Evaluation of GIMs of TEC as indicators of ionospheric variability at low latitudes

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# INTRODUCTION

The **EQUATORIAL IONOSPHERE OVER AFRICA** (**IONAF**) Pilot Study (Alcantara) has been carried out by **ICTP** in collaboration with **Nigerian scientists.**

The objective was to characterize the ionospheric electron density distribution and variability in the EIA over the African region, using TEC from GIM and available GNSS stations and other available ionospheric data.
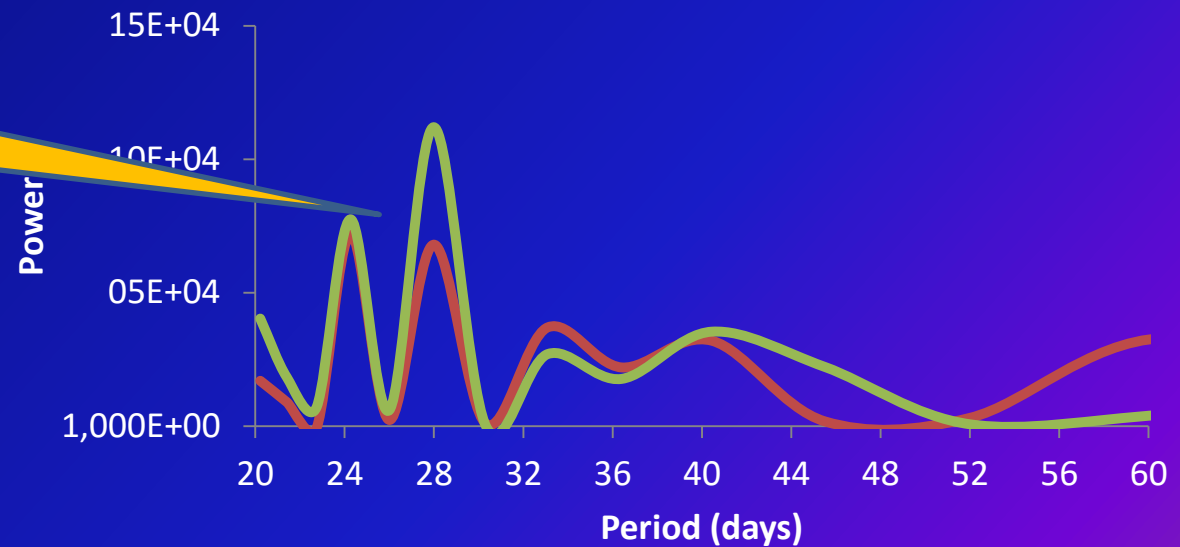
Lack of data in Africa.

PERIODOGRAM 2010
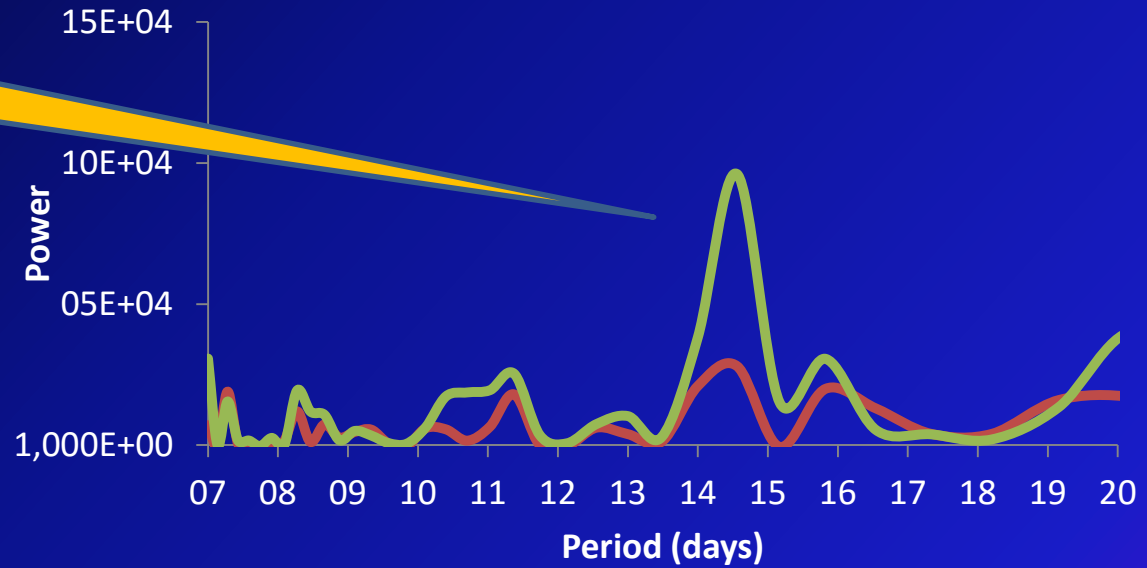
The main period of **14.5** days observed in the station data corresponds to the one of the map data.

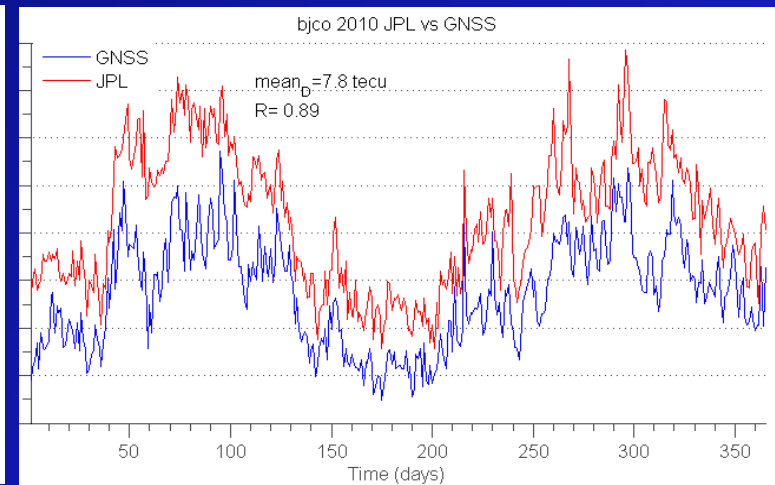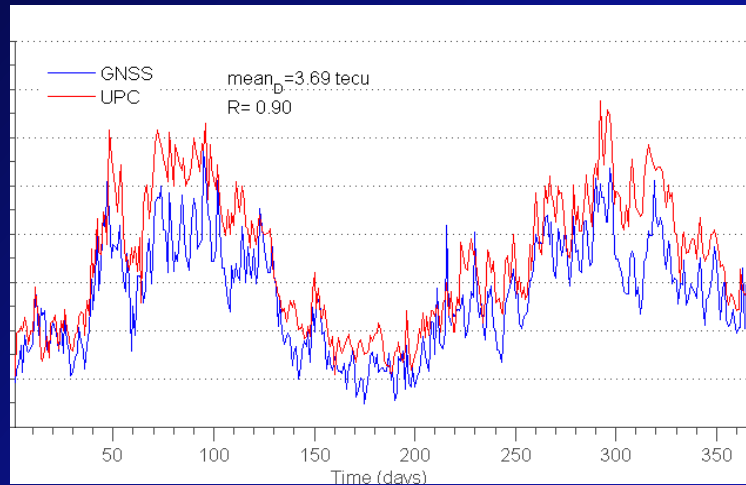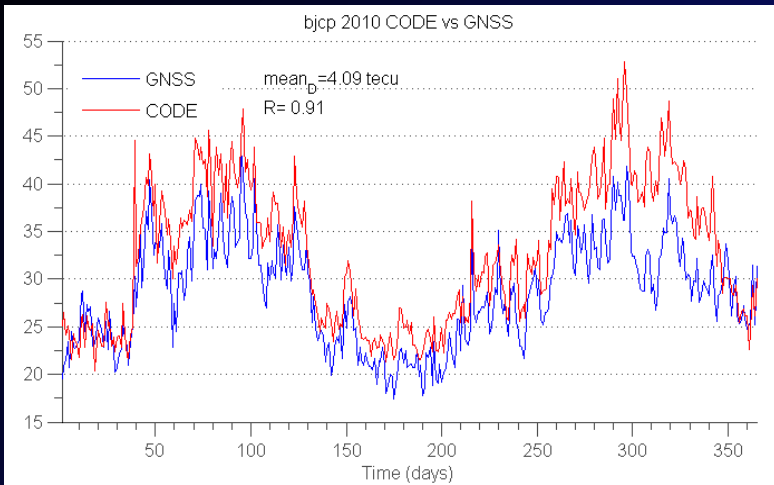The main periods at **28** and **24** days observed in the station data correspond to those of the map data.

PERIODOGRAM 2010

Motivation

How well correlated are GIM *with* individual GNSS stations *TEC data?*
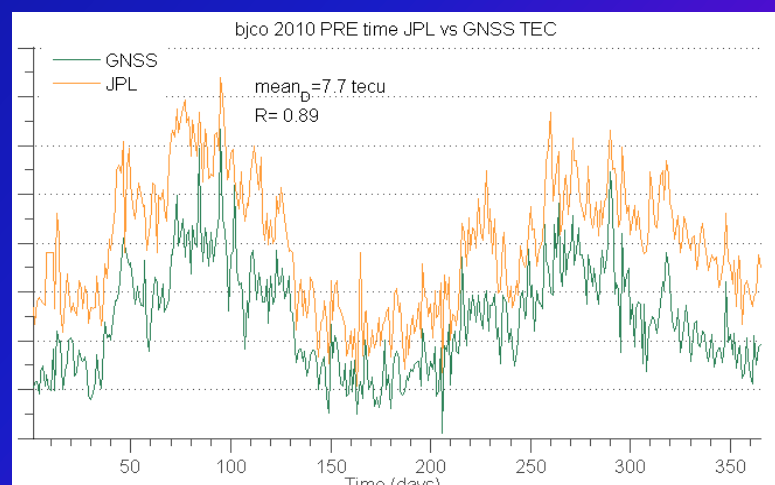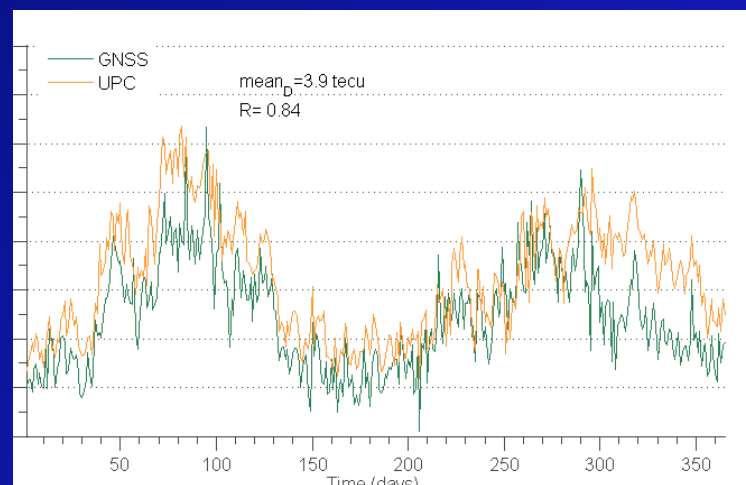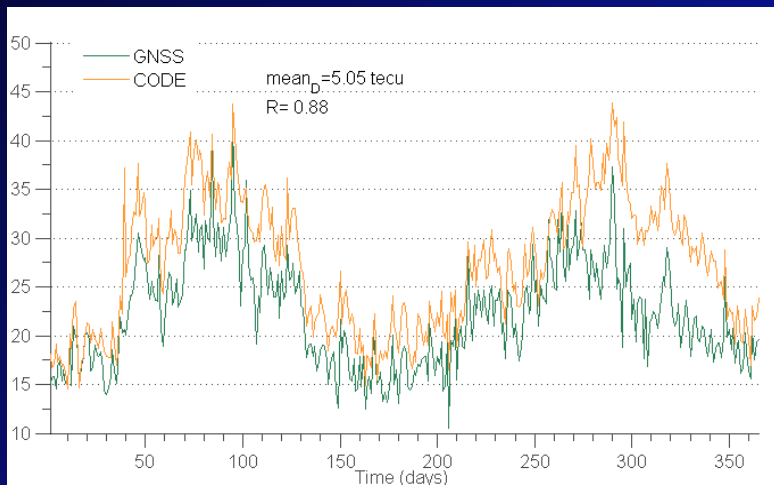
The validity of using TEC global maps from different Analysis Centers to study the regional day-to-day variability of the ionosphere was investigated.

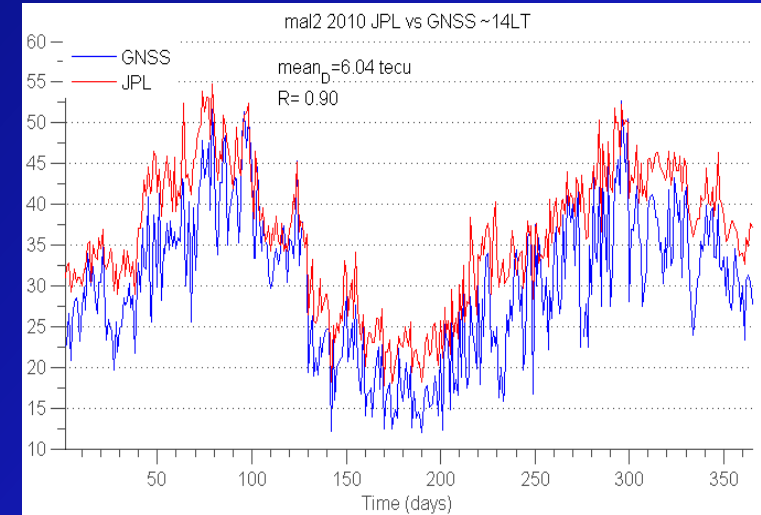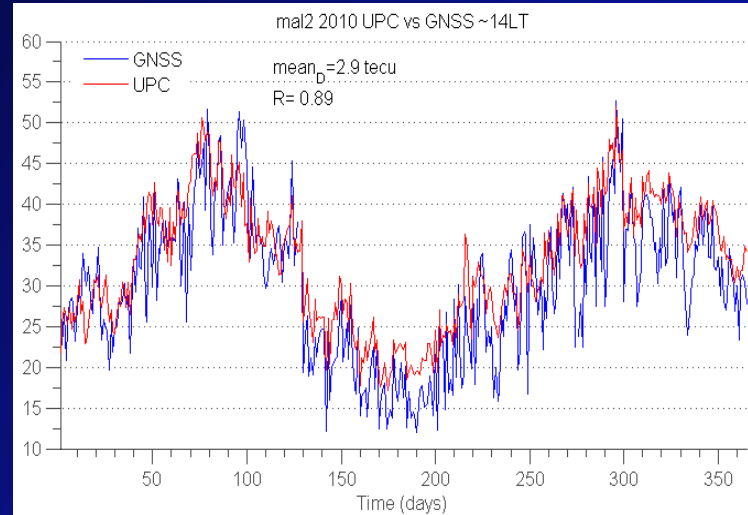TEC values above the stations of **bjco** (West Africa, 6.23°N 2.27°E) and **mal2** (East Africa, -2.59°N 40.11°E) corresponding to 2010 have been selected.
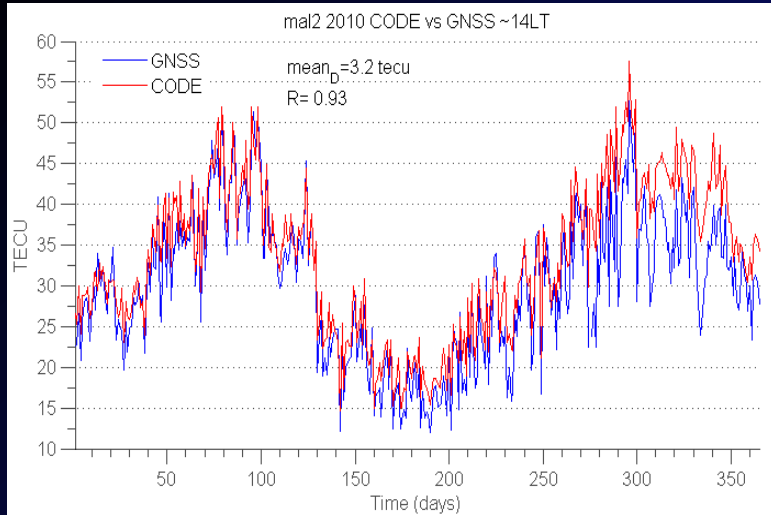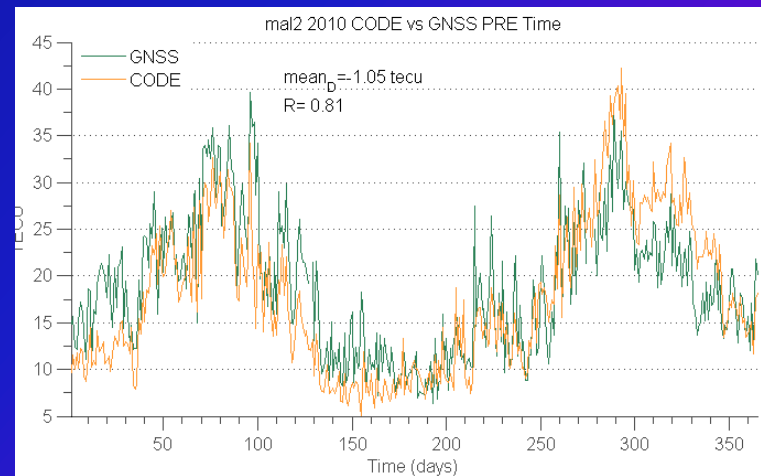
bjco year 2010 CODE – UPC – JPL ~ 14LT

bjcp 2010 CODE vs GNSS — GNSS, CODE — $mean_D$=4.09 tecu, R= 0.91

GNSS, UPC — $mean_D$=3.69 tecu, R= 0.90

bjco 2010 JPL vs GNSS — GNSS, JPL — $mean_D$=7.8 tecu, R= 0.89

bjco year 2010 CODE – UPC – JPL ~19LT

GNSS, CODE — $mean_D$=5.05 tecu, R= 0.88

GNSS, UPC — $mean_D$=3.9 tecu, R= 0.84

bjco 2010 PRE time JPL vs GNSS TEC — GNSS, JPL — $mean_D$=7.7 tecu, R= 0.89

mal2 year 2010 CODE – UPC – JPL ~ 14LT

mal2 2010 CODE vs GNSS ~14LT

$mean_D$=3.2 tecu
R= 0.93

mal2 2010 UPC vs GNSS ~14LT

$mean_D$=2.9 tecu
R= 0.89

mal2 2010 JPL vs GNSS ~14LT

$mean_D$=6.04 tecu
R= 0.90

mal2 year 2010 CODE – UPC – JPL ~19LT

mal2 2010 JPL vs GNSS PRE time

$mean_D$=-0.65 tecu
R= 0.88

mal2 2010 UPC vs GNSS PRE Time

$mean_D$=-2.65 tecu
R= 0.85

mal2 2010 CODE vs GNSS PRE Time

$mean_D$=-1.05 tecu
R= 0.81

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Wavelet Analysis

Limits of FFT analysis.

Wavelet analysis expand TS into *time frequency/space* and can therefore find localized intermittent periodicities [Grinsted, et al, 2004]

In order to gain further insights into the relationship of the TEC from GNSS and GIM, the (Morlet) wavelet transform is used.
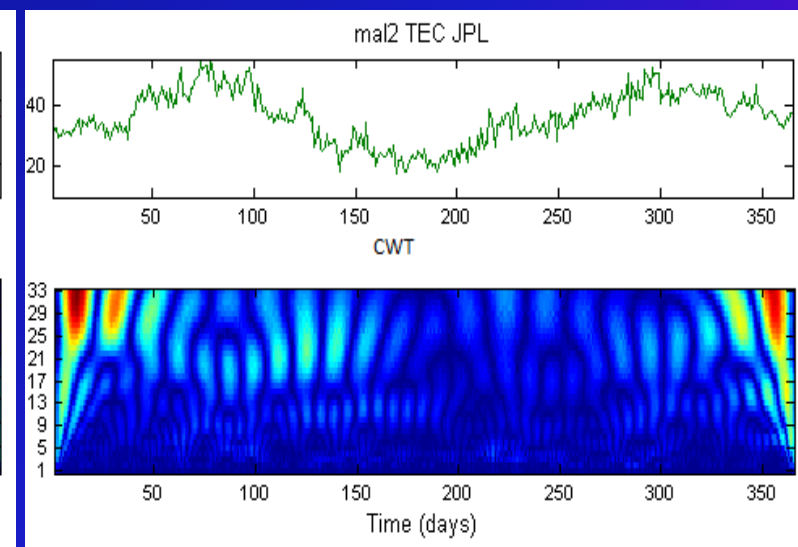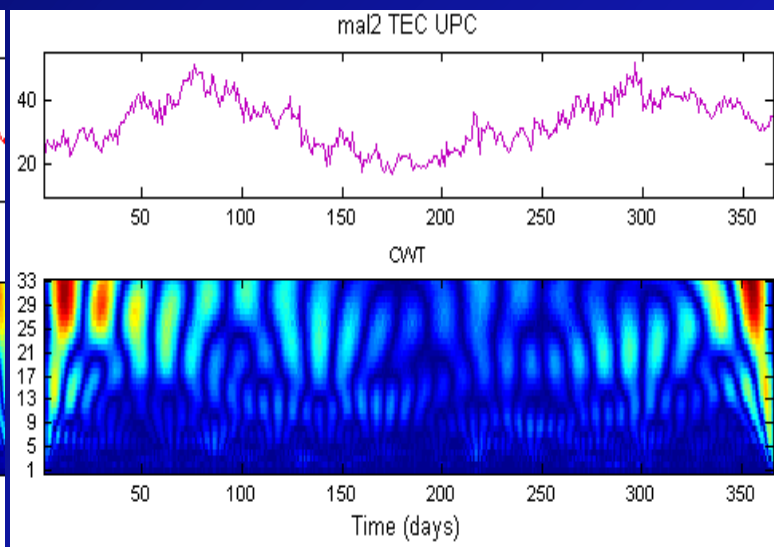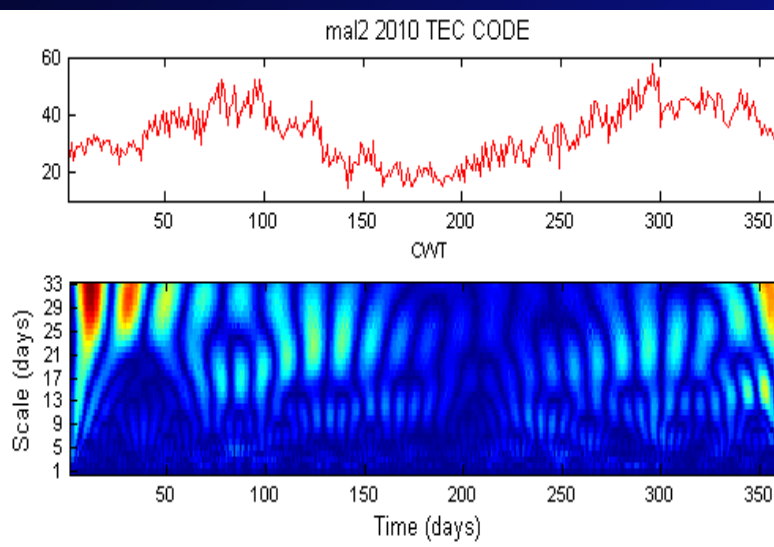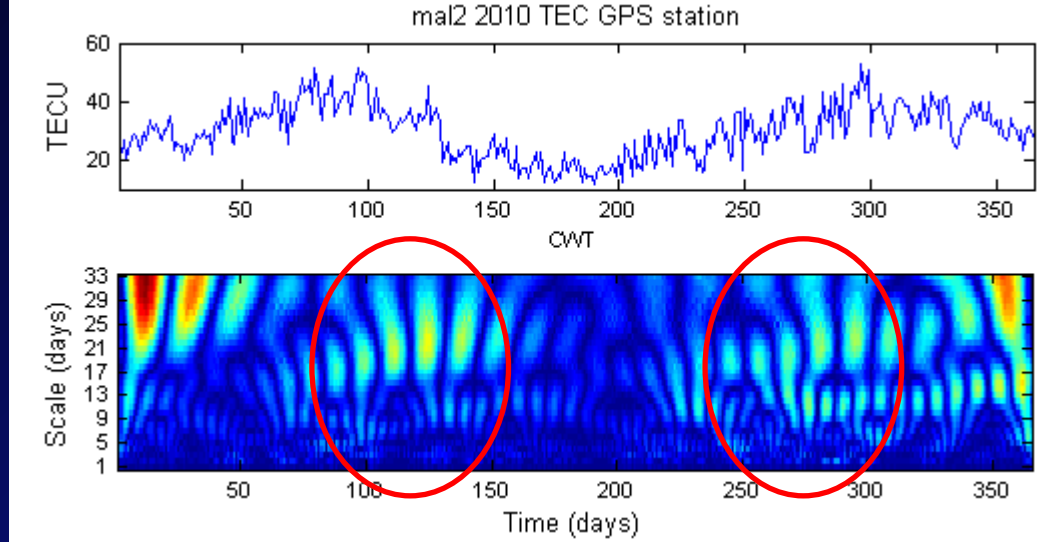
$$\mathrm{CWT}(u,s) = \int_{-\infty}^{\infty} h(t) \frac{1}{|s|^{0.5}} \Psi^* \left(\frac{t-u}{s} \right) \mathrm{d}t,$$

Mallat, 1998
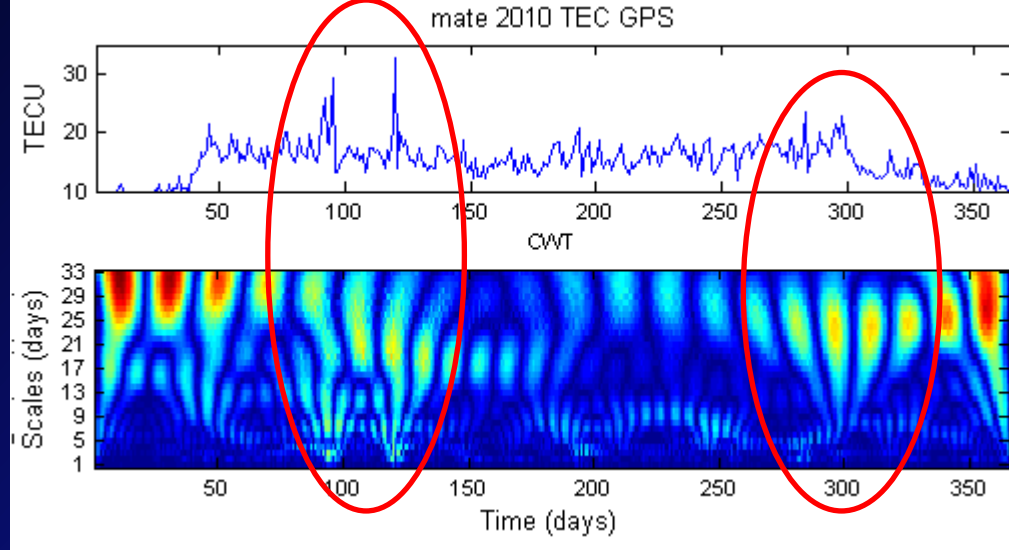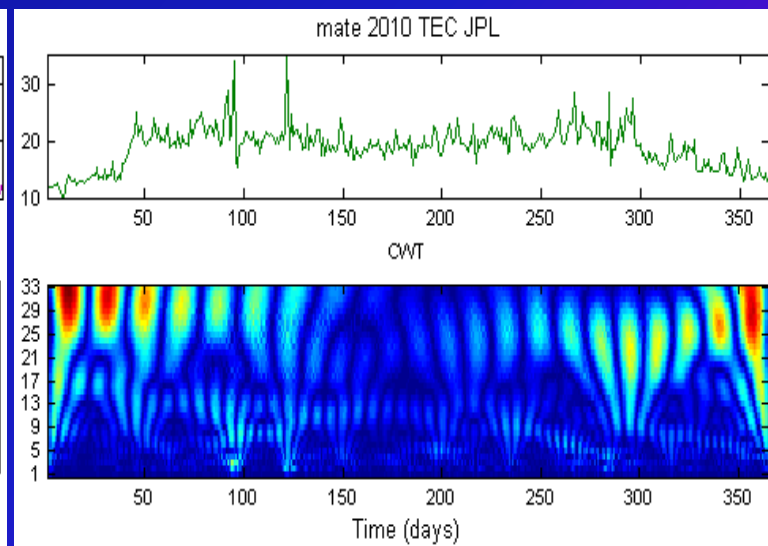
bjco

CWT bjco year 2010 CODE – UPC – JPL ~ 14LT

mal2

CWT mal2 year 2010 CODE – UPC – JPL ~ 14LT

mate

Fuller Rowell et al. 1996

CWT mate year 2010 CODE – UPC - JPL ~ 14LT
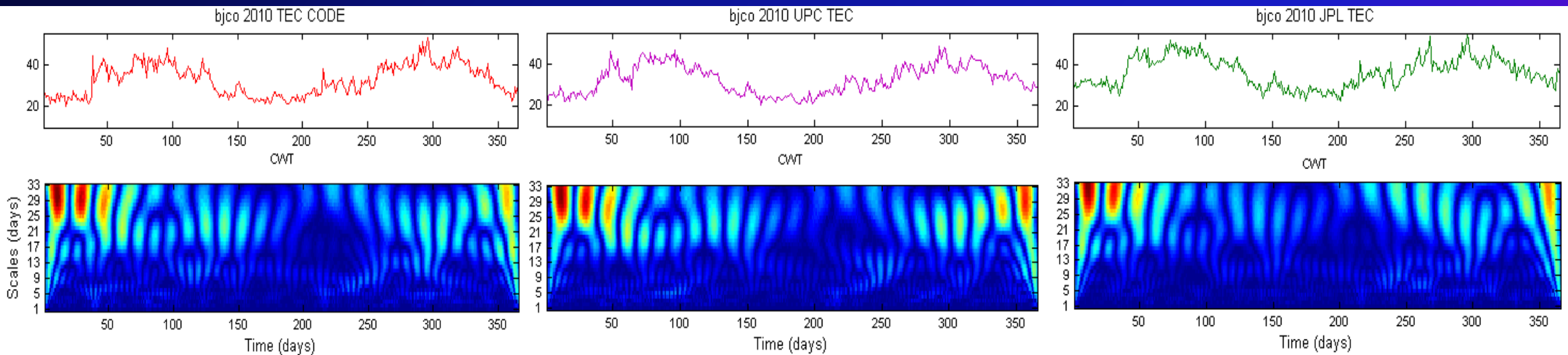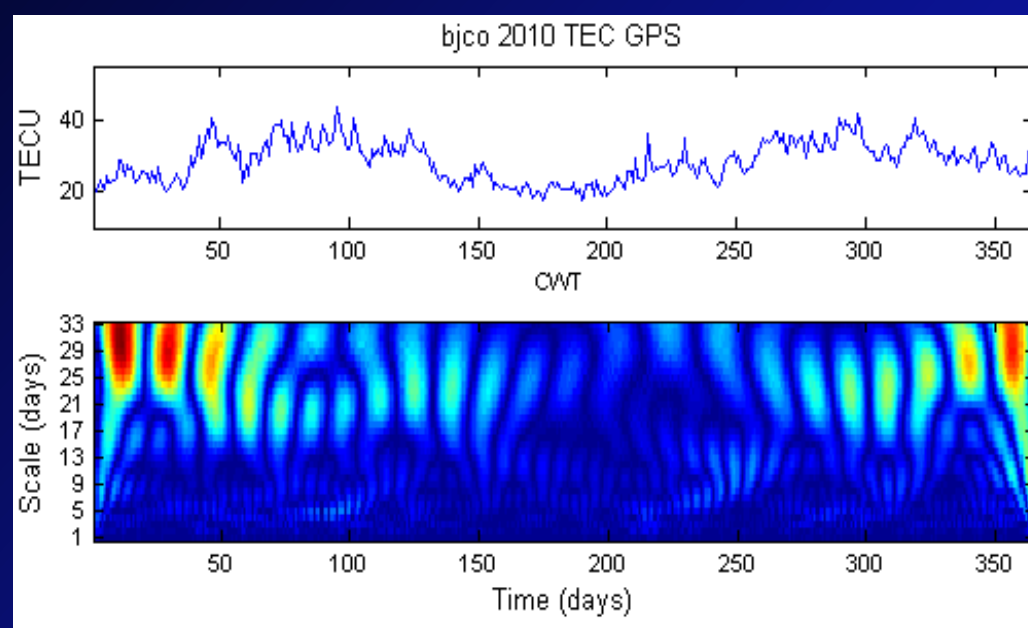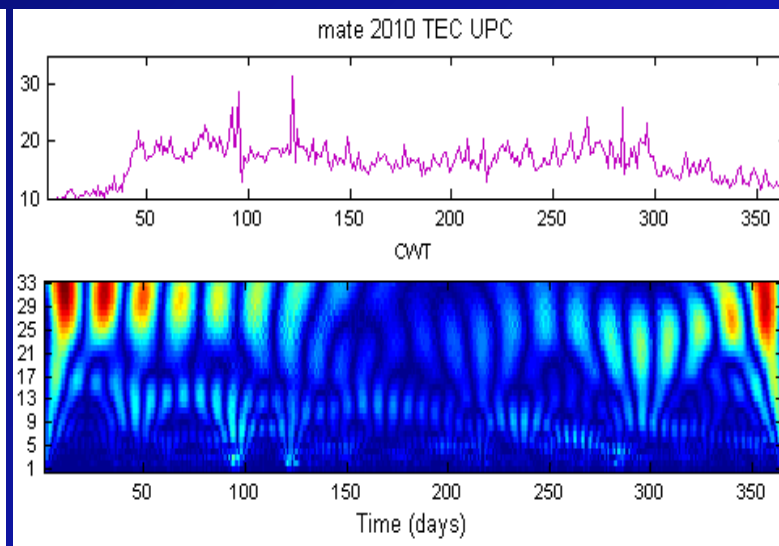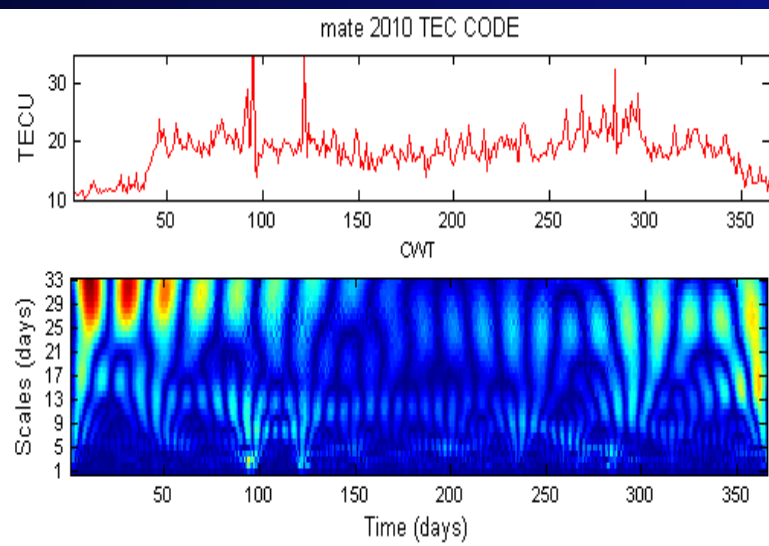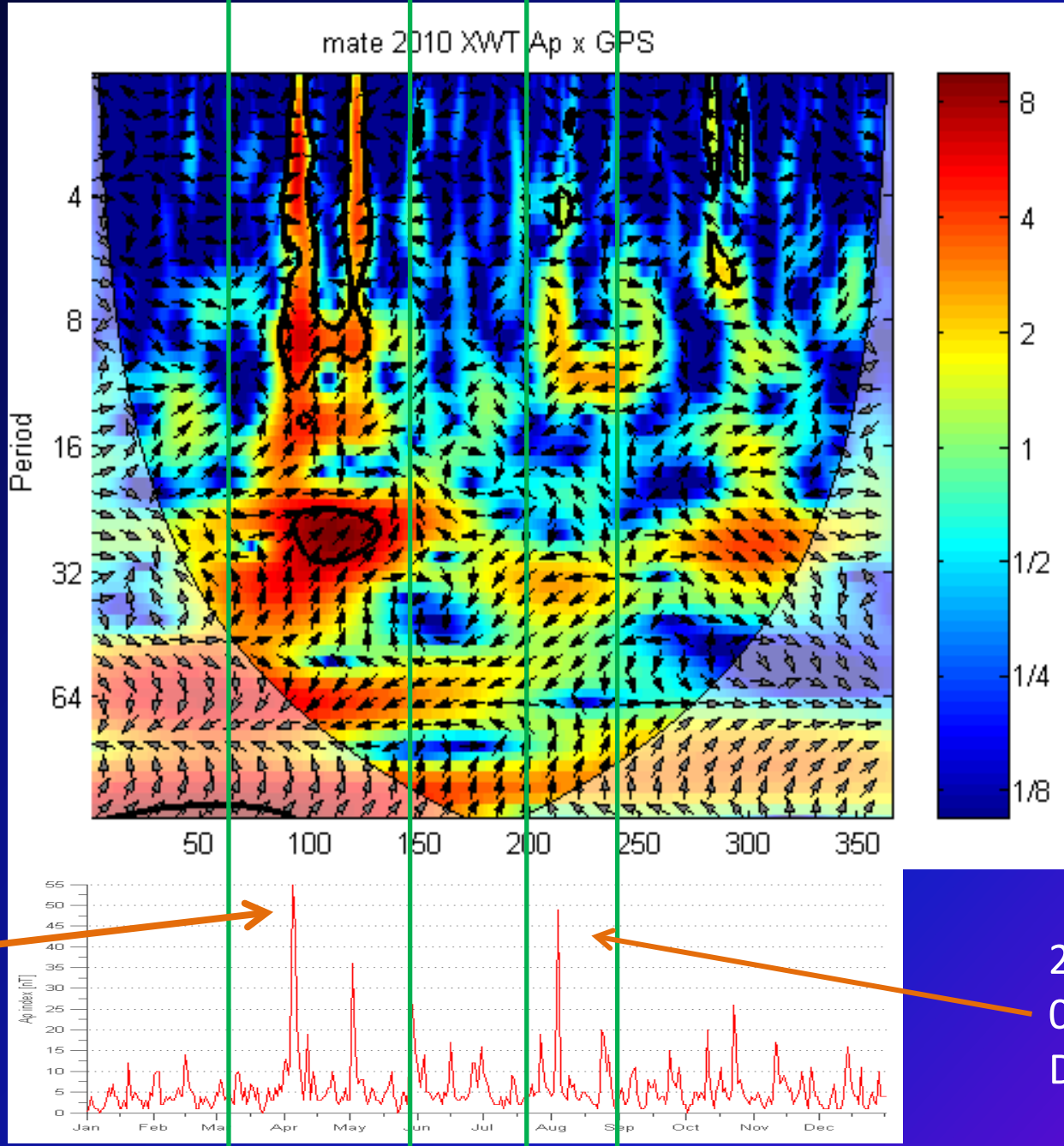
Cross Wavelet Transform (XWT)

Torrence and Compo, 1998

$$W^{XY} = W^X * W^Y$$

mate 2010 XWT Ap x GPS
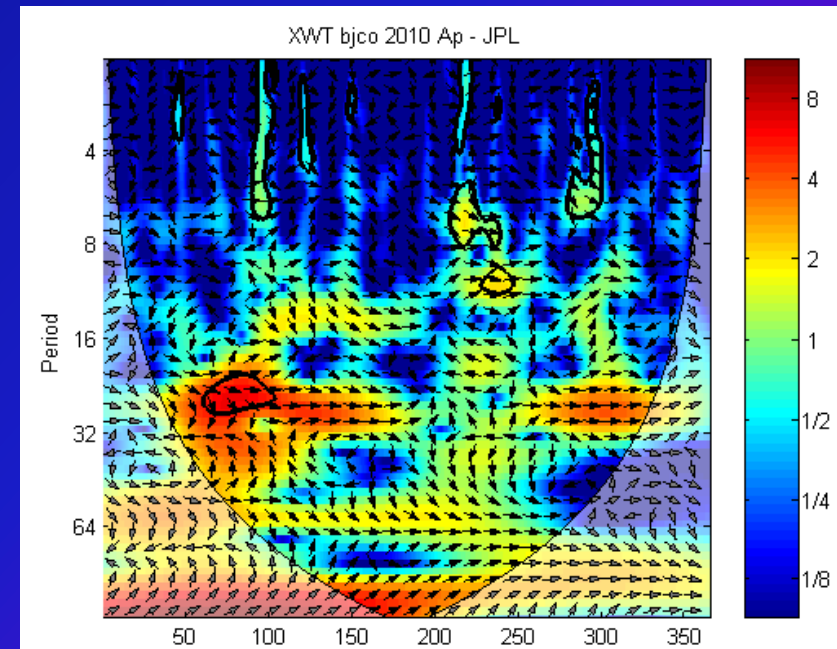
Storm (HSSW)
05/04/2010
Dst ~ -80

2 CME impacts
03 and 05/08/2010
Dst ~ -70

Cross Wavelet Transform (XWT)

bjco
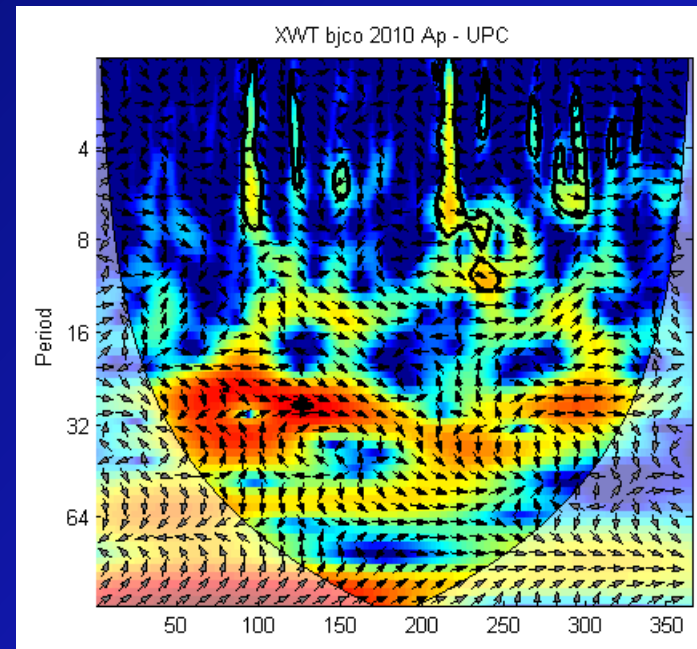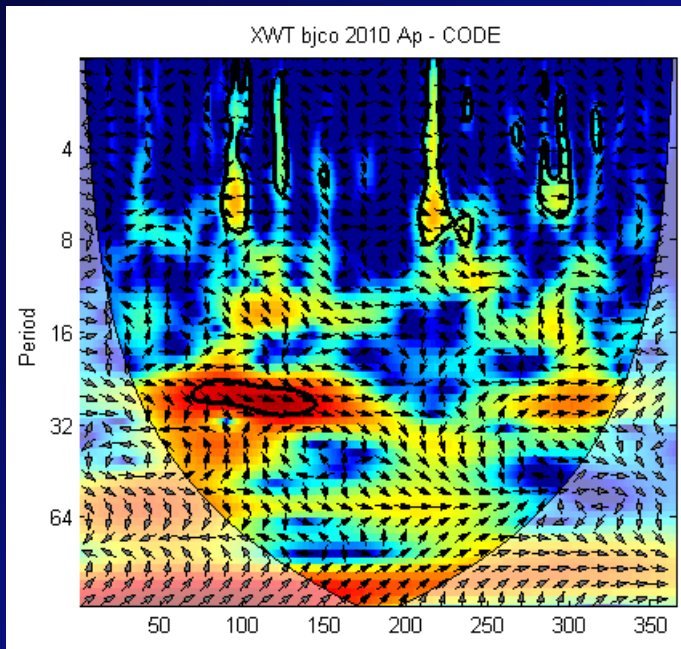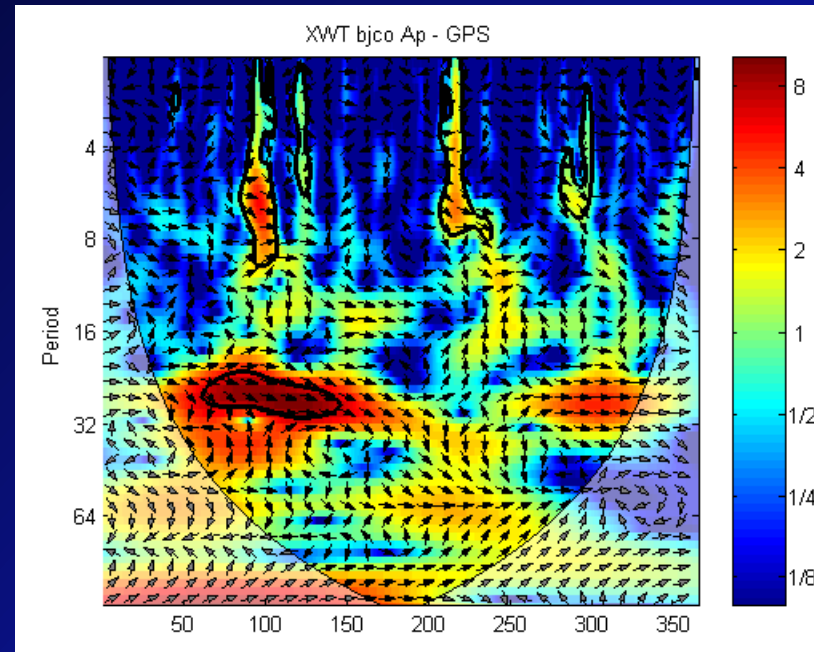
mal2
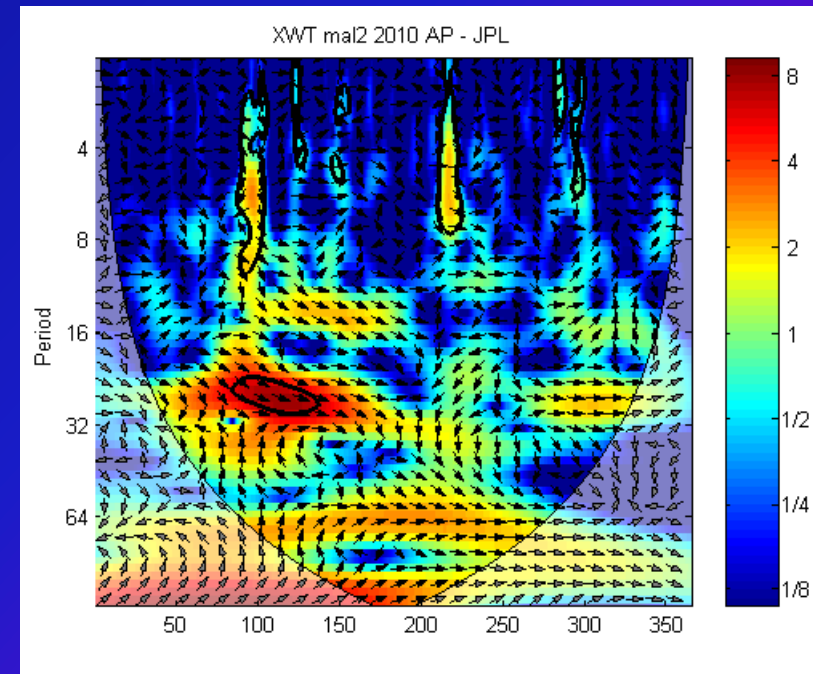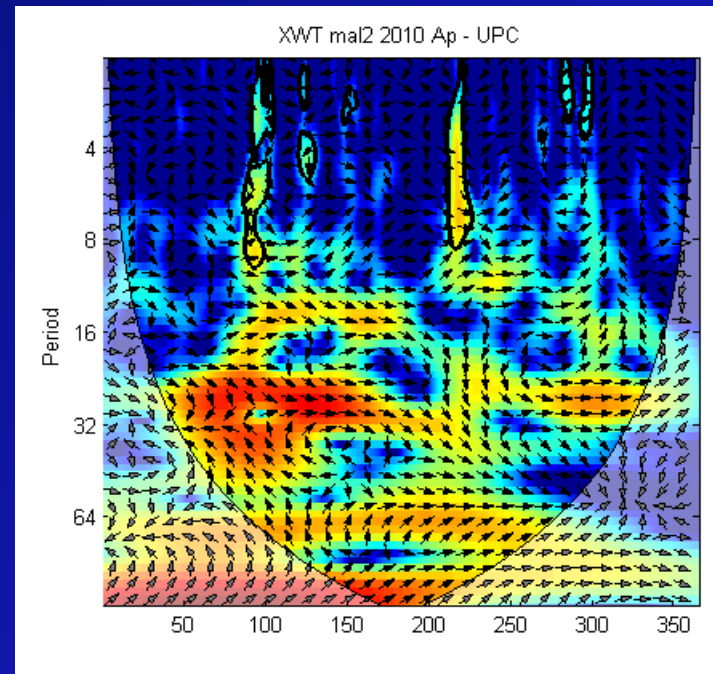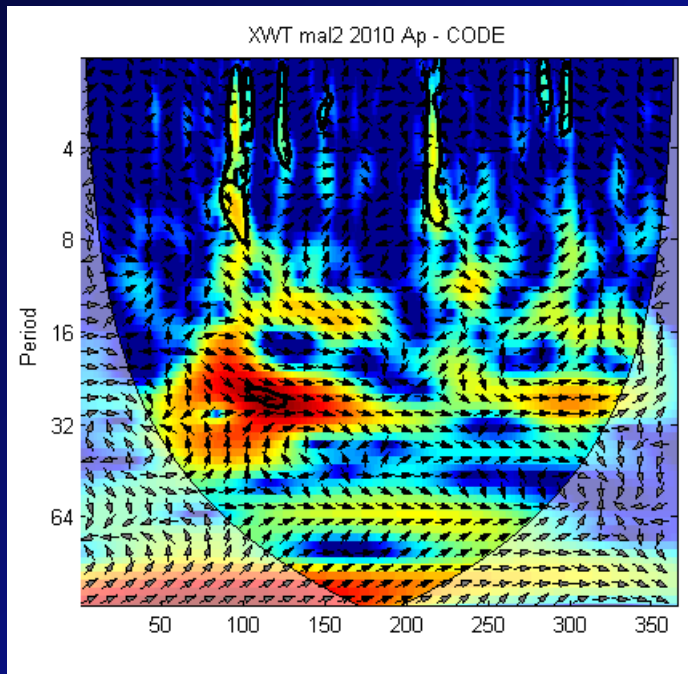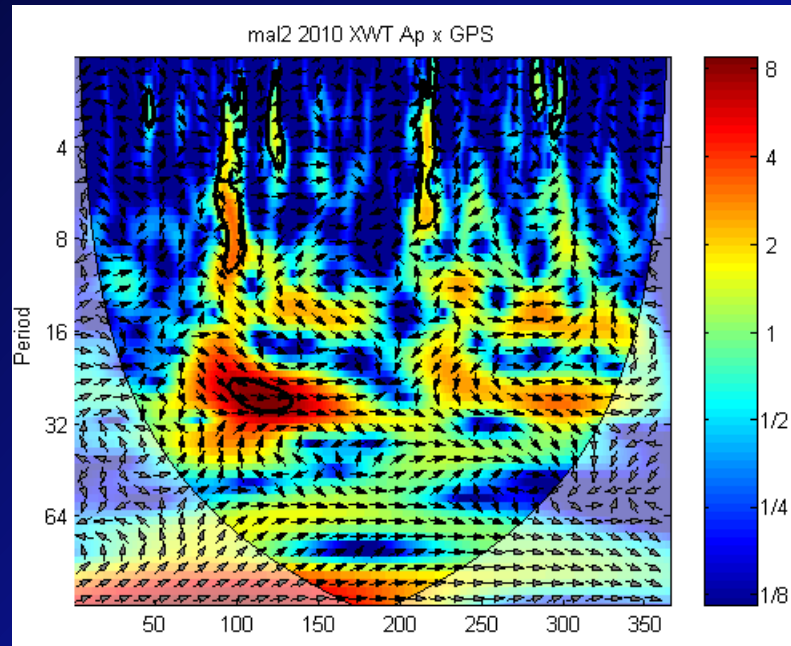
Wavelet based *Semblance* Analysis

Semblance *(S)* filtering compares two datasets based on correlations between their phase angles, as a function of frequency.

$$S = \cos^n(\theta)$$

Values range from -1 (inversely correlated) through zero (uncorrelated) to +1 (correlated).

Cooper and Cowan, 2007

Wavelet based Semblance Analysis

bjco

Wavelet based Semblance Analysis

mal2
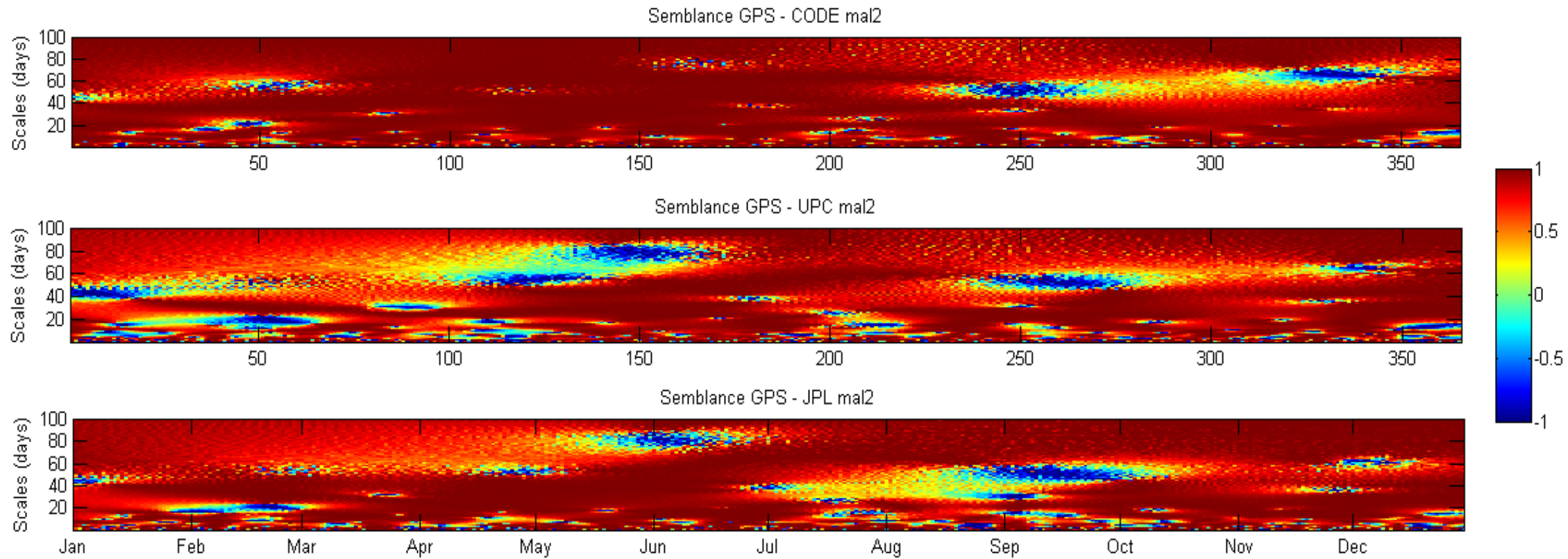
CONCLUSIONS

The present study investigated periodic variations using a WTA of TEC between GIM and single GPS Equatorial African stations during the year 2010.

TEC from the different maps in the stations analyzed show the same resonant periods at daily, ~28 days and ~ 14 days cycles with a time varying relationship along the year.

The correlation between TEC and Ap index based on the XWT gives proof of the sensibility of the maps to high solar geomagnetic activity.

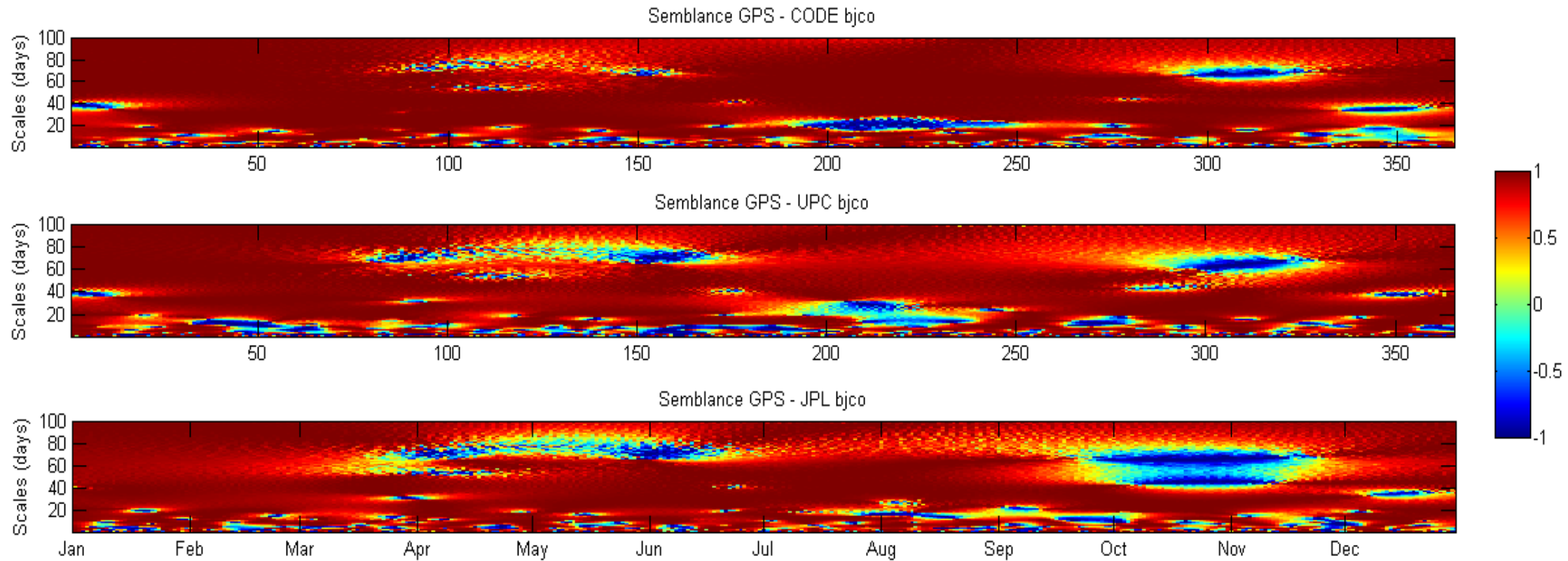The Semblance analysis allows to determine a general good correlation among different GIM in the selected African stations for the year 2010 at all scales, except for periods between Apr – June, Oct – Nov and Aug, when they appear anticorrelated on scales of 60 days and 18-30 days, respectively.

CONCLUSIONS (cont)

The analysis done put in evidence some features and periodicities in TEC that were common for both, GIMs and individual stations data.

Besides the differences in TEC magnitude of the GIM analyzed wrt the single stations (sistematic offsets), the results justify the use of GIM to study the day-to-day variability of the ionosphere in terms of vertical TEC in places with scarcity of GNSS receivers stations, as the case of Equatorial African region.

Future in depth analysis to characterize other regions, a complete solar cycle, as well as a better resolution of the GIM would give further insights.

ACKNOWLEDGEMENTS

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We thank the Analysis Centers to provide GIM and IGS stations.
Special thank to Nike, Katy, Gigi and Christine.

Thank you for the attention!

REFERENCES

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-Torrence and Compo, A practical guide to wavelet analysis, 1998