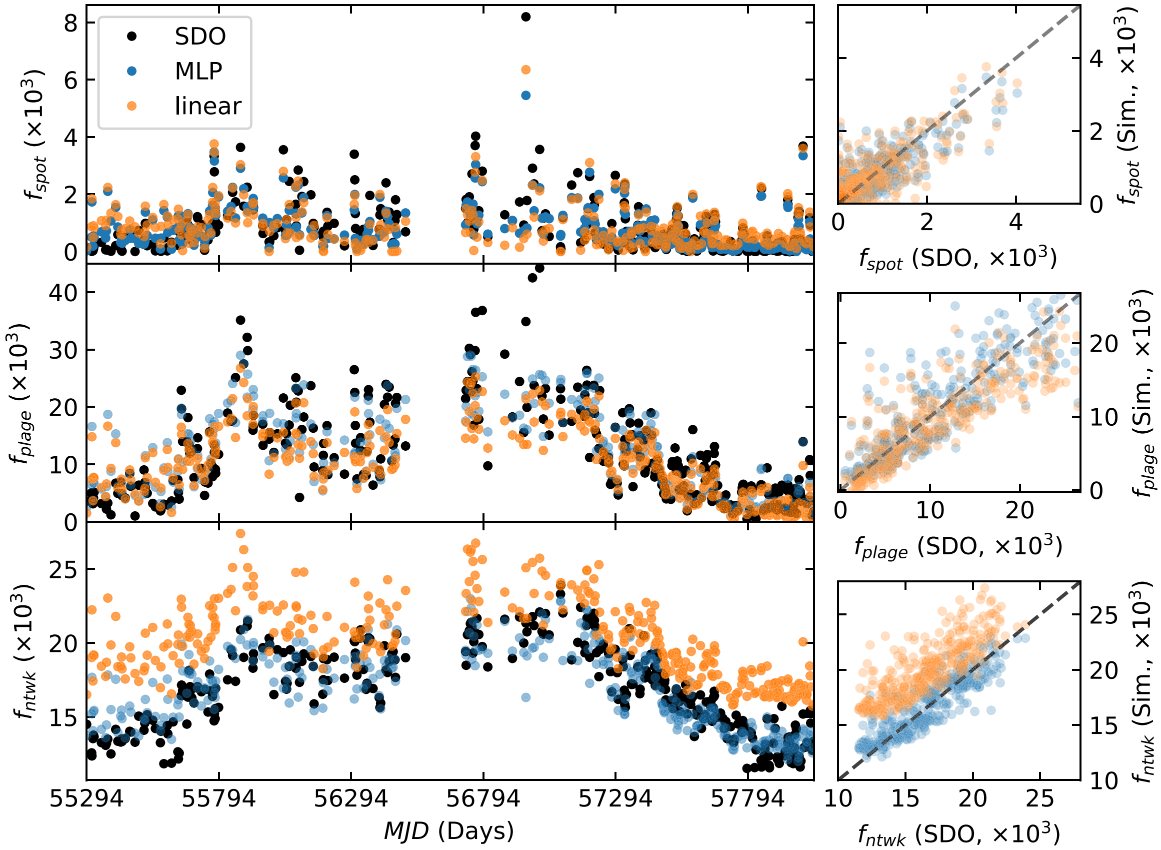

Figure 4. Comparison of the SDO/HMI-measured magnetic filling factors (black) to the machine learning (blue) and linear (orange) estimates derived from the S-index and TSI. The time series for the three filling factors are plotted in the left column. The estimated filling factors are plotted as a function of the HMI filling factors in the right column—the gray dashed lines indicate a slope of 1 and are meant to guide the eye. Both the linear and machine learning techniques reproduce the directly observed values of f_{spot}, f_{plage}, and f_{ntwk}. Note that there is a slight offset between the linear estimate of f_{ntwk} and the SDO measurements. However, this offset is well within the expected 20%–50% definitional variations reported by Meunier et al. (2010a).

Δv_{phot} are less correlated with the actual photometric shift, but still show good agreement. Interestingly, including the contributions of plage and network regions in Equation (14)—that is, adding terms $\propto f_{plage} \times \left(\frac{df_{plage}}{dt}\right)$ and $\propto f_{ntwk} \times \left(\frac{df_{ntwk}}{dt}\right)$—does not appear to increase the correlation coefficient. However, we may still conclude that the RVs calculated using Equation (15) indeed do correspond to the combination of suppression of convective blueshift and photometric RV shift described by Equation (12).

5. Discussion

5.1. Filling Factor Estimates

As shown in Figures 4 and 5, the linear and MLP estimated filling factors successfully reproduce the expected SDO spot, plage, and network filling factors. However, we note that there is a systematic $\sim$0.004 offset between the linear estimates of f_{ntwk} and the SDO-measured values. This is likely the result of the significant covariance between b_1 and $\mathcal{A}\sigma T^4_{quiet}$ in Equation (3). Any systematic errors in the measured values of $R_\odot$ and T^4_{quiet} will change the resulting value of b_1, resulting in an offset in the estimated values of f_{ntwk}. Small changes to these parameters can dramatically change the observed offset in f_{ntwk}: artificially increasing T^4_{quiet} by 0.15 K eliminates the offset entirely. This is well below the precision achieved for measurement of stellar temperatures. While we attain good precision in the solar case, in general linear estimates of f_{ntwk} should be assumed to be true up to a constant offset. As stated previously, using these filling factors to remove activity-driven signals from RV measurements only requires values correlated with the filling factor value, making this offset unimportant.

We also note that, while $R_\odot$ and T^4_{quiet} are assumed to be constants in our model, they do change in time as the result of physical processes not included in our model. These quantities also vary with wavelength: since here we are using the Ca II H&K lines and integrated visible intensity to reproduce filling factors measured at 6173.3 Å, uncertainties in these parameters associated with their wavelength dependence are inevitable. Indeed, Meunier et al. (2010a) note that measured filling factors will vary by 20% to 50% as a result of these dependencies and other definitional differences: our estimated f_{ntwk} values are certainly consistent with the SDO-measured values within these margins.

Fitting the SDO and estimated filling factors to the HARPS-N solar RVs using Equation (15) successfully reproduces the expected activity-driven RV variation. As shown in Table 7, for both the SDO-measured and MLP-derived filling factors, we see $C > D$. This is consistent with the idea that the denser magnetic interconnections available in photospheric plages are more successful in inhibiting convection and thus convective blueshifts than the sparser network magnetizations, as suggested in MH19. Indeed, we see that, using MLP estimates, the network contribution is consistent with zero and using SDO observations, the network contribution is only $\sim 2\sigma$ above zero.