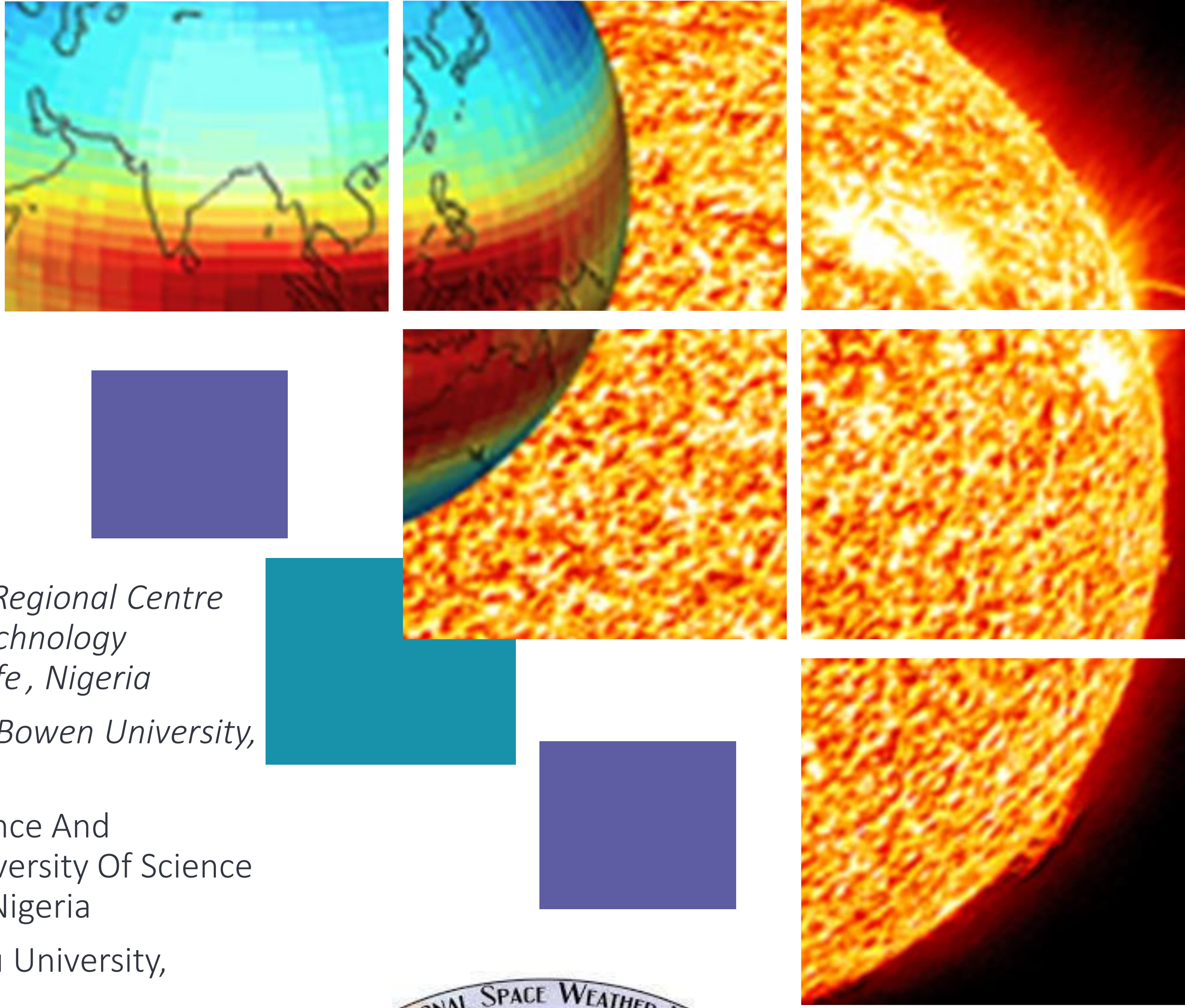
On the coupling between the equatorial electrojet & the solar quiet daily variation Sq current using ground observation.



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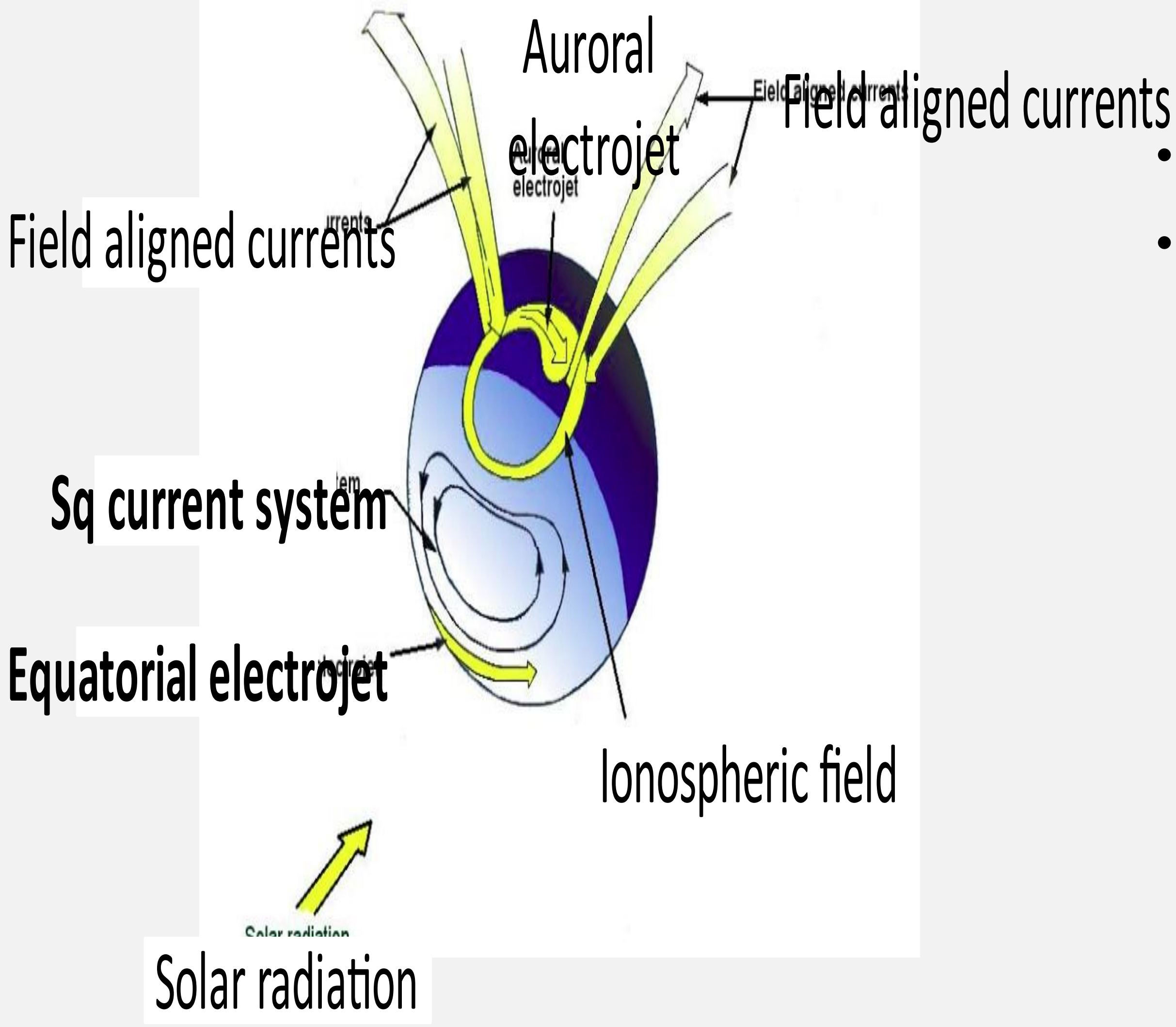
UN Workshop on ISWI, Vienna, 26-30 June 2023

The Ionospheric current system



- Solar quiet (Sq): Due to electric currents- at E layer
- Equatorial electrojet (EEJ): Due to local enhancement of ionospheric conductivity flows eastward around the dip equator at altitude centering at 106 ± 2 km.

WSq & EEJ

- The E (dynamo) region of the equatorial ionosphere consists of 2 layers of currents responsible for the quiet solar daily variations in Earth's magnetic field:
- Worldwide solar quiet daily variation, WSq (altitude 118 $\pm$ 7 km), responsible for the global quiet daily variation observed in the earth's magnetic field.
- Equatorial electrojet, EEJ - an intense current flowing eastward in the low latitude ionosphere within the narrow region, $\pm 3^{o}$, flanking the dip equator (altitude 106 $\pm$ 2 km) (Chapman, 1951, Onwumechili, 1992)
- Enhanced (Cowling) conductivity associated with the special equatorial magnetic field configuration results in the strong daytime EEJ currents

Equatorial Electrojet

- The equatorial electrojet (EEJ) flows as an enhanced eastward current in the daytime E region ionosphere between 100 and 120 km height at the Earth's magnetic equator.
- The flowing currents in the ionosphere induce magnetic perturbations on the ground.

Scientific Questions

Aim

The aim of this study is to investigate the coupling between EEJ and Sq currents of the ionosphere.

Objectives

1. Quantify the degree of complexity associated with EEJ and Sq
2. Determine the degree of coupling between EEJ and Sq currents
3. Estimate the spatial dependence of coupling between EEJ and Sq currents

Why coupling and nonlinear?

1. Identifying the existence and the degree of coupling between natural phenomena
2. Help in understanding & modelling their relationship
3. Overcome the shortcomings of the linear approaches
4. they have been shown to be more efficient, especially with noisy systems (Fuwape et al, 2016)
5. Does not consider the underlying probability distribution of the time series.

Experimental site and data

Stations inside the EEJ	Stations outside the EEJ
Huancayo	Trelew
Ilorin	Lagos
Addis Ababa	Nairobi
Langkawi	Hualien
Davao	
Yap	

- Sq: Estimated from the magnetic data of stations outside the electrojet (± 3°).
- Sq': Estimated from the magnetic data of stations within the electrojet.
- EEJ: Sq' - Sq

Data	Source
Sq	Magnetic data from Magnetometers
EEJ	Magnetic data from Magnetometers

Data:

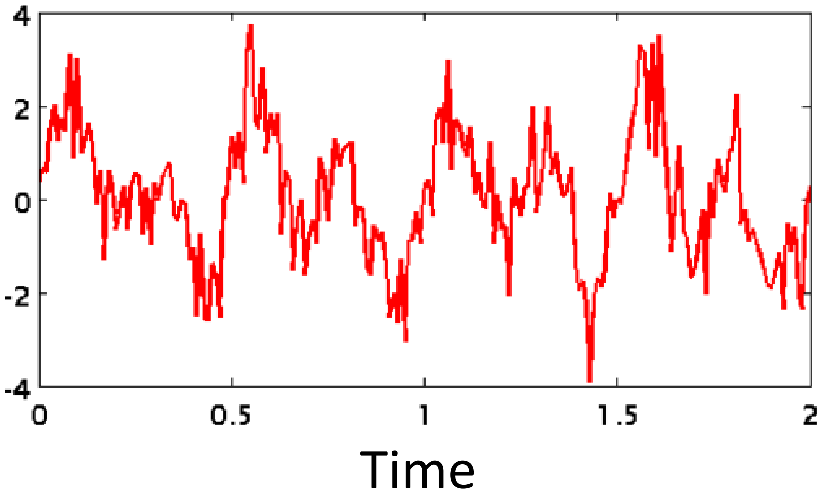
01 Jan

–

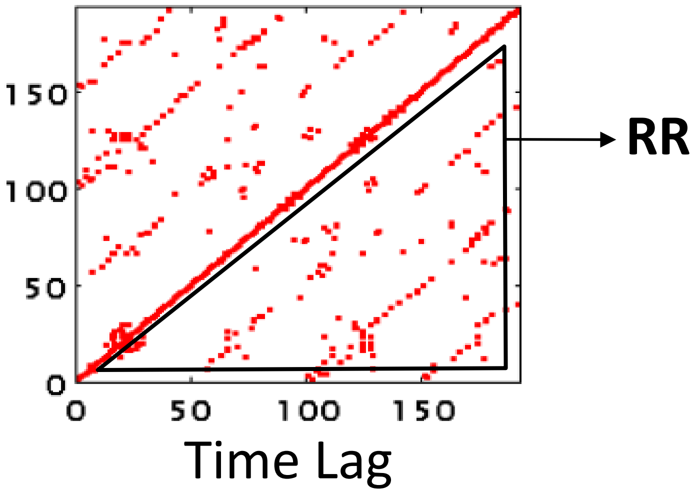
31 Dec 2009

Metrics Description *(Complexity Analysis)*

Time series of chaotic data **A**

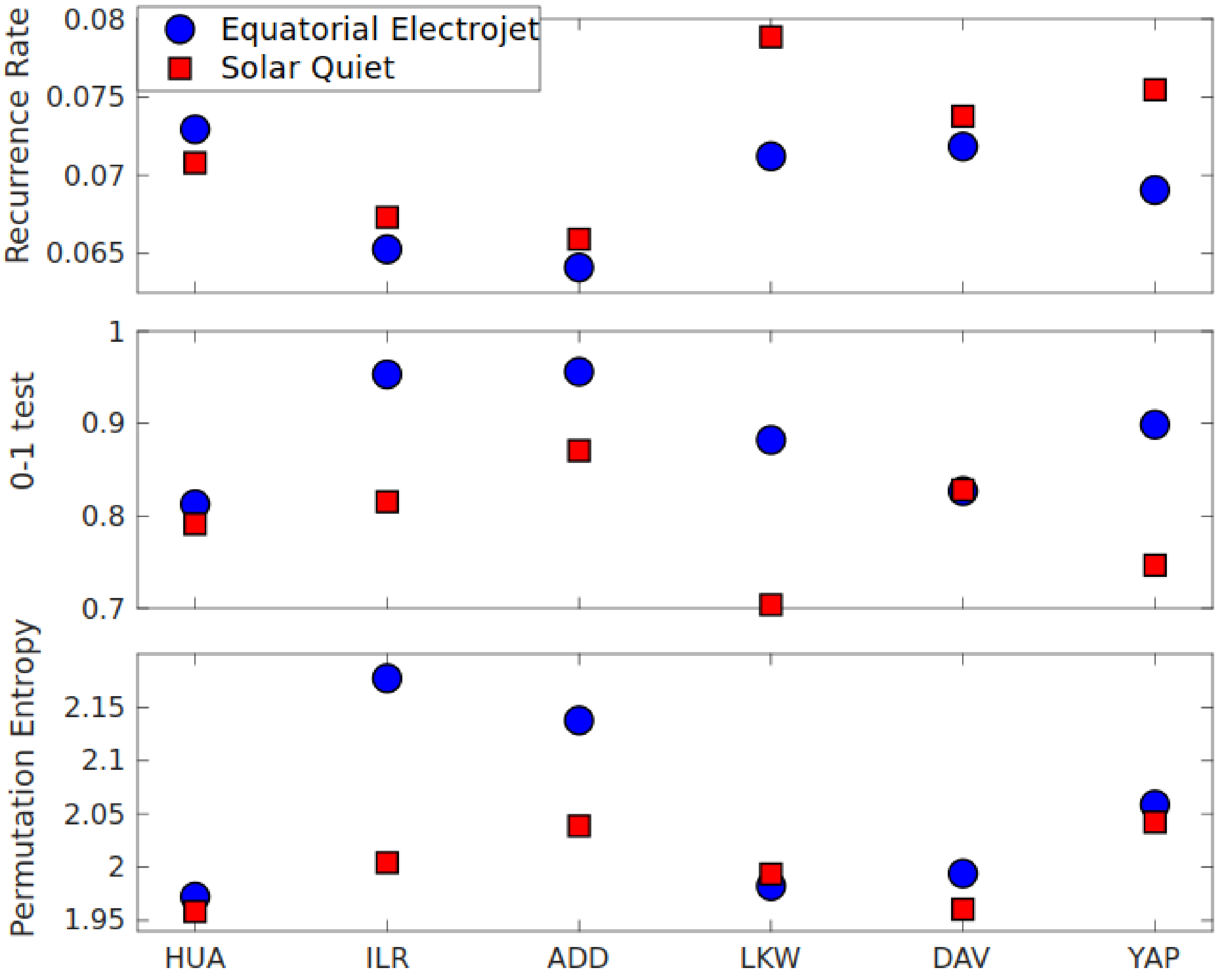


Recurrence plot of chaotic data **A**



- Recurrence Rate (RR): Measures the number of recurrence points.
- Permutation Entropy (PEE): Captures ordinal patterns in signals.
- 0-1 Test (TST): Distinguishes periodic and chaotic signals.

Variation of non-linear quantifiers across different stations



- On average, $EEJ_{chaos} > Sq_{chaos}$.
- Highest current complexity over Africa.
- $EEJ_{chaos} \approx Sq_{chaos}$ in HUA and DAV.

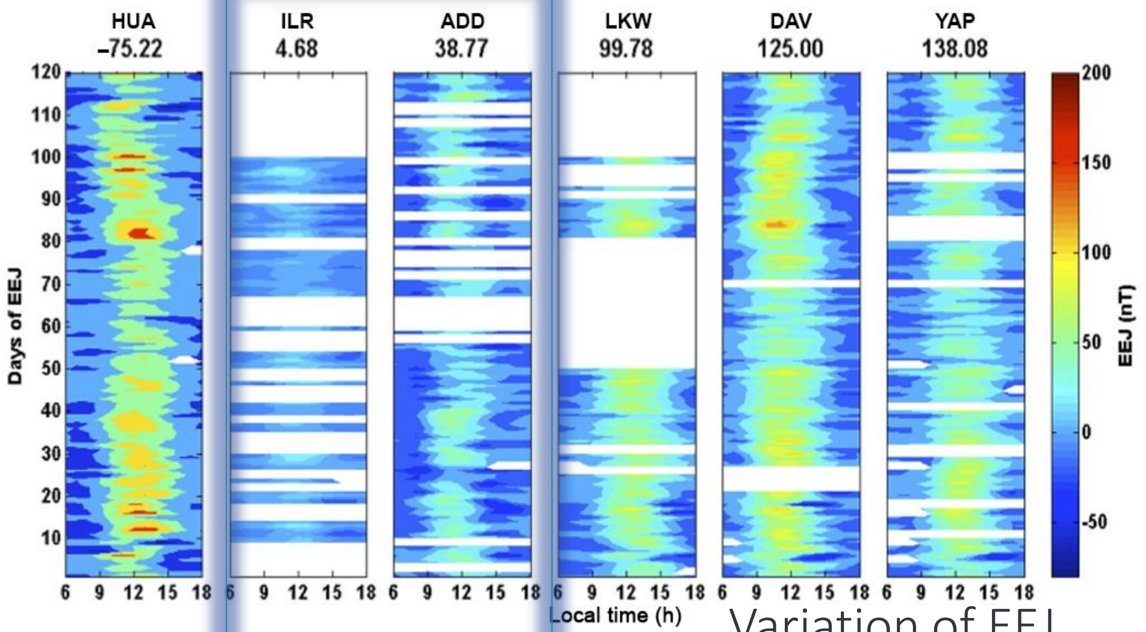
Key

RR = 0 (high chaoticity)

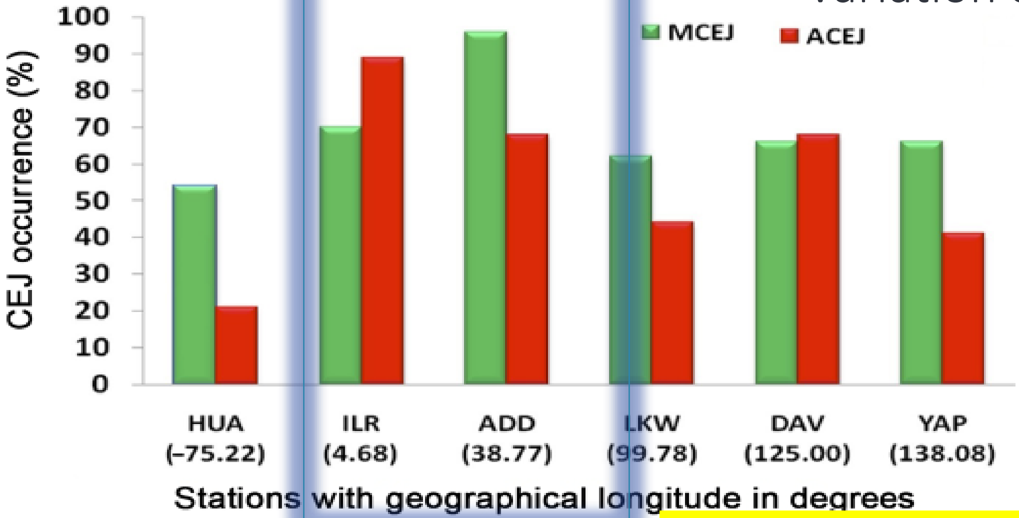
0-1 test = 0 (Low chaoticity)

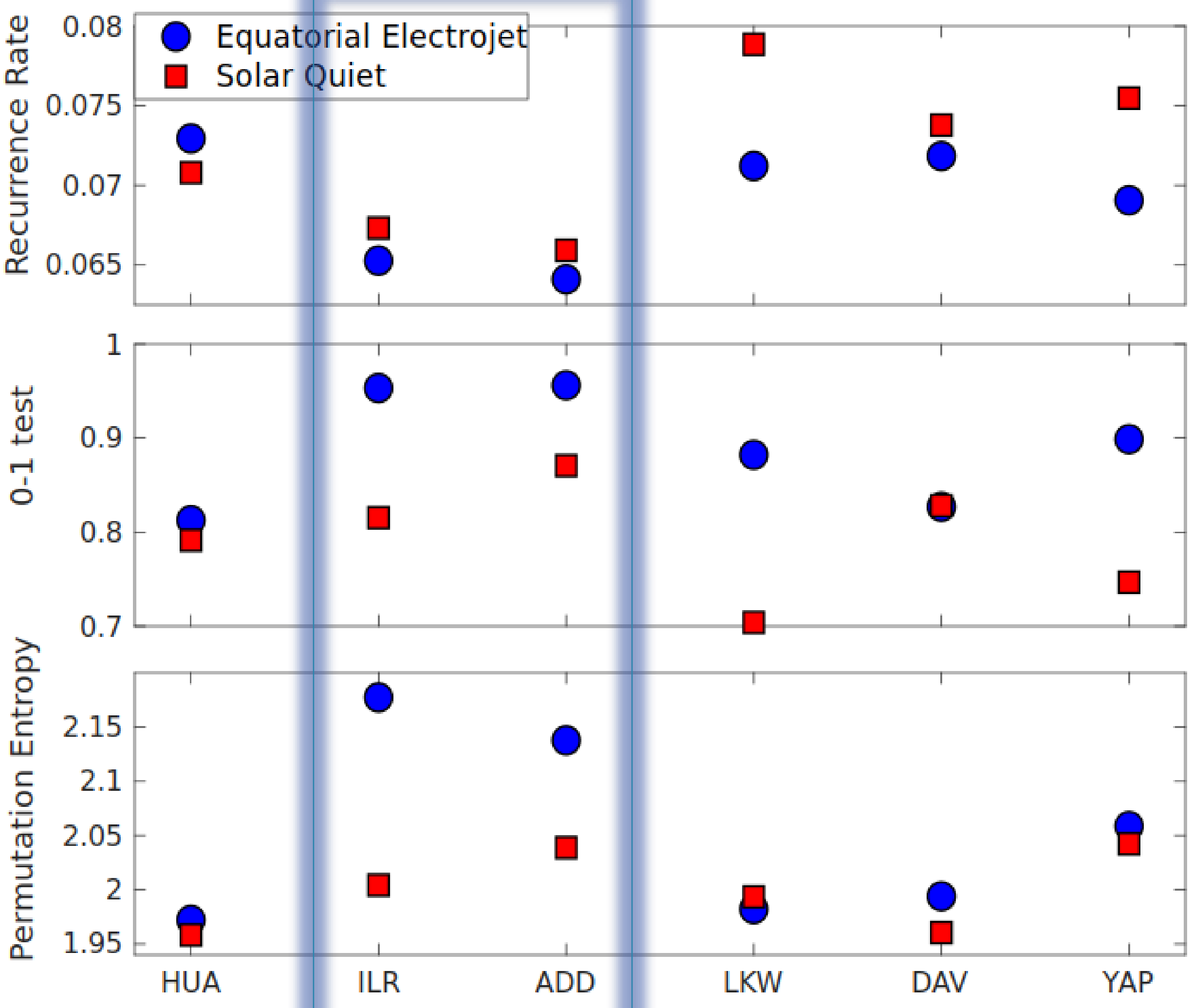
PEE = 0 (Low chaoticity)

Longitudinal variation of EEJ & its complexities



Variation of EEJ





Rabiu et al, 2016, 2017

Yearly % of occurrence of CEJ

Coupling analysis

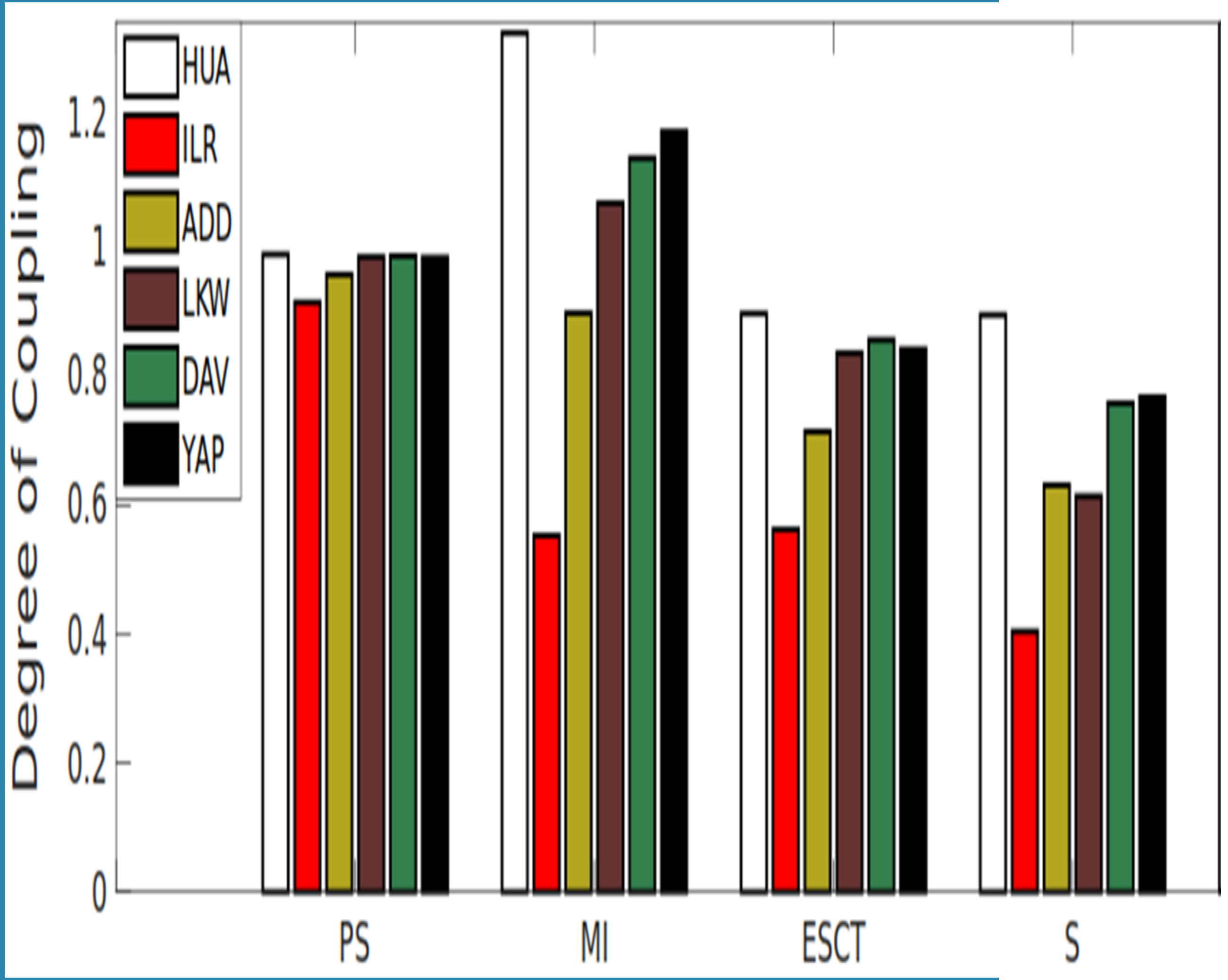
0 = Independent signals

Ensemble Symbolic Coupling Traces (ESCT)

Phase Synchronization (PS)

Mutual Information (MI)

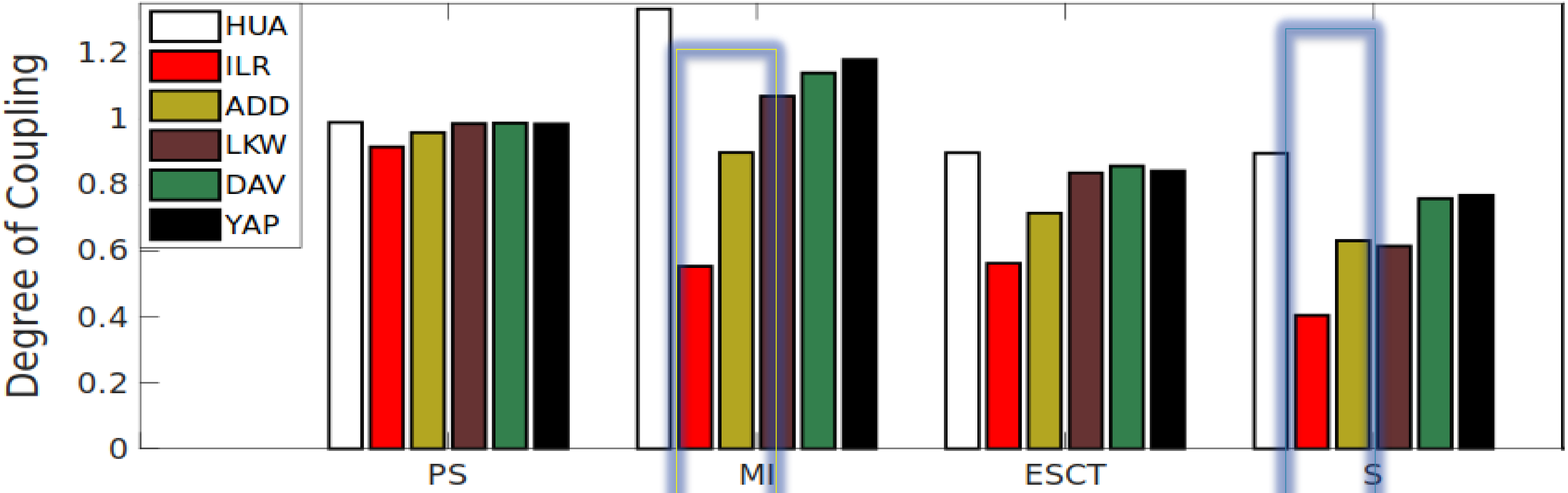
S-independence measure

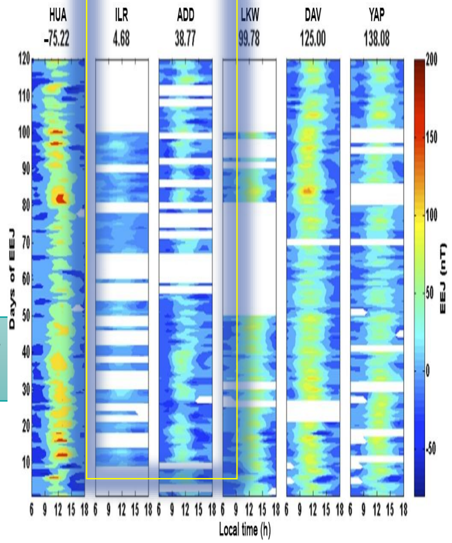


Evaluation of non-linear coupling of EEJ and Sq

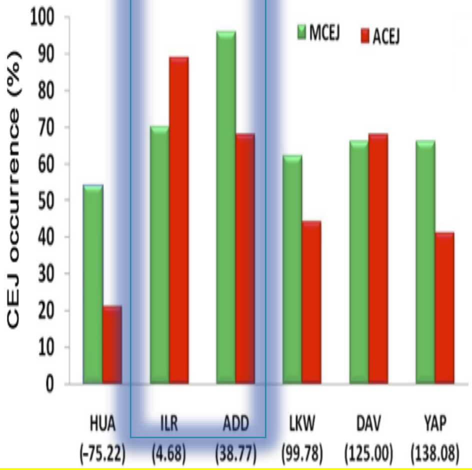
- All indices suggest strong coupling between EEJ and Sq in all locations.
- Strong and consistent varying with longitudinal sectors
- Strongest coupling in HUA
- Weakest coupling in ILR

Longitudinal variation the coupling





Rabiu et al, 2016, 2017



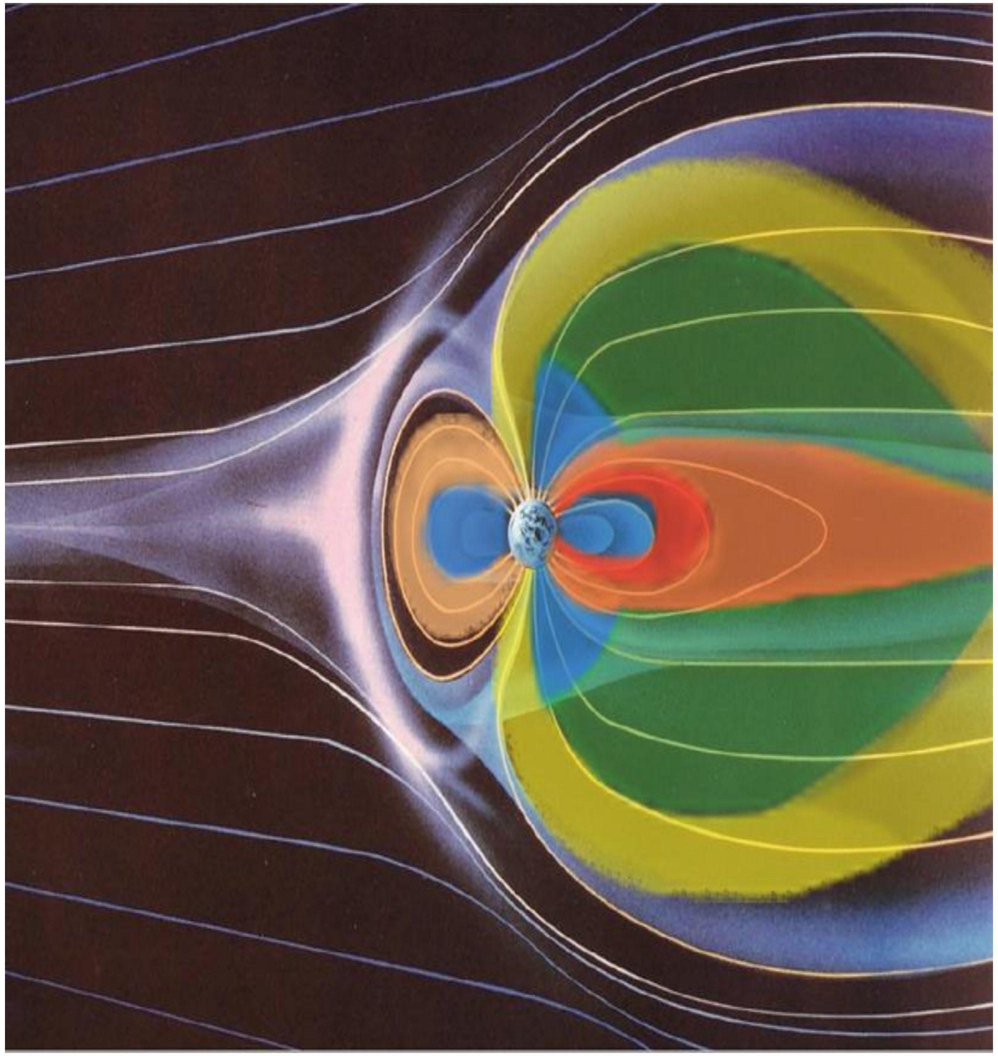
Yearly % of occurrence of CEJ

Indices	Geomagnetic Long.	Geographic Lat.
Phase synchronization	0.63	-0.37
Mutual Information	0.80	-0.57
S-Independence	0.72	-0.48
H-Independence	0.81	-0.62
ESCT	0.61	-0.33

Correlation between location coordinates and Coupling indices

- ❑ Significant correlation between coupling strength and geomagnetic longitude (0.61-0.81).
- ❑ An increase in geographical latitude corresponds to weaker coupling.

Conclusion



The EEJ is more complex and chaotic than the Sq current.

Highest EEJ current complexity over Africa

The strongest/weakest EEJ - Sq coupling occurred at HUA/ILR respectively

There is a strong geomagnetic longitudinal dependence in the EEJ-Sq coupling

The coupling becomes weaker as one moves away from the dip equator

Expected contributions

Theoretical scientists can integrate the results of this study into numerical models for better and efficient predictions of EEJ and Sq currents.

Results from this research will give further insight into the intrinsic coupling between EEJ and Sq current that has not been revealed by available models

ARCSSTE-E

Thank you