Observed and Modeled Thermospheric Winds at Low Latitudes

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Introduction

Measurements and understandings of thermospheric wind dynamics can address many scientific questions regarding geospace phenomena. This poster aims to evaluate the performances of few modeled (LLIONS, CTIPe, HWM-14, MENTAT, and SAMI3) wind results and observed (SOFDI) equatorial thermospheric winds in Huancayo, Peru.

- **SOFDI Observation:**

Second-generation, Optimized, Fabry-Perot Doppler Imager (SOFDI), a triple-etalon Fabry-Perot interferometer, is the relocatable FPI system which is currently deployed and operating near the geomagnetic equatorial latitude in Huancayo, Peru (Geo:12.1°S, 75.3°W; Mag: 1.9°N), and utilized the OI 630-nm emission for 24-hour thermospheric wind observations.

SOFDI Wind Climatology

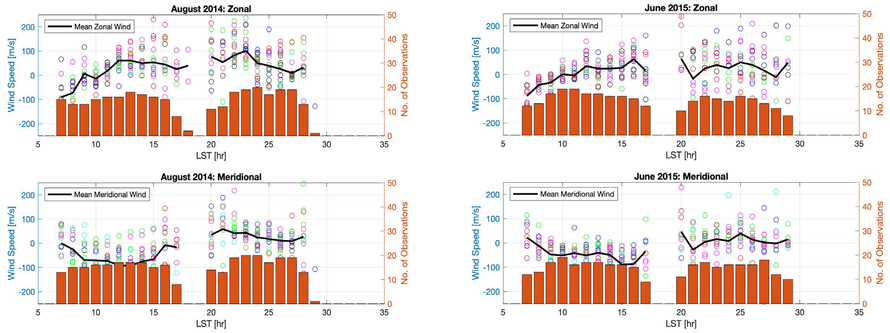

Figure-1

Left Panel: The zonal (top) and meridional (bottom) 630-nm winds measured by SOFDI placed into 1- hour time bins (colored circles) for August, 2014. The black curve represents the monthly mean wind. The red bar graphs showing the number of observations that are done in each hourly bin.

Right Panel: Same as left panel, but for June, 2015.

- **LLIONS Model:**

Low-Latitude IONospheric Sector (LLIONS) model is originally inspired by the Low-latitude ionosphere model (LOWLAT) [Anderson, 1973], and mainly based on the low-latitude portion of the Ionospheric Forecast Model [Schunk et al., 1997]. Here, neutral winds are estimated using a physics-based inverse-modeling approach on the LLIONS model, which utilizes vertical drift measured from Jicamarca Incoherent Scatter Radar (ISR) as one of the inputs in this analysis.

- **HWM-14:**

The horizontal wind model 2014 (HWM-14), an empirical model, is used here to calculate the meridional and zonal components of the horizontal neutral wind at equatorial thermosphere for 250 km altitude.

- **CTIPe Model:**

The Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe) model is a non-linear, coupled thermosphere-ionosphere-plasmasphere physically based numerical code that includes a self-consistent electrodynamics scheme for the computation of dynamo electric fields. Wind components are modeled for 250 km altitude range at equatorial latitude.

- **SAMI3 Model:**

The SAMI3 is a 3D, physics-based model of the ionosphere developed at the Naval Research Laboratory (NRL). The neutral composition and temperature in SAMI3 model are provided by NRLMSISE00 model. SAMI3 uses the HWM-14 as its internal neutral wind model and also uses a unique, nonorthogonal, nonuniform, fixed grid.

- **MENTAT Model:**

The Magnetic mEridional NeuTrAl Thermospheric (MENTAT) model provides an improved time-dependent, global empirical specification of the upper atmospheric tides and general circulation patterns. The magnetic meridional winds are similar to those from the well-known HWM14 model but there are important differences. The HWM14 has no solar activity dependence but MENTAT incorporates that as well.

Effects of Meridional Winds on EIAs

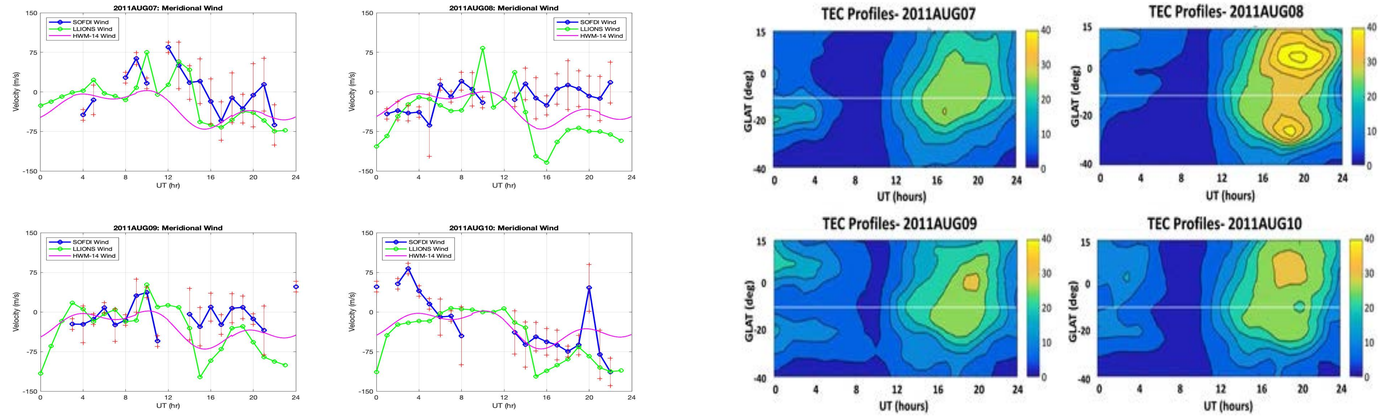

Figure-2

Left 4 Panels: The blue (green & magenta) curve with circles is the observed (modeled) meridional wind velocity by SOFDI (LLIONS & HWM-14), and the vertical red lines represent the error bars of the measured wind as a function of Universal time (UT) for 4 days (07, 08, 09, and 10 August 2011). The modeled results show reasonably good agreement within the error range of measurements by SOFDI at the geomagnetic equator for similar conditions.

Right 4 Panels: Contour plots of total electron content (TEC) distribution corresponding to left panel days. The white horizontal line represents the location of the geomagnetic equatorial line. GLAT, geographic latitude. The equatorial ionization anomaly (EIA) corresponding to weak meridional wind velocities are the most symmetric.

[Adapted from *Khadka, et al.*, 2018]

Winds from SOFDI, HWM-14, CTIPe Model, SAMI3 Model, and MENTAT Model

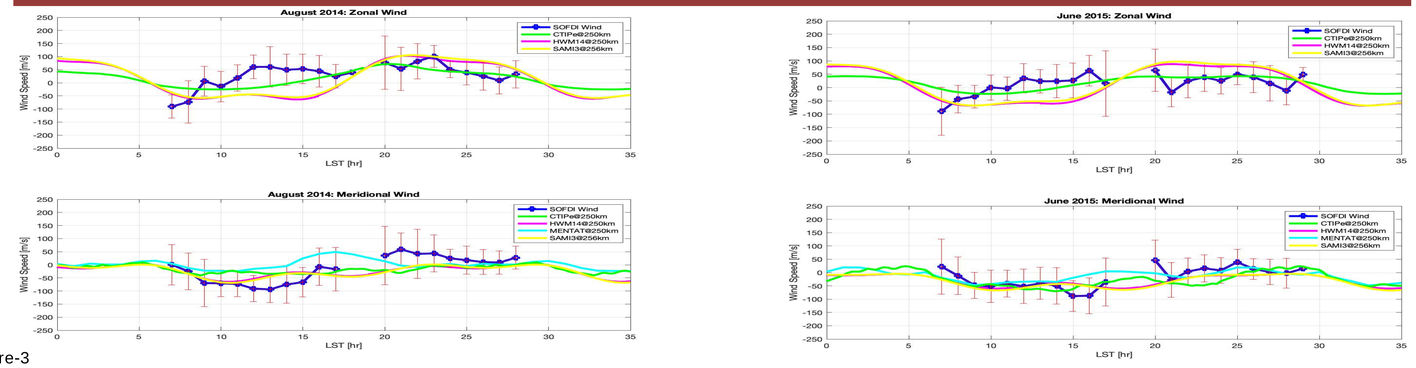

Figure-3

The blue (green, magenta, cyan, & yellow) curve with circles is the observed (modeled) zonal and meridional monthly averaged wind components into 1- hour time bins by SOFDI (CTIPe, HWM-14, MENTAT, & SAMI3), and the vertical red lines represent the error bars of the observed wind for August, 2014 and June, 2015. The modeled results show reasonably good agreement within the error range of measurements by SOFDI at the geomagnetic equator.

Takeaway: The measured and modeled meridional winds obtained from the SOFDI instrument, CTIPe, HWM-14 model, SAMI3, and MENTAT respectively match climatology. Zonal winds are likewise consistent, EXCEPT for the daytime portion. The SOFDI zonal winds matched better with CTIPe model results than that of the HWM-14 and SAMI3 model in the daytime portion. The deviation of measured winds from modeled climatological averages might be due to lower atmospheric waves dripping up in the thermosphere or/and change in emission layer heights.

Summary

- The ground-based observed SOFDI wind data system can be used as a benchmark for validating/ improving various thermospheric neutral wind models and also be used as inputs or boundary conditions for physics-based models of the upper atmosphere.
- The overall agreement between the observed and modeled wind results is very good. The measured SOFDI meridional winds correspond well to modeled (LLIONS, CTIPe, HWM-14, SAMI3,, and MENTAT) wind results, EXCEPT for the daytime eastward winds seen in the 630-nm emission.
- The daytime SOFDI zonal winds matched better with CTIPe results than that of other models. For instance, by increasing the model spatial resolution, including prompt penetration electric fields from an empirical model, improving the lower boundary conditions, implementing the International Geomagnetic Reference Field (IGRF) might overcome the above discrepancies between observed and modeled results. Some of these works are in progress now.

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