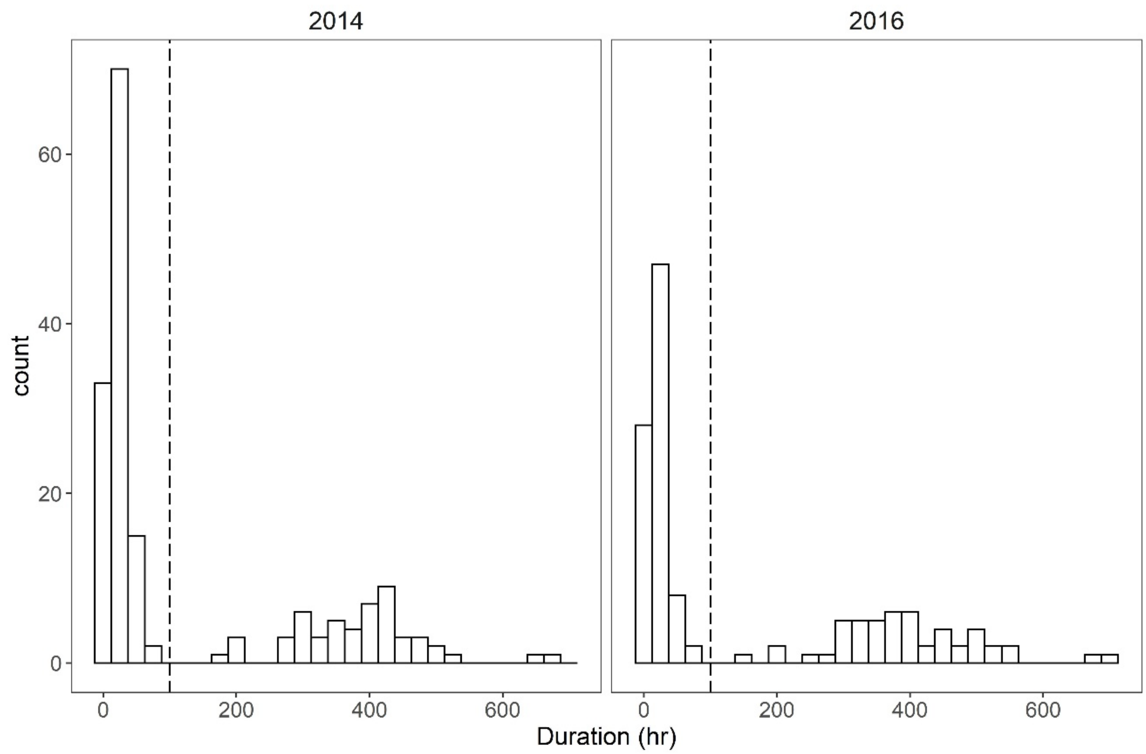

Figure S1: Histograms of Laysan albatross complete trip durations (hr) in 2014 (left panel; n = 21 birds and 172 trips; does not include one bird whose sex was unknown) and 2016 (right panel; n = 11 birds and 135 trips). Trip duration did not differ between colonies or sexes and were pooled for plotting purposes. Dashed line indicates 100 hr and was used as the cut-off duration to categorize short and long foraging trips.

The use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the US Government.

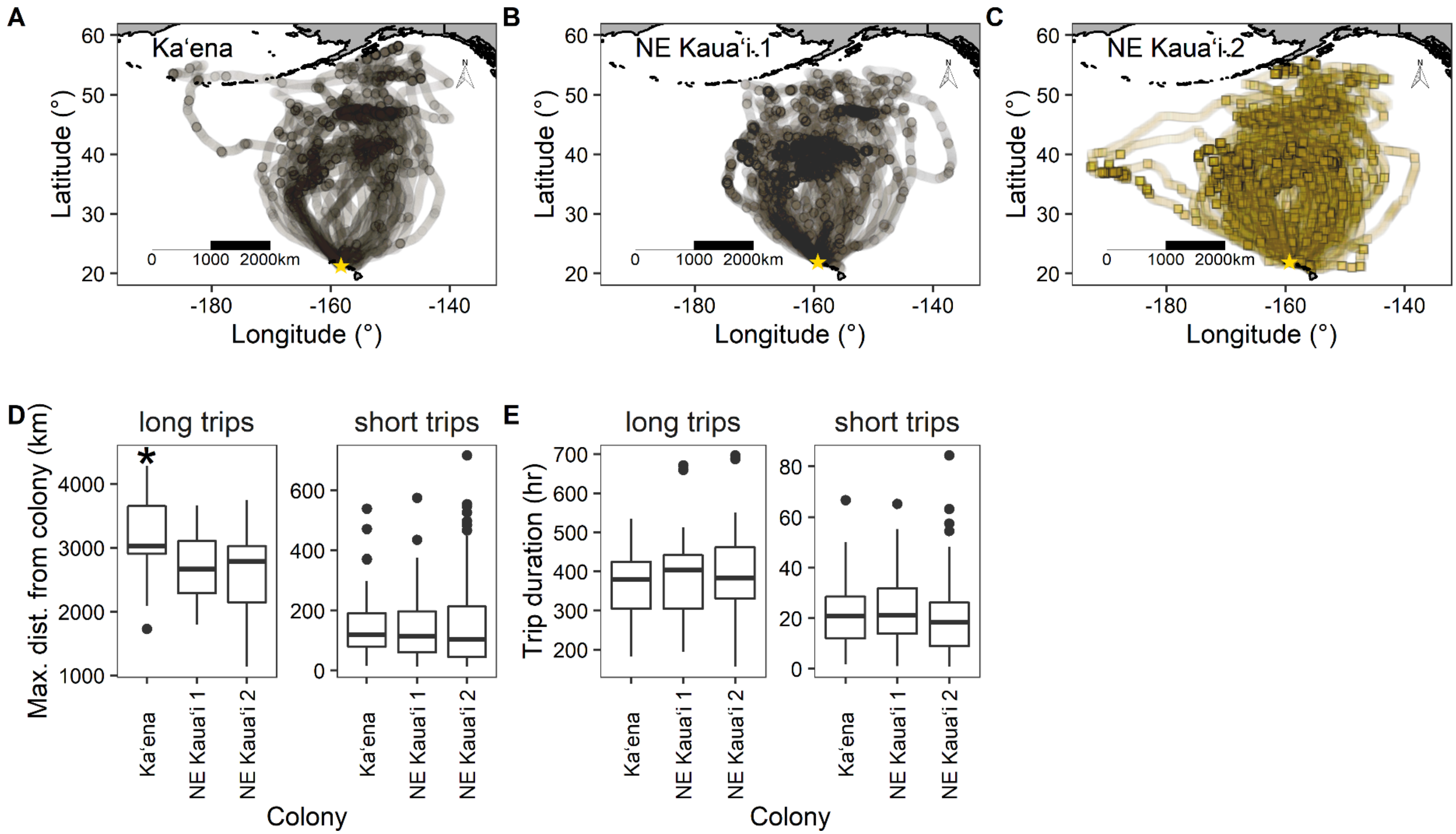

Figure S2: Laysan albatross long trips from each colony. Tracks from **(A)** Ka'ena Point (O'ahu); **(B)** northeastern Kaua'i 1; and **(C)** northeastern Kaua'i 2 colonies in 2014 (grey circles) and 2016 (yellow squares). **(D)** Boxplots of maximum distances (km) traveled from the colony and (E) trip duration (hr) for long (>100 hr) and short (<100 hr) foraging trips. Ka'ena Point foraging trips were significantly further from the colony than the other colonies (indicated by asterisk). Short trips had similar maximum distances among colonies. Trip durations were similar between colonies for both short and long trips. Yellow stars indicate colony locations. Locations colored with R-package "seabiRd" (Humphries 2021).

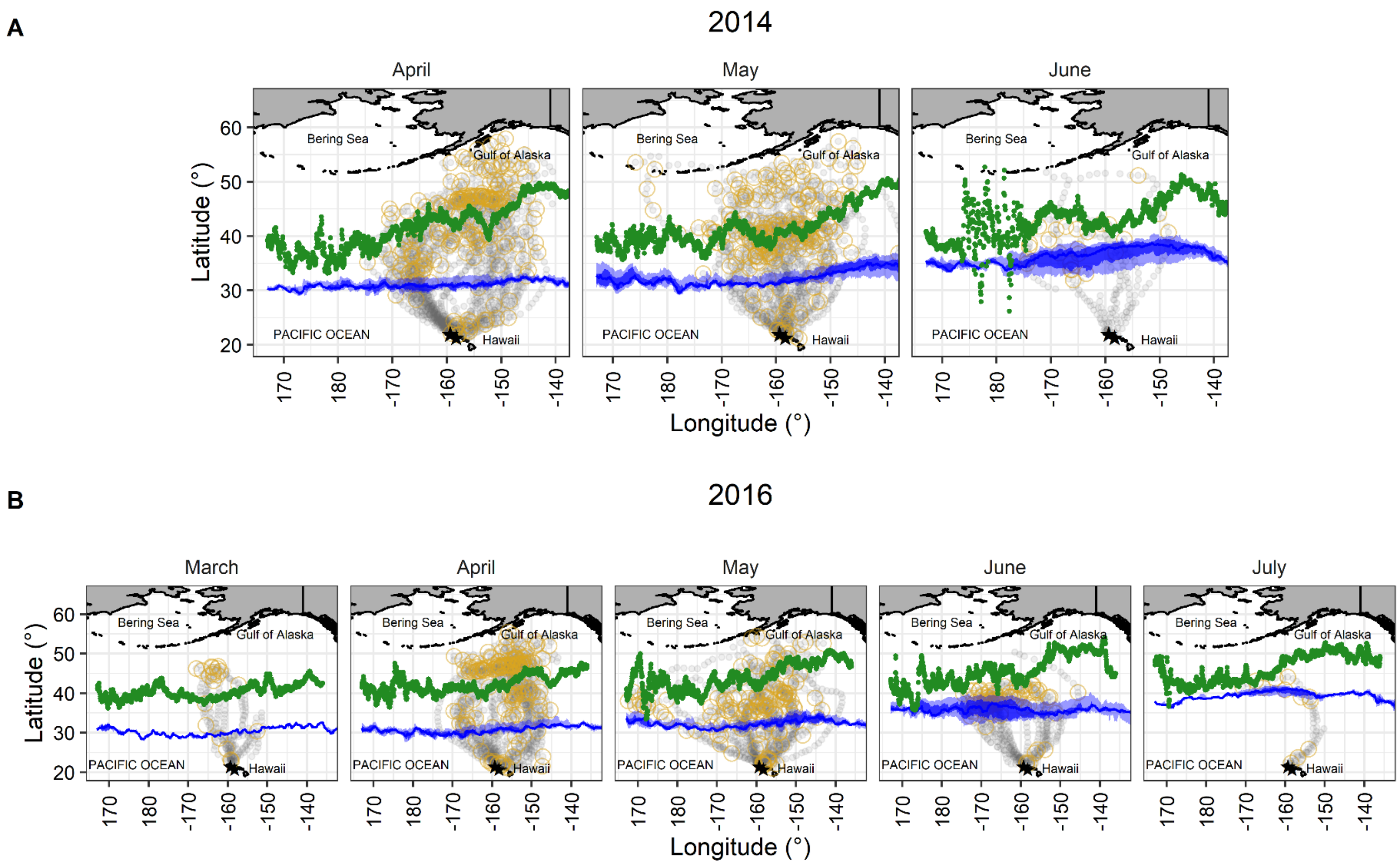

Figure S3: Laysan albatross chick-provisioning foraging trips relative to the 18°C sea surface temperature isotherm (subtropical frontal zone, STFZ) and the 0.2 mg m^{-3} chlorophyll-*a* contour (transition zone chlorophyll front, TZCF) in (A) 2014 and (B) 2016. The mean latitude at which the 18°C isotherm occurred is denoted by the dark blue line with quantiles shaded in lighter blue. The mean latitude at which the 0.2 mg m^{-3} chlorophyll-*a* contour occurred is denoted by green points; because the temporal resolution of the chlorophyll-*a* dataset was monthly, quantiles per month could not be calculated. Laysan albatross non-overlapping ARS zones with a radius = 50 km are depicted with grey circles.

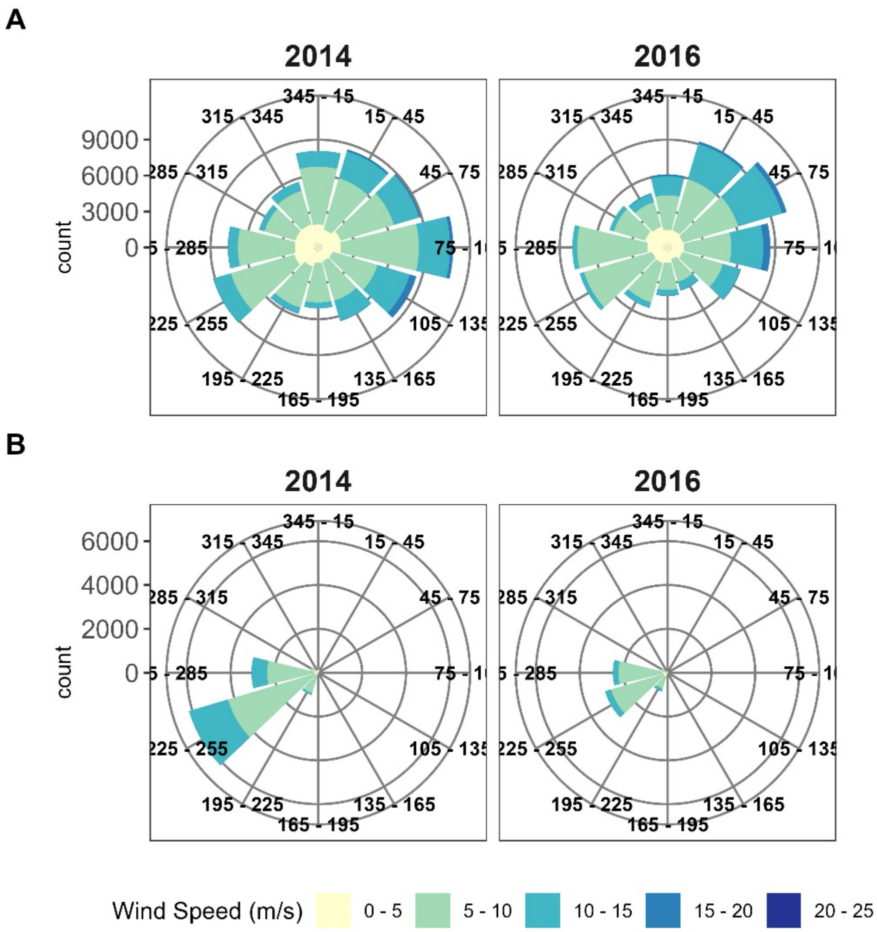

Figure S4: Rose plots of wind conditions encountered during chick-provisioning Laysan albatross foraging trips. Wind conditions (direction and velocity (m sec^{-1})) during **(A)** long trips and **(B)** short tips in 2014 and 2016. Wind direction is represented as the direction to where the wind is going (pointing away from plot center).

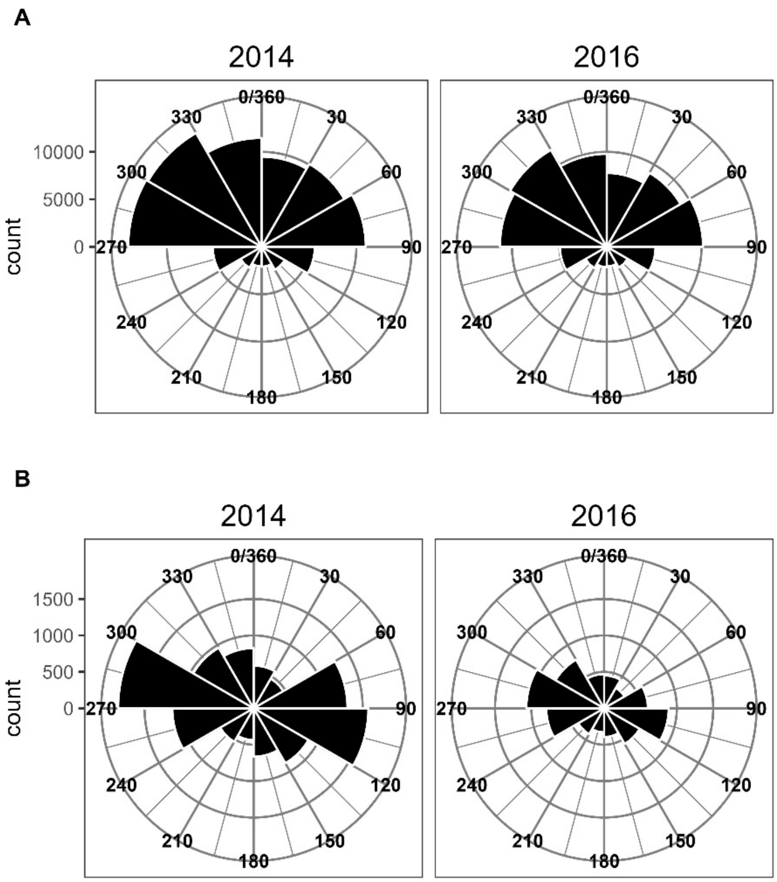

Figure S5: Rose plots of wind direction relative to chick-provisioning Laysan albatross foraging trips. (A) Birds experienced quartering tailwinds during long trips. **(B)** Birds experienced crosswinds during short trips. Rose plots are oriented such that the bird's flight direction is towards 0/360 (i.e., north), and relative wind direction (black bars) represent the direction to where the wind is going relative to the bird, so the direction is pointing away from the bird (away from the plot center).

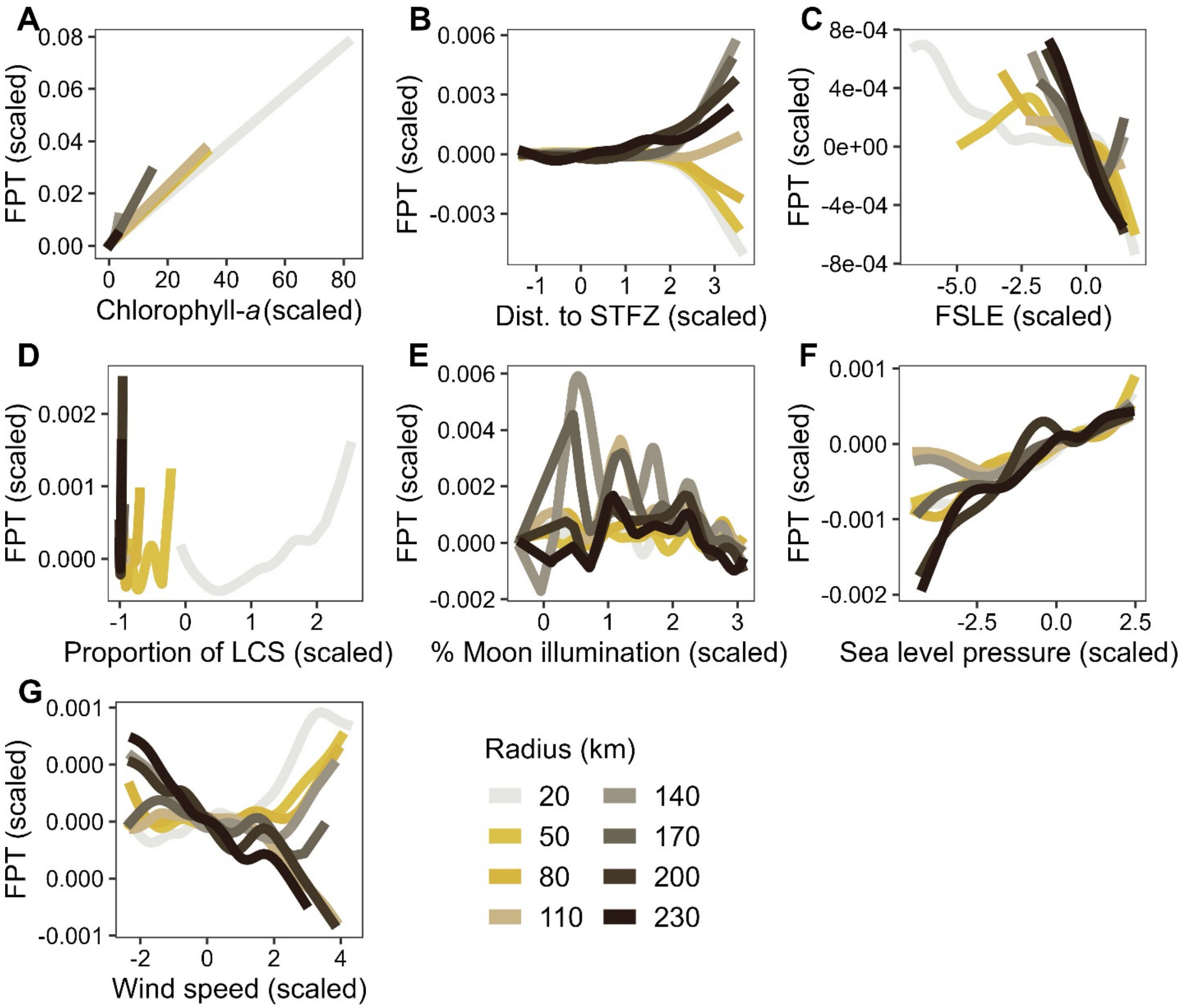

Figure S6: Interactions of radius with continuous environmental covariates for Laysan albatross long trips during chick-provisioning. Penalized varying coefficient terms were included for radius and each continuous environmental covariate in generalized additive mixed models for location, scale and shape. Marginal effect plots are shown for the partial effects of **(A)** chlorophyll-*a*; **(B)** distance to the 18°C sea surface temperature (SST) isotherm (subtropical frontal zone; STFZ); **(C)** finite-size Lyapunov exponents (FSLE); **(D)** proportion of Lagrangian coherent structures (LCS); **(E)** percent moon illumination; **(F)** sea level pressure; and **(G)** wind speed on first passage time during 110 long trips by 32 birds. Continuous variables were centered and scaled before analyses and are unitless. Color legend for radii was colored with R-package "seabiRd" (Humphries 2021).

Table S1: Summary of reduced penalized varying coefficient (pvc) generalized additive mixed models for location, scale, and shape (gamlss) of first passage time during chick-provisioning Laysan albatross long trips. Results from the full parametric model and the final model without the radius interaction are presented for comparison. pvc terms were constructed with radius and each continuous environmental covariate. Covariate terms that were significant at $p < 0.05$ are bolded. Effective degrees of freedom (EDF) are presented for smoothed μ terms with penalized beta splines, and for the final model with the radius interaction, EDF for smoothed terms with pvc are presented in parentheses. The Cox Snell pseudo R^2 value for the full parametric model was 0.23, for the model without the radius interaction was 0.25, and for the pvc model was 0.27. The reference levels for categorical factors are: radius = 20 km; year = 2014; sex = female. Abbreviations: FSLE = finite-size Lyapunov exponents; LCS = Lagrangian coherent structures.

	Full parametric model			**Final model without radius interaction**				**Final model with radius interaction**			
	Estimate ± SE	**t-value**	**p-value**	**Estimate ± SE**	**t-value**	**p-value**	**EDF**	**Estimate ± SE**	**t-value**	**p-value**	**EDF**
Intercept (μ)	$8.92\text{x}10^{-3} \pm 3.89\text{x}10^{-5}$	229.327	**$< 2\text{x}10^{-16}$**	$9.22\text{x}10^{-3} \pm 3.87\text{x}10^{-5}$	238.626	**$< 2\text{x}10^{-16}$**		$9.56\text{x}10^{-3} \pm 3.94\text{x}10^{-5}$	242.323	**$< 2\text{x}10^{-16}$**	
Chlorophyll-*a*	$6.46\text{x}10^{-4} \pm 4.27\text{x}10^{-5}$	15.131	**$< 2\text{x}10^{-16}$**	$1.82\text{x}10^{-4} \pm 3.30\text{x}10^{-5}$	5.523	**$3.35\text{x}10^{-8}$**	6.27	$-2.04\text{x}10^{-3} \pm 3.19\text{x}10^{-5}$	-63.961	**$< 2\text{x}10^{-16}$**	6.62 (18.35)
Depth	$3.07\text{x}10^{-5} \pm 2.15\text{x}10^{-5}$	1.430	0.153	$2.56\text{x}10^{-5} \pm 1.33\text{x}10^{-5}$	1.927	0.054		$1.78\text{x}10^{-5} \pm 2.86\text{x}10^{-5}$	0.622	0.534	
Distance to 18°C SST isotherm	$1.41\text{x}10^{-4} \pm 3.01\text{x}10^{-5}$	4.684	**$2.82\text{x}10^{-6}$**	$1.21\text{x}10^{-4} \pm 2.72\text{x}10^{-5}$	4.464	**$8.07\text{x}10^{-6}$**	12.96	$2.93\text{x}10^{-4} \pm 3.13\text{x}10^{-5}$	9.365	**$< 2\text{x}10^{-16}$**	12.97 (64.32)
FSLE	$4.82\text{x}10^{-5} \pm 2.02\text{x}10^{-5}$	2.381	**0.017**	$1.79\text{x}10^{-4} \pm 2.02\text{x}10^{-5}$	8.867	**$< 2\text{x}10^{-16}$**	12.10	$5.50\text{x}10^{-4} \pm 2.13\text{x}10^{-5}$	25.841	**$< 2\text{x}10^{-16}$**	12.18 (45.45)
Proportion of LCS	$-2.11\text{x}10^{-4} \pm 3.38\text{x}10^{-5}$	-6.245	**$4.29\text{x}10^{-10}$**	$-5.79\text{x}10^{-4} \pm 3.57\text{x}10^{-5}$	-16.214	**$< 2\text{x}10^{-16}$**	12.23	$-1.22\text{x}10^{-3} \pm 2.94\text{x}10^{-5}$	-41.344	**$< 2\text{x}10^{-16}$**	12.42 (31.85)
% Moon illumination	$1.49\text{x}10^{-4} \pm 1.75\text{x}10^{-5}$	8.516	**$< 2\text{x}10^{-16}$**	$1.21\text{x}10^{-4} \pm 8.85\text{x}10^{-6}$	13.646	**$< 2\text{x}10^{-16}$**	9.98	$9.67\text{x}10^{-5} \pm 2.30\text{x}10^{-5}$	4.207	**$2.59\text{x}10^{-5}$**	10.11 (103.37)
Sea level pressure	$-1.32\text{x}10^{-4} \pm 2.81\text{x}10^{-5}$	-4.712	**$2.47\text{x}10^{-6}$**	$-6.5510\text{x}^{-5} \pm 2.60\text{x}10^{-5}$	-2.515	**0.012**	12.02	$3.69\text{x}10^{-} \pm 2.51\text{x}10^{-5}$	-14.688	**$< 2\text{x}10^{-16}$**	12.08 (59.13)
Wind speed	$-1.07\text{x}10^{-3} \pm 1.97\text{x}10^{-5}$	-54.227	**$< 2\text{x}10^{-16}$**	$-1.01\text{x}10^{-3} \pm 1.96\text{x}10^{-5}$	-51.311	**$< 2\text{x}10^{-16}$**	12.57	$-8.67\text{x}10^{-4} \pm 1.90\text{x}10^{-5}$	-45.647	**$< 2\text{x}10^{-16}$**	12.65 (61.30)
Radius (50)	$2.36\text{x}10^{-4} \pm 5.73\text{x}10^{-5}$	4.117	**$3.85\text{x}10^{-5}$**	$-4.91\text{x}10^{-4} \pm 5.69\text{x}10^{-5}$	-8.627	**$< 2\text{x}10^{-16}$**		$-1.70\text{x}10^{-3} \pm 5.70\text{x}10^{-5}$	-29.844	**$< 2\text{x}10^{-16}$**	
Radius (80)	$3.90\text{x}10^{-4} \pm 6.76\text{x}10^{-5}$	5.775	**$7.75\text{x}10^{-9}$**	$-4.69\text{x}10^{-4} \pm 6.75\text{x}10^{-5}$	-6.942	**$3.94\text{x}10^{-12}$**		$-2.11\text{x}10^{-3} \pm 6.73\text{x}10^{-5}$	-31.330	**$< 2\text{x}10^{-16}$**	
Radius (110)	$5.32\text{x}10^{-4} \pm 7.44\text{x}10^{-5}$	7.156	**$8.49\text{x}10^{-13}$**	$-4.26\text{x}10^{-4} \pm 7.40\text{x}10^{-5}$	-5.752	**$8.92\text{x}10^{-9}$**		$-1.92\text{x}10^{-3} \pm 7.34\text{x}10^{-5}$	-26.185	**$< 2\text{x}10^{-16}$**	

Radius (140)	$6.81\times10^{-4} \pm 8.07\times10^{-5}$	8.434	**< 2×10^{-16}**	$-3.28\times10^{-4} \pm 8.08\times10^{-5}$	-4.059	**4.94×10^{-5}**	$-1.66\times10^{-3} \pm 7.87\times10^{-5}$	-21.075	**< 2×10^{-16}**
Radius (170)	$7.98\times10^{-4} \pm 8.48\times10^{-5}$	9.408	**< 2×10^{-16}**	$-2.48\times10^{-4} \pm 8.74\times10^{-5}$	-2.842	**0.005**	$-1.25\times10^{-3} \pm 8.30\times10^{-5}$	-15.009	**< 2×10^{-16}**
Radius (200)	$9.39\times10^{-4} \pm 8.90\times10^{-5}$	10.554	**< 2×10^{-16}**	$-1.32\times10^{-4} \pm 9.16\times10^{-5}$	-1.440	0.150	$-1.28\times10^{-3} \pm 8.88\times10^{-5}$	-14.366	**< 2×10^{-16}**
Radius (230)	$1.20\times10^{-3} \pm 9.39\times10^{-5}$	12.746	**< 2×10^{-16}**	$9.68\times10^{-5} \pm 9.25\times10^{-5}$	1.046	0.295	$-9.57\times10^{-4} \pm 9.45\times10^{-5}$	-10.120	**< 2×10^{-16}**
Sex (male)	$-1.57\times10^{-4} \pm 2.09\times10^{-5}$	-7.476	**7.85×10^{-14}**	$-1.48\times10^{-4} \pm 2.08\times10^{-5}$	-7.114	**1.15×10^{-12}**	$-1.49\times10^{-4} \pm 2.07\times10^{-5}$	-7.211	**5.70×10^{-13}**
Year (2016)	$1.11\times10^{-4} \pm 2.16\times10^{-5}$	5.107	**3.29×10^{-7}**	$7.63\times10^{-5} \pm 2.14\times10^{-5}$	3.57	**3.63×10^{-4}**	$6.40\times10^{-5} \pm 2.19\times10^{-5}$	2.930	**0.004**
Intercept (σ)	-5.25 ± 0.03	-178.709	**< 2×10^{-16}**	-5.27 ± 0.03	-162.070	**< 2×10^{-16}**	-5.30 ± 0.03	-179.198	**< 2×10^{-16}**
Distance to 18°C SST isotherm	0.11 ± 0.02	6.501	**8.08×10^{-11}**	0.11 ± 0.02	7.140	**9.51×10^{-13}**	0.11 ± 0.02	6.746	**1.55×10^{-11}**
FSLE	0.24 ± 0.02	15.230	**< 2×10^{-16}**	0.24 ± 0.02	14.409	**< 2×10^{-16}**	0.24 ± 0.02	15.773	**< 2×10^{-16}**
Proportion of LCS	0.02 ± 0.02	0.773	**0.44**	0.01 ± 0.03	0.331	0.741	0.01 ± 0.02	0.452	0.651
Sea level pressure	0.07 ± 0.02	4.679	**2.90×10^{-6}**	0.09 ± 0.02	5.690	**1.28×10^{-8}**	0.08 ± 0.02	5.345	**9.11×10^{-8}**
Intercept (ν)	0.99 ± 0.03	39.417	**< 2×10^{-16}**	1.00 ± 0.03	35.648	**< 2×10^{-16}**	0.98 ± 0.03	38.816	**< 2×10^{-16}**
Chlorophyll-*a*	-0.15 ± 0.01	-11.116	**< 2×10^{-16}**	-0.13 ± 0.01	-12.198	**< 2×10^{-16}**	-0.12 ± 0.01	-11.194	**< 2×10^{-16}**
Depth	0.02 ± 0.01	1.755	0.079	$4.74\times10^{-3} \pm 3.62\times10^{-3}$	1.309	0.191	0.01 ± 0.01	0.876	0.381
Distance to 18°C SST isotherm	0.11 ± 0.02	6.685	**2.34×10^{-11}**	0.10 ± 0.02	6.207	**5.47×10^{-7}**	0.08 ± 0.02	5.133	**2.88×10^{-7}**
FSLE	0.20 ± 0.02	13.293	**< 2×10^{-16}**	0.20 ± 0.02	12.834	**< 2×10^{-16}**	0.20 ± 0.01	15.329	**< 2×10^{-16}**
Proportion of LCS	0.13 ± 0.02	7.570	**3.82×10^{-14}**	0.12 ± 0.03	4.804	**1.57×10^{-6}**	0.13 ± 0.02	8.147	**3.87×10^{-16}**
% Moon illumination	-3.88×10^{-3} ± 0.01	-0.628	0.530	$-1.34\times10^{-3} \pm 9.23\times10^{-4}$	-1.451	0.147	0.01 ± 0.01	0.466	0.641
Sea level pressure	0.11 ± 0.01	7.802	**6.27×10^{-15}**	0.11 ± 0.01	7.410	**1.29×10^{-13}**	0.11 ± 0.02	7.639	**2.24×10^{-14}**
Wind speed	0.09 ± 0.01	12.907	**< 2×10^{-16}**	0.09 ± 0.01	13.058	**< 2×10^{-16}**	0.10 ± 0.01	15.146	**< 2×10^{-16}**

Methods S1

The following function was used to calculate wind direction relative to birds' flight paths in the program R (R Core Team 2020).

```
# relative_wind.R

# Given a flight trajectory [(t, x, y)] and co-located wind vectors [(u, v)],
# calculate the relative angle between flight and wind along the trajectory

library(dplyr)
library(geosphere)
library(glue)
library(ggplot2)
library(mapproj)

# Example data frame
set.seed(1)
tracks <- tibble(
  time = 1:5,
  lon = -122 + cumsum(rnorm(5)),
  lat = 37 + cumsum(rnorm(5)),
  u = cumsum(rnorm(5)),
  v = cumsum(rnorm(5)))

# Visualize tracks and wind vectors. Wind vectors in blue
(p <- ggplot(tracks) +
   geom_segment(aes(x = lon, y = lat, xend = lead(lon), yend = lead(lat)),
             arrow = arrow(angle = 15,
                        length = unit(10, "points"),
                        type = "closed")) +
   geom_segment(aes(x = lon, y = lat,
                xend = lon + u / 4, yend = lat + v / 4),
             arrow = arrow(angle = 15,
                        length = unit(10, "points"),
                        type = "closed"),
             color = "blue") +
   geom_label(aes(x = lon, y = lat, label = time), nudge_x = -0.15) +
   coord_map() +
   theme_classic())

# Calculate wind direction relative to travel
relative_direction <- function(x, y, u, v) {
  # Divide the vu vector by its norm to get the unit vector along vu
```

```
  vu <- cbind(v, u)
  norm_vu <- apply(vu, 1, function(row) sqrt(sum(row^2)))
  vu_unit <- vu / cbind(norm_vu, norm_vu)
  # Track unit vectors calculated from sequential bearing
  # Bearing by default is in "degrees east of north", but we need "radians north
  # of east" to compare against vu
  track_bearing <- (90 - bearing(cbind(x, y))) * pi / 180
  track_unit <- cbind(sin(track_bearing), cos(track_bearing))
  # Angle between track and wind is the difference of the arctangents
  atan2(track_unit[,1], track_unit[,2]) - atan2(vu_unit[,1], vu_unit[,2])
}
annotated_tracks <- tracks %>%
  mutate(winddir = relative_direction(lon, lat, u, v))

# Show plot with wind angle
p + geom_label(aes(x = lon, y = lat,
               label = glue("{format(winddir*180/pi, digits=2)}º")),
             annotated_tracks,
             nudge_x = 0.3, nudge_y = 0.1)

# Sanity checks
# A track and wind in the same direction should get 0 rad
relative_direction(x = c(0, 1), y = c(0, 0),
               u = c(1, 1), v = c(0, 0))
# A track and wind in opposite directions should get -pi rad
relative_direction(x = c(0, 1), y = c(0, 0),
               u = c(-1, -1), v = c(0, 0))
# Wind *from* the left should get pi/2 rad
relative_direction(x = c(0, 0), y = c(0, 1),
               u = c(1, 1), v = c(0, 0))
# Wind *from* the right should get -pi/2 rad
relative_direction(x = c(0, 0), y = c(0, 1),
               u = c(-1, -1), v = c(0, 0))

# Display relative wind direction in a wind rose plot
# NOTE: winddir unit=radians; change to degrees by multiplying by 180 and then dividing by pi
plot_relative_wind<-ggplot(data=annotated_tracks, aes(x=(winddir*180)/pi)+
          theme_bw()+
          geom_histogram(position=position_dodge2(),
                    breaks=seq(0,360,by=30),
                    fill="black",
                    colour="white")+
          scale_x_continuous(labels=seq(0,360,by=30),
               breaks=seq(0,360,by=30),
```

```
        limits=c(0,360))+
    coord_polar()+
    theme(legend.position = "bottom",
          plot.margin = margin(0,0,0,-1), #top, right, bottom, left
          panel.grid = element_line(colour="grey50"),
          strip.background = element_blank(),
          strip.text = element_text(colour="black",size=14),
          axis.text.x = element_text(face="bold",colour="black"),
          axis.title.x = element_blank())
```

Literature Cited

Humphries G (2021) SeabiRd: Seabird-focused colour themes for R. R package version 0.1.0. https://github.com/grwhumphries/seabiRd.

R Core Team (2020) R: A language and environment for statistical computing.