Spatial and Temporal Variation of the FORMOSAT-3/ COSMIC S4 scintillation index using Tidal Analysis

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Abstract

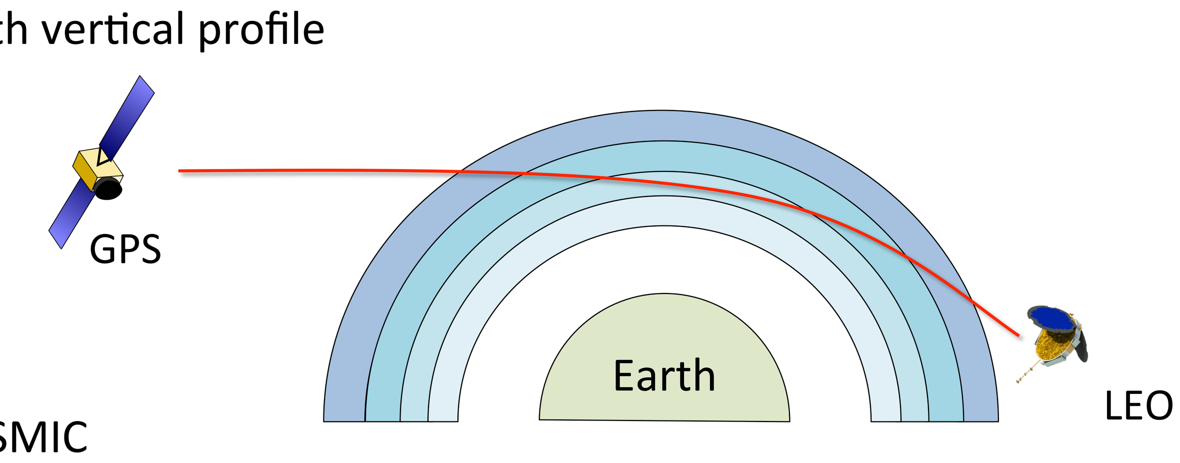
The tides generated from the lower atmosphere can propagate upwards, causing ionospheric perturbations. By using GPS radio occultation (RO) signals, FORMOSAT-3/COSMIC satellites can provide global morphology of the S4 scintillation index, quantifying the distribution of GPS and satellite communications disruptions. In this study, we analyze the the local time and spatial variation of the COSMIC S4 index, and quantify the major variation modes through tidal analysis from 2007 to 2014. The seasonal variations of the S4 index are presented in this method and the tidal signatures examined, to determine their distribution and overall effect on ionospheric scintillation. The global S4 index longitudinal and local time distribution is reconstructed using the results of our tidal analysis, and compared with the zonal mean background in solar minimum year (2009) and solar maximum year (2012), to determine the significance of zonal irregularities resulting from nonmigrating tidal disturbances.

Introduction

- Scintillation
  - A rapid fluctuation of radio signal phase and amplitude when propagating through irregular structure or highly varied media
  - Scintillation may cause GPS and satellite communications disruptions
  - S4 index
    Signal-to-noise intensity fluctuations of GPS 50-Hz L1 amplitude

$$S_4 = \frac{\sqrt{\langle (I - \langle I \rangle')^2 \rangle}}{\langle I \rangle'}$$

- Radio Occultation (RO)
  - RO observations can provide global distribution of atmospheric and ionospheric parameters with vertical profile



- FORMOST-3 / COSMIC
  - A joint U.S./Taiwan mission consisting of 6 identical micro-satellites launched into a circular orbits with a separation angle between neighboring orbital planes of 30° longitude, providing high spatial coverage in 24 hours
  - 72° inclination orbit at an altitude about 800 km with period of 100 minutes

Methodology

- S4 index is binned into grid cells of 5° (magnetic latitude) × 36° (longitude) × 20 km (altitude) × 1-h (LT) resolution from 2007 to 2014
- We obtain the time and spatial variation via tidal analysis

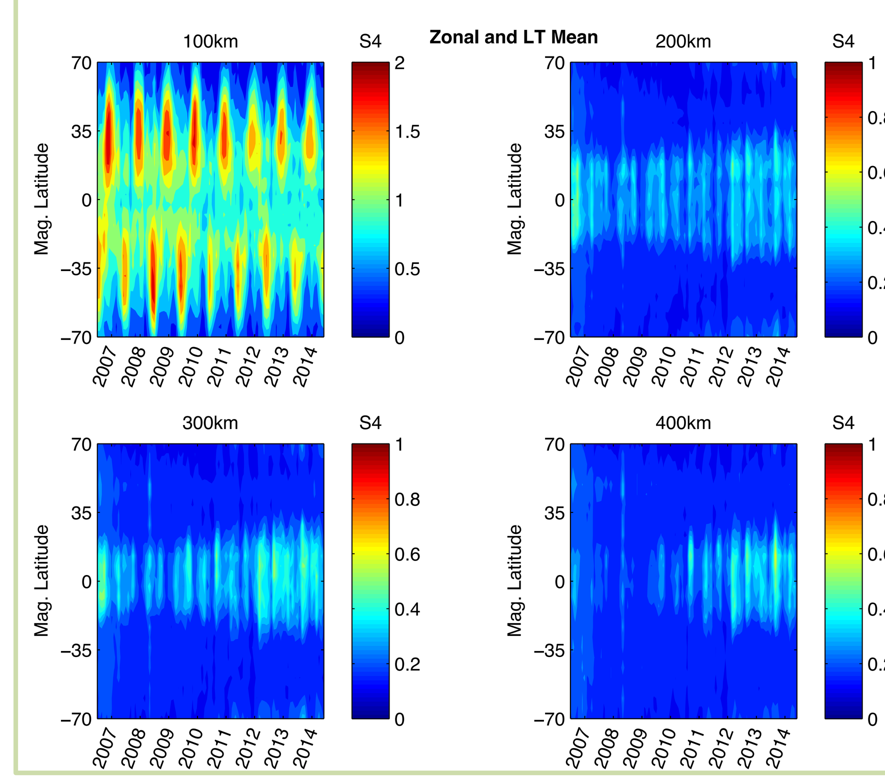
$$S4(t_{LT},\lambda) = S4_{zm} + \sum_{s=1}^{5} A_{0,s}\cos(-s\lambda + \varphi_{0,s}) + \sum_{n=1}^{3}\sum_{-5}^{5} A_{n,s}\cos(n\Omega t_{LT} - (s+n)\lambda + \varphi_{n,s})$$

n: cycle(s) per day
s: zonal wave number
λ: longitude
Ω: angular velocity of the earth

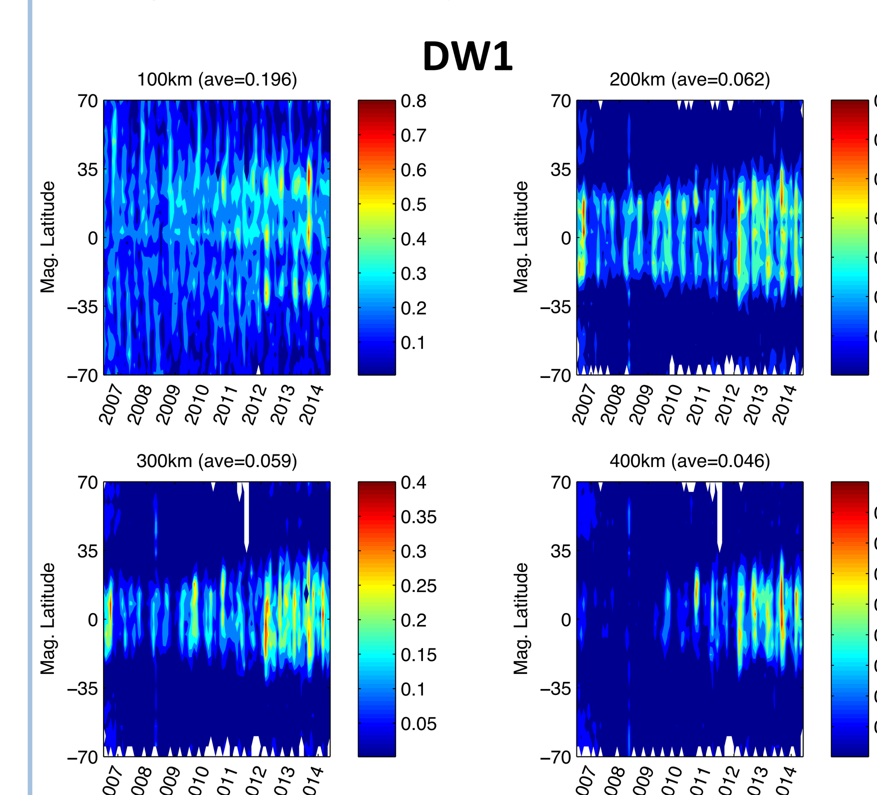
➩Tidal Analysis Result

n \ s	W4	W3	W2	W1	0	E1	E2	E3
SPW	0.065	0.07	0.1	0.17	-	0.17	0.1	0.07
D	0.055	0.06	0.07	0.2	0.07	0.06	0.055	0.054
S	0.05	0.05	0.08	0.053	0.05	0.048	0.05	0.05

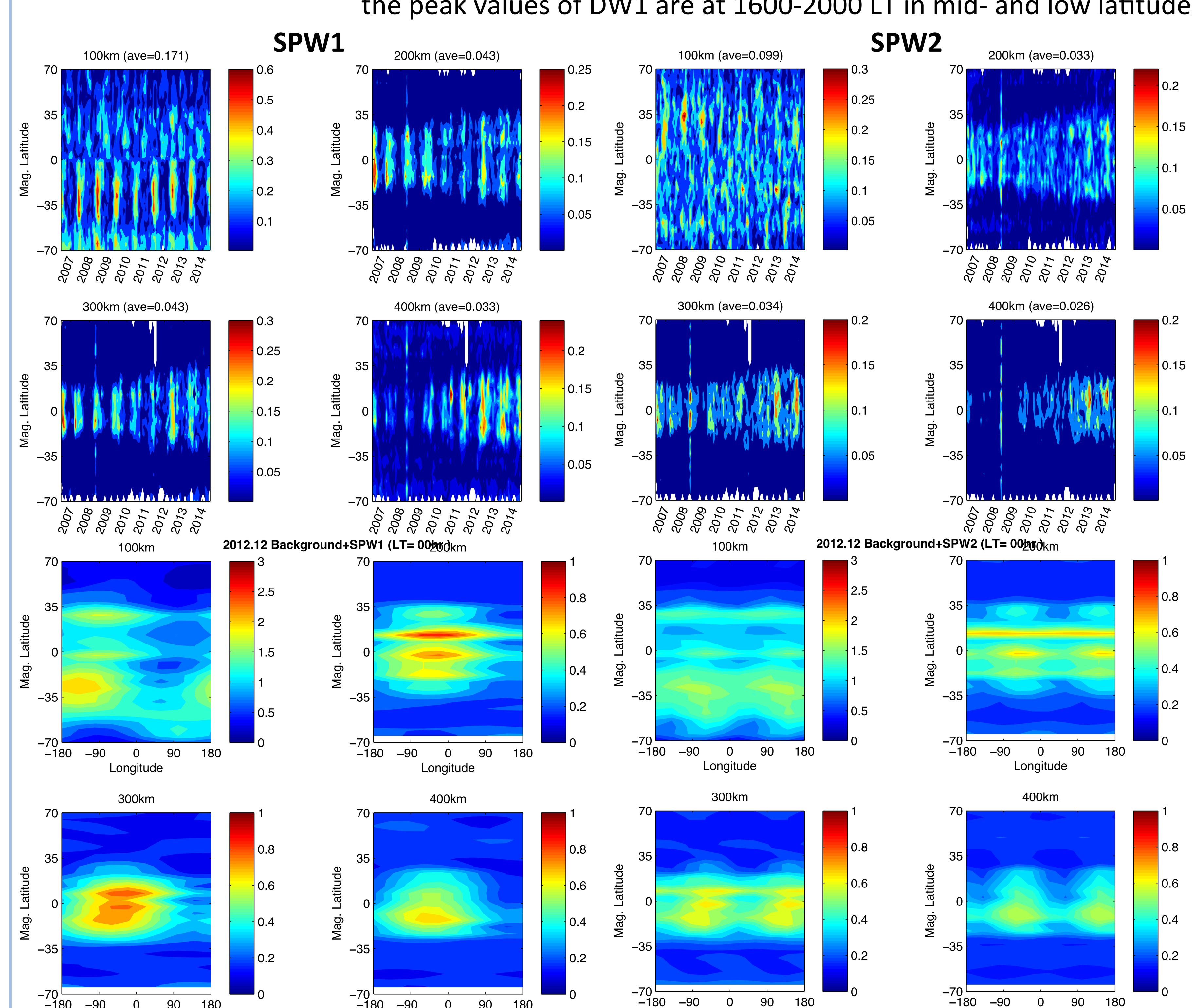
Zonal & LT Mean



Major S4 Components



DW1 corresponds to zonal mean diurnal variation
the peak values of DW1 are at 1600-2000 LT in mid- and low latitude



SPWs correspond to the stationary longitudinal variation of S4.
The distribution of higher value are listed right side.

	SPW1	SPW2
June	E: 0°~180° F: 90°~180°	E: -90°~0°, 90°~180° F: -45°~45°, 135°~180°, -180°~135°
December	E: -180°~-90°, 90°~180° F: -90°~0°	E: -90°~0°, 90°~180° F: -90°~0°, 90°~180°

Acknowledgement

This research is supported by grant MOST 103-2111-M-008-019-MY3 from the Taiwan National Science Council. We thank TACC and CDAAC for providing the dataset used in this study, as well as fellow students in NCU ISS for helpful discussions.

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Discussion

- The mechanism of the scintillations in E- and F-region are different, which agree with the already known ionospheric irregularities sporadic E (Es) and spread F (Fs).
- The spectral analysis of S4 index show that the major spectral components consist of SPW1, SPW2, migrating tides DW1, SW2 and non-migrating tides D0, DW2.
- The tidal component SPW4, DE3 and SE2 which may be related to coupling of the MLT and the thermosphere, while their amplitudes are not dominant.

Future Work

- We will study the seasonal and spatial variation contribute to S4 index from the major tidal components and discuss the sources or generating mechanism of the scintillation.
- The scintillation effects of SPW4, DE3 and SE2 component will be examined to see if they are related to coupling of the MLT and the ionosphere.