Reliability and Resilience

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Presentation Objectives

- **Explore relationship between reliability and resilience**
- **Is resilience a new issue?**
- **Preliminary approaches for assessment**

Based on my reply comments to FERC
http://www.milligangridsolutions.com/milligan%20ferc%20comments%20AD%2018-7-000%20from%20FERC%20web.pdf

Outline

- **Background:**
  - DOE NOPR, resilience. FERC opened new docket
  - FERC call for comments, RTO responses
- **What is the central issue: resilience**
- **Data for extreme events**
- **Risk-based framework is provided by LOLP-related approaches**
- **Examples**

FERC's Interest

- **RM18-1-000 introduced by US DOE to examine out-of-market payments for resources with on-site fuel**
- **Attempt to value/pay for resilience**
- **FERC discontinued RM18-1-000 and launched AD18-7-000, asking industry to describe how resilience is assessed and how BES is hardened against potential threats**
- **Collaboration with GridLab, AWEA, ESIG to provide reply comments after the RTO/ISO responses**
  (http://www.milligangridsolutions.com/milligan%20ferc%20comments%20AD%2018-7-000%20from%20FERC%20web.pdf)

FERC's Resilience Focus & RTO/ISOs

- **RTO comments to FERC indicated strong relationship between reliability and resilience**
- **May be difficult to cleanly separate them**
- **Resilience interest appears focused on high-impact/low-frequency (HILF) events, such as Polar Vortex storm of 2014.**
- **Existing metrics (customer outages, LOLE-related, etc) can in principle capture resilience failures such as the Polar Vortex of 2014.**
- **Difficulties in**
  - Long-term data
  - Characterizing HILF events in modeling framework

RTO responses

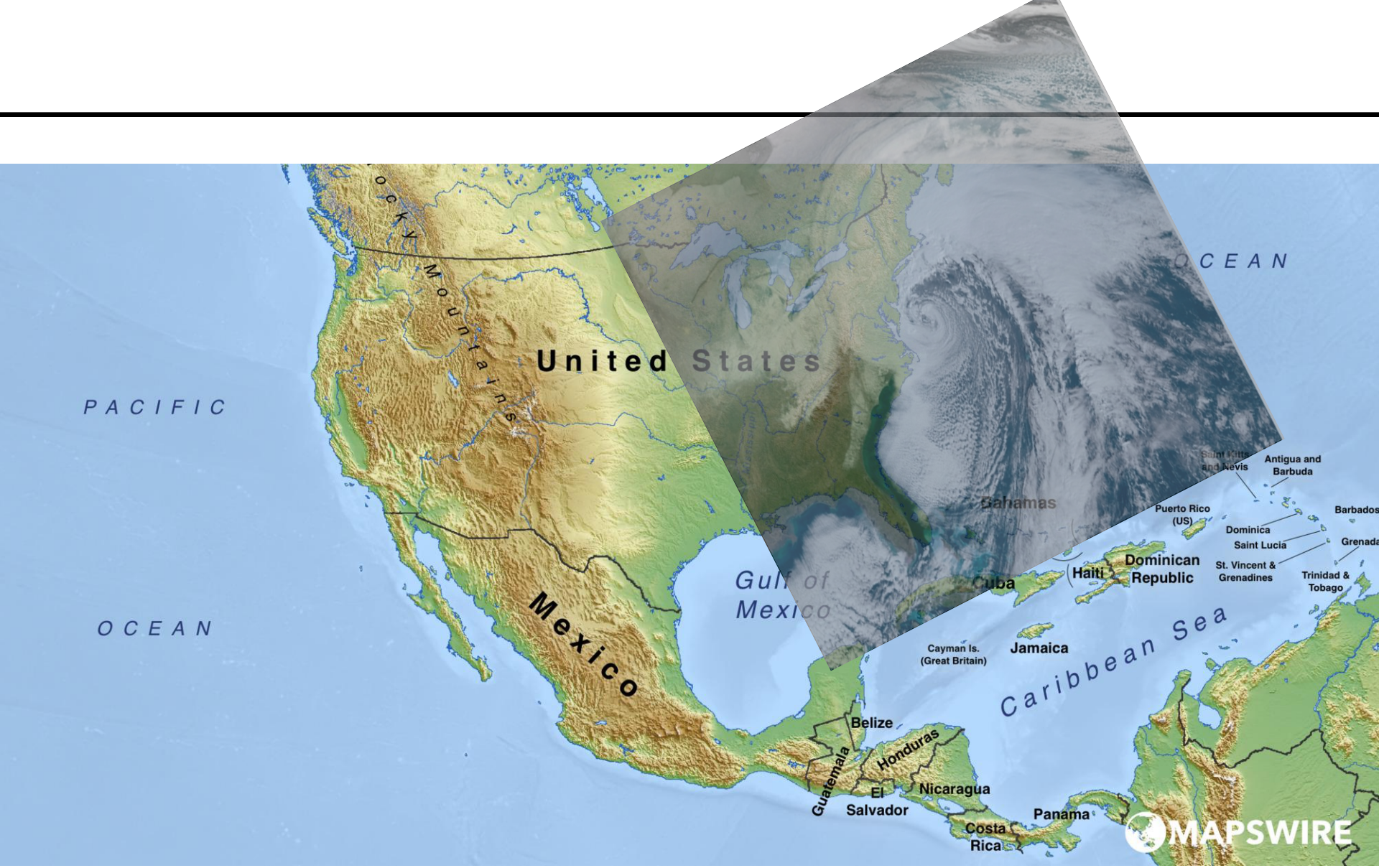
- **Role of planning reserve to mitigate resilience events**
- **NYSIO: role of operating reserves and ancillary services to help**
- **SPP noted that to adhere to BAL, the BAA must ensure sufficient grid services via market**
- **PJM: resilience not simply HILF, but also other potential threats to safe, reliable ops. Some of these threats may be new/unanticipated to the planning process. May be difficult to analyze in quantitative probabilistic way *because they are so infrequent* (emphasis added)**

Resilient to what?

- **FERC:**
  - "The ability to *withstand* and *reduce* the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event."
  - Italics added. "Reduce" magnitude is not well-defined
- **Weather – large-scale storms such as PV14**
- **Cyber attacks**
- **Physical attacks**
- **Earthquake**
- **Fires**

- ***For simplicity we focus mainly on weather events, but it is clear from recent events that cyber attacks are likely***

All threats are not equal…and differ by region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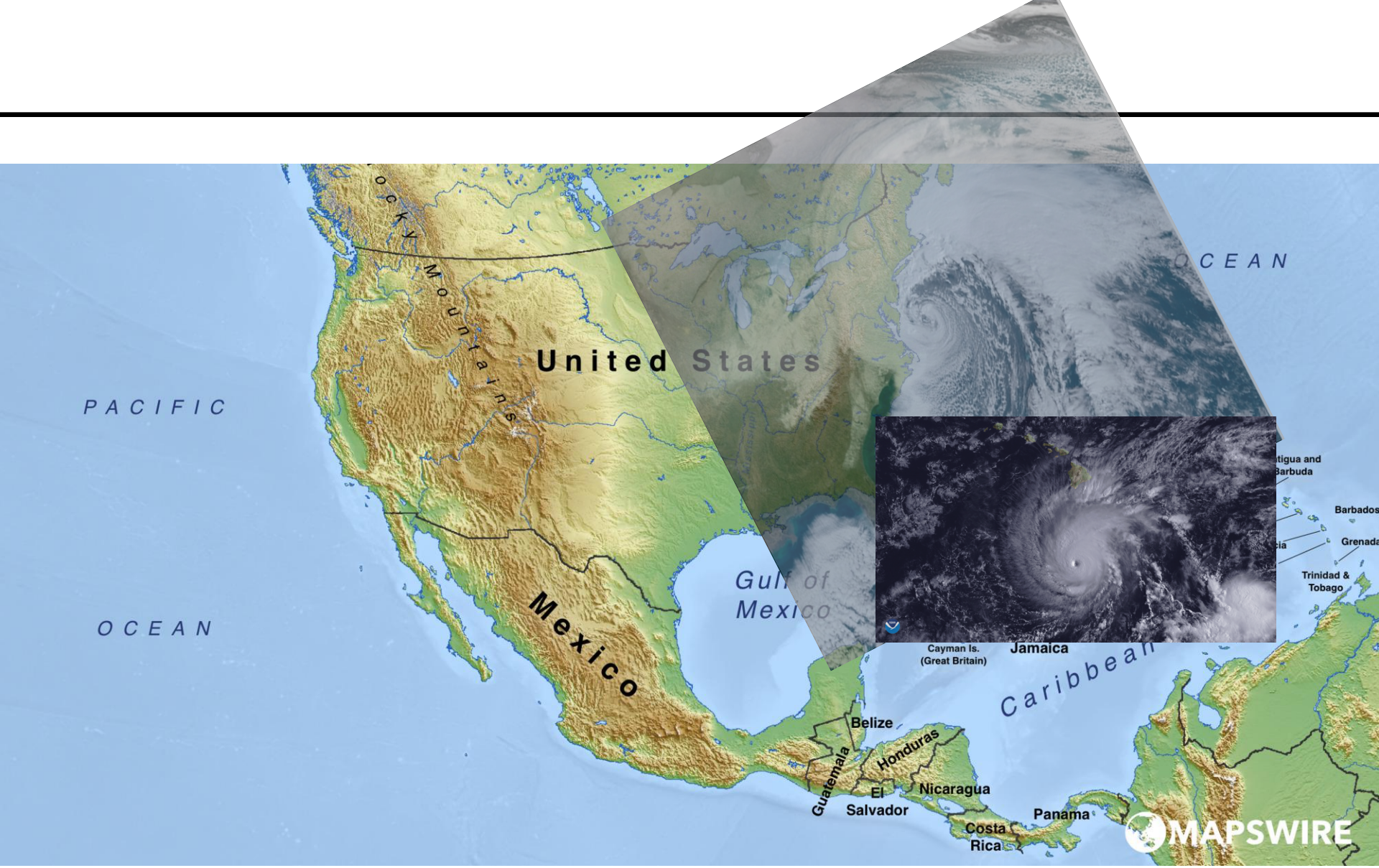
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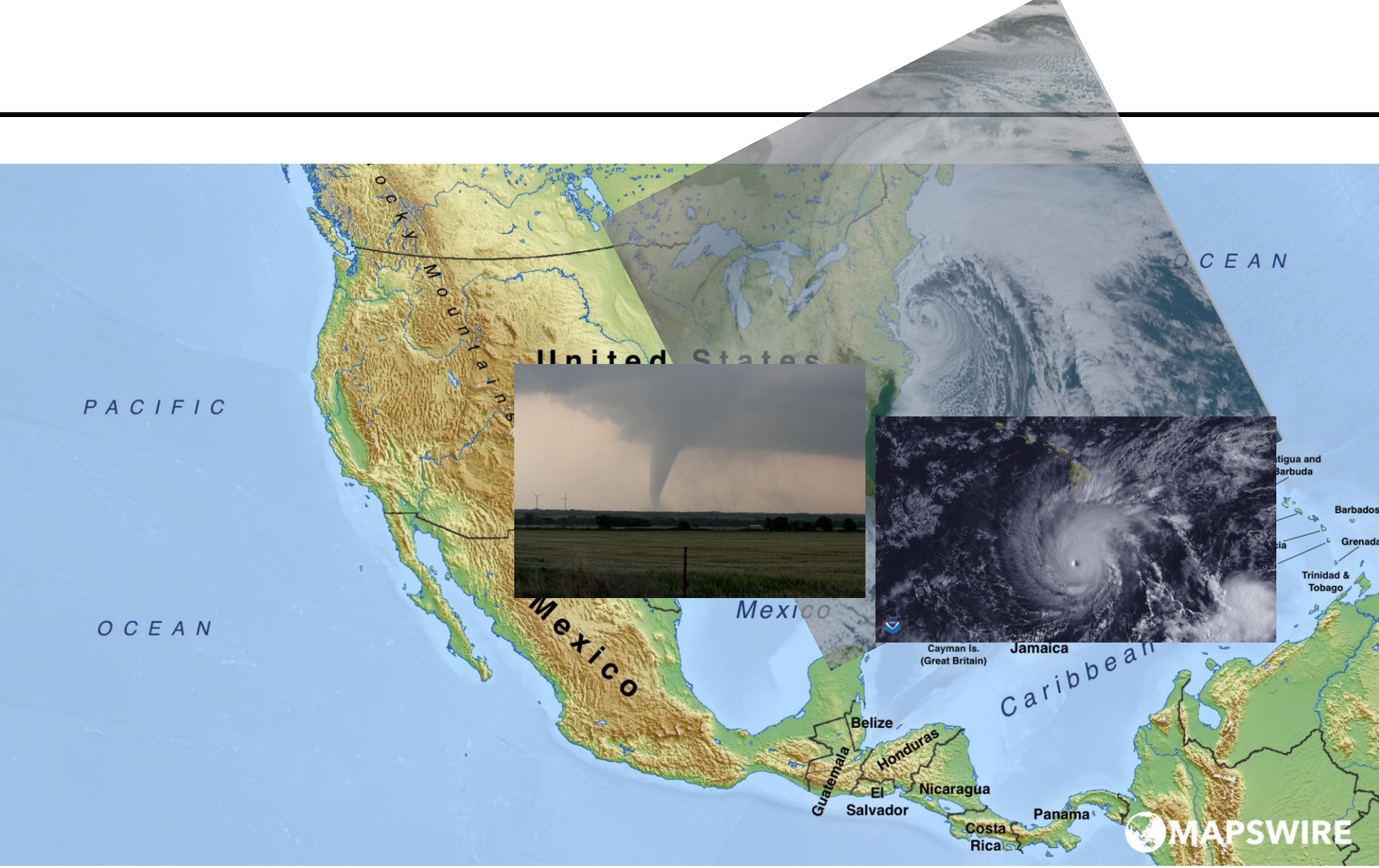
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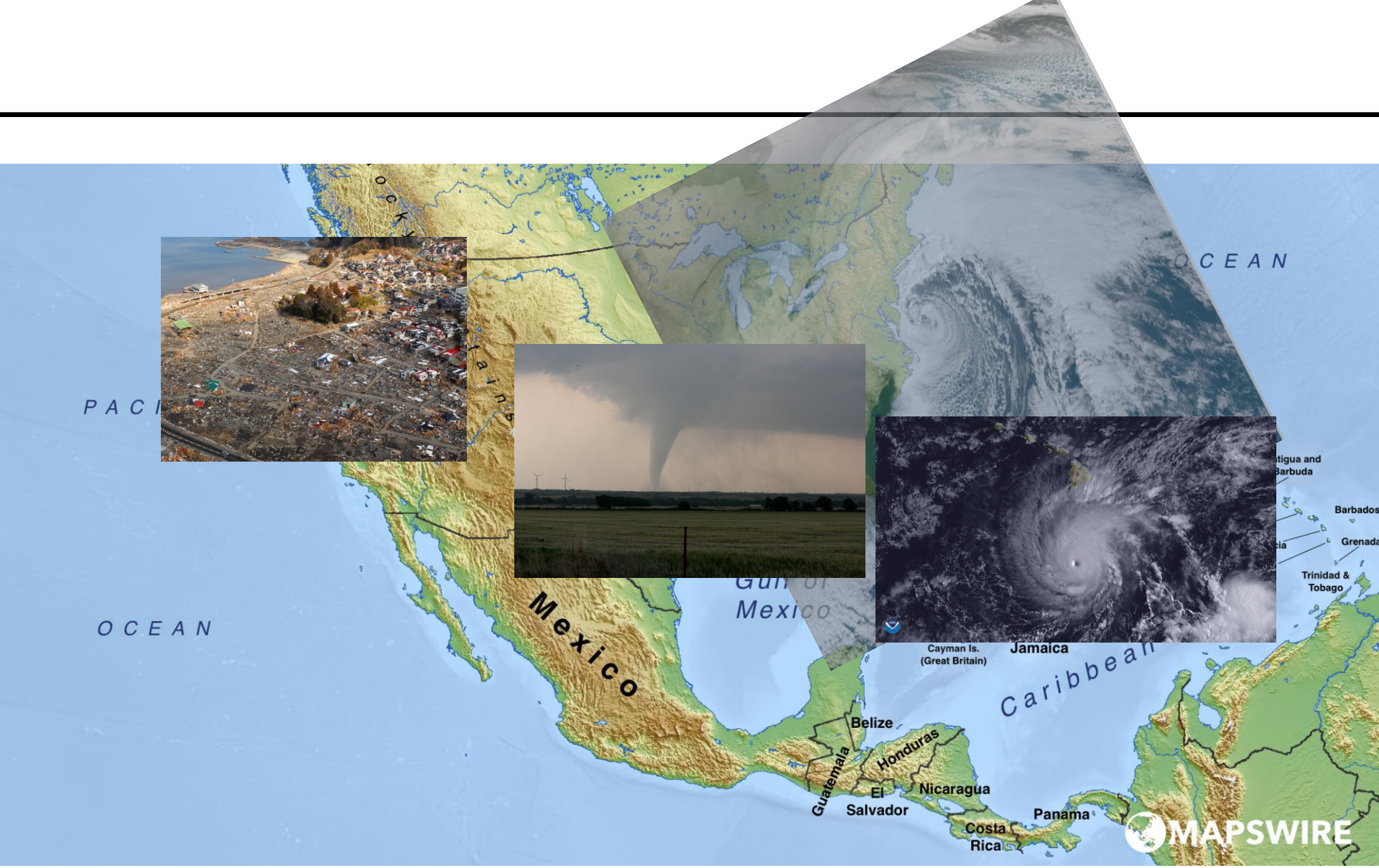
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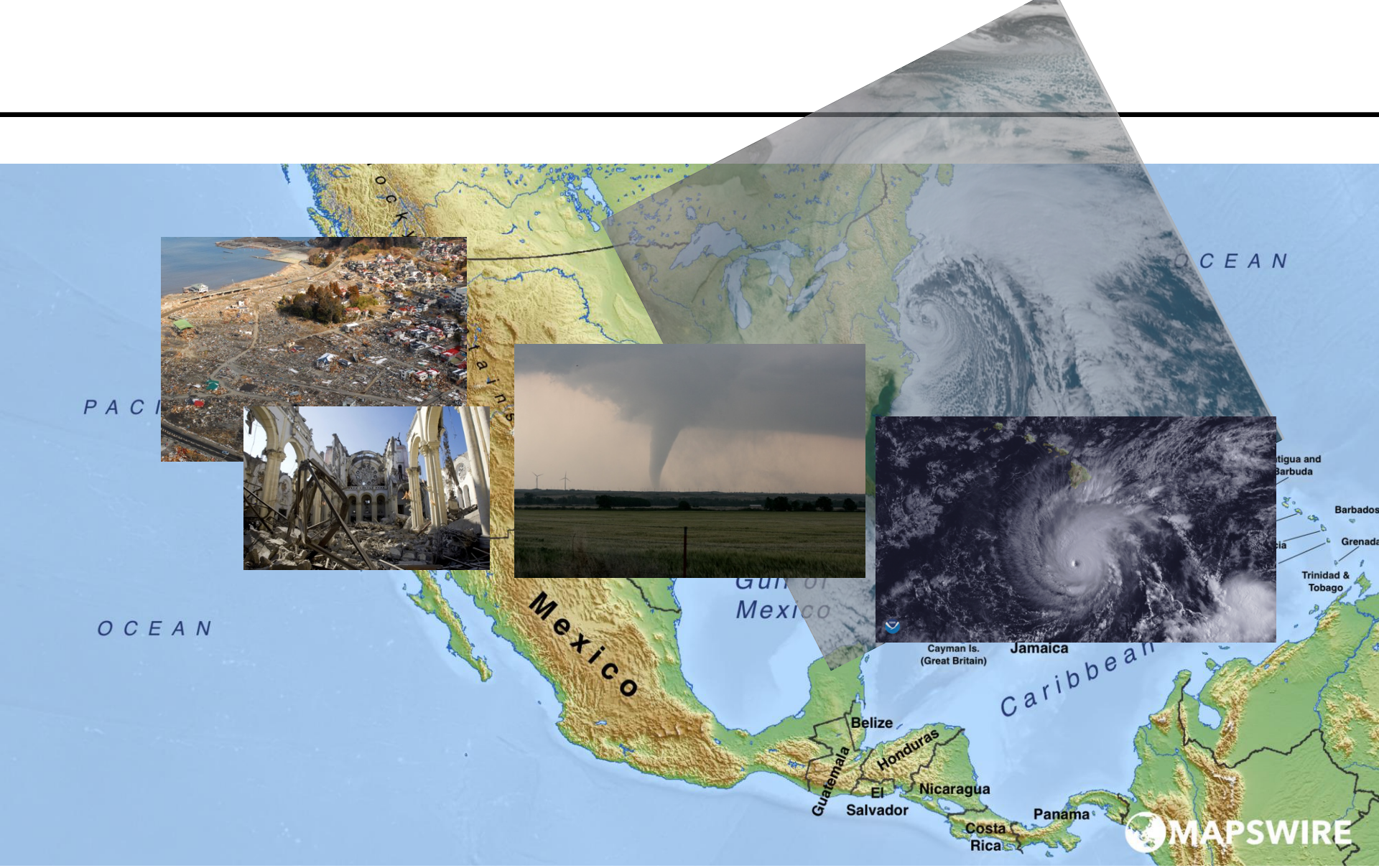
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We have a national reliability organization that pays attention to resilience issues

- **North American Electric Reliability Corp. has done assessments on the 2014 Polar Vortex and other large-scale outages**
- **NERC's Standard TPL-004-0—System Performance Following Extreme BES Events (https://www.nerc.com/files/tpl-004-0.pdf)**
  - "Purpose: System simulations and associated assessments are needed periodically to ensure that reliable systems are developed that meet specified performance requirements, with sufficient lead time and continue to be modified or upgraded as necessary to meet present and future System needs."
  - "The Planning Authority and Transmission Planner shall each demonstrate through a valid assessment that its portion of the interconnected transmission system is evaluated for the risks and consequences of a number of each of the extreme contingencies that are listed under Category D of Table I."
  - "May involve substantial loss of customer Demand and generation in a widespread area or areas."
  - "Portions or all of the interconnected systems may or may not achieve a new, stable operating point."
  - "Evaluation of these events may require joint studies with neighboring systems."

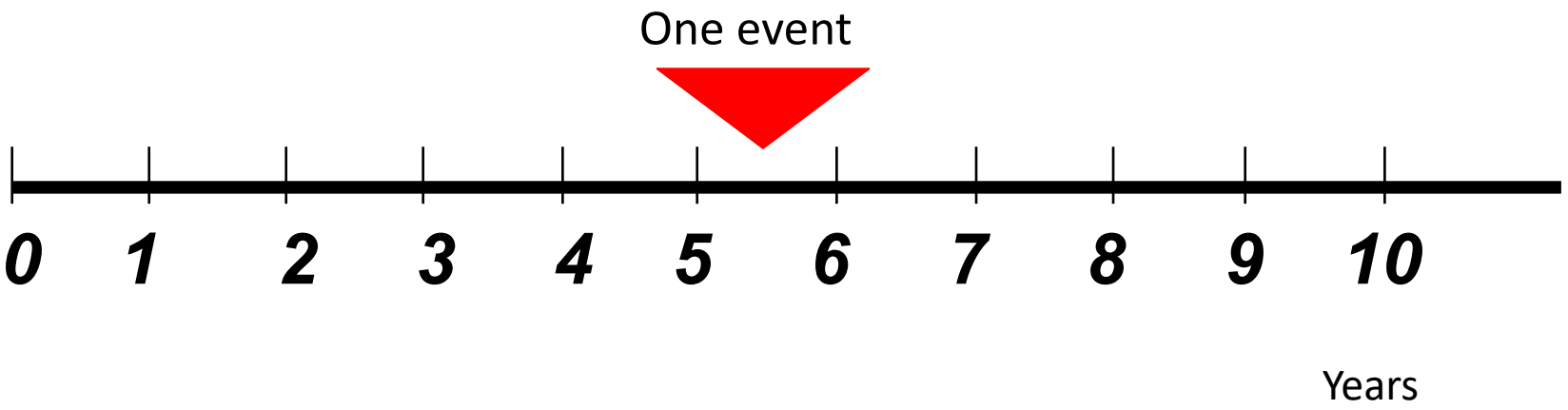
https://www.nerc.com/pa/rrm/January%202014%20Polar%20Vortex%20Review/Polar_Vortex_Review_29_Sept_2014_Final.pdf

We have well-developed approaches to assessing power system risk

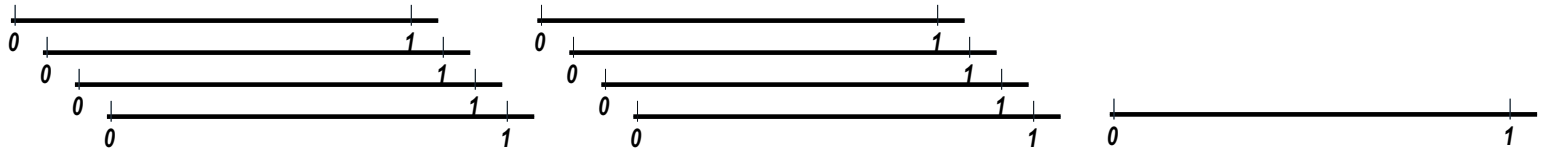
- **System loss of load probability (LOLP)**
- **Generator forced outage rates assumed statistically independent**
  - Problematic for many of the wide-scale events considered under TPL-004, but not a show-stopper
- **Monte Carlo or probabilistic convolution approaches are common**
- **LOLP is only concerned with counting events**
- **Other metrics include LOLH, which counts hours of outages, and expected unserved energy (EUE) which is concerned about the expected energy shortfall from outage events**

Data and Measurement Issues: Loss of load event

- **What is 1d/10y?**

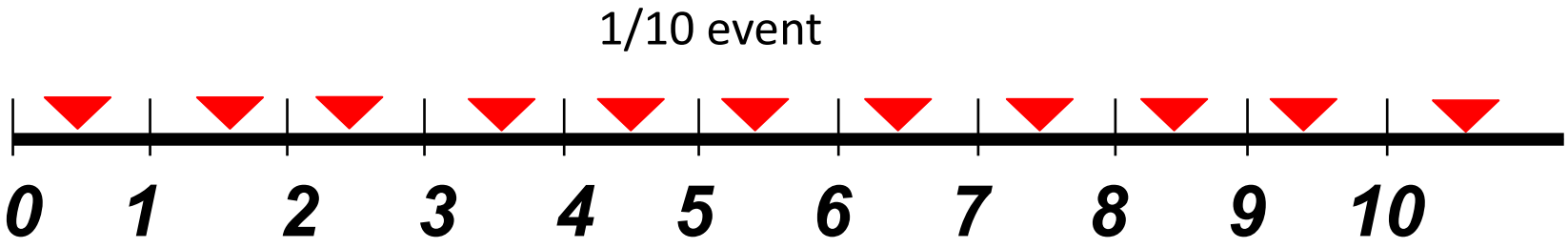


- **9 years have no recordable events**



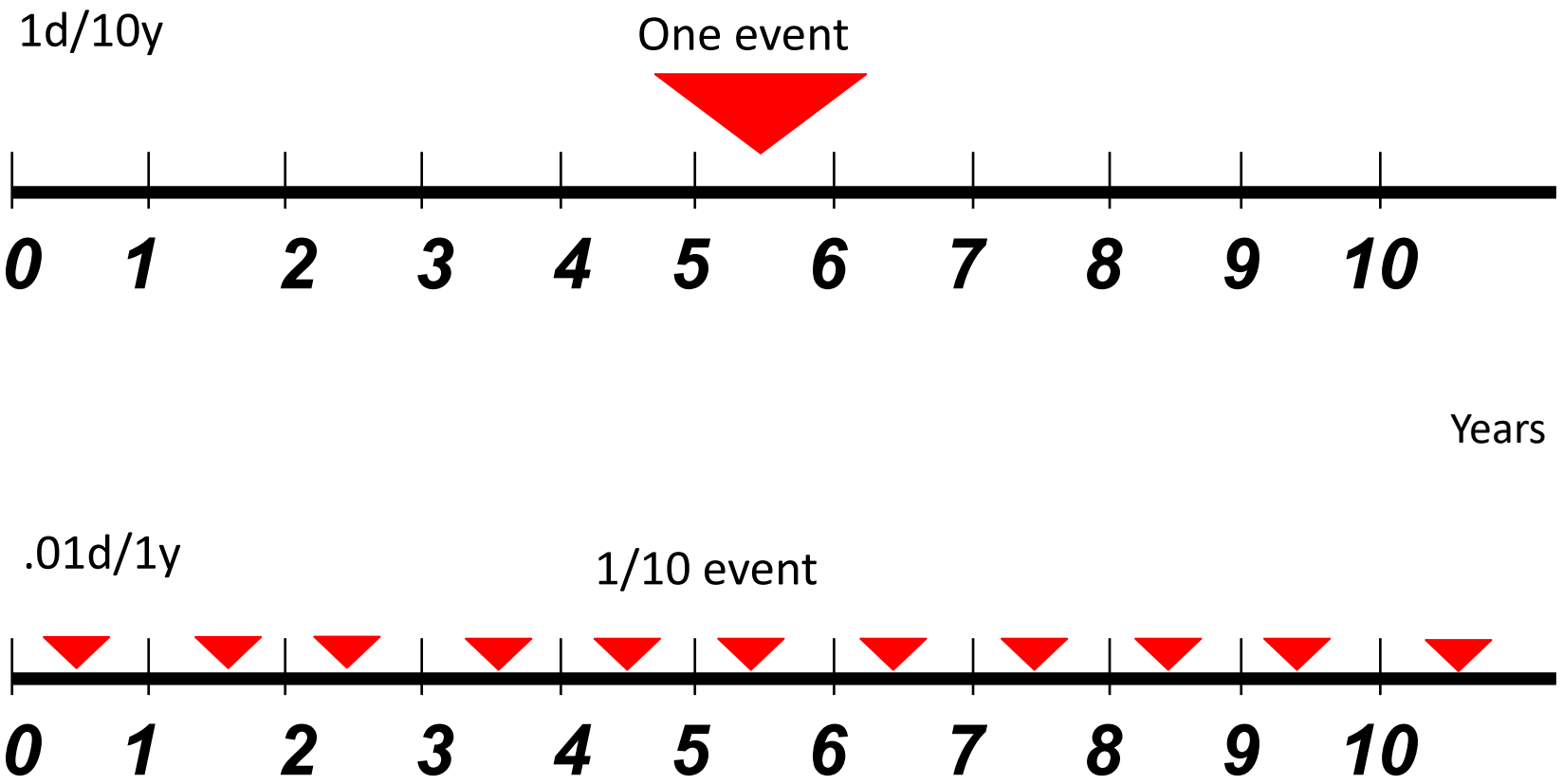
1d/10y is not the same as 0.1d/y

- **What is 0.1d/y?**



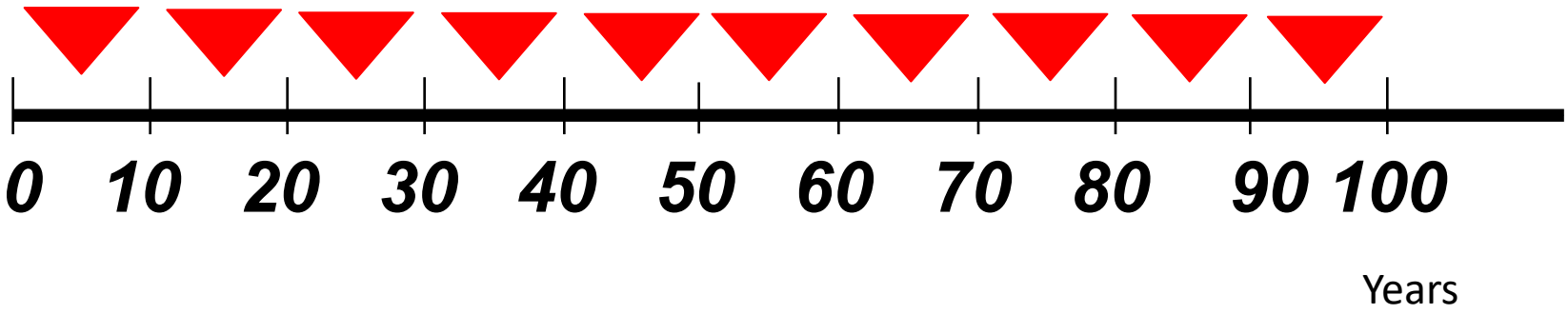
- **All 10 years have an event, albeit smaller than the 1d/10y event**

Comparing 1d/10y to 0.1d/10y



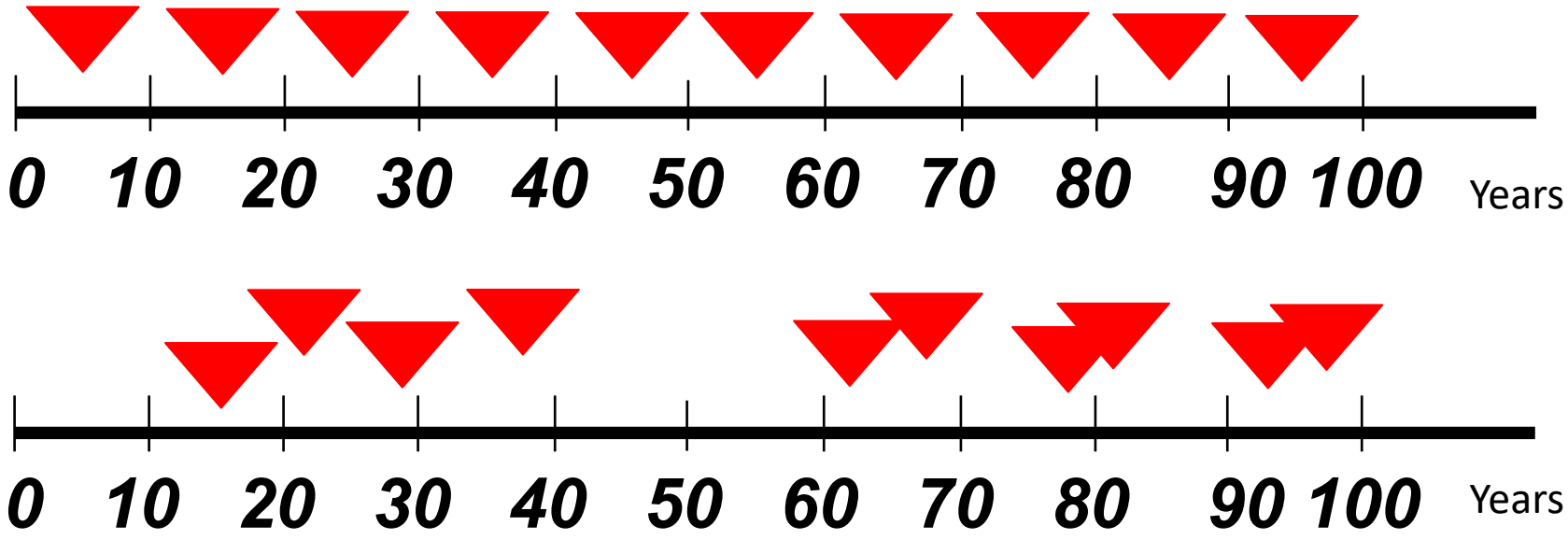
Longer time horizons

- **With 1d/10y event we would expect ~10 of them in a century**



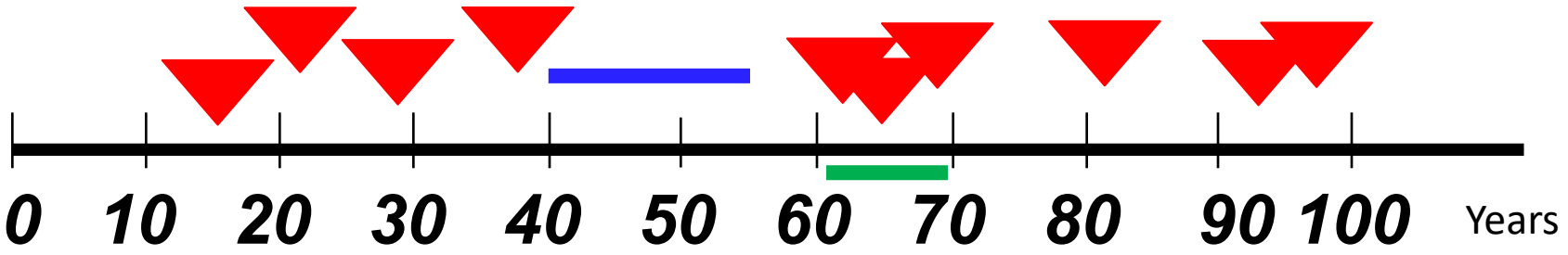
Longer time horizons

- **With 1d/10y event we would expect ~10 of them in a century…but not necessarily each 10-year period**

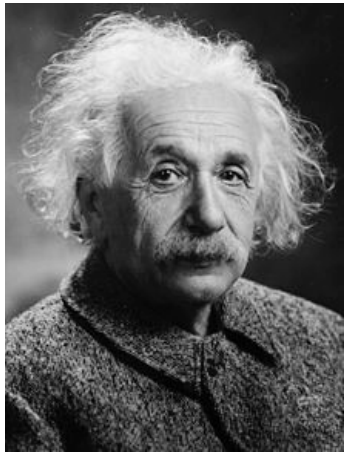


A Theory of Special Relativity for Power System Modelers

- A modeler in year 55 with 15 years of data would conclude 0d/15y reliability —

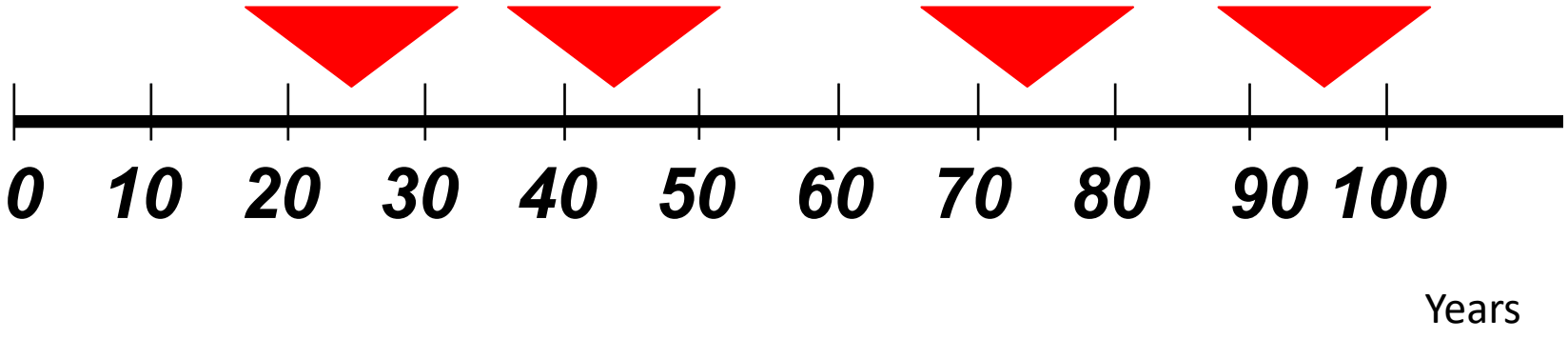


- A modeler in year 70 with 10 years of data would conclude 3d/10y —



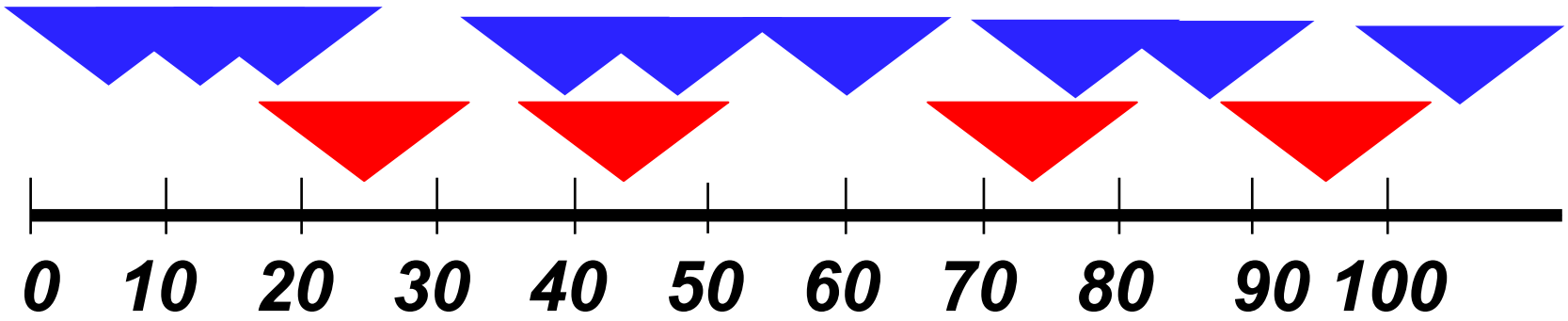
Infrequent events

- **What is the risk of**
  - “major” earthquake every 25 years
  - “major” hurricane every 13 years
  - Etc
- **And how do collect good data sets?**



Infrequent events

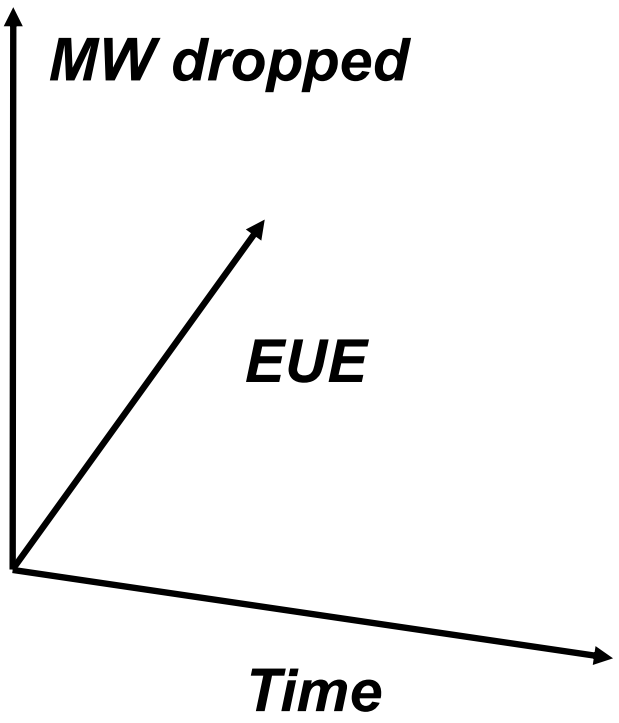
- **What is the risk of**
  - “major” earthquake every 25 years
  - “major” hurricane every 13 years
  - Etc
- **And how do collect good data sets and assess resilience?**



- **How to account for impact of climate change on these variables?**

How to assess resilience?

- **Depth (MW loss), Duration (time), volume (MWh) with various statistical characteristics**
- **Reliability models may not accommodate modeling of single-mode "failure" such as multiple gas plants on same pipeline, *but could be modified to do so***
- **NERC should work w/industry and FERC to develop this further**
- **Prob methods since at least 1947. LOLE and related metrics for long-term reliability; N-1 (or similar) for operational. They are linked.**



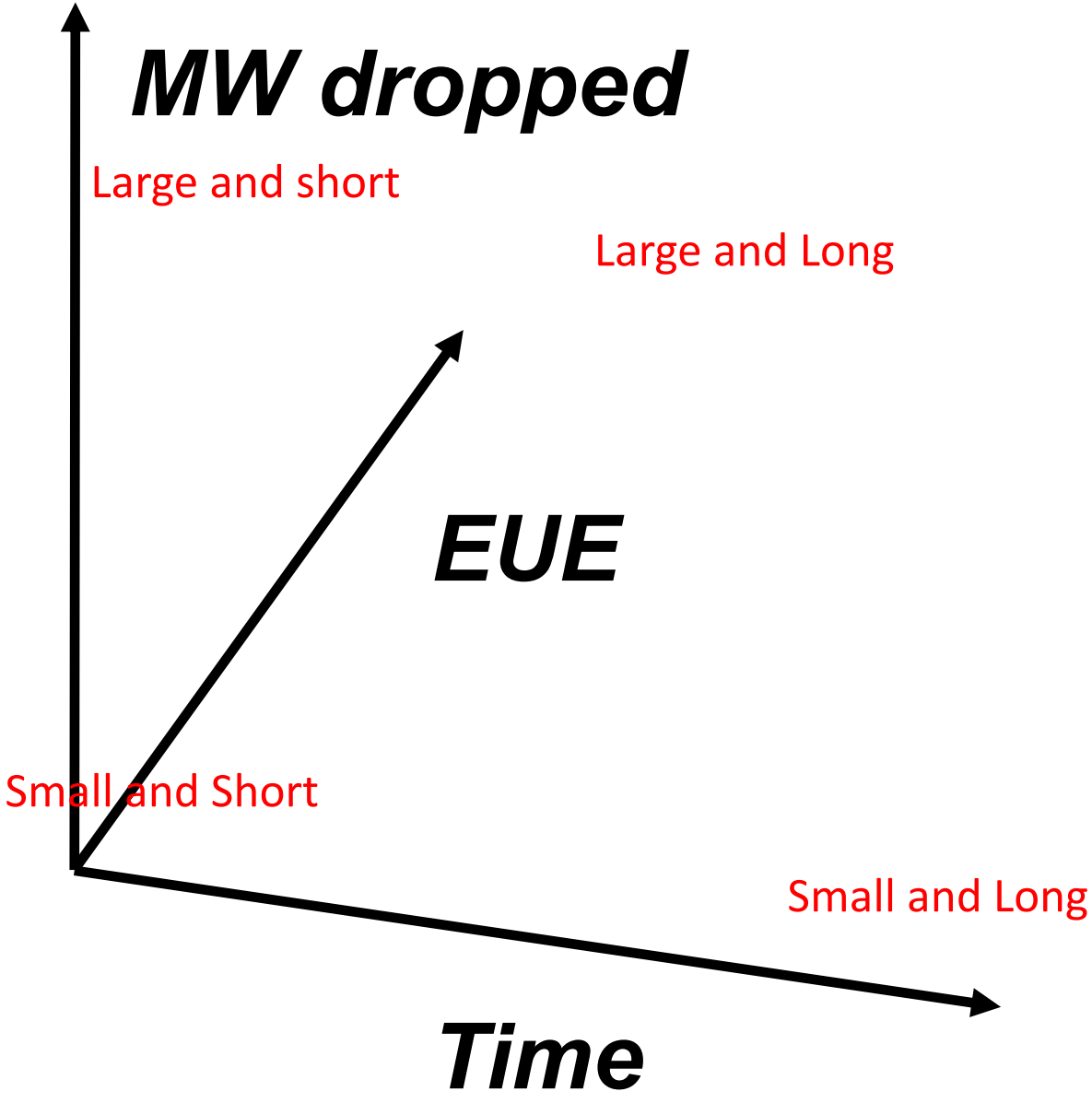
Do LOLP-related metrics work?

- **Yes, *if* data exists, or can be constructed, to capture the event(s) of interest**
- **Can use scenario analysis, assess change in LOLP (see NERC IVGTF 1.6)**
- **However: Reliability models may not consider common-mode failure (multiple gas units on same pipeline); convolution methods assume statistical independence**
- **May lead to more complex Monte Carlo and/or scenario modeling; multiple energy systems (gas, electric, etc.)**

https://www.nerc.com/comm/PC/Integration%20of%20Variable%20Generation%20Task%20Force%20I1/IVGTF%20Task%201-6_09182014.pdf

Examples

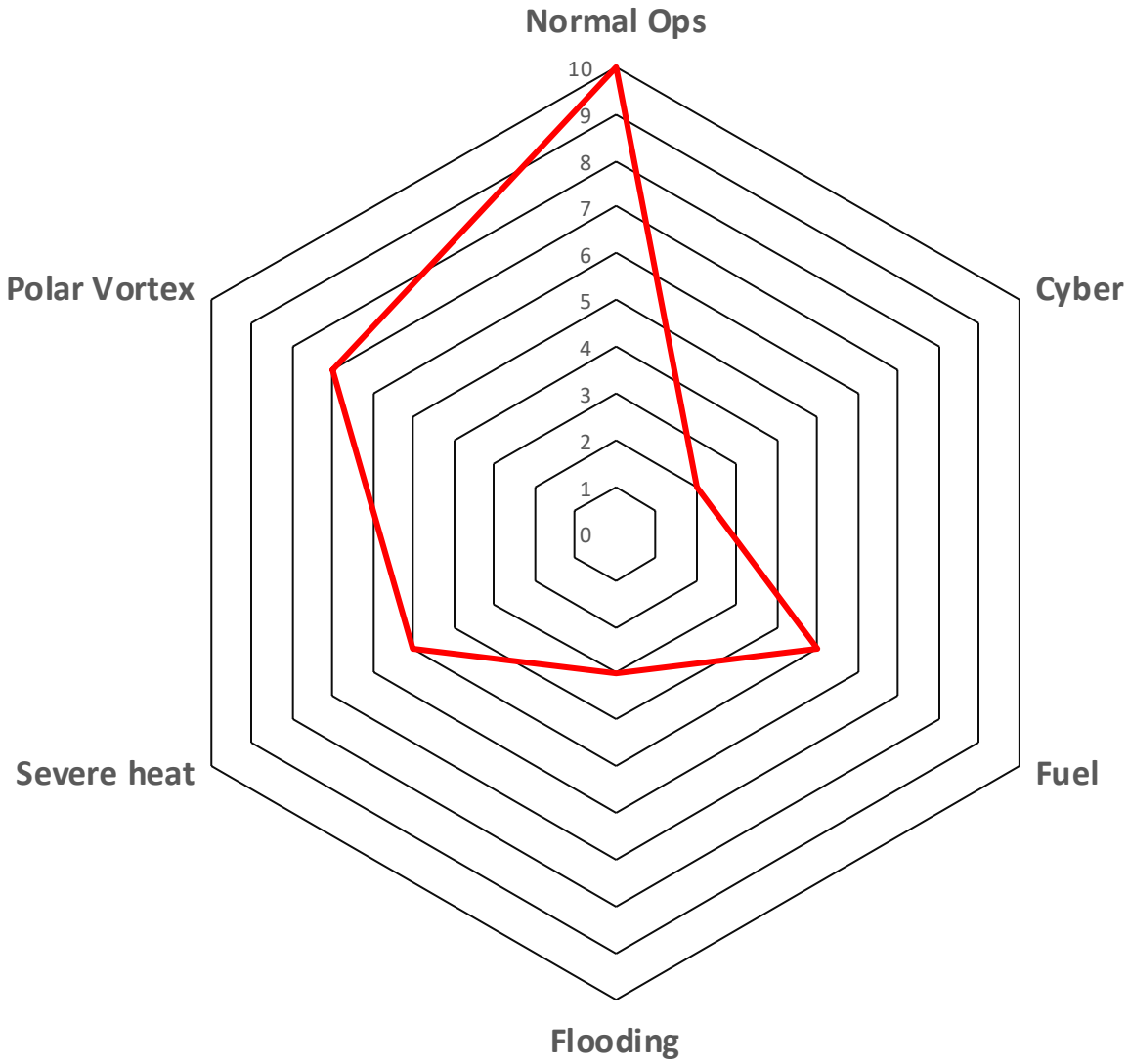
- **Case 1, No outage: then the system performed reliably and there is no reliability penalty. LOLE would be zero. EUE = 0 (note that all "expectations" could be replaced by "actual;" expectations can be calculated by standard LOLE reliability models).**
- **Case 2, Single, shallow outage (SSO): Small LOLE with small EUE. If the frequency of these SSO events were to increase, then LOLE and EUE would both increase, not necessarily proportionately.**
- **Case 3, Single, deep outage (SDO): Small LOLE with large relative EUE.**
- **Case 4, Multiple, shallow outages (MSO): High LOLE, relatively small EUE.**
- **Case 5, Multiple, deep outages (MDO): High LOLE, high EUE.**


MW dropped
Large and short
Large and Long
EUE
Small and Short
Small and Long
Time

Issues in assessment

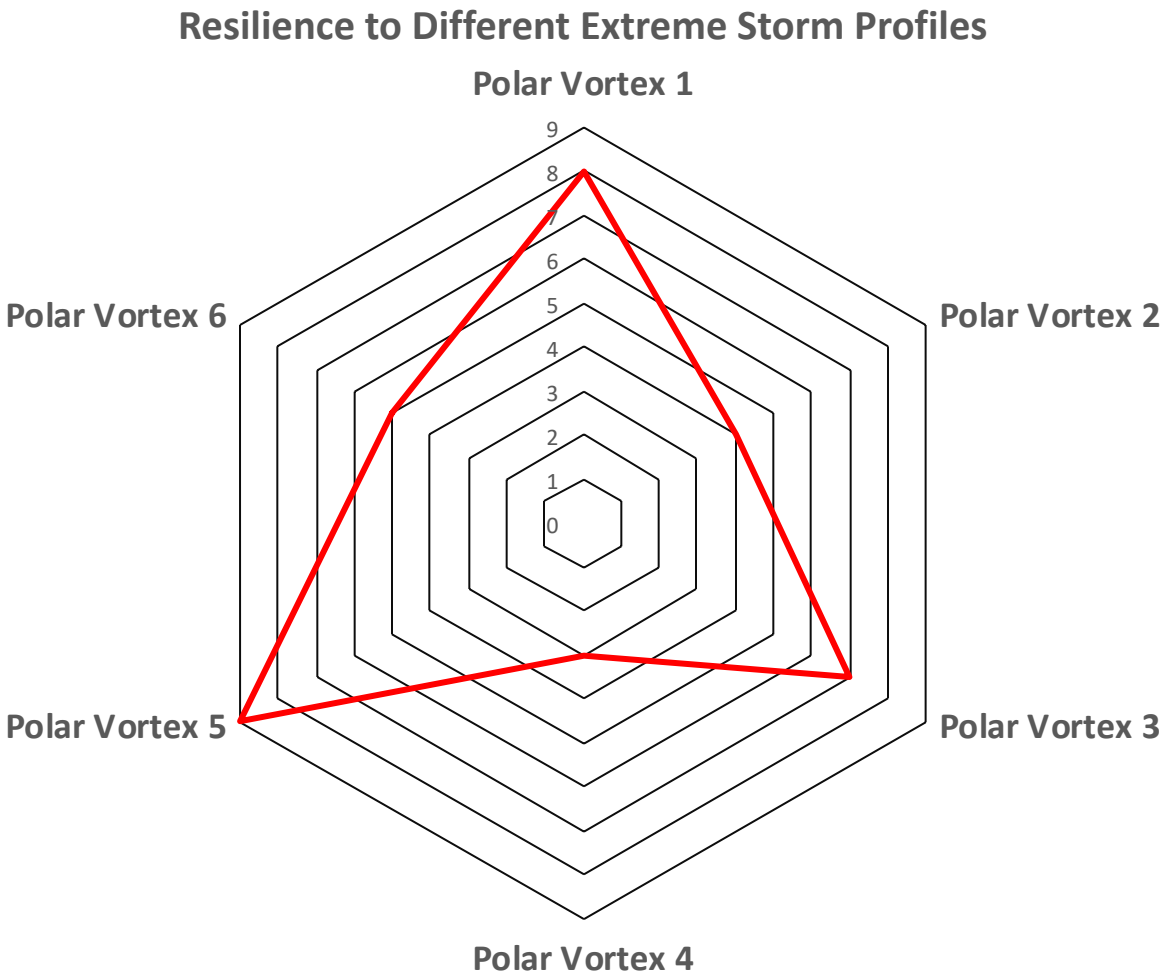
- **Is event outside "normal" data sets?**
- **How to define large-scale threats; i.e. what happens and where? What damage/outages?**
  - Link with weather or other models for damage assessment
- **Each region will have different risk profile, for example:**
  - SERC: hurricanes
  - SPP: tornados
  - ISO-NE: cold weather, gas supply disruption
  - CAISO: forest fires
- **Normalize reliability score to scale 0-10 based on metric of choice (LOLH, EUE, ??). 10= resilient, 0=failure**

Example Resilience Diagram



Scoring: 10=reliability target met; 0 = severe outages

Resilience to different storm profiles



Scoring: 10=reliability target met; 0 = severe outages

Does a resilient system require more planning reserve?

- **Perhaps; depends on policy outcome of whether 1d/10y is appropriate metric, or is there something better**
- **Additional planning reserve, *if needed*, can come from a combination of new resources, DR, or transmission (Ibanez & Milligan, https://www.nrel.gov/docs/fy12osti/53482.pdf) for example)**
- **Do we want economic solution where "some" LOL is acceptable to avoid extremely high cost?**

Summary

- **Resilience isn't a new concept**
- **Hard to separate from reliability**
- **NERC standards exist – do they need enhancing?**
- **Long-term reliability models can be used to assess, but may need enhancements**
- **Scenario analysis, coupled with the output of weather models or other models that can assess various types of storm damage can be used**


Thank you!
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