Ionospheric disturbances due to the 2017 American solar eclipse detected at a European observatory

Solar-Terrestrial Centre of Excellence

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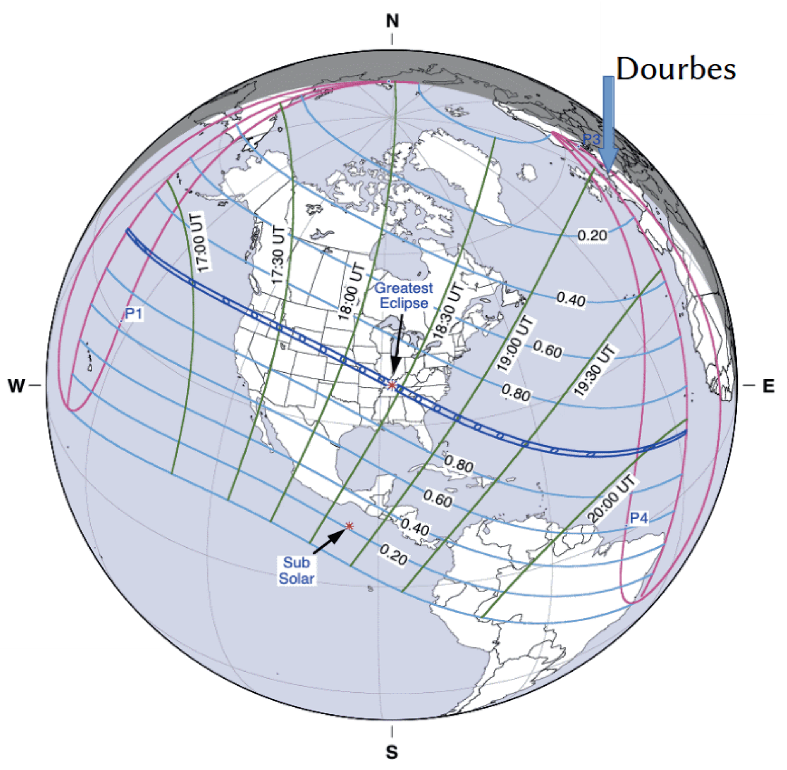
A total solar eclipse occurred on 21 August 2017, with the path of totality crossing the entirety of North America, starting in the Pacific Ocean and ending over the Mid-Atlantic Ocean. The ionospheric observatory in Dourbes, Belgium, was at the edge of the partial eclipse and was exposed for only few minutes just before the local sunset. A special campaign of high time resolution ionospheric measurements—identical to the one used to observe the 2015 European eclipse—was carried out at the observatory with collocated digital ionosonde and GNSS receiver.

Various data sets were obtained from the ionosonde and GNSS receiver on the day of the eclipse as well as the days before and after. Analyses of these data series reveal wave-like disturbances in the ionosphere arriving before the local onset of the eclipse.

The solar eclipse



Map showing the path of the 21 August 2017 solar eclipse (credit: NASA). The location of the ionospheric observatory at Dourbes, at the very edge of the eclipse path, is indicated.

A total solar eclipse occurred on 21 August 2017. The first contact of the penumbra occurred in the Pacific Ocean at 15:46:52 UT, followed by the passing of the path of totality through North America and the final contact of the penumbra at 21:04:24 UT in the Atlantic Ocean.

The Center for Geophysics in Dourbes (50.1°N, 4.6°E), Belgium, was almost exactly located on the line where the eclipse started at sunset. Nevertheless, effects of the eclipse were expected to be seen here for two reasons. First, sunset occurs slightly later at the altitude of the ionosphere, and second waves generated in the ionosphere by the eclipse can travel beyond the area directly in its path

Observational campaign

The key instrument for our observations is a Lowell Digisonde-4D® digital ionosonde. For the purpose of this campaign of observations, the ionosonde is used in two different modes of operation. Ionograms are produced by sweeping through frequencies from 1 MHz to 10 MHz and SkyMaps are obtained by using a fixed sounding frequency of 5 MHz. The ionograms are first scaled automatically using the ARTIST-5 software followed by manual corrections; the SkyMaps are analysed using the Digisonde Drift Analysis program.

The ionogram and SkyMap observations were programmed in such a way that each sounding takes less than fifteen seconds. This allows us to perform both soundings at thirty second intervals.

	Ionogram	SkyMap
Frequencies	1–10 MHz coarse 25 kHz	5 MHz five 50 kHz steps
Polarity	O only	O only
Integrated repeats	4	128
Wave form	$66.\bar{6}\mu s$ pulse	16-Chip comp.
Starting seconds	00 & 30	15 & 45
Sounding time	14.470 s	12.830 s

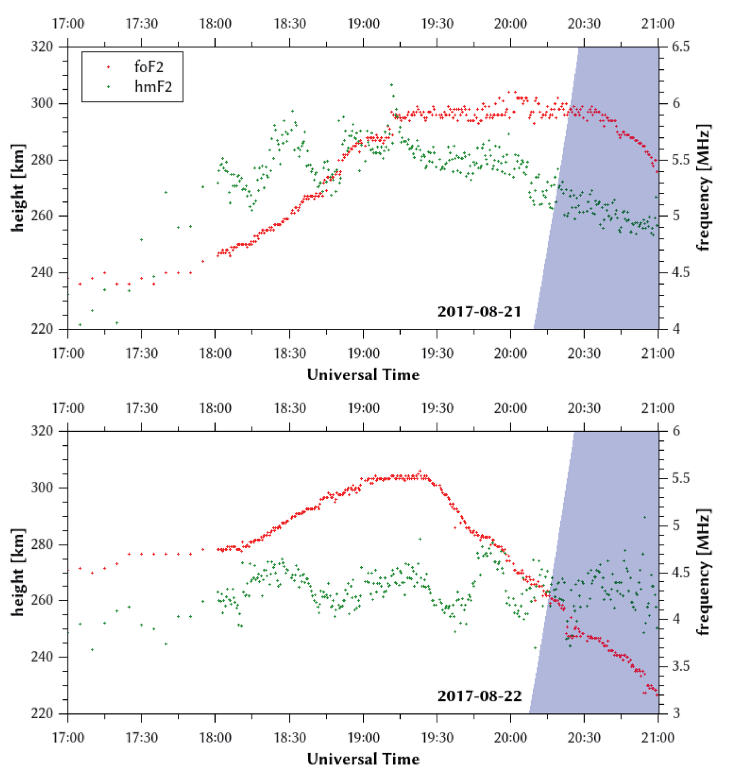
Digisonde settings used for the solar eclipse observations. For more details, see: Verhulst et al. (2016), "High-resolution ionospheric observations and modeling over Belgium during the solar eclipse of 20 March 2015 including first results of ionospheric tilt and plasma drift measurements," Adv. Space Res. 57, 2407–2419.

In addition to the ionosonde, a collocated NovAtel GPStation-6™ was used for GNSS *TEC* measurements. We calculate the *TEC* at one minute intervals.

The observational campaign was run on three days, from 20 August to 22 August, each day from 18:00 UT to 21:00 UT. However, on the first day strong sporadic *E* layers were observed, making it difficult to obtain continuous observations of the relevant ionospheric characteristics. Therefore, 22 August is used as the reference day to compare the observations during the eclipse to.

Results

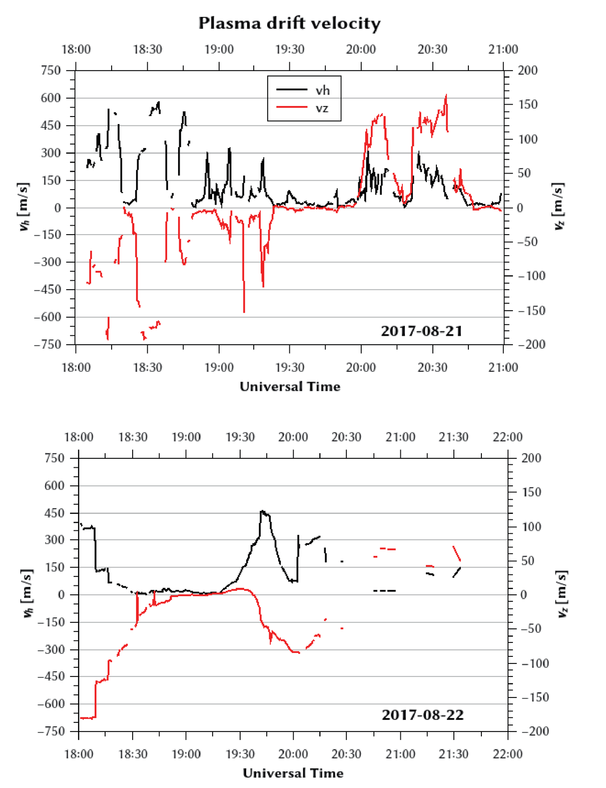
Ionogram characteristics



This picture shows the critical frequency foF_2 and peak electron density hmF_2 on the day of the eclipse (top) and the day after the eclipse (bottom). The shaded areas show the altitudes where the sun s below the horizon. The eclipse began locally at 18:41:03 UT.

A wave pattern is visible on the day of the eclipse starting around 18:00 UT. However, some wave-like disturbances are also present on the reference day. Thus, these observations alone don't reveal much.

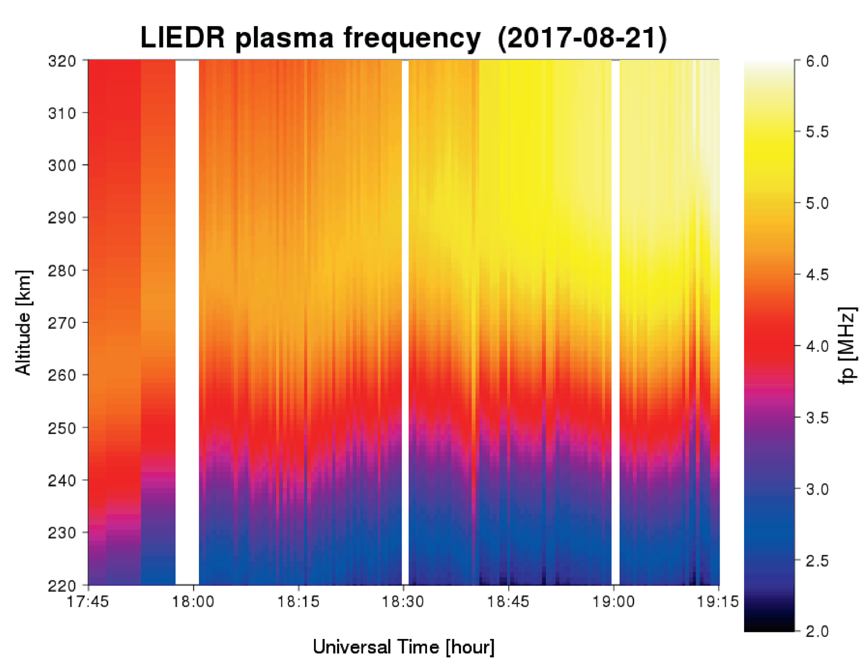
Bulk plasma drift



From the SkyMap soundings, both the horizontal and the vertical component of the bulk plasma drift can be calculated. Both components are shown in the figure, on the day of the eclipse (top), and on the reference day (bottom).

On the day of the eclipse, strong peaks can be seen in the plasma drift, coinciding with those observed in the peak height. The peaks in the plasma drift are positive for the horizontal component and negative for the vertical component. Note the different pattern, in the top panel, that appears around the solar terminator, when both components exhibit a positive peak.

LIEDR



The LIEDR model reconstructs the local ionospheric electron density profile (expressed as plasma frequency) above the observatory using the parameters scaled from the ionograms in combination with the local *TEC* measurements from the GNSS receiver. This picture shows a detail of the reconstructed profilograms at the time of the eclipse around the height of the F_2 peak. The wave-like pattern observed in the peak altitude is visible here as well.

Conclusions

The following are the main conclusions obtained from these observations:

- Using specially designed configurations, the digisonde can be used to obtain ionograms as well as SkyMaps with a time resolution of 15 seconds.
- Each individual ionospheric characteristic can be influenced by a variety of drivers. Therefore, it is useful to look for disturbances simultaneously visible in multiple parameters.
- Wave-like disturbances can be seen around the time of the eclipse in the peak height as well as both components of the bulk plasma drift.
- These waves are most likely generated at a region of higher obscuration, and move outwards like a bow wave.

Download the paper:

Verhulst & Stankov, *Ionospheric wave signature of the American solar eclipse on 21 August 2017 in Europe*, Advances in Space Research (2018).