Effects of disturbance wind on equatorial regions recorded by the Fabry-Perot Interferometer network over Peru

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ABSTRACT

We used zonal and meridional winds measurements from the Fabry-Perot Interferometers (FPI) at Jicamarca, Nazca and Arequipa and ionosonde data from the Jicamarca Radio Observatory to study nighttime disturbance dynamo wind effects over Peru due to the May 2016 and April 2012 geomagnetic storms. We used the novel data technique developed by Harding et al [2015] to obtain the smoothest thermospheric wind field from the line-of-sight winds measured by the FPI network. The quiet-time wind pattern are in good agreement with results from the HWM14. The storm and post storm zonal winds are westward, have large amplitudes (up to about 80 m/s) over the whole nighttime period and last for about 3 days after the storm main. The meridional wind disturbances have amplitudes of up to about 50 m/s but are short-lived (lifetimes about 2-3 hours) and have faster recovery times. The DWM model significantly underestimate the amplitudes and lifetime of the zonal wind disturbances and does account for the short-lived meridional wind disturbances. TIEGCM simulations correctly the storm and post storm westward wind disturbances and the faster decay of the meridional wind perturbations, but overestimate the life time of the zonal wind disturbances.

INTRODUCTION

Fabry-Perot interferometer measurements have been made from Arequipa (16°27' 56.60''S, 71°29'35.6''W), Peru since 1983. These measurements determined the seasonal and solar cycle dependence of the nighttime thermospheric neutral winds and temperatures and their relationship to equatorial airglow depletions [e.g. Biondi and Meriwether, 1985; Meriwether et al., 1997, Biondi et al., 1999].

FPI measurements over Peru made from Jicamarca (11°57'29.72''S, 76°51'32.44''W) since 2009, and from Nazca (14°58'21.72''S, 74°53'29.01''W) since 2011 were used in numerous more recent studies and in climatological neutral wind models [e.g., Drob et al., 2015; Meriwether et al. 2016]. The extensive the Peruvian thermospheric neutral measurements for significantly more detailed studies of their quiet and storm time variability and of their drift coupling to plasma drifts measured by Jicamarca radar.

We present our initial results on the response of nighttime thermospheric neutral winds to enhanced geomagnetic activity using data during and after the April and May 2016 geomagnetic storms analyzed with the using the novel technique presented by Harding et al. [2015].

INSTRUMENTATION & DATABASE

• **Fabry-Perot Interferometer network**: Mechanical-Optical instrument designed to collect airglow photons using an etalon and a 630nm oxygen line filter. Located at 3 specific locations: Jicamarca (MRH), Nazca(NZK) and Arequipa(A3O), as observed in Figure 1, they point to different common locations and cardinal points in the sky to map out the thermospheric wind. These instrumentation has been taking data since 1983 at A3O, since 2009 at MRH and since 2011 at NZK as observed in Figure 2 collecting up to 47535 hours of operation since 2009.

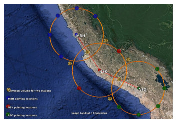

Figure 1. Geographic locations of the FPI network in Peru labeled as MRH, NZK and A3O. Multi point locations of the data recorded by each of the instrument (blue, green and red dots) with common volume locations (yellow dots).

	Hours per year									Total
	<2009	2009	2010	2011	2012	2013	2014	2015	2016	
JRO	-	888	2664	2425	3272	2438	2343	2624	1711	18365
A3O	7547	1130	1490		1337	1846	818	1457	1465	17090
NZK	-	-	96	2119	3434	2780	619	753	2279	12080

Table 1. Number of operation hours for available for each FPI.

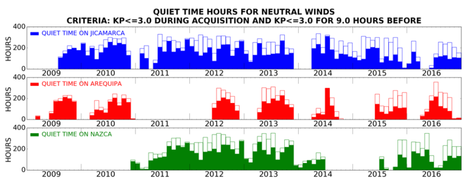

Figure 2. Timeline of the number of operations available for each FPI. Colored regions show the number of quiet time hours available for each FPI.

METHODOLOGY

The standard method of estimating the zonal and meridional winds consists in expressing the wind components in terms of smooth pre-determined functions. Recently, Harding et al. [2015] described a novel analysis technique for estimating the neutral wind field using multi-site observations that makes no assumptions on functional dependence of the wind field. This technique determines the smoothest wind field that agrees with observations using an inverse optimization theory.

In this procedure, the line of sight wind velocities from the FPI network, are used to estimate the thermospheric wind map that best fits the data, under the constraint of finding the smoothest wind field (defined in terms of the roughness of the wind field). The roughness is defined to the first and second derivatives on every pixel of the field.

This procedure was applied for the extensive database available to get the zonal and meridional equatorial winds for the central region of Peru. For this we did not estimated by the vertical winds due to reduce the number of unknowns to estimate to and used a grid of 1x1 points due to the small number of FPI in the network.

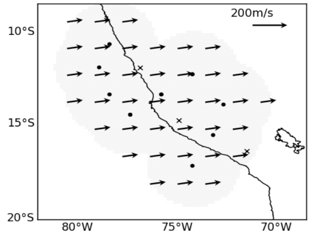

Figure 3. Thermospheric wind map for the central region of Peru for the 8 May at 0145 UT (2045 LT) estimated from the FPI network measurements.

RESULTS

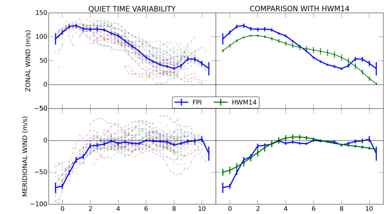

Figure 4. Quiet time (average Kp< 3 over the previous 9 hours) equatorial thermospheric wind variability over Peru for May 2010-2016.

- The large initial westward wind disturbances were observed at about 06 UT (01 LT) on 8 May which persisted throughout the night in Figure 5. In this case there were large relatively short-lived northward wind perturbations near 06 UT. Also, there is a increment of the HmF2 at about 02 UT (21 LT) which onset Spread-F instabilities around midnight and about 08 UT (03 LT).
- Large westward wind perturbations were observed from about 03 to 10 UT on 9 May, following the large increase in the HmF2 shown by the ionosonde data. Strong spread F occurrence precluded HmF2 measurements between 01:30 and 03:30 UT. Large southward perturbation is observed at midnight.
- The amplitudes of the westward wind perturbations were significantly smaller on 10 May. In this case the there was again a large short-lived northward wind perturbation around 06 UT. The ionosonde stopped operations due to some maintenance procedure.
- The westward and northward perturbations are gone for 11 May and wind came back to normal. The HmF2 is also observed to come back to normal with the PRE at early night and increment at early morning.

- The zonal winds are eastward throughout the night with a maximum of about 120 m/s at about 02 LT (21 UT) with a secondary maximum at about 03 LT (08 UT) in Figure 4. This patterns agrees with the climatology presented by Meriwether et al [2008].
- The meridional winds are strongly southward at early night and decreases in magnitude as the night progresses. They are close to zero from about midnight to close to sunrise, also consistent with results from earlier studies.
- The measured winds are in a general agreement with the climatological Horizontal Wind Model [Drob et al., 2015]. This is expected since this models used extensive Peruvian Fabry-Perot measurements.

The data quality of the wind measurements is directly related to the airglow intensity, which varies with changes in the O production layer. This height is usually highest shortly after sunset, as a result of the prereversal enhancement of the equatorial vertical drifts. This can be monitored with the Hmf2 recorded with a ionosonde at JRO. On the other hand, this rising of the layer cause plasma instabilities like Spread-F causing both lack of Hmf2 data and weak airglow intensity. These height perturbations are due to enhanced geomagnetic activity indicated by the geomagnetic indices shown in the top panels of Figure 5.

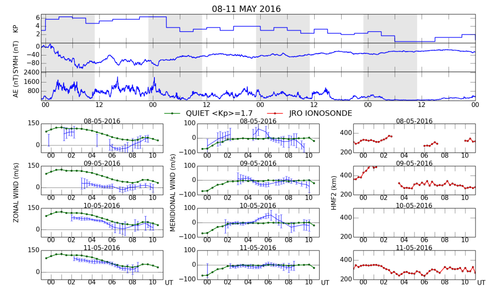

Figure 5. (Left panels) Zonal and meridional equatorial nighttime winds over Peru during and after the May 2016 storm and their quiet values (smooth curves). (Right panel) HmF2 measured by the Jicamarca ionosonde.

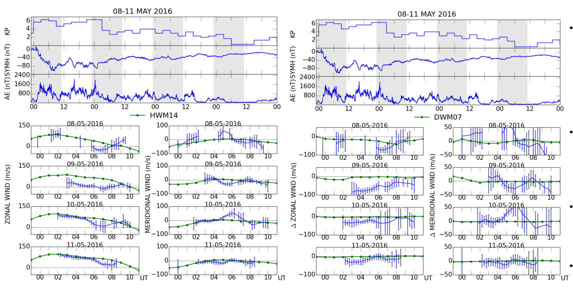

Figure 6. (Left panel) Comparisons of the nighttime winds during and after the May 2016 storm and the corresponding predictions by the Horizontal Wind Model (HWM14). (Right panel) Comparisons of the disturbance measured winds and predictions from the DWM07 model.

- The zonal wind residuals and the DWM07 [Emmert et al. 2008] in Figure 6 show westward perturbations for 8 May. DWM07 shows a maximum perturbation of about -40m/s at 08 UT (03 LT) whereas the data zonal wind show a maximum perturbation of about -80 m/s around 06 UT (01 LT). The large short-lived northward perturbation is not reproduced by the DWM07, which predicts only southwest perturbations for the same time.
- Large westward perturbation is observed for the zonal winds through the night for 9 May which are not reproduced by the DWM07. This model predicts a maximum of -10 m/s westward perturbation at early night only. Similarly, the southward perturbation is not reproduced by the DWM07.
- Small westward perturbations of about -20m/s throughout the night and a large northward perturbation peak of about 50 m/s at 06 UT (01 LT) are observed on the zonal and meridional winds at 10 May whereas the DWM07 does not predict disturbances for this night.
- Small westward perturbation is still observed around 02 to 04 UT for 11 May but and there is no noticeable perturbation for the meridional winds. DWM07 predicts no disturbances for this day.

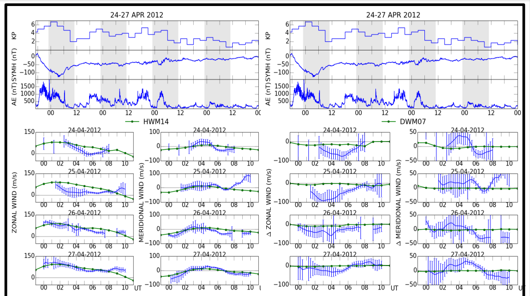

Figure 7. (Left panels) Nighttime winds during and after the April 2016 storm and the corresponding quiet time patterns. (Right panels) comparisons of the disturbance measured winds and predictions from the DWM07 model.

- The data show westward perturbations of about -80 m/s for 24 April at midnight while for the DWM07 show perturbations of about -20 m/s and throughout the night. Large northward perturbation are not reproduced by the DWM07.
- Large westward perturbations (about 100 m/s) are also observed for 25 April around 03 UT (21 LT) which are not reproduced by the DWM07. Similarly, the northward perturbations are not reproduced by the DWM07. The smaller westward meridional perturbations on 26 -27 April are not accounted for by the DWM07 as well.

SUMMARY

- We have presented equatorial FPI wind measurement during the large May 2016 and April 2012 geomagnetic storms and used ionosonde measurements to monitor the height of the equatorial F layer and the quality of the FPI data. The observed storm and post-storm effects result disturbance dynamo process [e.g., Blanc and Richmond, 1980] driven by enhanced energy deposition into the high altitude ionosphere.
- Automated FPI network enables large database to monitor effects of the disturbance wind dynamo. The wind map estimator brings a better smooth field estimation over noisy measurements for quiet and disturbed periods.
- HmF2 proves to be a good method way to monitor the quality data of FPI wind estimation.
- Our data show large (up to about 80 m/s) nighttime westward disturbances lasting for about 3 days and short-lived northward/southward perturbations with faster recovery.
- Empirical model HWM14 [Drob et al. 2015] shows a general agreement for quiet period but does not reproduce the disturbed periods.
- Empirical model DWM07 [Emmert et al. 2008] underestimates the disturbance winds for the Post-storm recovery and shows a faster recovery of about 1 day with perturbations of 3 m/s that are not consistent with measured perturbations.
- TIEGCM model studies correctly predict westward storm and post storm wind disturbances and faster decay of meridional wind perturbations, but overestimate the life time of the zonal post storm winds by a fact of about two.
- We are carrying out extensive studies on the seasonal and solar cycle of the disturbance winds and on their relationship to storm time plasma drifts measured by the Jicamarca radar.

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