The following supplement accompanies the article

Effects of windscape on three-dimensional foraging behaviour in a wide-ranging marine predator, the northern gannet

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SUPPLEMENTARY MATERIALS

Supplement 1: Estimating flight height

To calculate birds' heights during periods of flight, we first removed pressure observations ≤5 s before and ≤3 s after dives (identified by a rapid increase in pressure above ambient), as there was typically high variation in pressure within these periods due to acceleration and turbulence. Individual anomalous pressure readings (i.e. 1-s 'spikes') suggesting abrupt and implausibly rapid changes in height or turbulence around the logger, for instance as a result of the bird flexing its tail in flight, were also removed. Following Cleasby et al. (2015) we smoothed the pressure data using a running median calculated using a moving window of 11 observations centred on each successive pressure reading (i.e. over a period of 5 s before and after each reading). We then selected those smoothed pressure records that coincided with GPS data-points, to give a location- and activity-specific measurement of pressure every 2 min. In doing so we discounted short periods of flight and on the water (<6 min; i.e. fewer than 3 consecutive GPS points) to ensure accurate classification of behaviour from GPS data.

We used periods classified as in flight, whether commuting or active foraging, to obtain height-specific pressure data P and then used either the previous or the subsequent period on the water (whichever was closer in time) to estimate calibration pressure P_0 in each case. Before calculating P_0 we removed the first and final pressure records for each period on the water, to avoid including pressures during take-off or landing. P_0 was then calculated as the mean smoothed pressure over either the final remaining 8 min of the previous period or the first remaining 8 min of the subsequent period on the water (i.e. a mean of four smoothed data points generated from a total of 44 unsmoothed pressure readings in each case). This procedure required a minimum period of 10 min on the water to estimate P_0. Hence, because periods on water were often shorter than 10 min, in those cases we allowed up to two intervening flight periods before or after the period on the water used to estimate P_0.

Temporal changes in atmospheric pressure can affect estimates of height at a single location, and an average error of ~5 m of height can occur with an interval of 2 h between measurement of P and P_0

(calculated from data in Cleasby et al. 2015 supplementary online material). Hence, since gannets can sustain flight for much longer than this (Hamer et al. 2007) we additionally refined estimates of P_0 during flights using ERA-Interim reanalysis sea surface pressure data (6-hourly data at 0.125 × 0.125° or approximately 8 km resolution) produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) (Dee et al., 2011). We established the interpolated ERA-Interim pressure for each of a bird's locations at sea. Then for every location in flight, the corresponding calibration pressure was adjusted by applying the change in interpolated ERA-Interim pressure between the time and place of measurement of P_0 and P. Thus we accounted for both temporal and spatial changes in sea surface pressure throughout a flight bout, not just between bouts.

Supplement 2: Prevailing wind speed and direction

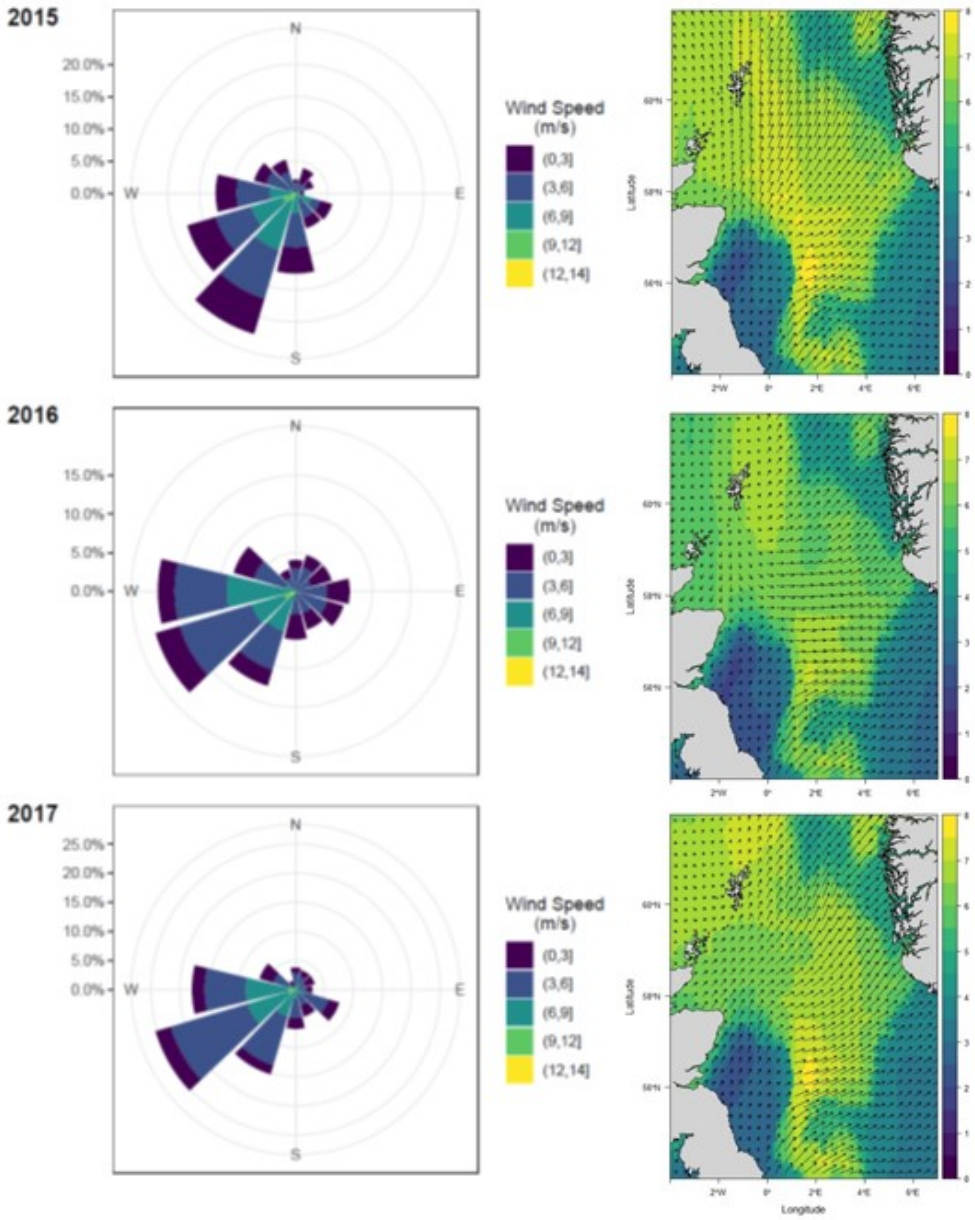

Fig. S1. Wind speed and direction (wind origin) at Bass Rock (left column) and across the northern and central North Sea (right column) during the breeding seasons (June-August) of 2015, 2016 and 2017. Left column: Axis represents percentage of time. Right column: wind data are represented on a 0.125 × 0.125° grid. Shading represents wind speed (m s^{-1}) from 0 (dark blue) to 8 (yellow). Black arrows represent wind direction and their length is proportional to wind speed. Data from European Centre for Medium-Range Weather Forecasts https://apps.ecmwf.int

LITERATURE CITED

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