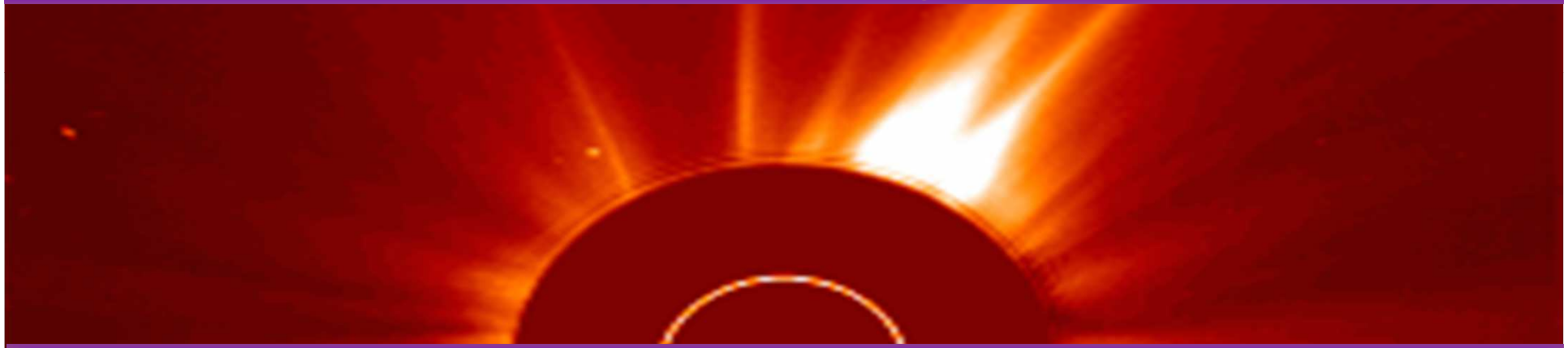
# Do Countries Under the Equatorial Electrojet Belt Worry About GIC?

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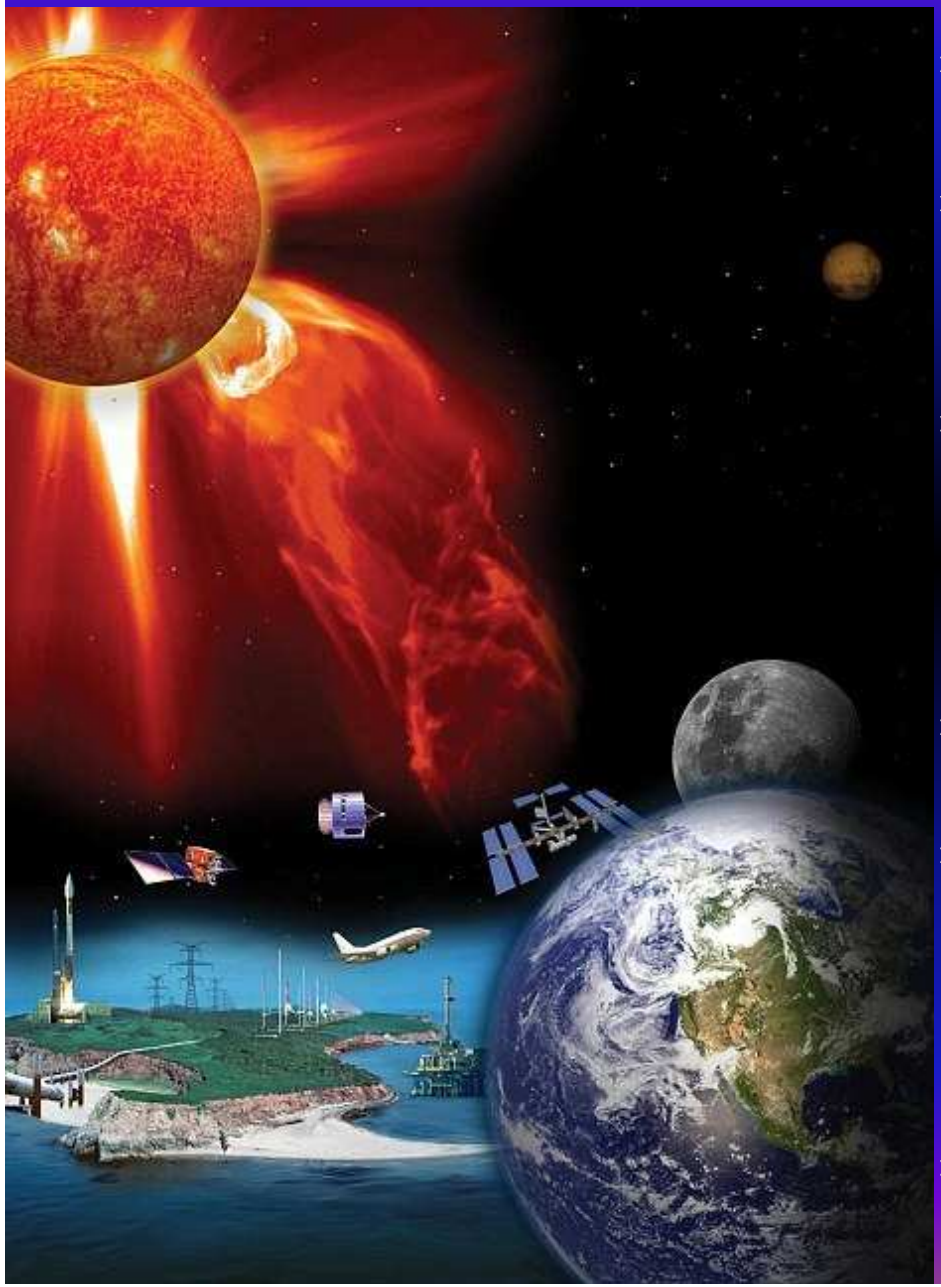
# Content



- Background and Motivation
- What is the current belief about GICs?
- What are the potential reasons to worry about GIC at the equator?
- Is GIC a storm time event?
- Why the GICs are comparably stronger at the equatorial region?
- Conclusion

# Space Weather Driven GICs and Power Grids

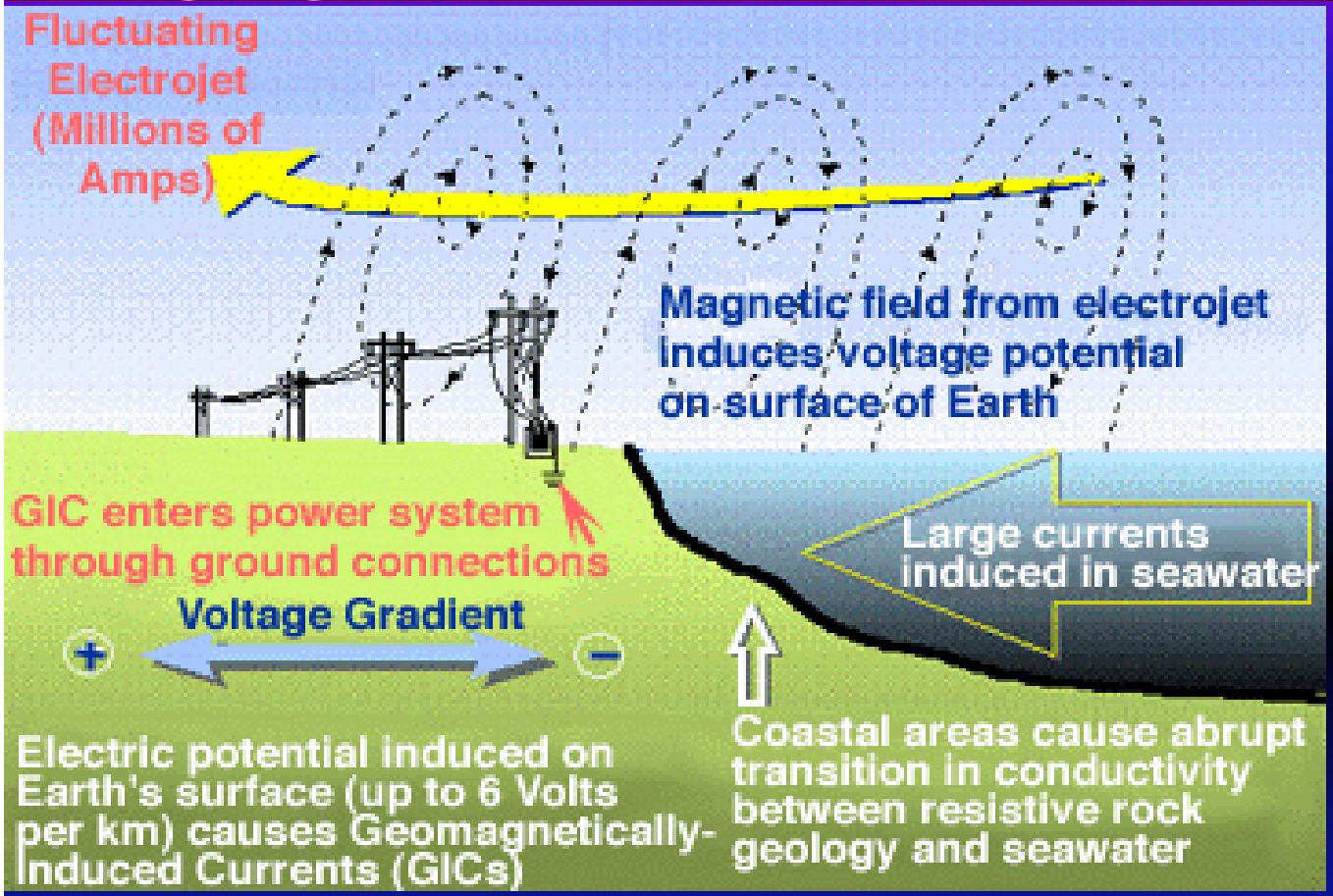
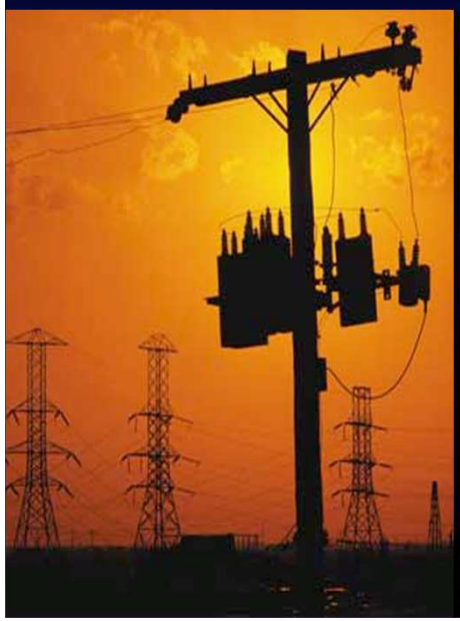


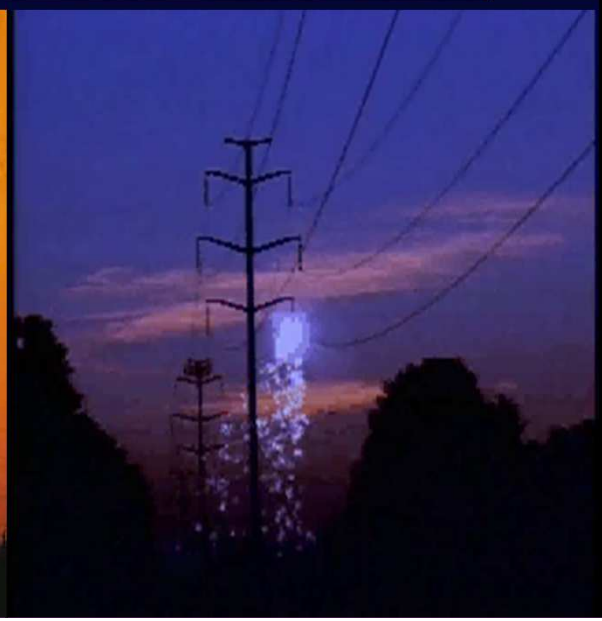

*Image courtesy of* ***John Kappenm***

- **Normally, the current on the power grid systems is AC, but the space weather driven GIC is DC, which is bad for power grids.**
- **When transformers get too much DC current: it may heats up, parts of the transformer can even melt, oil in the transformer may caught on fire, and some transformers even explode!**

# Motivation: Societal effects

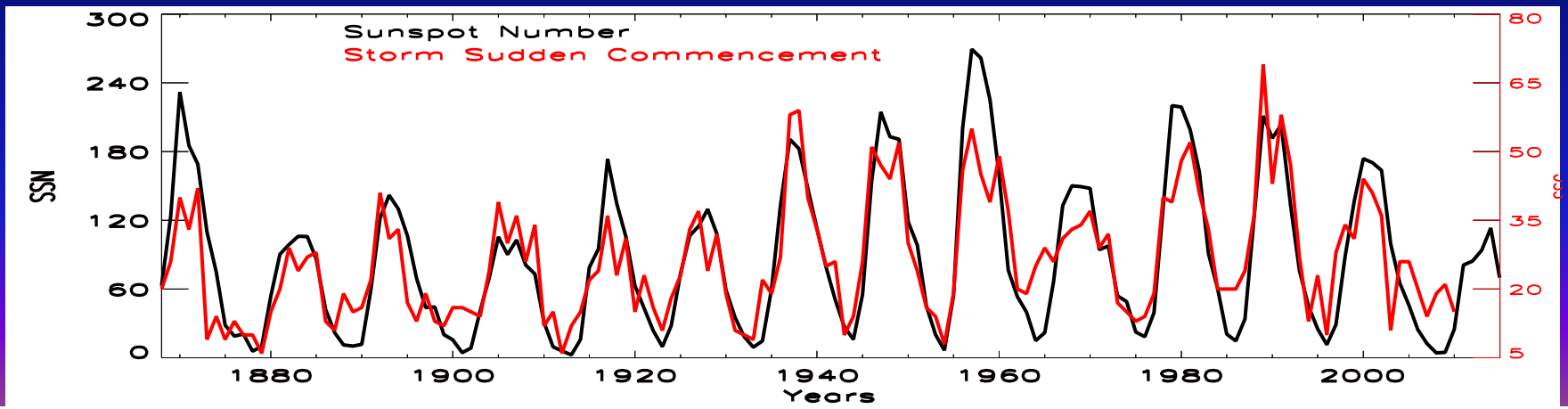
- GIC causes half cycle saturation of power transformers
- Transformer damage
- Electric blackout





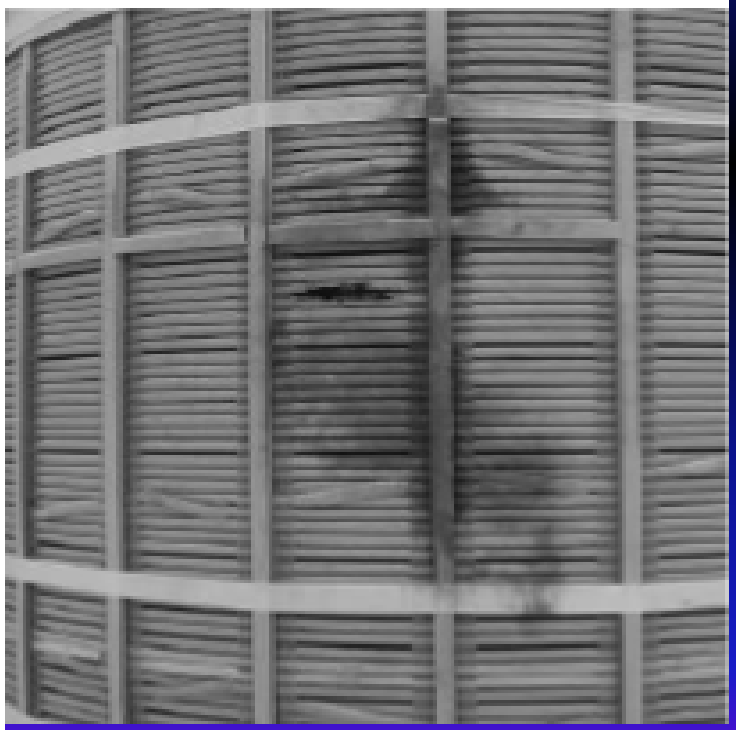
# Possible Drivers of GIC currents

- **Substorms:** Possible GIC drivers in the Auroal region
- **Enhanced Ionospheric Convection:** A direct response to the solar wind driver that can drive GIC current at high latitudes.
- **Storm Sudden Commencements (SSCs):** The magnetic signature of SSC can be observed globally and can also drive GIC at lower latitudes



# What are the current beliefs about GICs?

- **The first existing general understanding: smaller geomagnetic response (dB/dt) at low-latitude than at auroral latitudes.**
  - **Reality: the d*B*/d*t* ≈ 65−120 nT/min were reported at mid-latitudes during the 2003 Halloween storm that led to power equipment failures in South Africa.**

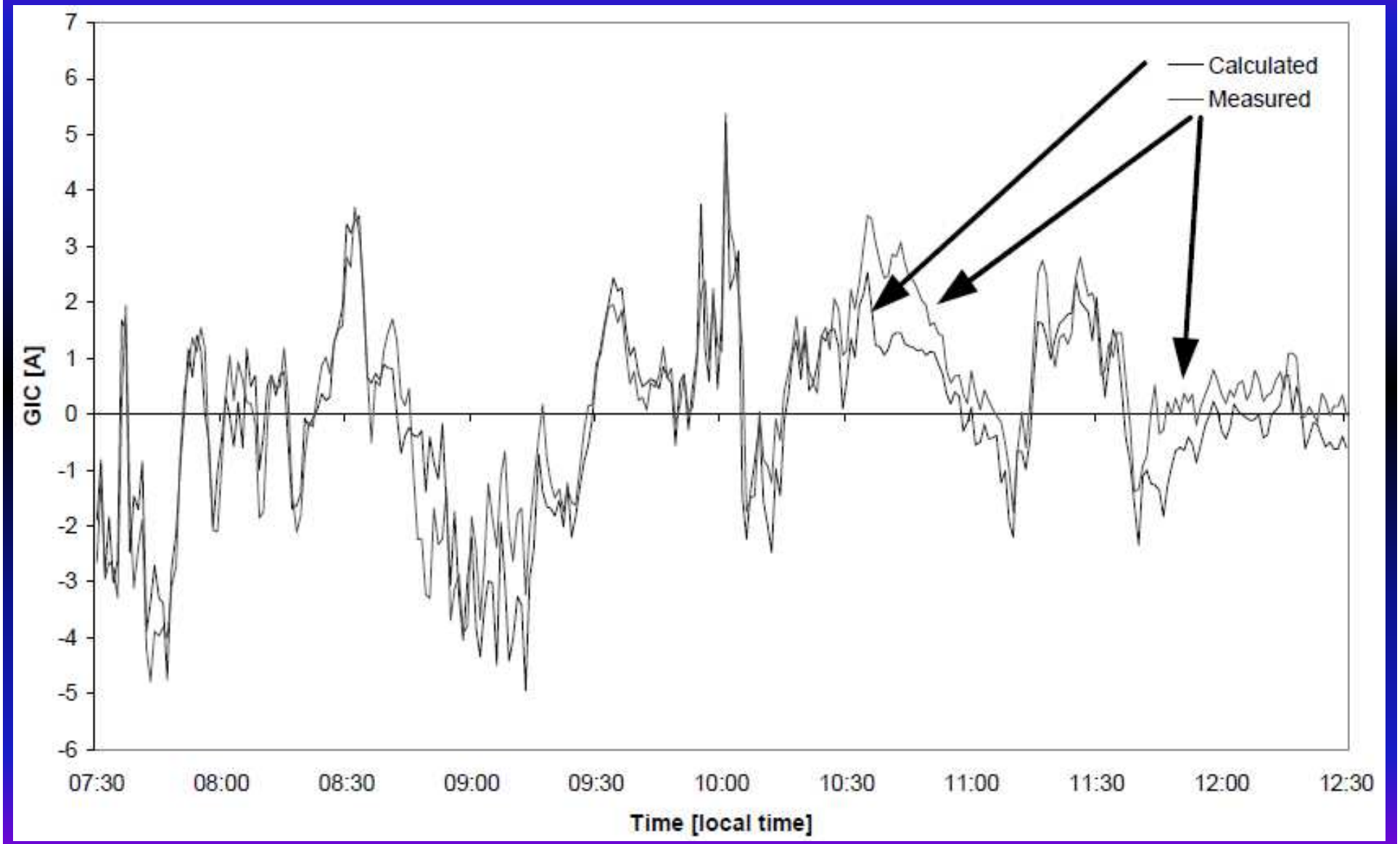


*Gaunt & Coetzee, IEEE, 2007*

Fig 6: Failure in HV winding of Lethabo #6

- **How do we know whether this is due to GIC or due to local heating, such as overloading the transformer?**

# What are the current beliefs about GICs?




*Gaunt & Coetzee, IEEE, 2007*

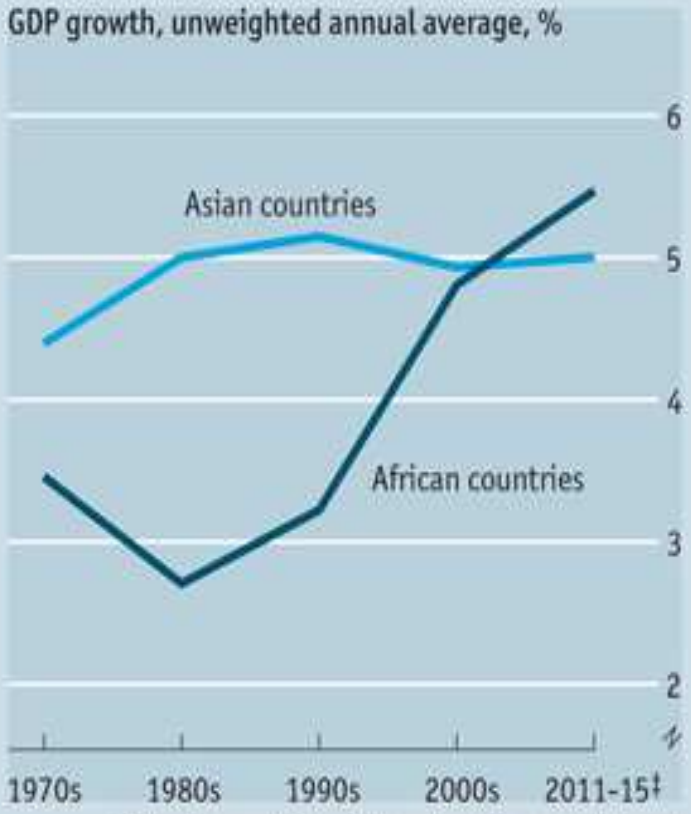
# What are the current beliefs about GICs?

- **The second existing general understanding:** The continental scale power grid infrastructures in the low-latitude regions are less developed.
  - **Reality: the current World Bank & IMF global economic growth data shows otherwise.**

**World's ten fastest-growing economies***
Annual average GDP growth, %

| 2001-2010† | | 2011-2015‡ | |
|---|---|---|---|
| Angola | 11.1 | China | 9.5 |
| China | 10.5 | India | 8.2 |
| Myanmar | 10.3 | Ethiopia | 8.1 |
| Nigeria | 8.9 | Mozambique | 7.7 |
| Ethiopia | 8.4 | Tanzania | 7.2 |
| Kazakhstan | 8.2 | Vietnam | 7.2 |
| Chad | 7.9 | Congo | 7.0 |
| Mozambique | 7.9 | Ghana | 7.0 |
| Cambodia | 7.7 | Zambia | 6.9 |
| Rwanda | 7.6 | Nigeria | 6.8 |

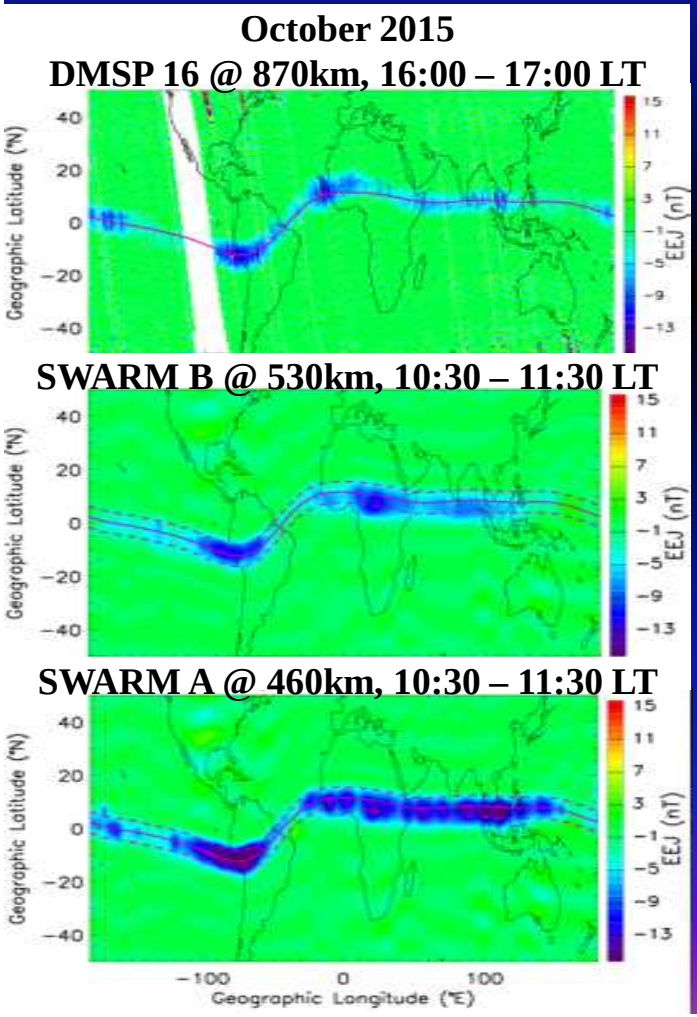
Sources: *The Economist*; IMF



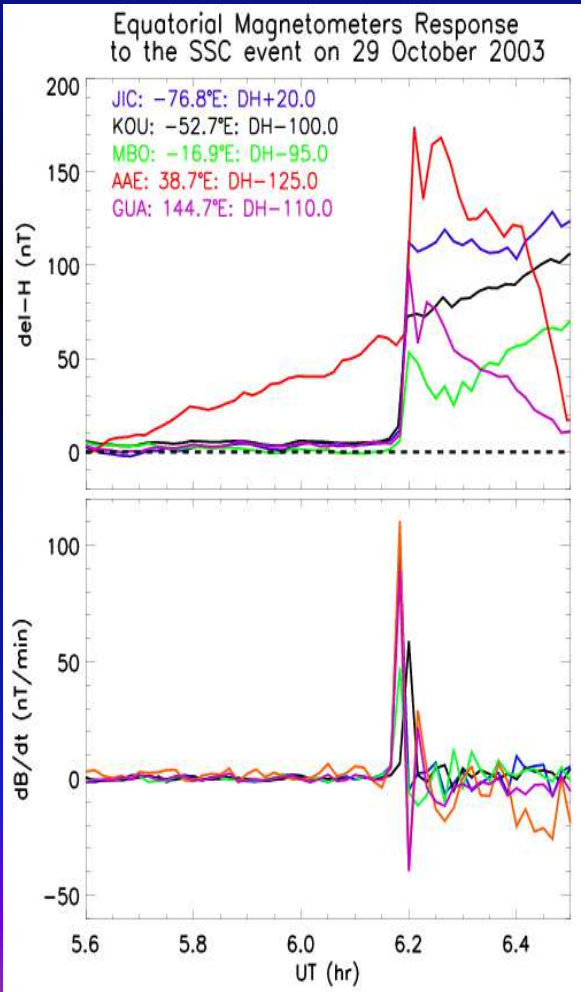

*Courtesy of IMF/The Economics*

# Potential reasons to worry about GIC at the equatorial region!

- During strong interplanetary shock Equatorial Electrojet (EEJ) can give rise to large *dB/dt* and hence large GIC

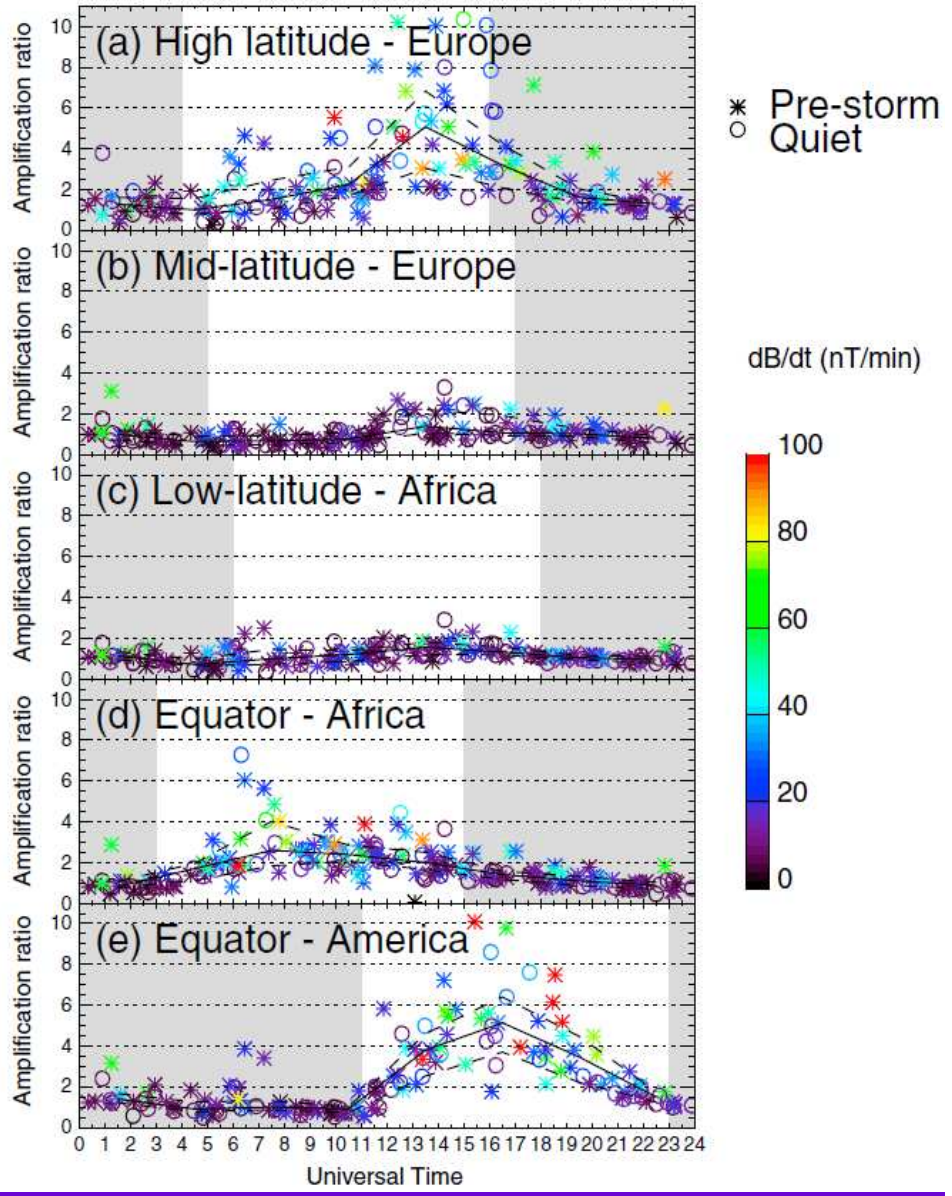



- The EEJ responds strongly to the solar wind dynamic pressure changes
- Magnetometers located within EEJ belt shows ~ *150 nT/min* - Comparable to *dB/dt* within AEJ region during major storms (March 89 AEJ *450 nT/min*)



# By how much percent EEJ can amplify GIC?

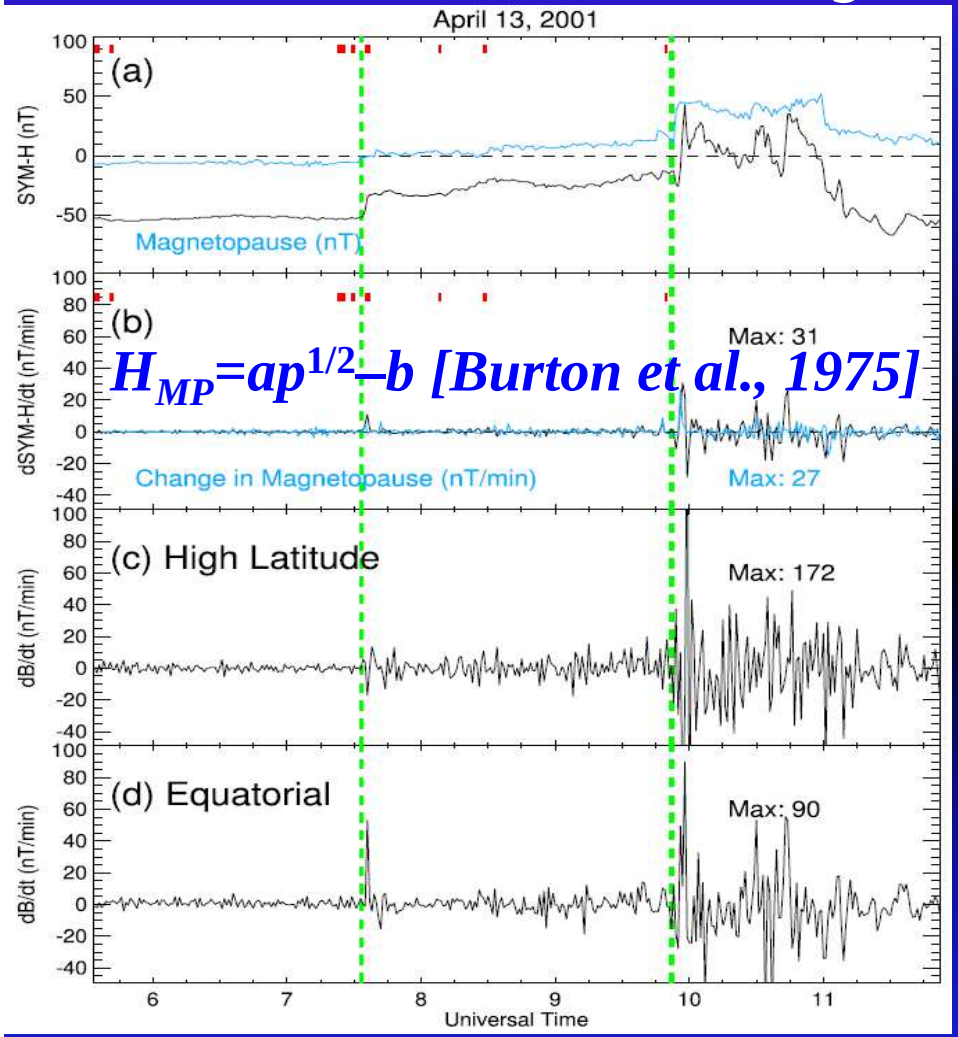
- ***The SYM-H index includes***
  $SYM_H = B_{RC}+B_{TC}+B_{MP}$
- **Magnetometer at the equator**
  $B_{Obs}=B_{main}+B_{SQ}+B_{RC}+B_{EJ}+B_{MP}+B_{TC}$
- **To better understand how EEJs amplify the GIC (caused by sudden impulse) at the equator, we define the amplification ratio as** $(dB_{Obs}/dt)/(d(SYM\text{-}H)/dt)$.
- **The EEJ significantly amplify GIC current even to the level of GIC at high-latitudes.**



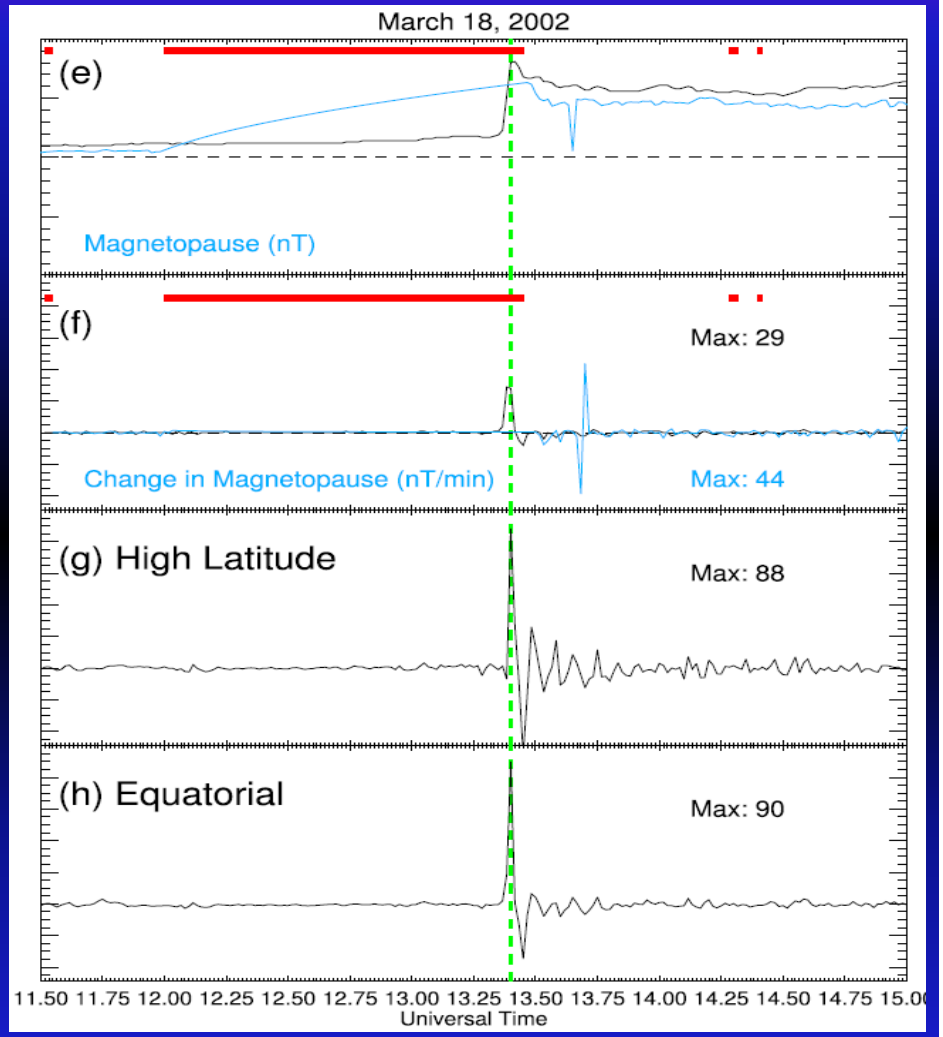

*Carter, Yizengaw, et al, GRL, 2015*

# Is GIC only storm time event and affects only high latitude region?

## *Carter, Yizengaw et al., GRL, 2015*



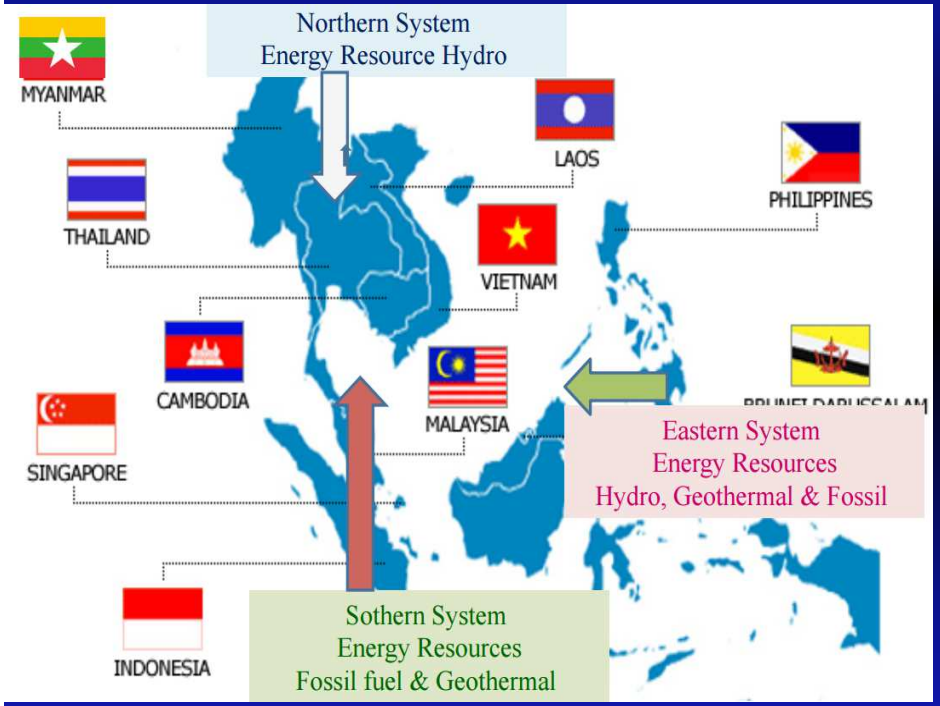

$H_{MP}=ap^{1/2}-b$ *[Burton et al., 1975]*




- **Significant *dB/dt* difference between high- and equatorial-latitudes during geomagnetic storm time**
- **Almost equal but significant *dB/dt* during quiet time**

# Why GIC can be a threat for power interruptions at low-latitude regions?

- Countries under the EEJ region are developing large-scale interconnected power transmission systems



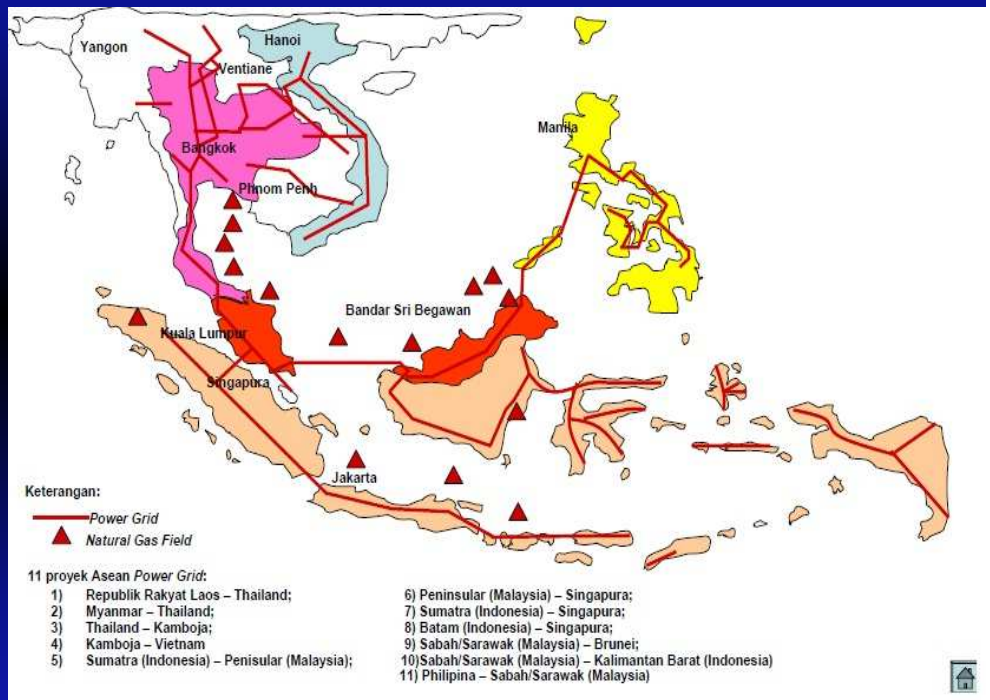
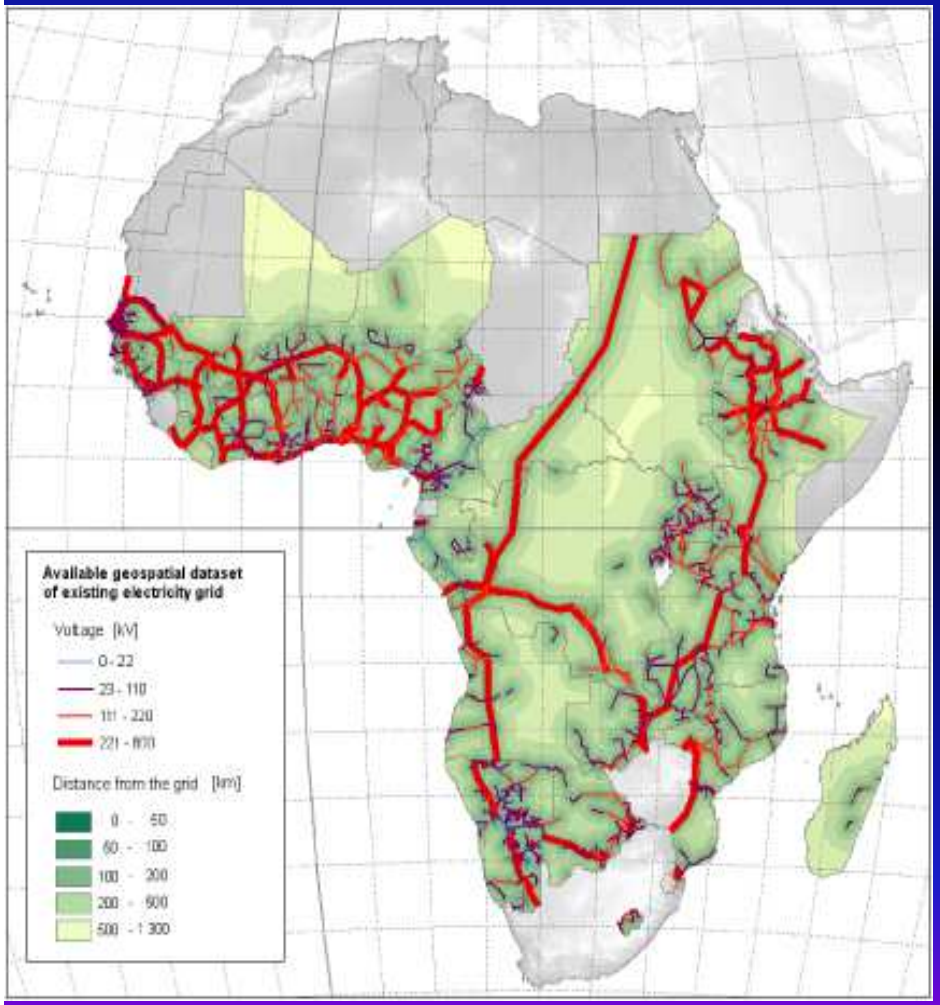




*Image courtesy of* ENERGY STUDIES INSTITUTE National University of Singapore

- **Such power grid interconnection may be highly exposed to GICs (up 6V/km potential can be induced to the Earth's surface)**

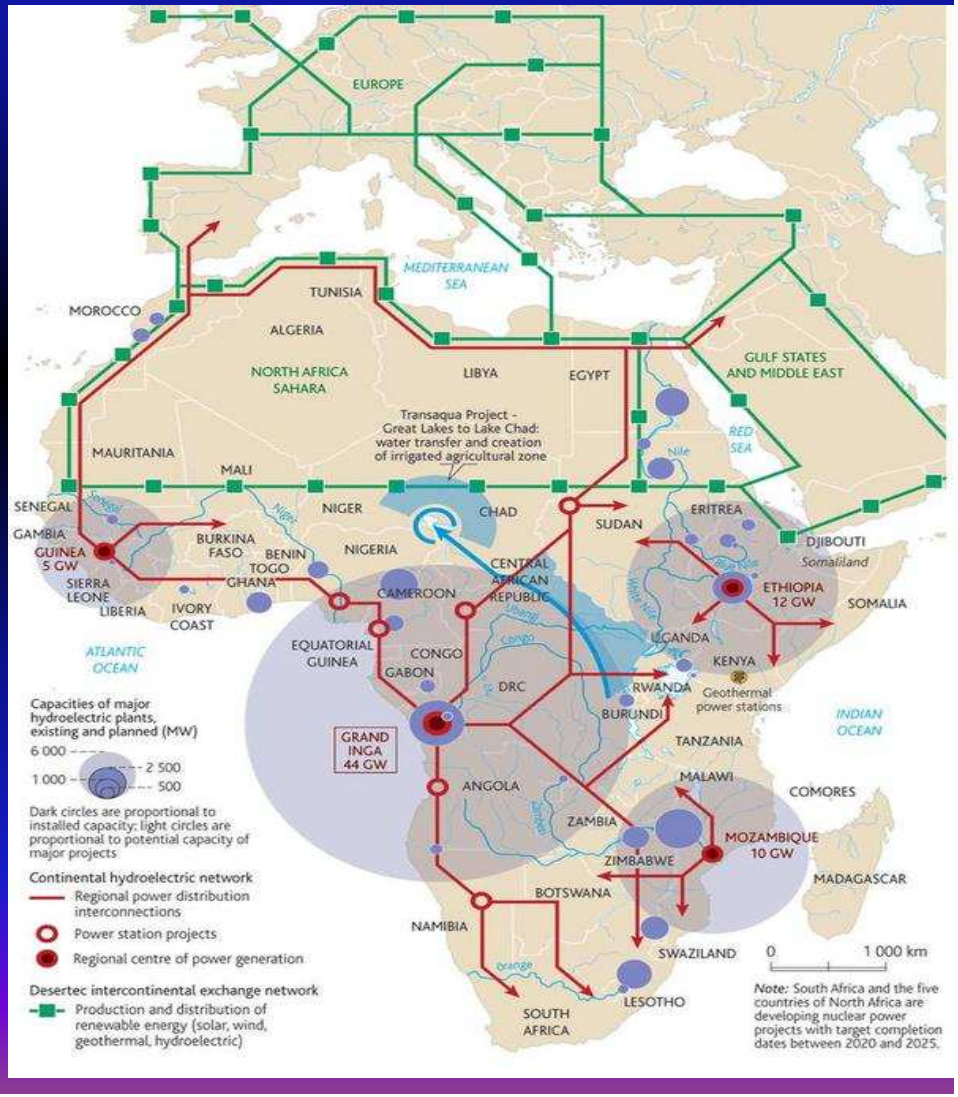
# Why GIC can be a threat for power interruptions at low-latitude regions?

## *Current power grid network*




*Szabo et al., ERL, 2011*

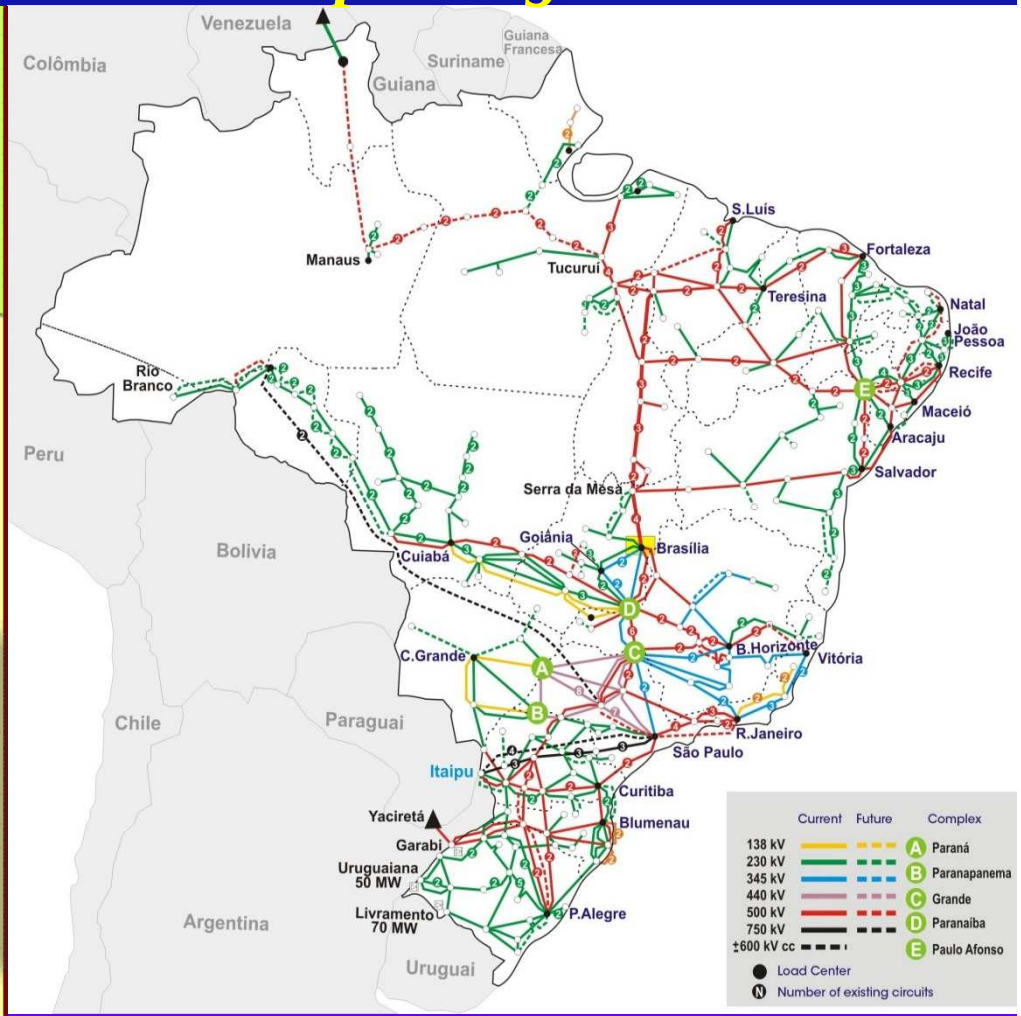
## *Planned power grid connection*



# Why GIC can be a threat for power interruptions at low-latitude regions?

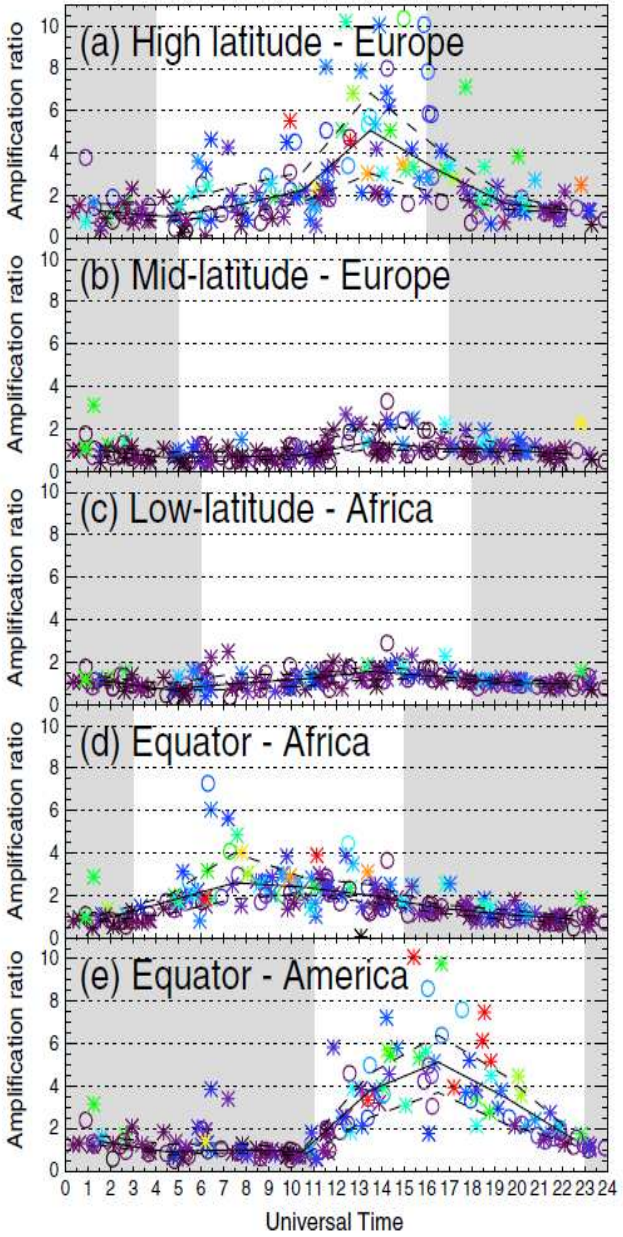
## *Peru power grid network*

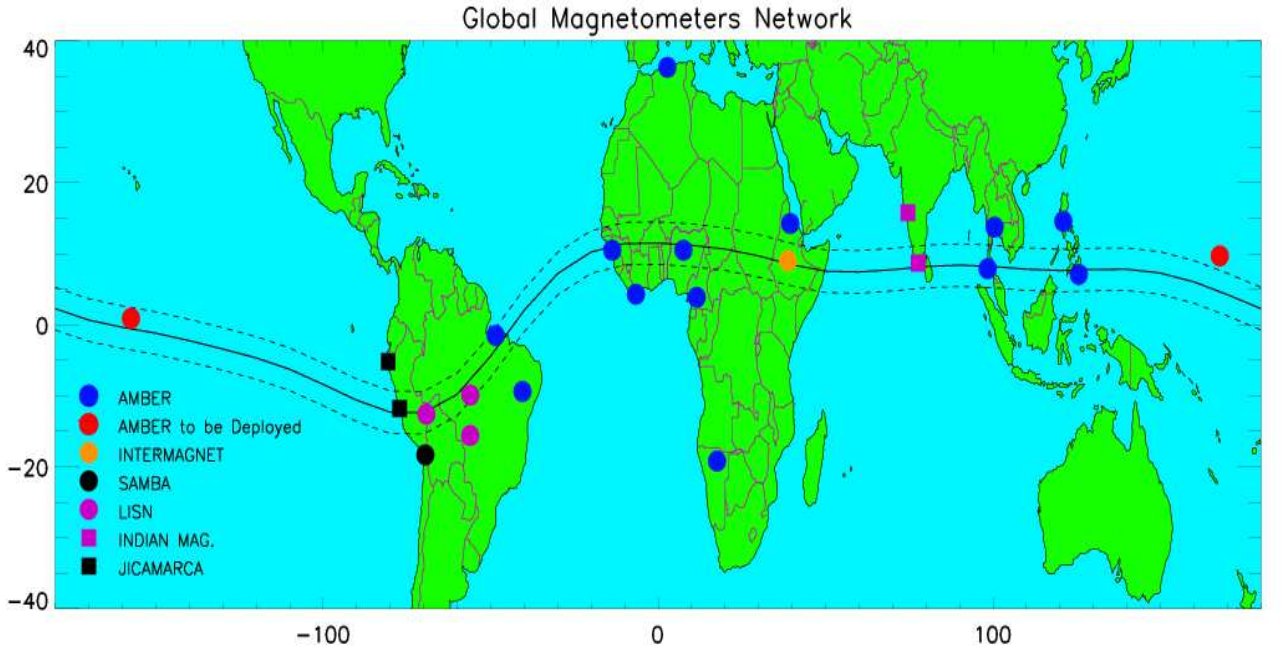

## *Brazil power grid connection*




*Moldwin and Tsu, AGU, 2016*

# Future Direction!

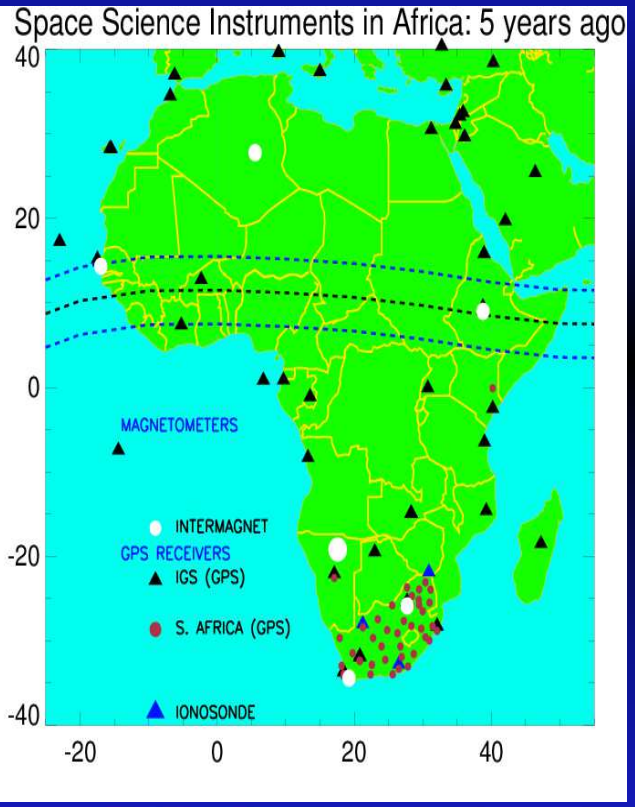


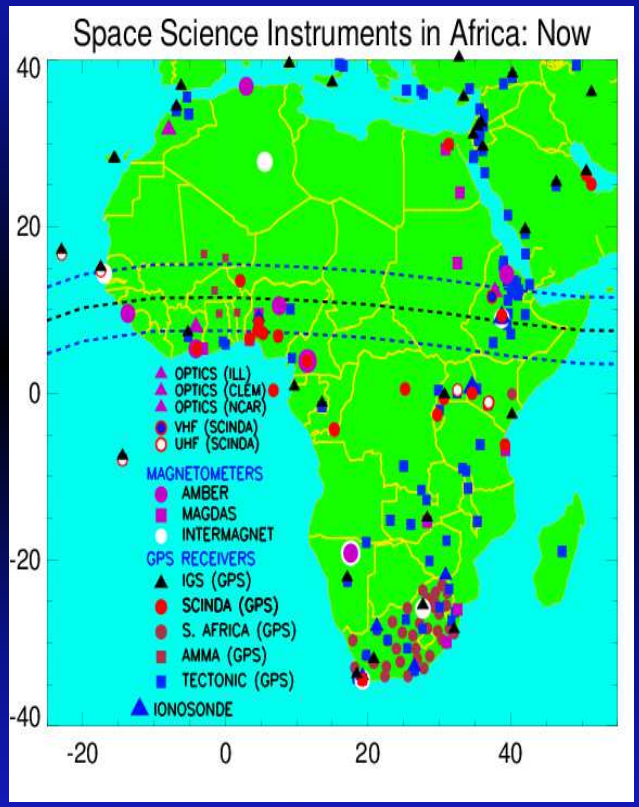

- We will use this chain of magnetometers to understand the longitudinal dependence of GIC strength at the equator!
- Use our current healthy collaboration to work with local peoples to differentiate between transformer damages due to GIC or overloading!

# Evolution of Instrumentation in Africa and Its Significant Outputs!

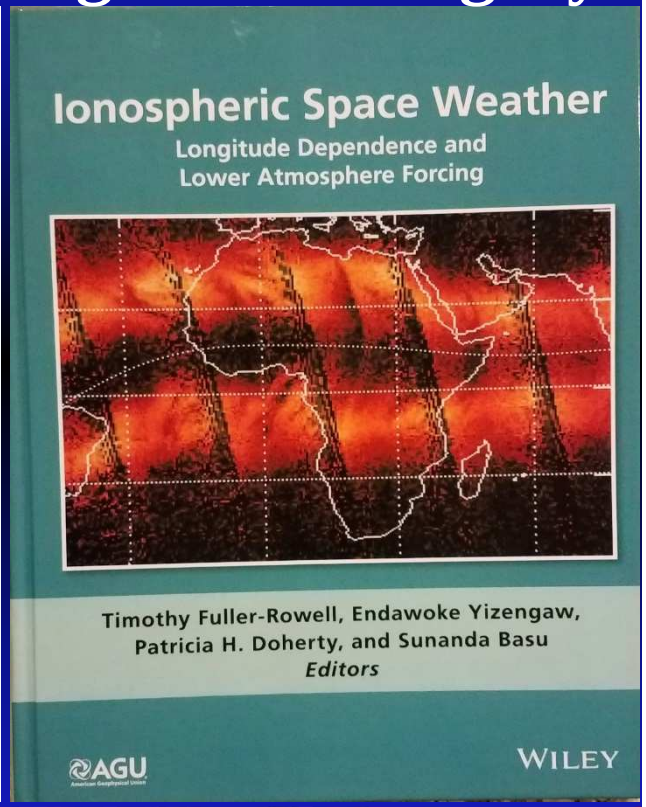
## In 2007




## In 2015




## Significant Legacy!




# Thank You!