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Ballynahone Bog SAC Wind Data for Modelling

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1 Introduction / background

Elevated atmospheric ammonia (NH_3) concentrations and nitrogen (N) deposition pose a substantial threat to nitrogen sensitive vegetation in Northern Ireland. Large areas of Northern Ireland (NI) experience NH_3 concentrations above 1 µg m^{-3} therefore exceeding the critical level for sensitive lichens, mosses and other lower plants. C. 50 % of land in NI experiences NH_3 concentrations > 3 µg m^{-3}, which is in exceedance of the critical level for higher-plants. Local prevailing wind patterns play a key role in the dispersion of NH_3 emissions and the resulting NH_3 concentrations and N deposition received by sites.

Ballynahone Bog SAC is situated in an agriculturally intensive region of NI and experiences high NH_3 concentrations. NH_3 concentrations have been measured at site since 2014, when a sampling scheme was set up to monitor the status of the bog. A Met Station was installed on the bog in 2016 to analyse local wind conditions. Unfortunately, this met site has only worked intermittently and large gaps in the data exist.

The aim of this study is to investigate whether met stations located near to Ballynahone Bog or gridded model estimates could be used as an alternative source of wind data to the measurements recorded from the met station located on Ballynahone bog.

The work aims to:

1. Identify local met stations (recording equivalent wind parameters) near Ballynahone Bog
2. Compare wind patterns at those other met sites to those recorded on Ballynahone Bog SAC (over the same time period)
3. Compare Met Office modelled wind data to those recorded on Ballynahone Bog SAC (over the same time period)
4. Establish which dataset is the most suitable proxy for gap filling the missing wind data at Ballynahone Bog SAC

2 Identification of met stations surrounding Ballynahone Bog SAC

Two nearby met-stations were identified from the Met Office MIDAS dataset[1] (Figure 2):

- Lough Fea (~10 km to the SW of the site); and
- Portglenone (~15 km to the NW of the site).

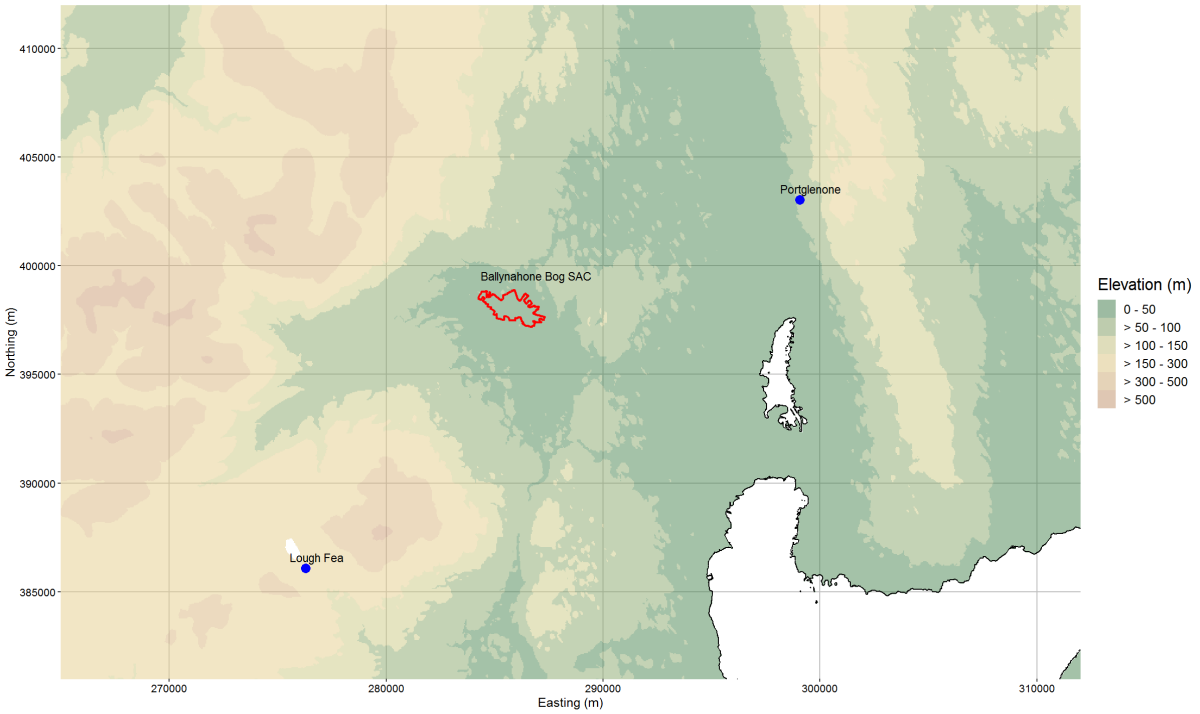

Figure 1: Map showing location of the Met Office MIDAS Portglenone and Lough Fea met stations in relation to Ballynahone Bog and terrain of the area. Uses OSNI Open Data 10M DTM as elevation data (Land and Property Services 2015). Contains public sector information licensed under the Open Government Licence v3.0.

Data recorded at Lough Fea and Portglenone were more complete than those from the met station located at Ballynahone Bog SAC. Between the months January 2019 and June 2020 as shown in Figure 2, Portglenone had only three days with < 100% data coverage, and Lough Fea only had 8 days < 100% data coverage.

The land surrounding Lough Fea and Portglenone is higher in elevation and more complex and undulating than the relatively flat terrain surrounding Ballynahone Bog (Figure 1). This makes the two MIDAS Met Office stations potentially less suitable as a proxy for wind patterns at Ballynahone Bog. However, in terms of data capture, the two MIDAS stations are more reliable than the Ballynahone met station. The Portglenone MIDAS station is situated in an area of relatively flat land NE of the bog, and may be sheltered from easterly winds recorded at the Ballynahone met station (due to its location at the foot of a low slope to the east).

[1] Met Office (2006): MIDAS: UK Hourly Weather Observation Data. NCAS British Atmospheric Data Centre, *accessed 02/2020*. https://catalogue.ceda.ac.uk/uuid/916ac4bbc46f7685ae9a5e10451bae7c

3 Comparison of wind patterns at Ballynahone Bog versus nearby met stations

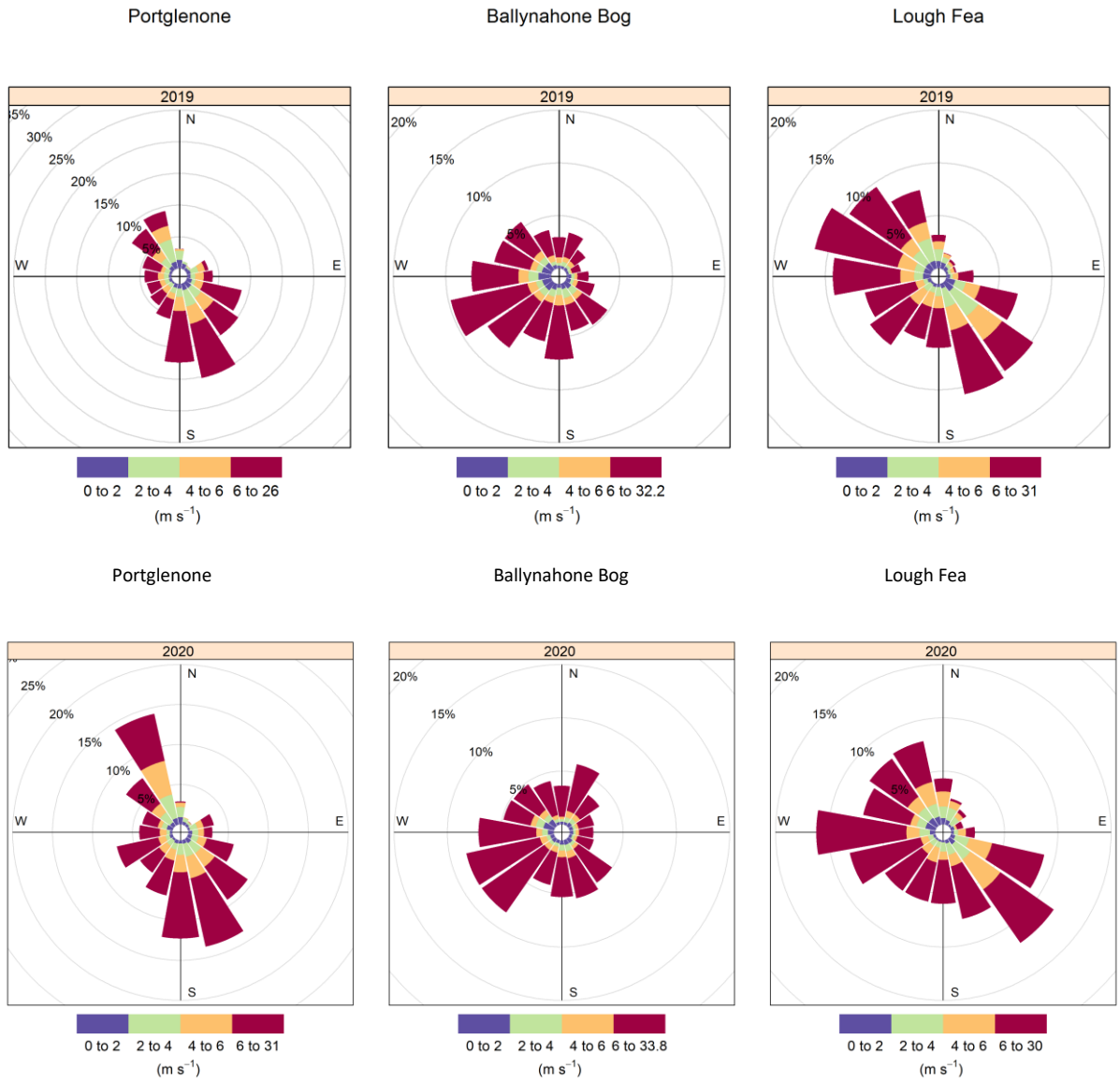

Figure 2: Wind roses for the Met Office MIDAS met stations at Portglenone, Ballynahone Bog and Lough Fea between January 2019 and June 2020, showing wind speed and direction. Data have been subset to compare only the matching period(s) where data are available.

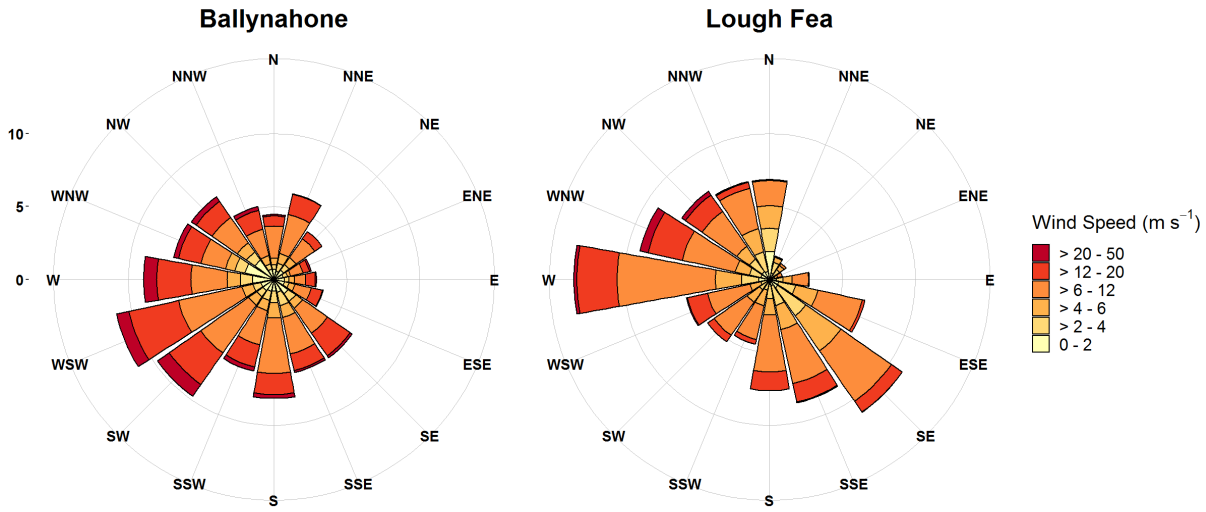

Figure 3: Overall comparison prevailing wind direction and speed at the MIDAS site Lough Fea and the met station installed on Ballynahone Bog SAC. The Ballynahone wind rose is created from intermittent data from 16th July 2019 to 17th June 2020 and Lough Fea represents a complete time period of Jan 2019 to Aug 2020.

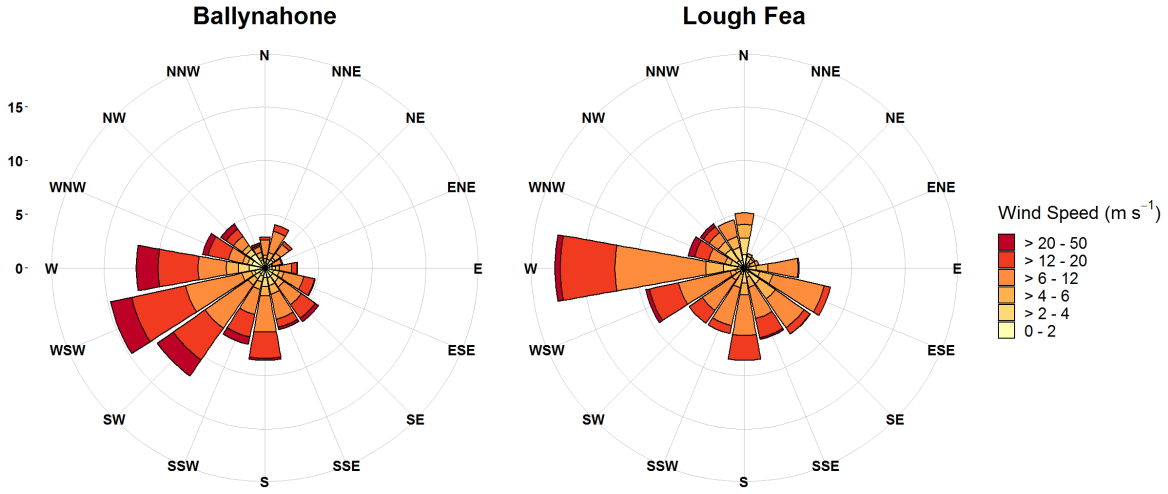

Figure 4: Comparison of prevailing wind direction and speed at Lough Fea and Ballynahone Bog SAC for the overlapping period where both met stations were recording (16th July 2019 to 17th June 2020).

For the period 16th July 2019 to 17th June 2020 where data are available from all three met stations, Ballynahone Bog shows a prevalence of SW winds (Figure 3). Both Lough Fea and Portglenone show a prevalence of NW/SE winds (Figure 2), which is a consistent pattern across 2014 – 2019 data (longer-term data not shown).

When monthly profiles of wind direction are compared between the 3 met stations, Lough Fea shows better agreement in wind direction with the station installed on Ballynahone Bog (Figure 3) than Portglenone. This suggests that Lough Fea could provide useful information to estimate the wind patterns surrounding Ballynahone Bog for the periods where the station was unable to collect data, and for the longer period back to 2014, when NH_3 concentrations measurements started on the bog itself.

Figure 4 presents the overall wind patterns for the period 16th July 2019 to 17th June 2020 (Figure 4) at Lough Fea and Ballynahone. The figure clearly shows that higher wind speeds were recorded at Ballynahone Bog than at Lough Fea. Additionally Lough Fea appears to experience a westerly prevailing wind, compared to Ballynahone Bog which is more south westerly.

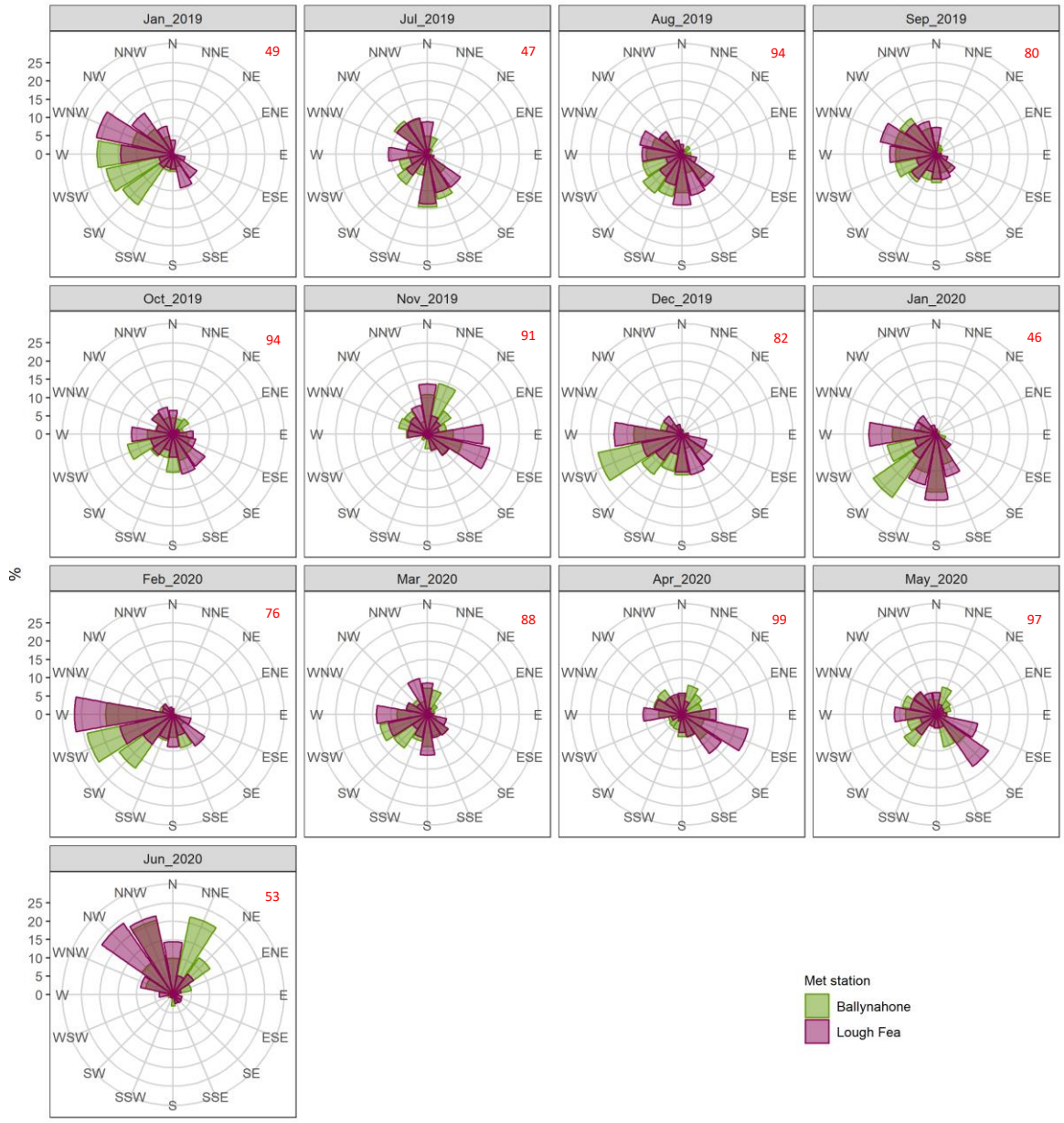

Figure 5: Monthly wind roses for met stations at Ballynahone Bog and Lough Fea. Lough Fea data have been subset to show only wind direction data from dates where data are available from Ballynahone Bog for comparison. Number in red font indicates percentage of monthly data included in each month from both met stations.

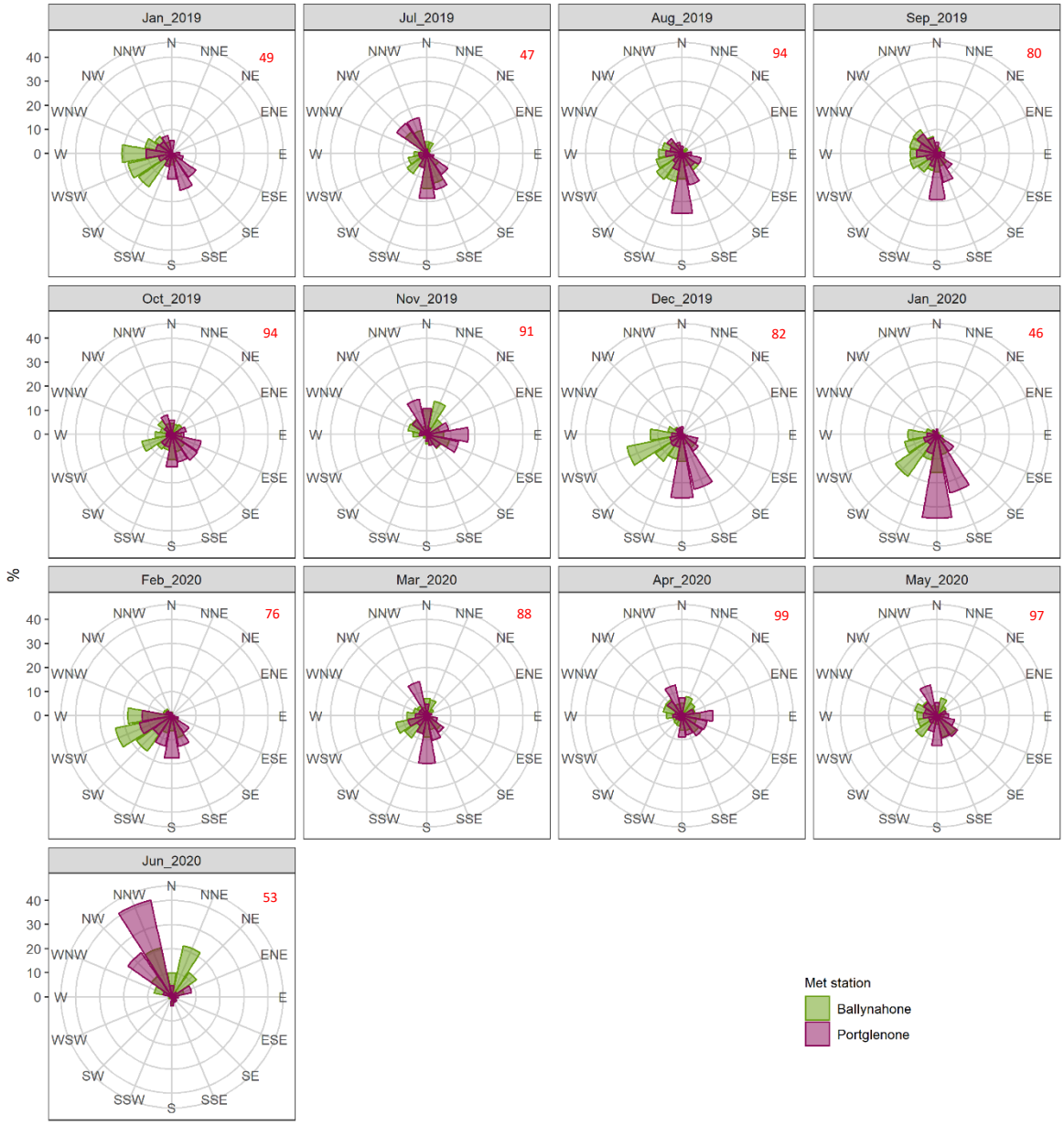

Figure 6: Monthly wind roses for met stations at Ballynahone Bog and Portglenone. Portglenone data have been subset to show only wind direction on dates where data are available from Ballynahone Bog for comparison. Number in red font indicates percentage of monthly data included in each month from both met stations.

Although the Portglenone met station is situated in an area that appears to be similar terrain to Ballynahone (Figure 1), the wind direction data are not easily comparable to Ballynahone Bog and Lough Fea. Portglenone has a strong prevalence of Southerly winds (Figure 6). The air-flow surrounding the Portglenone site is likely influenced by local topography, i.e its close proximity to an elevated ridge on the east side of the met station (Figure 1) which may channel winds in a different direction.

Portglenone therefore is likely to be unrepresentative of the winds experienced at Ballynahone Bog and would not make a reliable proxy for the Ballynahone Bog site.

4 Comparision to modelled wind data

Modelled wind speed and direction data are available from the UK Met Office's Unified Model (UM, Met Office 2016) at a grid resolution of 2 x 2 km. The UM estimates hourly wind direction and speed at a height of 10 m above the earth's surface. While this differs from conditions on the Bog itself (as recorded by the met station) these estimates were assessed to check if they could provide an acceptable proxy for the missing wind data.

The UM data was accessed from the Centre for Environmental Data Analysis (ceda.ac.uk) and the 2 x 2 km grid-square associated with the met station on Ballynahone Bog met station was extracted using R. A period of 6,894 hours, for which wind data was recorded on the Bog was compared to modelled data for and this is presented as a wind rose in Figure 7. The figure shows a relatively good agreement between the modelled and measured wind direction, however wind speeds are typically lower in the modelled data than are captured by the met station on the bog. It is clear from the figure that the modelled wind speed is systematically lower than the measured data.

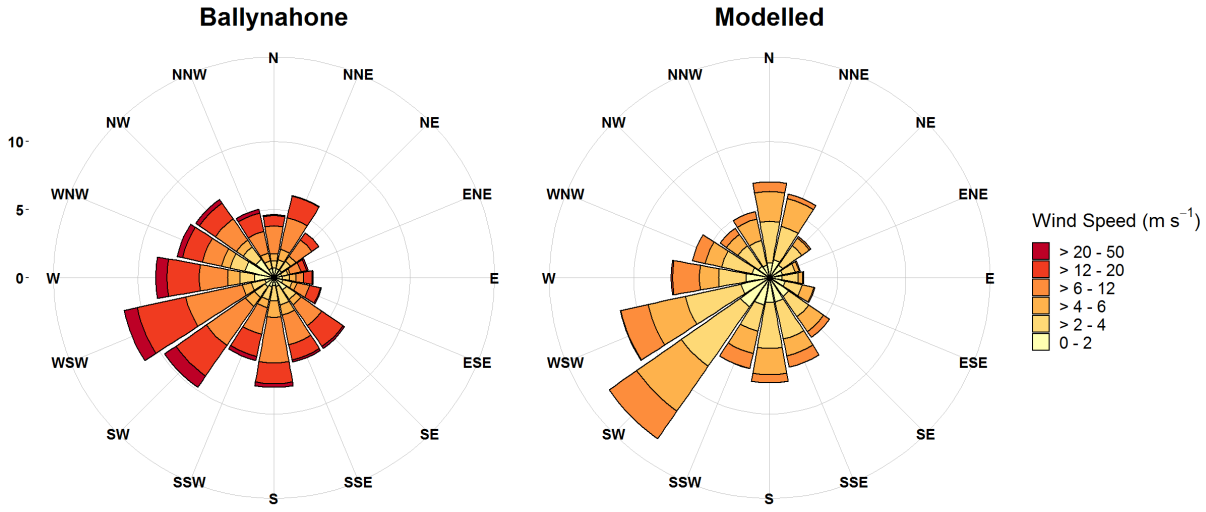

Figure 7: Comparison between measured and UM modelled wind speed/direction data for the period where the Ballynahone met station was operational (16th July 2019 to 17th June 2020).

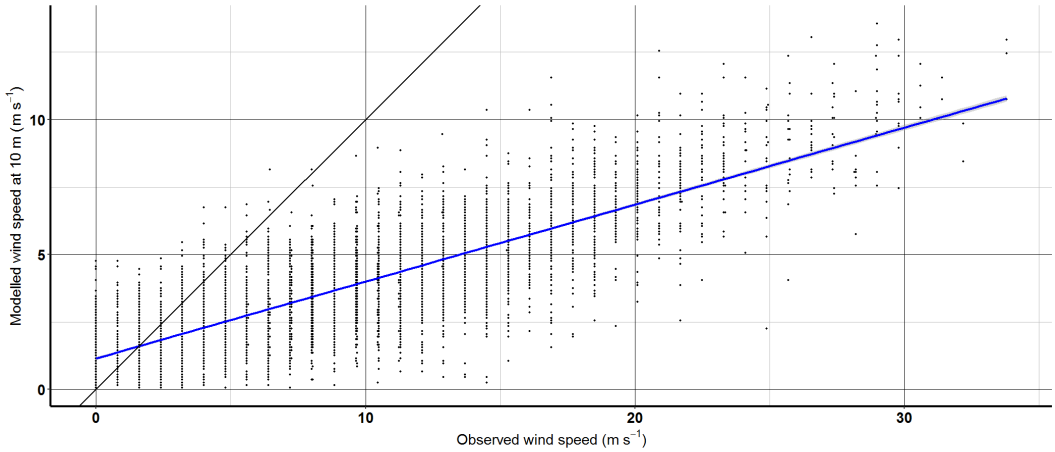

Figure 8: Scatter plot comparing observed wind speeds at Ballynahone bog to modelled wind speed at 10 m. Each point represents an hourly meauserment of wind speed (n = 6894) when the met station on Ballynahone Bog was operational. A 1:1 is shown in black and a linear regression line in blue.

Figure 8 shows a strong correlation between modelled and measured wind speeds at Ballynahone Bog. The R^2 for the 6,894 hours of measurment is 0.68. The figure indicates that measured wind speeds on the bog are systematically higher than the UM data. This may be due to the met station being in an open exposed location, and therefore associated to higher winds compared to more sheltered areas of the 2 x 2 km modelled grid. It may also be partly attributed to the difference in height of the measurements/estimates.

Linearly interpolating the modelled data, provides a reasonabe estimation of measured wind speeds on the site (Figure 9)

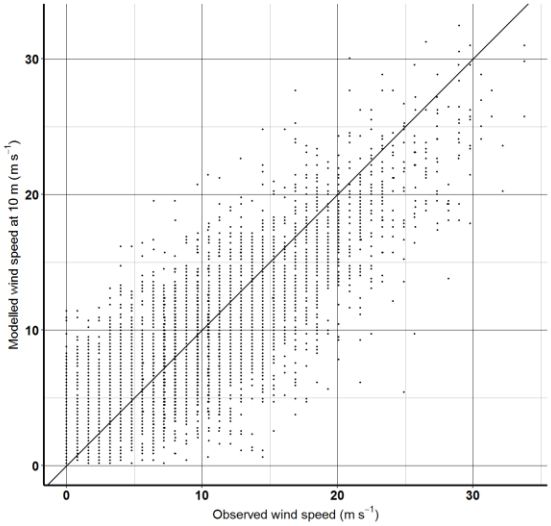

Figure 9: Scatter plot comparing observed wind speeds at Ballynahone bog to adjusted modelled wind speeds. Each point represents an hourly meauserment of wind speed (n = 6894) when the met station on Ballynahone Bog was operational. A 1:1 is shown in black.

5 Establishing the most suitable proxy for gap filling the wind data at Ballynahone Bog SAC

Overall, the Met Office modelled wind direction data appear be most representative of the conditions recorded by the met station on Ballynahone Bog, compared with the other nearby met stations. The wind conditions recorded at the met stations nearest to Ballynahone Bog (Portglenone and Lough Fea) appear to experience different conditions due to their location and altitude. Figure 10 presents a gap-filled time series of wind data on Ballynahone Bog. For periods when the met station on the bog was operational, these measurements were used and modelled data were used to gap fill the remaining period. Measured wind direction data were for 43 % of 2019 and for 46 % of 2020 (with 57 % and 54 % gap-filled, respectively). The overall pattern of the modelled and measured wind data appears to be comparable for 2019 and 2020 in Figure 10.

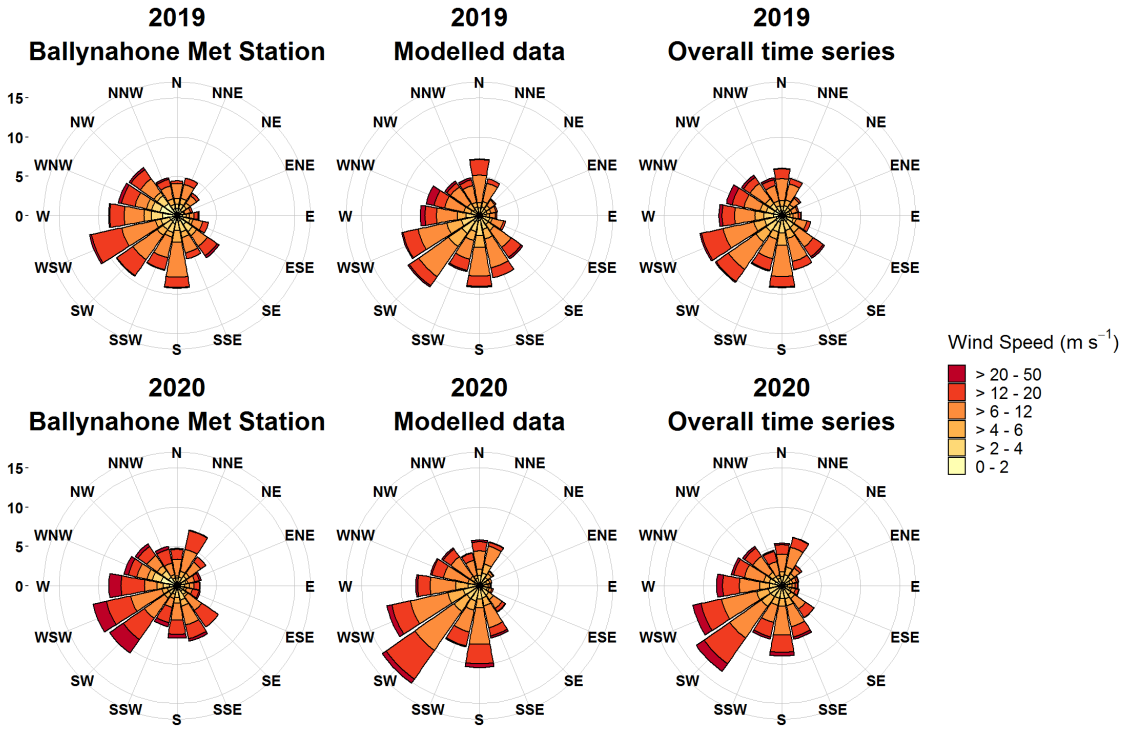

Figure 10: Complete (gap filled) annual 2019 and 2020 wind roses for Ballynahone Bog, created using measurements from Ballynahone Bog met station (where available) and Met Office modelled wind direction. Modelled wind speeds have been fitted to a linear model to correct for systematically lower speeds than recorded on the bog.

6 Discussion and conclusions

Wind direction and wind speed data can provide a valuable insight into inferring the sources of high ammonia concentrations measured at a site. Continued parallel monitoring of wind direction and NH_3 concentrations at the site will be useful to capture a whole cycle of relevant emission sources and events throughout a year as this was not possible due to the met station at Ballynahone Bog intermittently working and COVID-19 restrictions.

The work reported here explored whether Lough Fea (the more suitable of the nearby met stations) wind patterns could be used to fill in data gaps in wind data for the most recent years (2019-2020), for use in a local scale modelling task for the landscape surrounding the bog, and to generate multi-year time series of measurements at Ballynahone Bog dating back to September 2014. Neither Lough Fea nor Portglenone met stations are entirely suitable as a proxy for wind direction at Ballynahone Bog, having a reliable source of met data on site would be key to ensure accurate interpretation of concentration data.

In addition to exploring the suitability of nearby met stations, modelled wind data from the Met Office's Unified Model (UM) were compared with wind measurements on Ballynahone Bog. There is a relatively good agreement between modelled and recorded wind direction on the bog. Both datasets show prevalent south westerlies and similar patterns in other wind sectors. Modelled wind speeds appear to be lower than recorded by the met station, but there is a good correlation between the modelled and measured wind speeds, allowing an adjustment of the modelled speeds. In summary, the modelled data (UM) appear to be more representative of wind conditions on the bog than the nearby met stations and will be useful for periods where the met station on the bog was not operational.

The wider Ballynahone Bog Ammonia project will benefit from a new DAERA-procured weather station with remote downloading facilities, to increase the reliability and accessibility of data, so that malfunctions can be remotely identified and quickly rectified. With the new met station operational since 1st October 2020 further analysis and interpretation of ammonia concentration patterns in combination with weather data will be carried out and reported separately. Further work will also include assessing how the UM data compares to measurements on the site, this will be useful for gap-filling missing periods in future (if needed), in addition to reconstructing met data for the period before met stations were installed on the site, i.e. 2016 – 2019 when the modelled data are available..

References

Met Office (2016): NWP-UKV: Met Office UK Atmospheric High Resolution Model data. Centre for Environmental Data Analysis, accessed *30/03/21*.

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