Climatology of the nighttime thermospheric winds over Sutherland, South Africa.

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Abstract

We present first observation of climatology of nighttime thermospheric neutral winds between February 2018 and January 2019 measured by a Fabry-Perot interferometer (FPI) located in Sutherland, South Africa (32.2◦S, 20.48◦E; geomagnetic latitude: 40.7◦S). This FPI measures the nighttime oxygen airglow emission at 630.0 nm, which has a peak emission at an altitude of roughly 250 km. The annual meridional and zonal winds at this location vary between -100 and 150 m/s and show typical midlatitude seasonal variations. During local summer months (December-February), the meridional wind is predominantly equatorward from dusk to predawn. During the winter months, the meridional wind is poleward from dusk, turns equatorward around midnight.

The zonal wind velocity is generally eastward during the evening until before midnight, changing westward post-midnight. The zonal wind peaks at higher velocities during the winter months compared to the summer months. The eastward-to-westward transition occurs later during the winter months compared to the summer months. We compared horizontal wind model (HWM14) with the FPI measurements and found a better agreement between measured winds and predicted winds for the meridional component compared to the zonal component.

Introduction: Thermospheric wind

- Thermospheric neutral wind is defined as the mean velocities of particles within a small parcel of air in the thermospheric altitiudes (Harding, 2017).
- Wind dynamics depend on and are affected by time of day, season, solar activity, geomagnetic storms, gravity waves, and tides.
- Thermospheric wind plays an important role in both structure and motion of the ionosphere-thermosphere (Liu et al.,2003) , for example thermospheric wind affects the shape height and evolution of F2 layer (e.g., Rishbeth, 1967, Titheridge, 1995).

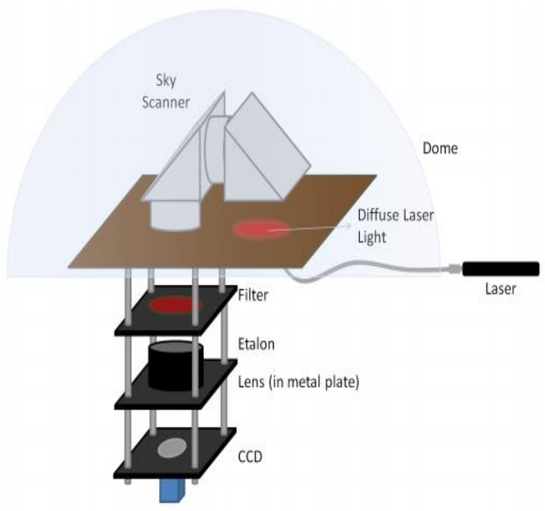
Despite their significant contribution to ionosphere-thermosphere dynamics, they are generally insufficiently sampled due to lack of instrumentation, in particular over the African continent, leading to lack of insufficient information on global wind dynamics.

Objectives of study

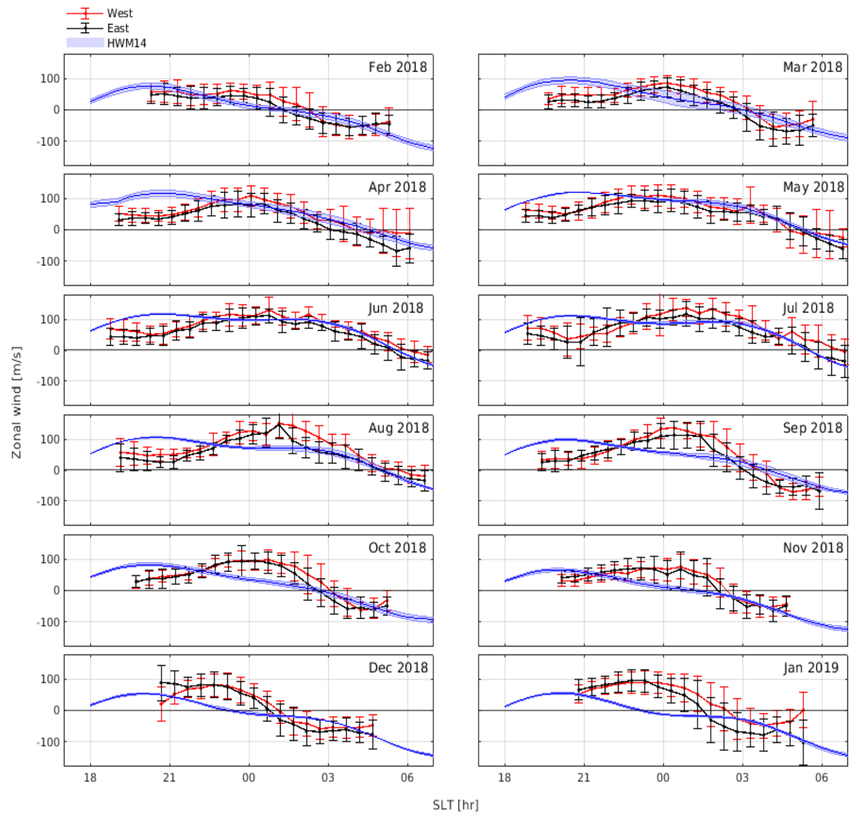
- Study temporal variations of neutral winds measured by Fabry-Perot interferometer (FPI) in Sutherland, South Africa.
- Validate and improve 2014 horizontal wind model (HWM14) predictions of this region.

Data and Method

- The FPI used is designed to measure the spectral line shape of the airglow emission at a specific wavelength of 630.0 nm.
- The nighttime redline emission naturally occurs at an altitude of approximately 250 km. By measuring the doppler shift of this emission at high spectral resolution, the FPI can be used to estimate line-of-sight neutral wind velocities.
- A typical observing set up for our FPI deployment observes the zenith direction, followed by each of the four cardinal directions (north, east, south and west) at an elevation angle of 45◦.
- FPI winds measurements that remain after data quality check are used to calculated monthly averages and standard deviations at 30 minutes time intervals.
- We compare the measurements to HWM14, which is a quiet time model for the upper atmosphere, therefore any night where Kp > 3 is removed.



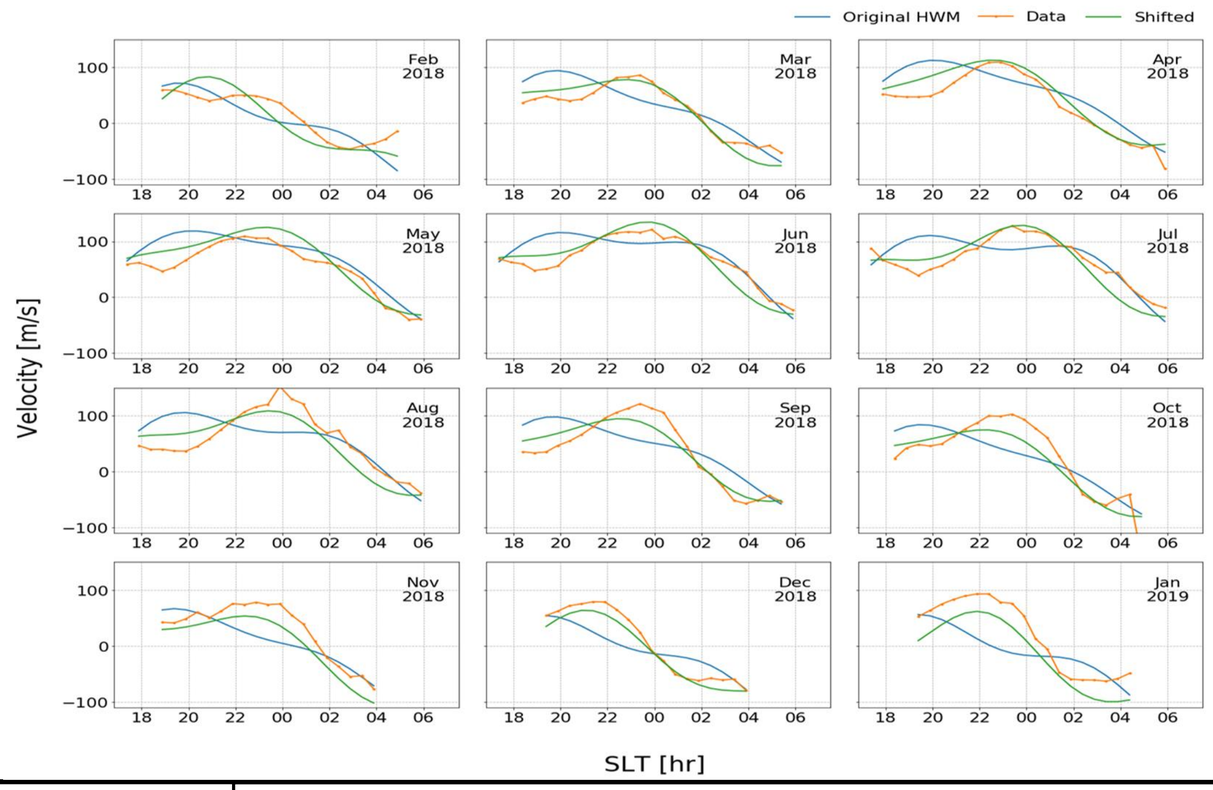
Results and discussions: Zonal wind



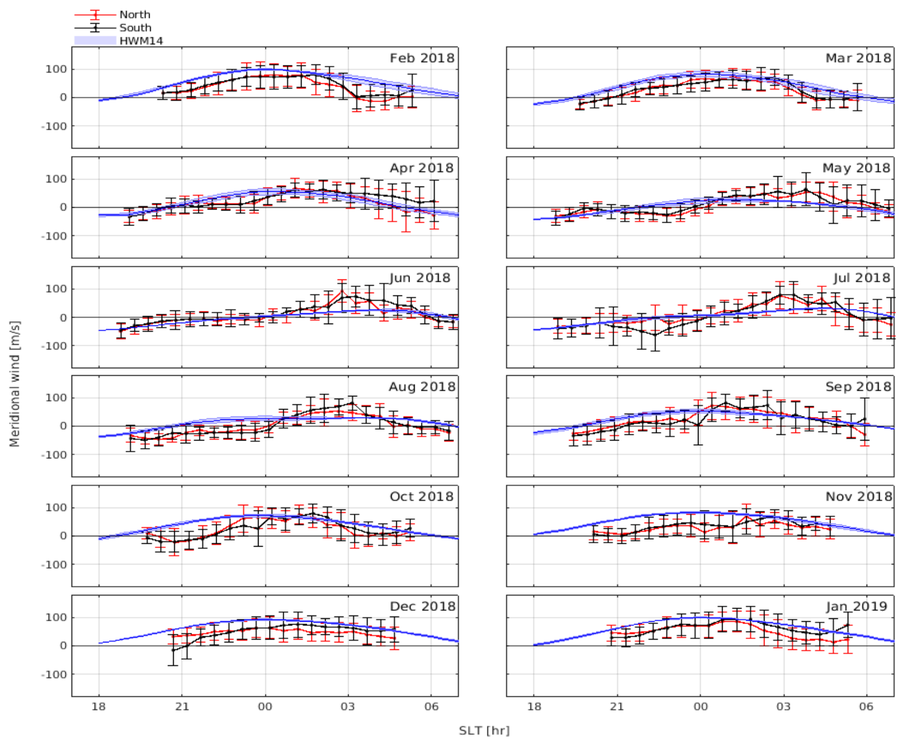
- Zonal winds is predominantly eastward before midnight, and westward post-midnight until predawn.
- The eastward-to-westward transition time is earlier around summer (e.g. 01:30-02:00 SLT for November-February) and later for winter (e.g. 04:00-5:30 SLT for March-October).
- Zonal wind peaks at ~90-120 m/s, with lower values during spring and autumn compared to winter and summer.

Comparison with HWM14

- The eastward-to-westward transition time predicted by the HWM14 model is similar to those measured by the FPI for most months, e.g. February-October, except for November-January which shows discrepancies as large as ~2 hours.
- The amplitude of the peak zonal wind estimated by HWM matches the data relatively well, however the time of the peak is seems to be phase shifted.
- Investigations revealed that the apparent phase shift is due to terdiurnal tide in HWM zonal wind. Shifting the HWM14 wind by this tidal component yielded better agreement between the model and measurements.



Results and discussions: Meridional wind



- For most months (March-October) the observed meridional wind is poleward after dusk, turning equatorward at ~21:00-02:00 SLT and remaining in this direction for the rest of the night or turning poleward again a couple of hours before dawn, except for summer winds (February, November-January) which are equatorward throughout nighttime.
- The poleward-to-equatorward transition time occurs earlier in autumn and spring compared to winter.
- Meridional wind peaks at ~70-90 m/s for most months, except in May-August (i.e. winter) where the peak is ~40-60 m/s.

Comparison with HWM14

- The HWM14 model generally captures a similar wind trend for spring and summer months (January-February, October-December) compared to other seasons.
- HWM14 similarly shows lower wind amplitudes during the winter months (May-August) compared to summer months (February, November-January).
- The model predicts peak of meridional wind much earlier during April, August-January, while peak occurs later during June-July compared to measurements from the FPI.

Summary

- For most months (March-November) the observed meridional wind is poleward after dusk, turning equatorward and remaining in this direction for the rest of the night or turning poleward again a couple of hours before dawn.
- The zonal wind is mostly eastward during pre-midnight hours and westward during post-midnight hours.
- There was better agreements between FPI measured winds and HWM14 predicted winds for the meridional component compared to the zonal component.
- The model predicted zonal wind peak and direction transition several hours before measurements, which was attributed to the turdinal tidal component in the model.

References

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