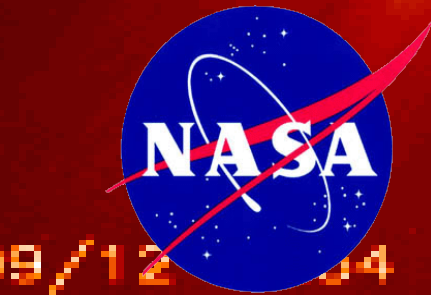


Should countries under the Equatorial Electrojet belt worry about Geomagnetically Induced Currents?

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- **What is the current belief about GICs?**
- **What are the potential reasons to worry about GIC at the equator?**
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- **Conclusion**

Space Weather Driven GICs and Power Grids

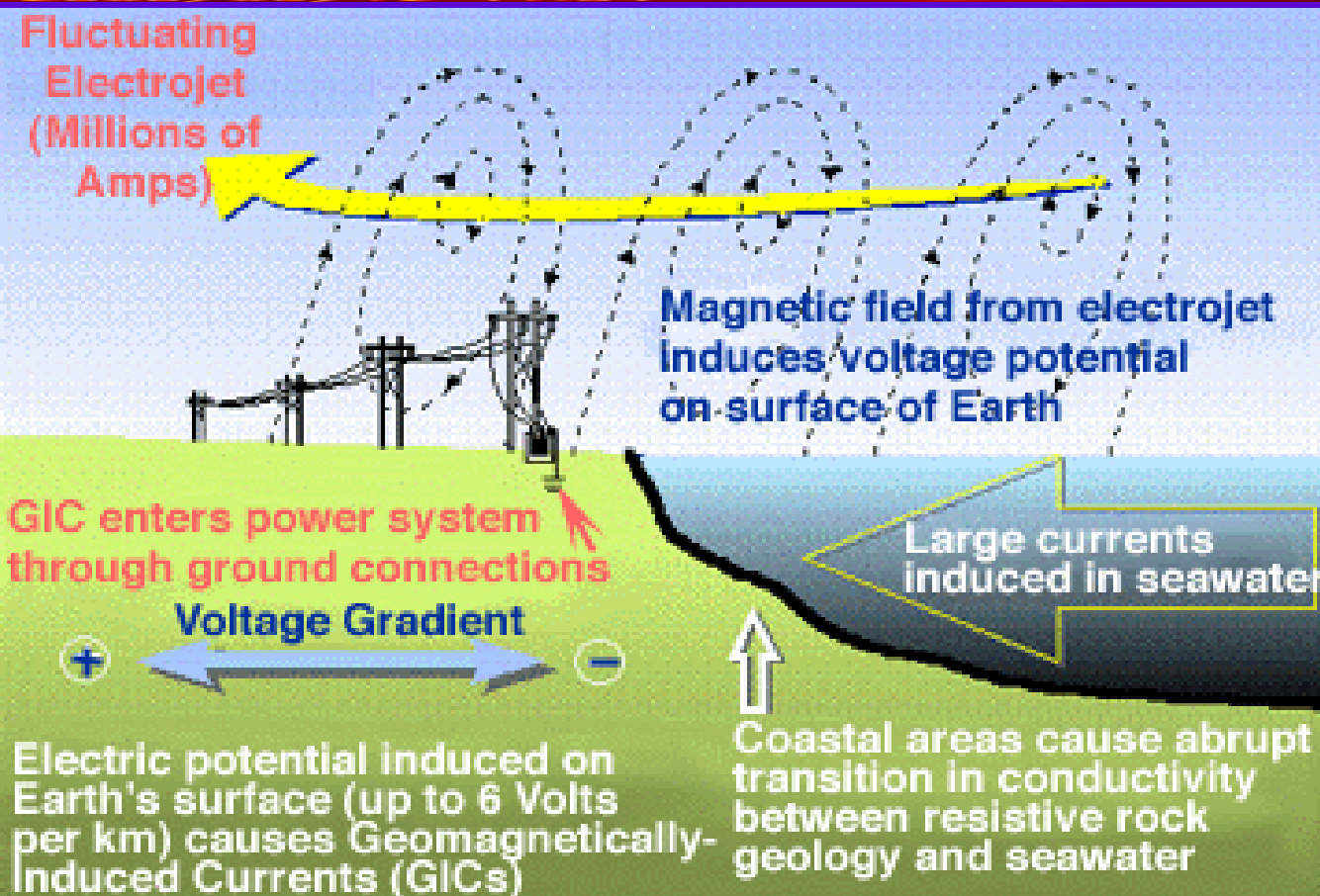


Image courtesy of John Kappenman

- ➔ 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 heat up, parts of the transformer can even melt, oil in the transformer may catch on fire, and some transformers even explode!

Motivation: Societal effects

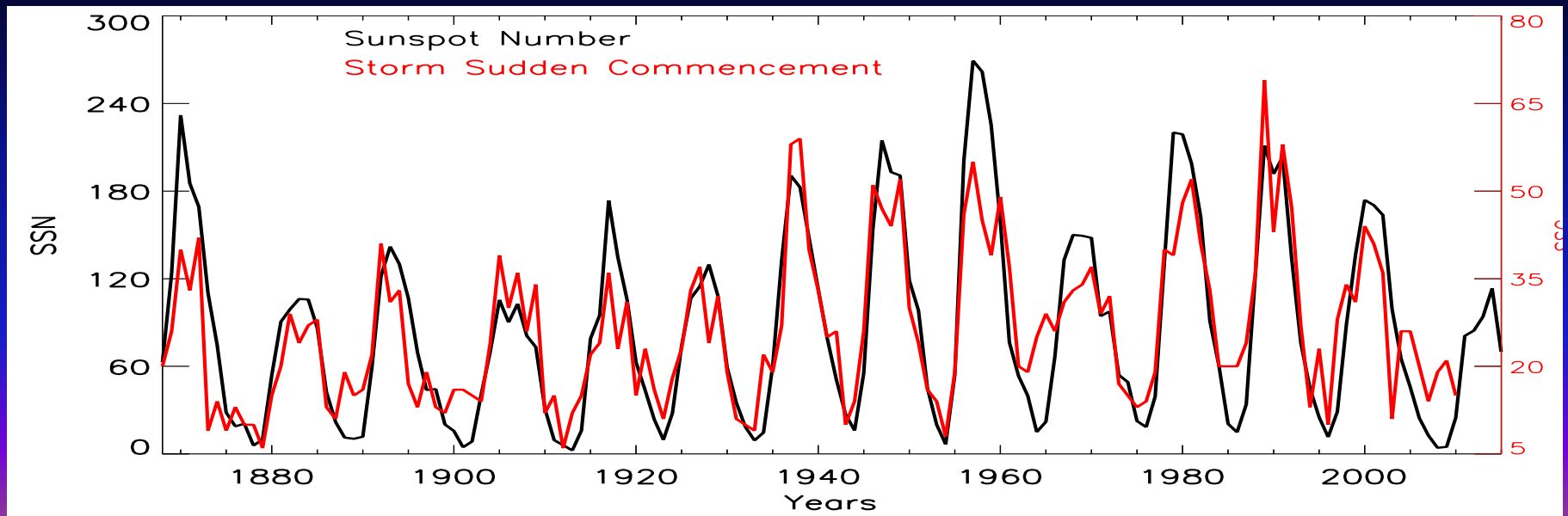


- GIC causes half cycle saturation of power transformers
- Transformer damage
- Electric blackout



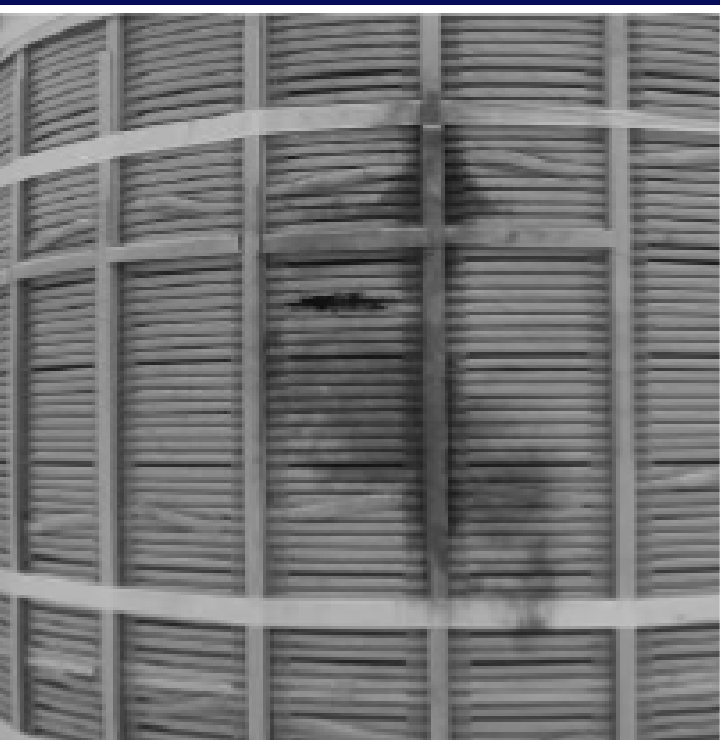
Possible Drivers of GIC currents

- **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?

- Current general understanding: smaller geomagnetic response (dB/dt) at low-latitude than at auroral latitudes.
- Reality: the dB/dt \approx 65–120 nT/min were reported at mid-latitudes during the 2003 Halloween storm that led to power equipment failures in South Africa.



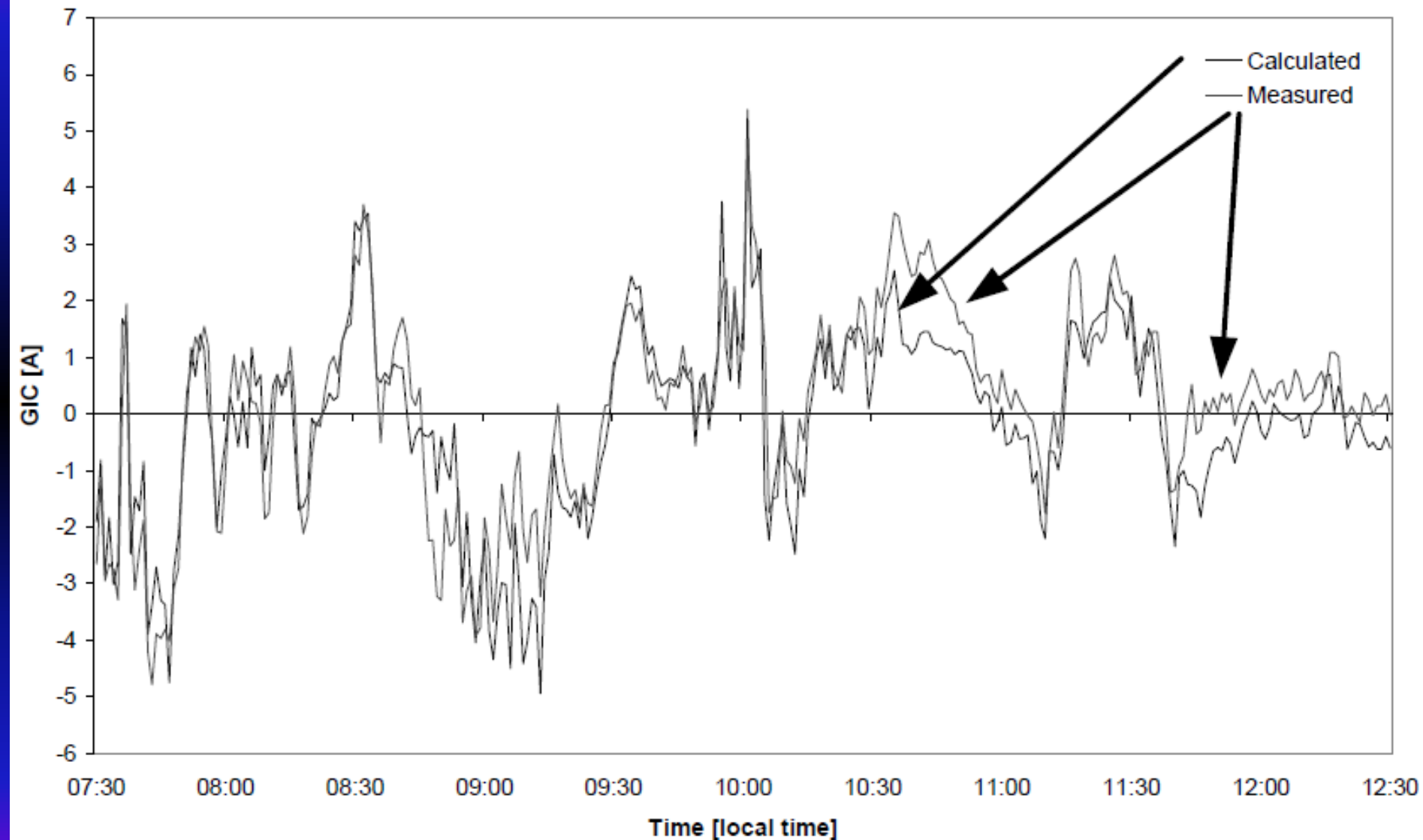
*Gaunt &
Coetzee, IEEE,
2007*



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?

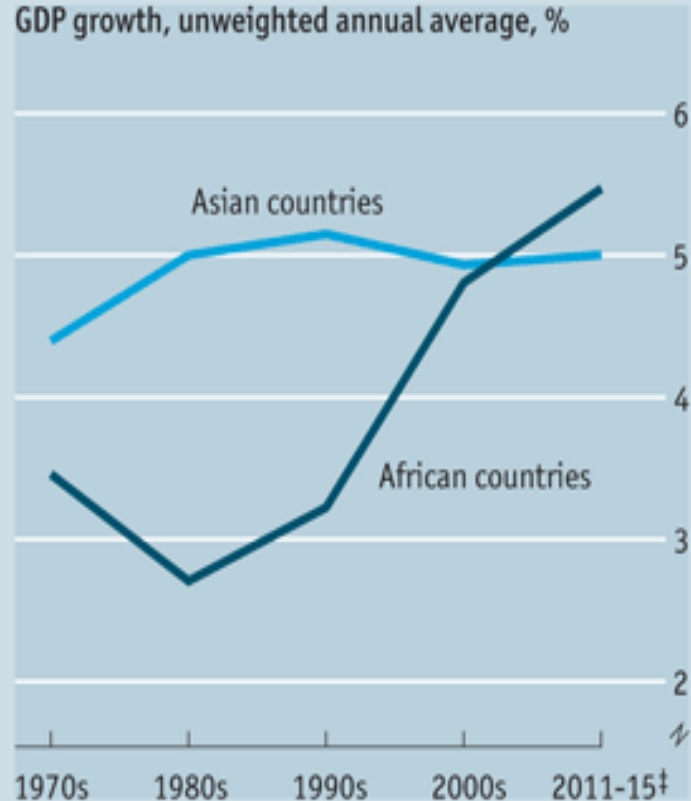
→ The continental scale power grid infrastructures in the low-latitude regions are less developed.

→ **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

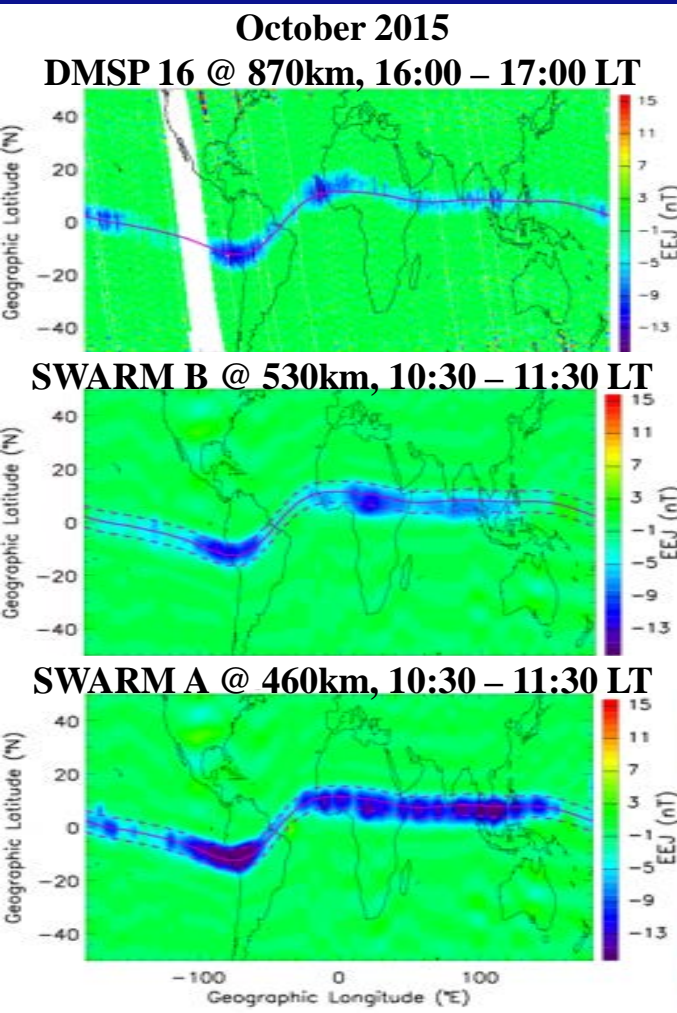


*Excluding countries with less than 10m population and Iraq and Afghanistan †2010 estimate ‡Forecast

*Courtesy of
IMF/The
Economics*

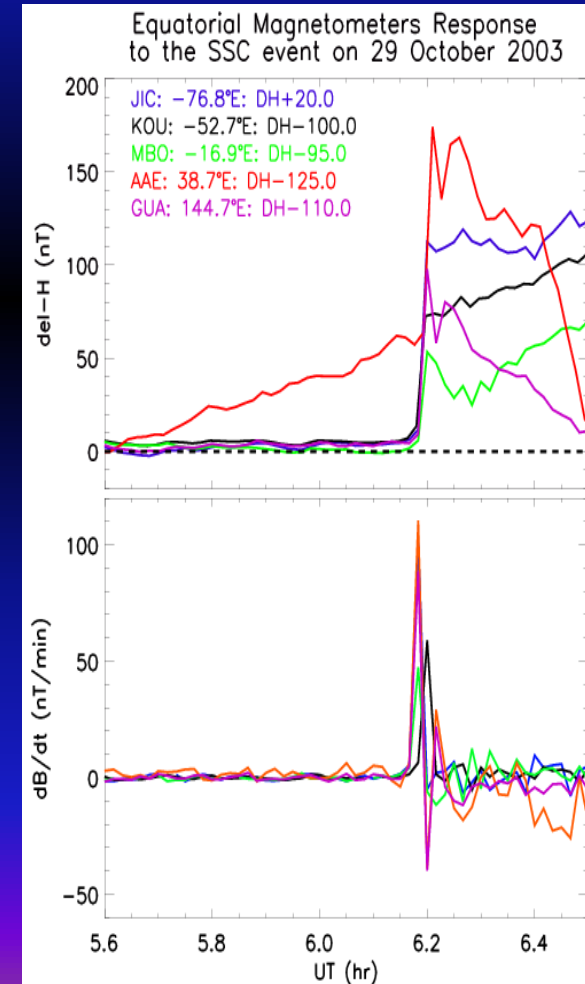
Potential reasons to worry about GIC at the equatorial region!

→ 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 500 nT/min)



By how much percent EEJ can amplify GIC?

→ The SYM-H index includes

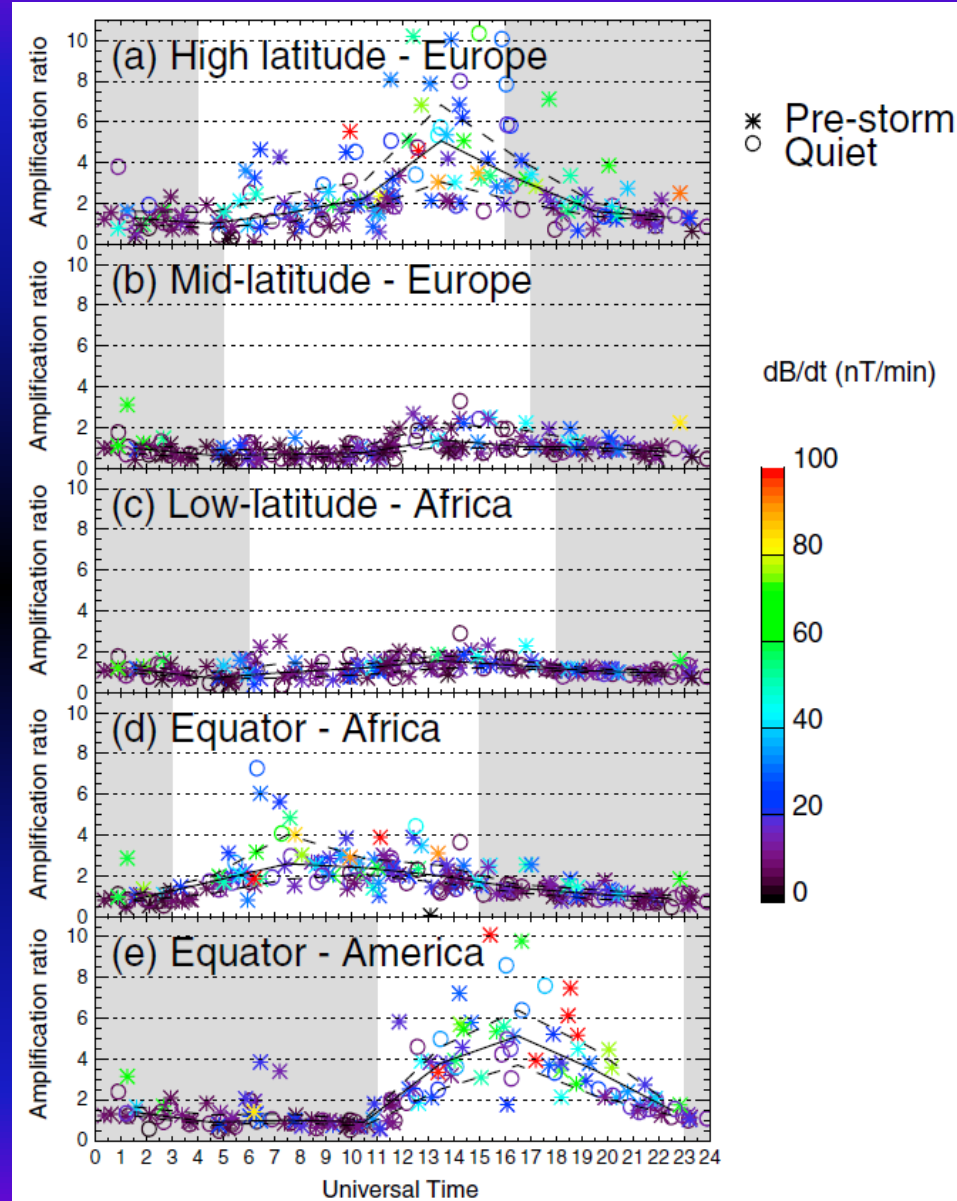
$$SYM_H = B_{RC} + B_{TC} + B_{MP}$$

→ 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 $(dB_{Obs}/dt)/(d(SYM-H)/dt)$.

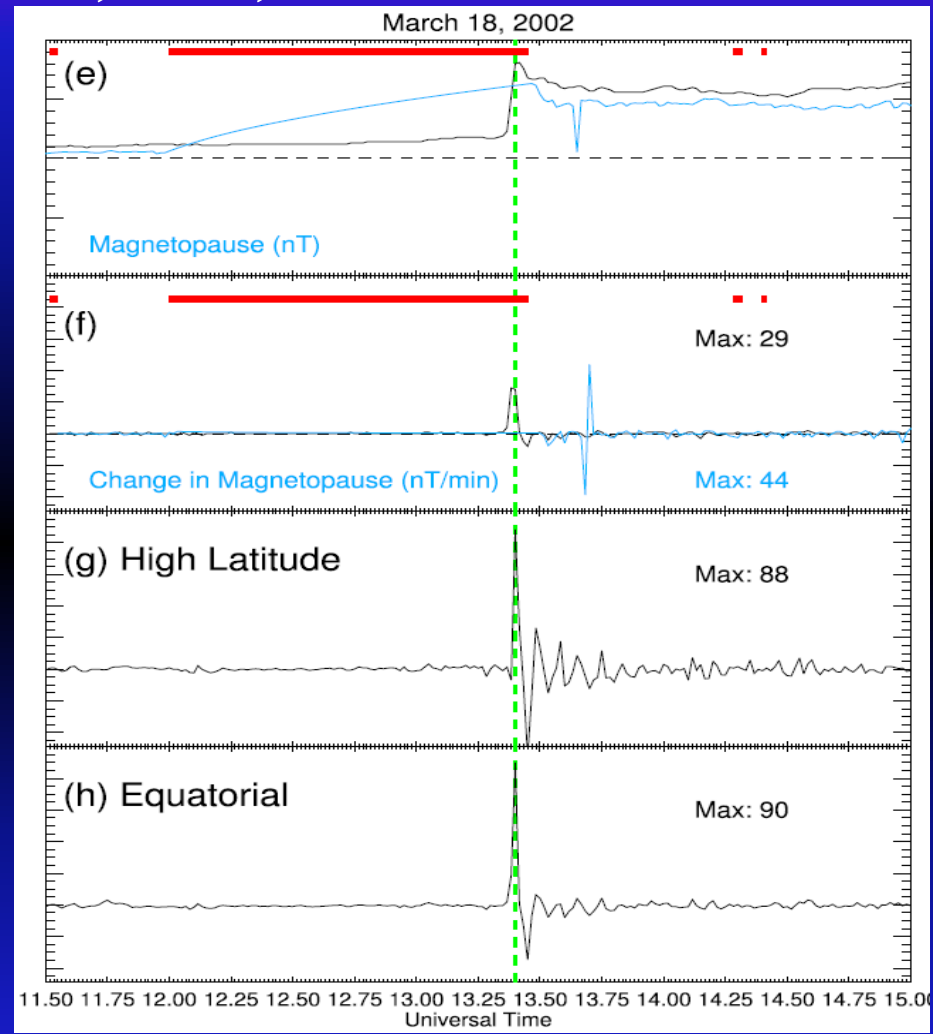
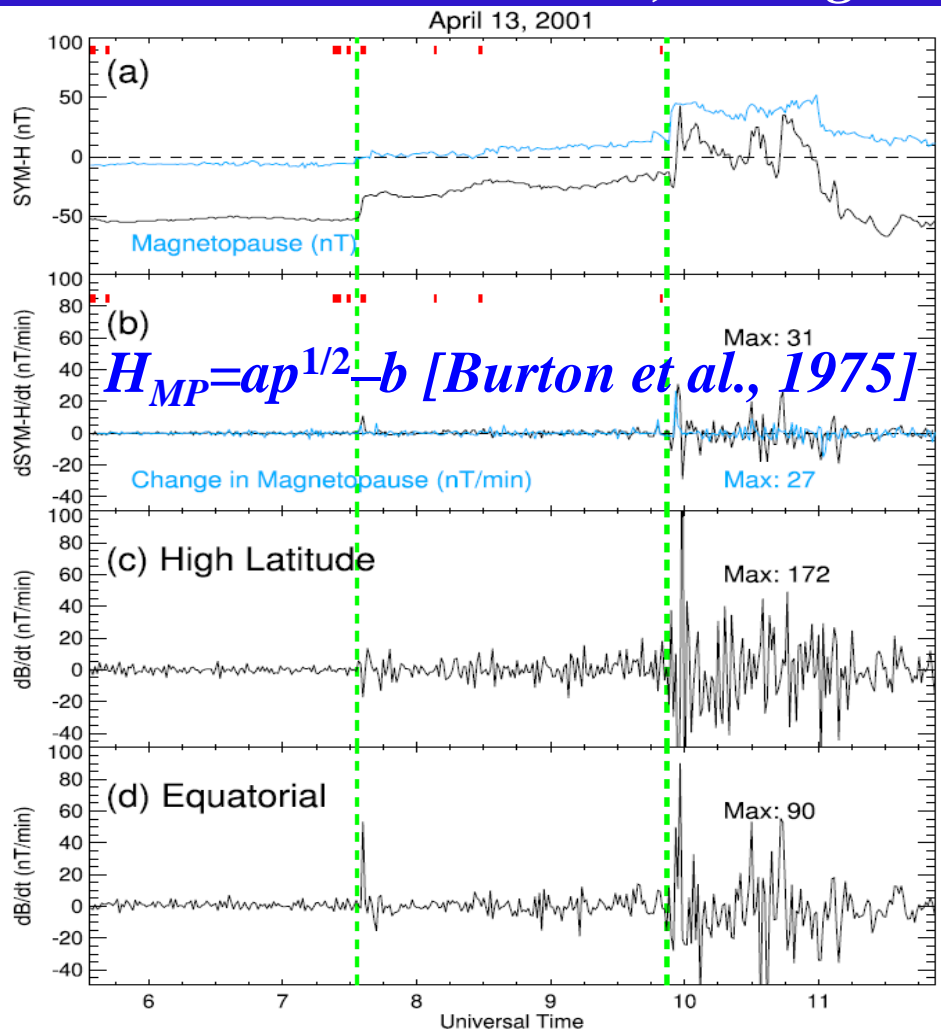
→ The EEJ significantly amplifies GIC current even to the level of GIC at high-latitudes.



Carter, Yizengaw, et al, GRL, 2015

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

Carter, Yizengaw et al., GRL, 2015



- ➔ 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

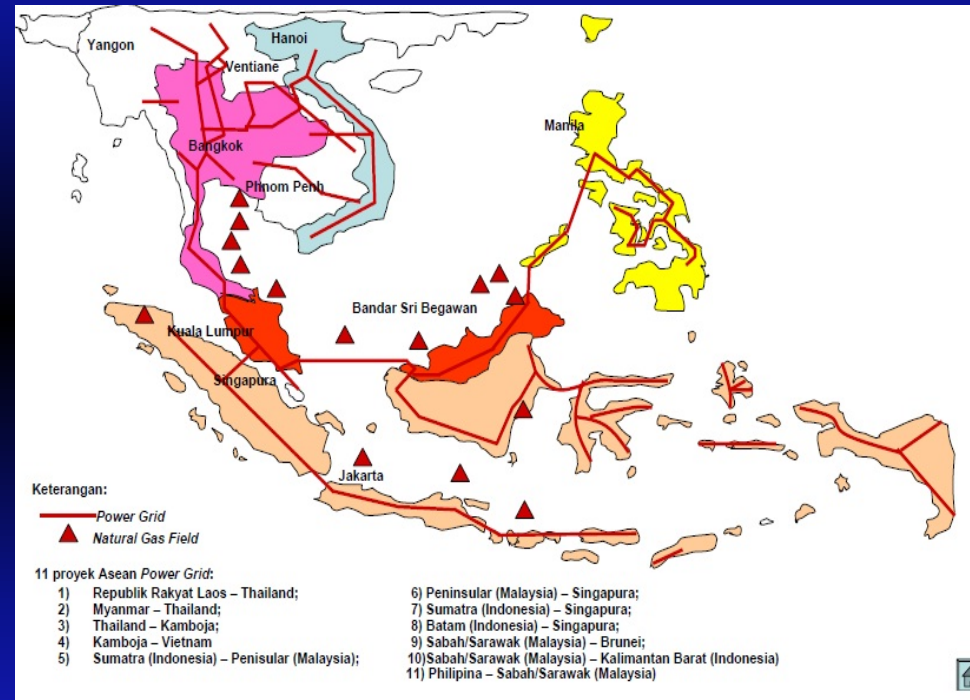
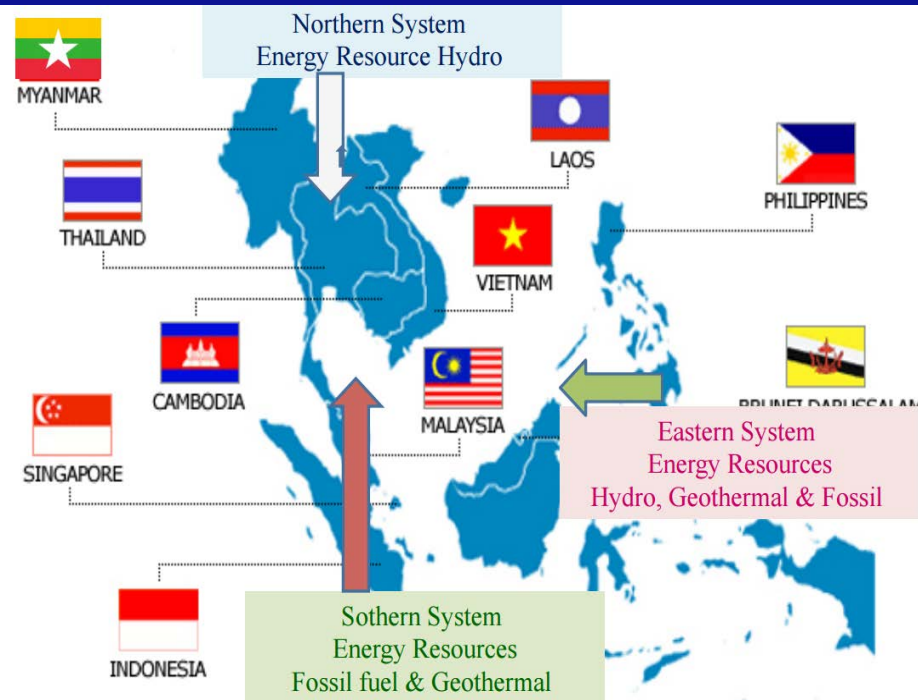
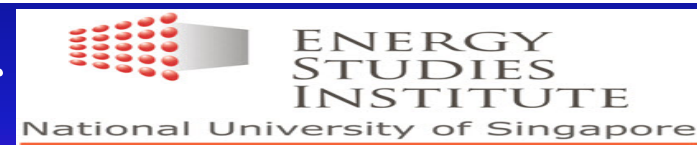


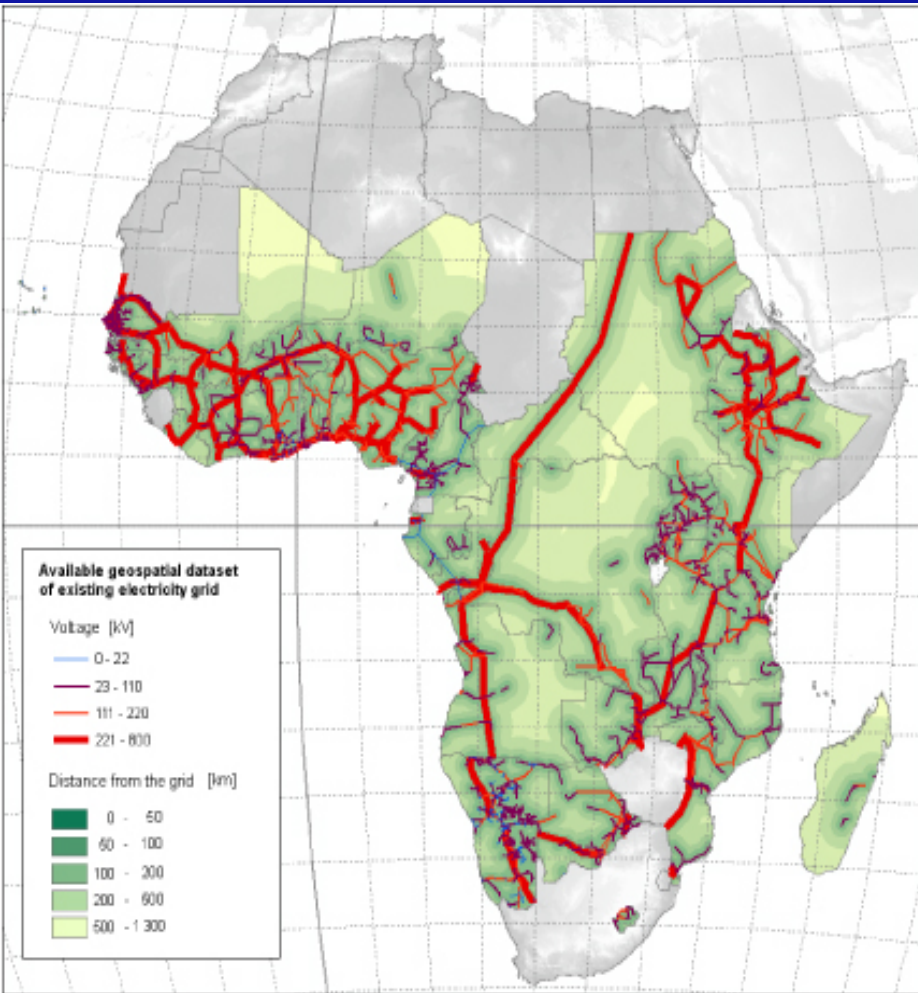
Image courtesy of



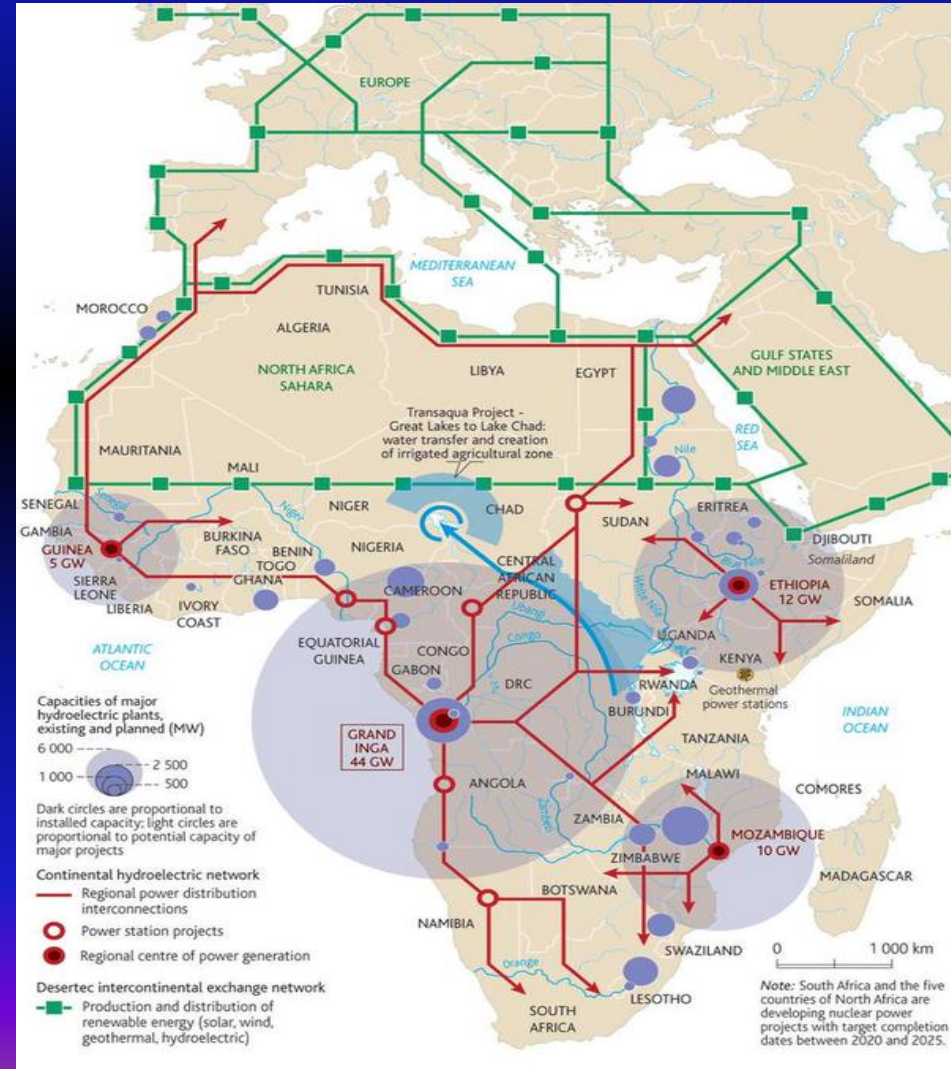
→ Such power grid interconnection may be highly exposed to GICs (up 6V/km potential can be induced to the Earth's surface)

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

Current power grid network



Planned power grid connection

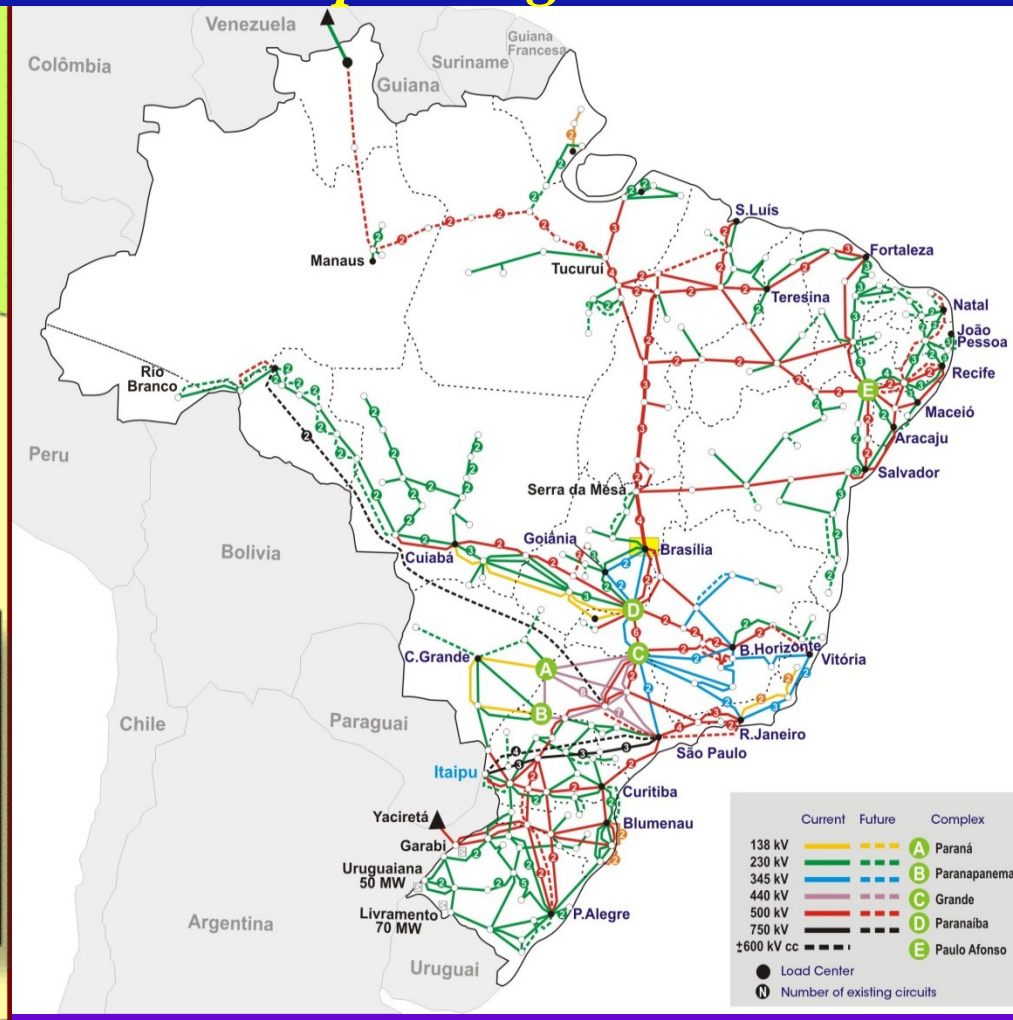


Why GIC can be a threat for power interruptions at low-latitude regions?

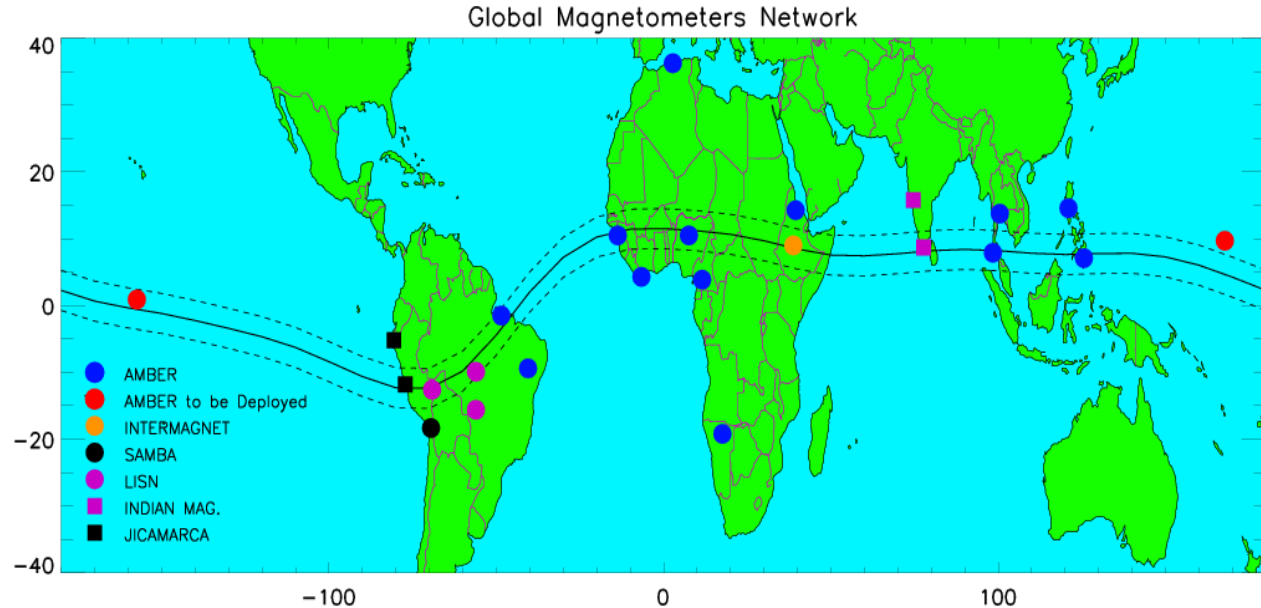
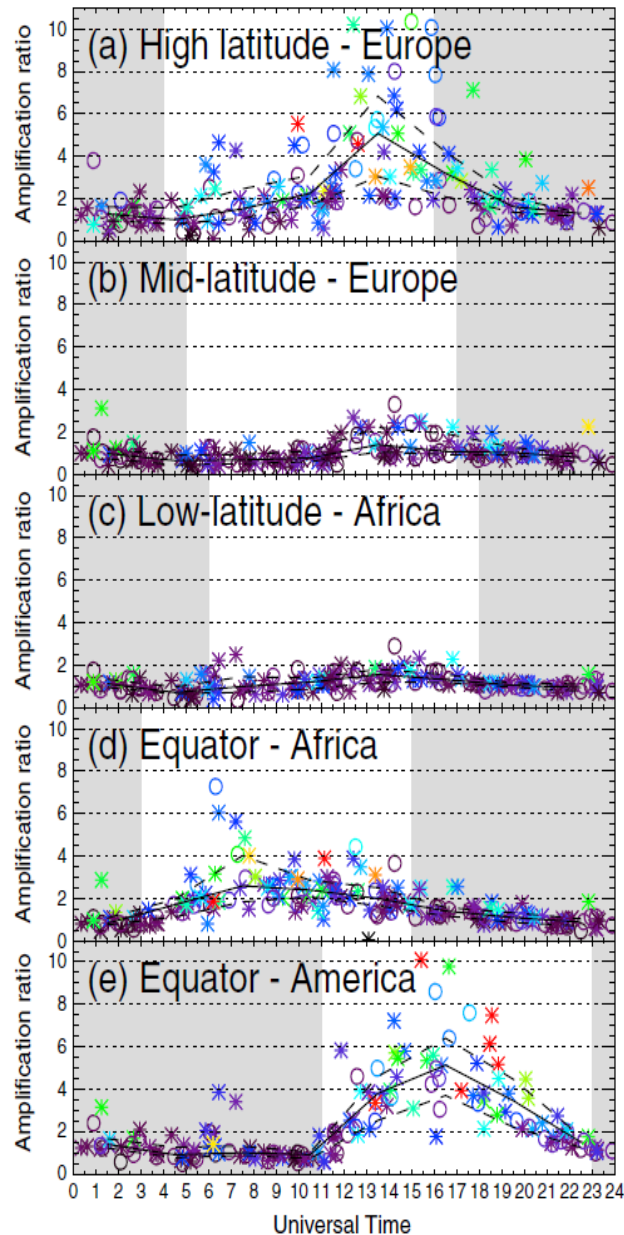
Peru power grid network



Brazil power grid connection



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!

Conclusion

- The arrival of interplanetary shocks drives GIC current even at lower latitudes, which can destroy transformers at equatorial region.
- The EEJ is found to be the primary cause for the amplification of GIC current, and thus the power grid infrastructure in the equatorial region is more susceptible to GICs than previously thought
- The economic growth of countries under EEJ region is booming, and are expanding their continental-scale power grids
- GIC should no longer be solely severe geomagnetic storms event but can occur during quiet periods, because many interplanetary sudden shock/impulses are sometimes followed by completely quiet conditions.

Thank You!

2008/09/12 11:54



Fig 7: Failure in HV winding of Matimba #4

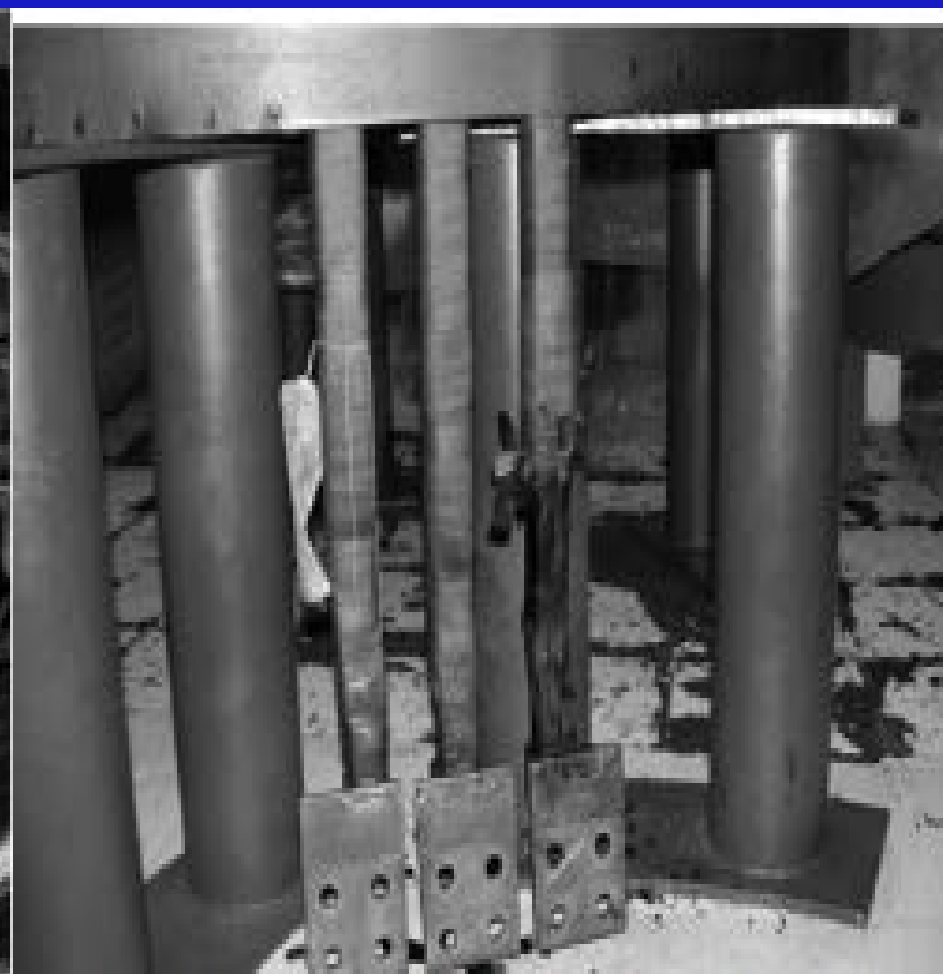
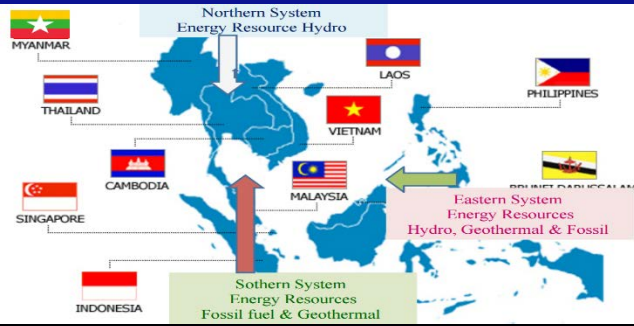


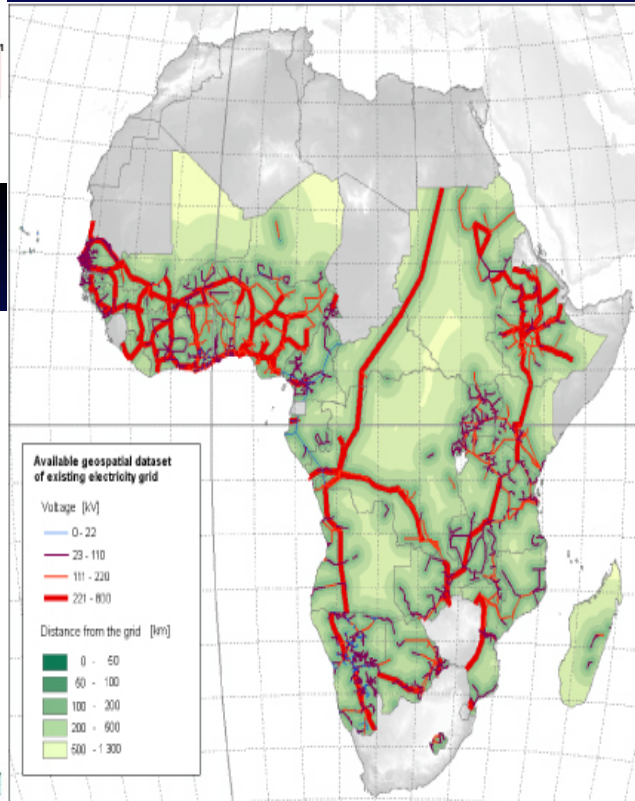
Fig 8: Overheating of LV terminals of Tutuka #1

Potential reasons to worry about GIC caused problems at low-latitude regions

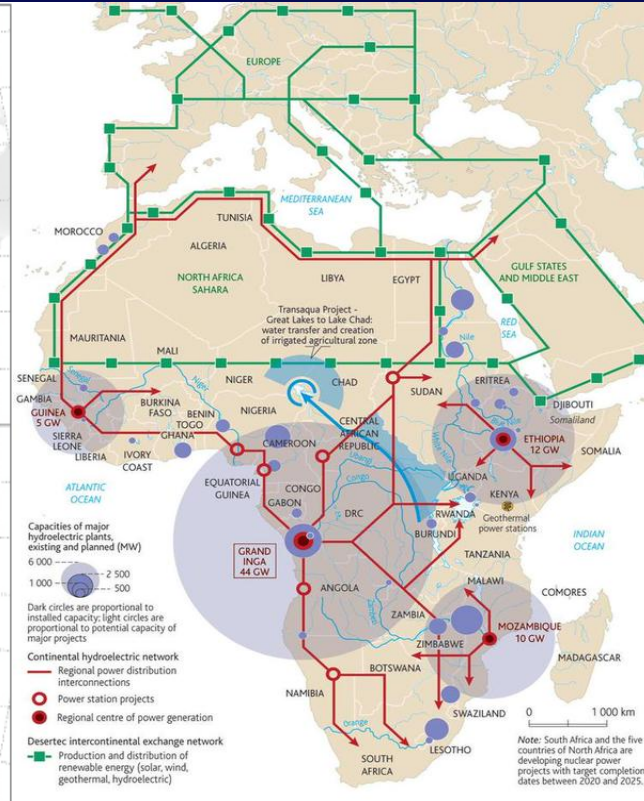
→ Countries under the EEJ belt are some of the fastest growing economies in the world and are developing large-scale power grids



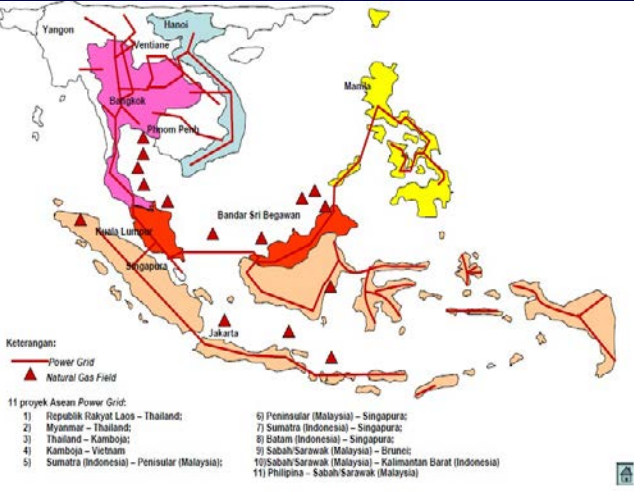
Current power grid network

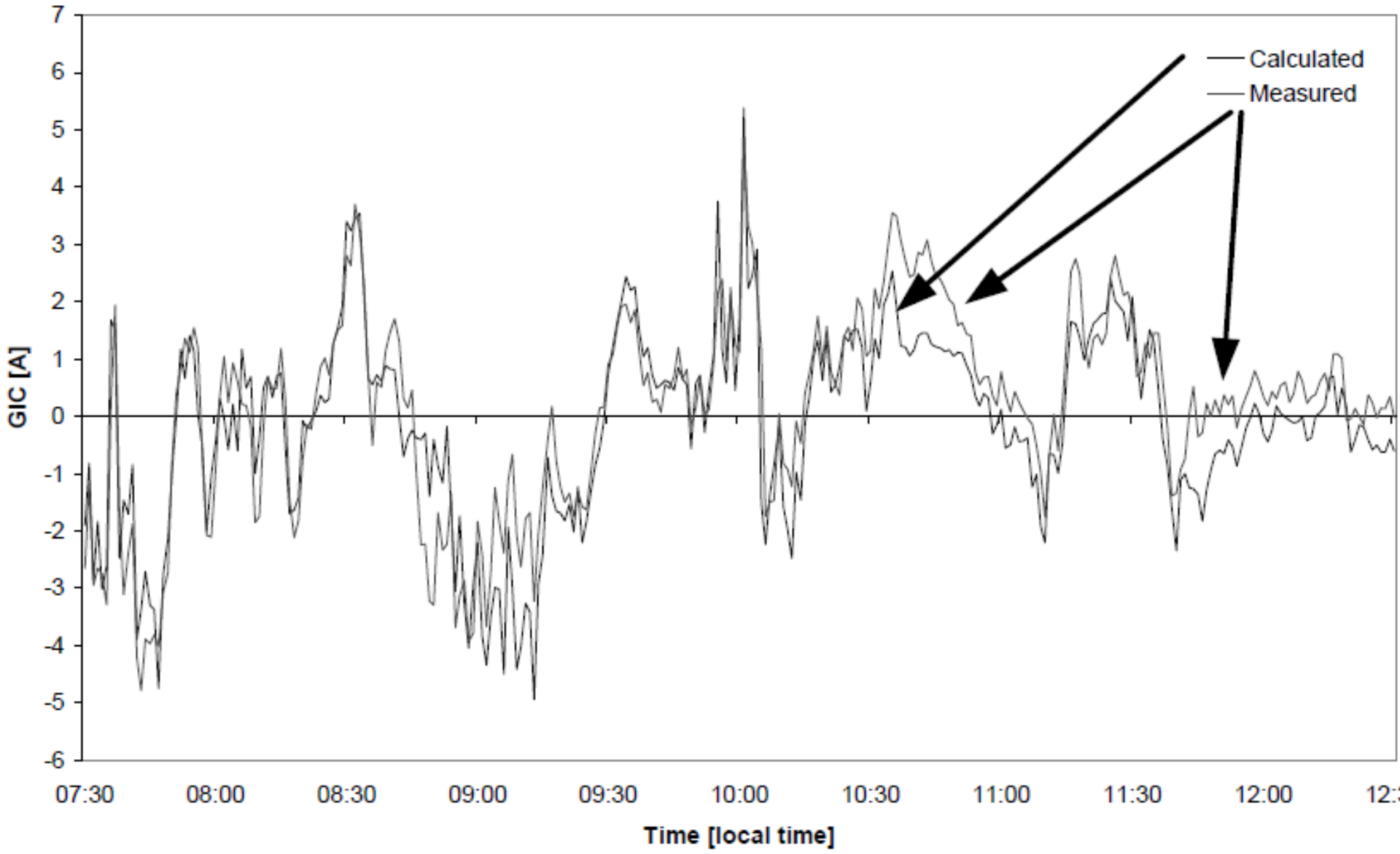


Planned power grid connection



Planned interstate power grid connection

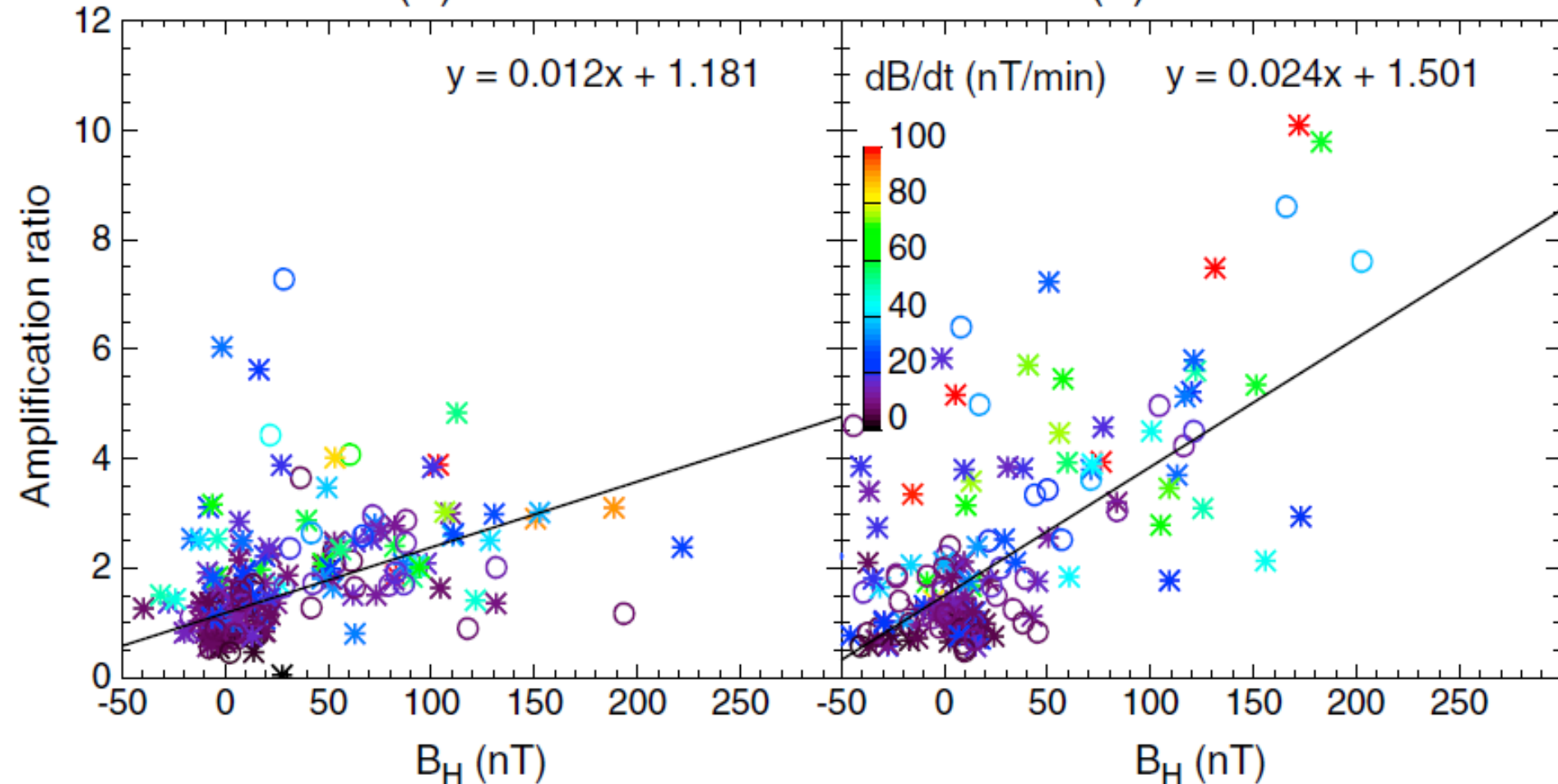




The correlation between EEJ and GIC amplification ratio!

(a) Africa

(b) America



$$B_H = B_{obs} - B_{main} - SYM_H = B_{EJ} + B_{SQ}$$