Sea-surface properties from the 100 kHz ground wave delay

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Abstract

In this study, we investigate effect of sea surface conductivity over a long all-seawater path, using the propagation delay in a 100 kHz radio signal. The change in delay, over such paths, is caused by changes in sea surface conductivity (due to changes in temperature and salinity) as well as atmospheric properties (temperature and pressure) that determine the refractive index of the atmosphere. In particular, we consider data of 17 months of propagation delay (at 100 kHz) on a 560 km all sea water path across the North Sea between Sylt in Germany and Harwich in the UK. We present the experimental results and compare with those from a basic model pertaining to both the atmospheric and sea surface contributions to the measured delay, with the aim to extract sea surface properties, including conductivity.

1. Introduction

Figure 1 shows data of 17 months of excess propagation delay at 30s resolution (at 100 kHz) on a 560 km all sea water path across the North Sea between Sylt in Germany and Harwich. The excess is over what would be expected for seawater with a conductivity of 5 S/m and a fixed atmospheric refractive index $n = 1.000338$ [1 & 2].

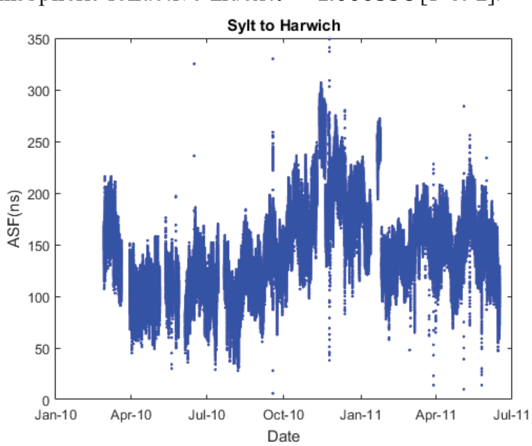

Figure 1. The excess propagation delay (at 100 kHz) on a 560 km all sea water between Sylt and Harwich.

Though there is a high variability in the excess delay there is a clear peak in November and December and troughs in April to July, as well as other shorter time scale features.

2. Discussion

A more realistic estimate the atmospheric refractive index, n, can be made using Eq. 1 [3] where p and T are the atmospheric pressure and temperature respectively at the sea surface.

$$n = 1 + \frac{77.6p}{T \times 10^6} \tag{1}$$

Figures 2 and 3 give the atmospheric surface pressure and temperature from ERA-Interim model data [4] at the centre of the path. It is clear from the derived refractive index values of Figure 4 derived from these data that the value for n is closer to that used by [5] ($n = 1.000284$), and the effect of the surface pressure is small. Eq 1 shows that an increase in temperature causes a reduction in refractive index, which is another way of saying a higher propagation speed and a lower propagation delay.

If due solely to changes in atmospheric refractive index, Figure 4 would imply a reduction in excess delay during July to October and an increase in January to February. However, this does not agree with what is found in Figure 1, which are out of phase by 2 or 3 months. This suggest that a significant part of the excess delay is also due to changes in seawater properties such as conductivity.

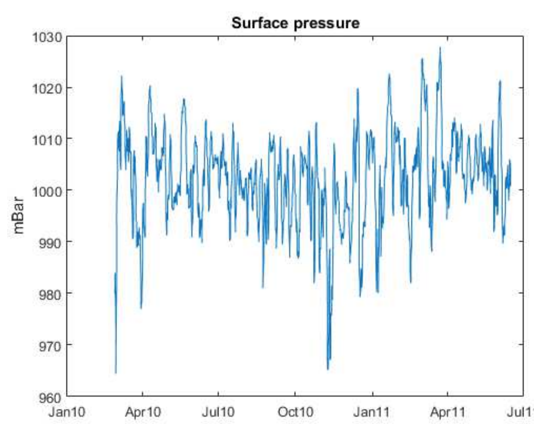

Figure 2. Atmospheric surface pressure at the centre of the path between Sylt and Harwich.

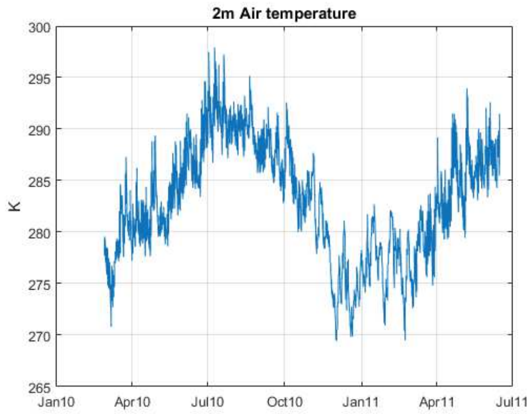

Figure 3. Atmospheric temperature, at 2m height, at the centre of the path between Sylt and Harwich.

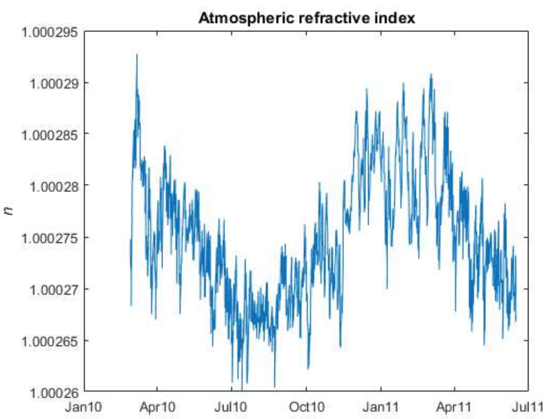

Figure 4. Atmospheric refractive index at 2m height, at the centre of the path between Sylt and Harwich.

The presentation will also discuss the significant features of the measured delay with reference to the theory of complex waves that propagate due to the air / sea interface, [6],[7],[8].

3. Conclusions

From the above discussion there appears a significant contribution to the delay due to sea surface conductivity, σ, which in turn is dependent on sea surface temperature SST (in Celsius) and salinity SSS (psu) [9].

$$\sigma = 0.18 \times SSS^{0.9} \times \big(1 + 0.02(SST - 20)\big) \qquad (2).$$

Assuming this to be the case, SSS was derived from the excess delay by [10] under the assumption that a 1 K increase in SST gives rise to approximately 1 ns for every 100 km of path length. This is comparison with SMOS (soil moisture and ocean salinity) showed that an increase in 1 psu is equivalent to 12.5 ns increase delay over the 560 km path.

4. Acknowledgements

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5. References

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