On the dependency between geodetic parameters

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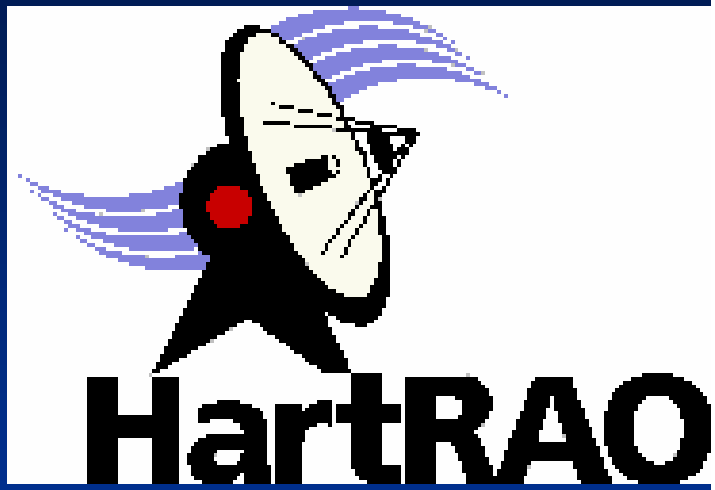

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Objective

- To investigate global correlations between UT, polar motion, site position & tropospheric delay determined from geodetic instruments at HartRAO between 1990 to 2006

Introduction

- Geodetic parameters (site position, UT1, polar motion, LOD, and tropo/iono- delay) are proxies variables: signatures of the physical conditions of a coupled system (Earth-Space).
- If the proxies are driven by causal processes:-

1. the proxies' Time Series (TS) evolve in a similar way AND/OR
2. there is recurrence (Memory) or SS/LRD in the T-S. Here, we use RP (Marwan et al, 2007) to visualize the patterns in the variables

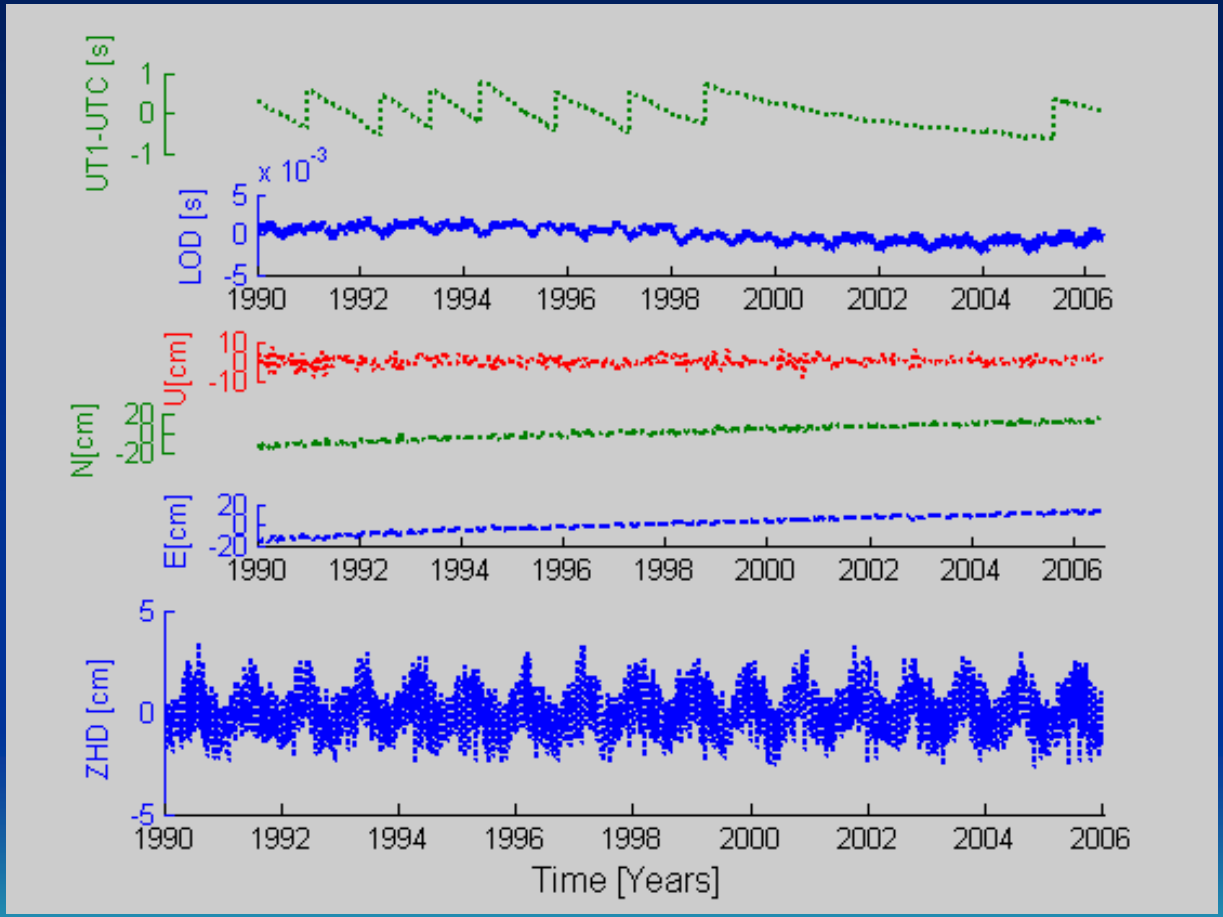
- The TS exhibit temporal variations driven by forces that are non-stationary (Verdes et al, 2001), yet any correlation analysis reported in literature (currently) accounts only for measures of linear correlation.
- In order to capture any links between the geodetic parameters, a global correlation index (measures both the linear & non-linear correlation) is required.

Estimation

- Concept of collocation [VLBI, GPS, SLR, DORIS, & possibly-LLR], see instruments at HartRAO
- Delay observable:- Model errors in the data, use geophysical models (loading [atmosphere, ocean etc], earth tides
- External correction (for troposphere & ionosphere)
- Use least squares & Kalman filter as estimators

Information in the time series !

- Is it a signal or noise?
- How do we attribute & detect noise & signal from a time series ?
- Linear or structured ?
- Stationary or non-stationary ?



Information in the time series !

- If linear/structured, & non-/stationary), then what?
- Choose method of dependency (correlation) analysis, (see for example in Dionisio et al, (2004) and Darbellay, G. A., 1999)
- Criteria:

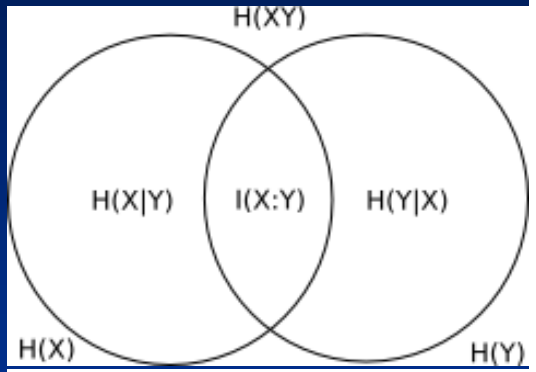
  a) correlation in the wavelet space – test for structure in the TS using wavelet coefficient.

  b) scaling factors of wavelet power spectra - test for non-stationarity

  c) structure functions – characterise the dominant stochastic processes & access de-correlation time (e.g temporal structure functions)

Information in the time series !

- Geodetic parameters measure properties of a coupled system (Earth -Space), therefore any changes on the physical conditions in one system propagates into the other….
- Require a global correlation coefficient (λ)
- Use Mutual information (MI)/the entropy- I, between the geodetic parameters
- No need for specifying any physical models a priori and probability distributions
- Can compare λ with linear correlation anyway!
- We can now use λ to determine dependency in the time series



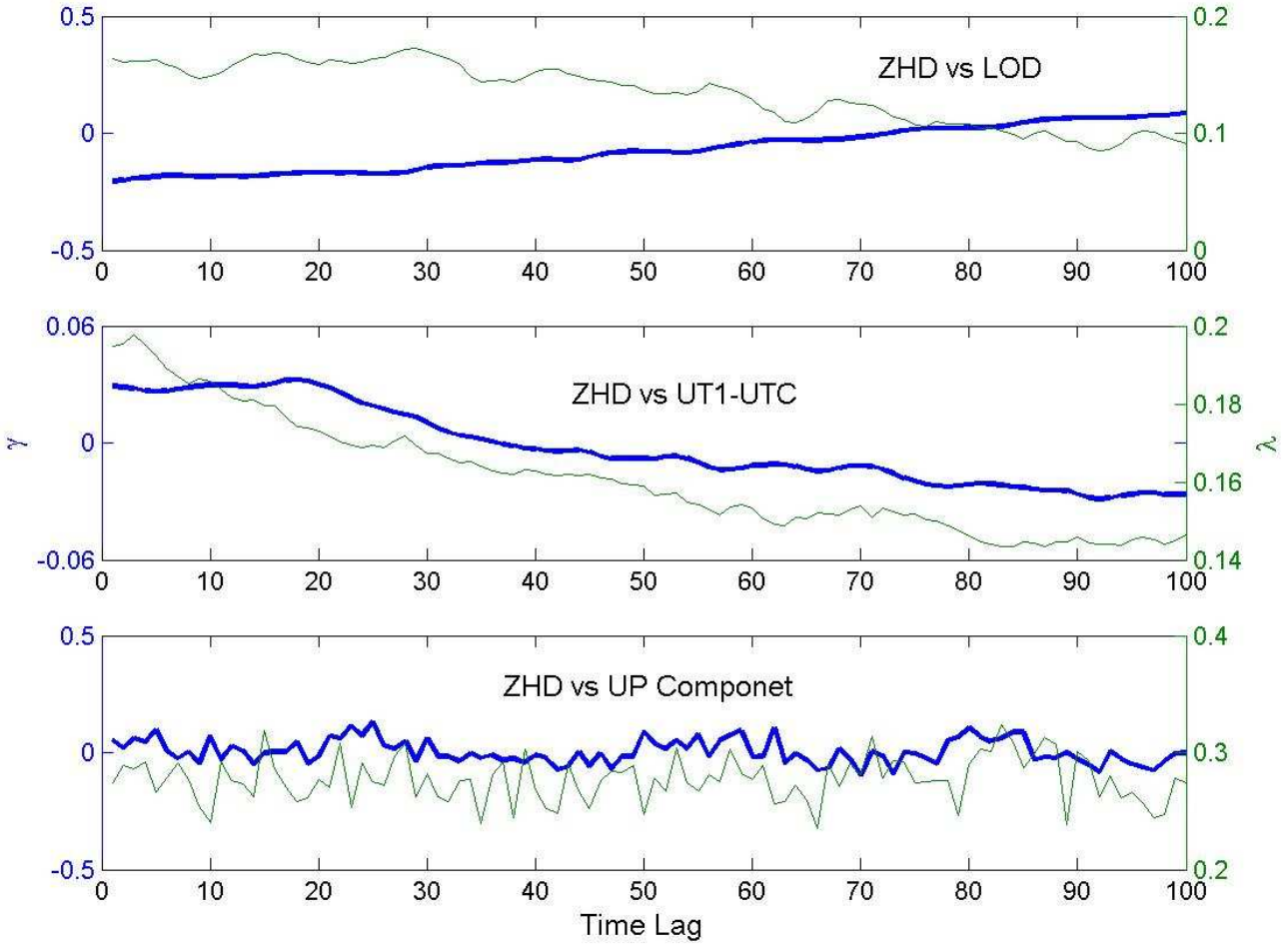
$$H_i^x \approx -\sum_i^m P_i^x \log_2 P_i^x$$

$$H(x,y) = \sum_i \sum_j P_{ij}^{xy}$$

$$\bar{I}(x,y) = \sum_{ij} P_{x,y}(x_i, y_j) \log_2 \left[\frac{P_{x,y}(x_i, y_j)}{P_x(s_i) P_y(q_j)} \right]$$

$$\lambda(x,y) = \sqrt{1 - e^{-2I(x,y)}}$$

Example: UT1-UTC, LOD, ZHD & UP component

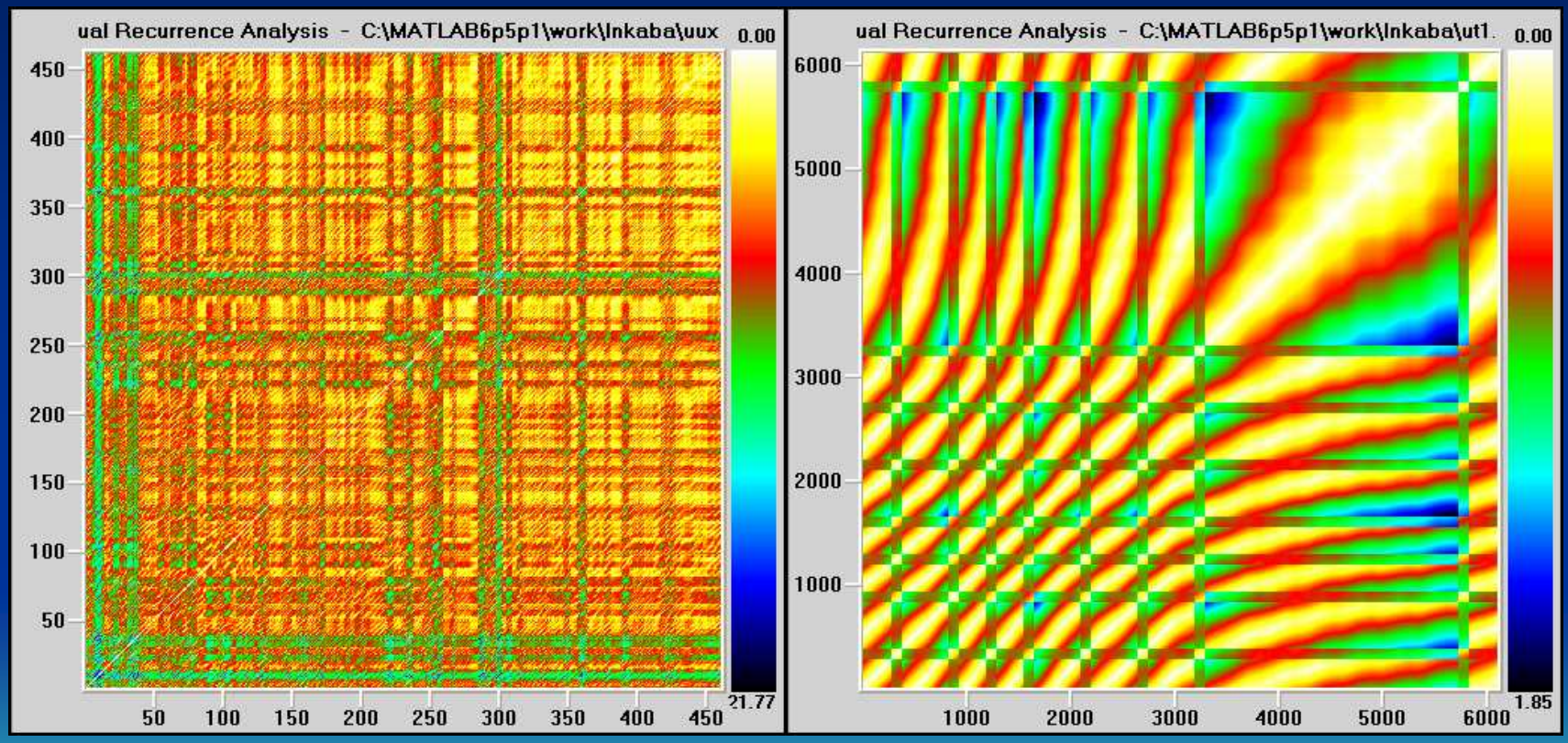


A λ measures the global correlation in the TS and accounts for both linear and nonlinear dependencies

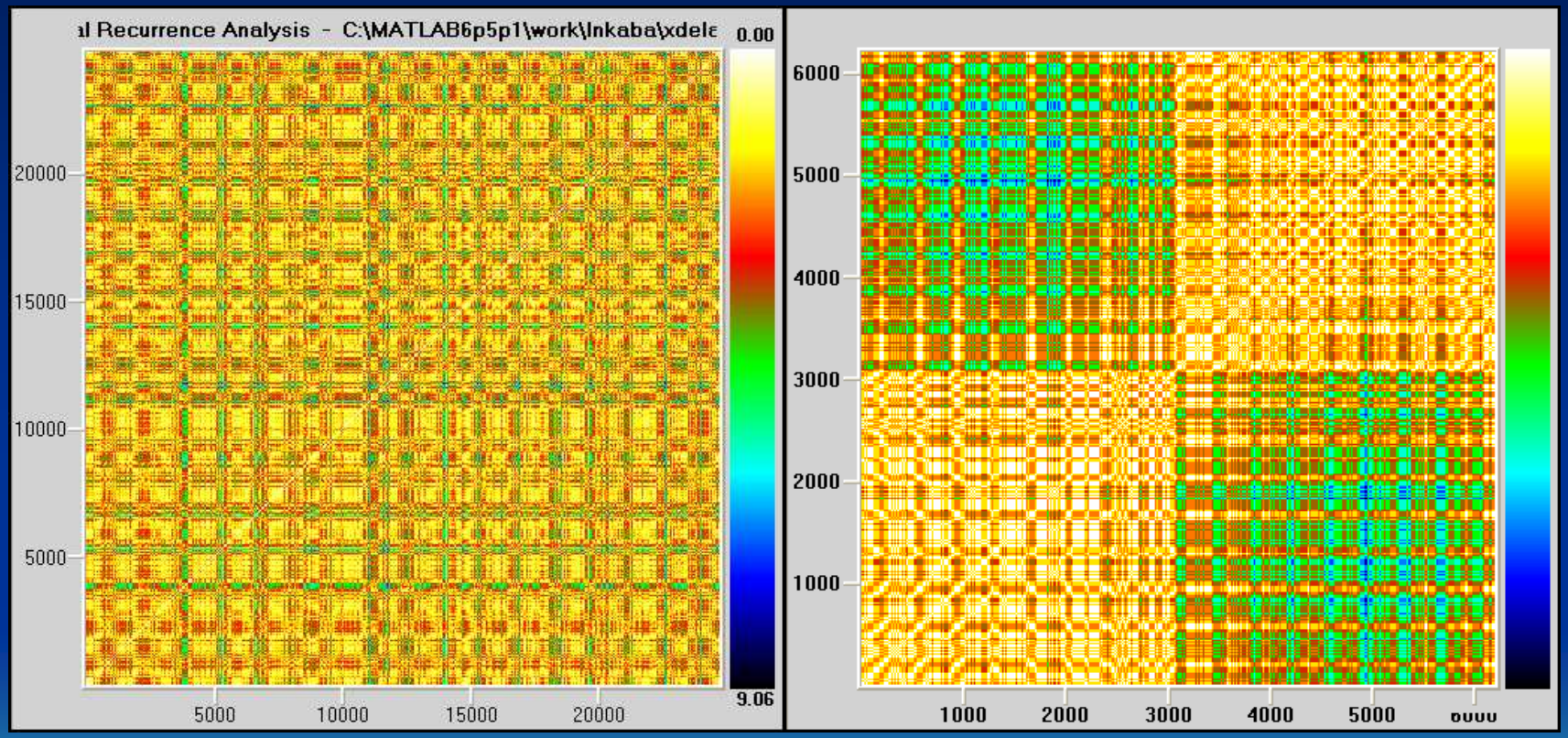
Visualizing correlation: RP

- If the geodetic variables are driven by same forces, then they have memory!
- Use Recurrence Plots (Marwan et al, 2007) to see the patterns in the TS as it evolves in the phase space…
- Over time, the variables have Long Range Dependence (LRD) or are they Self-Similar (SS)?
- See Abry et al (1987) for further details

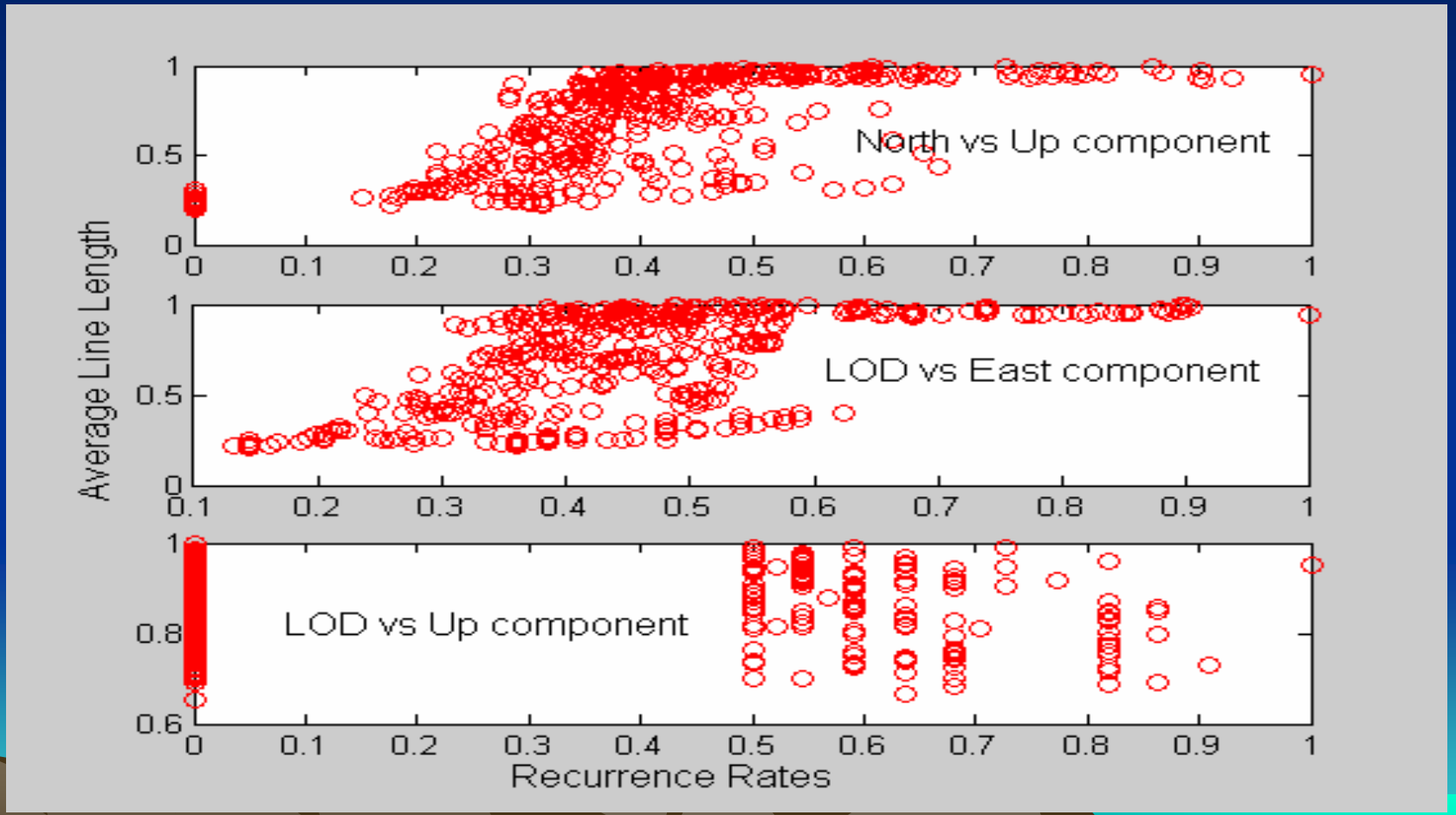
Geodetic variables show a drift from the diagonal: Indicates that they are driven by non-stationary systems



The geodetic variables have periodic or quasi-periodic recurrence structures



On the CRP: RR (probability of recurrence of similar states in the systems over a time delay) & L (measures the duration of similarity in the dynamics of the system) signify link between the geodetic parameters. LOD and site position correlation at a time lag of ~ 4 months



Conclusion

- Linear correlation measures of geodetic variables could be under/over estimating the links between system earth !
- The variables are proxies of processes that are non-stationary and therefore correlation measures should capture both linear and nonlinear dependencies.
- CRP analyses of

Acknowledgement

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References

- Abry P., and Veitch D. 2007, Wavelet Analysis of Long Range Dependence Traffic. *IEEE trans. on Infor. Theory*, (Dec. 1987)
- Marwan, N., Romano, M. C., Thiel, M. and Kurths, J. 2006, Recurrence plots for the analysis of complex systems, *Physics Reports*, **438** (2007), 237-329
- Darbellay, G. A. 1999, An Estimator for Mutual Information based on criterion for Independence, *Computational statistics and data analysis*, **32**, 1-17
- Verdes, P. F., Granitto, P. M., Navone, H. D. and Ceccatto, H. A. 2001, Nonstationary Time-Series Analysis: Accurate Reconstruction of Driving Forces, *Physical Rev. Lett.* **87**, 12