Cross Wavelet Analyses of Convection Electric field and Excess Equatorial Ionospheric TEC

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Preamble

- Space Weather affects the equatorial ionosphere
- One mean is through magnetosphere by generation of zonal electric field
  Solar wind and IMF interact with the geomagnetic field
  During Southward direction of IMF Bz, magnetic reconnection occurs
  Convectional process starts. Charge separation generates electric field at poles
- Electric field, readily gets transferred by Prompt Penetration.
  Global-scale electric fields are not confined to high-latitude region.
  A correlated but short lived zonal field appears at the equatorial region
  Occurs when the counter field by R2 current temporarily out of balance
- Zonal Electric field modulates the plasma drift and TEC
  This zonal field, modulates the ExB drift of the ionospheric plasma.
  Effective recombination rate changes and hence in turn the TEC of the region varies.

Preamble

- Earlier works and motivation

  Several models developed to relate equatorial electric field with IEF

  Works by Kikuchi (1996), Huba et al. (2005), Manoj and Maus (2012), Wang et al., 2004; Hui Wang et al. (2008), Wiltberger et al. (2004) etc are popular

  Few relate the IEF with the equatorial ionospheric TEC change occurring as a result

- This work

  Challenging to identify effectiveness of this convectional electric field source towards variation in equatorial TEC. Work done towards this understanding

  CWT is used on these two time series. CWT s better for feature extraction purposes. To examine how two time series are linked XCT and WTC used

  Exposes regions of common power and phase in time-frequency explaining causality and effectiveness

Approach

a. Inherent relationship is assumed

b. Convectional electric field used as one parameter.

Derived from measured plasma velocity and magnetic field intensity, using the relation
E = - v x B

c. Excess TEC over the quiet day nominal values is also obtained

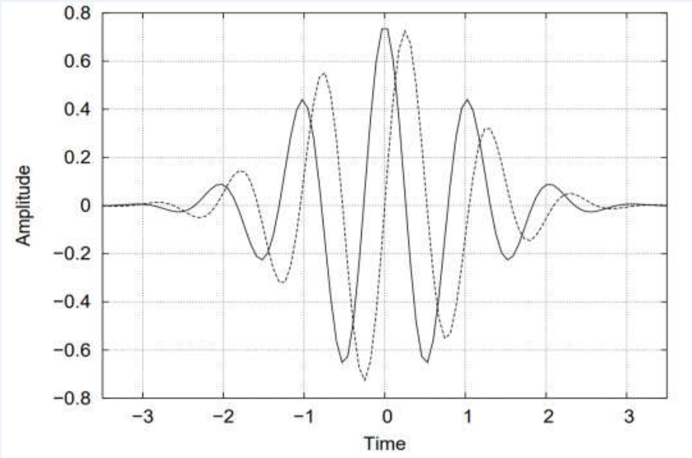
Excess TEC over quiet day nominal values obtained by differencing corresponding VTECs

d. Wavelet analyses is done on both using Morlet's wavelet.

- *Function:* $\Psi(\omega_0, \tau) = 1/\pi^{1/4}\ \exp(j\omega_0\tau)\ \exp(-\tau^2/2)$
- *CWT :* $W^x_n(s) = \sqrt{(\delta t/s)}\ \sum_{k=1}^{N} x_k\, \Psi(k-n)$

e. Cross wavelet transform is obtained

f. Observations made and Conclusions derived out of it



Data

- Event

  St. Patrick's Day storm : 17–18 March 2015

  2 CME on March, 15, 2015 and formed CIR in solar wind

  wind impinged upon magnetosphere at ~680 km/s.

  IMF Bz turned southwards ~0600 hrs and ~1200 hrs

  Effective electric field of 200 mV/km was induced

- IEF obtained from online repository

  IEF data obtained from the OmniWeb portal of the GSFC. IEF data derived from B and the v values

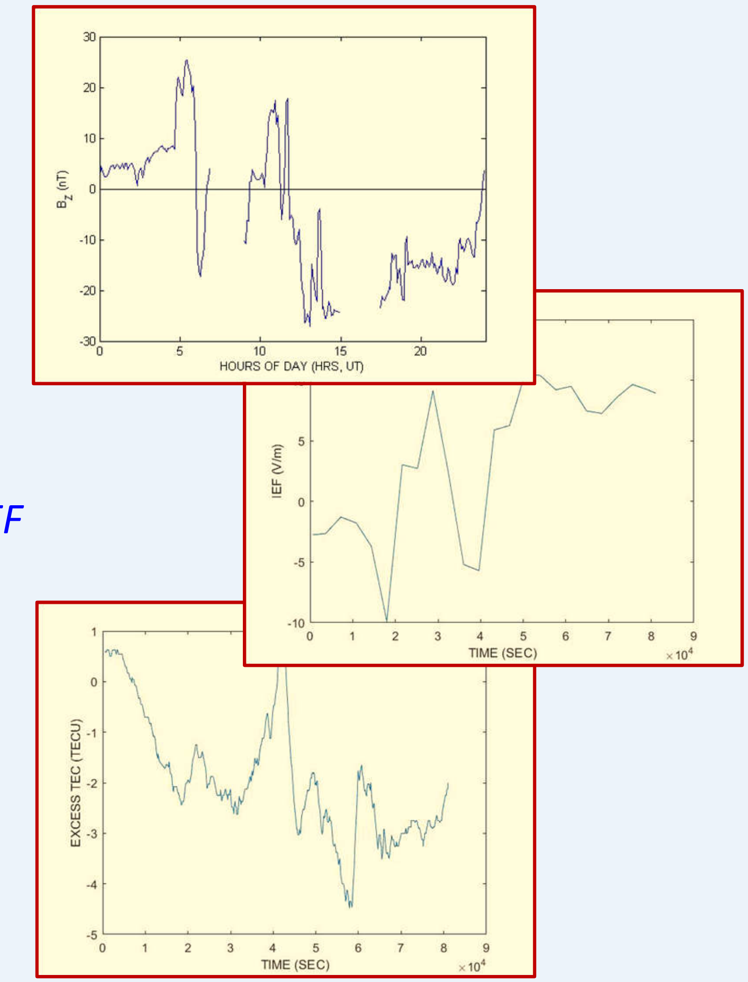
- Excess TEC estimated

  TEC derived from GAGAN grid delay data at 10°N, 75°E

  Excess TEC obtained as $TEC_{event} – TEC_{quiet}$

  TEC_{quiet} data obtained by averaging TEC of two quiet days

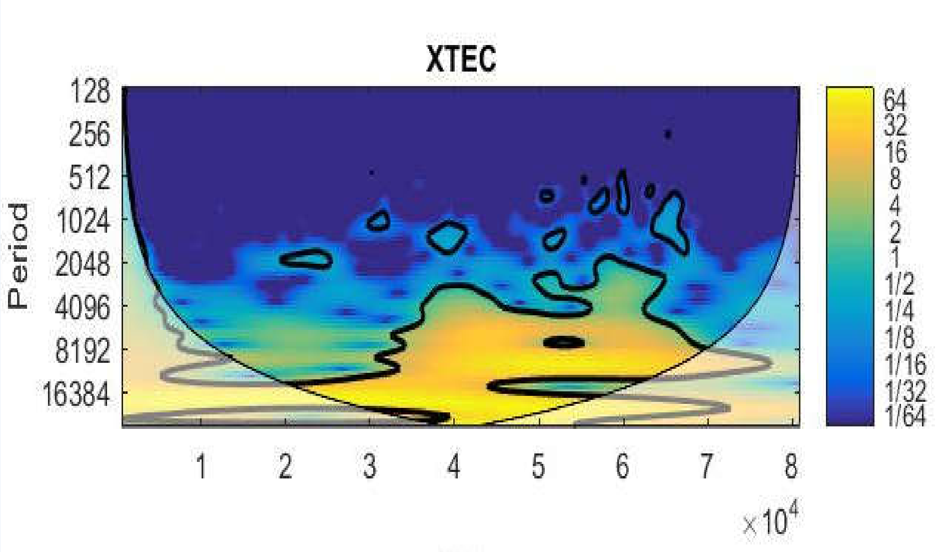
  Diurnal profile obtained is then used for the wavelet analysis.



Result

a. CWT coefficients of excess VTEC using Morlet wavelets.

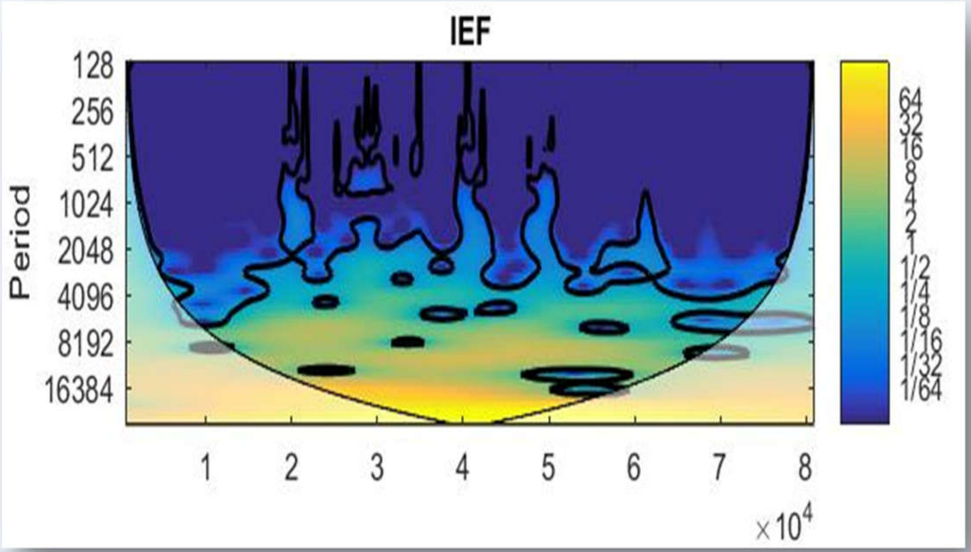
- *larger amplitudes at longer periods, particularly for periods > 2048 s*
- *Variations lesser than 30 minutes has negligible similarity with Morlet's wavelet*
- *Wavelet period 4096 – 8192 sec band showed high intensity after $3x10^4$ secs of day (~10 hrs) and continued till $6x10^4$ secs (~18 hrs) UT.*
- *For larger wavelengths, the maximum intensity remained near the noon*



Result

a. CWT coefficients of IEF using Morlet wavelets.

- *Here too, larger amplitudes at longer periods, particularly for periods > 2048 s*
- *Variations lesser than 30 minutes has negligible similarity with Morlet's wavelet*
- *Wavelet period 8192 – 16384 sec band showed high intensity after $2x10^4$ secs of day (~06 hrs) and continued till $6x10^4$ secs (~18 hrs) UT.*
- *For larger wavelengths, the maximum intensity remained near the noon*



Result

a. The XWT results:

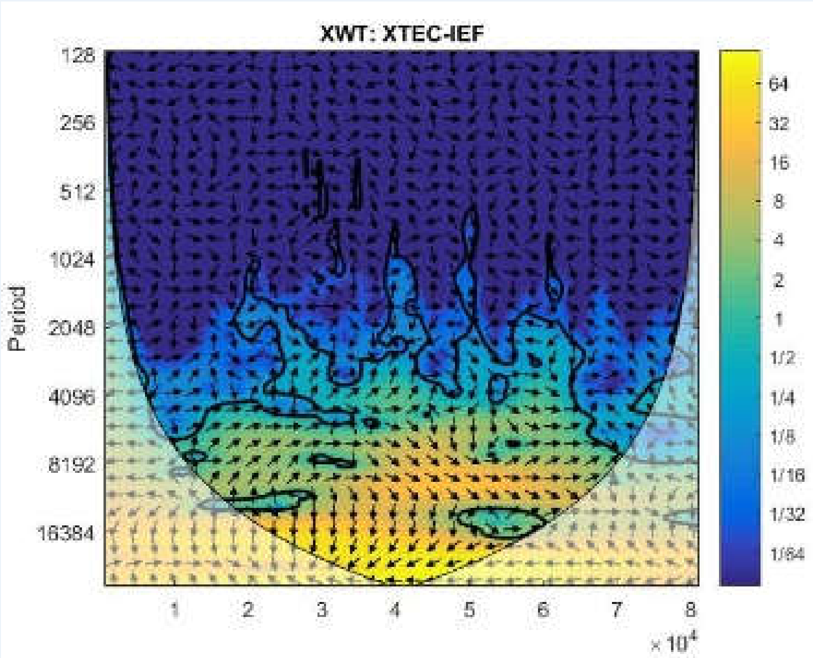
Cross Wavelet Transform (XWT) identifies the areas of common power of two processes (without normalization) in time-frequency space

Colour contour represents cross-wavelet power

Plot reveals large intensities are obtained for band of periods from 4096 and above around $4x10^4$ sec

Cross powers are not normalized and can imply artefacts. So, XWT is examined with phasors. Related phenomena show phase-locked XWT.

Phasor can be converted to time lag for specific period



Here, it is observed that different phase lag is obtained in different period bands

Result

a. The WTC results:

significant peak in the XWT might arise due to peak in one of the time series. To avoid such case, normalized WTC are calculated

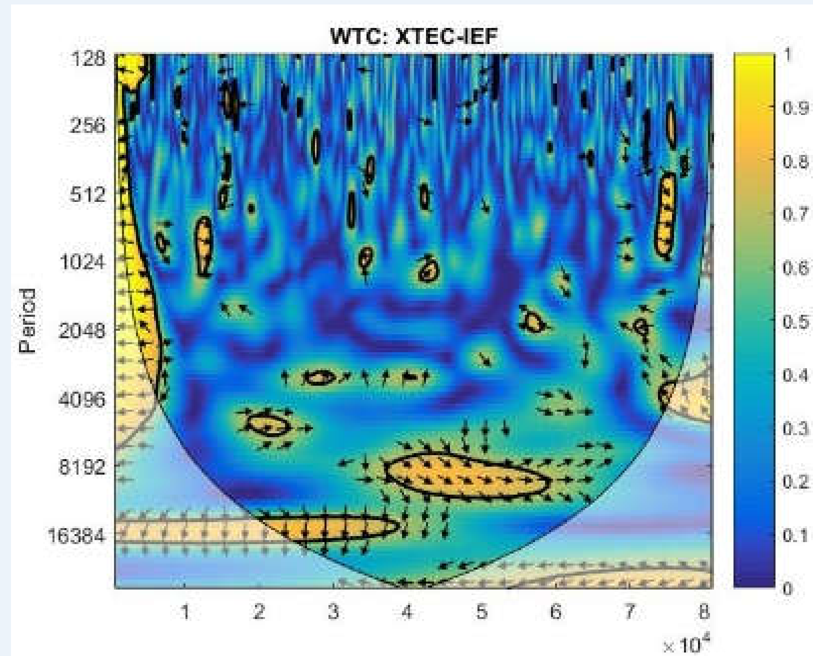
Bounded Colour contour represents wavelet coherence

Detect strong cross-amplitudes of strength >0.9 between the input electric field and the excess TEC which is in the 8192 sec period band.

Significant peaks around $4x10^4$ - $5x10^4$ sec

Compared to XWT, in WCT, most peaks vanish

The phasor angle ~-45° indicates a time lag of 1024 sec, ~17 minutes



Conclusions

The following conclusions can be drawn from the work

a. The cross wavelet amplitude strength of >0.9 re-establishes the causal relationship between the two variables in question

b. Significant peaks appear around $4x10^4$ sec. implying that the maximum correlation can be observed only after the IEF is generated as a result of the under-shielding process

c. The high WTC intensity for the wavelet period of 8162 corroborated to the earlier findings that the potential driving component has to be of period shorter than 8 hours.

d. Uniform phase differences observed showed the phasor angle ~-45° which corresponds to a time lag of 1024 sec . This points towards a delayed manifestation of the effect of about 17 minutes.

Thank You