SECS reconstruction of ionospheric flow fluctuations observed by SuperDARN on St. Patrick's day 2015 storm

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Our previous study reported that ULF-like fluctuations of ionospheric flow as seen by Super Dual Auroral Radar Network (SuperDARN) radars appeared in the sub-auroral region and they propagated westward over a wide range of local time during a stagnant period (~10:30-12:30 UT on March 17, 2015) in the main phase of the St. Patrick's day 2015 storm. In the present study, we further analyze the observed flow fluctuations to deduce the two-dimensional (2-D) ionospheric flow field. To reconstruct the 2-D flow distribution from the observed line-of-sight Doppler velocities (LOSV) of SuperDARN radars, we employ a method of 2-D vector field expansion with the spherical elementary current systems (SECS) [Amm, JGG, 1997, Amm et al., JGR, 2010]. The merits of using this technique are that the analysis region, where a flow map is deduced from the observed LOSVs, can have any shape on a sphere and does not need to assume any boundary condition nor wavelength of spatial variation, favorable for SuperDARN observations with highly variable, non-uniform backscatter occurrence. Since we use only a set of divergence-free base functions of SECS for the present analysis, the resultant flow map satisfies by definition the incompressible flow condition (div V = 0), which is expected to hold often in ionospheric plasma flows. We apply the technique to observations of two neighboring radars, the Christmas Valley East (CVE) and Fort Hays West (FHW) radars, which share a substantial part of their field-of-views (FOV) and actually have obtained LOSV data in the common FOV for this event. The result of the flow map reconstruction shows that the analysis region between CVE and FHW generally has a slow, irregular flow during the stagnant period, in opposite to a fast eastward flow before and after the period, corresponding to strong sunward convection expected for the sub-auroral region in the morning sector during a storm main phase. The general evolution of the flow pattern is consistent with that deduced by the conventional map potential technique [Ruohoniemi and Greenwald, 1998]. It is also found that some shear/vortex-like flow structures pass over the analysis region during the stagnant period which appear to be moving westward in association with the westward-propagating flow fluctuations examined by the previous study. The existence of the moving flow shear/vortex structures indicates that a field-aligned current flows between the ionospheric flows and their magnetospheric counterpart driving the electric field fluctuations. These ionospheric observations suggest that the driving source for the ULF-like fluctuations is providing a series of shear Alfven waves toward the ionosphere in the course of its westward drifting motion.