Monitoring plasma drifts over Europe using Digisondes

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Europe is one of the few regions worldwide that is covered exceptionally well by ionosondes (Digisondes-Figure 1). With the deployment of the Cyprus SuperDARN (CyDARN) in 2026, the opportunity of comparing Digisonde with CyDARN horizontal plasma velocities will arise. A list of mid-latitude European Digisondes that operate in the drift mode and contribute to Driftbase operated by University of Massachusetts Lowell (https://ulcar.uml.edu/DriftBase) is given in Table 1.

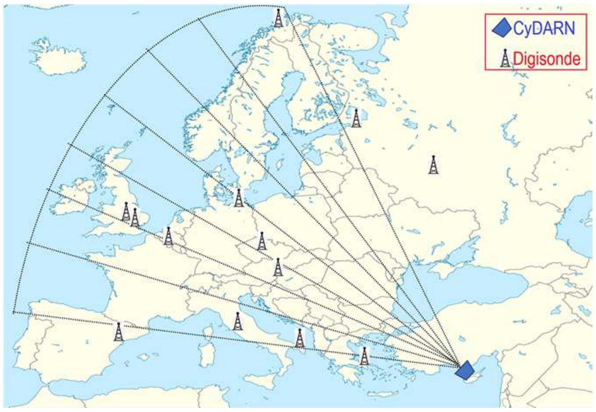

Figure 1. CyDARN field of view with overlapping European Digisonde locations.

SITE	Latitude (°)	Longitude (°)	DRIFT DATA Time resolution (min)
Athens	38.00	23.50	5
Nicosia	35.03	33.16	5
Dourbes	50.10	4.60	4.5
Fairford	51.70	1.50	15
Moscow	55.47	37.30	7.5
Pruhonice	50.00	14.60	7.5
Rome	41.80	12.50	15
San Vito	40.60	17.80	15
Tromso	69.60	19.20	15
Sopron	47.63	16.72	15
Juliusruh	54.60	13.40	15

Table 1. European Digisonde stations performing drift measurements.

Digisondes other than the time-of-flight of the signal resulting in ionograms from which they can extract ionospheric characteristics (foF2, hmF2 e.t.c.), also perform drift measurements. In between ionogram measurements (which also enable the calculation of the optimum frequency window for a drift measurement) they extract doppler shift to estimate plasma velocity components. If the ionosphere is smooth and horizontally stratified then measurements from a particular layer results in a single reflected signal. However, due to irregularities, signals are also reflected obliquely. The reflected echoes are then received by four antennas, arranged in a triangular configuration, and are subjected to Fourier analysis to identify the doppler shift in each signal. After extracting the doppler shift, the location of each source or reflection point is usually graphically interpreted on a skymap. Vertical echoes appear in the center of the skymap. Corresponding values of the doppler frequency shifts are usually distinguished by different colors of the plotted symbols. Examples of sky-maps during storm conditions over a European station (Juliusruh-Germany) are provided (Figure 2) during notable plasma convection on 17 March 2013 (upper plot) and 2015 (lower plot).

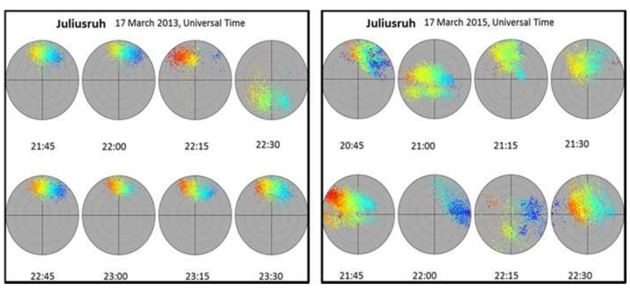

Figure 2. Sky maps over Juliusruh Digisonde in Germany on 17 March 2013 (left plot) and 2015 (right plot) indicating strong westward plasma convection.

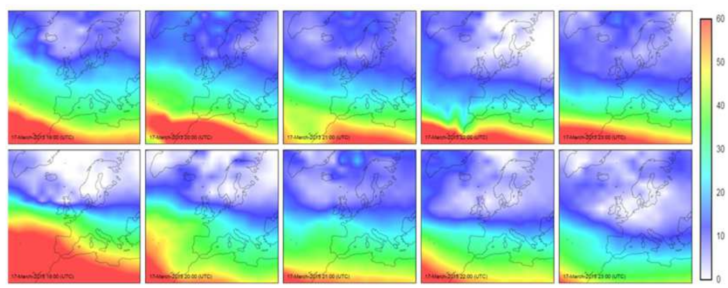

Figure 3. Strong plasma convection on 17 March 2013 (upper plot) and 2015 (lower plot) as shown on Total Electron Content maps.

Identified source locations can are further processed to calculate the bulk plasma velocity over a Digisonde. In an ideal situation, when plasma moves with a resultant velocity (in that special case the pattern of skymap points is bipolar), we can determine a velocity vector by a least-square fit of the skymap points. This approach is commonly referred to as the ''Digisonde Drift Analysis'' (DDA)''. F-region plasma drift components, (meridional (Vx), zonal (Vy) and perpendicular (Vz)) are determined using DDA under the assumption of uniform plasma velocity.

An example of the resultant estimation of the three velocity components for the 17 March 2013 and 2015 storms is given in Figure 4 over the European station of Juliusruh (Germany) indicating strong westward plasma convection during the recovery phase of the two events. Although the software incorporated into the Digisondes is capable of automatic estimation of the plasma velocity it was shown that the results are often biased due to improper layer identification. This often leads to incorrect statistical evaluation mainly because different ionospheric regions (E, F1 and F2) are treated as one homogeneous region giving unrealistic results.

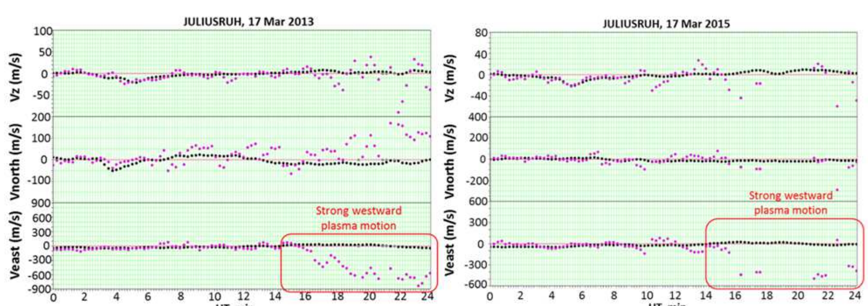

Figure 4. Calculated velocities from sky map analysis over Juliusruh Digisonde in Germany on 17 March 2013 and 2015 indicating strong westward plasma convection. Background monthly median velocity pattern is also shown (in black dots) as a reference.

References

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