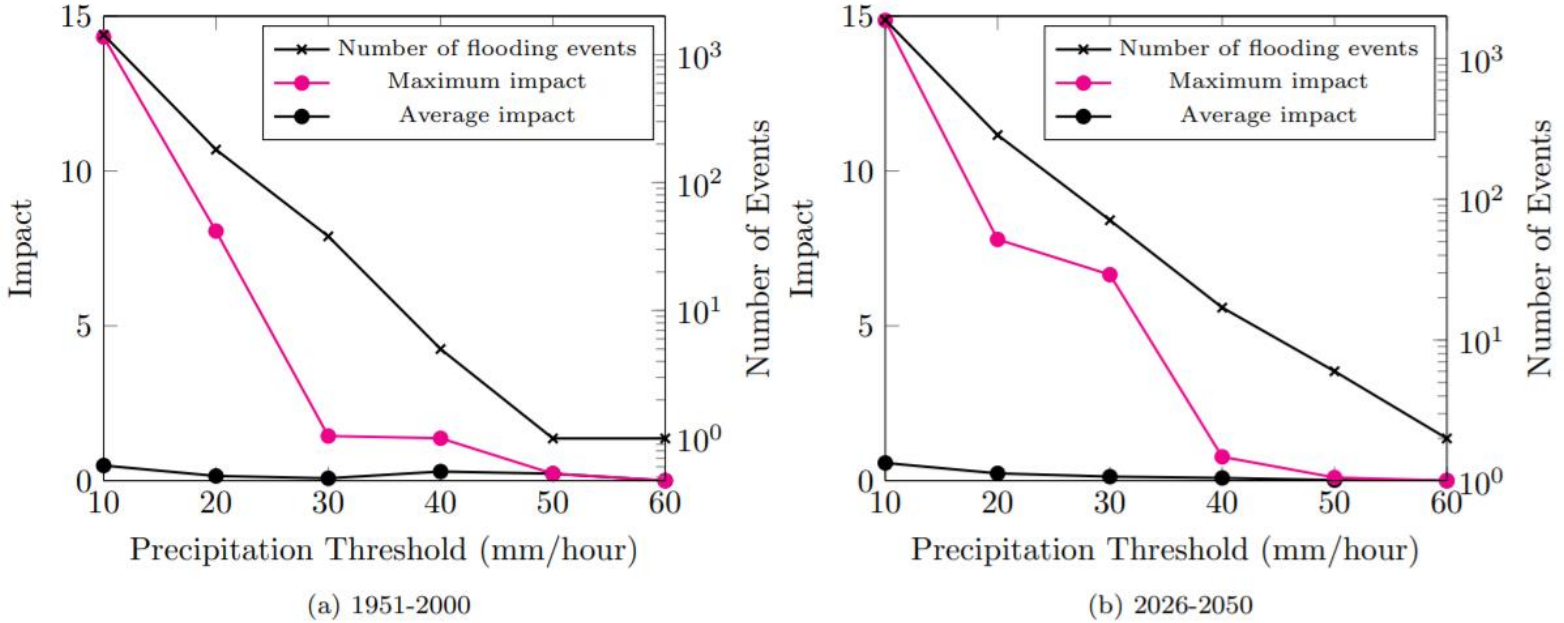
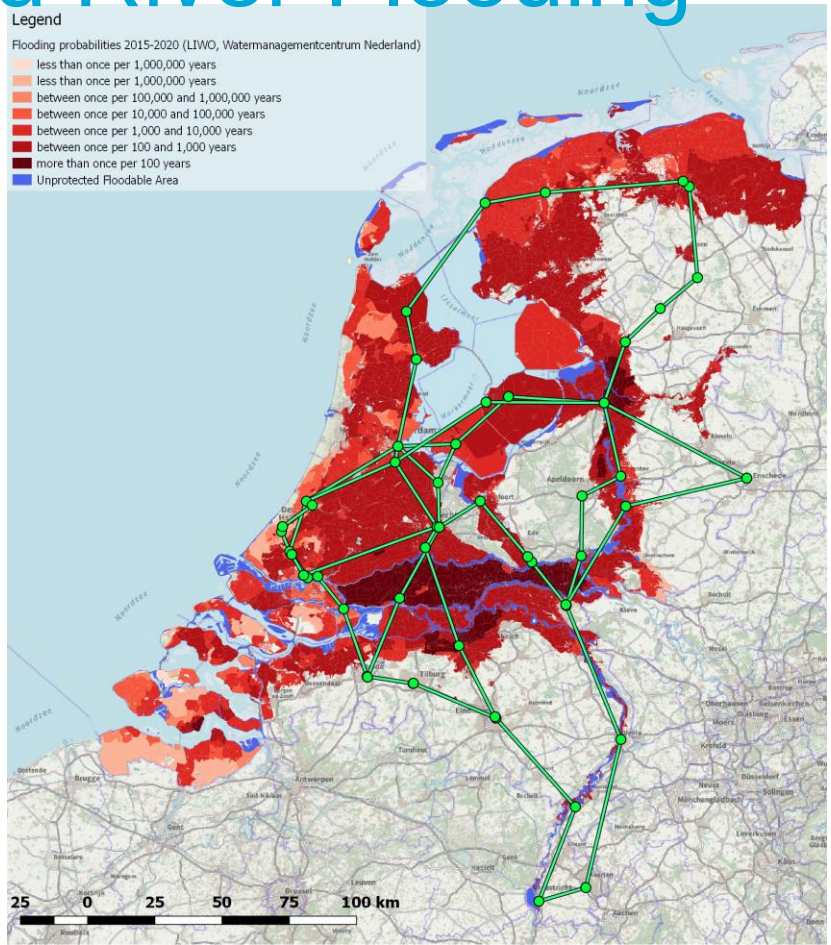



Figure 4.15: Number of and maximum and average impact (in ratio of disconnected node pairs × hour) of flooding events in the core network against the chosen precipitation threshold.

# Overall Results

- Found no evidence that core network is particularly vulnerable to pluvial flooding (in terms of disconnections!)
- SURFnet should check pluvial flooding risk at critical sites

# Coastal and River Flooding



# Conclusion

- Core network remarkably resilient against (many) HILF events
- Complete network surprisingly vulnerable, even to smaller events

- Large parts of the network at risk of coastal or river flooding

# Questions/Comments?

- Contact us!
  - J.Oostenbrink@tudelft.nl
  - F.A.Kuipers@tudelft.nl
- https://fernandokuipers.nl/LOIS