Non-linear analysis methods applied to observational and simulated climatic time series

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Aim of our work

The results of a simulated CO_2 (C) and a global ice volume (V) time series, derived from a simple relaxation model of the glacial-interglacial cycles (*García-Olivares and Herrero, 2013)* have been analyzed using non-linear techniques to quantify the performance of a model at reproducing the dynamics embedded in observational time series.

Model

The 3τ model predicts the change of three dimensionless variables: global ice volume, V , atmospheric CO_2 concentration, C, and the extent of Antarctic ice sheet, A.

$$\frac{dV}{dt} = \frac{(V_r - V)}{\tau_V}$$

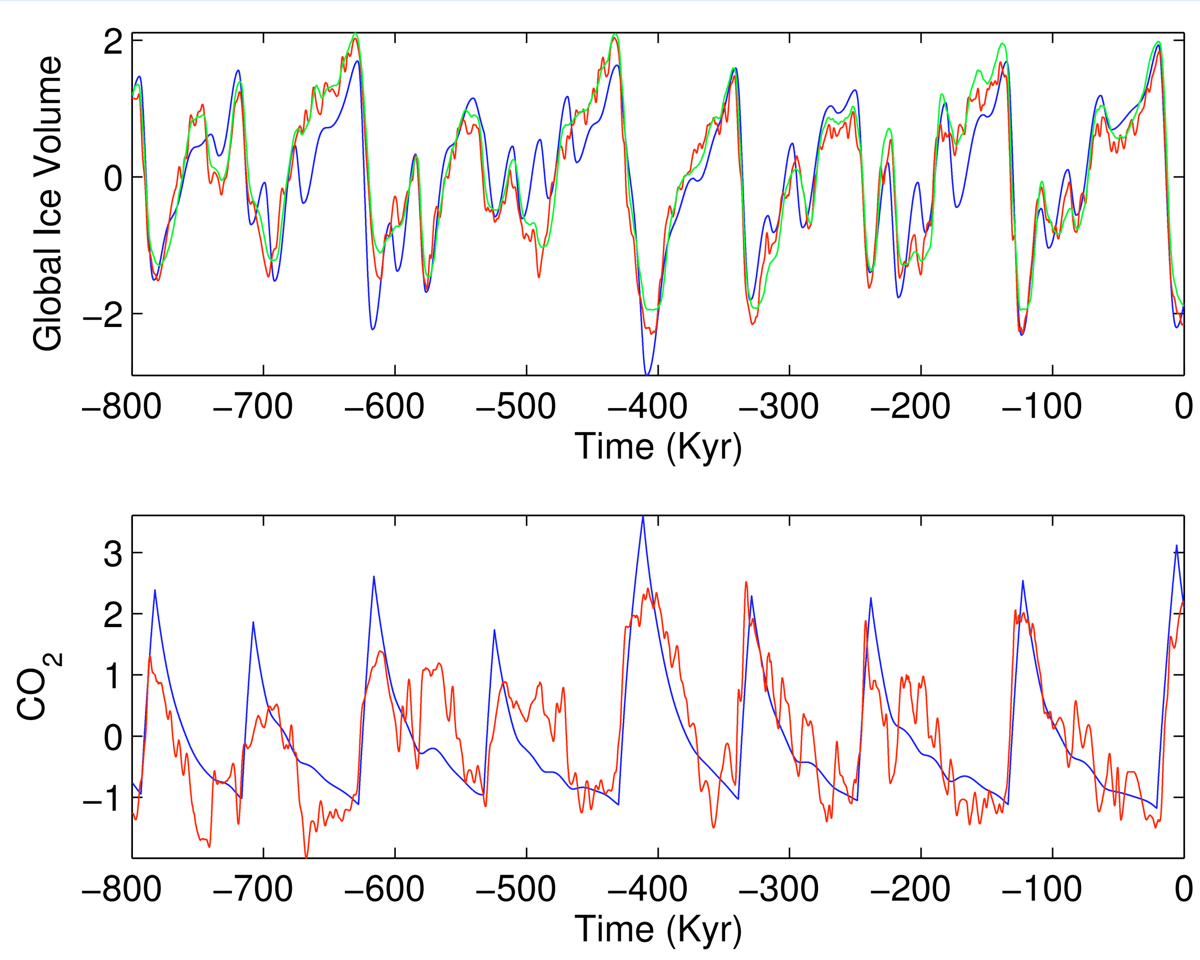
$$\frac{dA}{dt} = \frac{(V - A)}{\tau_A}$$

$$\frac{dC}{dt} = \frac{(C_r - C)}{\tau_C}$$

$$V_r = -xC - yI_{65} + z$$

$$C_r = -\beta V + \gamma H(-F) + \delta$$

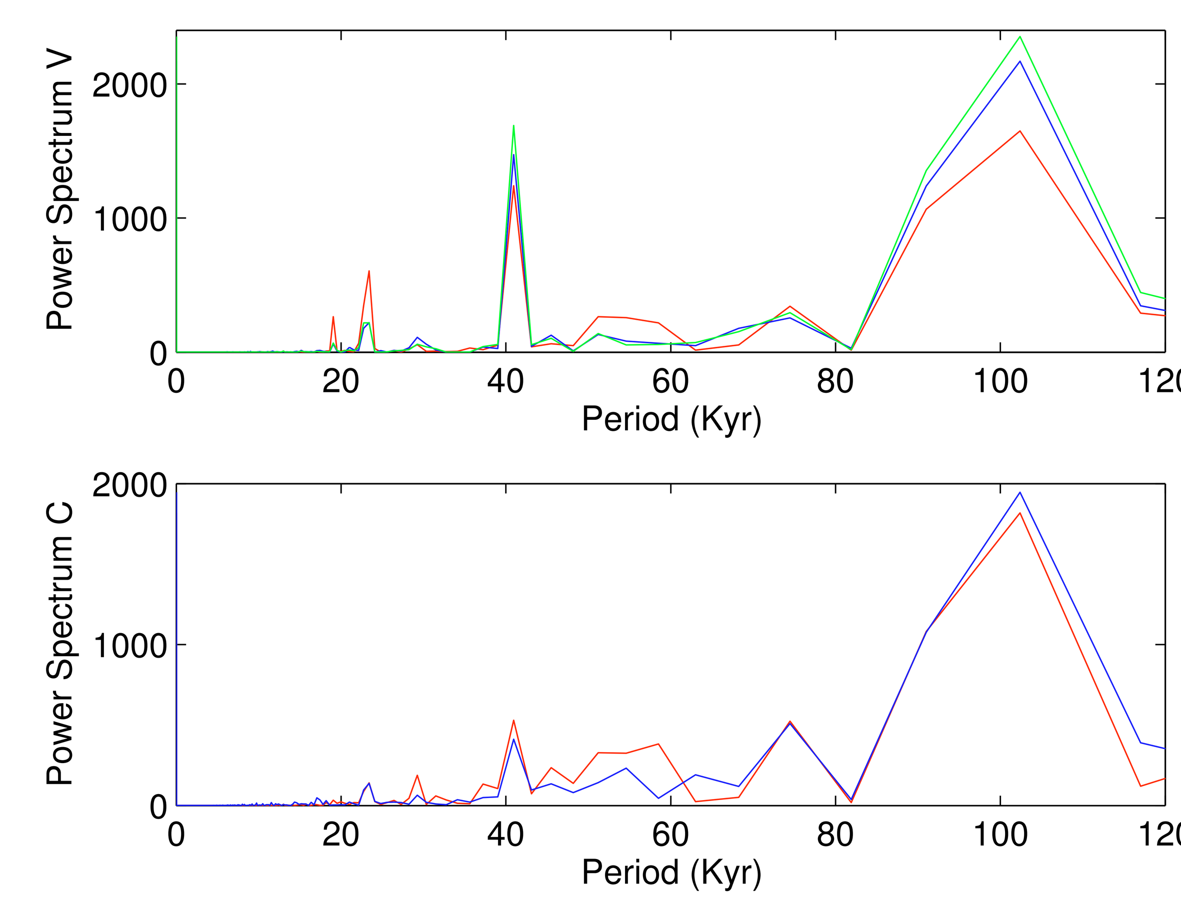
$$F = aV - bA + d$$



Parameter	3τ
τ_V	16585
τ_{V2}	3105.5
τ_C	13505
τ_A	9004
x	0.905
y	0.489
z	0.946
β	0.336
γ	2.044
δ	0.228
a	0.54
b	1.205
d	0.483
R_V	0.88 /0.90
R_C	0.79

1_ Fourier Transform

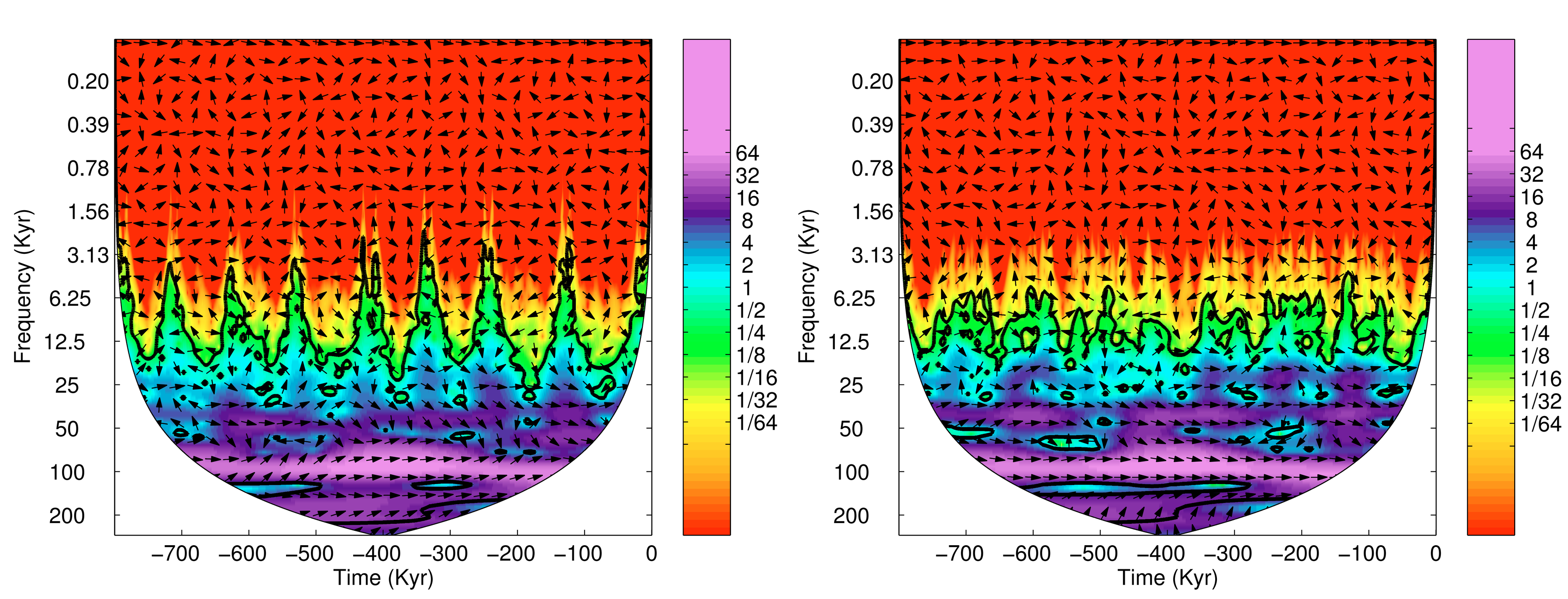
Useful to asses the principal components of a time series. Frequency content is comparable in all cases.



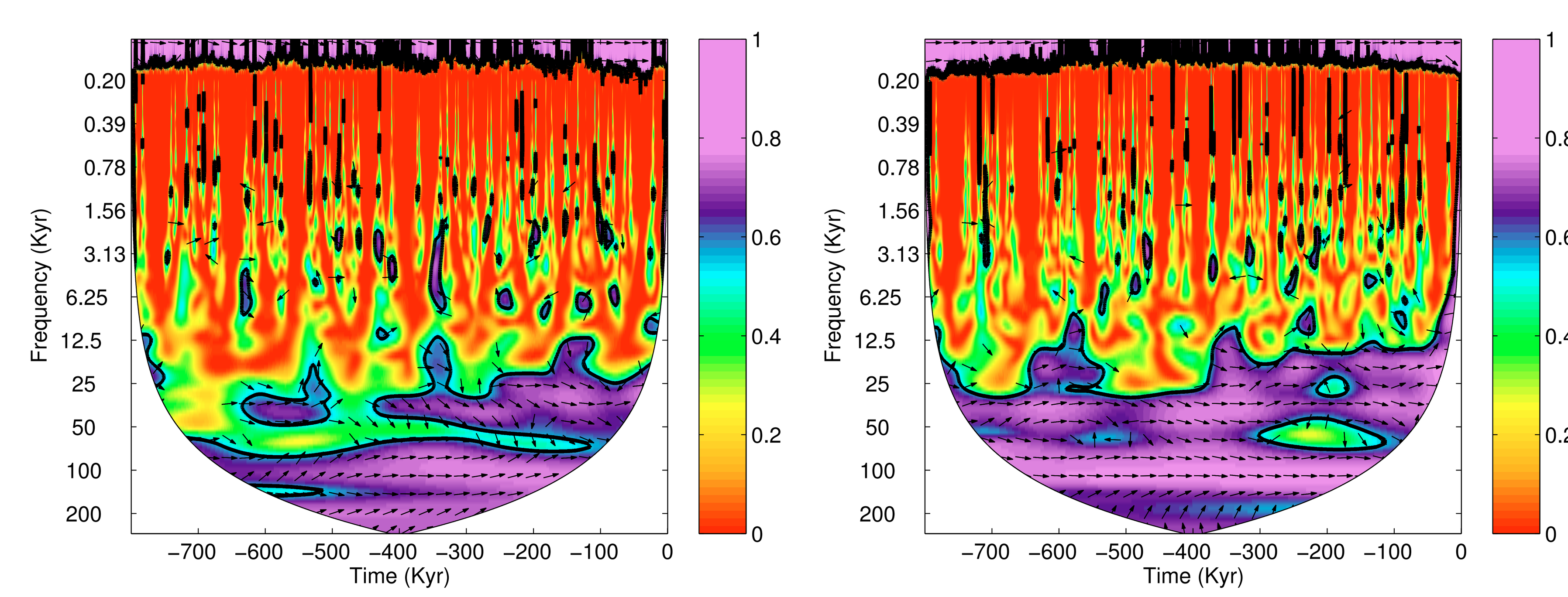
2_ Wavelet Transform

The **complex cross-wavelet transform** of two time series can be interpreted as the shared power in a given periodicity band (absolute value) and the local relative phase between the two series in time frequency space

Wavelet coherence of two series can be interpreted as a localized correlation coeficient in time frequency space.This tool is useful to find locally phase-locked behavior, that is, moments in which both series oscillate with the same frequency and a given phase difference



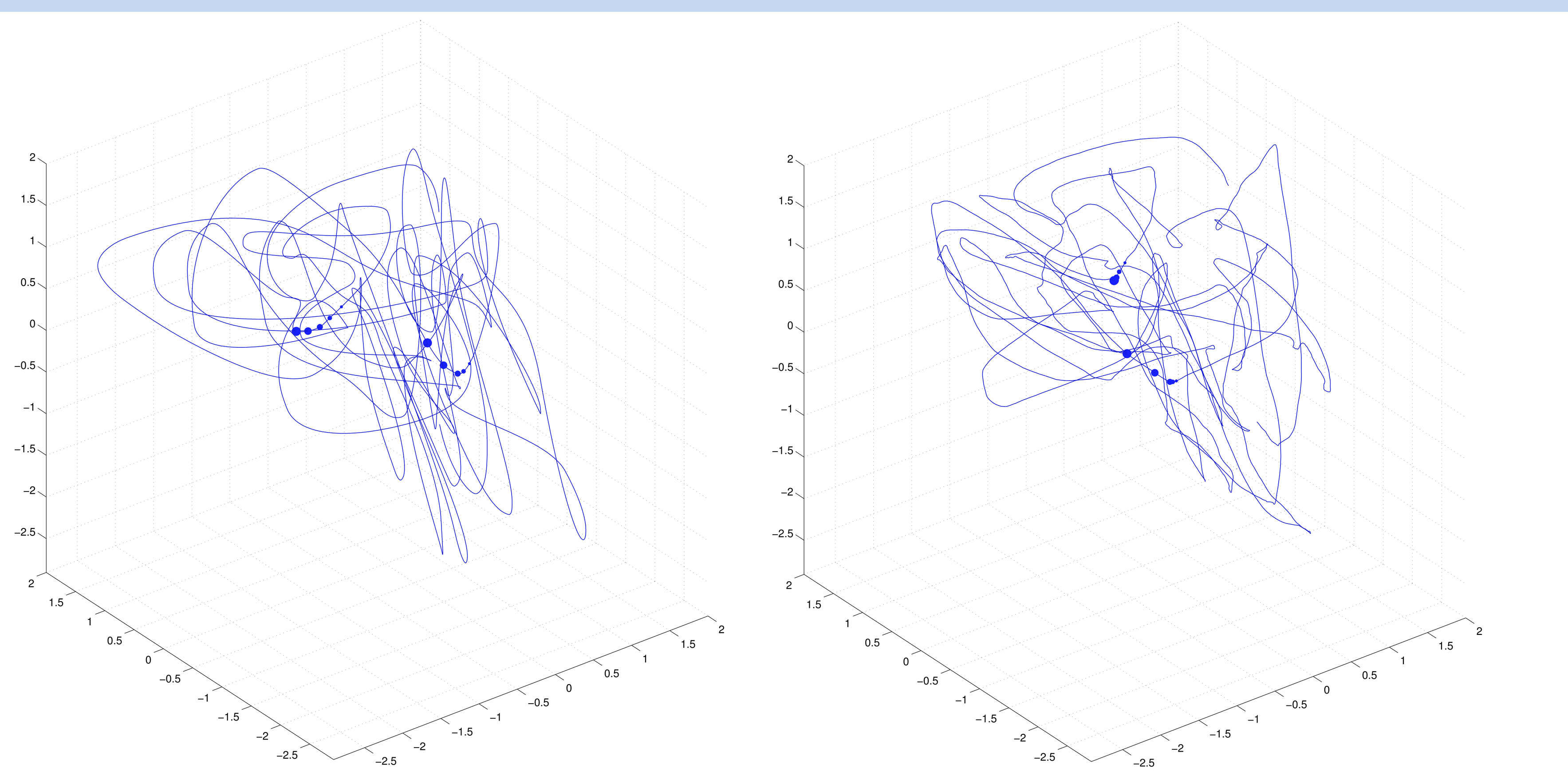
Complex Cross-Wavelet: C vs CO_2 (left) V vs Bintanja (right)



Wavelet coherence of C and CO_2 (left); V and Bintanja (right)

3_Phase Space Portraits

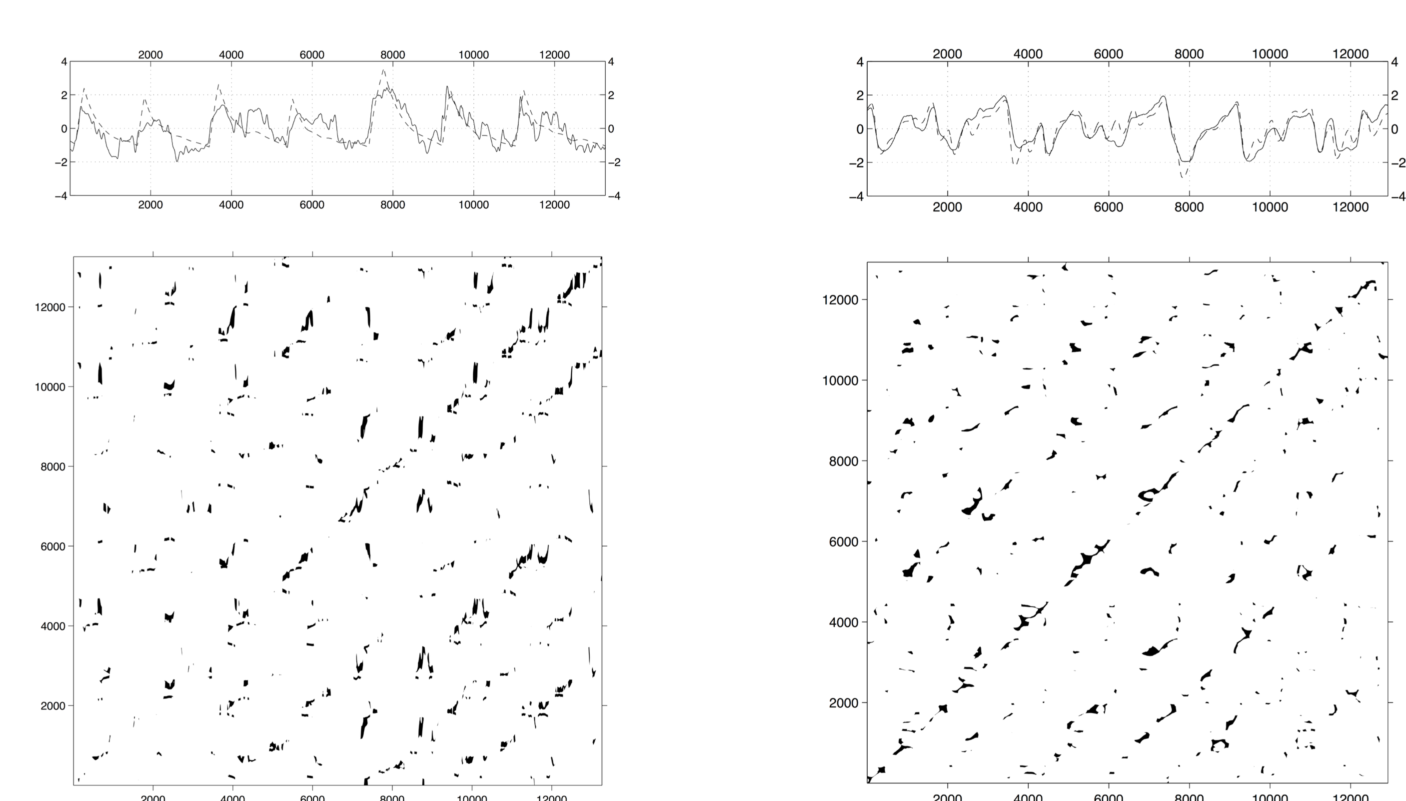
Useful for quantifying the performance of a simulated time series in matching the dynamical properties of an observational time series



Phase Space of V (left) and Bintanja Sea Level (right)

4_ Cross Recurrence Plots

Reveals the times when the phase space trajectory of the first system visits roughly the same area in the phase space where the phase space trajectory of the second system is. Confluence of states



CRP of C and smoothed CO_2 (left) and V and Bintanja SL (right)

Results

The analysis reinforces the hypothesis that some specific mechanisms included in the model are able to closely reproduce the glacial-interglacial oscillations and thus suggests which specific mechanisms should be more seriously investigated in the climate system. These techniques may be applied to other climatic time series to quantify the performance of a model simulating the dynamics of the climate system.

References

García-Olivares, A. and Herrero, C.: *Simulation of glacial-interglacial cycles by simple relaxation models: consistency with observational results. Climate Dynamics 41(5- 6) (2013) 1307–1331*

Acknowledgments

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