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Influences of migrating semidiurnal tide variabilities on the low latitude ionosphere

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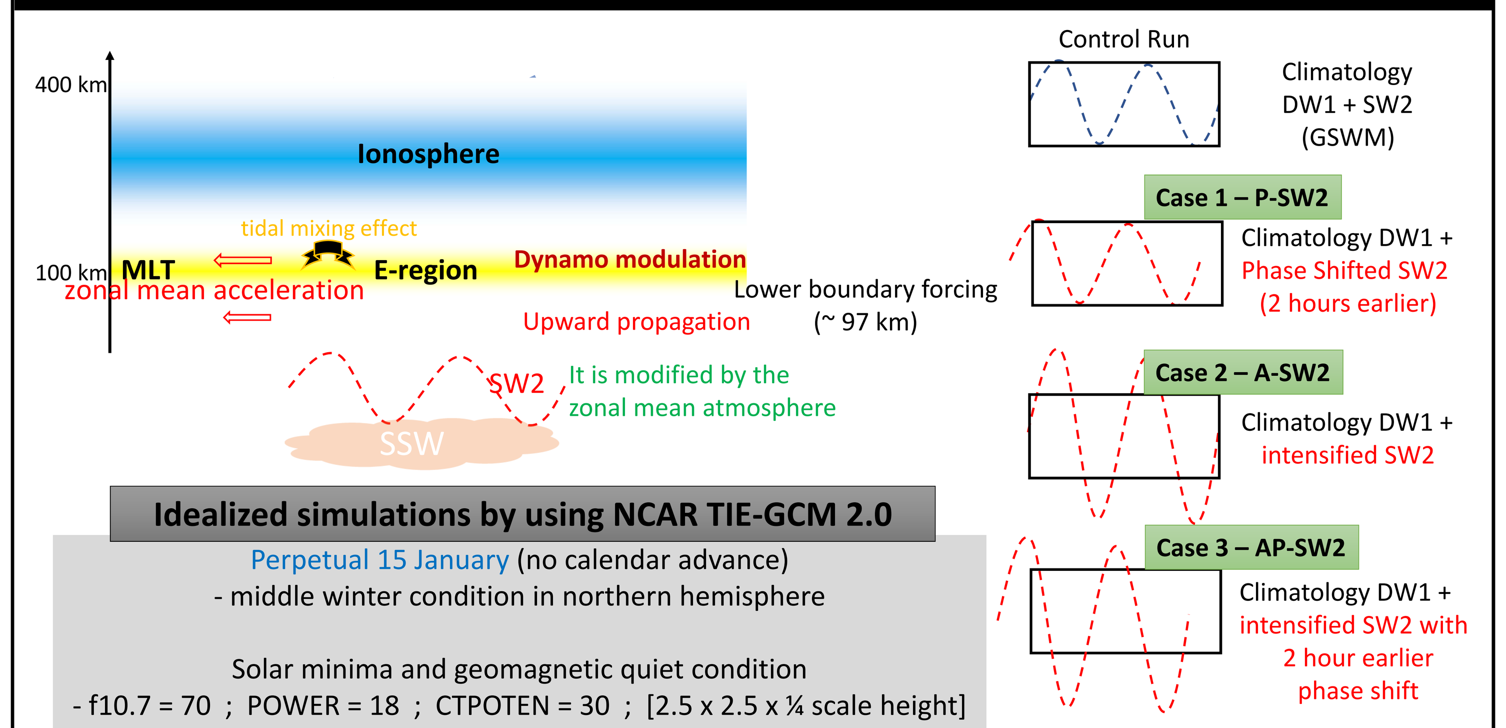
Abstract

In this study, we investigate the variability of ionosphere and its electrodynamic responses to various semi-diurnal migrating tide (SW2) variations associated with SSW using numerical experiments under solar minimum condition. The earlier phase shift of SW2 causes the morning-enhanced and afternoon-reduced TECs by modulating equatorial vertical ExB drift, which agrees with the observation qualitatively but with insufficient magnitude. The SW2 amplification, which previously considered as the main driver of ionosphere-SSW coupling, produces temporally ExB enhancement due to the westward acceleration of F-region zonal winds by SW2. Results from the experiment adopting both the phase shifted and amplified SW2 agree with the observation in both magnitude and long sustained ExB enhancement. Our results demonstrate that both phase shift and amplification of SW2 are required to reproduce ionospheric SSW effects.

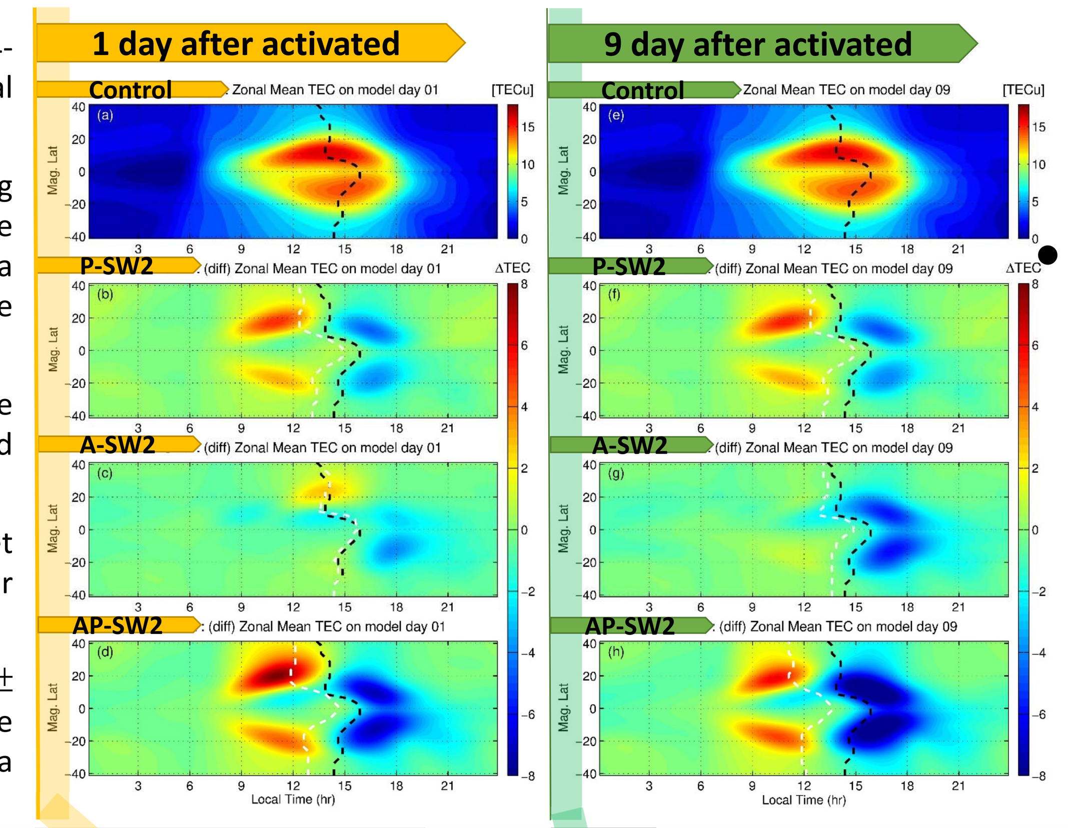
Motivation : Quantify the Ionospheric Responses to the Change of Amplitude and/or Phase in SW2



- Liu and Richmond (2013) suggest that the SW2 tidal winds in the MLT at middle-high latitude contributed a large portion of vertical drift on low latitude ionosphere.
- The amplitude and phase variability of SW2 during an average SSWs is found to be capable of producing temporal variability in the vertical plasma velocity that is similar to the observed variability [Pedatella and Liu, 2013]
- To elucidate the influence of amplitude/phase change in the SW2 on generating the ionosphere variability which is the potential driver during Stratospheric Sudden Warming.

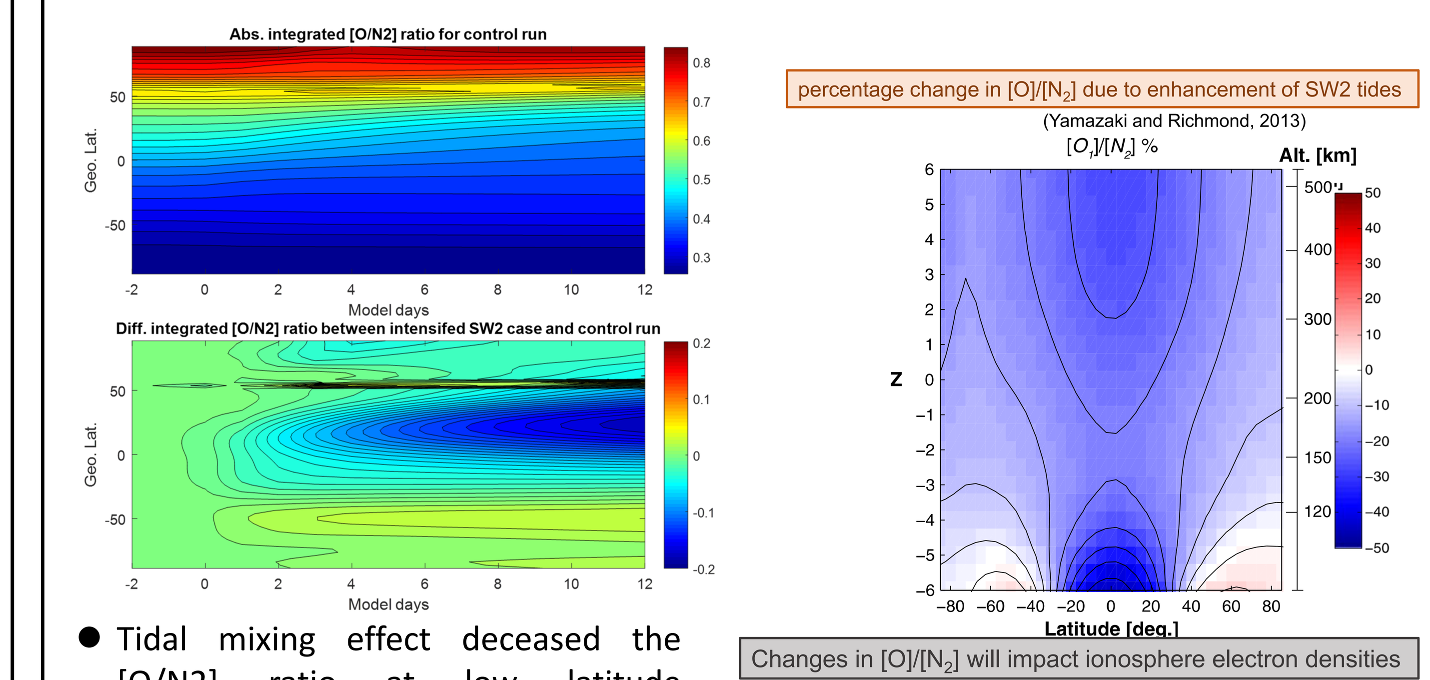
The Influences of Various SW2 on the Local Time Variation of TEC

- The EIA crests reach its maximum around LT 14-15 which can be considered as a normal diurnal variation in ionosphere TEC.
- A clear semi-diurnal variation (morning enhancement/afternoon reduction) can be produced by Phase shift only in SW2 with a roughly 2 hours earlier shift in the occurrence local time of peak.
- Standalone intensification of SW2 amplitude results in a morning & night decrease and a brief increase in the afternoon.
- For the AP-SW2 case, the signatures are quiet similar to "P-SW2" case, but with a larger magnitudes.
- The increased/decreased TEC mainly locates ± 20° magnetic latitude which implies the increased/decreased equatorial vertical plasma drift.



- long-term ionospheric effects from different SW2 tides, the induced TEC perturbations are shown an overall decrease of TEC during the daytime in the cases with intensified SW2.

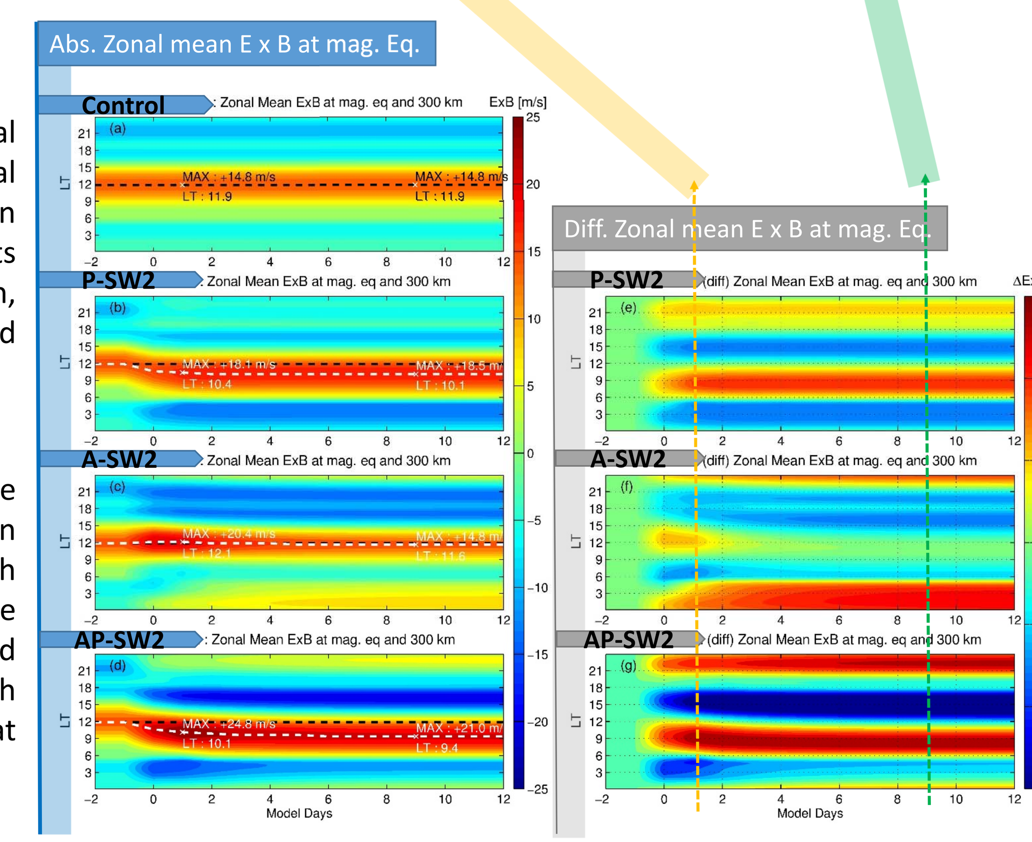
The Influences of Various SW2 on the Neutral $[O/N_2]$ Ratio



- Tidal mixing effect deceased the [O/N2] ratio at low latitude ionosphere due to the tidal dissipation from the increased SW2.

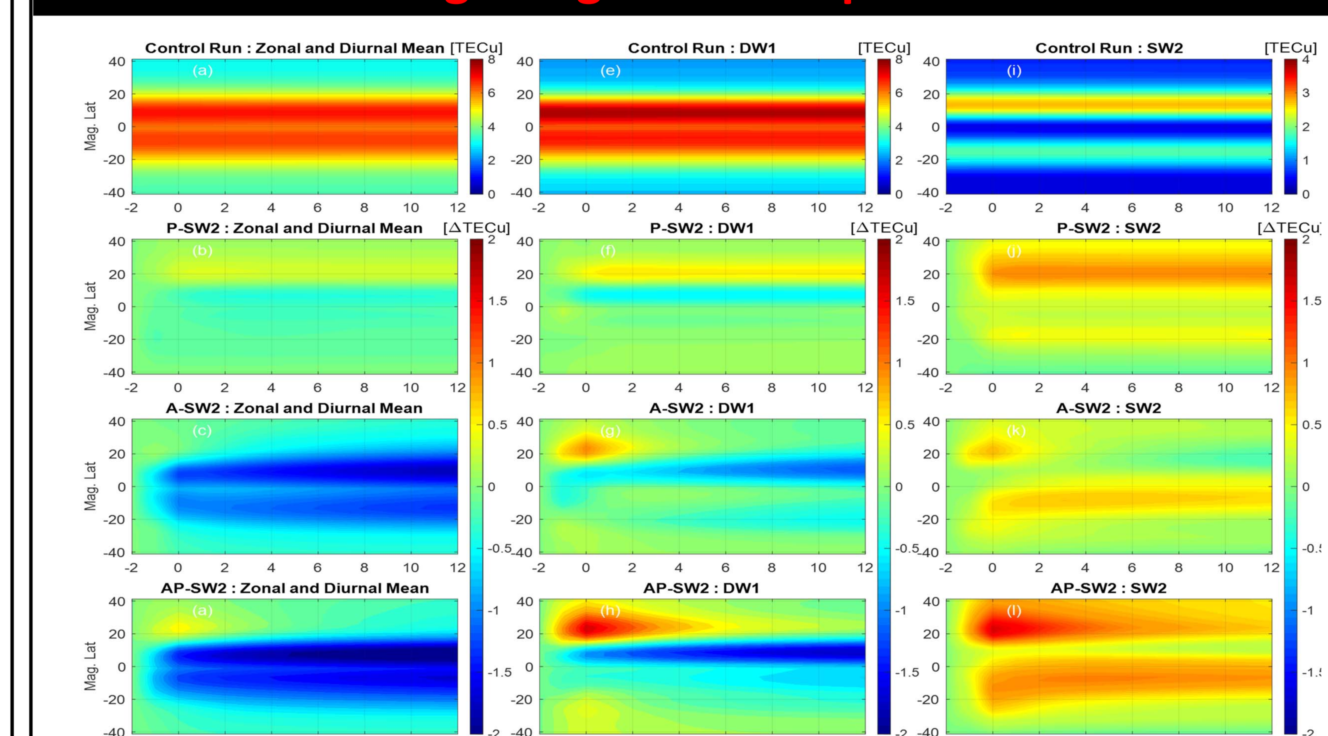
The Influences of Various SW2 on the Local Time Variation of Vertical E x B Plasma Drift

- Control run shows a typical diurnal variation of vertical drift with an upward drift in the morning, and reach its maximum around noon, then reverse to downward drift around dusk.
- Each case show a more clear semi-diurnal behavior in vertical plasma drift with earlier shift of occurrence time of maximum upward drift, which is identical with the phase shift of SW2 at lower boundary.



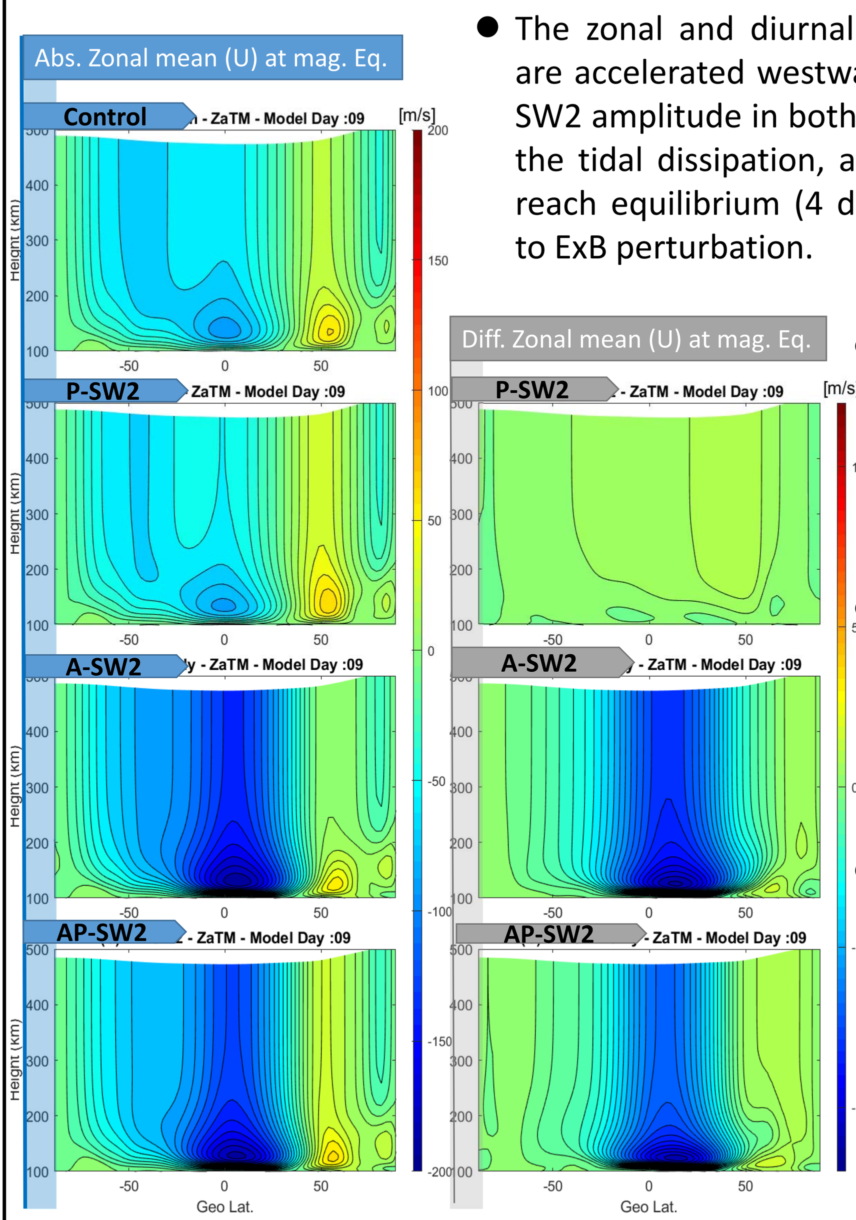
- The difference of vertical drift between each case and control all behavior a strong semi-diurnal variation, but with their own phase and amplitude.
- In the case of "P-SW2", indicates a morning enhancement of upward drift followed by afternoon reduction with a magnitude of ~6 m/s, and resulting in shift of the occurrence of daily maximum upward drift from LT 12 to LT 10.
- characterizing as a reduction in the early morning (5-10 LT) and intensification around noon that superposing around the original local time maximum, with no time shift in daily maximum.
- Additionally, one can be noticed that the induced plasma drift perturbation is not quite stable at the begin of doubling the SW2 forcing, it reaches the steady state and decreases slightly on its perturbation strength until 4 days after changing the lower boundary forcing.

The Influences of Various SW2 on the Major Ionospheric Migrating Tidal Components

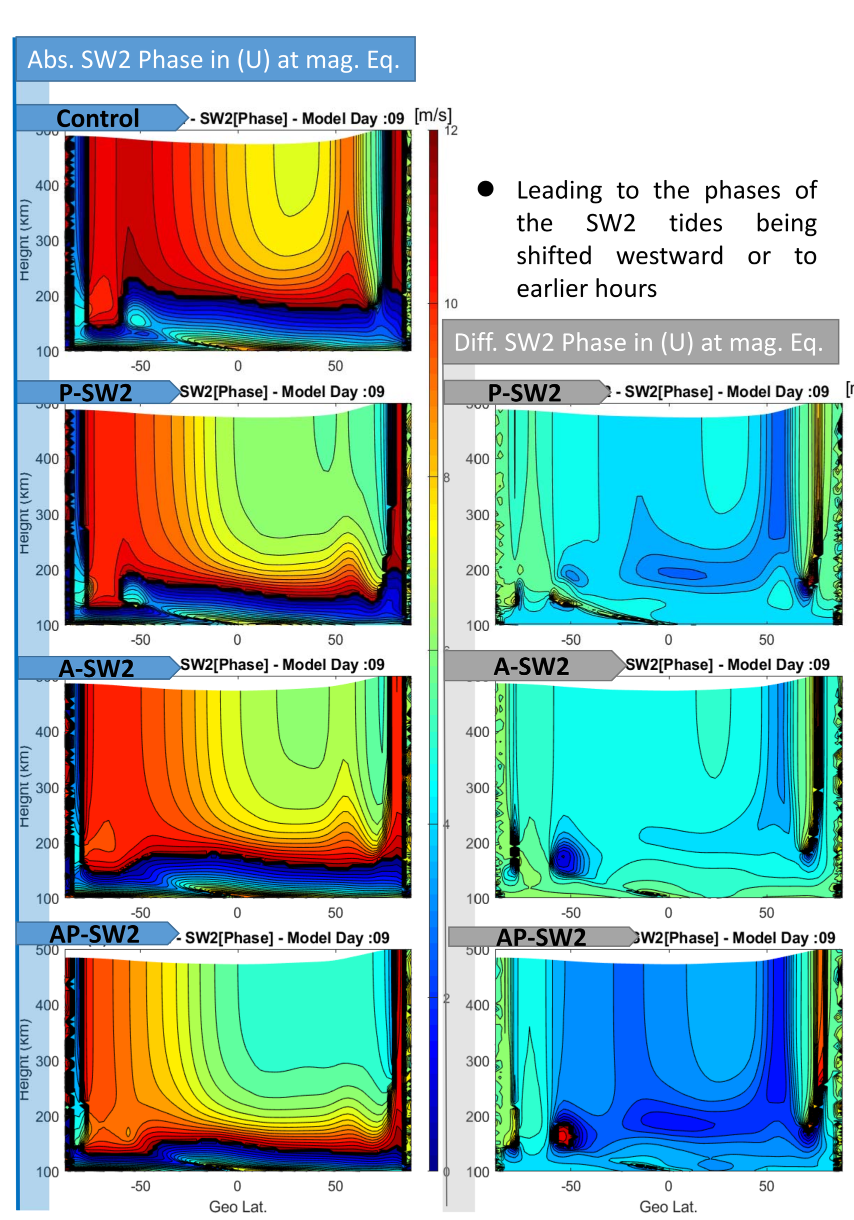


- The responses of SW2 components in the ionospheric TEC are sensitive to the SW2 tidal wind, which get intensified at both EIA crests by the increasing semi-diurnal E x B vertical drift.
- For the case, which the SW2 are intensified. The zonal and diurnal mean TEC decrease immediately, and become prominent along day. Can be attributed from:
  1) E x B vertical plasma drift modification at first three days.
  2) Decreased [O/N2] ratio due to tidal mixing effect
- o The asymmetry responses in tidal component may result from the meridional transportation of plasmas.

The Influences of Various SW2 on the Zonal and Diurnal Mean & SW2 tidal Phase in (U)



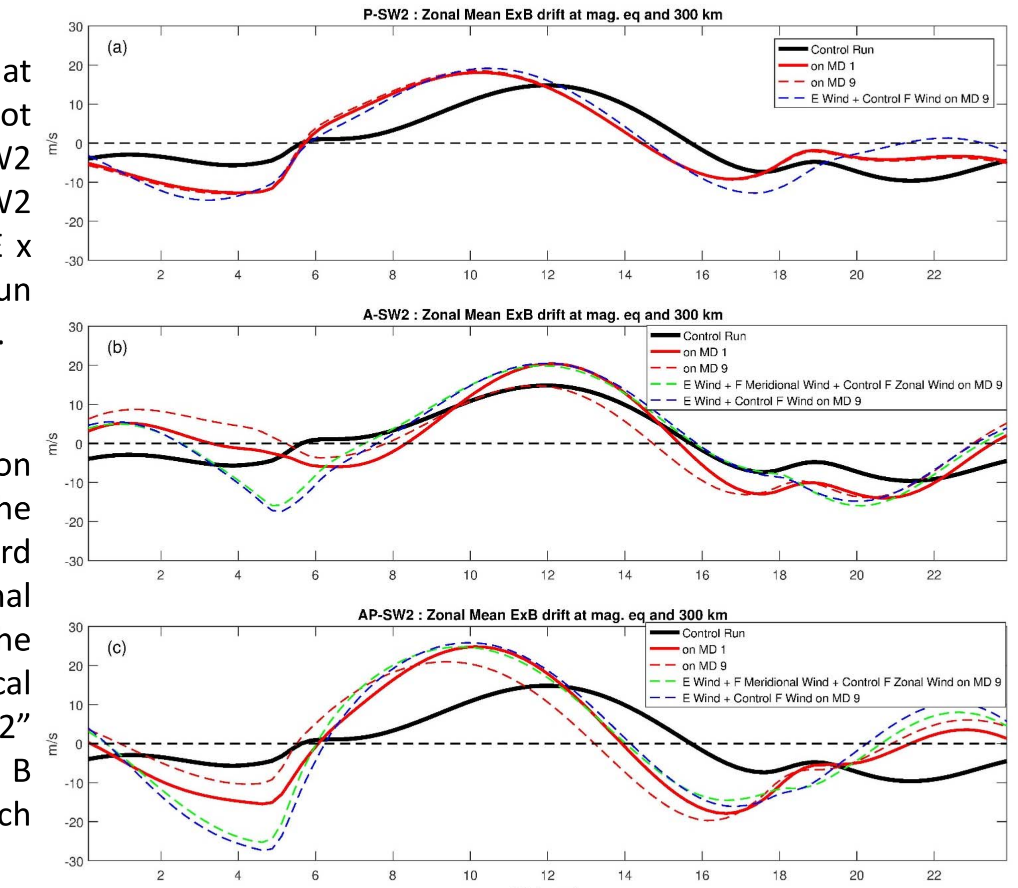
- The zonal and diurnal winds of zonal wind are accelerated westward by the increase of SW2 amplitude in both E and F region due to the tidal dissipation, and the time scales to reach equilibrium (4 days) are almost equal to ExB perturbation.
- Where the zonal wind are accelerated at low latitude mesosphere and thermosphere between ± 40 degress.
- The phases of SW2 in the F region decrease more than the phase shifts (2 hr earlier) at the lower boundary.
- The phase shift occurs due to the tides launched in the source region being pushed more in direction of the westward wind



- Leading to the phases of the SW2 tides being shifted westward or to earlier hours

The Influences of Zonal Wind Acceleration due to Tidal Dissipation on the Equatorial E x B Vertical Plasma Drift

- To further elucidate the contribution from the westward accelerated zonal mean zonal wind in the F region, an attribution method is applied (similar to Liu and Richmond, 2013), where the zonal mean zonal winds above 150 km are substituted by control run wind field, then a single step TIE-GCM simulations are performed for the cases of amplifying SW2 amplitude.
- It also clearly shows that increment of E x B could not sustain for the amplifying SW2 amplitude (A-SW2 & AP-SW2 case), even make the upward E x B drift lower than the control run for the "A-SW2" on model day 9.
- When applying the attribution method aforementioned, the results indicate that the westward acceleration of zonal mean zonal wind resulting in suppressing the daytime (LT 6-18) upward vertical E x B drift. But for the "AP-SW2" the daytime increment of E x B would not be suppressed as much as "A-SW2".



Summary and Conclusion

- A-SW2 results in general ionospheric TEC reduction during 5-12 and 18-21 LT with a brief enhancement around 15 LT, nevertheless, the TEC enhancement could not sustain for more than 3 days, contradicted to the typical observation of ionosphere SSW effect in TEC
- The typical ionosphere SSW effects featured by the morning enhancement and afternoon diminish of EIA (TEC and vertical E x B drift), are reproduced qualitatively by applying P-SW2. However, the magnitudes of variations are underestimated by 30 %.
- It takes 3-4 days for the responsed vertical E x B variation to become steady for A-SW2 and AP-SW2 modifications. Such delay is not seen for P-SW2.
- It is worth to consider that the SW2 variability during the SSW event, it has different time scale in producing ionospheric effect depend on amplitudes/phases modulation of SW2.
- The F-region wind plays a role to retard daytime vertical E x B drift to suppress the upward drift velocity though the significant westward acceleration of zonal wind for amplifying the SW2 amplitude