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Latitudinal dependence of the fall-effect observed in the D-region and mesosphere

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The seasonal variation of the daytime lower ionosphere over the North Atlantic, monitored using the propagation of Very Low Frequency (VLF) radio waves, shows an asymmetry when comparing the spring and autumn transitions. The signal variability shows a faster rate of change from summer to winter than from winter to summer, for which the responsible mechanism is still unknown. In this study, we perform a climatological (2008–2021) analysis to determine the northern-hemisphere latitudinal dependence of the spring-fall asymmetry. We employ VLF receivers located in Peru (low-latitude), USA (middle-latitude), UK (middle-latitude), Finland (high-latitude), and Norway (high-latitude). At the same time, we employ neutral mesospheric temperature from MLS, nitric oxide (NO) from SOFIE, and gravity wave (GW) kinetic energy derived from mesospheric horizontal winds. We find that at high-latitude the VLF amplitude variability before summer and during winter follows the seasonal variation of the solar zenith angle, but the measurements during fall do not. After removing the VLF background level, a large deviation is observed during fall, which we call the fall-effect. We explore the processes behind this effect by comparing against mean temperature, NO, and GW seasonal variabilities after removing their respective background levels. We found that the three mesospheric parameters display a fall-effect. Performing a similar analysis for middle latitudes shows that the fall-effect is not clearly observed in both ionospheric and mesospheric parameters. In the case of low-latitudes, no fall-effect is observed. We discuss the possible association between the mesospheric temperature and the VLF variability through collision and absorption. We also discuss the possible role of GW on the D-region.