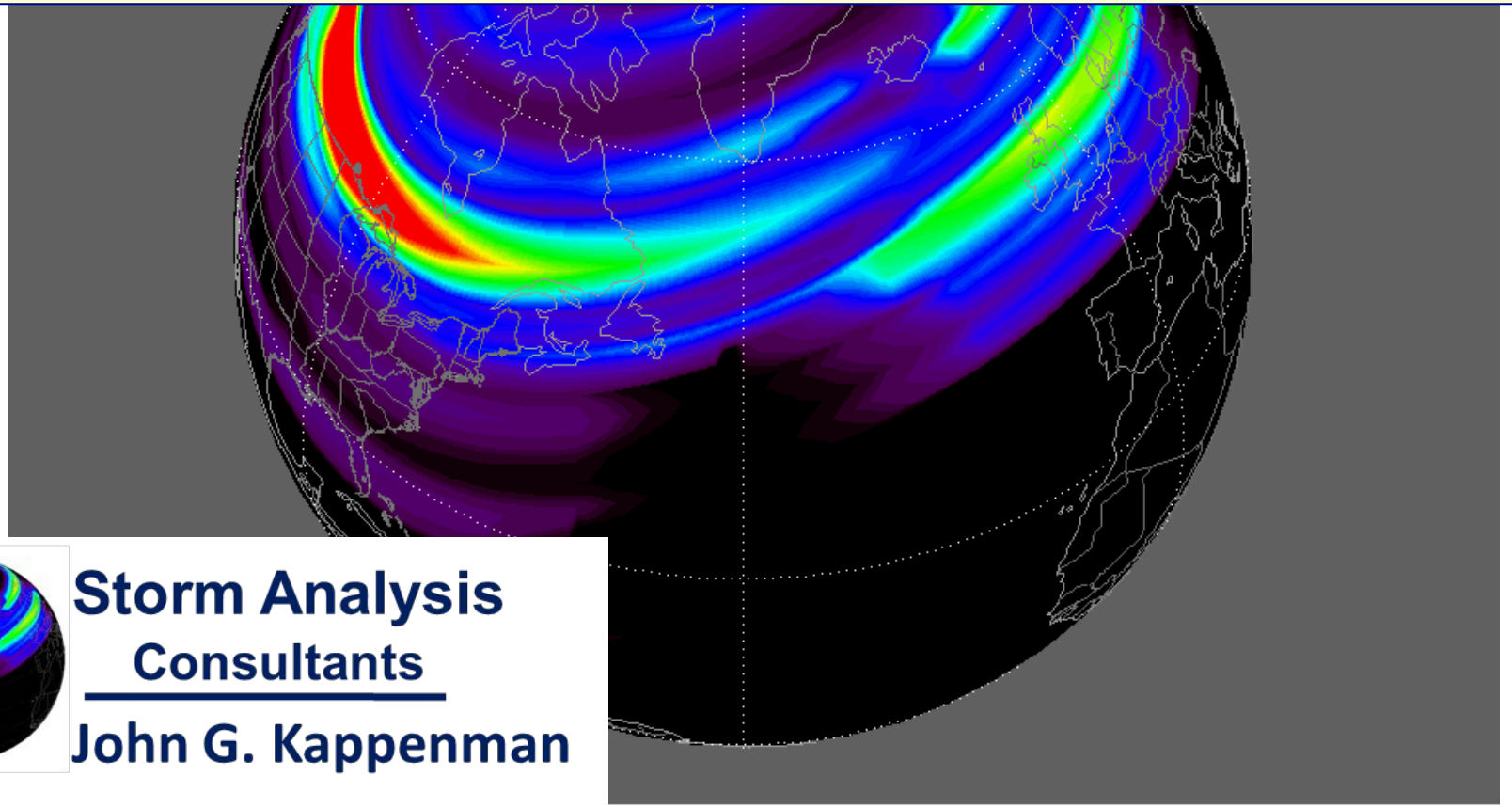
Proposed NERC Standards for Geomagnetic Storms

Concerns about Science & Engineering Adequacy



Storm Analysis Consultants

John G. Kappenman

Proposed GMD Standards from NERC

Concerns about Science & Engineering Adequacy

GMD Design Standards – Must Protect Society from Consequences

- Grids - Unchecked Increase in GMD Vulnerability of US Grid over many Decades
- Standard must Accurately Define Extremes of Storm Intensity & Footprint
- Standard must provide Assurance of Grid Security/Resilience
- NERC Draft Standard Claims to be 100 Year & Conservative – But falls short of even 30 Year Storm Events

Proposed GMD Standards from NERC

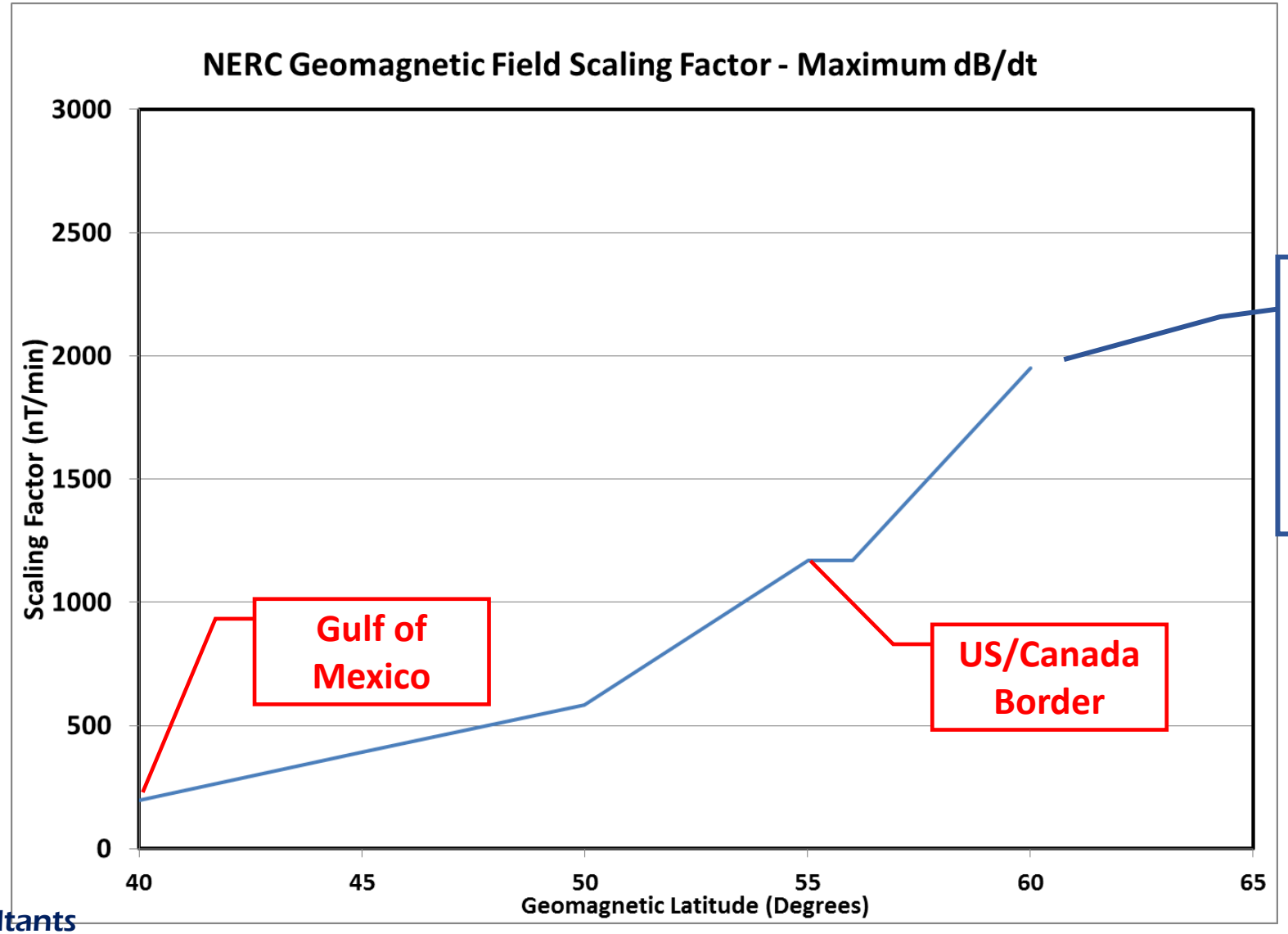
Concerns about Science & Engineering Adequacy

GMD Design Standards – Must Protect Society from Consequences

- NERC Hundred Year Threshold Profile design was based on limited number of observatories in Finland (IMAGE Array) and 1 in Japan (MMB)
- NERC Hundred Year Threshold Profile did not include US Observatories and Excludes all other World Observatories at US Latitudes – **Hence the NERC Standard did not consider a Single Observation at CONUS Latitudes**
- No Attempt was taken by NERC to Validate and Examine Accuracy of Simulation Models – Our Independent Assessments showed NERC Models Understated Actual Results by as much as Factor of 2 to Factor of 6
- Pulkkinen/Bernabeu and Roodman data sets for Extreme Event Analysis makes erroneous conclusions about Dst and Excludes the most likely scenarios for Extreme Storm Events – Hence their Results are based on Small Subset of Data that will Distort and Understate Extreme Event Risks
- Pulkkinen/Bernabeu and NERC Standard Analysis of Extreme Events Distorts and Understates the Geo-Electric Field Intensity of Historically Important Geomagnetic Storms like March 1989 and July 1982 which only exist in 1 Minute Data Cadences – **Hence their Analysis is not Credible!**

Proposed Standards from NERC

Concerns about Science & Engineering Adequacy

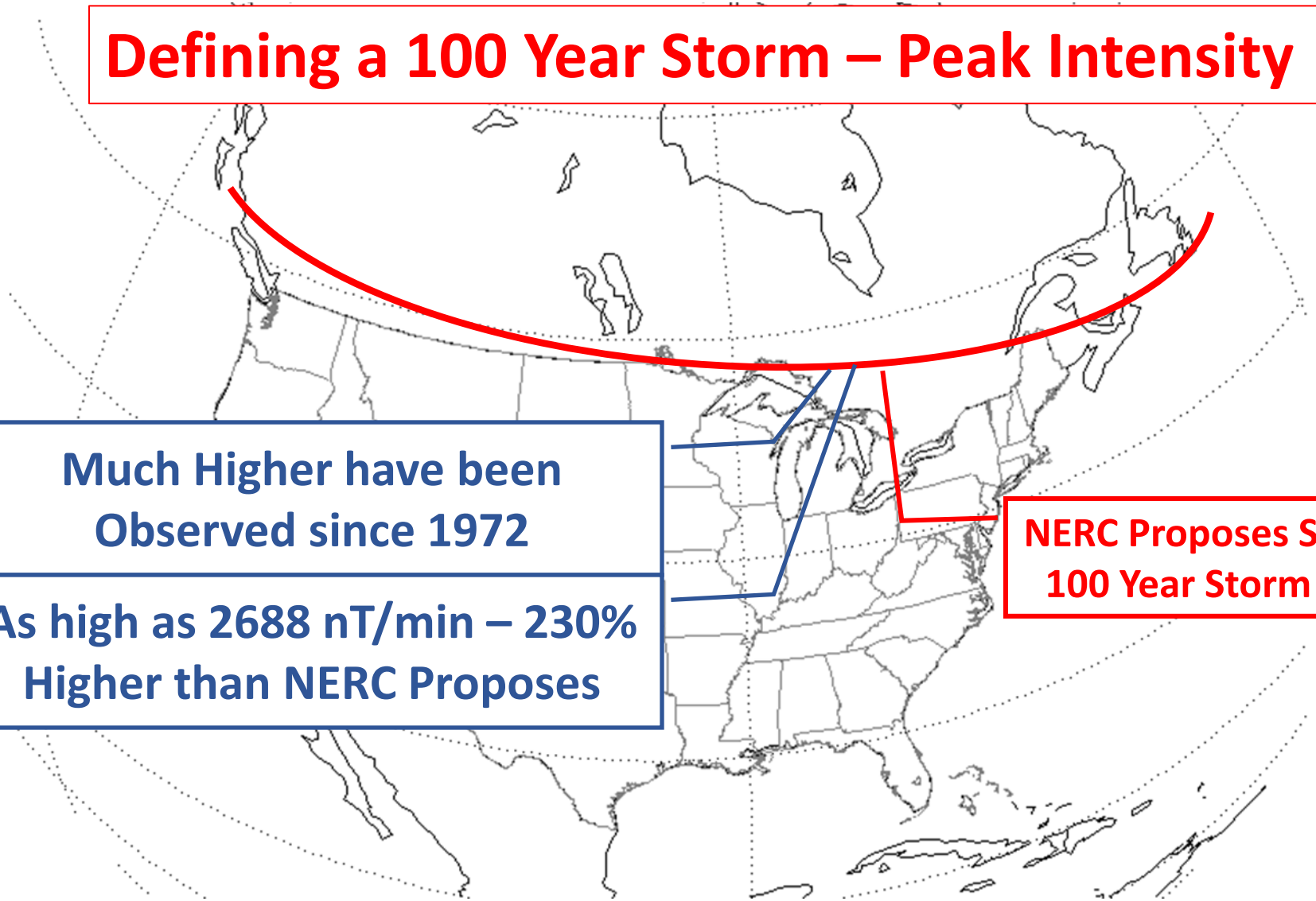


NERC's Proposed 100 Year Threat Profile

Proposed Standards from NERC

Concerns about Science & Engineering Adequacy

Defining a 100 Year Storm – Peak Intensity



Much Higher have been Observed since 1972

As high as 2688 nT/min – 230% Higher than NERC Proposes

NERC Proposes Storm Strength of 100 Year Storm of 1170 nT/min

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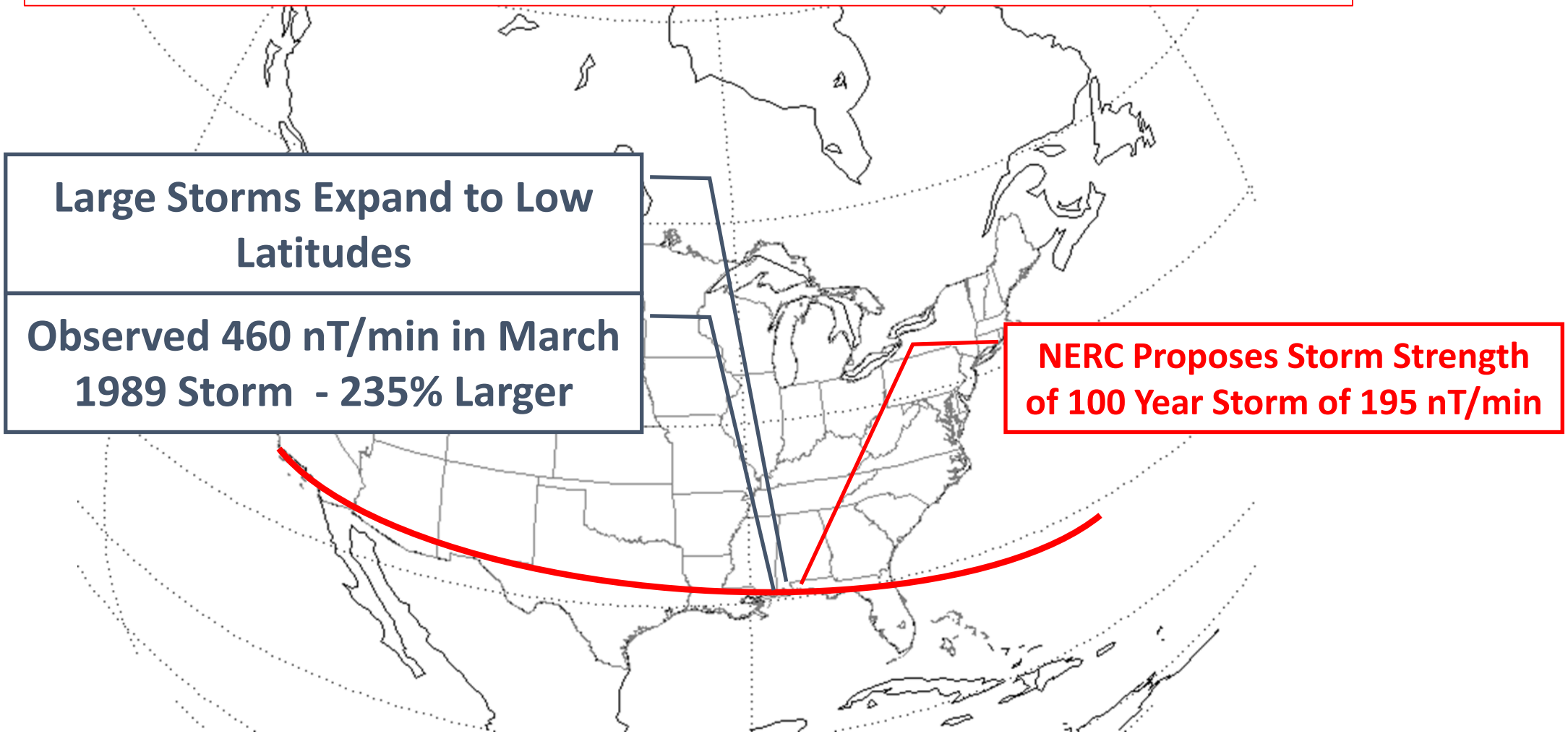
Proposed Standards from NERC

Concerns about Science & Engineering Adequacy

Defining a 100 Year Storm – Low Latitude Intensity



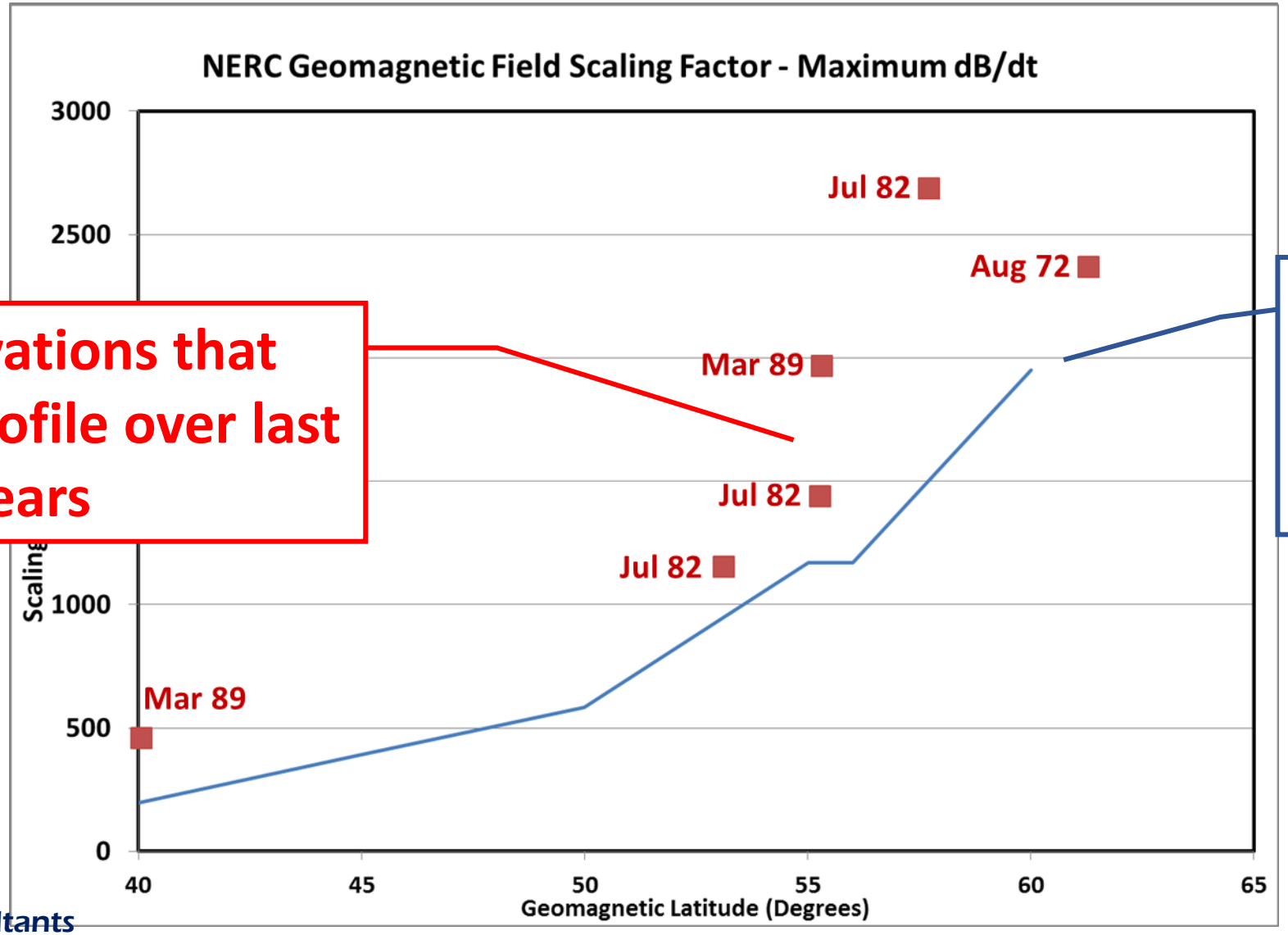
Large Storms Expand to Low Latitudes

Observed 460 nT/min in March 1989 Storm - 235% Larger

NERC Proposes Storm Strength of 100 Year Storm of 195 nT/min

Proposed Standards from NERC

Concerns about Science & Engineering Adequacy



Many Observations that Exceed NERC Profile over last ~30 Years

NERC's Proposed 100 Year Threat Profile

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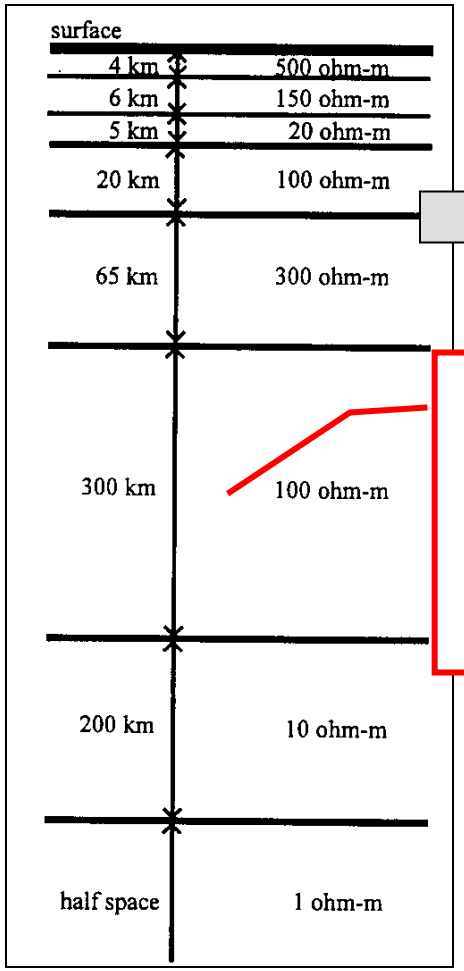
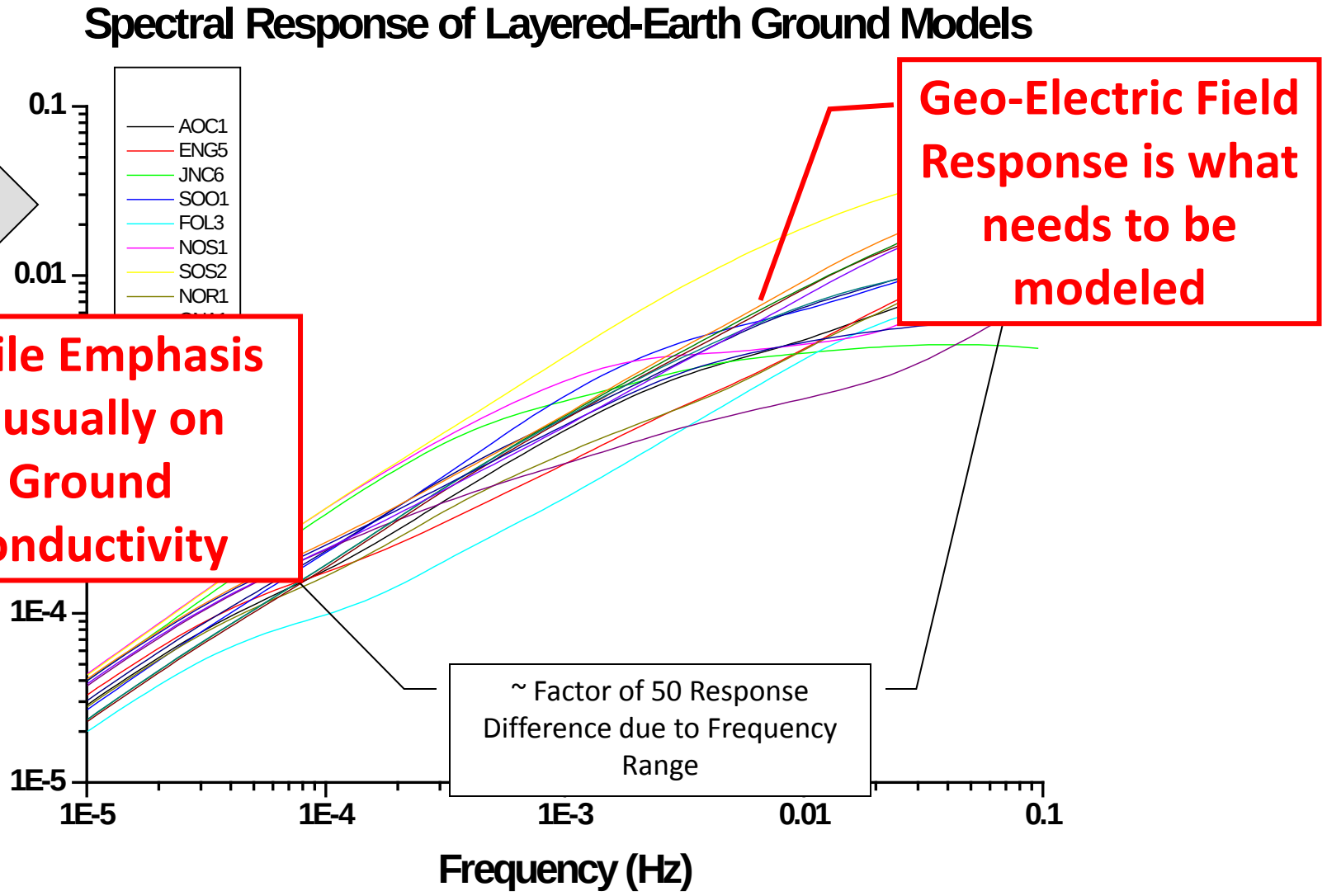
Modeling the Response of Layered-Earth Ground

- Layered Earth exhibits a frequency-dependent and non-linear response
- Considerable Lateral Heterogeneity in surface composition – more uniform at depth
- Models developed both from GIC Data Assimilation and review of plausible geological strata's



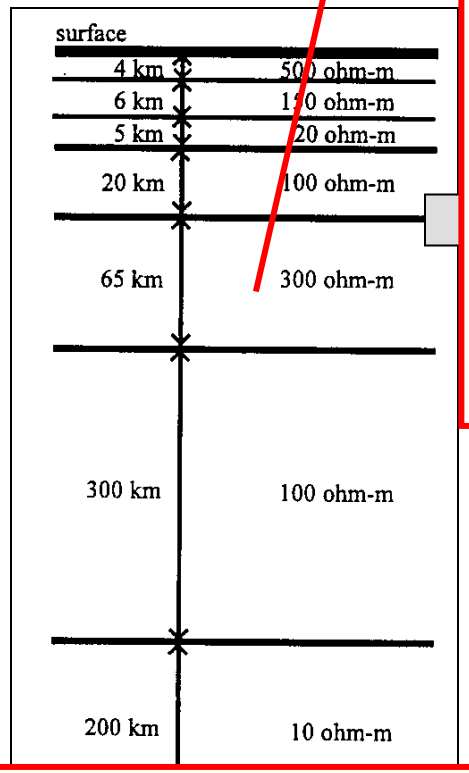


Modeling the Response of Layered-Earth Ground

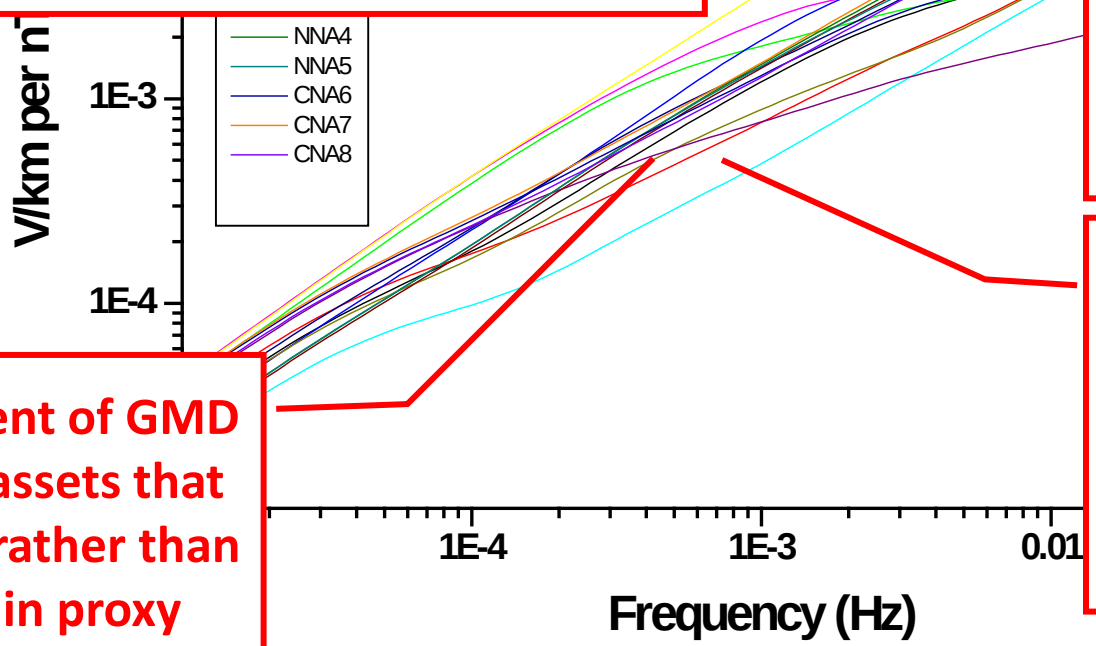
Ground Conductivity can only be Inferred for 1D & 3D Models – with Large Uncertainties!!

It is a Very Indirect and Imprecise Way of Getting to Geo-Electric Field & GIC Response to Disturbances

Accuracy Suffers from Inadequate Regional Sampling



ayered-Earth Ground Models



However using GIC Data the Response can be Directly & Accurately Measured

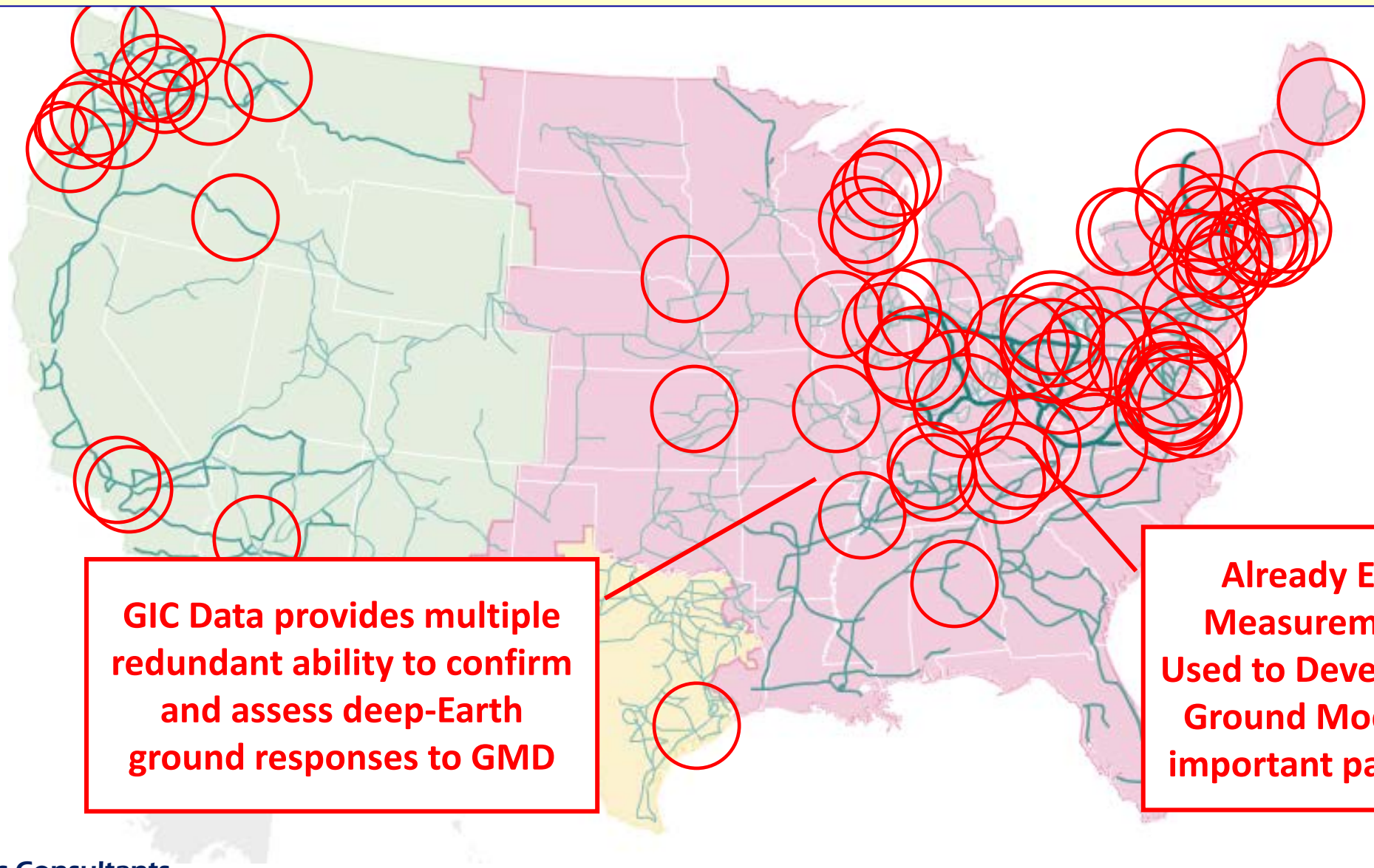
Avoids Unnecessary, Inaccurate and Expensive Steps of Conductivity Modeling

Since GIC is measured over Meso-Scale Power Grid Assets – It fully Integrates and Averages the 3D Complexities of the Region

GIC is an actual measurement of GMD Impact on the power grid assets that public is concerned about, rather than measuring some uncertain proxy

Proposed Standards from NERC/Industry

Concerns about Science & Engineering Adequacy



GIC Data provides multiple redundant ability to confirm and assess deep-Earth ground responses to GMD

Already Existing GIC Measurements can be Used to Develop & Validate Ground Models for most important parts of US Grid

Proposed GMD Standards from NERC

Concerns about Science & Engineering Adequacy

GMD Design Standards – Must Protect Society from Consequences

- More Specifically GIC Monitoring Can Tell Us A Lot About Storms and Responses of the Power Network and Apparatus that may be Harmed
- GIC Measures Meso-Scale Coupling of Storm to Critical Infrastructure
- Have Precise Information on Grid Asset Locations & Resistances
- GIC Monitoring Fills Important Knowledge Gaps

- Simpler, Faster to Implement, Less Expensive and More Accurate Approach to Modeling, Easy to continuously Forensic Audit / Update for Network Additions

Proposed GMD Standards from NERC

Concerns about Science & Engineering Adequacy

- **The GMD Standard should neither Over-Estimate or Under-Estimate Assessments of Grid Vulnerability – Rather it is in the Public Interest for the GMD Standard to simply be Realistic and therefore Accurate**
- **The GMD Standard should not be structured to Actively Ignore Forensic Data/Evidence which is available in abundance over several decades and Avoiding Validation testing – This is Contrary to Sound Science and Engineering Practices**
- **GIC Measurements provide the most Comprehensive and Accurate Assessments of Important GMD Environment Drivers and how they Couple with the Power Grid – It makes No Sense to Ignore the Equivalent of Black Box Data!**
- **These GIC Measurements can be easily and readily extended to provide Accurate Assessments for Extreme Threat Scenarios – *Faraday's Law of Induction which Governs GIC Process is Linear***
- **NERC Models are frequently in Error due to failure to incorporate forensic data inputs and can produce Unrealistic Results**
- **GIC Observations always incorporate all of the Science and is rooted in Realism – even when NERC models are still lacking that property**