EZDrifts: An analytic global model of the Equatorial F-region Zonal plasma Drifts

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Abstract: Equatorial F-region **E**×**B** drifts are a result of complex ion-neutral coupling interactions and current systems. An adequate model of the variability of the drifts indicates that the underlying drivers (e.g., neutral winds, neutral densities, collision frequencies, etc.) are properly specified. We present results of our efforts towards the development of a simple model to describe the global morphology of the Equatorial Zonal F-region Drifts (**EZDrifts**). EZDrifts is an analytic, physics-based model of the zonal plasma drifts which is driven by open-source climatological models of thermospheric and ionospheric parameters. It is a follow-up work of the zonal drift model developed by Shidler and Rodrigues (2021), hereafter referred to as SR21. In a variation to the SR21 data-model fusion approach that used as input vertical drift measurements from the Jicamarca Radio Observatory (JRO), we use vertical drifts from an equatorial empirical model to drive EZDrifts. The SR21 model was limited to the Peruvian sector and to two specific solar flux conditions. **EZDrifts, on the other hand, provides zonal drifts as a function of height for any day of year, longitude sector, and solar flux conditions. The behavior of the output zonal drifts is also controlled by input vertical drifts.** This poster describes the implementation of EZDrifts, examples of results, and a comparison with observations made by the C/NOFS satellite. The finding highlighted here is that EZDrifts can reproduce the observed longitudinal variability of the zonal drifts.

1. RELEVANCE

While vertical equatorial plasma drifts have been studied extensively, less studies have explored the importance of zonal drifts. Other researchers studying the equatorial ionosphere will therefore benefit from an easy-to-use, open-source zonal plasma drift model that is driven by a well-tested vertical drift model. Finally, studies indicate a close relationship between height-varying zonal drifts and F-region irregularities (e.g., Kudeki et al., 2007).

2. SCIENCE QUESTIONS

- **Question 1:** To what extent does a height-independent model of vertical drifts affect the height-dependence of the zonal drifts?
- **Question 2:** To what extent can EZDrifts reproduce the observed longitudinal variability of the zonal plasma drifts?

3. METHODS

- From a widely used two-dimensional model of the ionosphere (Haerendel et al., 1992), one can obtain the following field-line integrated relationship:

$$U_i = U_\phi^P + \frac{\Sigma_H}{\Sigma_P}U_L^H - \frac{\Sigma_H}{\Sigma_P}W_i - \frac{J_L}{B\Sigma_P}$$

  where U_i is the zonal plasma drift, Σ_H and Σ_P are the Pedersen and Hall conductivity, U_ϕ^P and U_L^H are the Pedersen weighted zonal neutral wind and the Hall weighted meridional neutral wind, W_i is the vertical plasma drift, J_L is the vertical current, and B is the magnitude of the geomagnetic field. Like previous studies (e.g., Richmond et al., 2015), we neglect $\frac{J_L}{B\Sigma_P}$.
- All terms are obtained from IGRF-12, NRLMSISE-00, IRI-2016, and HWM14. Note that W_i is obtained from the height-independent equatorial vertical drift model developed by Scherliess and Fejer (1999), hereafter referred to as SF99. SF99 is included in IRI-2016 but turned off by default.

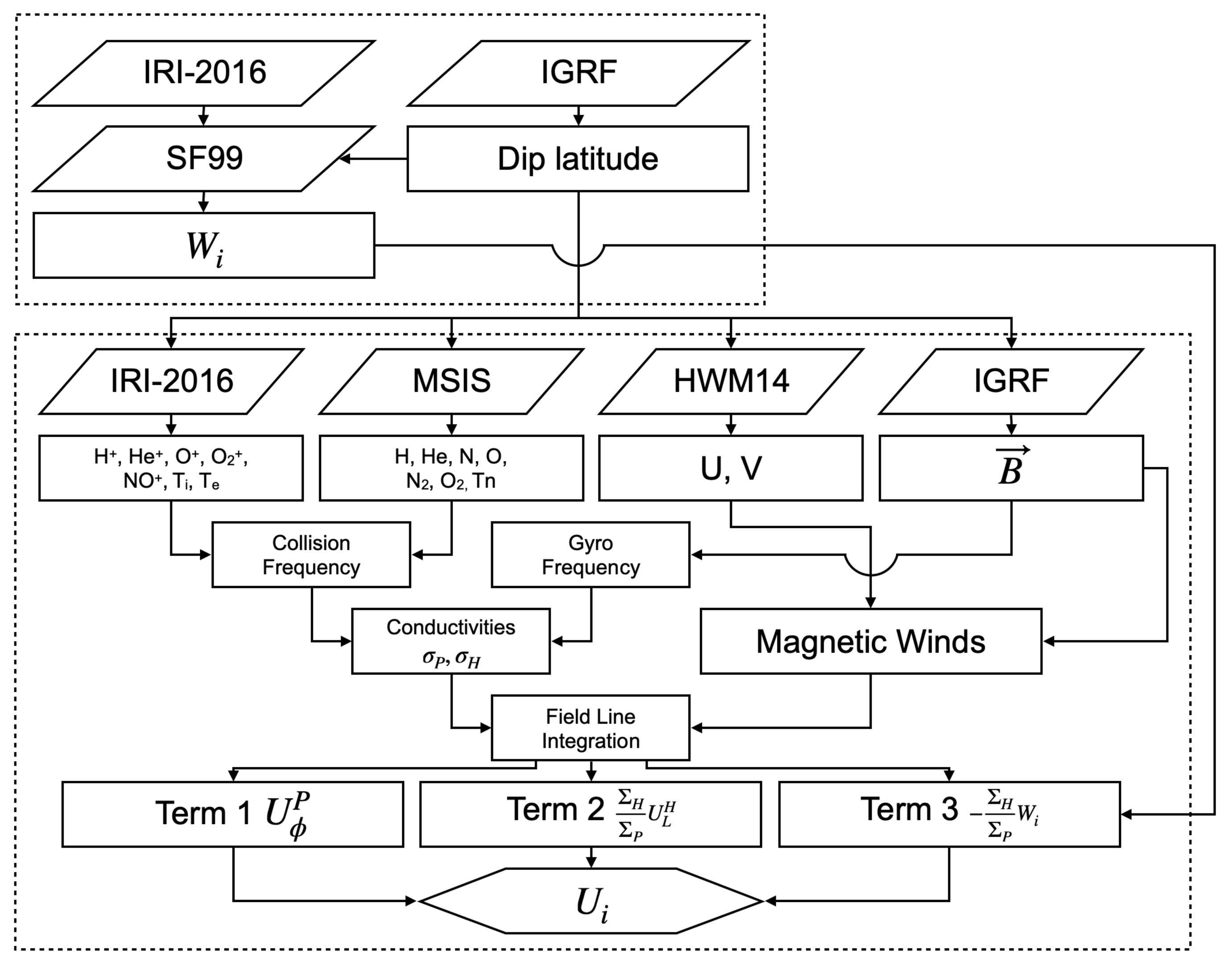


Figure 1. Block diagram of the modelling routine (EZDrifts) implemented in this work. The final output are the zonal plasma drifts (U_i).

4. RESULTS AND DISCUSSION

JRO Zonal Drifts – Low Solar Flux

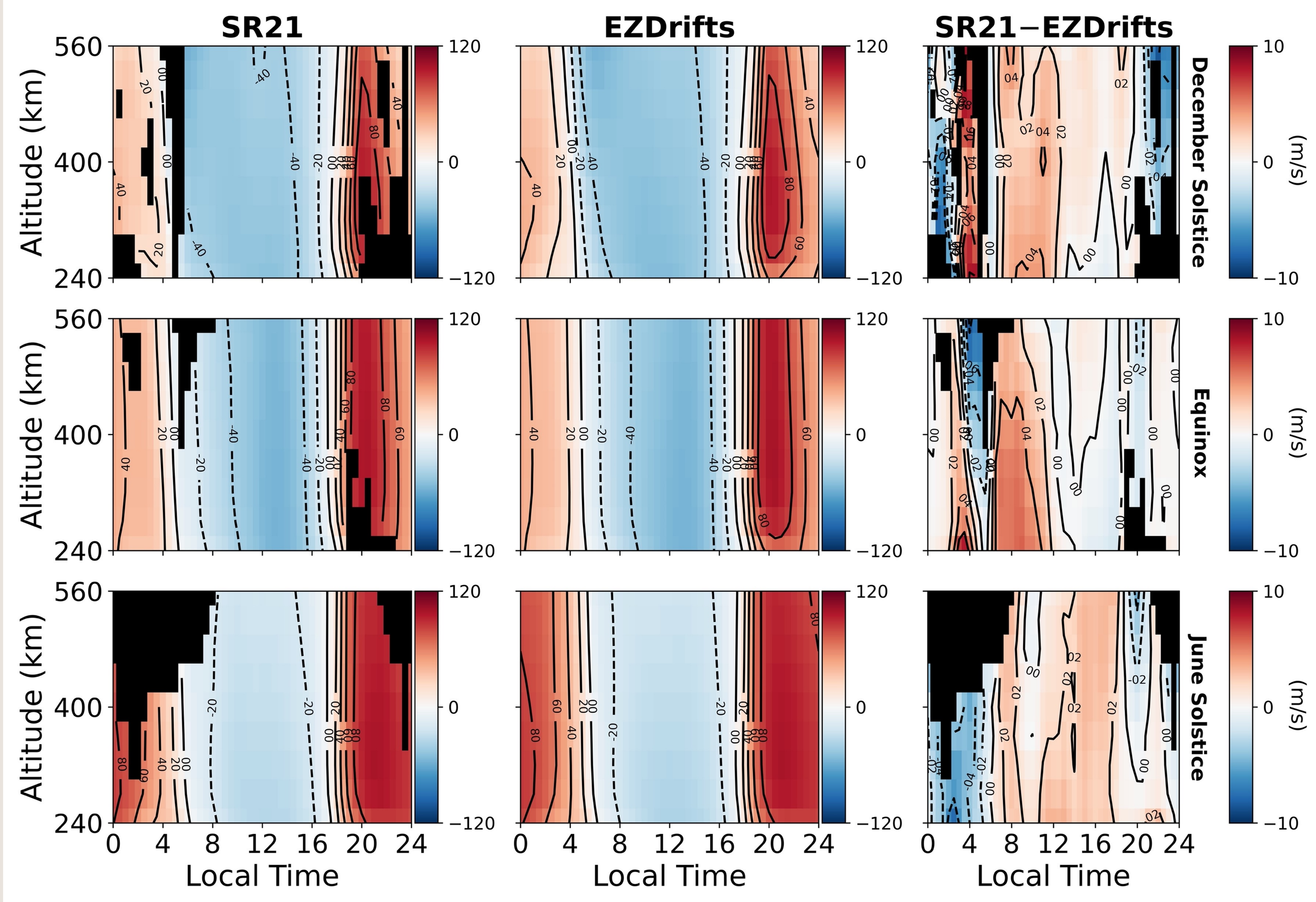


Figure 2. Zonal plasma drifts from SR21 (left column) and EZDrifts (middle column) at low solar flux ($F_{10.7}$ = 85 s.f.u. for each season). The difference between the two models is shown in the right column.

JRO Zonal Drifts – High Solar Flux

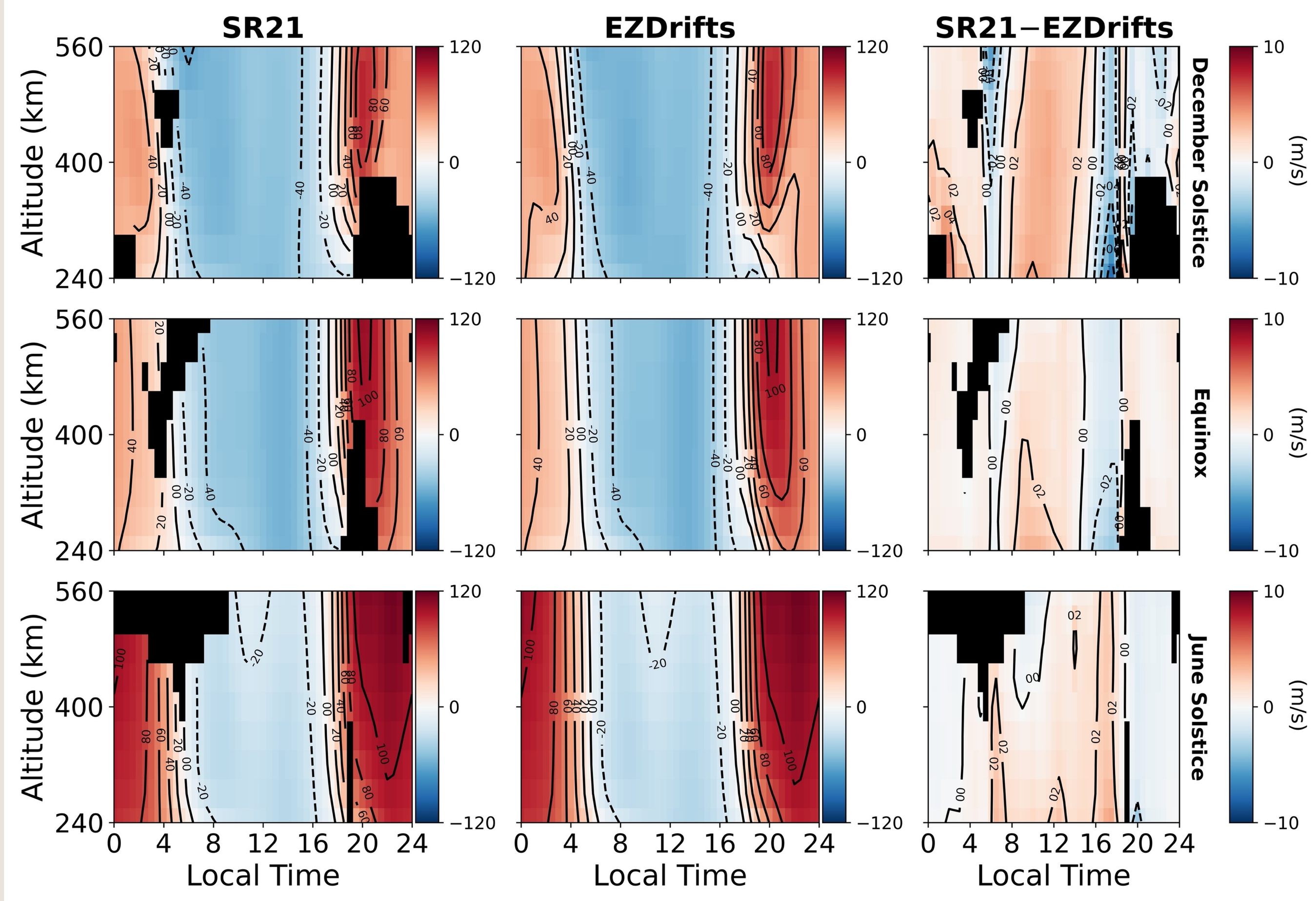
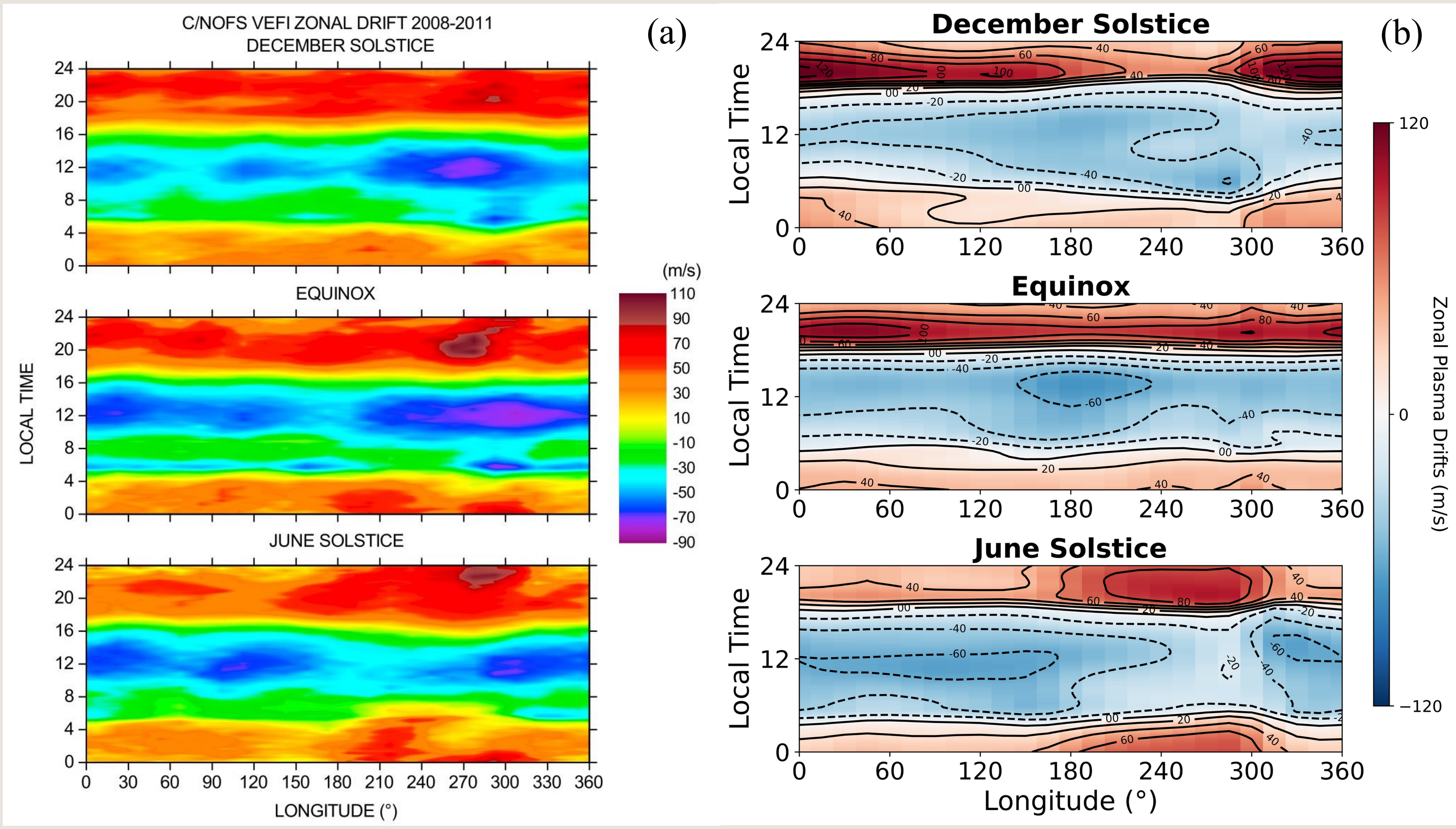


Figure 3. Zonal plasma drifts from SR21 (left column) and EZDrifts (middle column) at high solar flux (Mean $F_{10.7}$ = 143.3 s.f.u.). The difference between the two models is shown in the right column.

- Figures 2 and 3 show the height-dependence of EZDrifts and SR21 for low solar flux and high solar flux, respectively. The differences between the two model implementations show that despite using SF99, EZDrifts can reproduce a similar height-dependence of the zonal drifts as that produced by SR21.
- Figure 2 (low solar flux) shows a maximum difference between the models of 4 m/s. Figure 3 (high solar flux) shows an average difference of less than 2 m/s. At the local times when these differences occur, EZDrifts predicts zonal drifts with magnitudes as large as 60 m/s. Thus, the relative difference is small.
- We emphasize that EZDrifts uses height-independent SF99 predicted vertical drifts as input and still reproduces the height-dependence of SR21.



Parameter	Value
YYYY/MM/DD	2009/(12, 3, 6)/21
Altitude	650 km
$F_{10.7}$	73.7 SFU
IG12	3.5
Rz12	10.1
Ap	4

Table 1 (above). Input geomagnetic parameters to EZDrifts that are passed to IRI-2016, IGRF-12, NRLMSISE-00, HWM14, and SF99. Values are the averages over the dates of the C/NOFS observations. **Figure 4 (left).** (a) Seasonal averaged equatorial zonal plasma drifts measured by VEFI on the C/NOFS satellite from Fejer et al. (2013). (b) Equatorial zonal plasma drifts predicted by EZDrifts for average geophysical conditions of the C/NOFS observations.

- Panel (a) shows the average C/NOFS equatorial zonal drifts presented by Fejer et al. (2013) for the low solar flux period from May 2008 to February 2011. Note the strong longitudinal dependence of the zonal drifts for both solstices.
- Panel (b) shows our predicted zonal drifts when running EZDrifts with the inputs listed in Table 1. The zonal drifts predicted by EZDrifts show the same longitudinal variability measured by C/NOFS for each season.
- More specifically, EZDrifts predicts a weakening of the evening zonal drift magnitude in the 180°-300° longitude sector for December solstice, an enhancement in the same sector for June solstice, and a weaker longitudinal dependence for equinox.

5. MAIN FINDINGS AND FUTURE WORK

- EZDrifts reproduces well the height-dependence of the SR21 zonal drifts despite obtaining vertical drifts from the height-independent SF99 model.
- EZDrifts predicts the same seasonal longitudinal variability of the zonal drifts measured by C/NOFS for geomagnetic quiet conditions.
- We reiterate that EZDrifts can predict zonal plasma drifts for any day of year, F-region height, longitude sector, and solar flux conditions.
- We will make EZDrifts available for download so that others can model the equatorial zonal plasma drifts.

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