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Adrien Chaigne, Karine Delord, Bruno Mansoux, Charles-André Bost, Henri Weimerskirch, Christophe Barbraud

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SEABIRD DISTRIBUTION IN THE SOUTHERN INDIAN OCEAN

FOUR DECADES OF AT SEA SURVEY



CHAIGNE Adrien, DELORD Karine, MANSOUX Bruno, BOST Charles-André,
WEIMERSKIRCH Henri, BARBRAUD Christophe



Seabird distribution in the Southern Indian Ocean: four decades of at sea surveys

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Executive summary

Seabirds are conspicuous and important marine predators. They mostly forage on a diversity of zooplankton (copepods, euphausiids, amphipods) and nekton (squid and fish) prey. Because of their position in the trophic web, high energy requirements, mobility and longevity, these top marine predators can be used as indicators of the spatial variability of marine ecosystem functions and dynamics. We present here distribution maps of resident and migratory seabirds observed in two regions of the Southern Indian Ocean.

The present *Atlas* focuses on seabird's distribution in the Southern Indian Ocean using a unique long-term dataset (1978-2020) of at-sea observations made repeatedly over two time periods separated by 10 years to examine spatial and seasonal variation in seabird abundance and occurrence at a large spatial scale. Cruises encompassed a 30° latitudinal gradient through tropical, subtropical, subantarctic and Antarctic waters of the Southern Indian Ocean, allowing to explore the distribution of 71 seabird species (or pooled species). This is the first comprehensive summary of information on how some species or communities of seabirds of the Southern Indian Ocean use the habitats of this immense area.

The present *Atlas* aims (1) to summarize the information on the occurrence and abundance of subantarctic and Antarctic seabirds over the period 1978-2020, according to season (austral summer versus austral winter) in two distinct geographical areas in the Southern Indian Ocean (western and eastern areas), and (2) to quantify the species diversity using diverse metrics.

The produced maps provide insights on biogeographic affinities, habitat associations, and “hotspots” of biodiversity and potential predator-prey dynamics. Identifying hotspots is potentially valuable in the design of offshore marine protected area networks. Within the study regions, we found apparent hotspots in subantarctic and Antarctic waters, especially in the vicinity of subantarctic islands. We observed strong seasonal changes in the distribution and abundance of seabirds, which alters the relative importance of these hotspots. The value of hotspots for the protection of these far-ranging pelagic species deserves further study.

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Introduction

As upper trophic level predators feeding on a wide variety of food resources spanning from copepods to small pelagic fish, seabirds accumulate and integrate climatic, oceanographic, and food-web variation and provide immediate signals of changes in ecosystems that are difficult to observe directly, particularly in remote regions of the world (Furness and Camphuysen 1997; Constable et al. 2000; Trathan et al. 2007). Indeed, seabirds are considered as good indicators of changes in ecosystems at differential spatial and temporal scales (Piatt and Sydeman 2007). They are important components of the ecosystems and are by far the most studied taxa in the Southern Ocean marine environment (Barbraud et al. 2012; Constable et al. 2014). The presence of diverse and abundant top predators is indicative of other taxa, such as their prey (Wilson et al. 1994; Benoit-Bird et al. 2011) or other top predators with which they associate for feeding (Ballance et al. 1997; Thiebot and Weimerskirch 2013). In addition, top predators tend to congregate in highly productive areas and habitats, such as shelf slopes, seamounts and upwelling systems (Hunt et al. 1999; Nur et al. 2010; Lascelles et al. 2012).

Whereas changes in demographic parameters, population sizes and movements at sea of several Antarctic and subantarctic seabird species have been related to both local and large-scale climatic changes (Weimerskirch et al. 2003; Trathan et al. 2007; Forcada and Trathan 2009; Barbraud et al. 2012; Bost et al. 2015; Orgeret et al. 2022), there are few studies investigating the long-term changes in at-sea distribution based on tracking or at-sea observations. Péron et al. (2010) were the first to document a shift in species range and abundance in the Southern Ocean related to climate change.

The movements and distribution at sea of the largest species of seabirds have been studied for over thirty years thanks to the development of remote tracking instruments. The miniaturization of devices and technological developments have made it possible to study a large number of species and acquire increasingly precise information (Jouventin and Weimerskirch 1990; Prince et al. 1992; Weimerskirch and Wilson 2000; Weimerskirch et al. 2002; Phillips et al. 2007, 2017; Wakefield et al. 2009). Delord et al. (2013) compiled remote tracking data in the Southern Indian Ocean into the Atlas of top predators from French Southern Territories. Yet, due to the difficulty to access colonies on remote islands with harsh climate and due to technological limitations, there is still a lack of information on at sea distribution on many seabird species (Phillips et al. 2016; Rodriguez et al. 2019). As seabirds spend most of their time at sea, vessel-based surveys are precious tools to investigate species' occurrence and abundance. Their advantages are to provide information on abundance of (1) species inaccessible on land (Ballance, 2007), (2) small species under weight limits for logger equipment, and (3) the non-breeding fraction of the population, a component frequently ignored by land-based monitoring (Aebischer and Wanless 1992; Phillips et al. 2016). In addition, at-sea surveys are cost efficient when they involve opportunity cruises (supply operations or oceanographic cruises).

Most of the vessel-based surveys conducted in the Southern Ocean aimed at characterizing seabird communities and their oceanographic habitats using short-term monitoring surveys (Ainley *et al.*, 1994; Van Franeker *et al.*, 2002; Raymond and Woehler, 2003; Hyrenbach *et al.*, 2007). To our knowledge, there are few long-term studies of seabird abundance and distribution at sea in the Southern Ocean over recent decades. Woehler (1997) conducted annual observations of seabirds within Prydz Bay, East Antarctica, between the 1980/1981 and 1992/1993 seasons and revealed significant changes in abundance of the 9 resident and 15 non-resident species. In the Southern Indian Ocean, Stahl et al. (unpublished) produced an Atlas of Seabird Distribution in the South-West Indian Ocean that summarized results of quantitative seabird surveys undertaken on board RV *Marion Dufresne* in the Southern Indian Ocean between 1978 and 1988

The present *Atlas* focuses on seabird's distribution in the Southern Indian Ocean using a unique long-term dataset of at-sea observations made repeatedly from 1978 to 2020 using both occurrence and abundance data at a large spatial scale. Cruises encompassed a 30° latitudinal gradient through tropical, subtropical, subantarctic and Antarctic waters of the Southern Indian Ocean, allowing to explore the distribution of 71 species (or pooled species) of penguins, albatrosses, petrels, shearwaters, terns and jaegers. This *Atlas* includes data presented by Stahl et al. and represents the first comprehensive summary of information on seabird distribution and abundance covering the past 50 years in the Southern Indian Ocean.

For each of the 71 species (or pooled species), the present *Atlas* aims to present (1) occurrence and abundance maps of seabirds compiled between 1978 and 2020, according to season (austral summer versus austral winter) in two distinct geographical areas in the Southern Indian Ocean (western and eastern areas), and (2) to quantify the species diversity using diverse indices of diversity.

Methods

Study area

Two distinct geographic areas (Fig. 1) are considered in this study:

- the South-West Indian Ocean, between Mascarene Islands (La Reunion and Mauritius) and Antarctica, including the subantarctic and subtropical islands of the French Southern Territories (Crozet Archipelago, Kerguelen Archipelago, Saint-Paul Island and Amsterdam Island) and other subantarctic islands (Marion and Prince-Edward Islands, Heard and MacDonald Islands). Boundaries for seabird observations in this study area are 29° and 88° East, 68° and 19° South.
- the extreme South-East Indian Ocean, between Tasmania and Antarctica. Boundaries for seabird observations in this study area are 133° and 150° East, 68° and 43° South.

These areas include the voyages made by several oceanographic/supply vessels during supply operations of the French Antarctic and subantarctic stations (Alfred Faure, Crozet; Port-aux-Français, Kerguelen; Martin de Viviès, Amsterdam; Dumont d'Urville, Terre Adélie, Antarctica) and during oceanographic cruises.

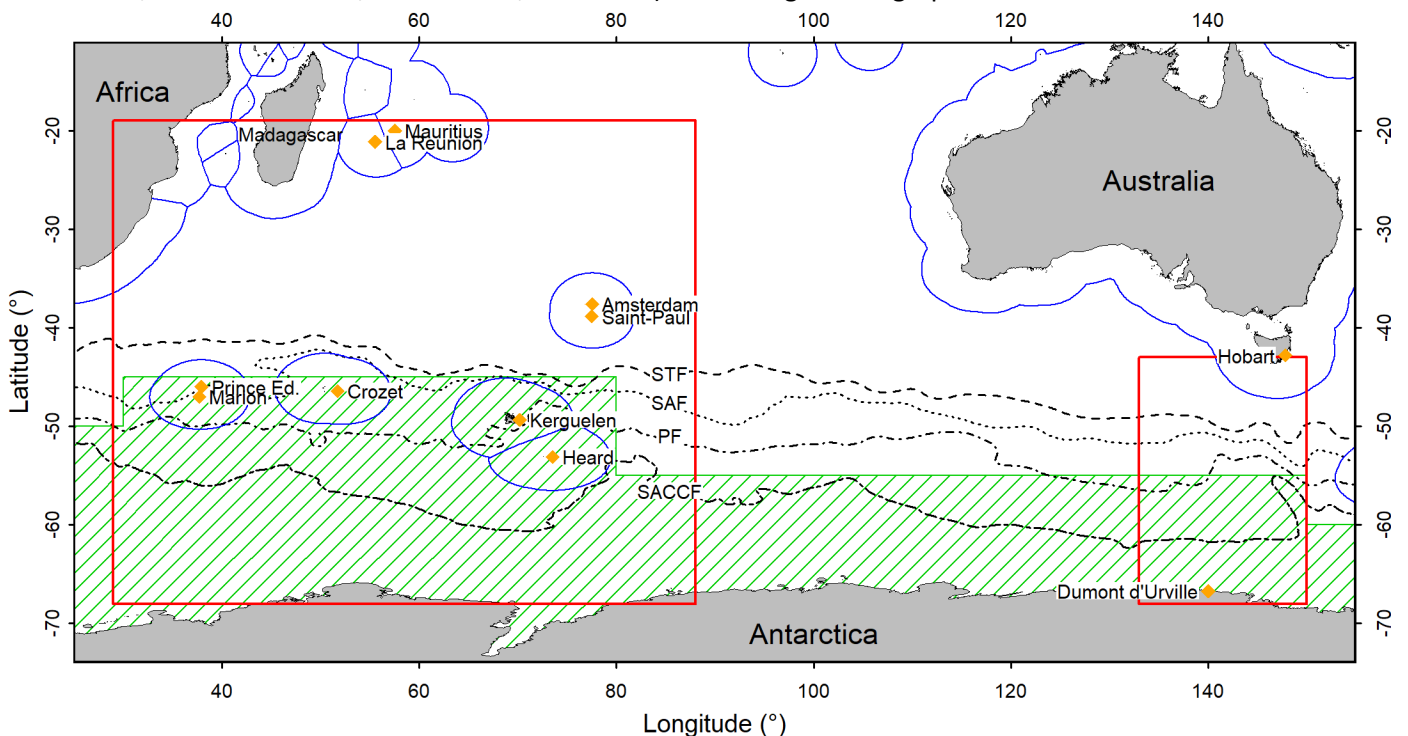


Figure 1 - Location of the two study areas in the Southern Indian Ocean. Red rectangle: study area, striped green background: Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) area, blue line: Economic Exclusive Zone, dotted lines: mean position of oceanographic fronts (Park & Durand 2019), STF: Subtropical Front, SAF: Subantarctic Front, PF: Polar Front, SACCF: Southern Antarctic Circumpolar Current Front

Seabird surveys

Seabird surveys from 1978 to 1998 were based on 10-minute observation periods during which all birds observed during repeated 360° scans from the bridge were recorded, regardless of their distance from the moving vessel. Time interval between observation sessions was variable. This observation protocol was adapted from the one developed for the Canadian PIROP project (Brown et al. 1975).

From 2002, this seabird survey program was reactivated and following a review of survey methods of seabirds at sea, seabirds were recorded using the strip transect method (Tasker *et al.*, 1984). Surveys were conducted while looking forward from the bridge of the moving vessel, scanning at a 90° angle from either the port or starboard side and

limiting observations to a transect band 300 m wide from the observer. Transects were continuously surveyed by eye to count and identify all seabirds present in air or on water. Only one observer at a time performed the observations. Binoculars were used to confirm species identification, and other details, such as age, moult, and behaviour. If large concentrations of seabirds were observed during a transect, a second observer assisted the first observer to count the most abundant species (usually prions or shearwaters). This method assumes that the probability of detecting seabirds equals 1 within the 300 m strip (Barbraud and Thiebot 2009).

For both protocols (*i.e.* before 1998 and after 2002) survey effort was maintained throughout daylight hours on the one side of the vessel with best visibility (least sun glare). Sighting position was determined by the Global Positioning System of the ship and observation conditions were recorded before each count (visibility, wind force, precipitation, sea state, ship speed, ship direction, etc...). Counts were stopped when ships were stationary. As many seabird species tend to follow ships (hereafter termed ship-followers), a second count was made immediately after each 10-minute observation session at the rear of the boat to provide a snapshot of birds following in the wake. In addition, all other species observed within the remaining hour (outside the 10-minute count period and rear count) were also recorded as opportunistic data. In January 2002 and 2003 and February 2003, a continuous survey was performed (Hyrenbach et al. 2006; Hyrenbach et al. 2007) and data were recorded in various time periods ranging from 3 to 10 minutes.

Seabird counts were performed by highly experienced or trained observers so that identifications were made to the lowest possible taxonomic level. Observers had experience working with seabirds and as strong knowledge of their behaviour and ecology, were able to rapidly identify Southern Ocean seabirds in all plumages, in various lighting conditions, reduced visibilities, and in rough ocean conditions. They were trained to follow the survey protocols and to accurately record data.

Observations were made during inter-island transects or oceanographic cruises in the two distinct study areas:

- In the South-West Indian Ocean. This included 224 inter-islands transects (supply operations) or oceanographic cruises aboard the supply and oceanographic ships *Marion Dufresne I* and *Marion Dufresne II* and opportunistically with other ships (*Leon Thevenin*: 1 cruise, *L’Austral*: 2 cruises, *Oceanic Viking*: 1 cruise).
- Between Tasmania and Antarctica. This included 8 transects between Hobart and Dumont-d’Urville French research station of the supply ships *L’Astrolabe I* and *L’Astrolabe II*.

Surveys were conducted between January 1978 and January 2020. A total of 17 644 data sheets (= stations) were recorded. Each data sheet can include a 10-minute count, a rear counts, a continuous recording and opportunistic data. It should be noted that a data sheet mainly includes several types of effort (for example, a 10-minute count is followed by a rear count and sometimes by an opportunistic record).

Sector	South-West Indian Ocean		Tasmania-Antarctica	
	1978-1995	2002-2020	1997-1998	2004-2020
Number of data sheets	6 784	10 481	30	349
with:				
- 10-min count	6 781	7 083	29	347
- rear count	0	7 083	0	347
- continuous recording	0	3 367*	0	0
- opportunistic data	45	2 117	25	207

Table 1: Number of data sheets (= stations) by type of effort, area and years. * years 2003 and 2004 only.

Survey effort is mapped on a 0.5°x0.5° grid (Fig. 2 to 4) and is defined as the number of 10-minute count and rear count sessions per square of 0.5°x0.5°.

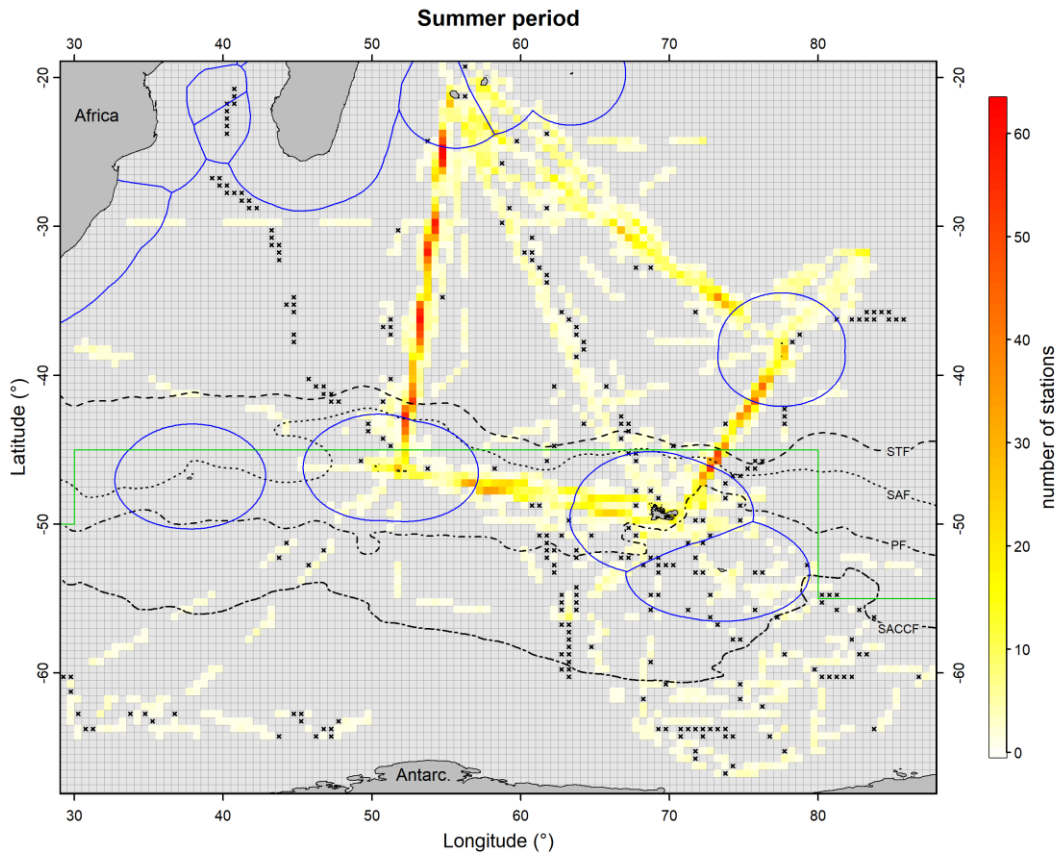


Figure 2 - Observation effort (number of stations with 10-min and rear counts per square $0.5^{\circ} \times 0.5^{\circ}$) in the south-west Indian Ocean area during summer. Grey "x" indicates presence of additional opportunistic or continuous records.

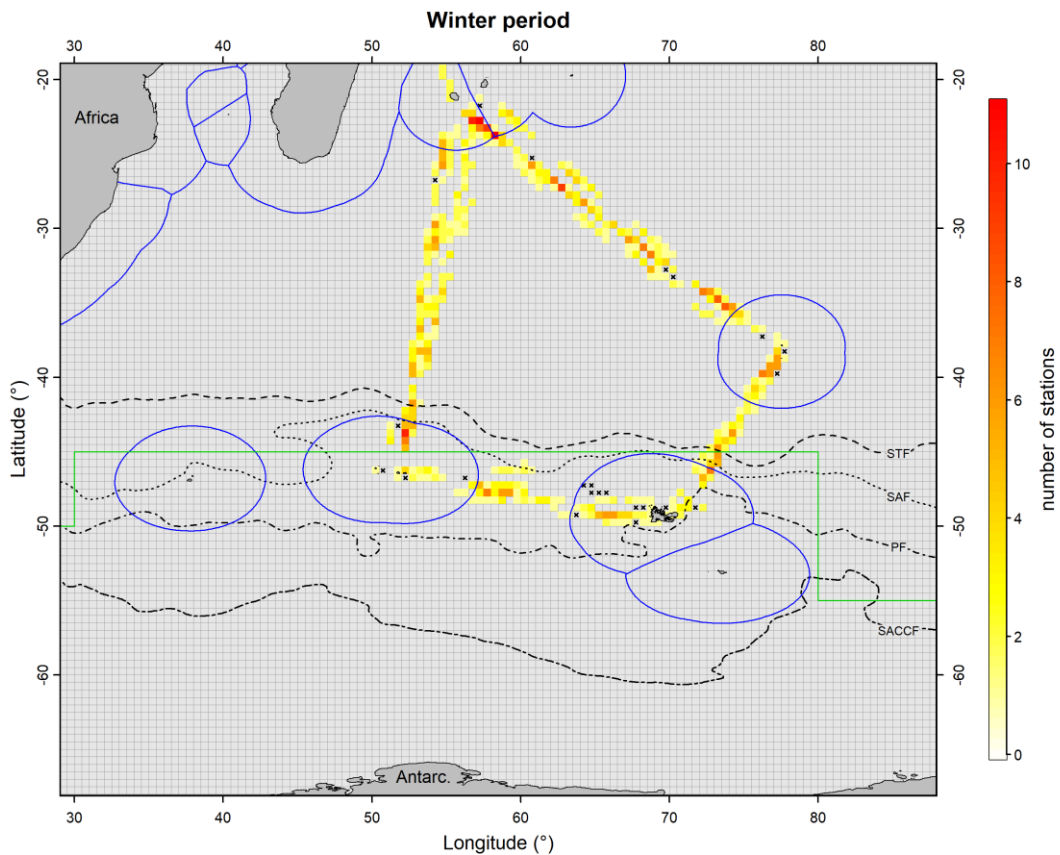


Figure 3 - Observation effort (number of stations with 10-min and rear counts per square $0.5^{\circ} \times 0.5^{\circ}$) in the south-west Indian Ocean area during winter. Grey "x" indicates presence of additional opportunistic records.

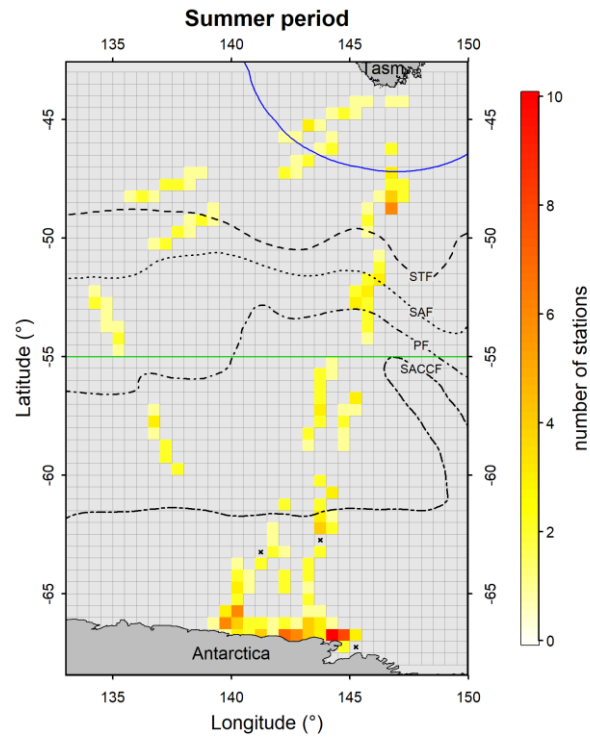


Figure 4 - Observation effort (number of stations with 10-min and rear counts per square 0.5°x0.5°) during Hobart-Dumont d'Urville transects. Grey "x" indicates presence of additional opportunistic records. No count was made during the winter period.

Survey effort (number of stations with 10-min and rear counts) by year and month is described in Figures 5 and Figure 6.

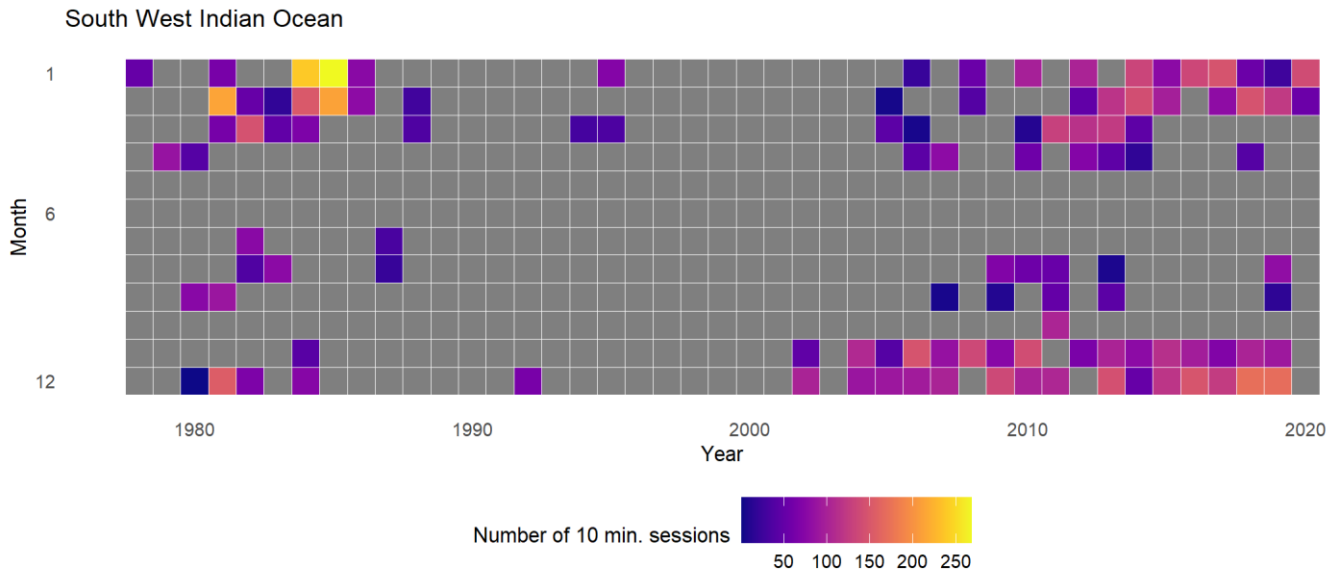


Figure 5 - Temporal distribution of survey effort (number of stations with 10-min and rear counts) by year and month in the south-west Indian Ocean area

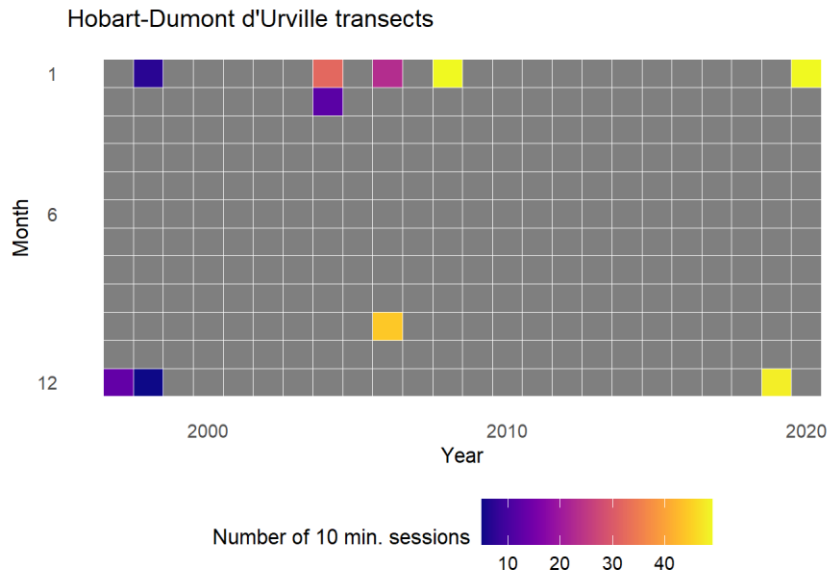


Figure 6 - Temporal distribution of survey effort (number of stations with 10-min and rear counts) by year and month during Hobart-Dumont d'Urville transects.

Data recording

Data are manually recorded by observers and include general information, ship conditions, meteorological conditions, sea conditions and seabird records details. Recorded field information are described in Table 2.

Data were stored in a database, first in an Access format (Seabird and marine mammal at-sea survey Chizé database) and then in a PostgreSQL format (database managed by Marine Predator team at CEBC in collaboration with UAR Pelagis & UAR BBEEES; see also <https://doi.org/10.15468/nutvhu> accessed via GBIF.org on 2024-09-09).

Field name	unit or value	format
General informations		
observer name	/	text
vessel name	/	text
campaign	/	text
date	UTC	dd/mm/yyyy
time at the start of the session	UTC	hh:mm
longitude and latitude	degree and minutes	decimal
comments	/	text
Ship conditions		
quadrant side	port/starboard	factor
ship activity	streaming/trawling/oceanography...	factor
ship speed	knots	decimal
ship course	degree	integer
Meteorological and sea conditions		
cloud coverage	clear/partly cloudy/continuous cloud	factor
precipitation	from "1 - none" to "6 – thunderstorms"	factor
wind force	Beaufort scale	factor
wind speed	knots	decimal
wind direction	degree	integer
air temperature	celsius degree	decimal
air pressure	hPa	decimal
sea state	Douglas scale	factor
sea temperature	celsius degree	decimal
iceberg	yes/no	boolean
sea ice cover	%	integer
visibility	kilometers	factor
salinity (if measurement available)	%	decimal
depth (if measurement available)	meters	integer
Species details		
type of observation	10 minutes/rear/between 10 min.	factor
species	4 letters code	factor
age (if possible)	Juvenile/immature/adulte	factor
count	individuals	integer
behaviour	flying past/following/sitting on water/...	factor
moult (not always recorded)	yes/no	factor
distance (not always recorded)	meters	integer

Table 2: Details of recorded information in the database.

Data analysis

Data extracted from the database were first filtered to detect erroneous values (error in position format, in date/time format...). A speed filter was implemented to detect outlier positions of the ship during transects. Missing or outlier positions were corrected by interpolation with previous and next known ship positions given their date/time (Figure 7). Observations of species outside their regular range were checked to evaluate their robustness and reliability. Species ranges were taken from various sources including Harrison (1983, 2021), Marchant & Higgins (1990), Brooke (2004), Onley & Scofield (2007) and the Seabird Tracking Database (<http://seabirdtracking.org/>). When observations of species outside their regular range were present in the database, we only retained those that were performed by highly experienced observers who had already performed several seabird surveys in the region. When there was any doubt in species identification, we retained a higher taxonomic level (genus or family) or a species group. Only few species taxa were not identified at the species level (e.g. *Pachyptila sp.*, *Anous stolidus/A. tenuirostris*, *Diomedea epomophora/D. sanfordi*, *Puffinus assimilis/P. lherminieri*, *Ardenna pacifica/A. carneipes*, *Morus serrator/M. capensis*, *Sterna vittata/S. paradisaea*), due to their difficult identification at sea.

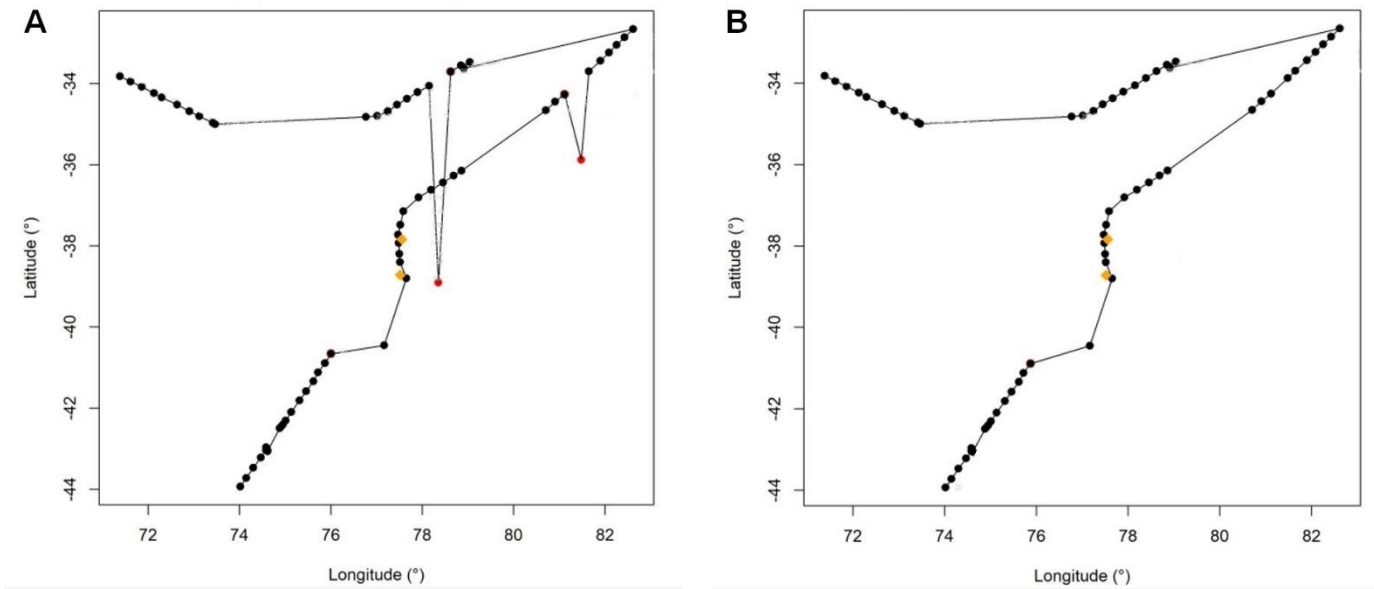


Figure 7 - Example of ship track before (A) and after (B) speed filtering and interpolation of outlier positions. Black dot: correct position, red dot: presumed outlier position, yellow diamond: island position.

The dataset was divided in two seasonal periods according to the breeding phenology of most seabird species breeding in the French Southern Territories. The “summer” period, from September to March, corresponds to the breeding period of most species. The “winter” period, from April to August, corresponds to the inter-breeding period of most species, except for the few winter-breeding species.

The study area was divided in $0.5^{\circ} \times 0.5^{\circ}$ cells in which presence of species and abundance were calculated. Presence/pseudo-absence matrices on the cells were generated with the whole dataset (10-min, rear and opportunistic counts), and were filled with values 0 (no observation), 1 (presence = at least one observation) or NA (no effort).

We only used the 10-minute count data to calculate and map the abundance of each species. To ensure a constant effort across years and to avoid spatial and temporal autocorrelation, data were resampled when they were collected with a time interval below 50 minutes. In January 2002 and 2003 and February 2003, continuous surveys were implemented (Hyrenbach et al. 2006; Hyrenbach et al. 2007). These data were removed from abundance estimates because of their heterogeneity with the rest of the dataset. To calculate and map the abundance, we only selected surveys made when the vessel cruising-speed was > 6 knots, visibility was > 300 m, sea state was not stronger than rough (swell lower than 4m) and no or moderate precipitation (remove of precipitation classified as “shower”). This data selection based on observation conditions limited bias in detection probability and counts, especially for small-sized species (Tasker *et al.*, 1984; Spear *et al.*, 2004; Barbraud & Thiebot 2009). We defined a “station” as a ship localization where a 10-minute session was performed. From these filtered data we calculated several metrics:

Mean abundance for each species as:

- $N_{s,j} = \sum_i N_{s,i,j} / E_j$

where $N_{s,j}$ is the abundance of species s in cell j , $N_{s,i,j}$ is the count of individuals from species s in the i^{th} station of the cell j and E_j is the number of stations in cell j .

Mean abundance for all seabird species as:

- $N_j = \sum_s N_{s,j}$

where N_j is the abundance in cell j . To display values on a log scale, abundances were log transformed using formula (see Hyrenbach et al. 2007):

- $N_{\log s,j} = \log_{10}(N_{s,j} + 0.1)$

and

- $N_log_j = \log_{10}(N_j + 0.1)$

Data transformation re-coded the minimum (0.00) and maximum (609.00) mean abundance per cell as -1.00 and 2.78, respectively.

Several indices were calculated on 0.5°x0.5° cells:

- Richness, calculated as the number of species recorded at least once, irrespective of the number of stations in each cell.
- Threatened species ratio, calculated as the number of threatened species (IUCN status “CR”, “EN” or “VU”) divided by the total number of species recorded.
- Shannon’s diversity index, calculated with species abundance on 10-minute counts. It is a way to measure the evenness of species in a community, where evenness refers to how similar the abundances of different species are in the community.
- Simpson’s diversity index, calculated with species abundance on 10-minute counts. This index equals the probability that two entities taken at random from the dataset represent the same species. It is constrained to values between 0 and 1.

Data extraction from the Seabird and marine mammal at-sea survey Chizé database was carried out with pgAdmin software. Analyzes were carried out with R software (R Core Team 2020). The “sf” package (Pebesma 2018) was used to manipulate spatial data. The Shannon's and Simpson's indices were calculated with the “Vegan” package (Oksanen 2019).

For each species listed in table 3, presence/pseudo-absence matrices and log transformed mean species abundance matrices are displayed on a 0.5°x0.5° resolution grid map. Abundance maps are provided for only the most common species (at least 10 records). Southern Ocean oceanographic fronts (Park & Durand 2019), Economic Exclusive Zones (EEZ) and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) area are displayed on maps.

Distribution and abundance maps

For each species listed in table 3, we first display presence/pseudo-absence maps in summer and winter on the sector where it has been recorded (south-west Indian Ocean or between Tasmania and Antarctica). We then display abundance maps with the same arrangement. For scarce species (less than 10 records), abundance maps are not displayed.

Table 3: List of seabird species recorded during at sea surveys and species' pooling (Procellariiformes are classified following Onley & Scofield 2007; other orders are classified following Shirihai 2007). * IUCN 2020.

Scientific name	English name	French name	Status*
<i>Aptenodytes patagonicus</i>	King Penguin	Manchot royal	LC
<i>Aptenodytes forsteri</i>	Emperor Penguin	Manchot empereur	NT
<i>Pygoscelis papua</i>	Gentoo Penguin	Manchot papou	NT
<i>Pygoscelis adeliae</i>	Adélie Penguin	Manchot Adélie	LC
<i>Pygoscelis antarctica</i>	Chinstrap Penguin	Manchot à jugulaire	LC
<i>Eudyptes sp.</i>	Eudyptes sp.	Gorfou indéterminé	/
<i>Diomedea exulans</i>	Wandering Albatross	Albatros hurleur	VU
<i>Diomedea amsterdamensis</i>	Amsterdam Albatross	Albatros d'Amsterdam	EN
<i>Diomedea epomophora / D. sanfordi</i>	Southern / Northern Royal Albatross	Albatros royal du Sud / du Nord	VU / EN
<i>Phoebastria immutabilis</i>	Laysan Albatross	Albatros de Laysan	NT
<i>Thalassarche melanophrys / T. impavida</i>	Black-browed Albatross / Campbell Albatross	Albatros à sourcils noirs / Albatros de Campbell	LC / VU
<i>Thalassarche cauta / T. salvini</i>	Shy Albatross / Salvin's Albatross	Albatros timide / Albatros de Salvin	NT / VU
<i>Thalassarche eremita</i>	Chatham Albatross	Albatros de Chatham	VU
<i>Thalassarche chrysostoma</i>	Grey-headed Albatross	Albatros à tête grise	VU
<i>Thalassarche carteri</i>	Indian yellow-nosed Albatross	Albatros à bec jaune de l'Océan Indien	EN
<i>Thalassarche bulleri</i>	Buller's Albatross	Albatros de Buller	NT
<i>Phoebetria fusca</i>	Sooty Albatross	Albatros fuligineux à dos sombre	EN
<i>Phoebetria palpebrata</i>	Light-mantled Sooty Albatross	Albatros fuligineux à dos clair	NT
<i>Macronectes giganteus</i>	Southern Giant Petrel	Pétrel géant antarctique	LC
<i>Macronectes halli</i>	Northern Giant Petrel	Pétrel géant subantarctique	LC
<i>Macronectes sp.</i>	Giant Petrel sp.	Pétrel géant indéterminé	LC
<i>Fulmarus glacialisoides</i>	Southern Fulmar	Fulmar antarctique	LC
<i>Thalassoica antarctica</i>	Antarctic Petrel	Pétrel antarctique	LC
<i>Daption capense</i>	Cape Petrel	Damier du Cap	LC
<i>Pagodroma nivea</i>	Snow Petrel	Pétrel des neiges	LC
<i>Lugensa brevirostris</i>	Kerguelen Petrel	Pétrel de Kerguelen	LC

<i>Halobaena caerulea</i>	Blue Petrel	Pétrel bleu	LC
<i>Pachyptila sp.</i>	Prion sp.	Prion indéterminé	LC
<i>Pachyptila turtur</i>	Fairy Prion	Petit Prion	LC
<i>Bulweria bulwerii</i> / <i>B. fallax</i> / <i>Pseudobulweria aterrima</i>	Bulweria sp. / Pseudobulweria sp.	Bulweria / Pseudobulweria indéterminé	LC / NT / CR
<i>Pterodroma nigripennis</i> / <i>P. cookii</i> / <i>P. leucoptera</i>	“cookilaria” petrel	Pétrel de type “cookilaria”	LC / VU / VU
<i>Pterodroma inexpectata</i>	Mottled Petrel	Pétrel maculé	NT
<i>Pterodroma baraui</i>	Barau's Petrel	Pétrel de Barau	EN
<i>Pterodroma macroptera</i>	Great-winged Petrel	Pétrel noir	LC
<i>Pterodroma lessonii</i>	White-headed Petrel	Pétrel à tête blanche	LC
<i>Pterodroma mollis</i>	Soft-plumaged Petrel	Pétrel soyeux	LC
<i>Pterodroma cervicalis</i> / <i>P. incerta</i> / <i>P. arminjoniana</i> / <i>P. externa</i>	Other large Pterodroma	Autre Pterodrome de grande taille	VU / EN / VU
<i>Procellaria aequinoctialis</i>	White-chinned Petrel	Pétrel à menton blanc	VU
<i>Procellaria cinerea</i>	Grey Petrel	Pétrel gris	NT
<i>Calonectris diomedea</i>	Cory's Shearwater	Puffin cendré	LC
<i>Ardenna pacifica</i> / <i>A. carneipes</i>	Wedge-tailed Shearwater / Flesh-footed Shearwater	Puffin du Pacifique/ Puffin à pieds pâles	LC / NT
<i>Ardenna gravis</i>	Great Shearwater	Puffin majeur	LC
<i>Ardenna tenuirostris</i>	Short-tailed Shearwater	Puffin à bec grêle	LC
<i>Ardenna grisea</i>	Sooty Shearwater	Puffin fuligineux	NT
<i>Puffinus assimilis</i> / <i>P. lherminieri</i> / <i>P. elegans</i>	Little Shearwater / Baillon's Shearwater / Subantarctic Shearwater	Puffin semblable / Puffin de Baillon / Puffin élégant	LC / LC / LC
<i>Oceanites oceanicus</i>	Wilson's Storm-petrel	Océanite de Wilson	LC
<i>Garodia nereis</i>	Grey-backed Storm-petrel	Océanite à croupion gris	LC
<i>Pelagodroma marina</i>	White-faced Storm-petrel	Océanite frégate	LC
<i>Fregetta grallaria</i>	White-bellied Storm-petrel	Océanite à ventre blanc	LC
<i>Fregetta tropica</i>	Black-bellied Storm-petrel	Océanite à ventre noir	LC
<i>Pelecanoides georgicus</i> / <i>P. urinatrix</i>	South Georgia Diving-petrel / Common Diving-petrel	Pétrel plongeur de Géorgie du Sud / Pétrel plongeur commun	LC / LC
<i>Phalacrocorax melanogenis</i>	Crozet Shag	Cormoran de Crozet	LC
<i>Phalacrocorax verrucosus</i>	Kerguelen Shag	Cormoran de Kerguelen	LC
<i>Sula dactylatra</i>	Masked Booby	Fou masqué	LC
<i>Sula sula</i>	Red-footed Booby	Fou à pieds rouges	LC
<i>Morus serrator</i> / <i>M. capensis</i>	Australasian Gannet / Cape Gannet	Fou austral / Fou du Cap	LC / EN
<i>Catharacta maccormicki</i>	South Polar Skua	Labbe de Maccormick	LC
<i>Catharacta antarctica lonnbergi</i>	Brown Skua	Labbe subantarctique	LC
<i>Stercorarius longicaudus</i>	Long-tailed Jaeger	Labbe à longue queue	LC

<i>Stercorarius parasiticus</i>	Parasitic Jaeger	Labbe parasite	LC
<i>Stercorarius pomarinus</i>	Pomarine Jaeger	Labbe pomarin	LC
<i>Larus dominicanus</i>	Kelp Gull	Goéland dominicain	LC
<i>Sterna vittata / S. paradisaea</i>	Antarctic Tern / Arctic Tern	Sterne arctique / Sterne antarctique	LC / LC
<i>Sterna virgata</i>	Kerguelen Tern	Sterne de Kerguelen	NT
<i>Onychoprion fuscata / O. anaethetus</i>	Sooty Tern / Bridled Tern	Sterne fuligineuse / Sterne bridée	LC / LC
<i>Thalasseus bengalensis / T. bergii</i>	Lesser Crested Tern / Greater Crested Tern	Sterne voyageuse / Sterne huppée	LC / LC
<i>Sterna sumatrana</i>	Black-naped Tern	Sterne diamant	LC
<i>Gygis alba</i>	White Tern	Gygis blanche	LC
<i>Anous stolidus / A. tenuirostris</i>	Brown Noddy / Lesser Noddy	Noddi brun / Noddi marianne	LC / LC
<i>Phaeton rubricauda</i>	Red-tailed Tropicbird	Paille-en-queue à brins rouges	LC
<i>Phaeton lepturus</i>	White-tailed Tropicbird	Paille-en-queue à brins blancs	LC
<i>Fregata ariel/ F. minor</i>	Lesser Frigatebird / Great Frigatebird	Frégate ariel / Frégate du Pacifique	LC / LC

King Penguin *Aptenodytes patagonicus* (LC)

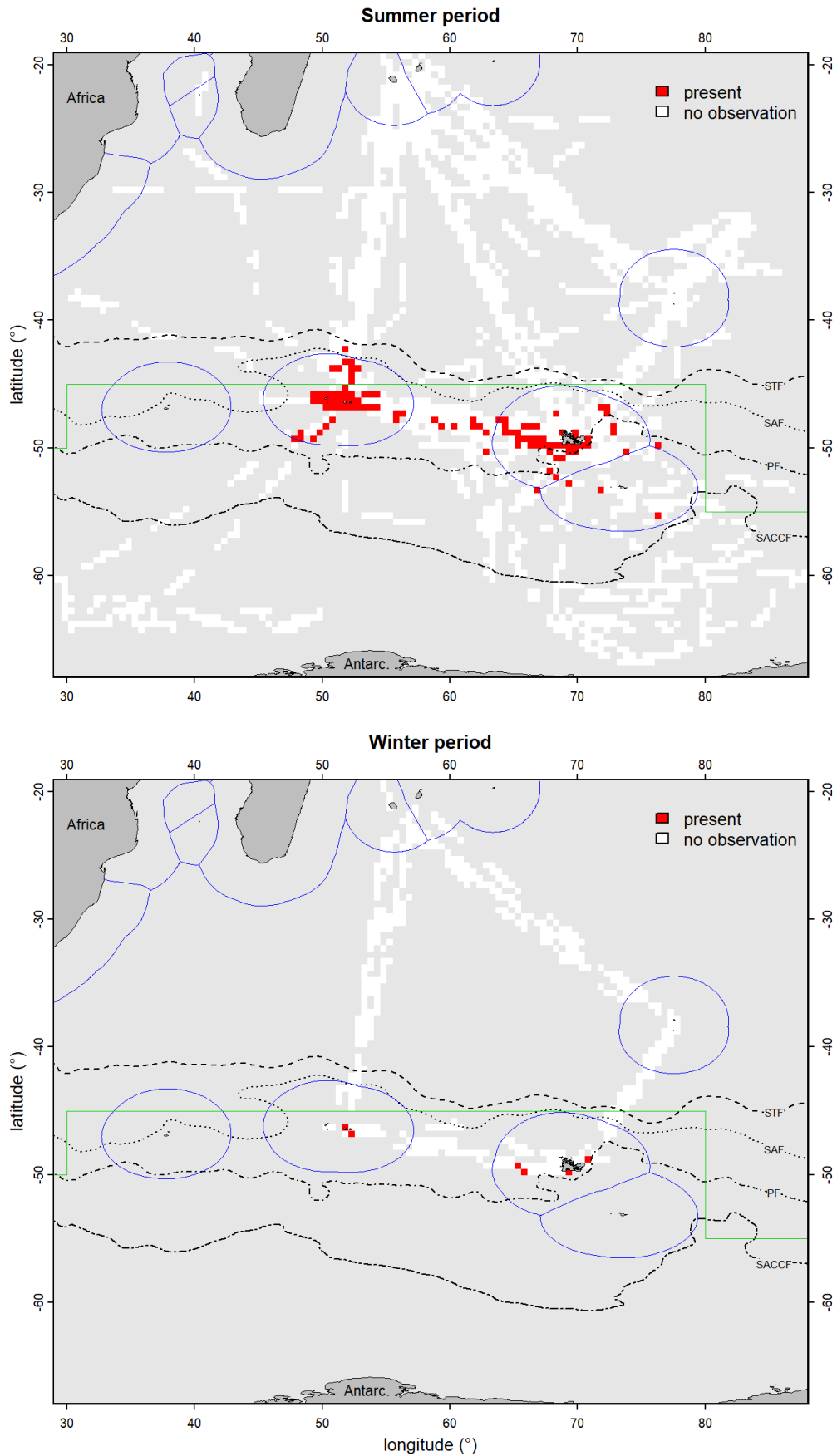


Figure 8 - Presence of King Penguin in each 0.5°x0.5° square in the south-west Indian Ocean area

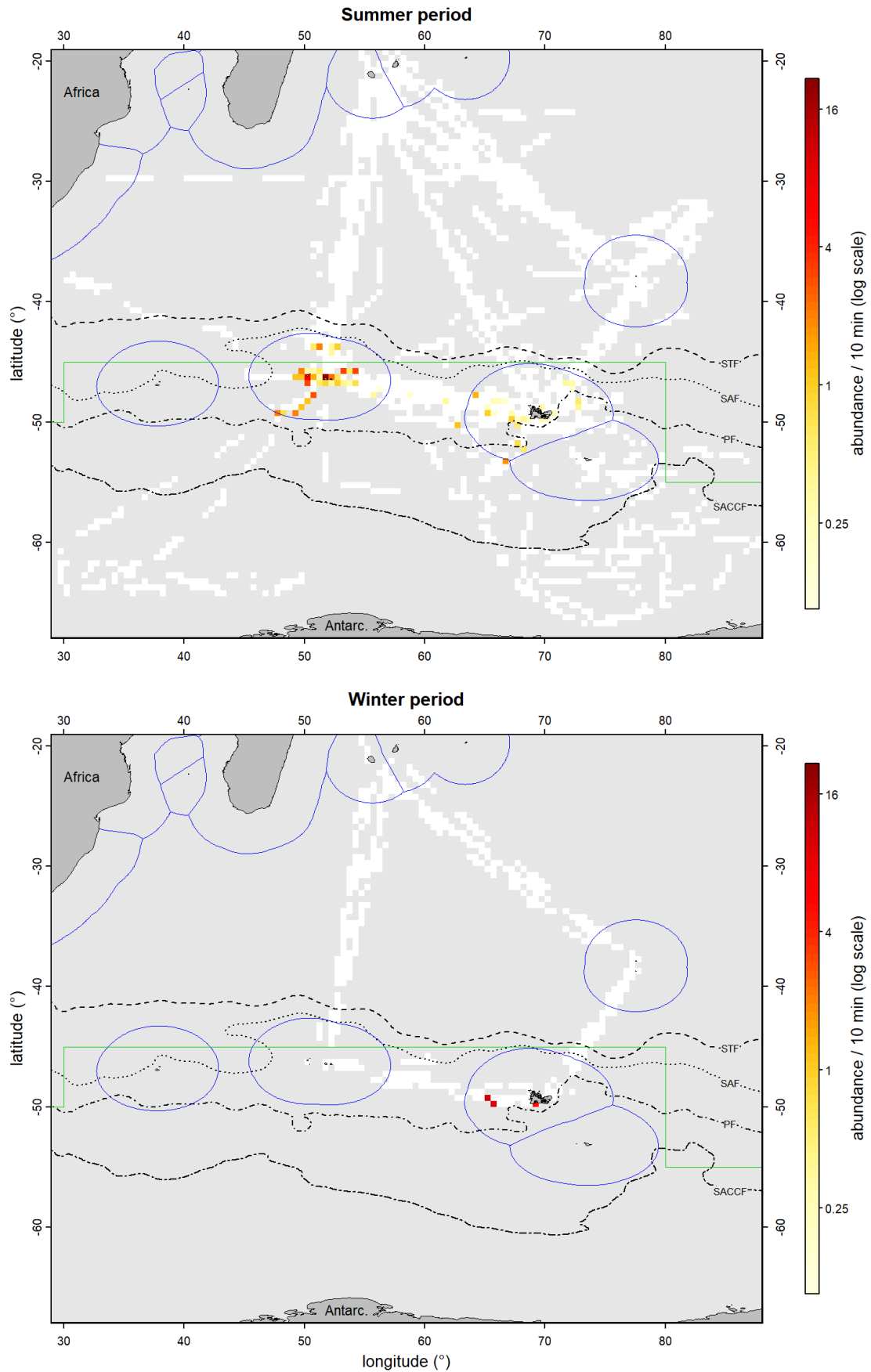


Figure 9 - Mean abundance of King Penguin during 10-min counts in each $0.5^{\circ} \times 0.5^{\circ}$ square in the south-west Indian Ocean area

Emperor Penguin *Aptenodytes forsteri* (NT)

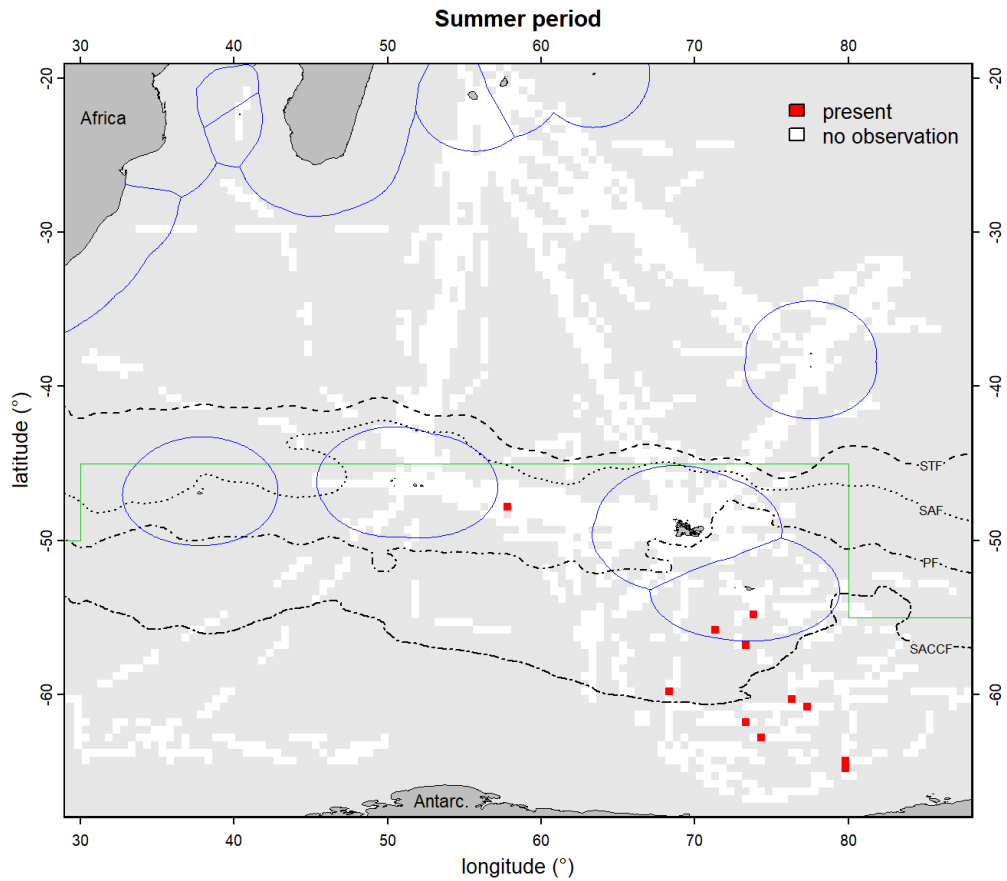


Figure 10 - Presence of Emperor Penguin in each 0.5°x0.5° square in the south-west Indian Ocean area

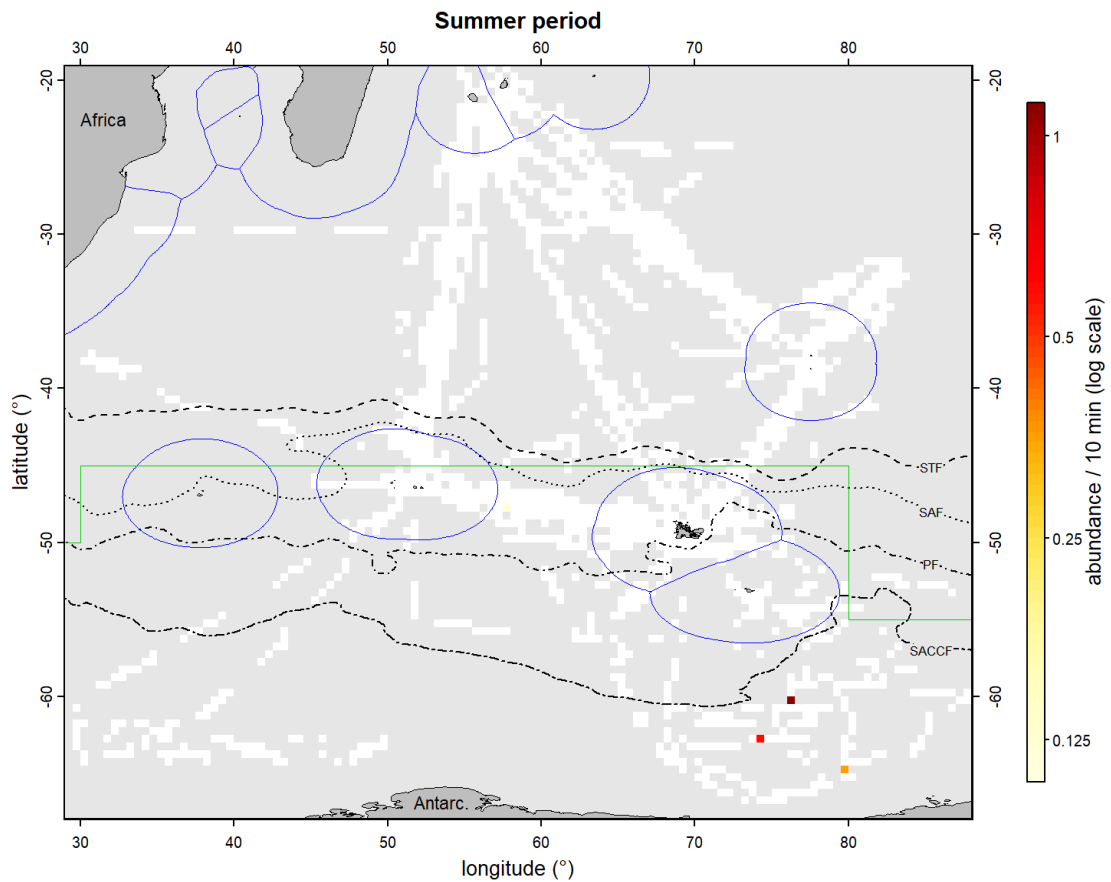


Figure 11 - Mean abundance of Emperor Penguin during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Gentoo Penguin *Pygoscelis papua* (NT)

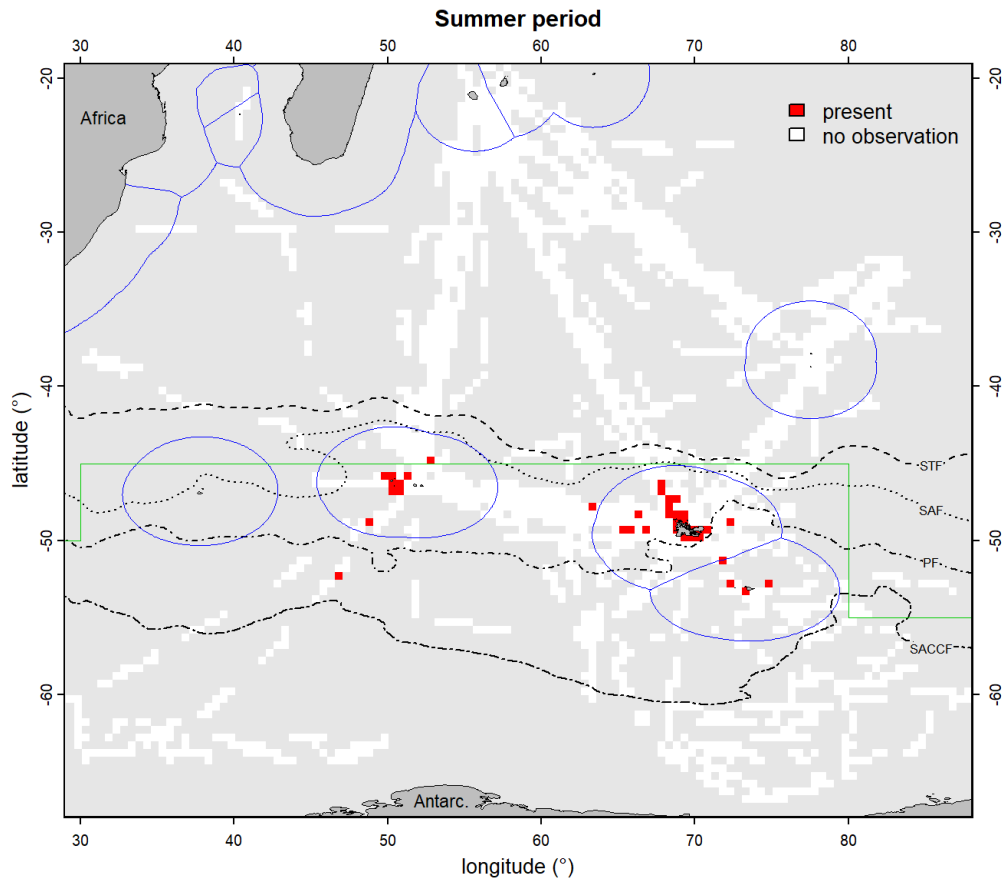


Figure 12 - Presence of Gentoo Penguin in each 0.5°x0.5° square in the south-west Indian Ocean area

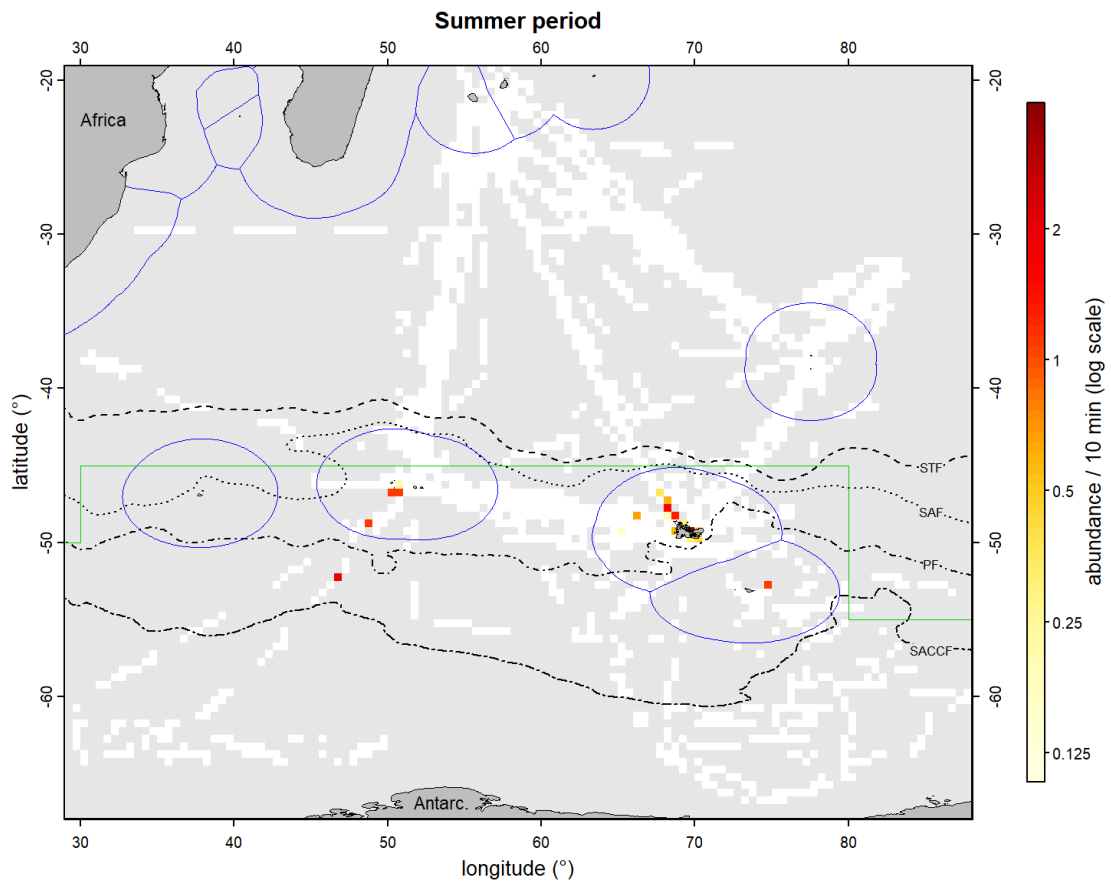
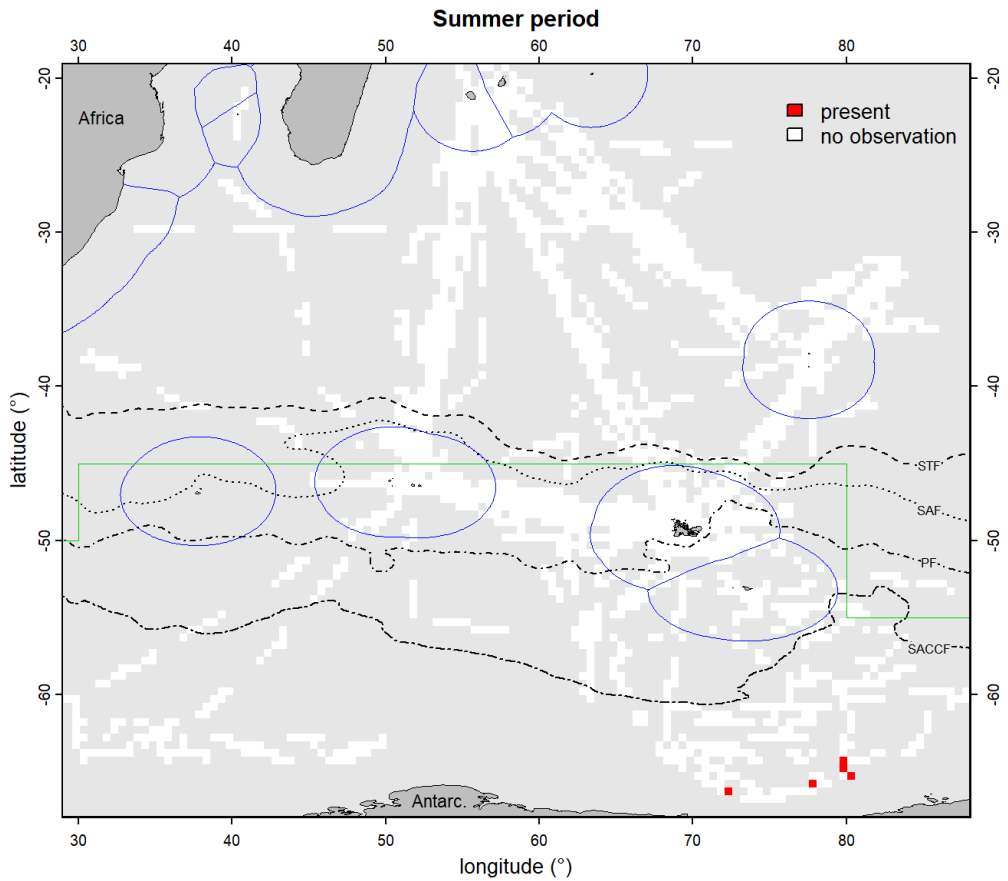


Figure 13 - Mean abundance of Gentoo Penguin during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Adélie Penguin *Pygoscelis adeliae* (LC)



Presence of Adélie Penguin in each 0.5°x0.5° square in the south-west Indian Ocean area

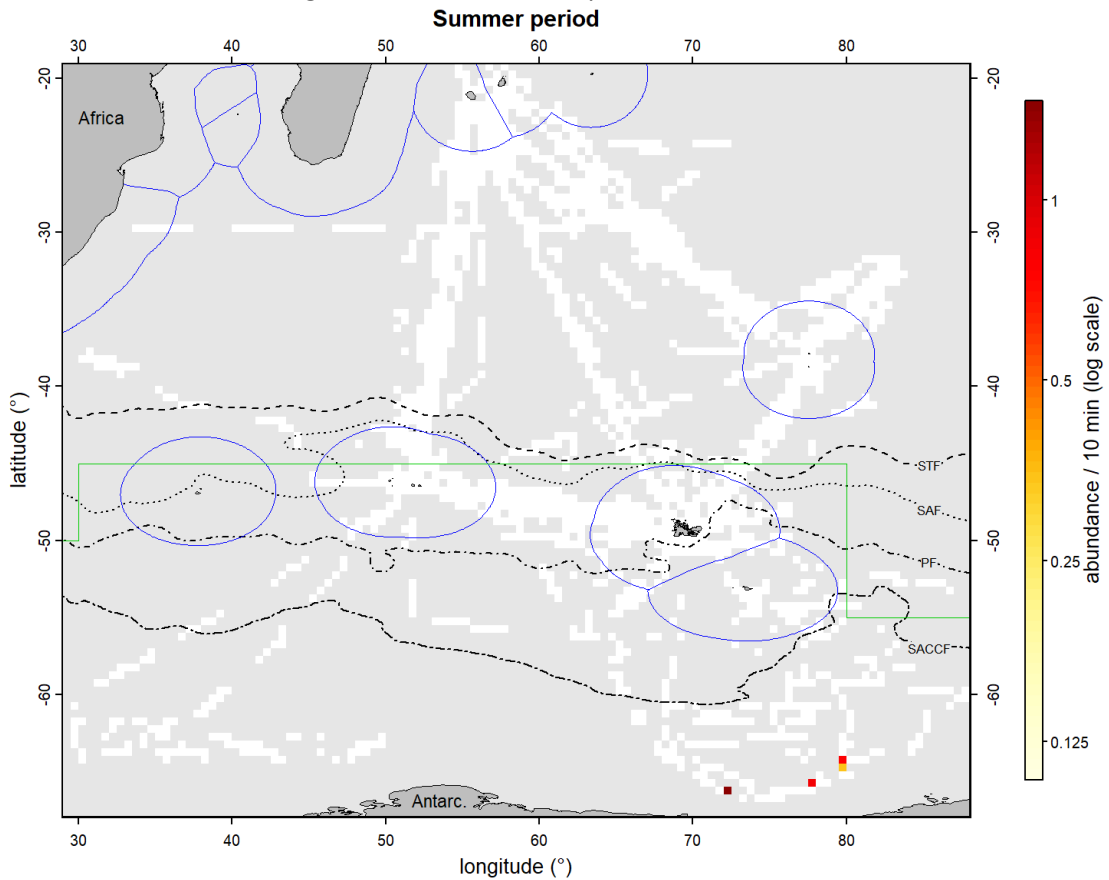


Figure 14 - Mean abundance of Adélie Penguin during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

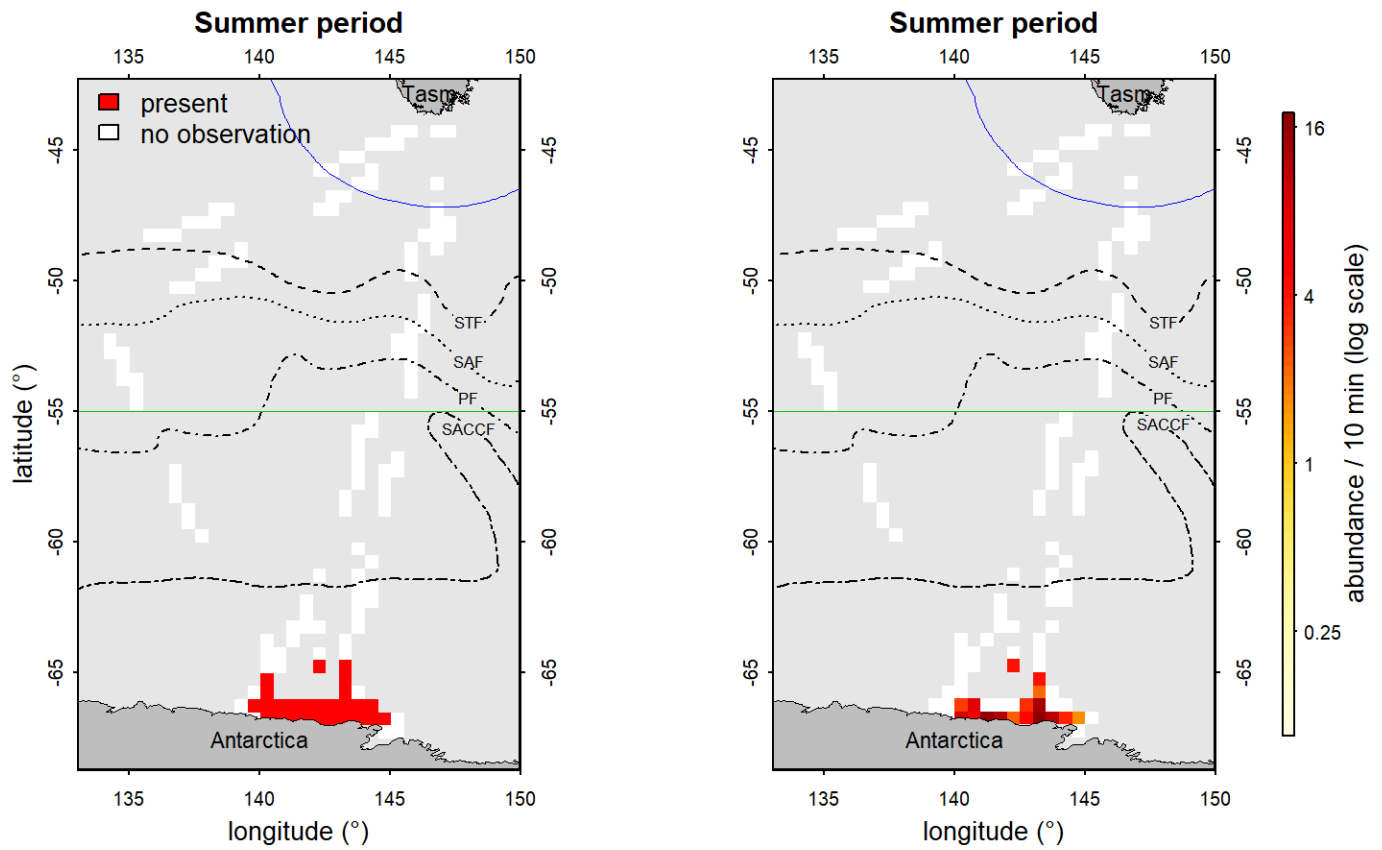


Figure 15 - Presence of Adélie Penguin and mean abundance during 10-min counts in each 0.5°x0.5° between Tasmania and Antarctica

Chinstrap Penguin *Pygoscelis antarctica* (LC)

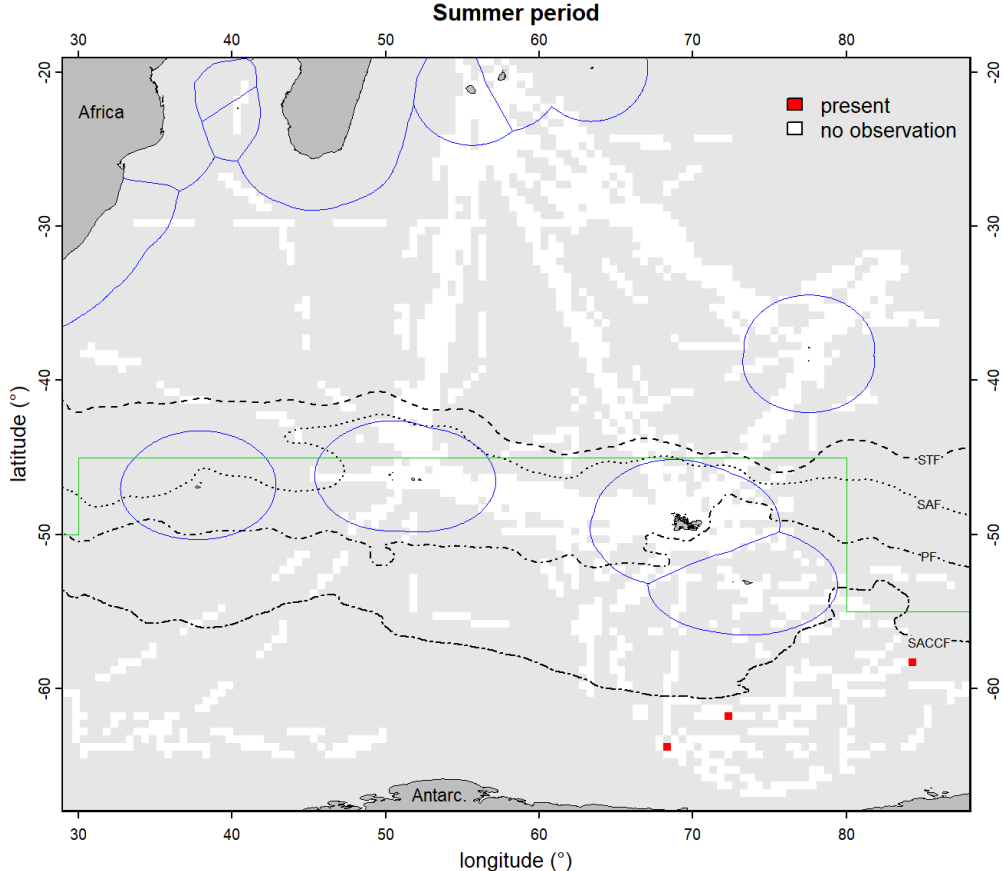


Figure 16 - Presence of Chinstrap Penguin in each 0.5°x0.5° square in the south-west Indian Ocean area

Eudyptes sp. *Eudyptes sp.*

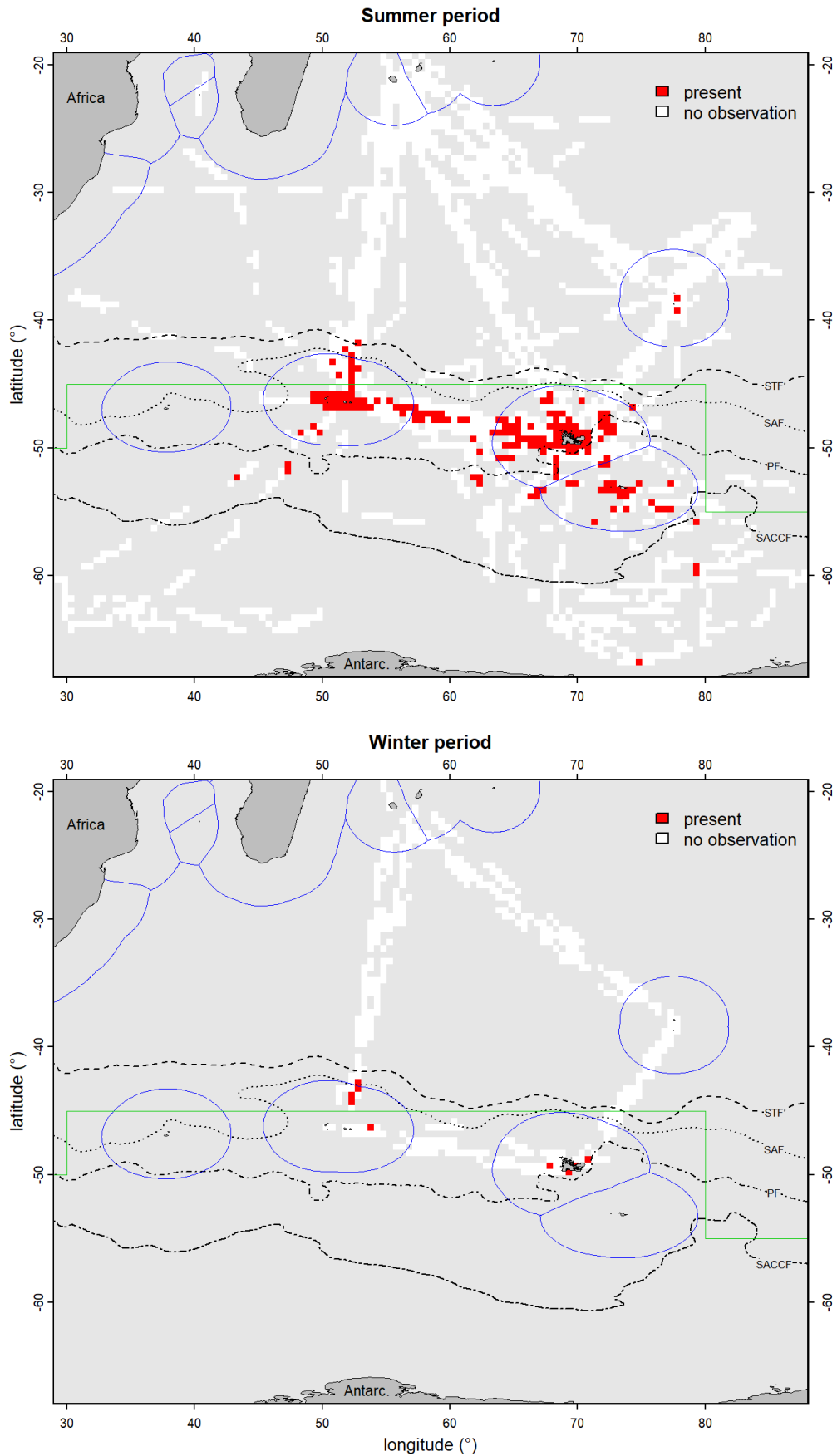


Figure 17 - Presence of *Eudyptes sp.* in each 0.5°x0.5° square in the south-west Indian Ocean area

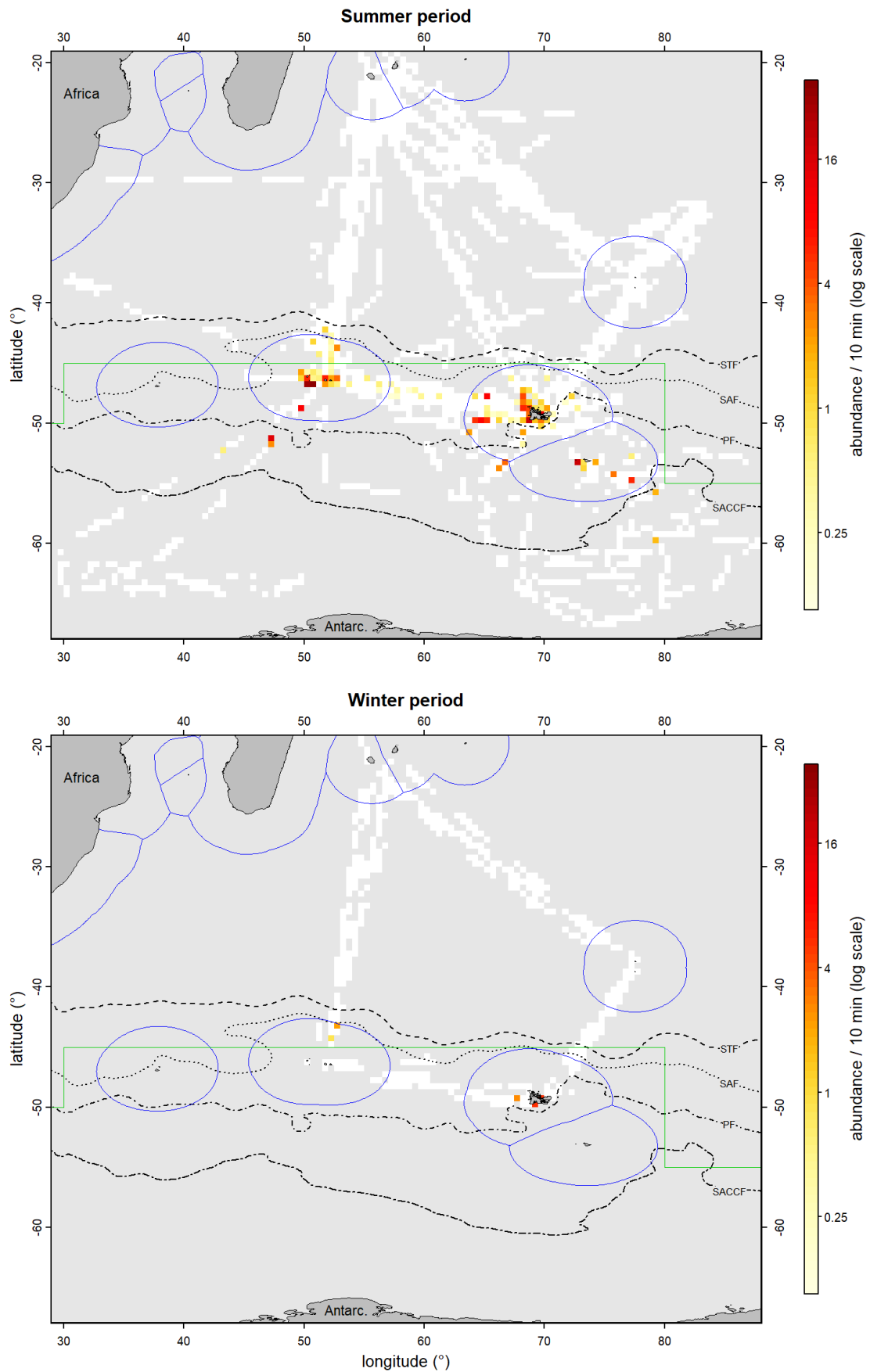


Figure 18 - Mean abundance of *Eudyptes* sp. during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Wandering Albatross *Diomedea exulans* (VU)

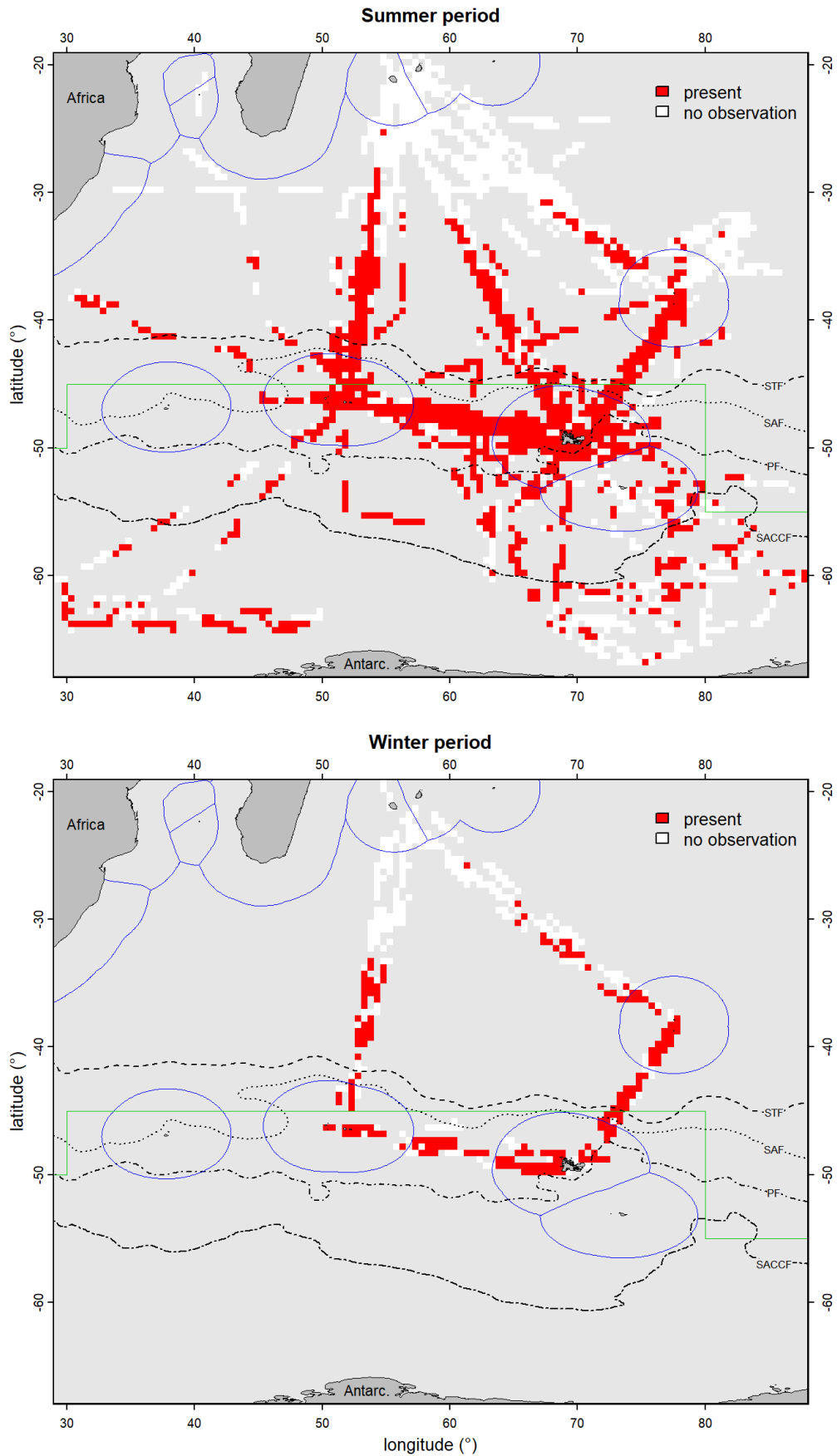


Figure 19 - Presence of Wandering Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

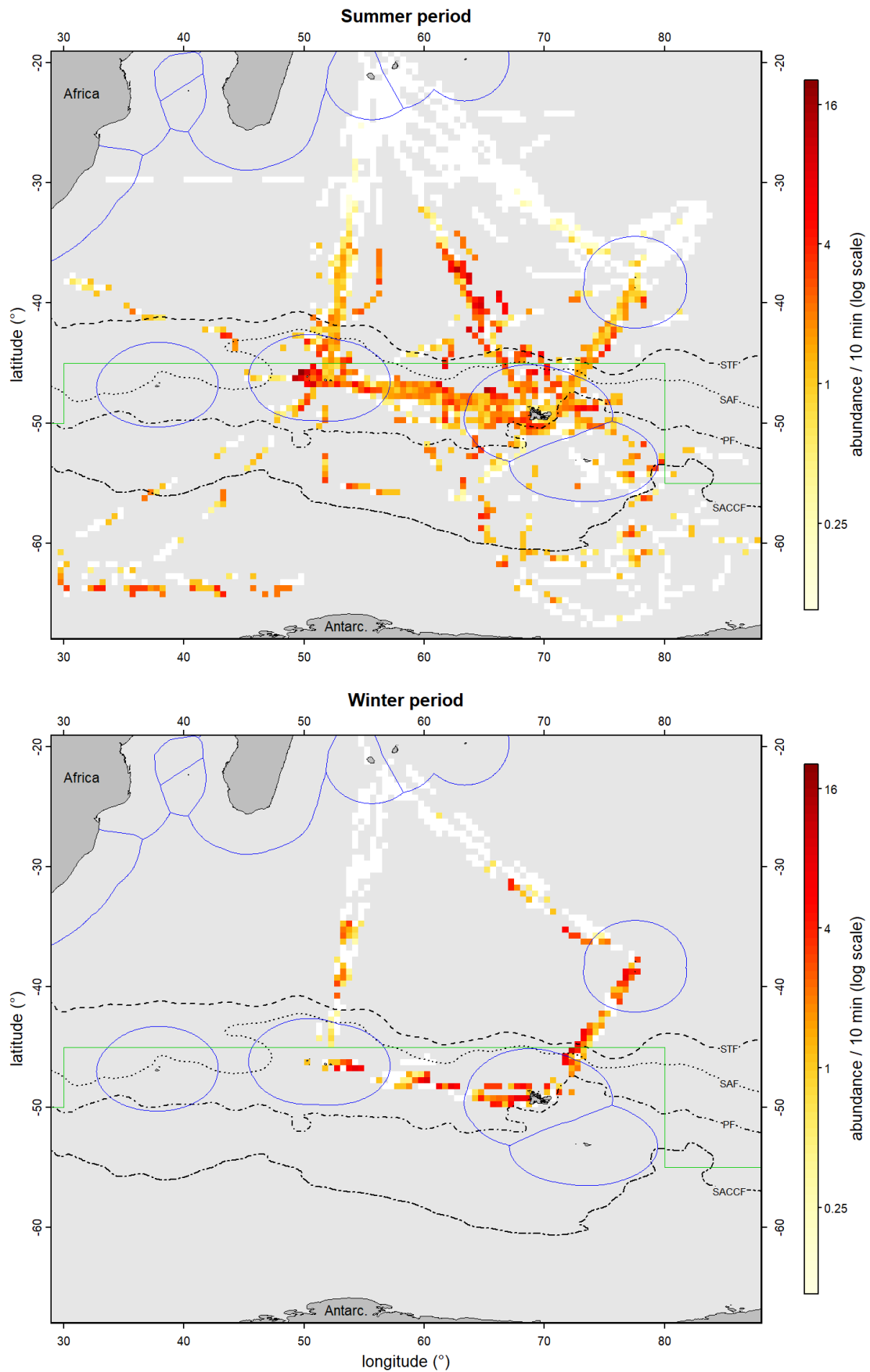


Figure 20 - Mean abundance of Wandering Albatross during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

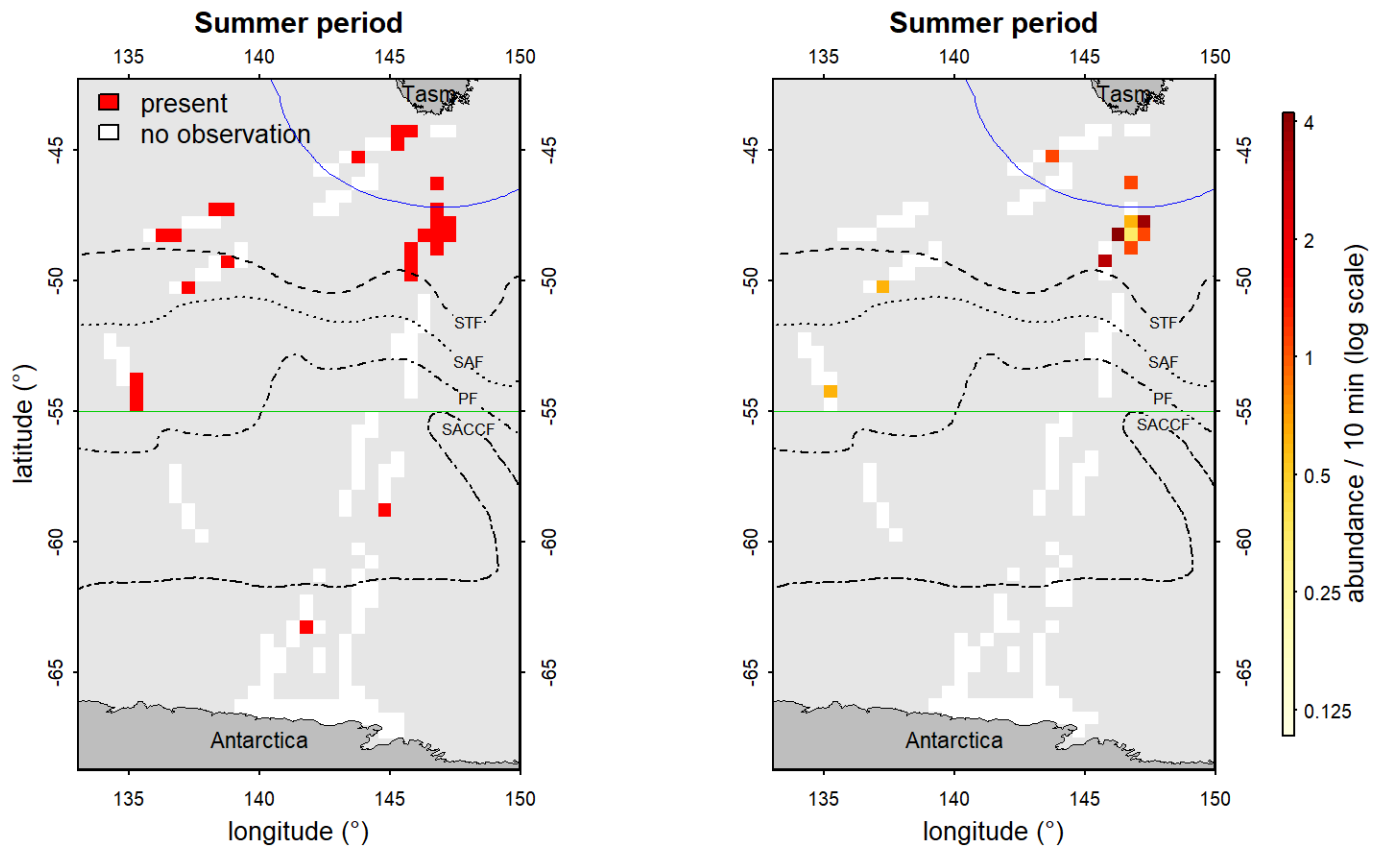


Figure 21 - Presence of Wandering Albatross and mean abundance during 10-min counts in each 0.5°x0.5° between Tasmania and Antarctica

Amsterdam Albatross *Diomedea amsterdamensis* (EN)

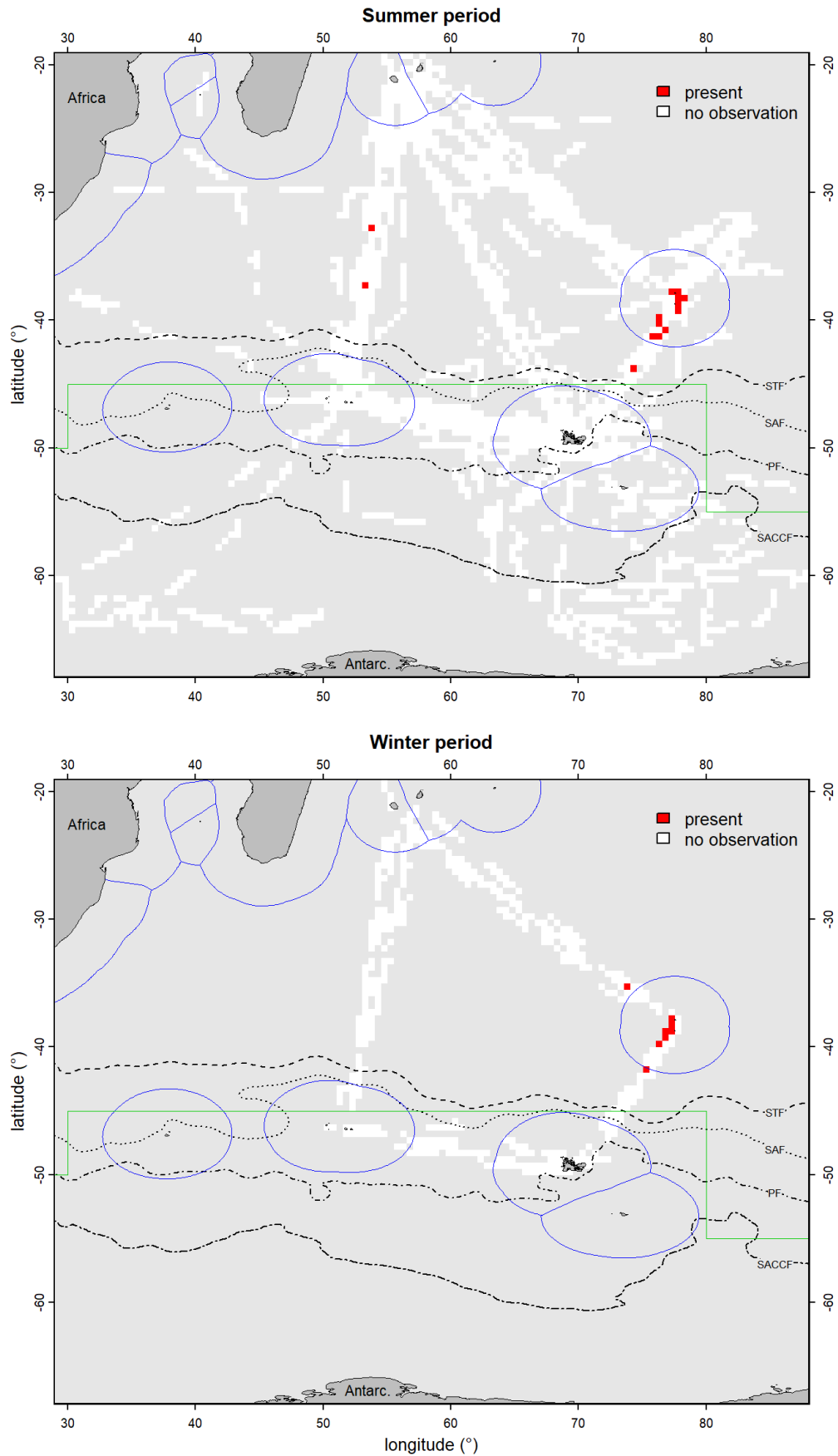


Figure 22 - Presence of Amsterdam Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

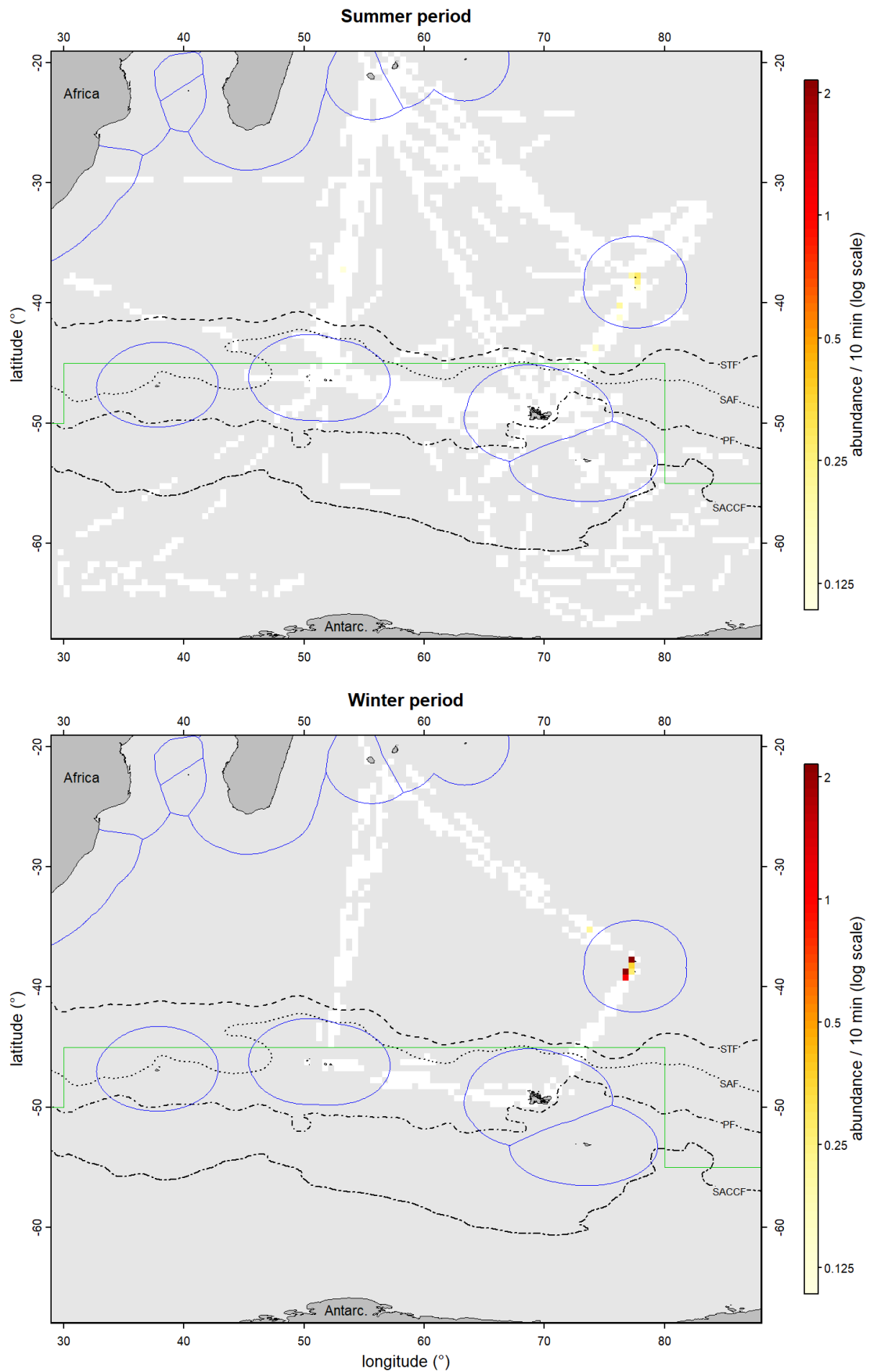


Figure 23 - Mean abundance of Amsterdam Albatross during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

Southern / Northern Royal Albatross sp. *Diomedea epomophora* / *D. sanfordi* (VU/EN)

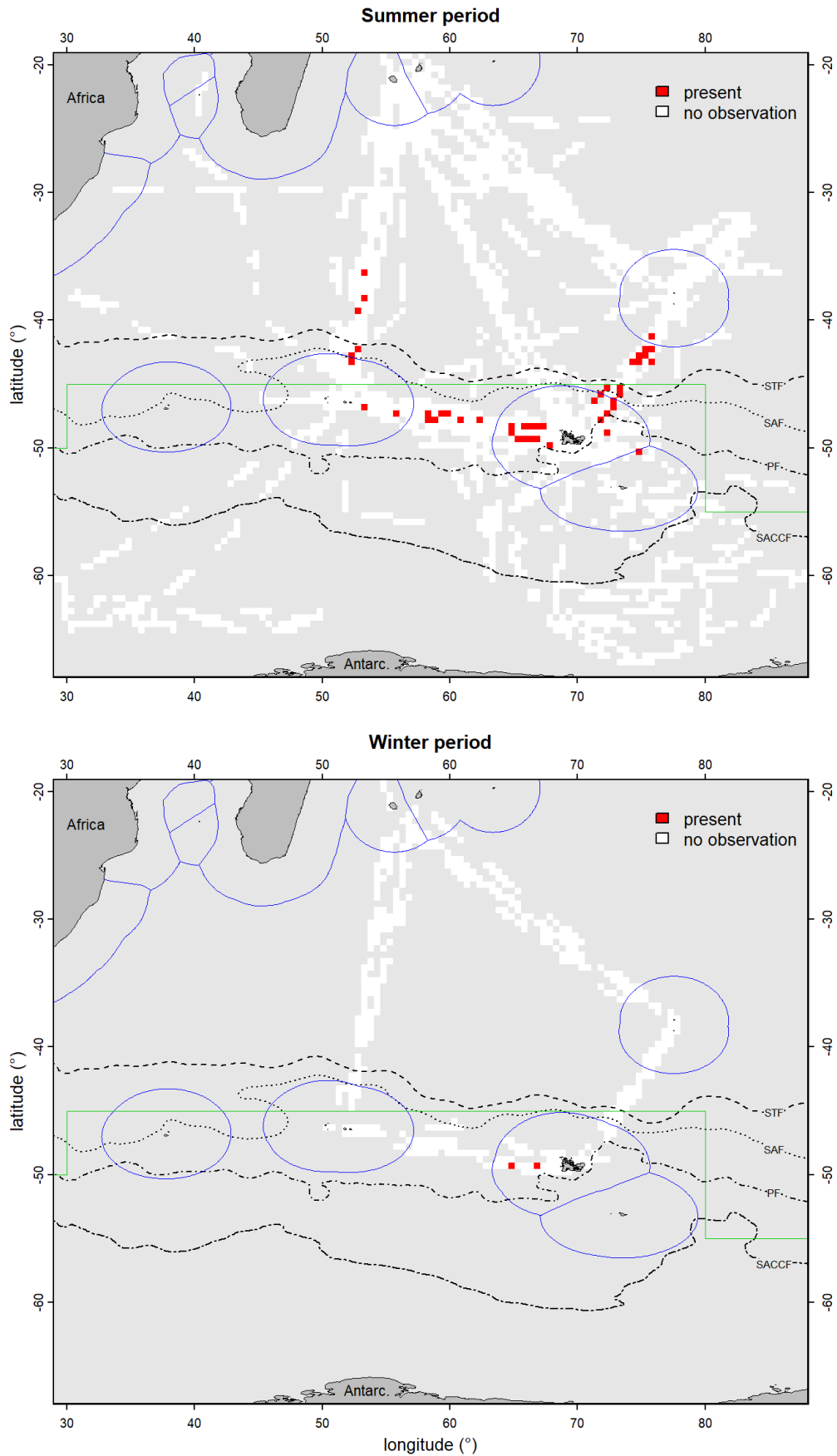


Figure 24 - Presence of Royal Albatross sp. in each 0.5°x0.5° square in the south-west Indian Ocean area

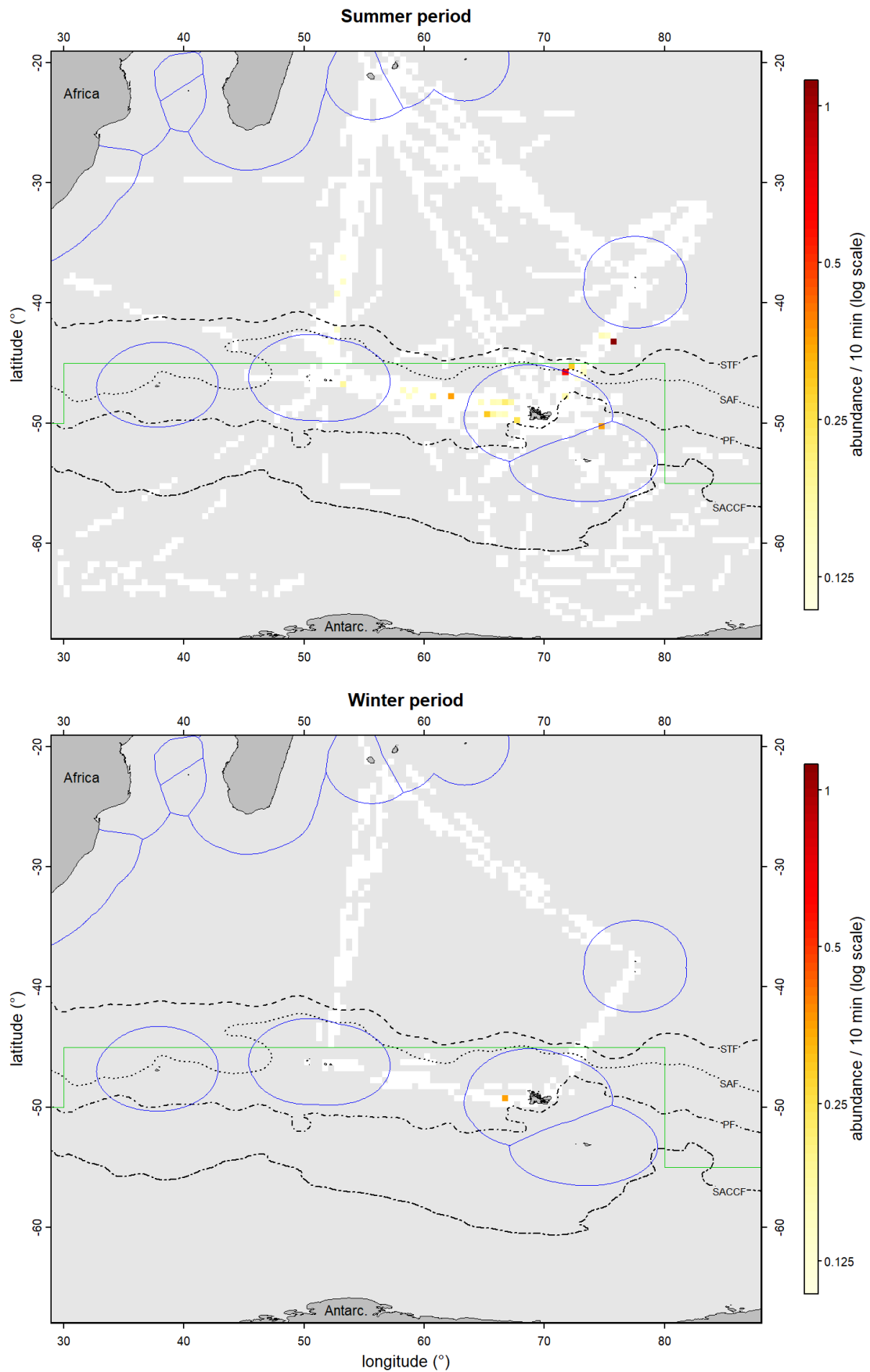


Figure 25 - Mean abundance of Royal Albatross sp. during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

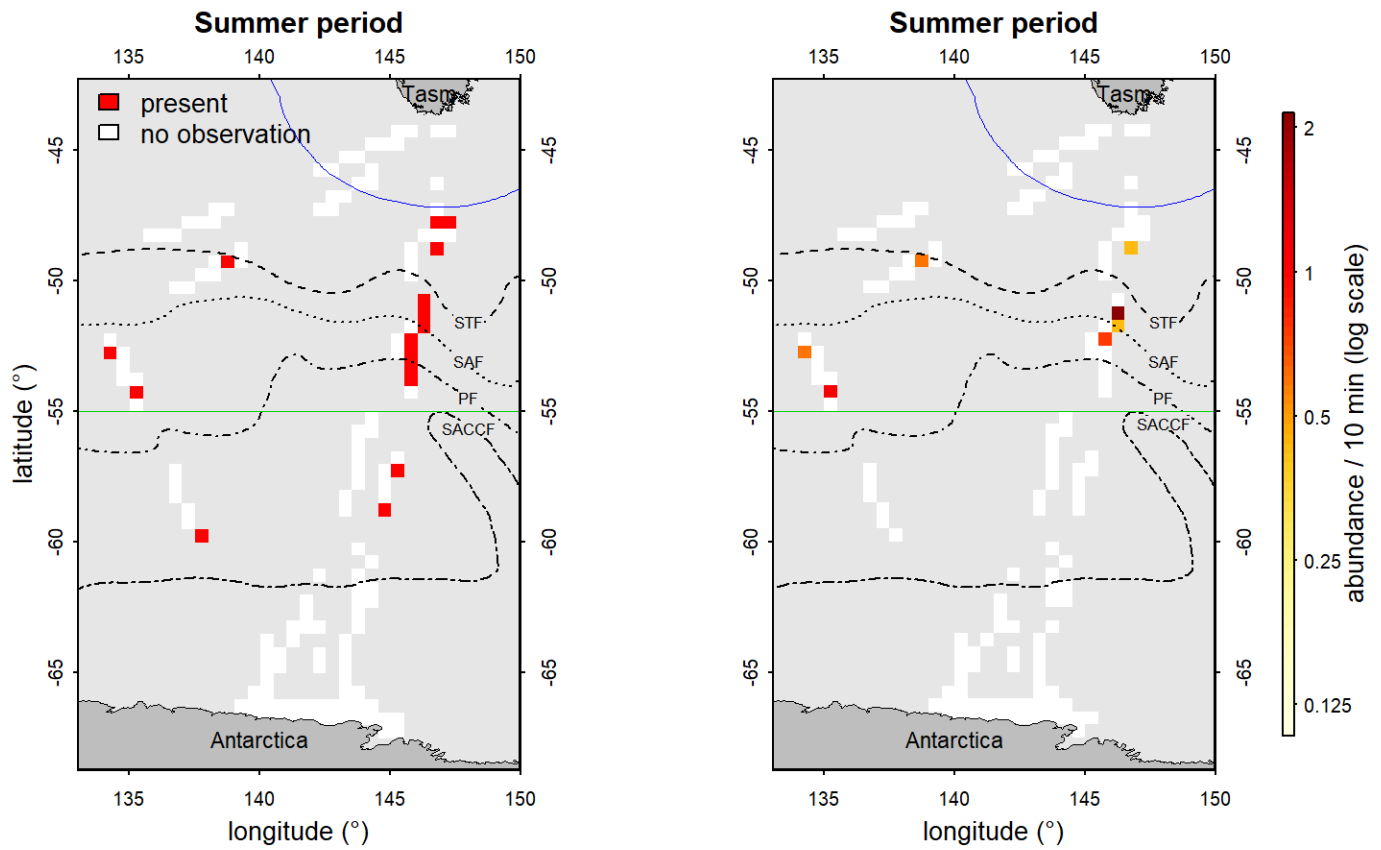


Figure 26 - Presence of Royal Albatross sp. and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Laysan Albatross *Phoebastria immutabilis* (NT)

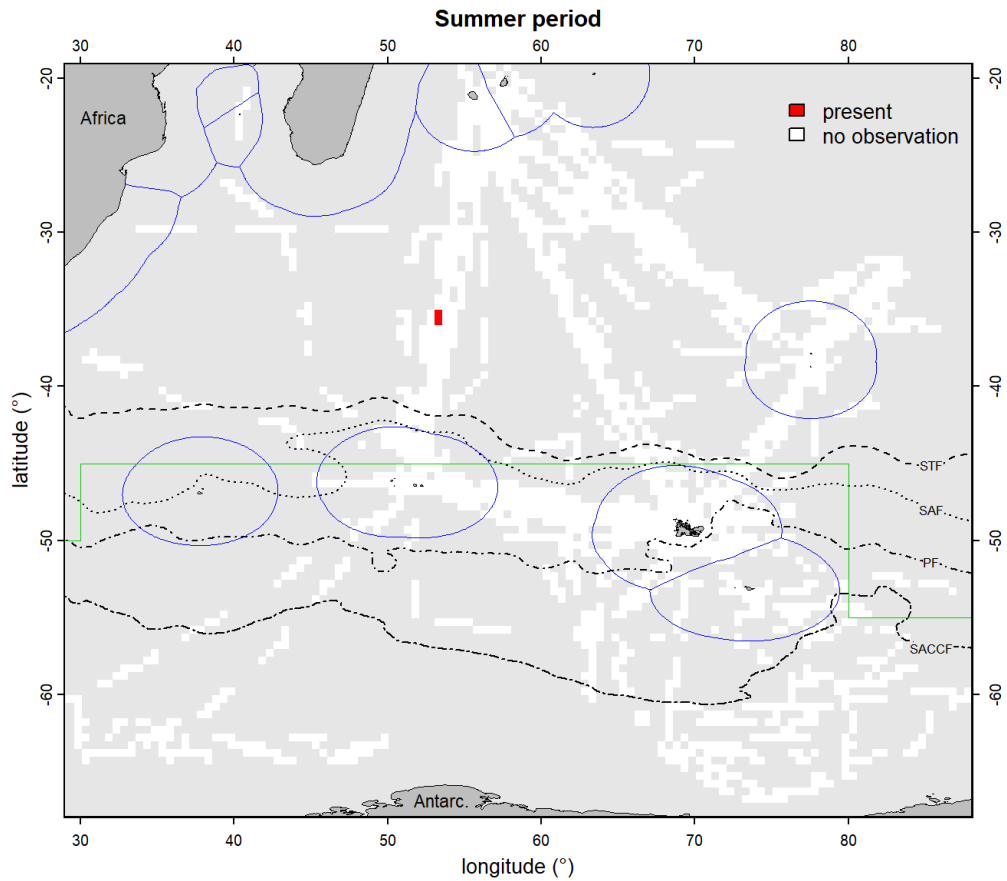


Figure 27 - Presence of Laysan Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

Black-browed Albatross / Campbell Albatross *Thalassarche melanophrys* / *T. impavida* (LC/VU)

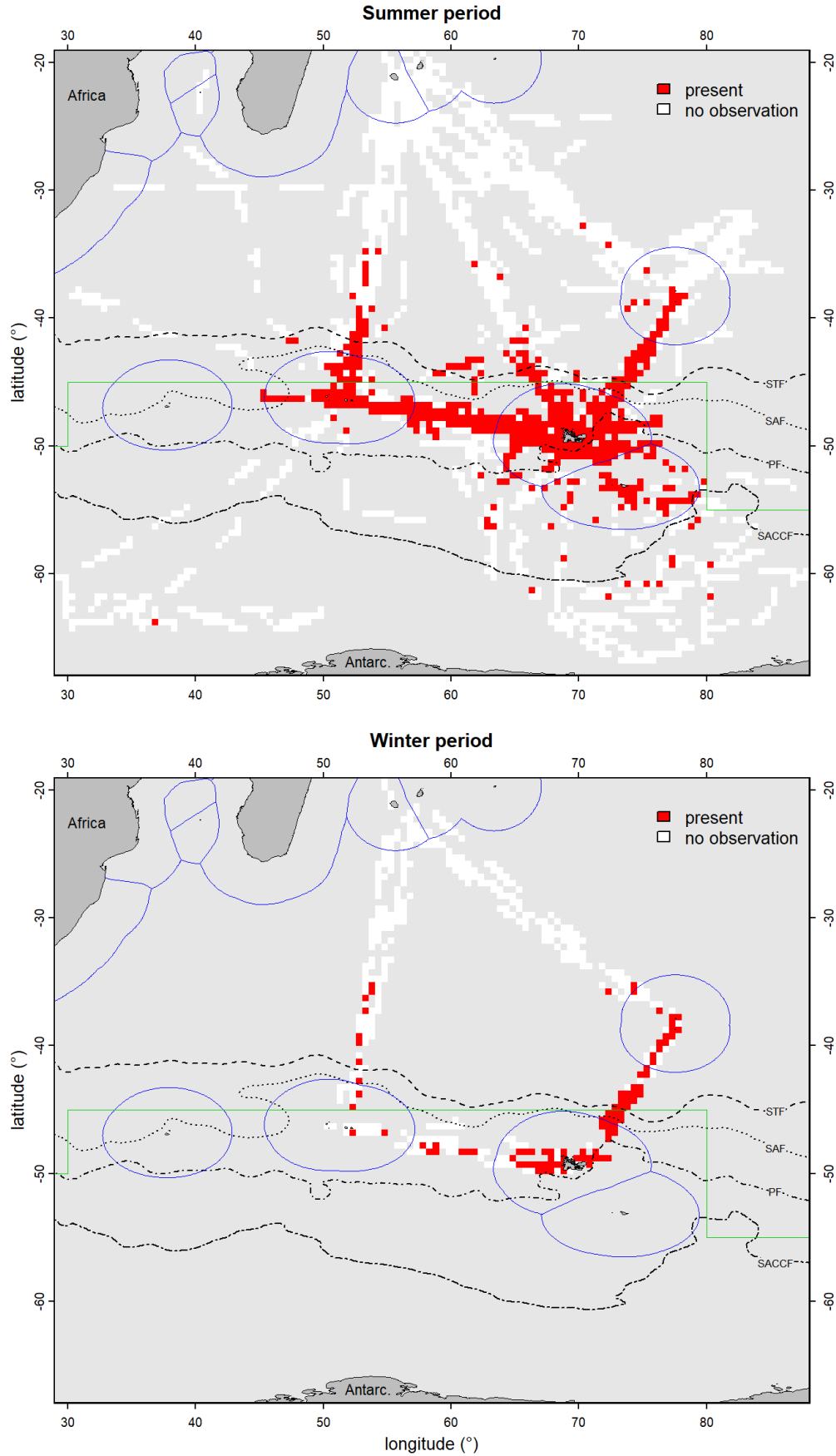


Figure 28 - Presence of Black-browed Albatross / Campbell Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

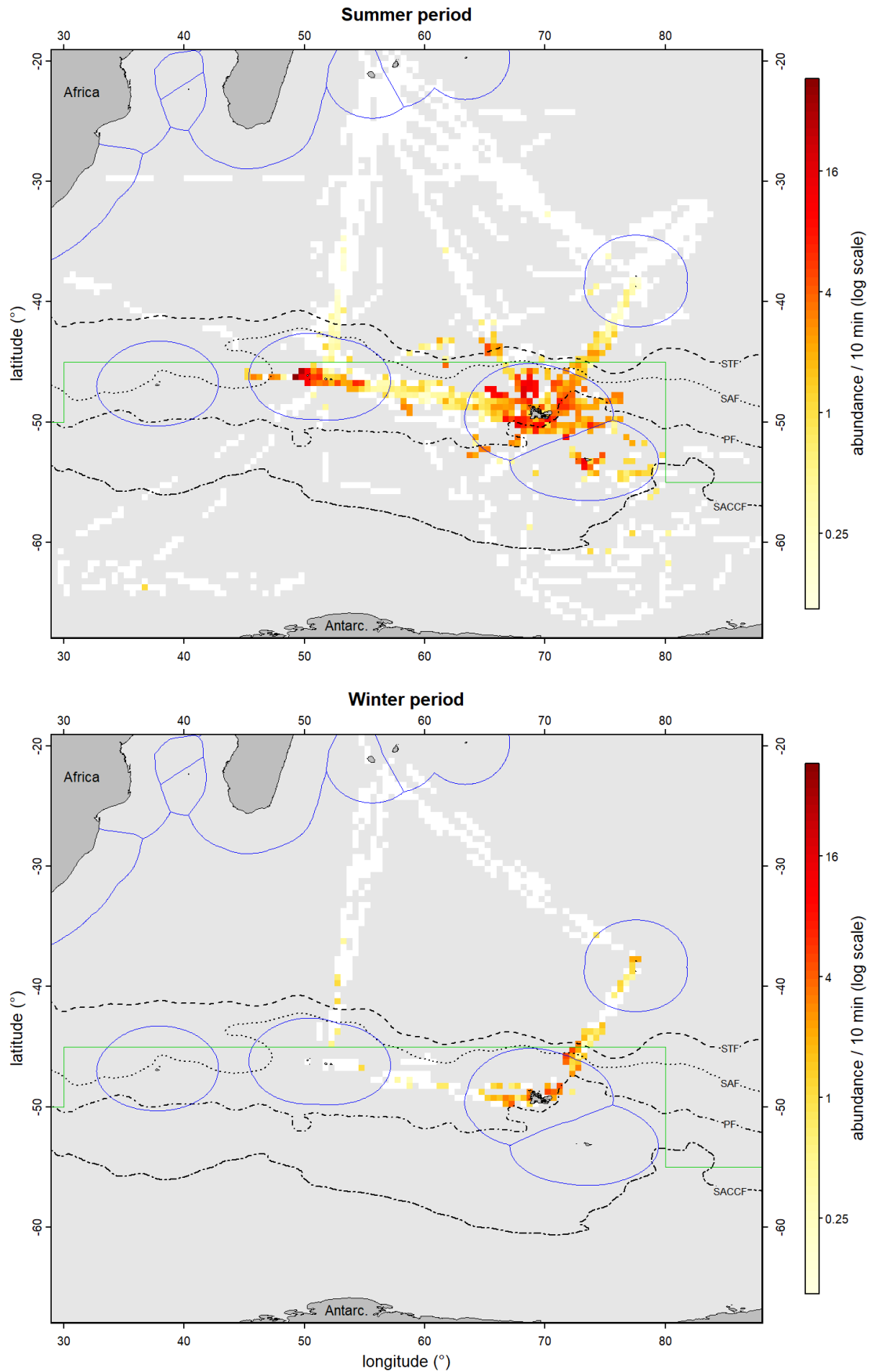


Figure 29 - Mean abundance of Black-browed Albatross / Campbell Albatross during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

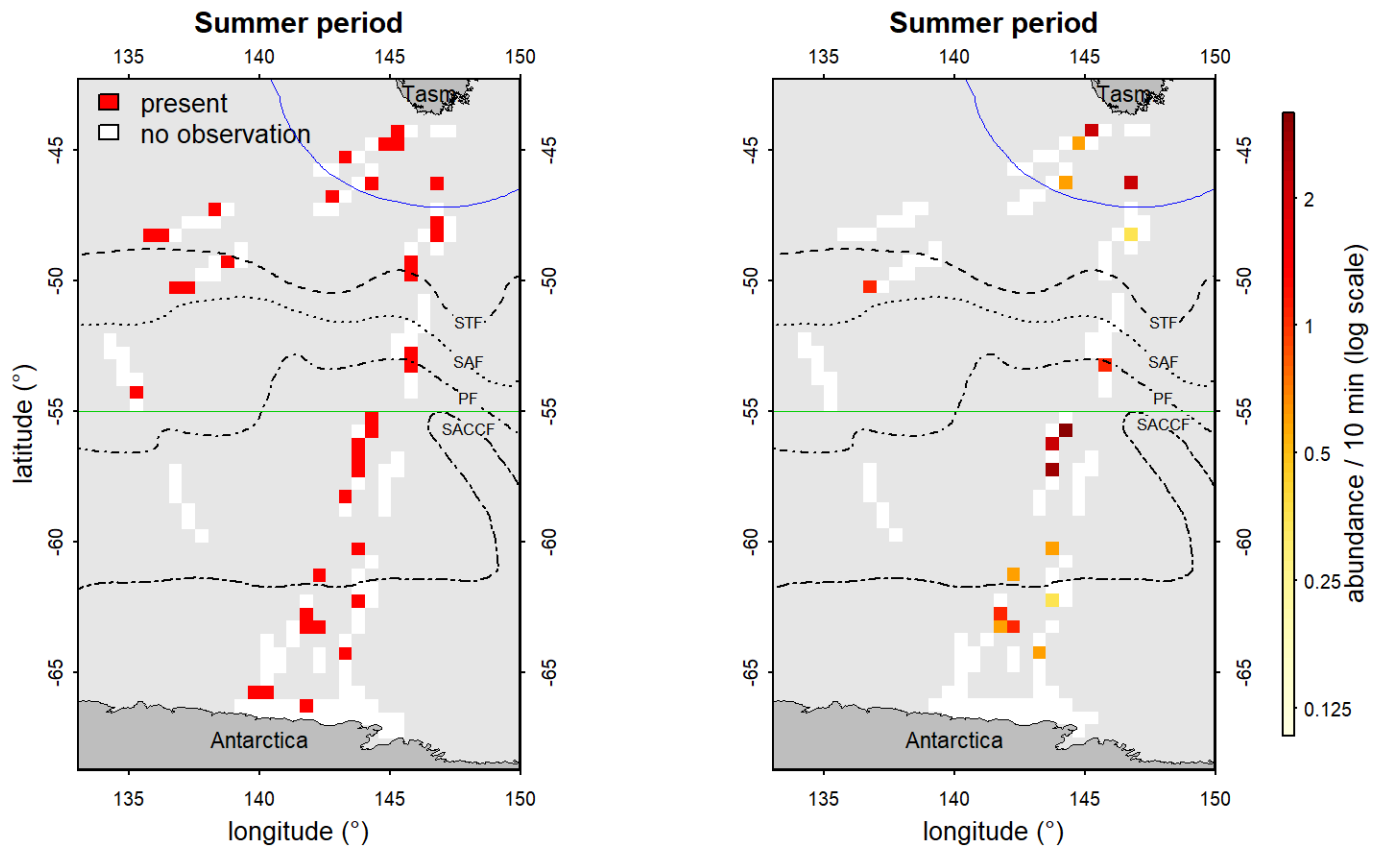


Figure 30 - Presence of Black-browed Albatross / Campbell Albatross and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Shy Albatross / Salvin's Albatross *Thalassarche cauta* / *T. salvini* (NT/VU)

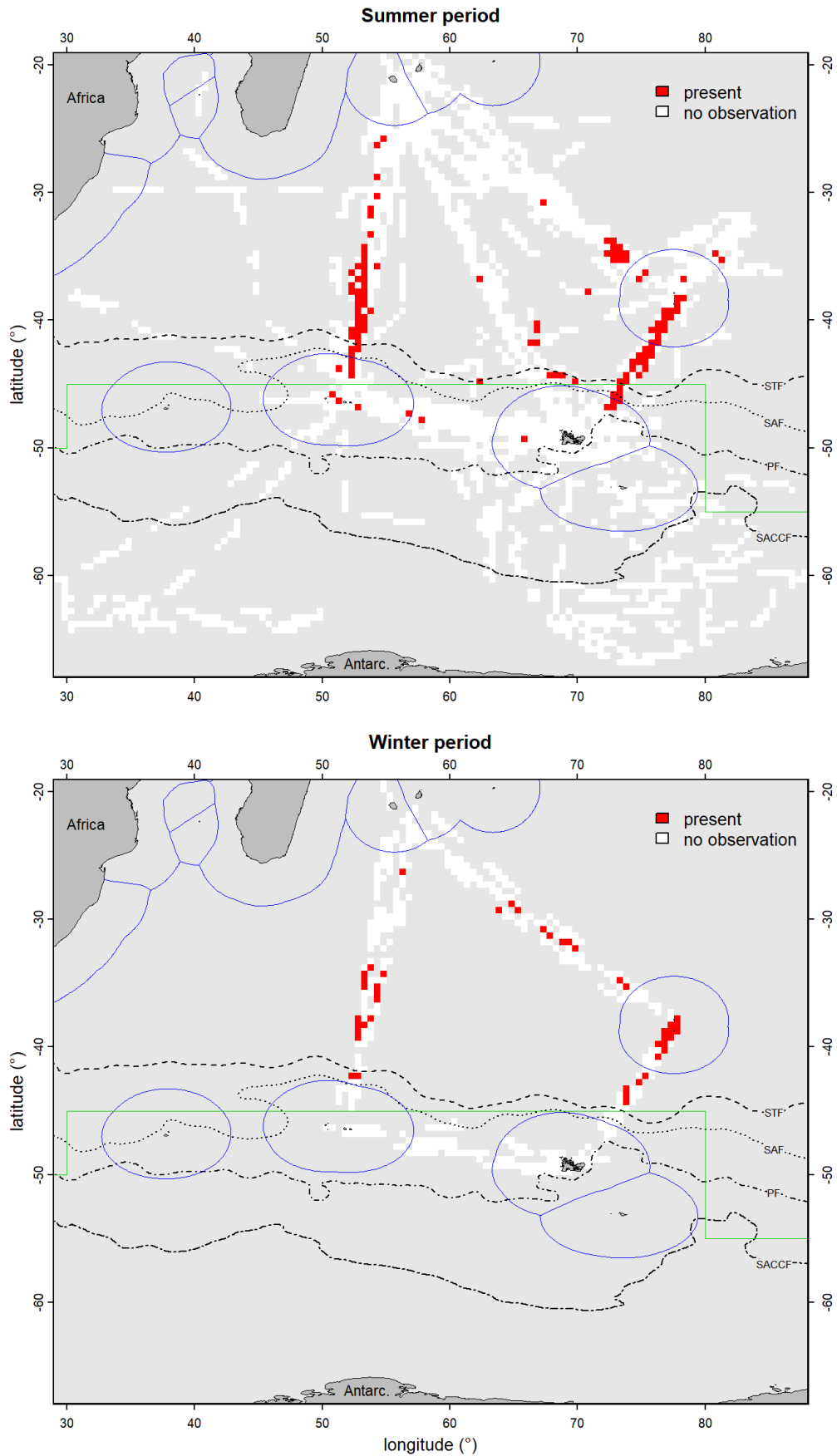


Figure 31 - Presence of Shy Albatross / Salvin's Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

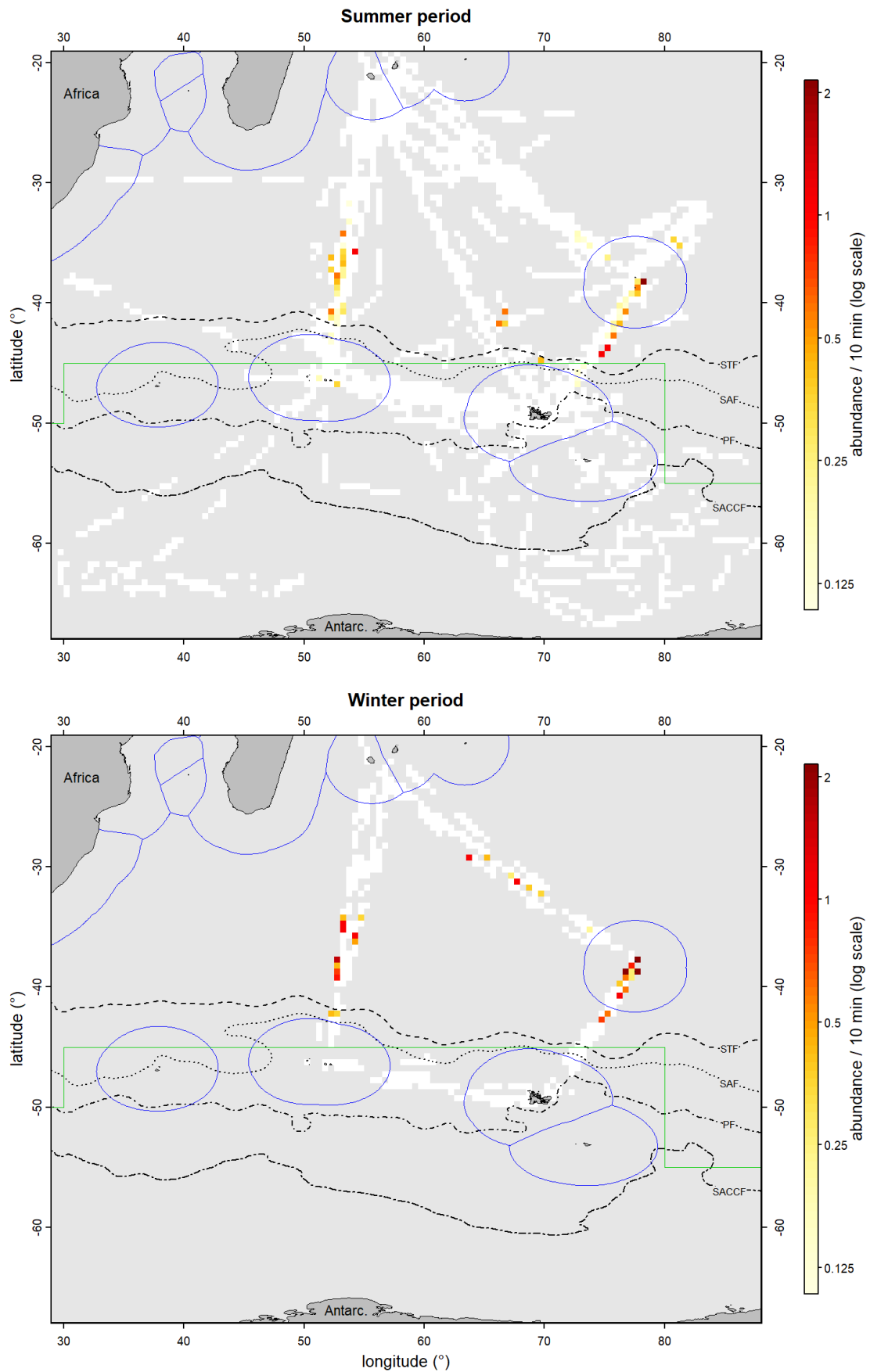


Figure 32 - Mean abundance of Shy Albatross / Salvin's Albatross during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

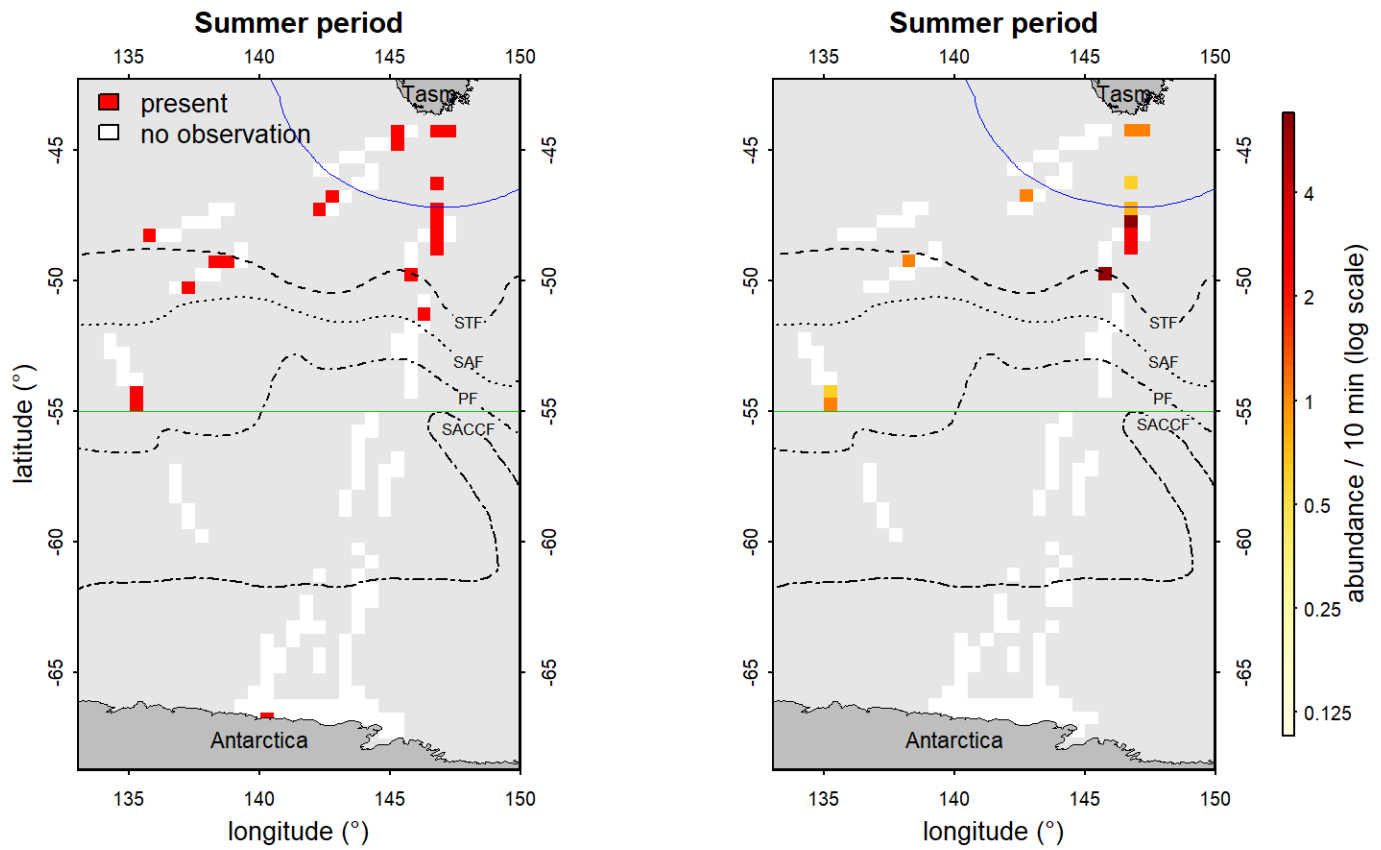


Figure 33 - Presence of Shy Albatross / Salvin's Albatross and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Chatham Albatross *Thalassarche eremita* (VU)

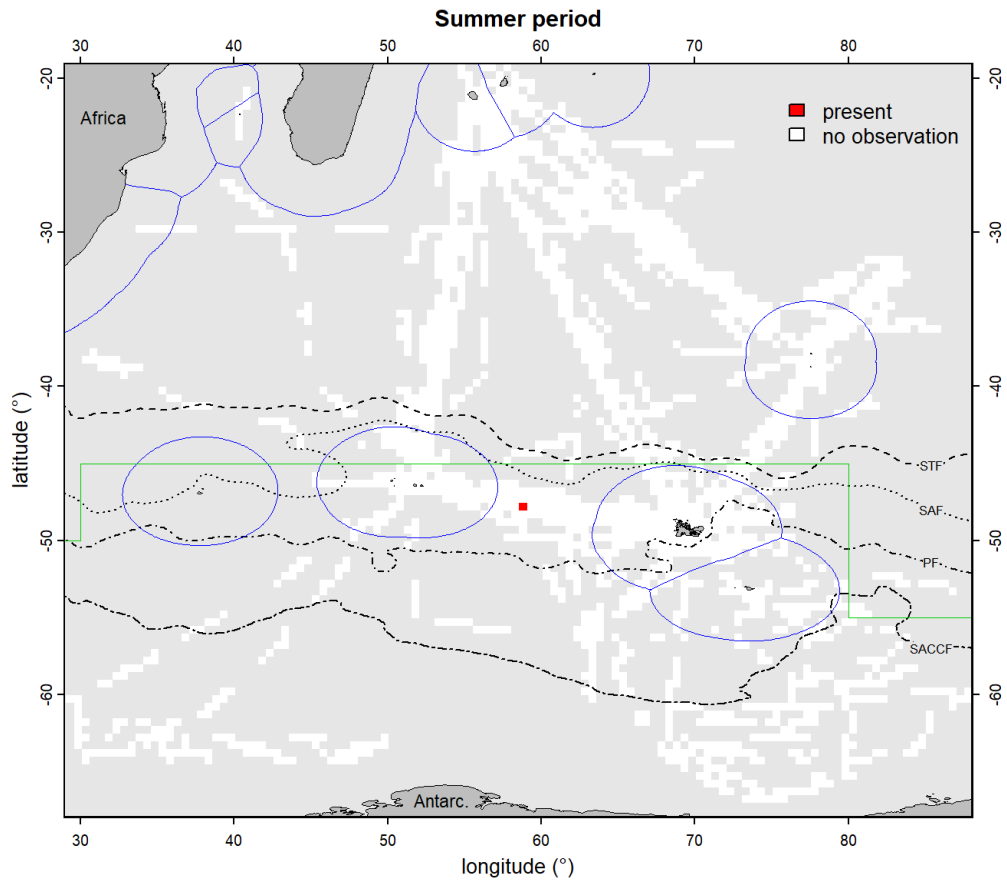


Figure 34 - Presence of Chatham Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

Grey-headed Albatross *Thalassarche chrysostoma* (VU)

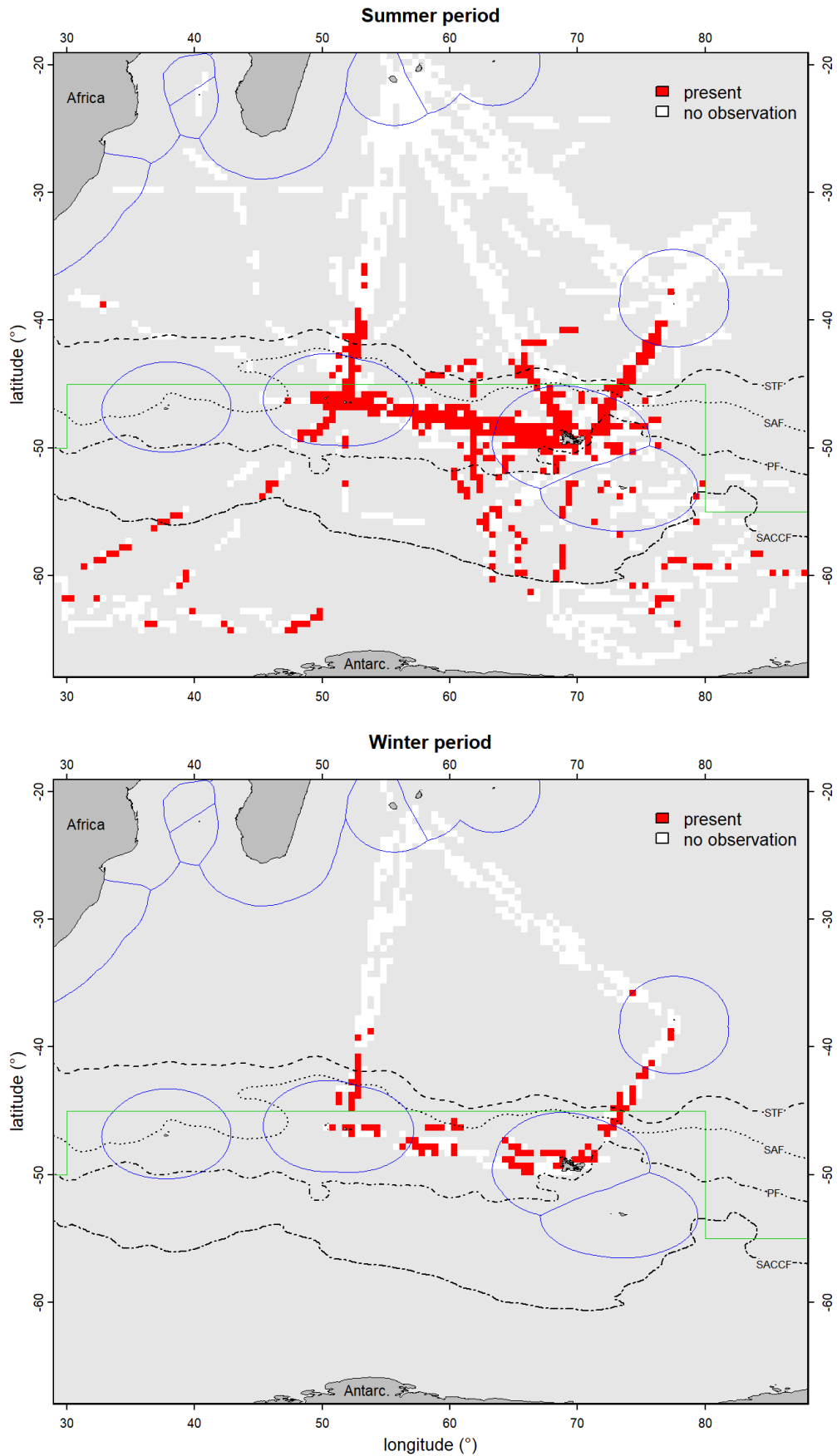


Figure 35 - Presence of Grey-headed Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

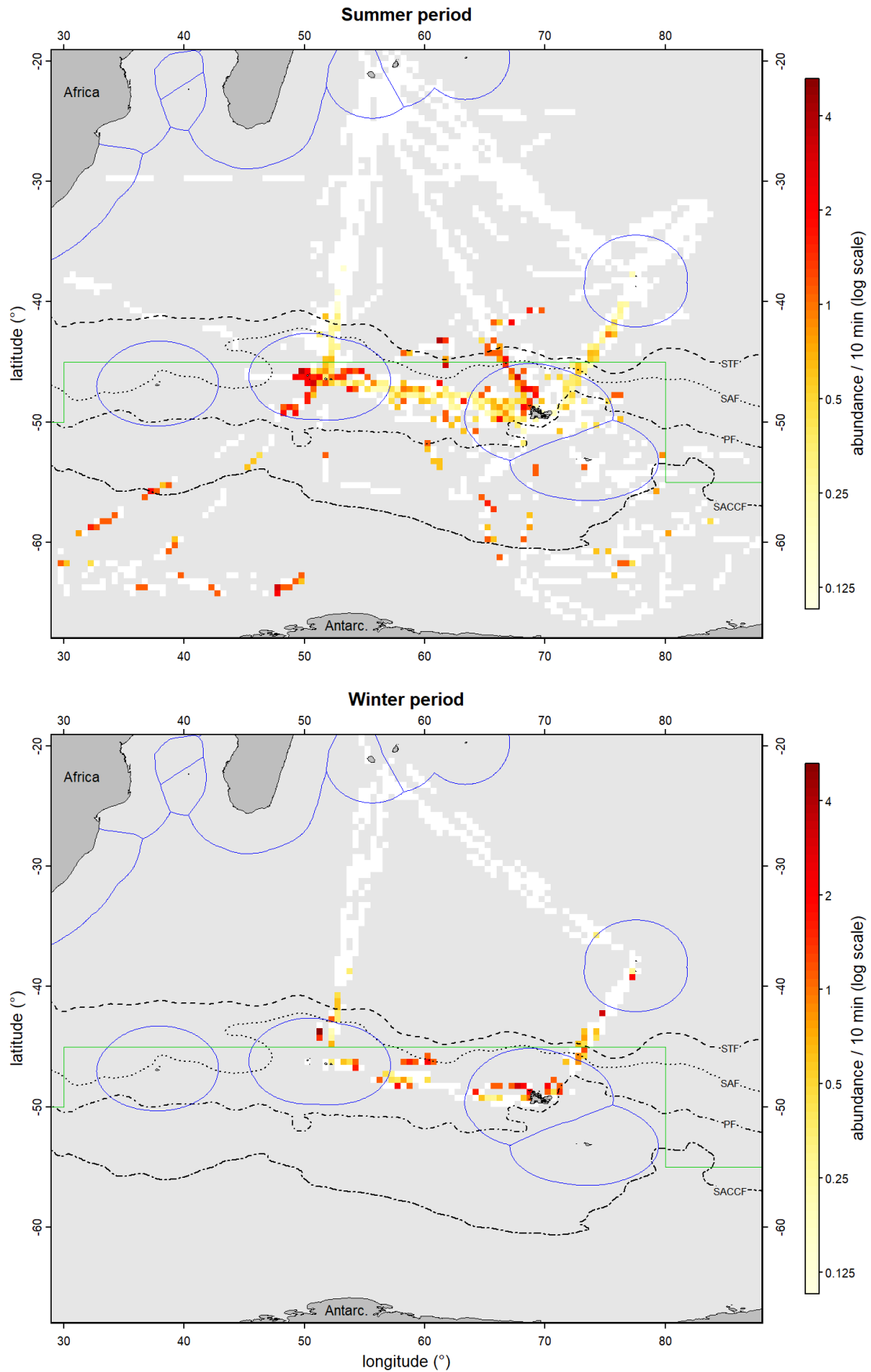


Figure 36 - Mean abundance of Grey-headed Albatross during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

Indian yellow-nosed Albatross *Thalassarche carteri* (EN)

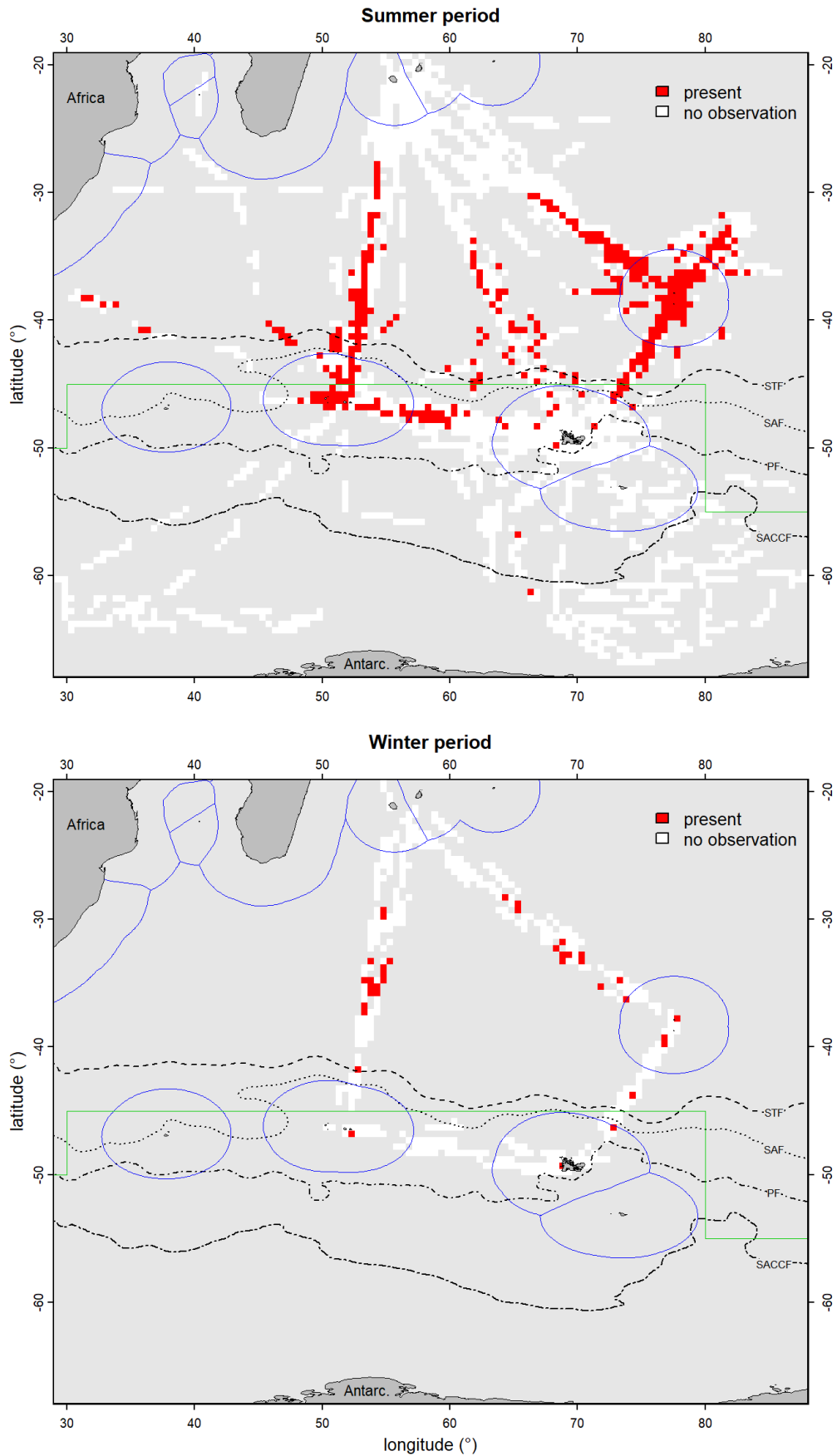


Figure 37 - Presence of Yellow-nosed Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

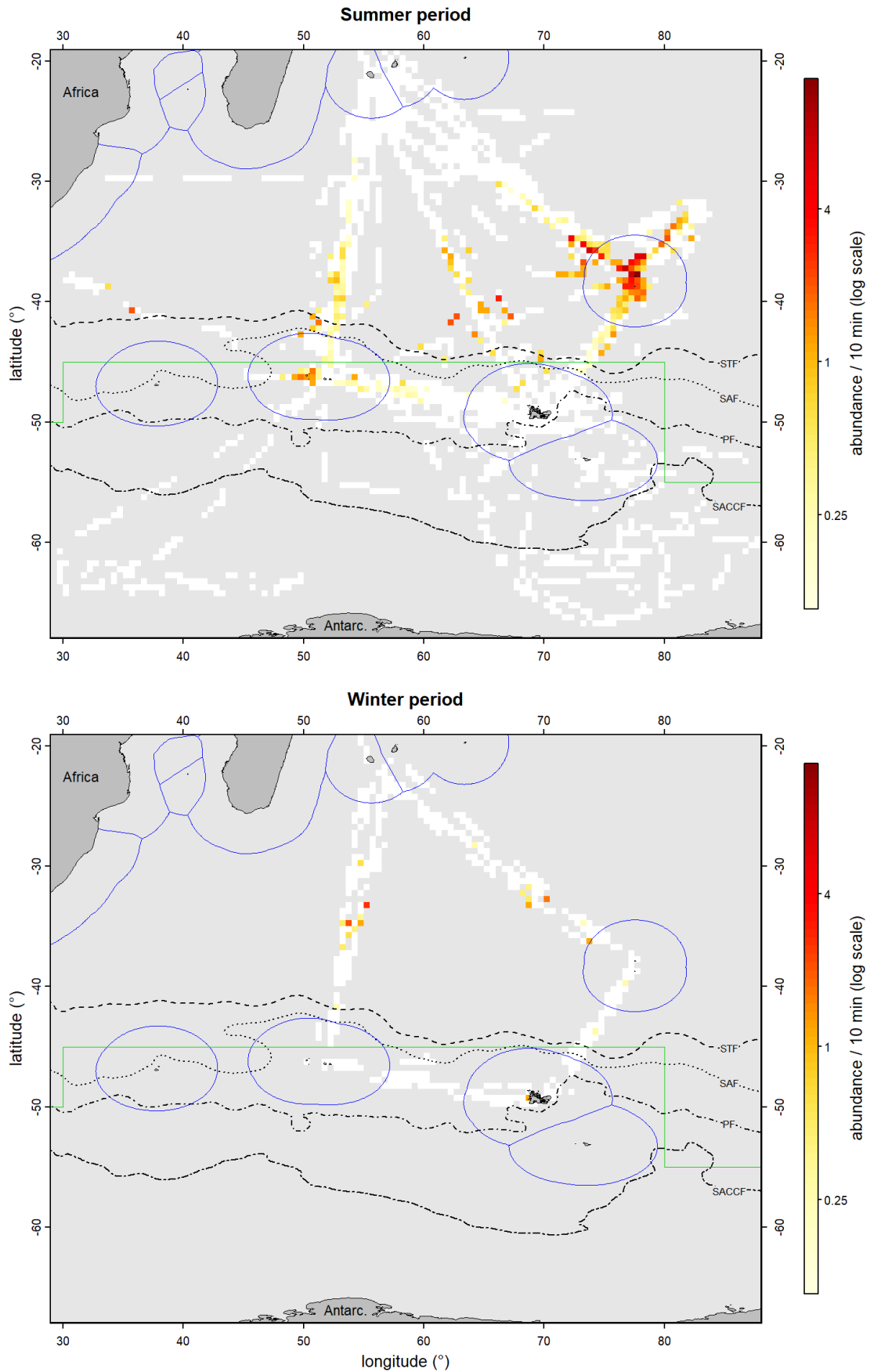


Figure 38 - Mean abundance of Yellow-nosed Albatross during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

Buller's albatross *Thalassarche bulleri* (NT)

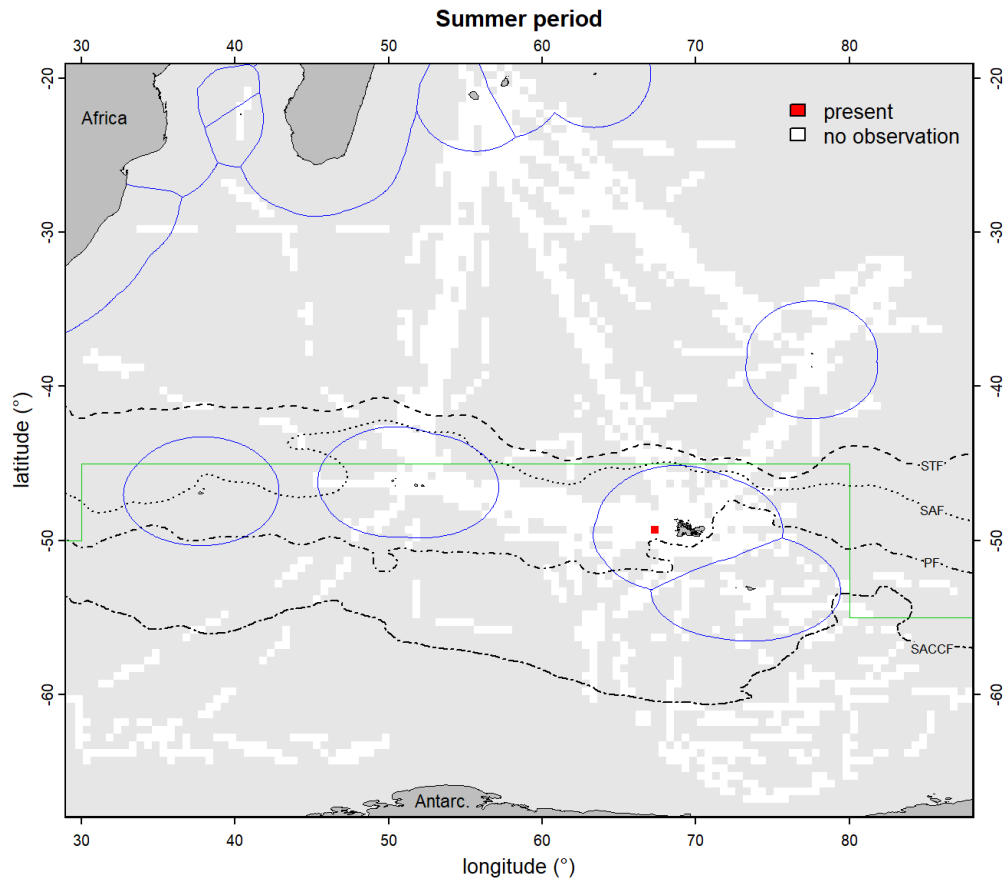


Figure 39 - Presence of Buller's albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

Sooty Albatross *Phoebetria fusca* (EN)

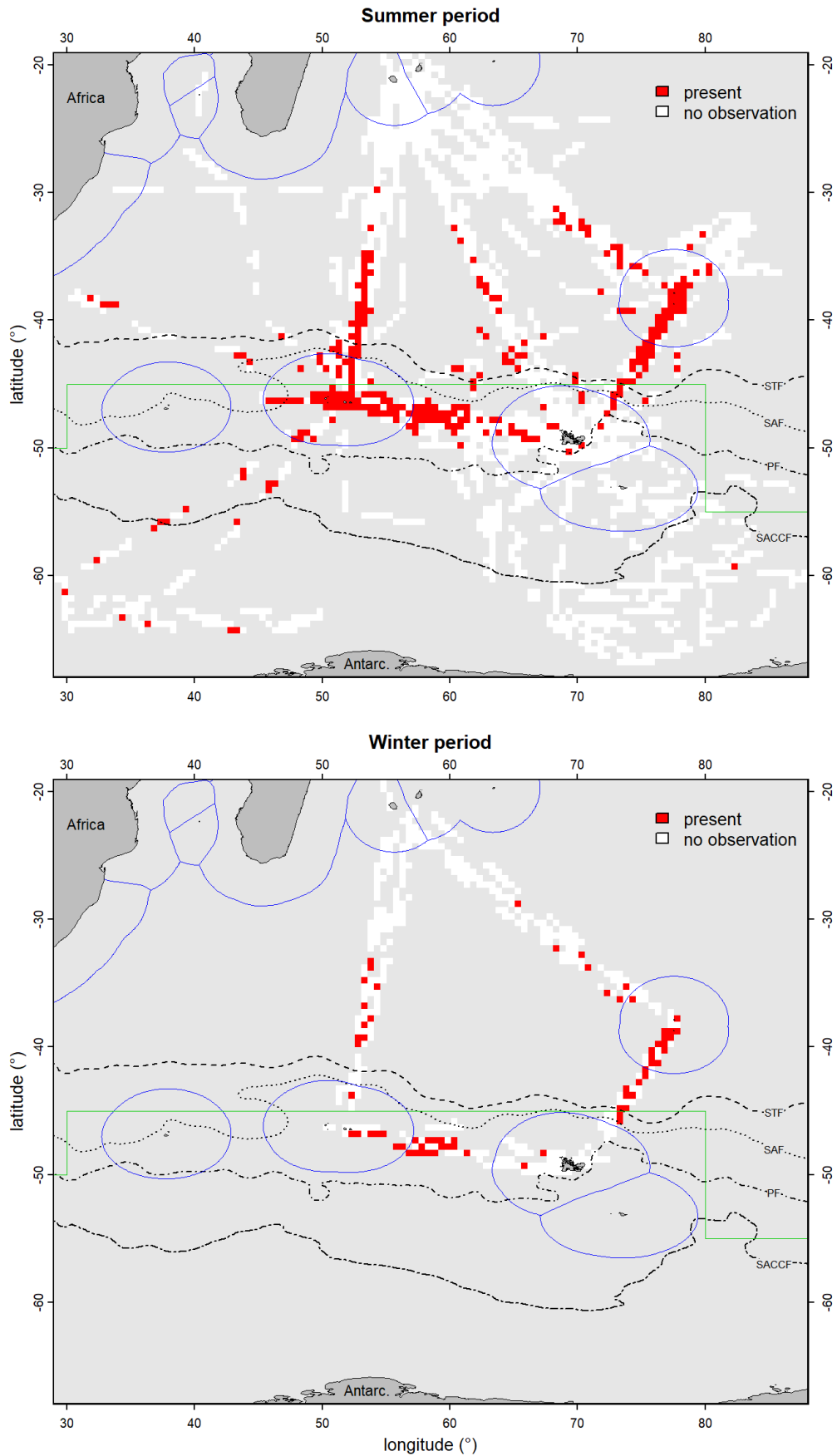


Figure 40 - Presence of Sooty Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

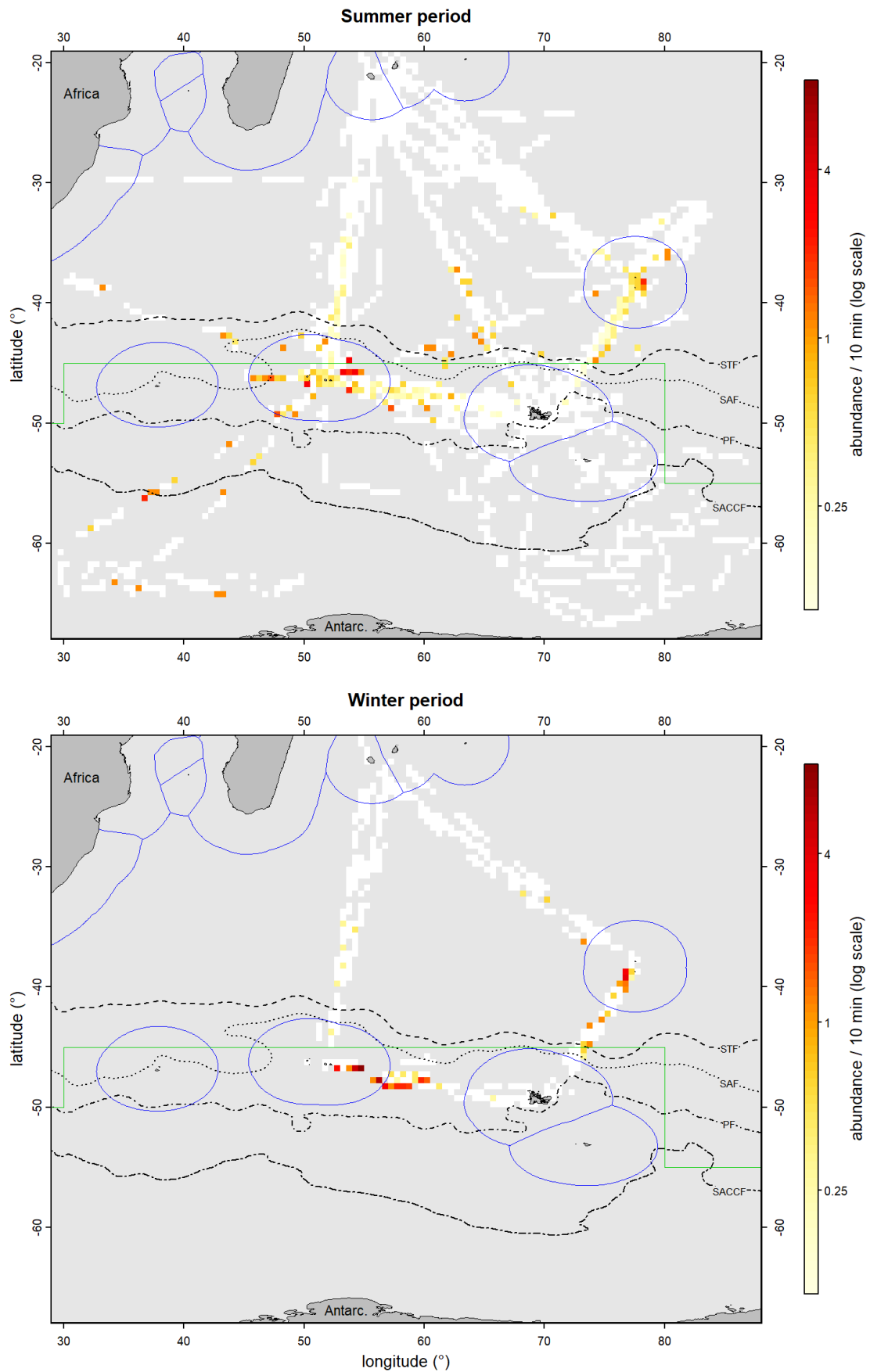


Figure 41 - Mean abundance of Sooty Albatross during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Light-mantled Sooty Albatross *Phoebetria palpebrata* (NT)

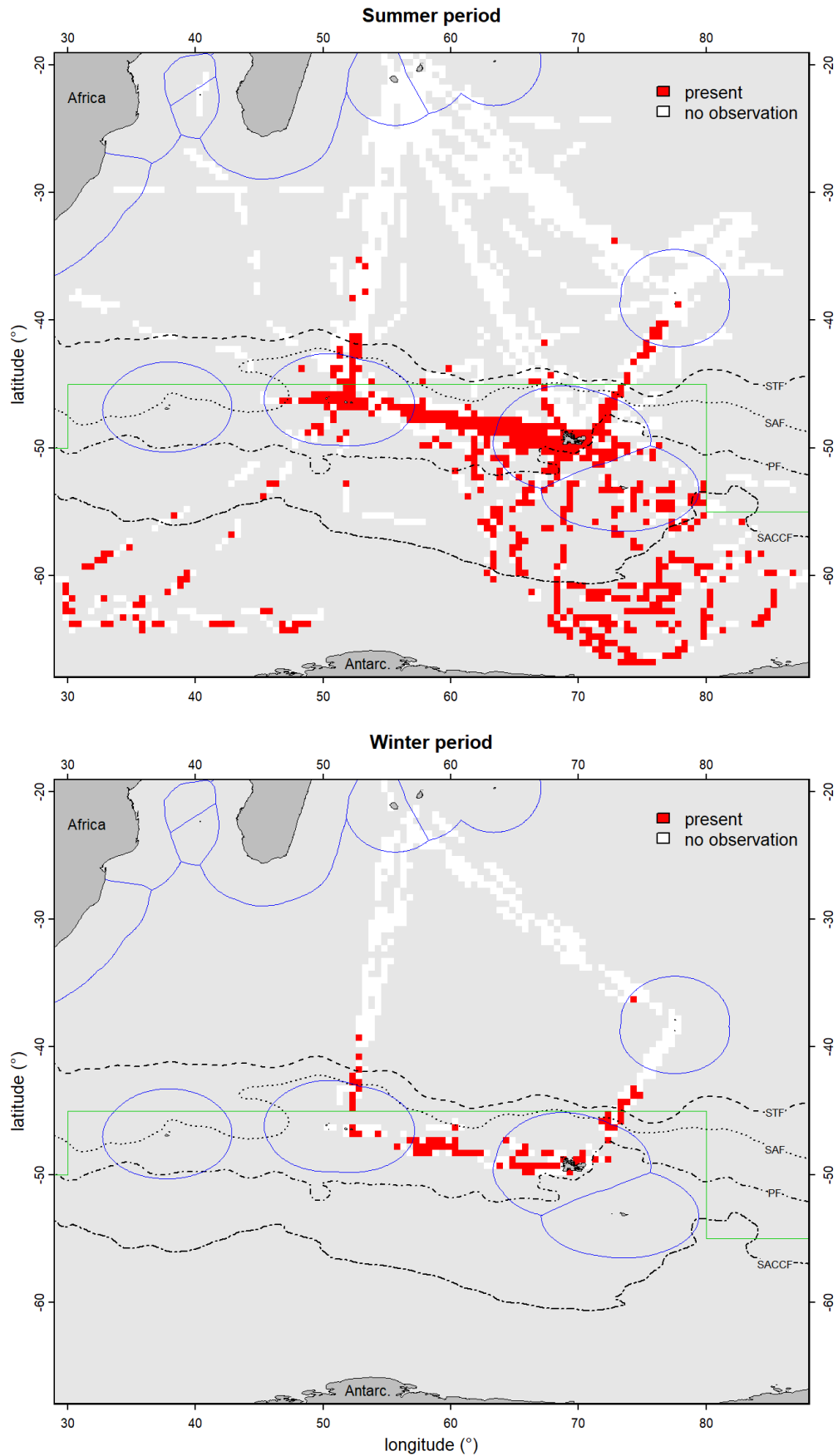


Figure 42 - Presence of Light-mantled Sooty Albatross in each 0.5°x0.5° square in the south-west Indian Ocean area

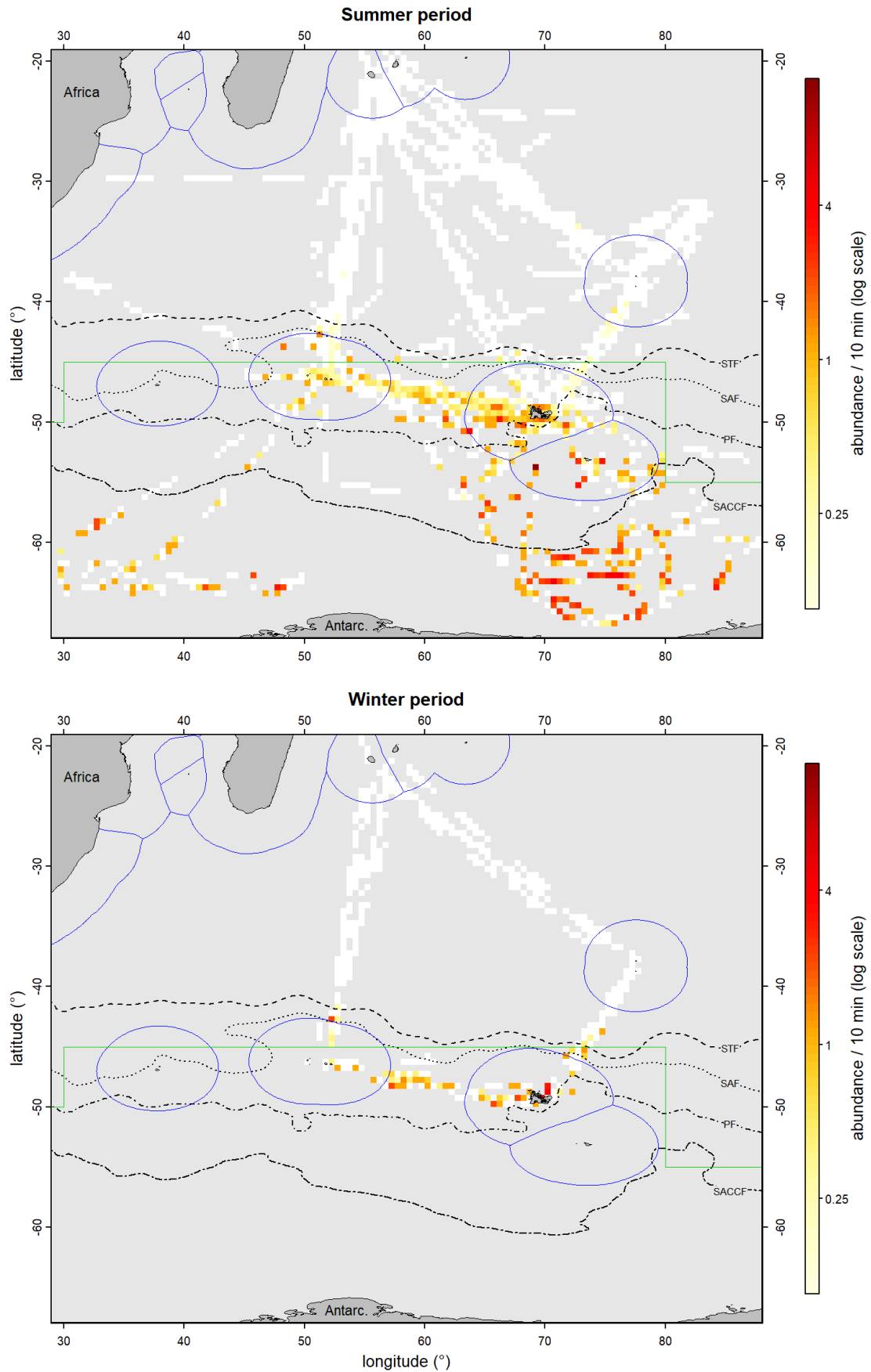


Figure 43 - Mean abundance of Light-mantled Sooty Albatross during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

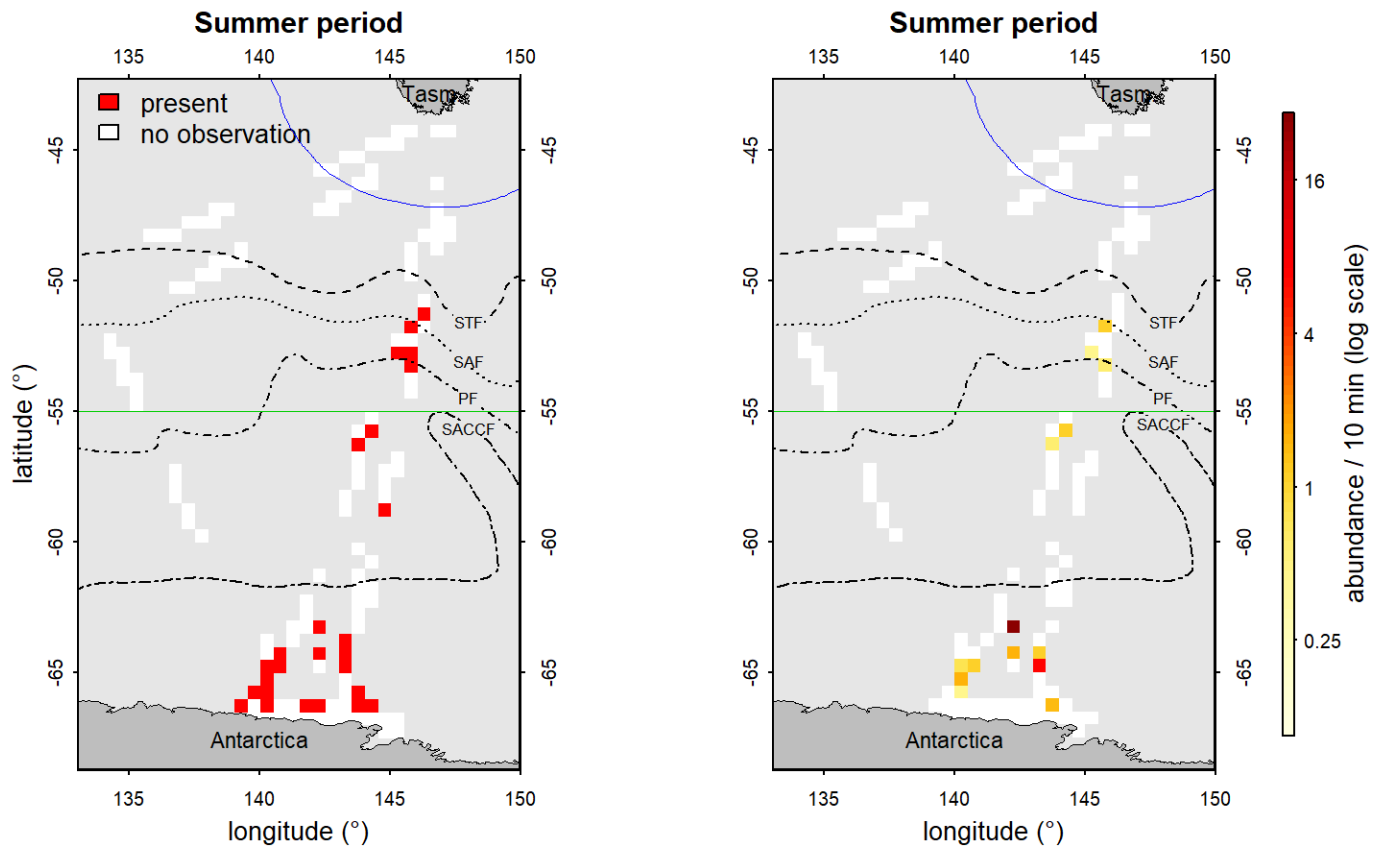


Figure 44 - Presence of Light-mantled Sooty Albatross and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Southern Giant Petrel *Macronectes giganteus* (LC)

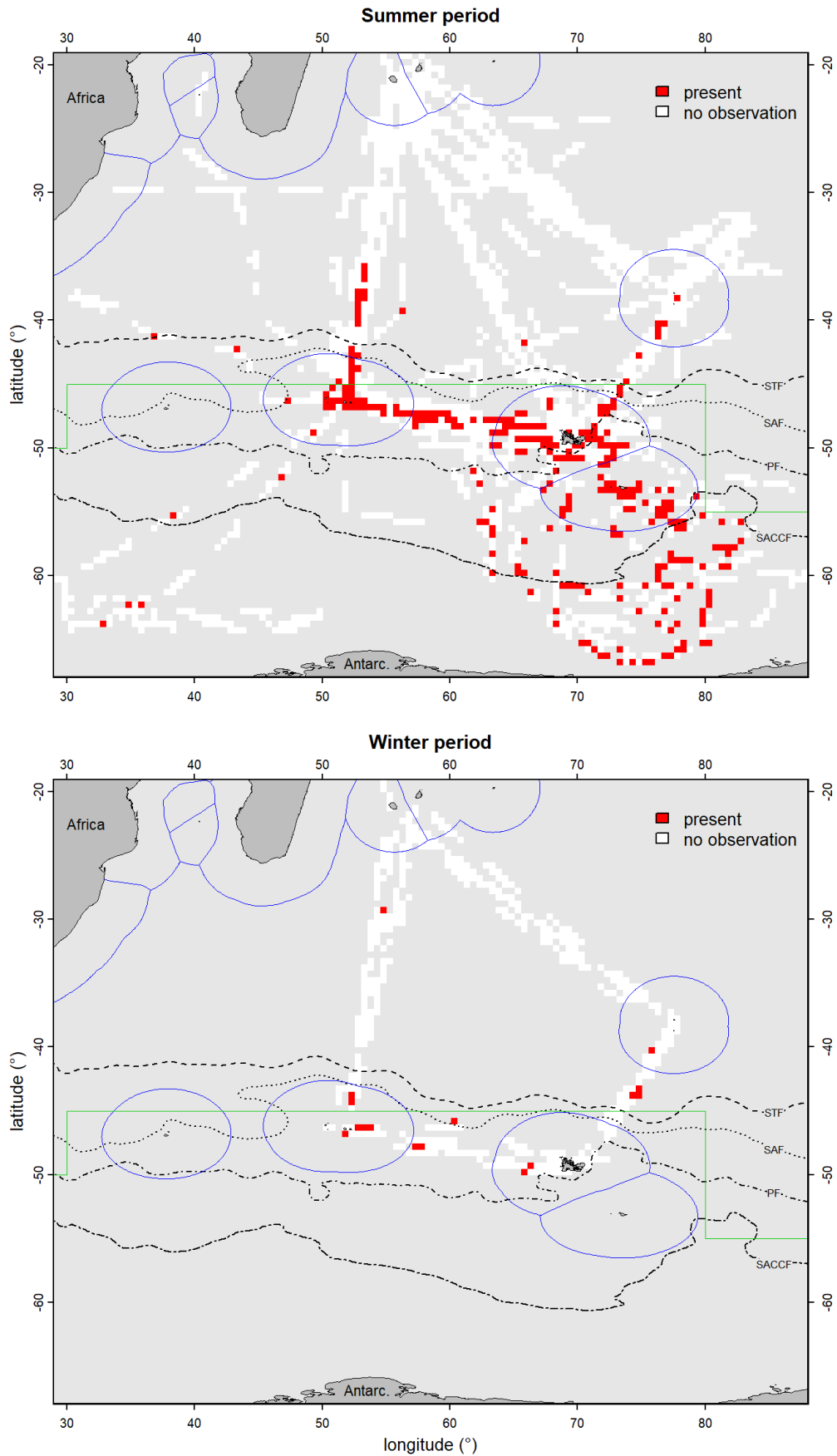


Figure 45 - Presence of Southern Giant Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

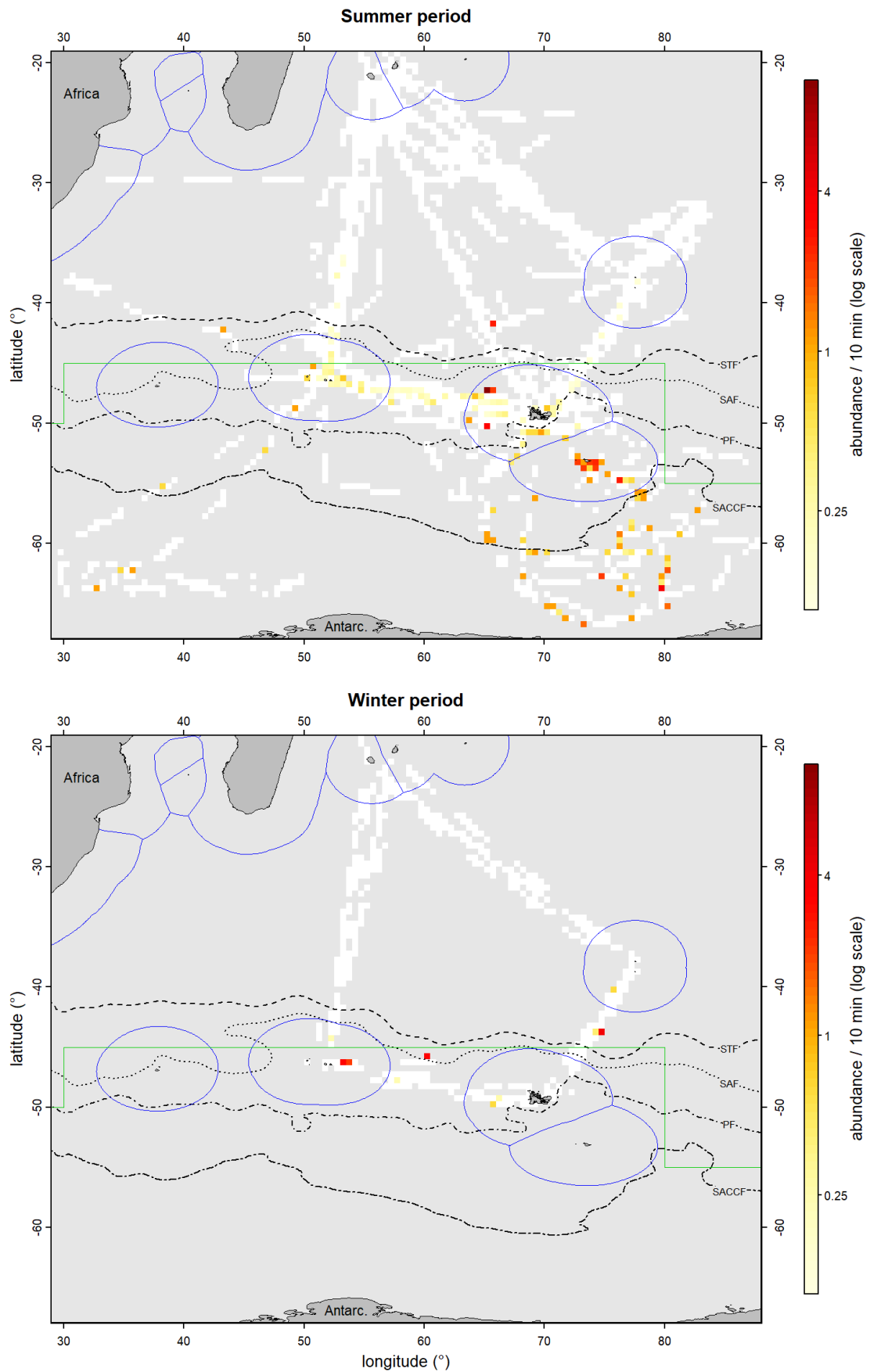


Figure 46 - Mean abundance of Southern Giant Petrel during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

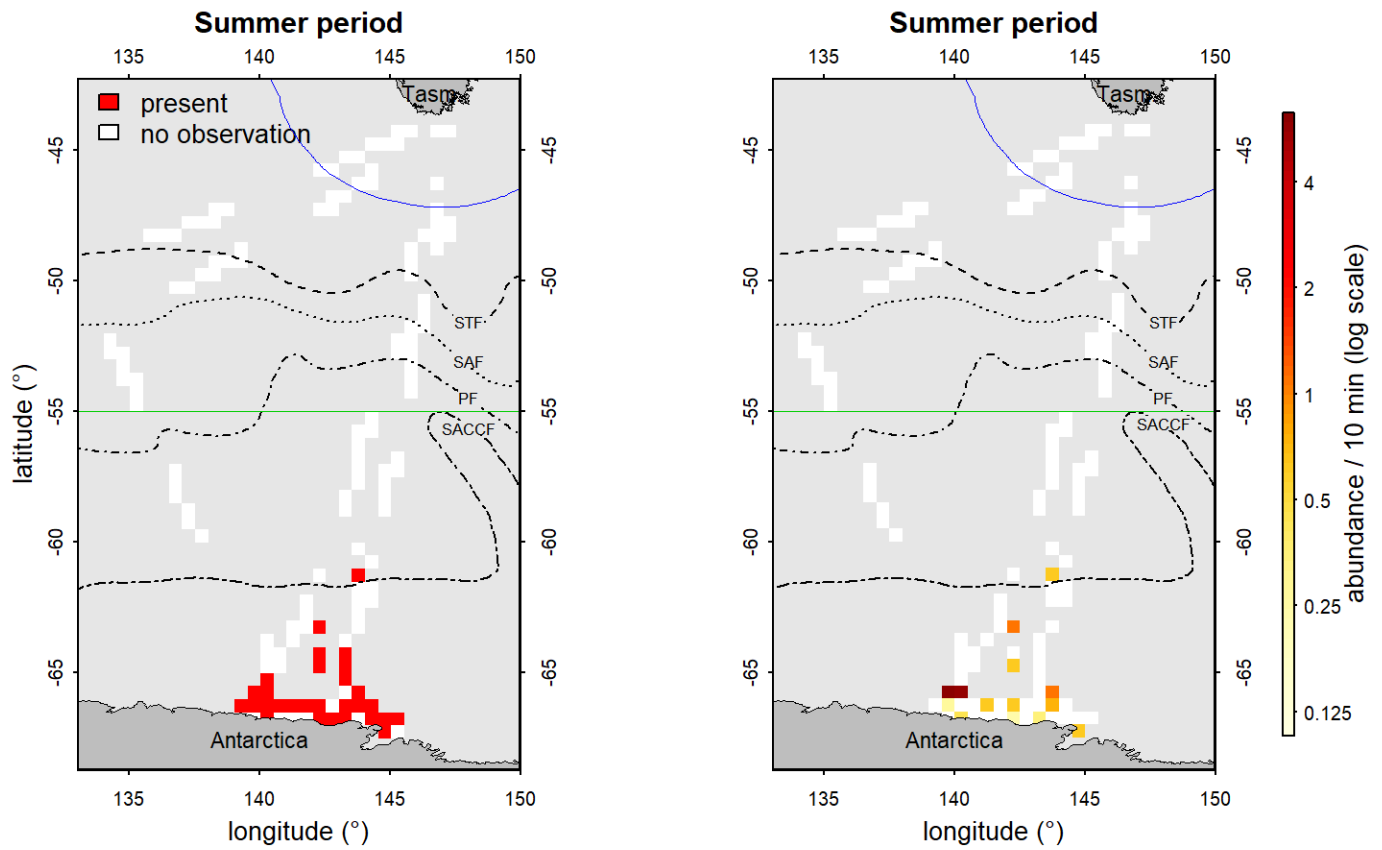


Figure 47 - Presence of Southern Giant Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Northern Giant Petrel *Macronectes halli* (LC)

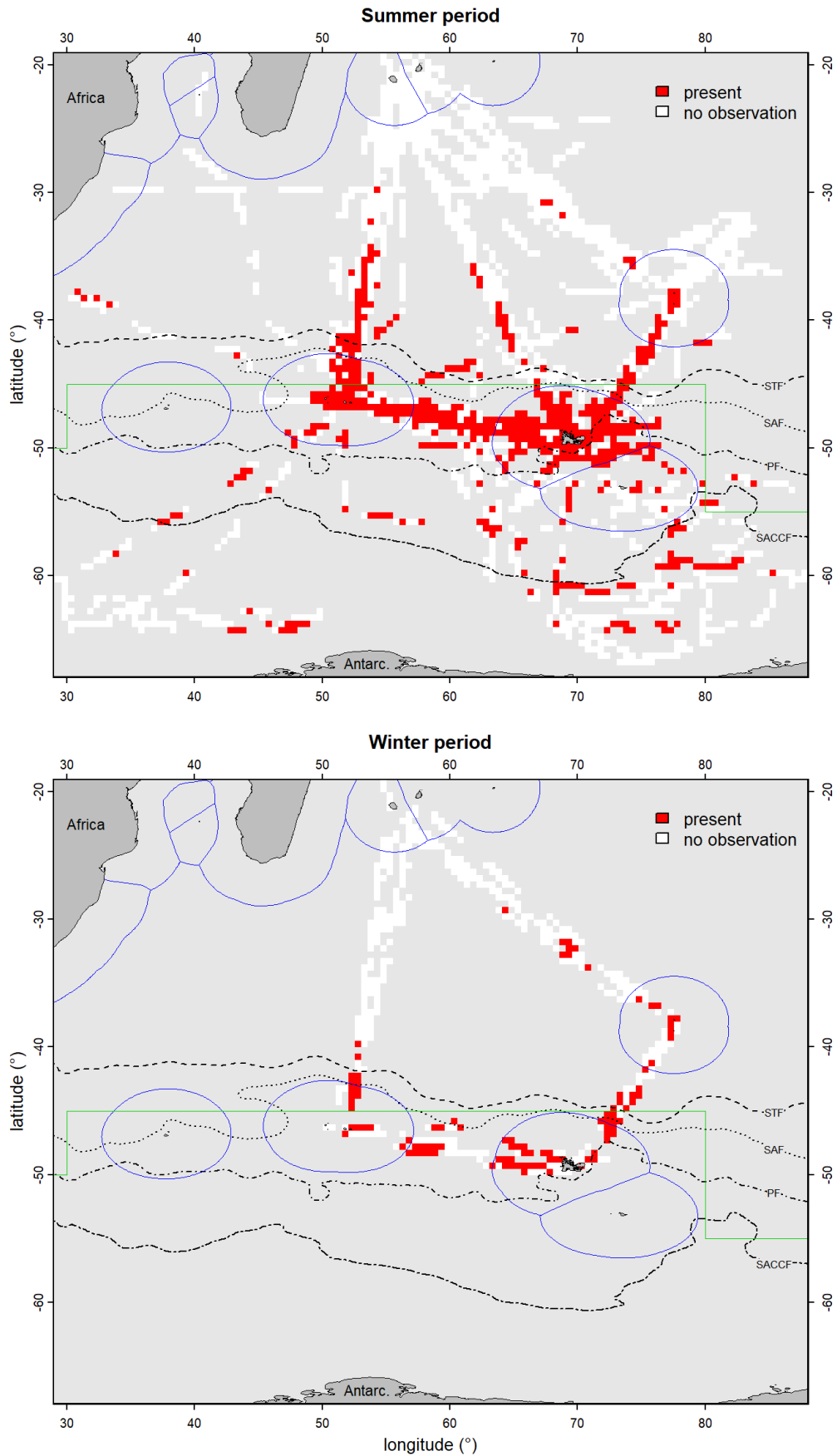


Figure 48 - Presence of Northern Giant Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

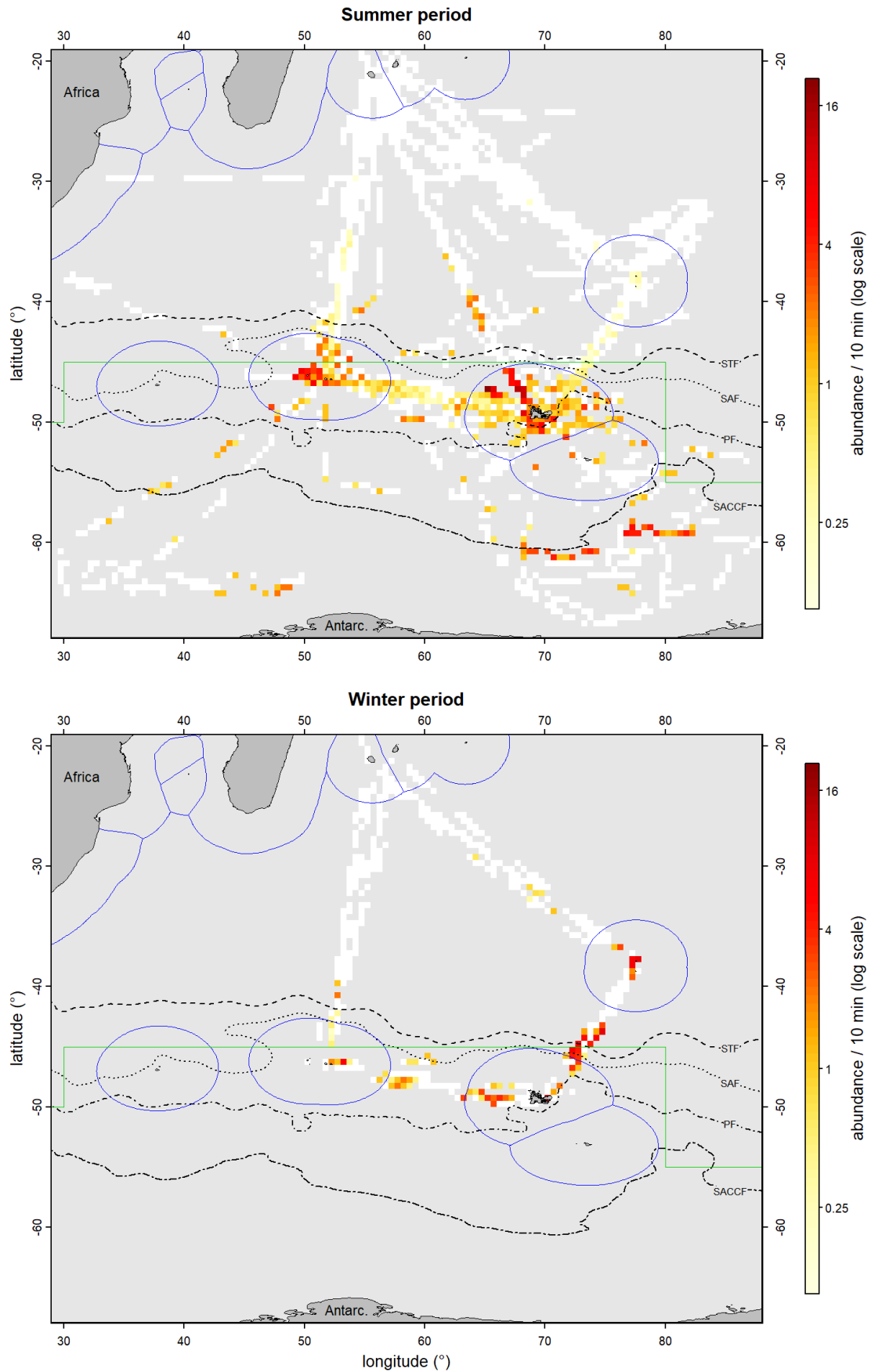


Figure 49 - Mean abundance of Northern Giant Petrel during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

Southern Fulmar *Fulmarus glacialisoides* (LC)

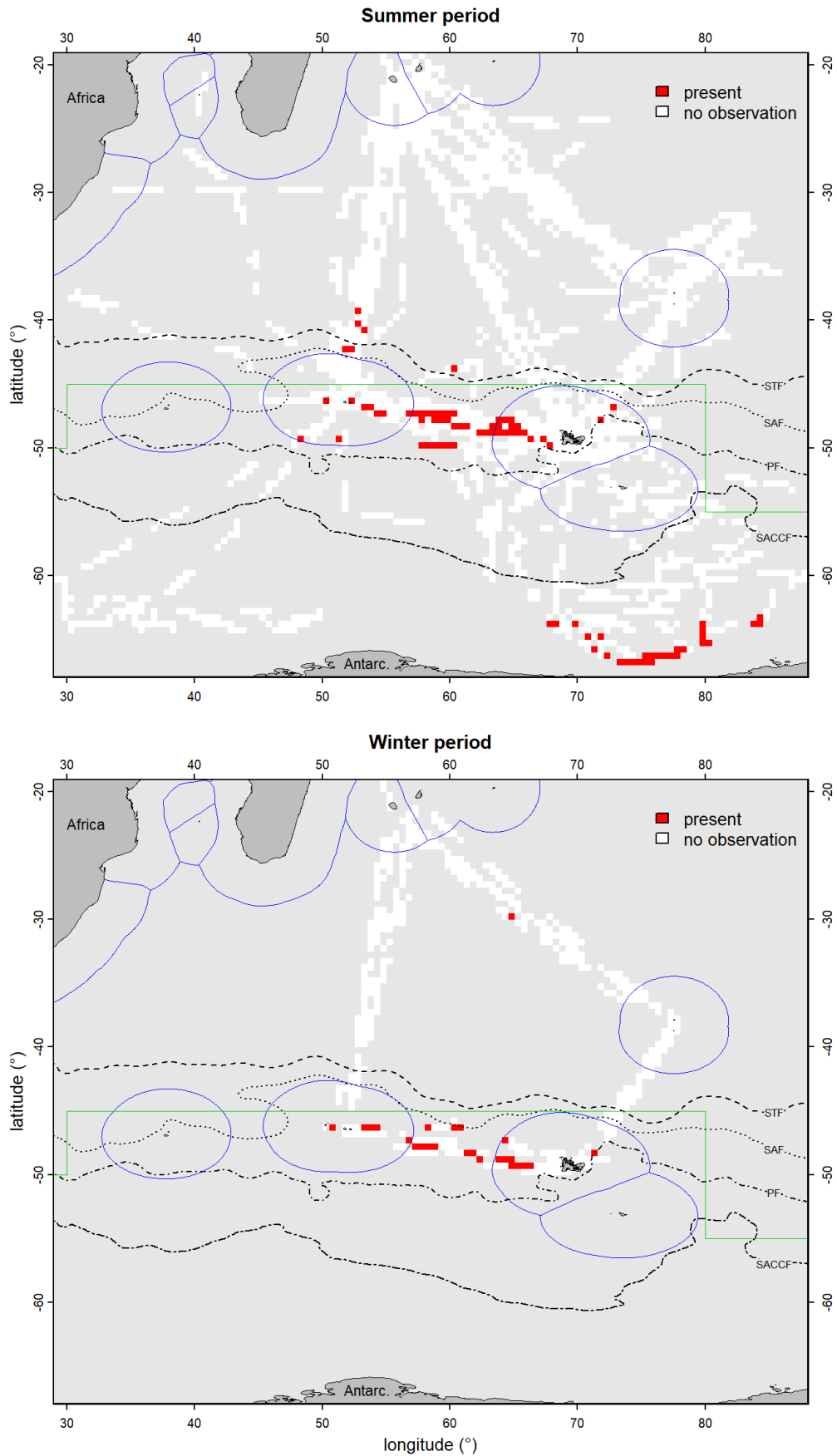


Figure 50 - Presence of Southern Fulmar in each 0.5°x0.5° square in the south-west Indian Ocean area

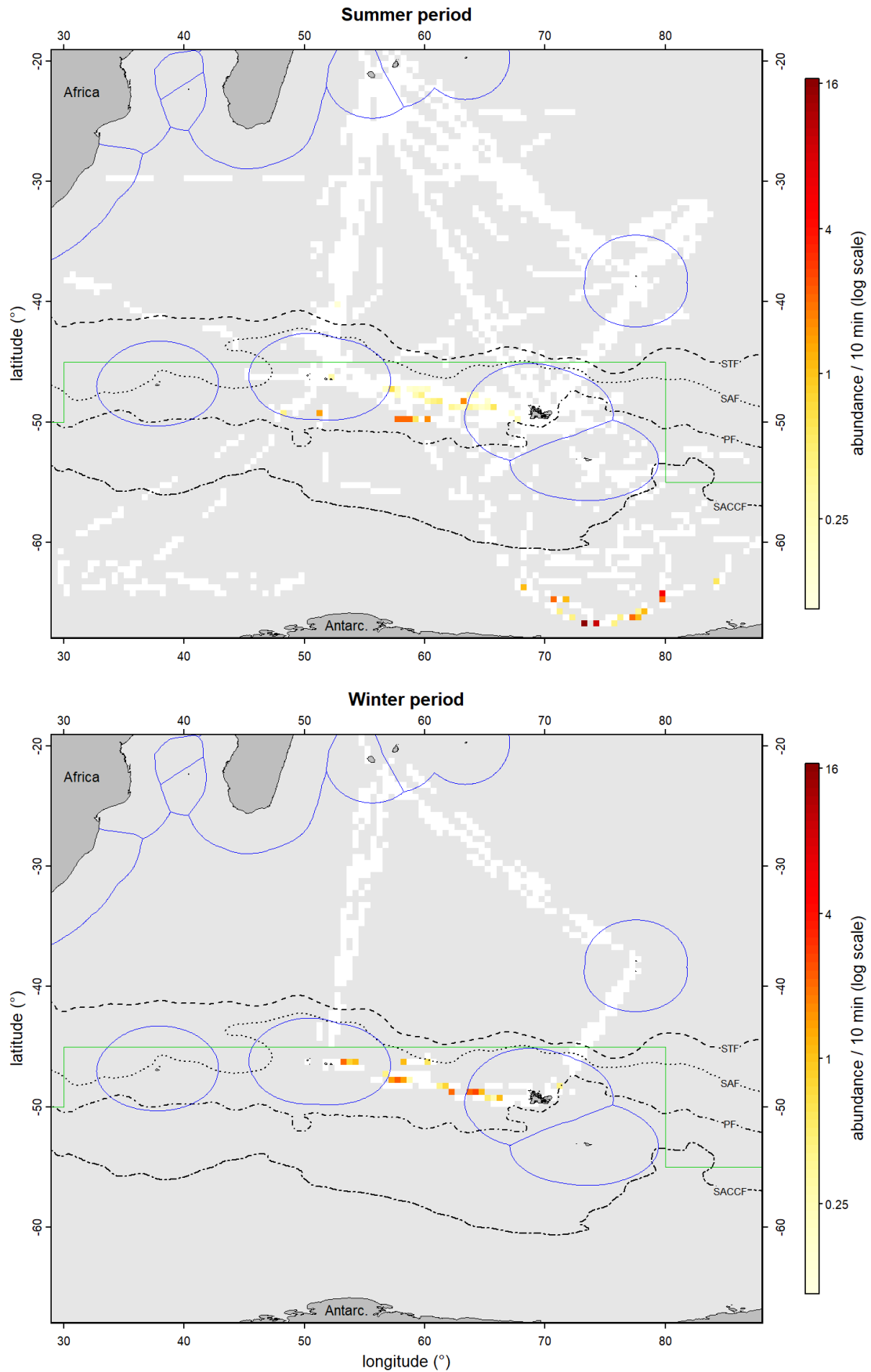


Figure 51 - Mean abundance of Southern Fulmar during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

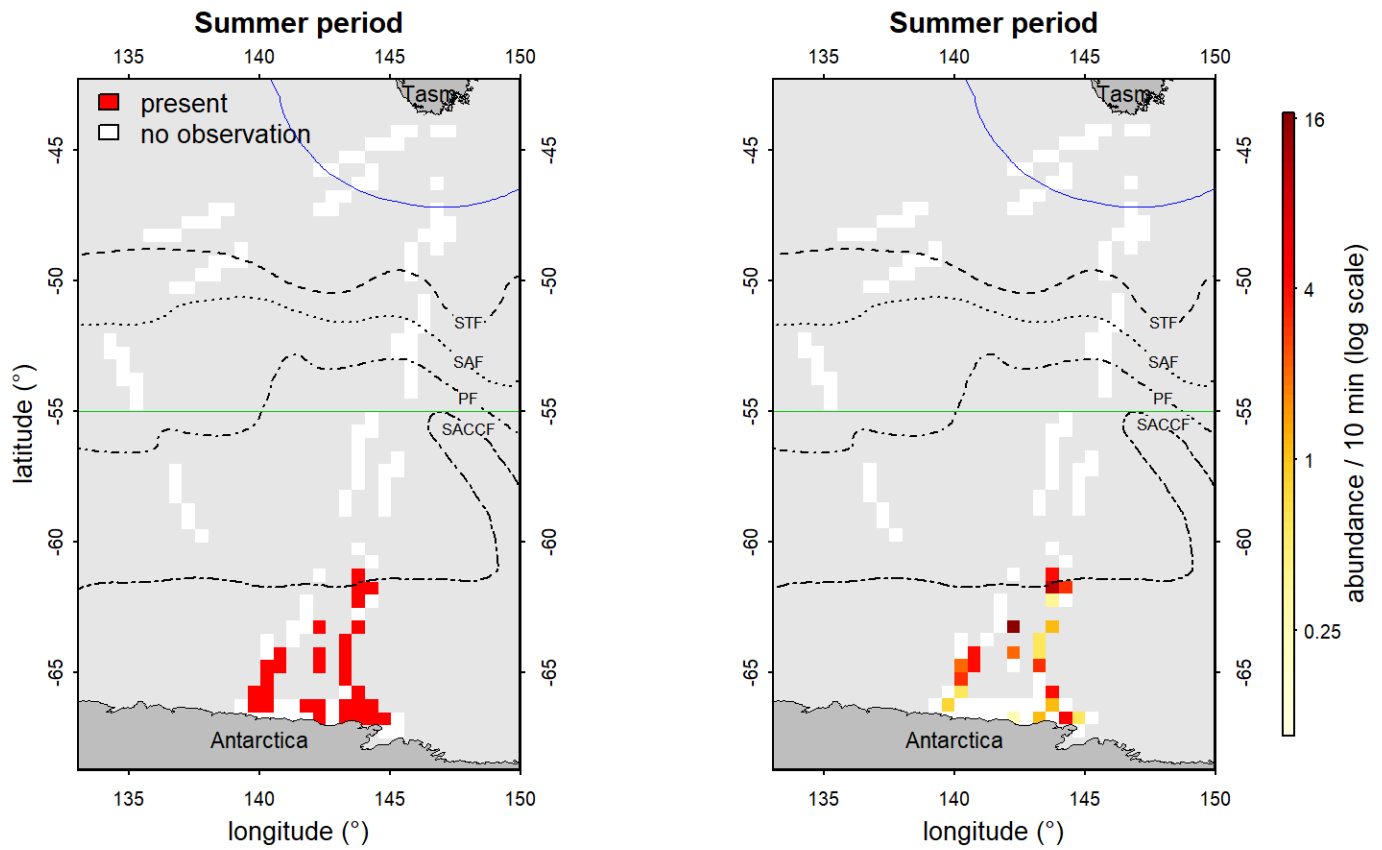


Figure 52 - Presence of Southern Fulmar and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Antarctic Petrel *Thalassoica antarctica* (LC)

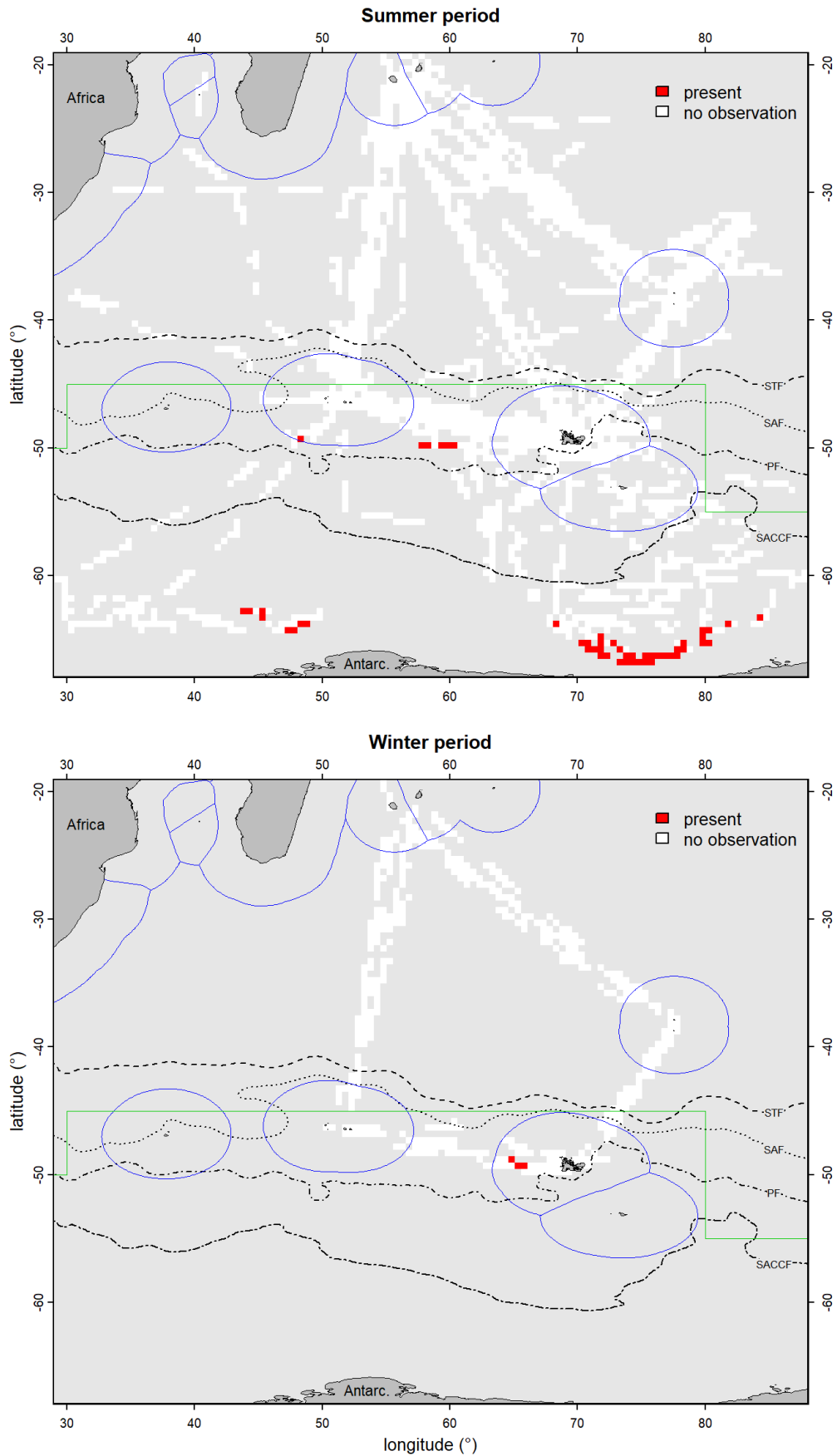


Figure 53 - Presence of Antarctic Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

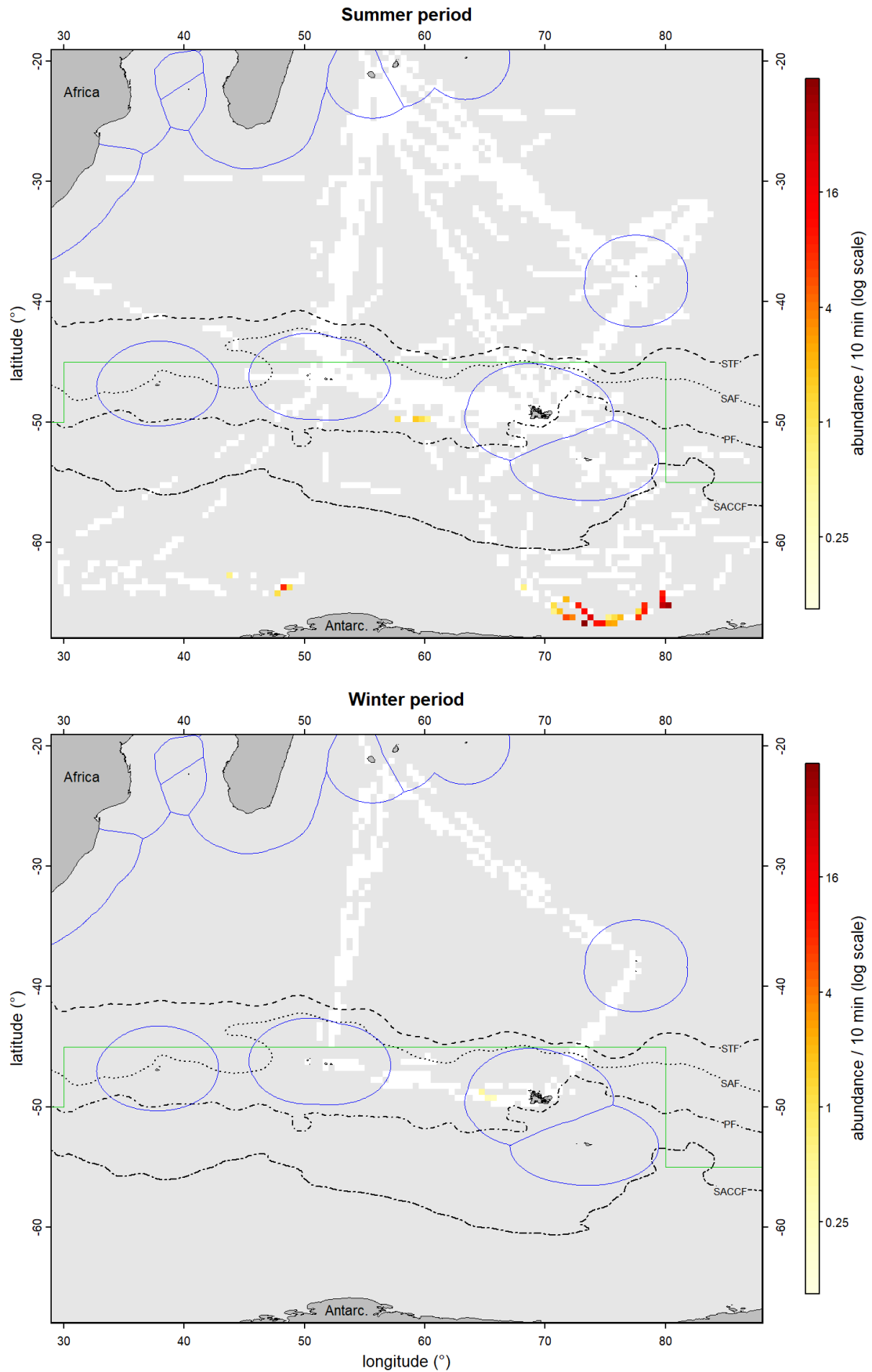


Figure 54 - Mean abundance of Antarctic Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

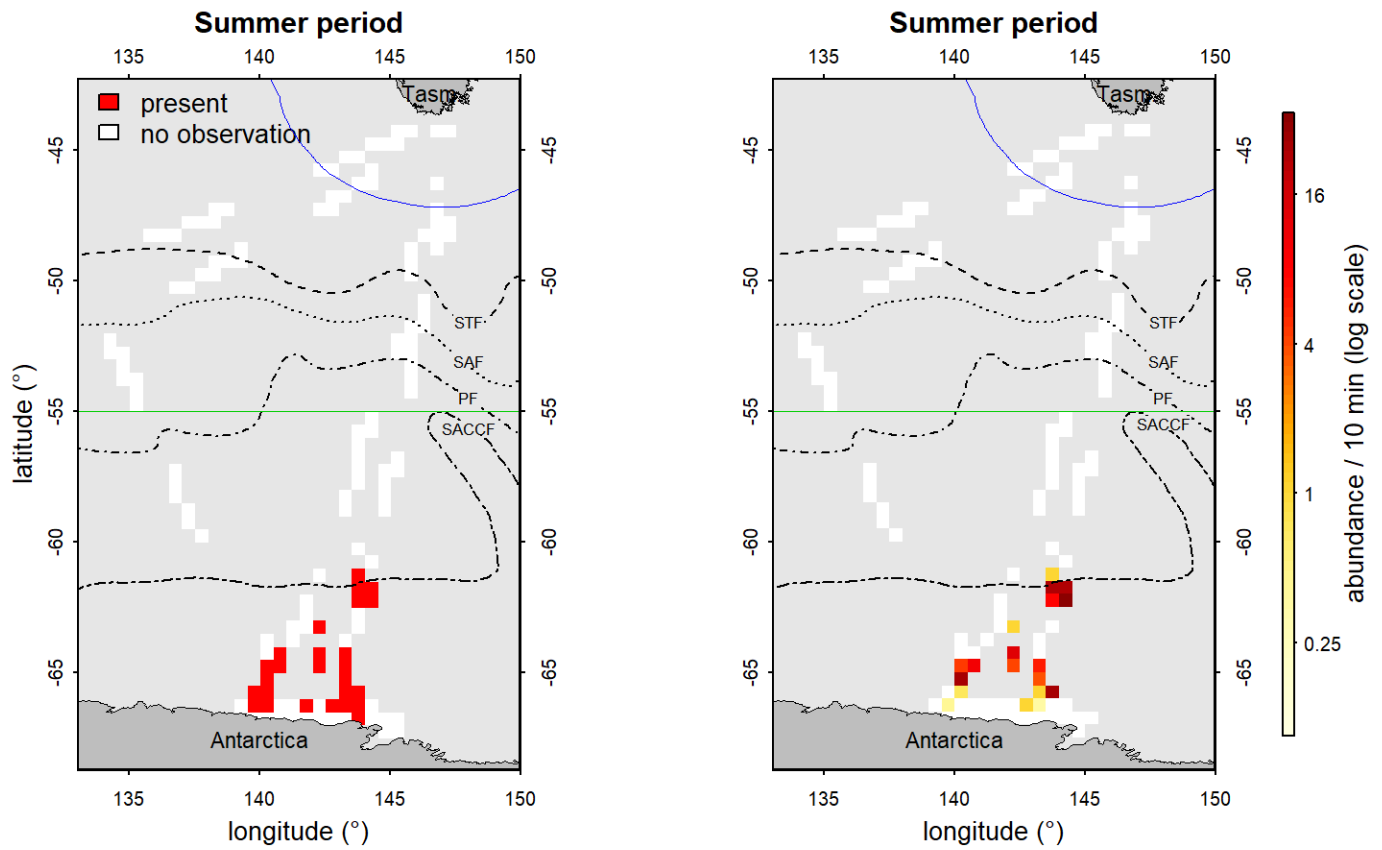


Figure 55 - Presence of Antarctic Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Cape Petrel *Daption capense* (LC)

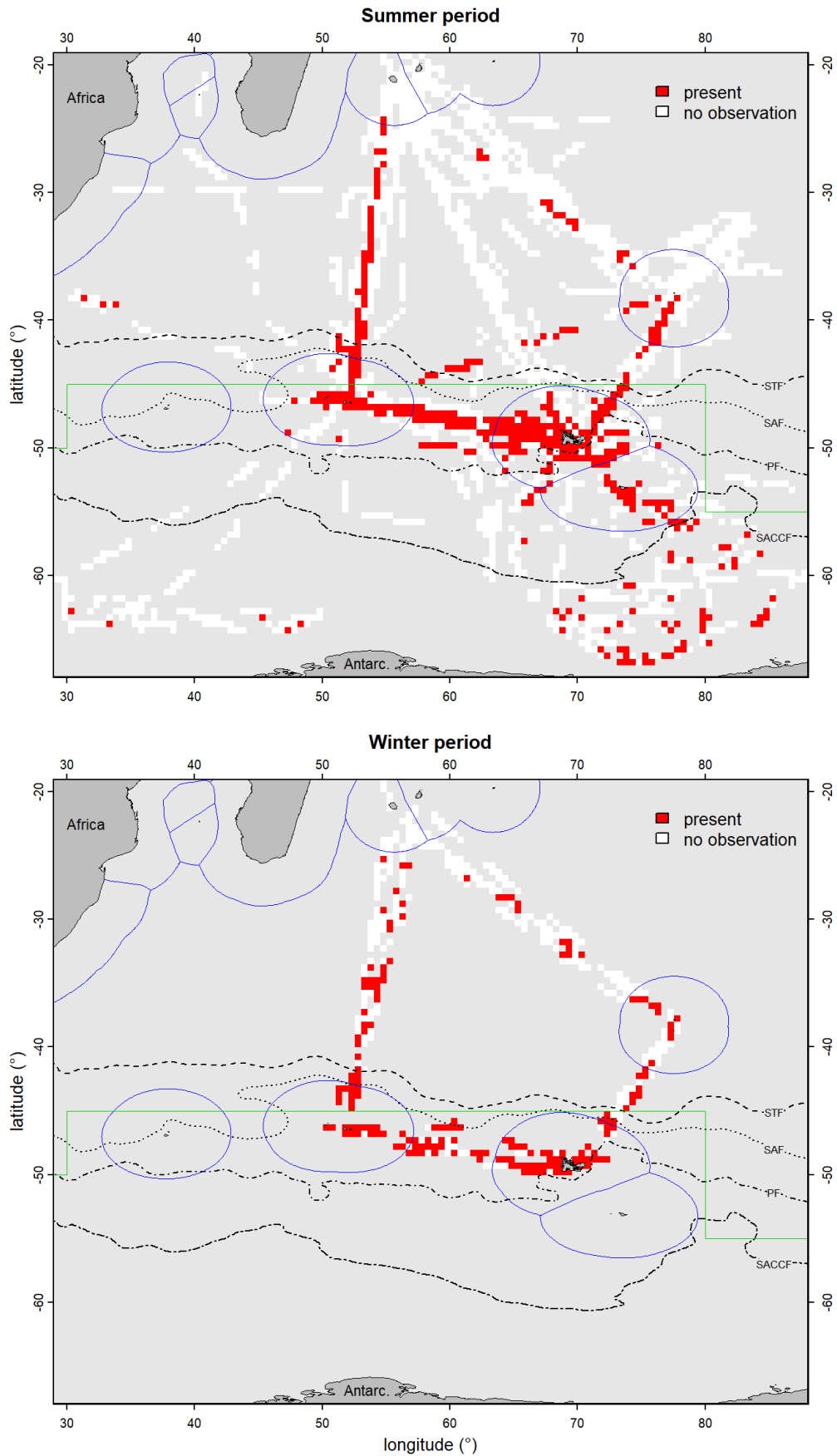


Figure 56 - Presence of Cape Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

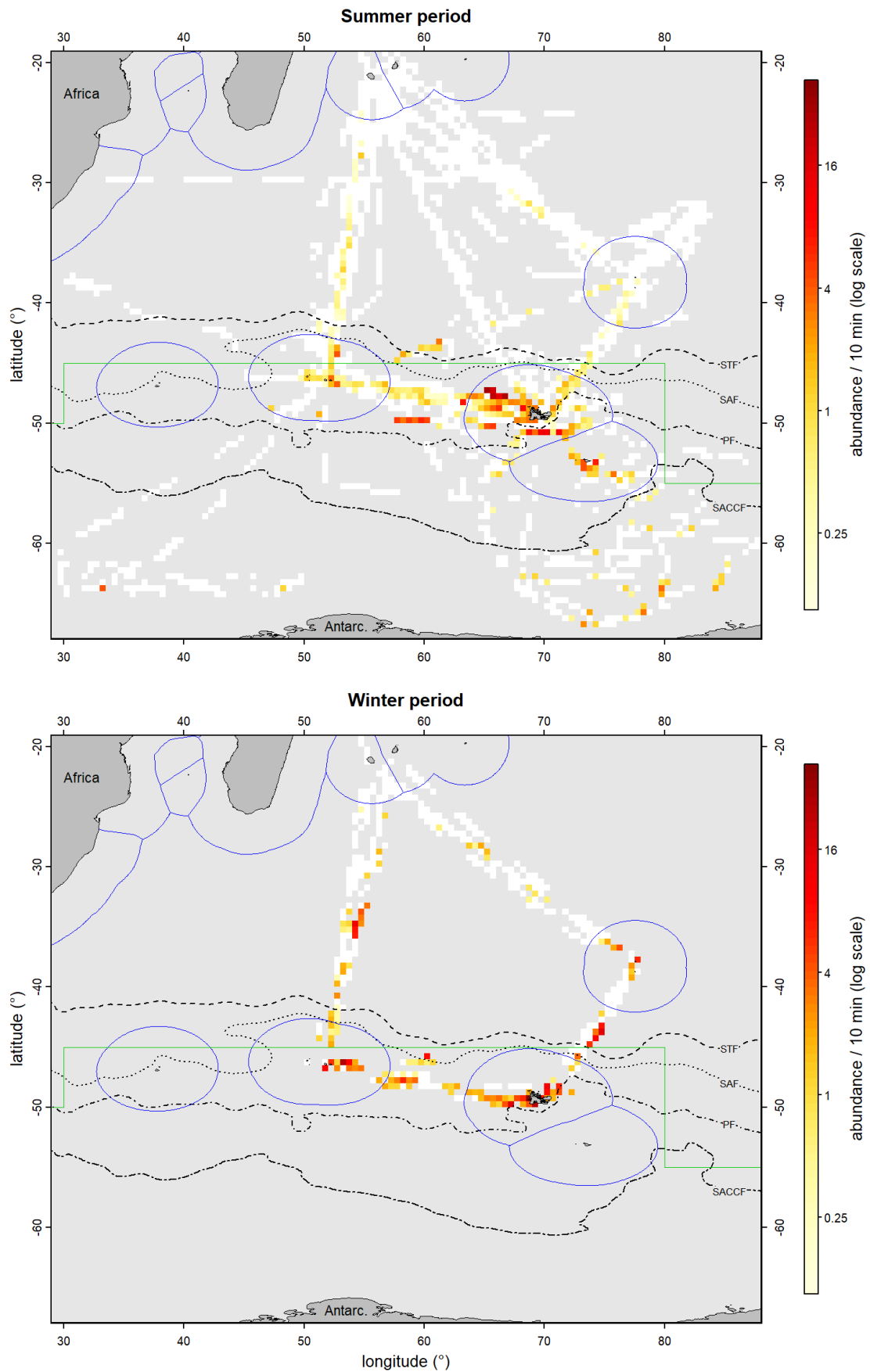


Figure 57 - Mean abundance of Cape Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

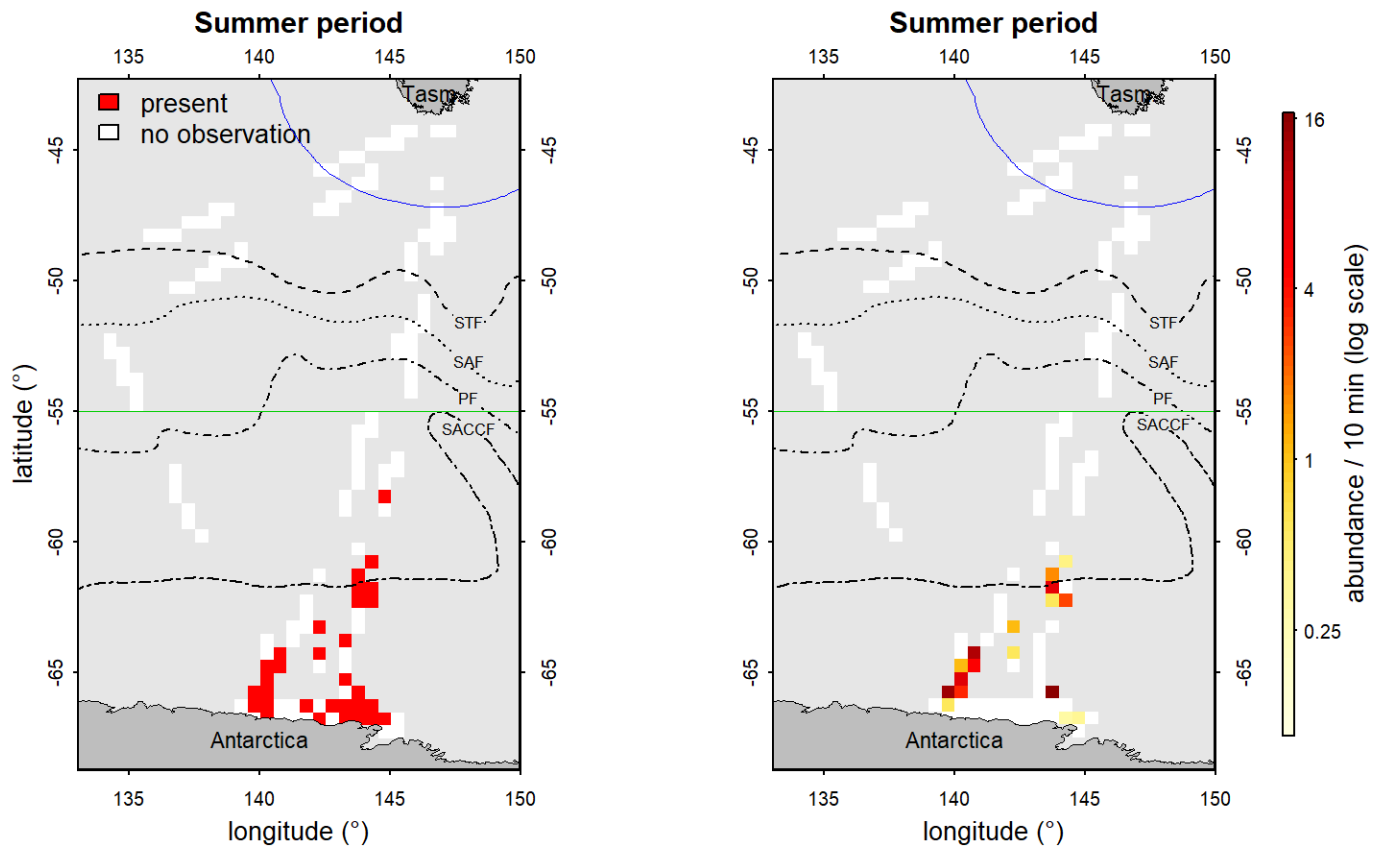


Figure 58 - Presence of Cape Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Snow Petrel *Pagodroma nivea* (LC)

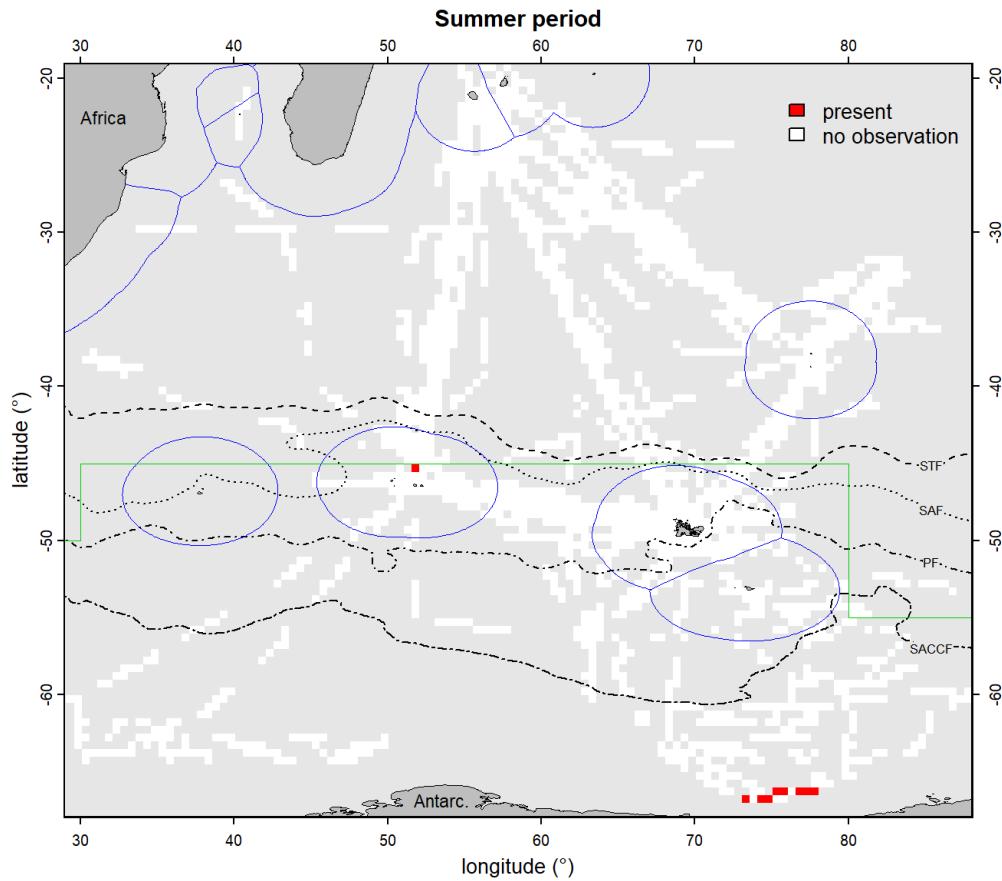


Figure 59 - Presence of Snow Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

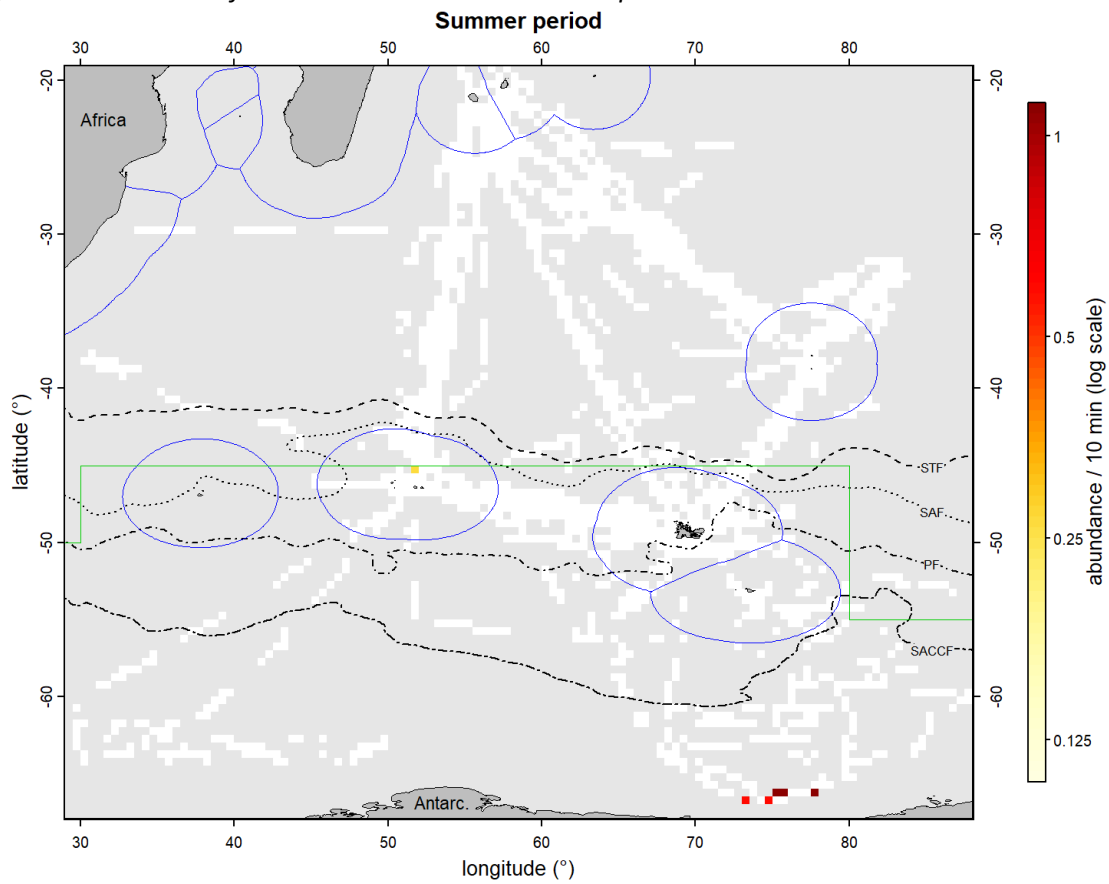


Figure 60 - Mean abundance of Snow Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

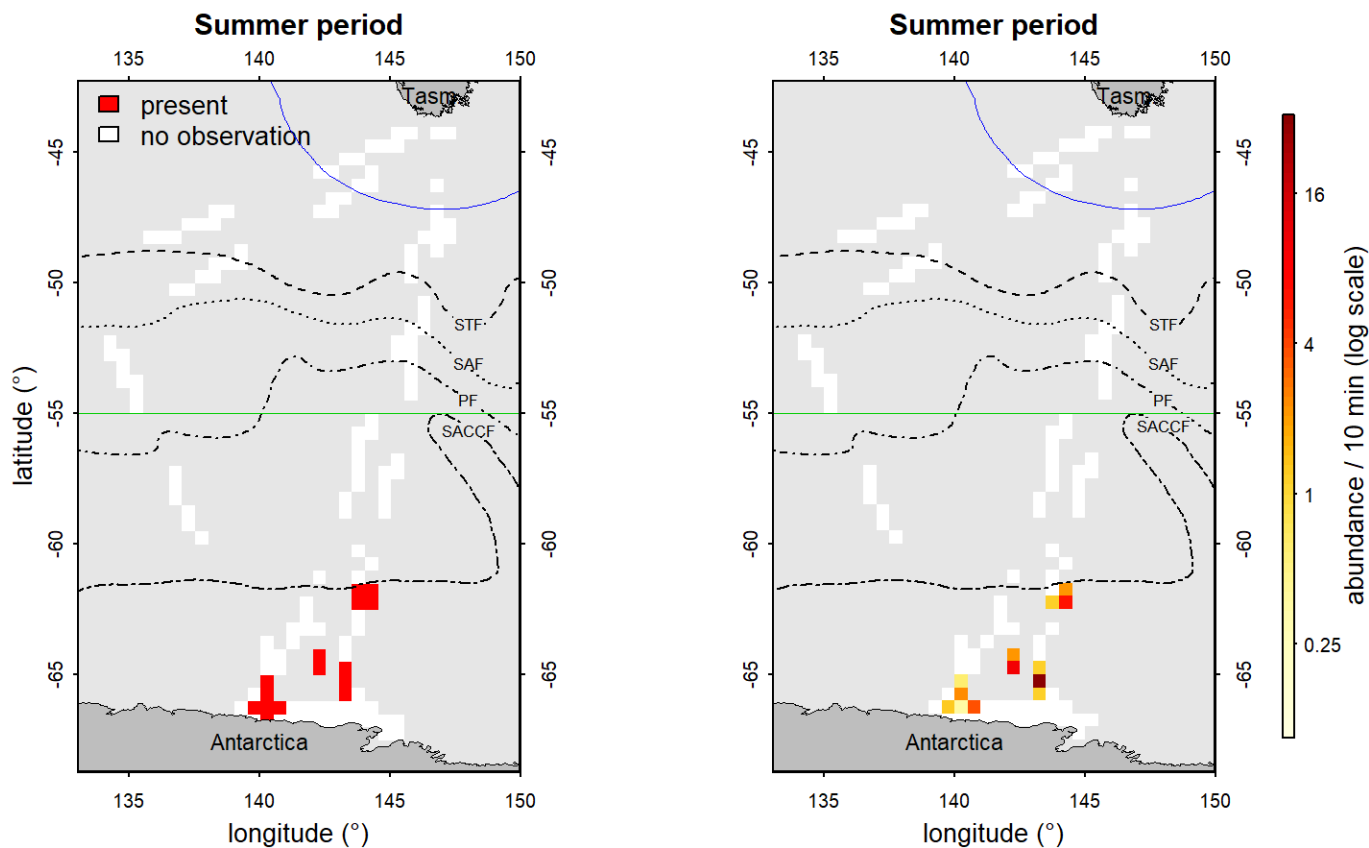


Figure 61 - Presence of Snow Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Kerguelen Petrel *Lugensa brevirostris* (LC)

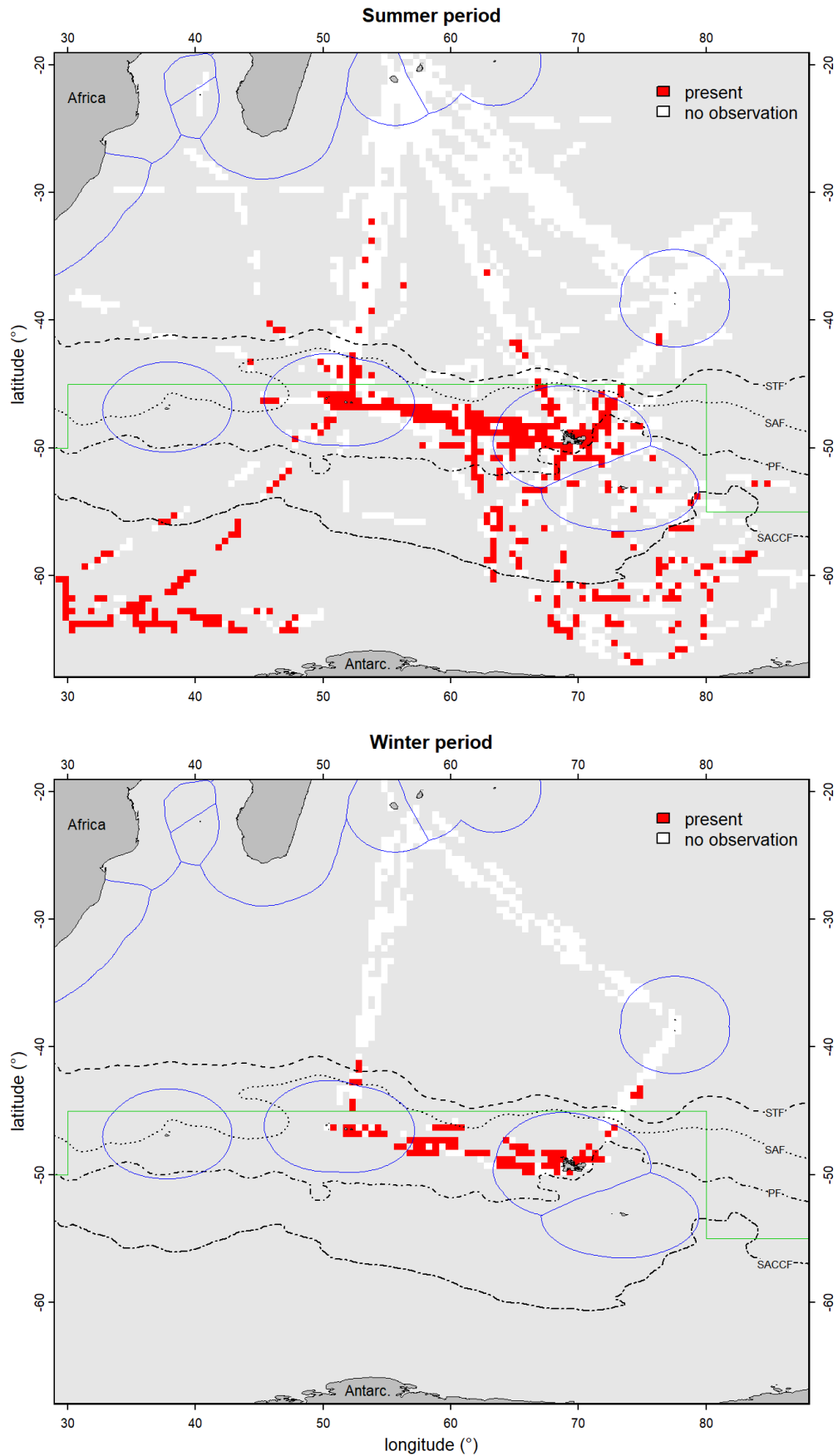


Figure 62 - Presence of Kerguelen Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

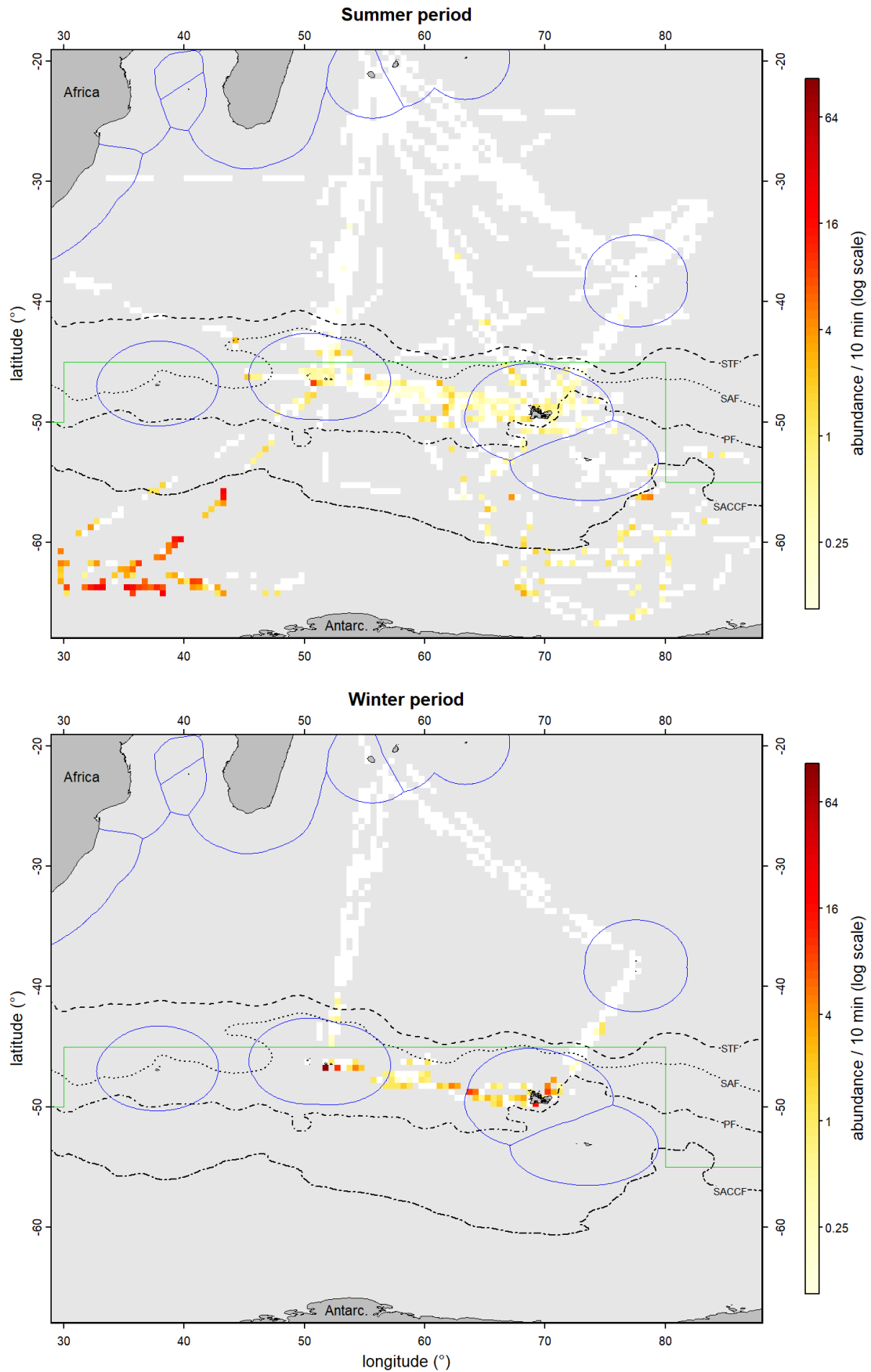


Figure 63 - Mean abundance of Kerguelen Petrel during 10-min counts in each $0.5^{\circ} \times 0.5^{\circ}$ square in the south-west Indian Ocean area

Blue Petrel *Halobaena caerulea* (LC)

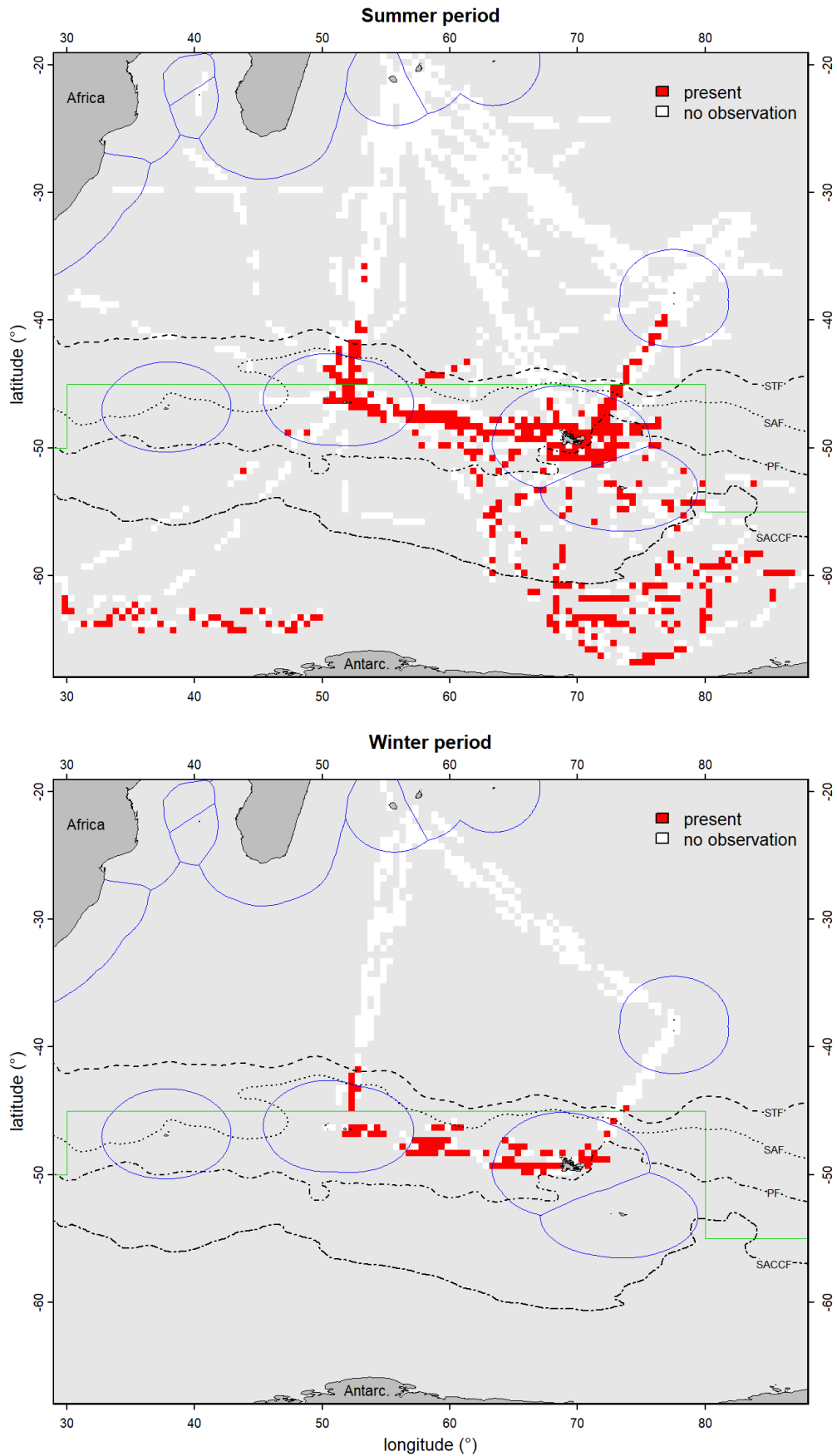


Figure 64 - Presence of Blue Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

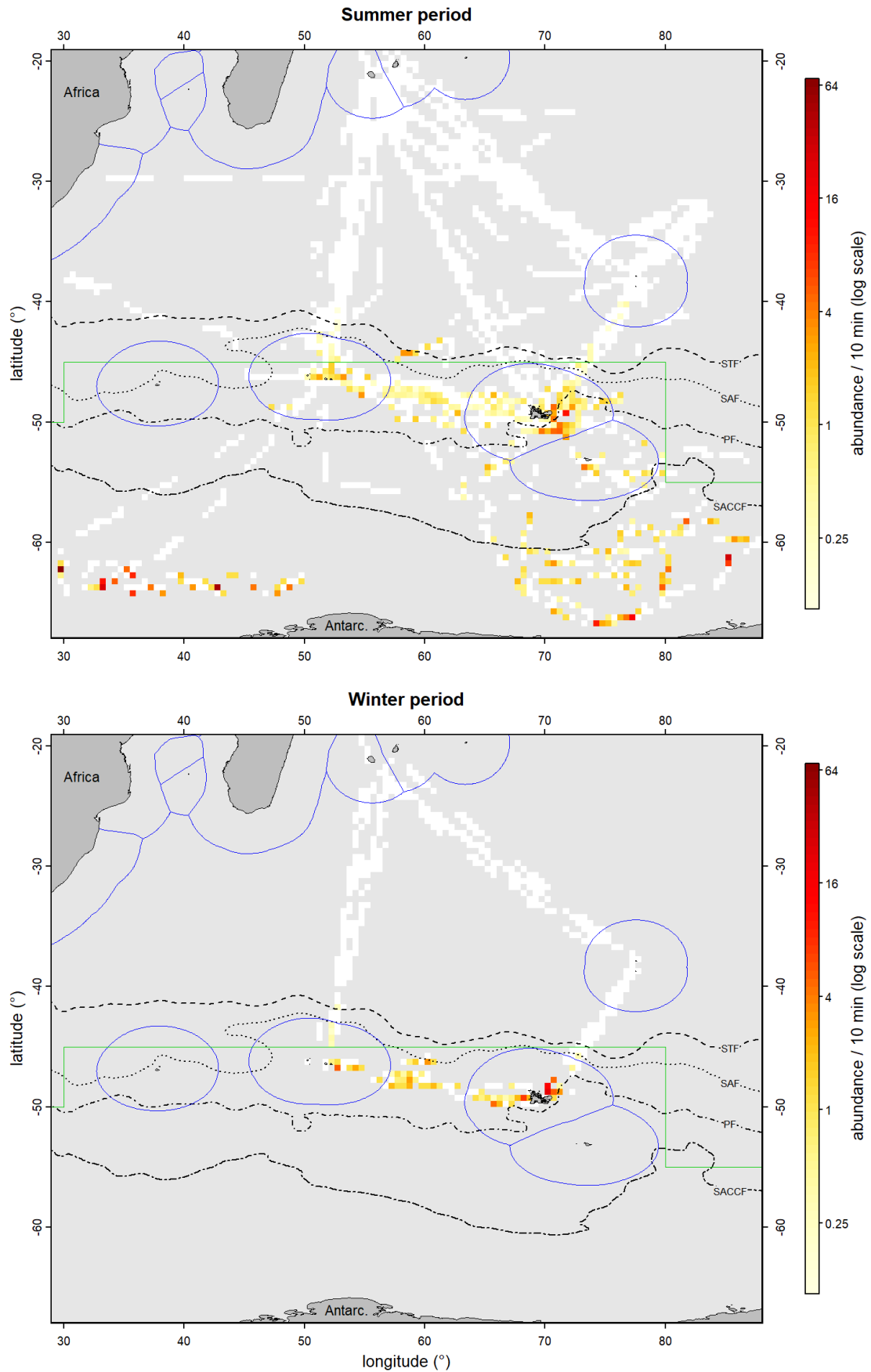


Figure 65 - Mean abundance of Blue Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

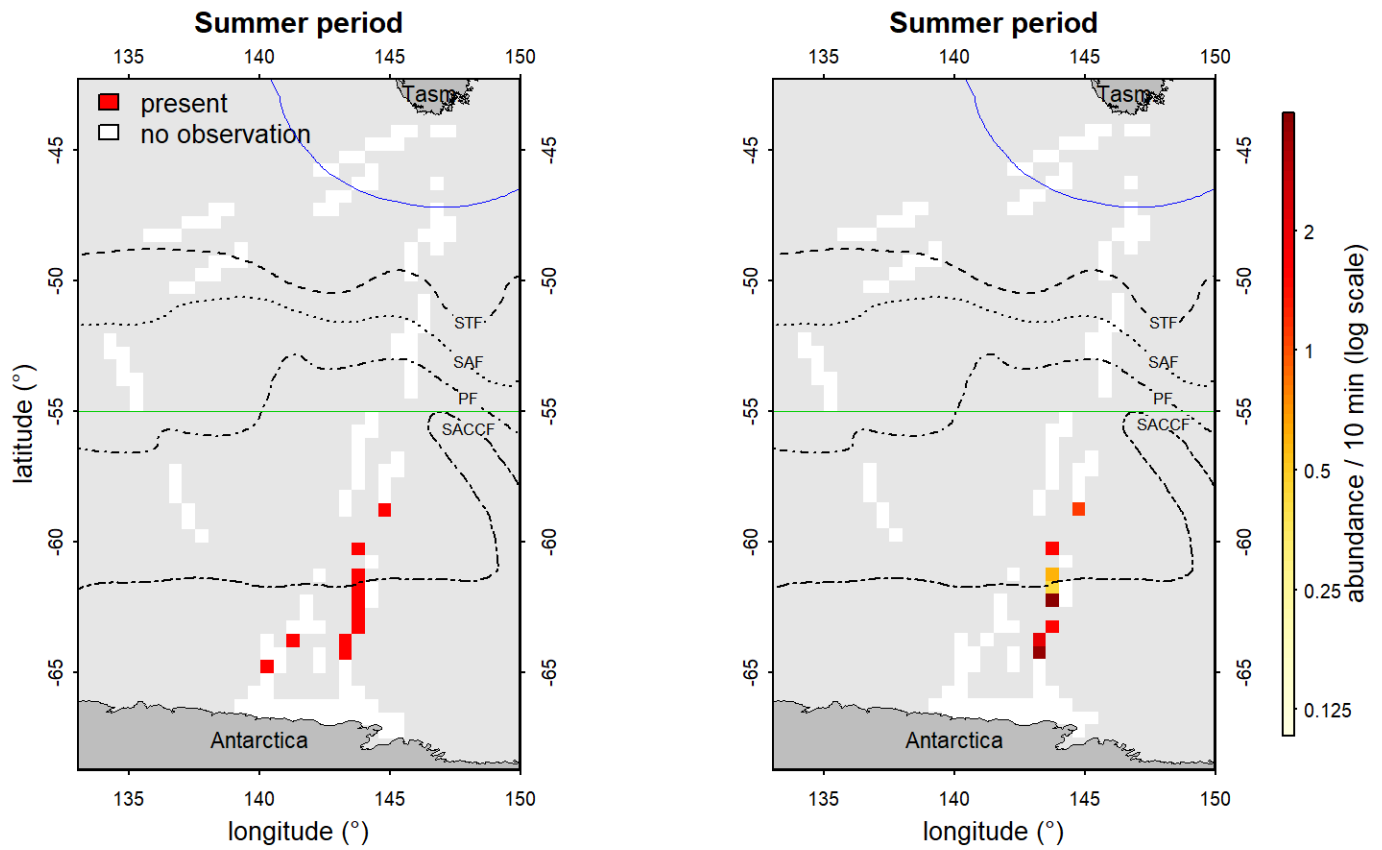


Figure 66 - Presence of Blue Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Prion sp. *Pachyptila* sp. (LC)

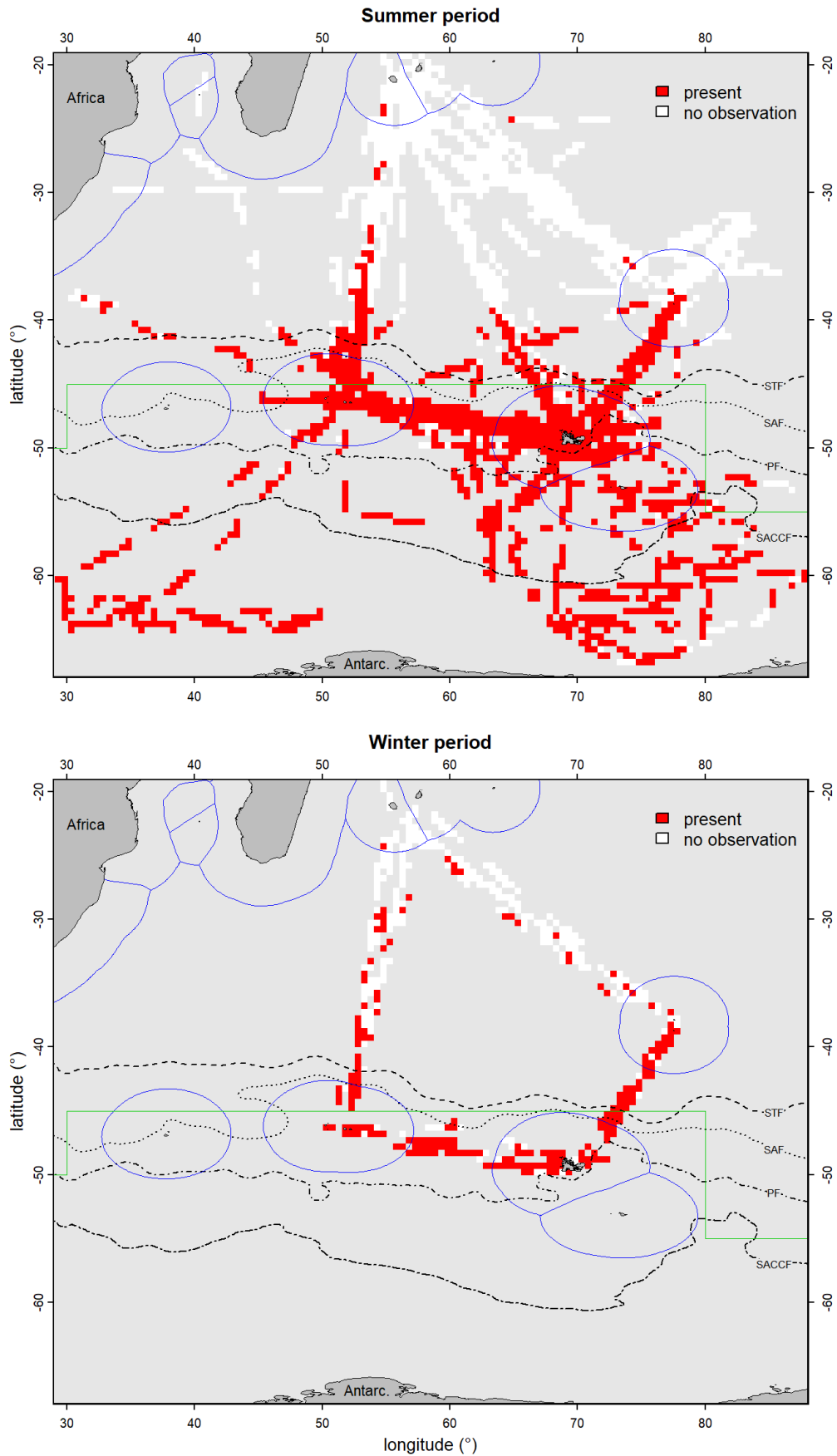


Figure 67 - Presence of *Prion* sp. in each 0.5°x0.5° square in the south-west Indian Ocean area

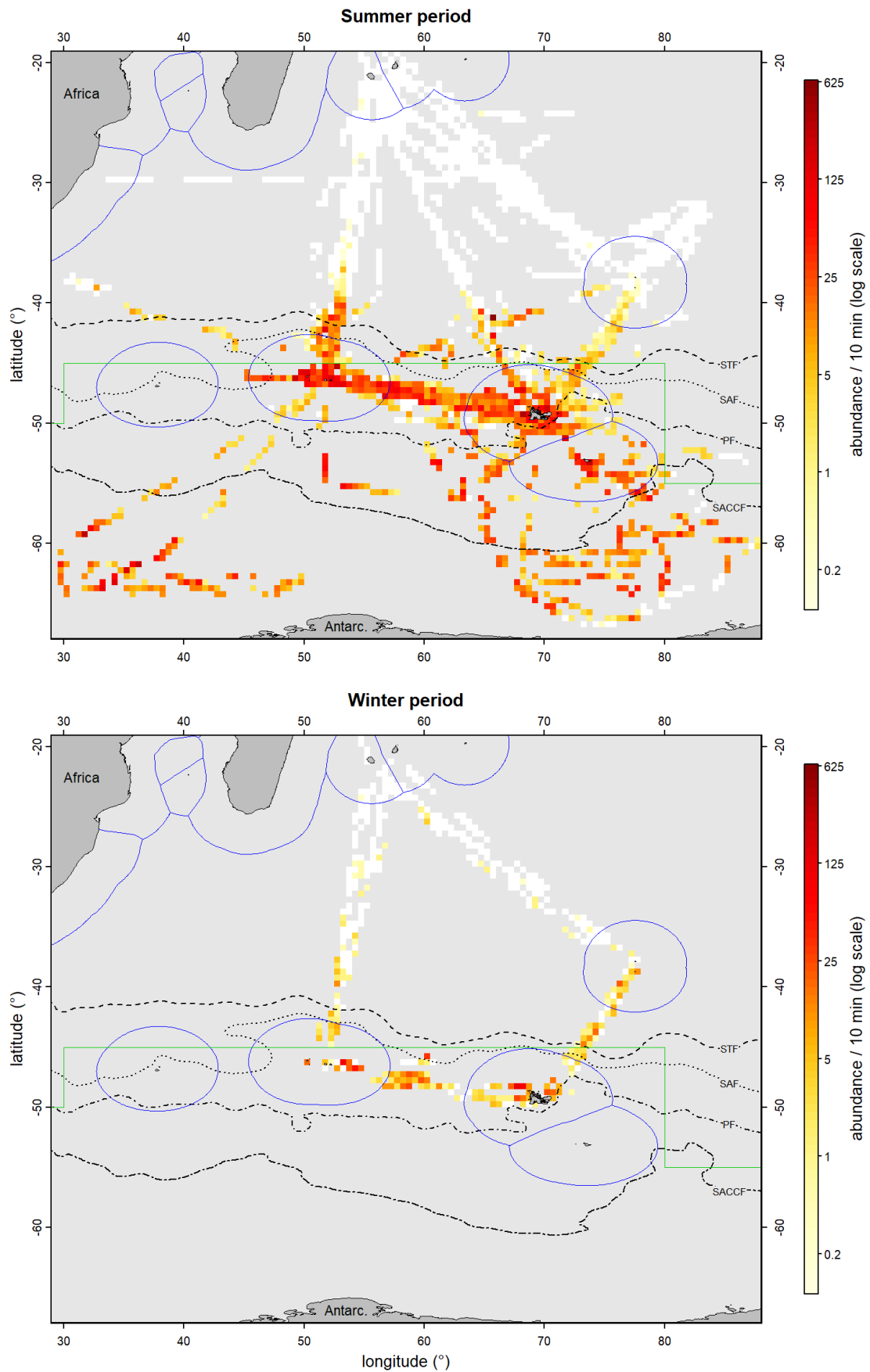


Figure 68 - Mean abundance of *Prion* sp. during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

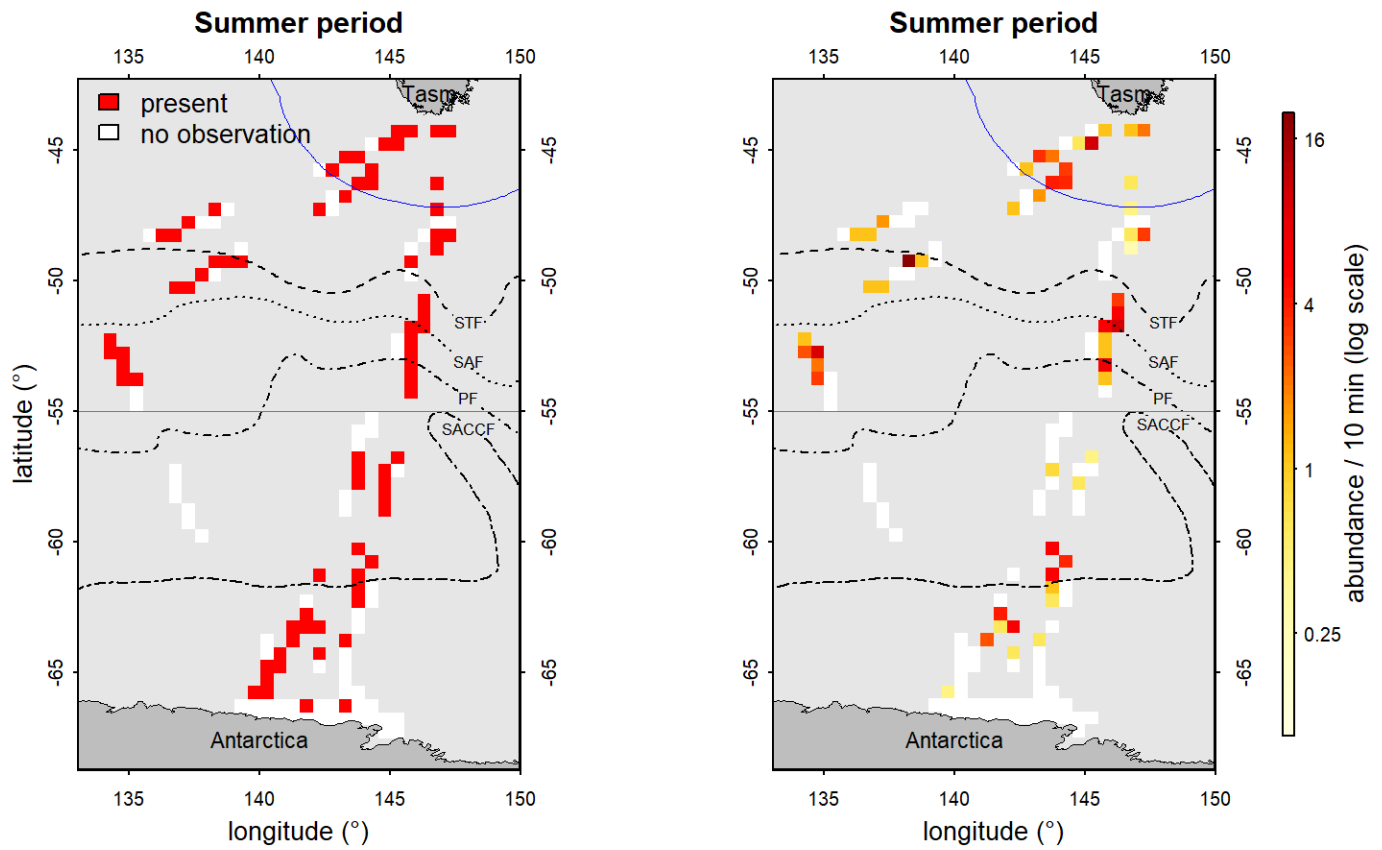


Figure 69 - Presence of *Prion* sp. and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Fairy Prion *Pachyptila turtur* (LC)

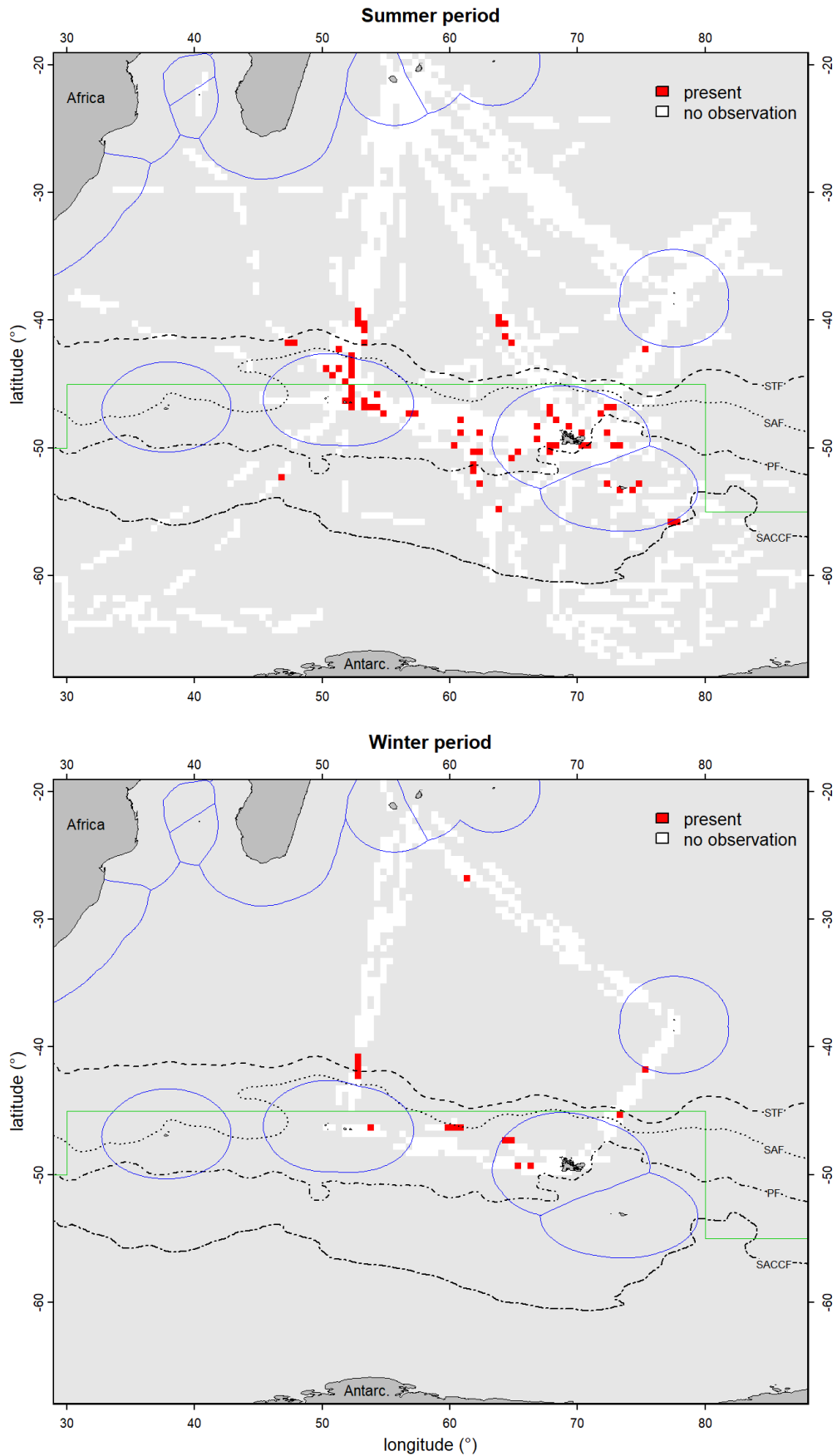


Figure 70 - Presence of Fairy Prion in each 0.5°x0.5° square in the south-west Indian Ocean area

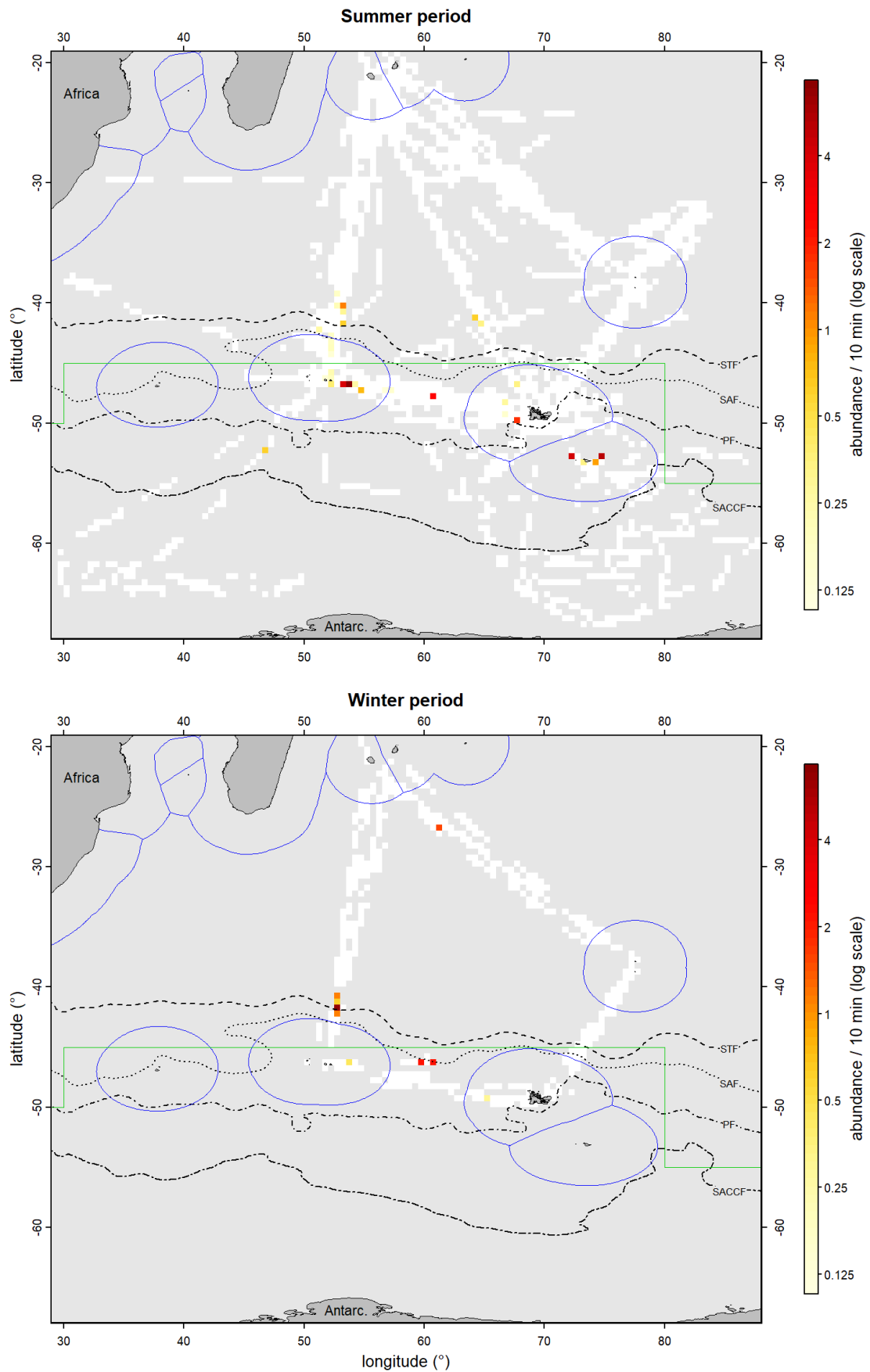


Figure 71 - Mean abundance of Fairy Prion during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

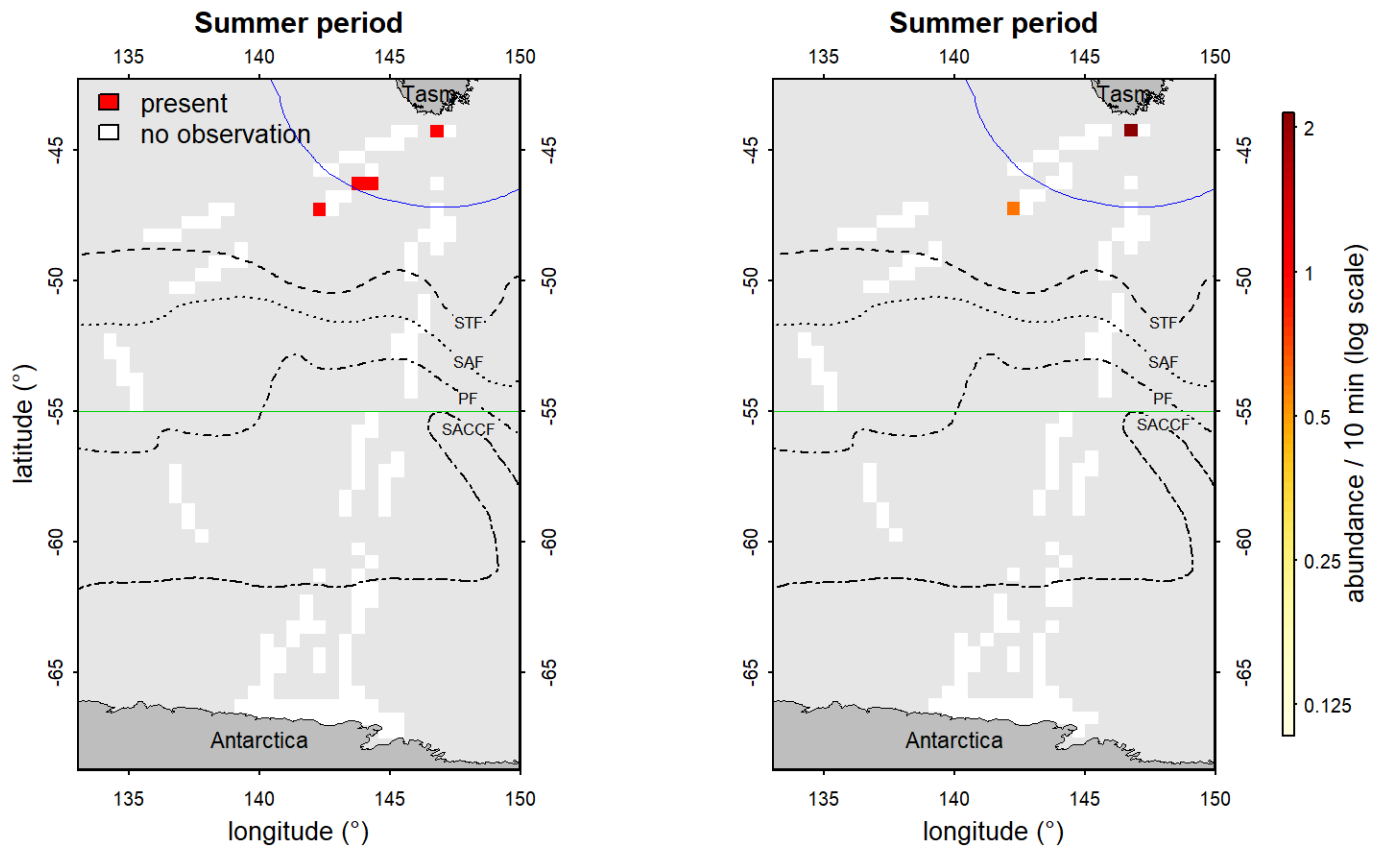


Figure 72 - Presence of Fairy Prion and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Bulweria sp. / Pseudobulweria sp. *Bulweria bulwerii* / *B. fallax* / *Pseudobulweria aterrima* (LC/NT/CR)

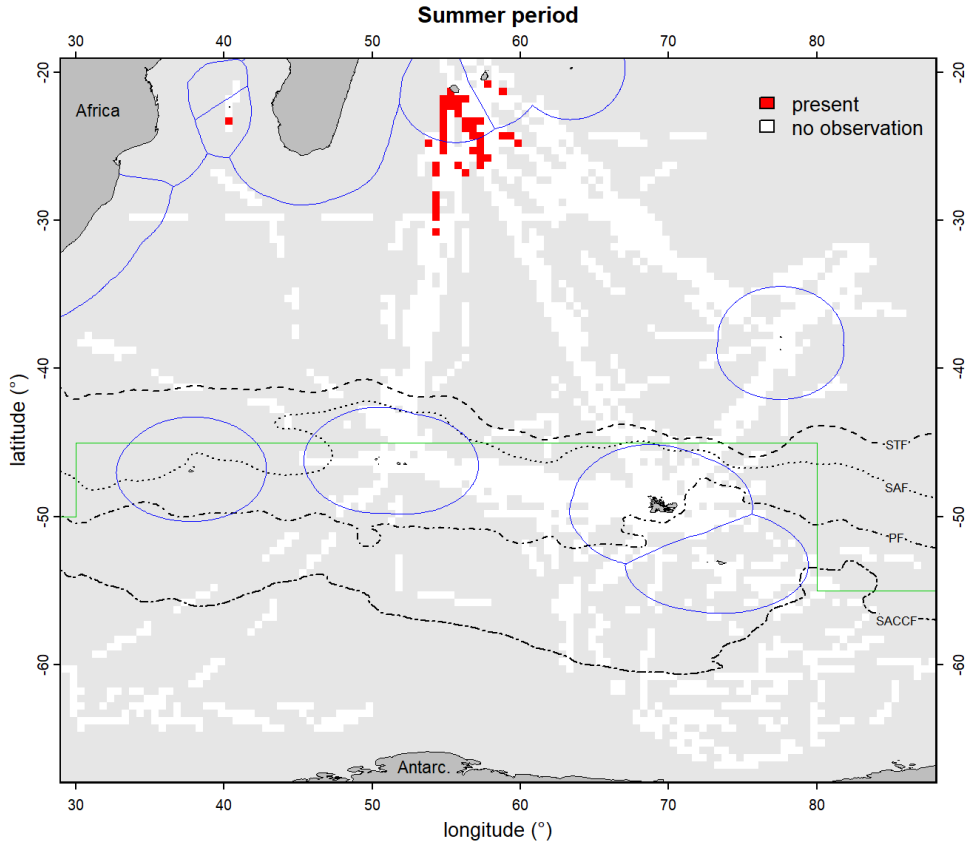


Figure 73 - Presence of *Bulweria* / *Pseudobulweria* sp. in each 0.5°x0.5° square in the south-west Indian Ocean area

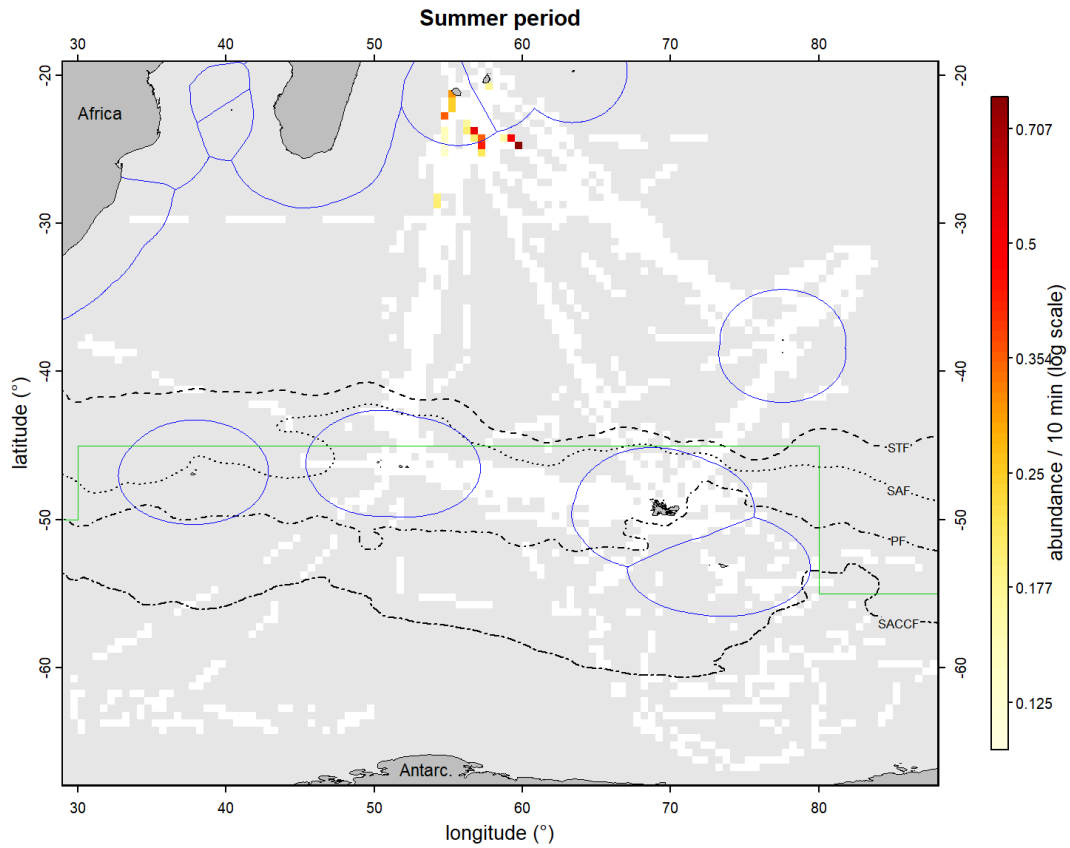


Figure 74 - Mean abundance of *Bulweria* / *Pseudobulweria* sp. during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

“cookilaria” petrel *Pterodroma nigripennis* / *P. cookii* / *P. leucoptera* (LC/VU/VU)

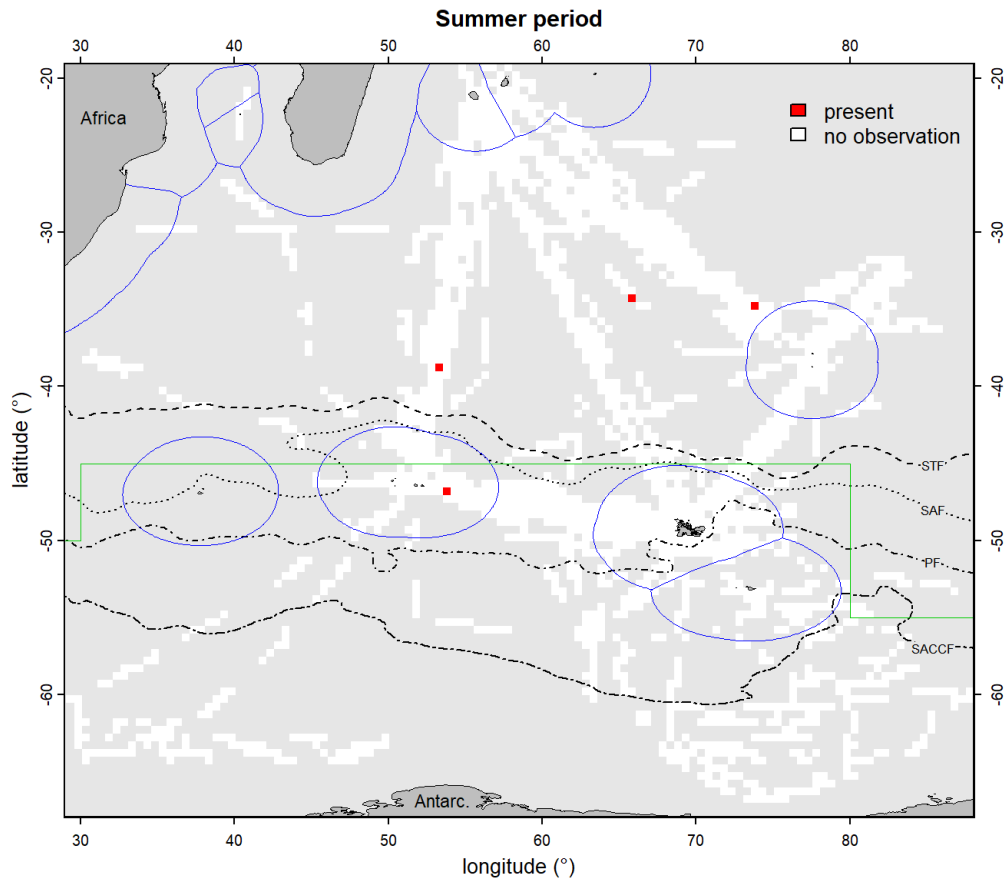


Figure 75 - Presence of “cookilaria” petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

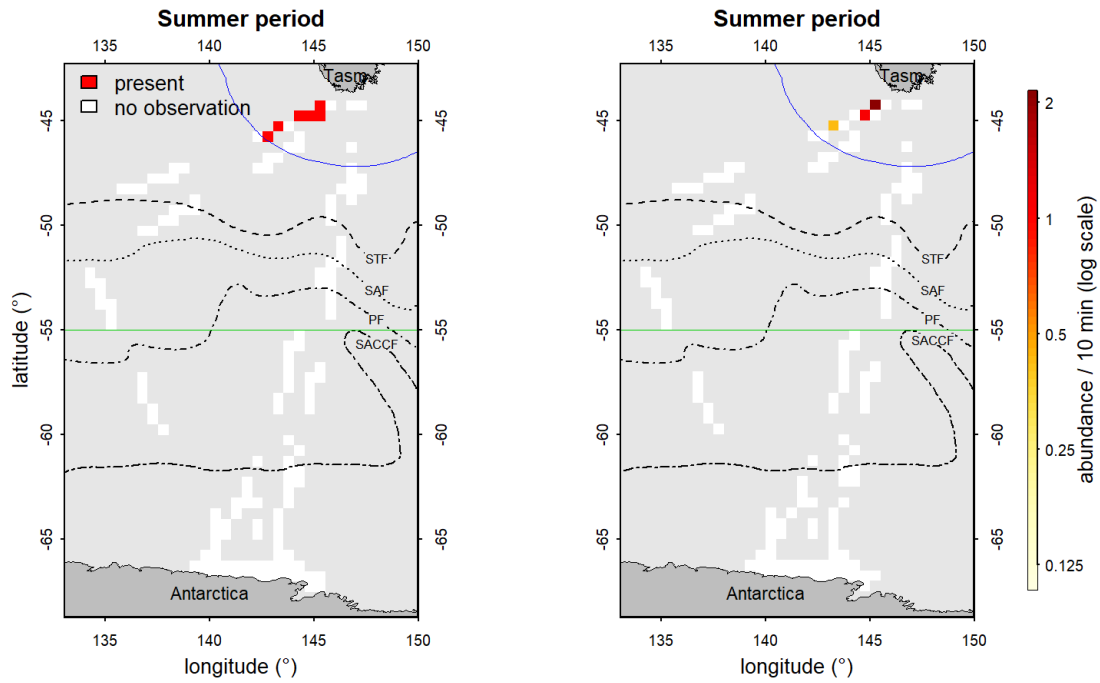


Figure 76 - Presence of "cookilaria" petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Mottled Petrel *Pterodroma inexpectata* (NT)

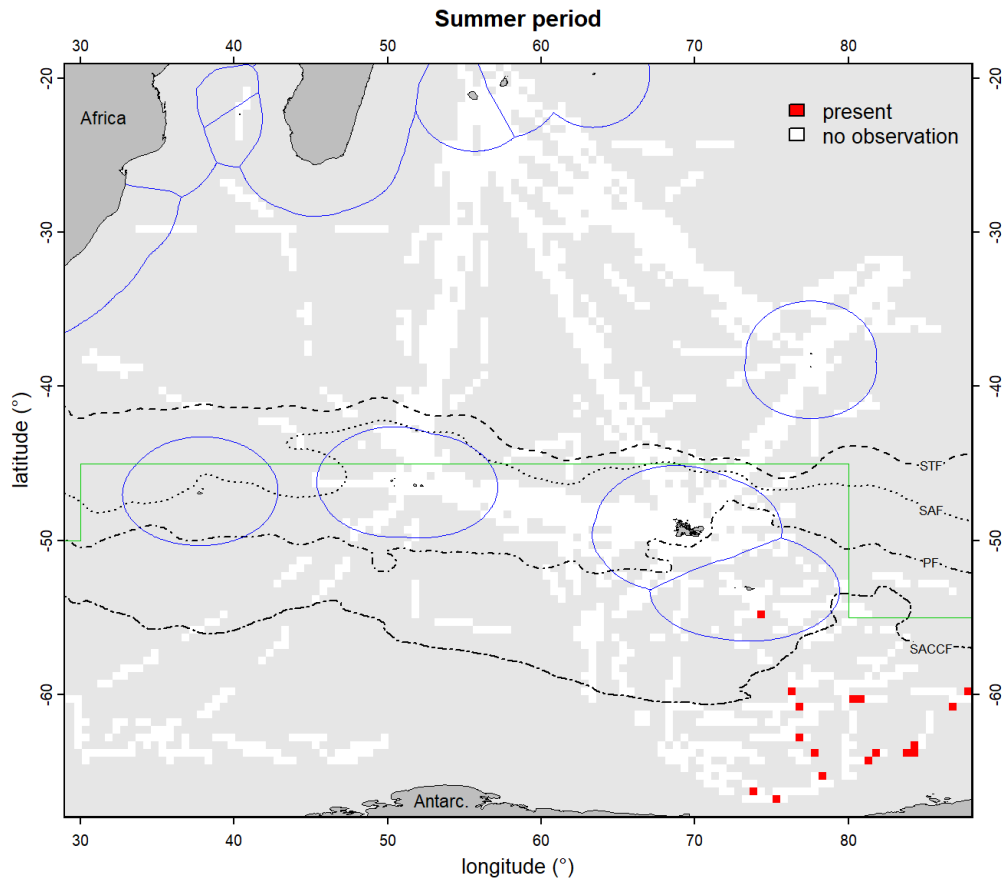


Figure 77 - Presence of Mottled Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

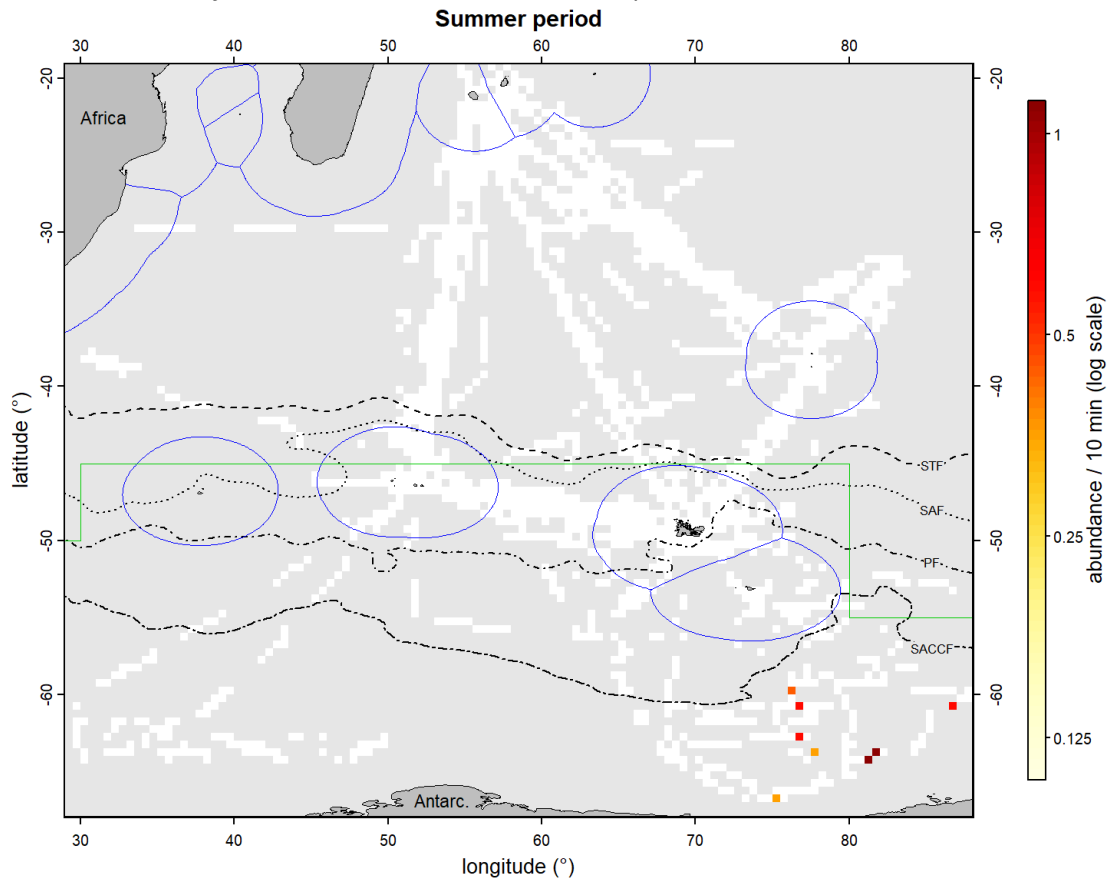


Figure 78 - Mean abundance of Mottled Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

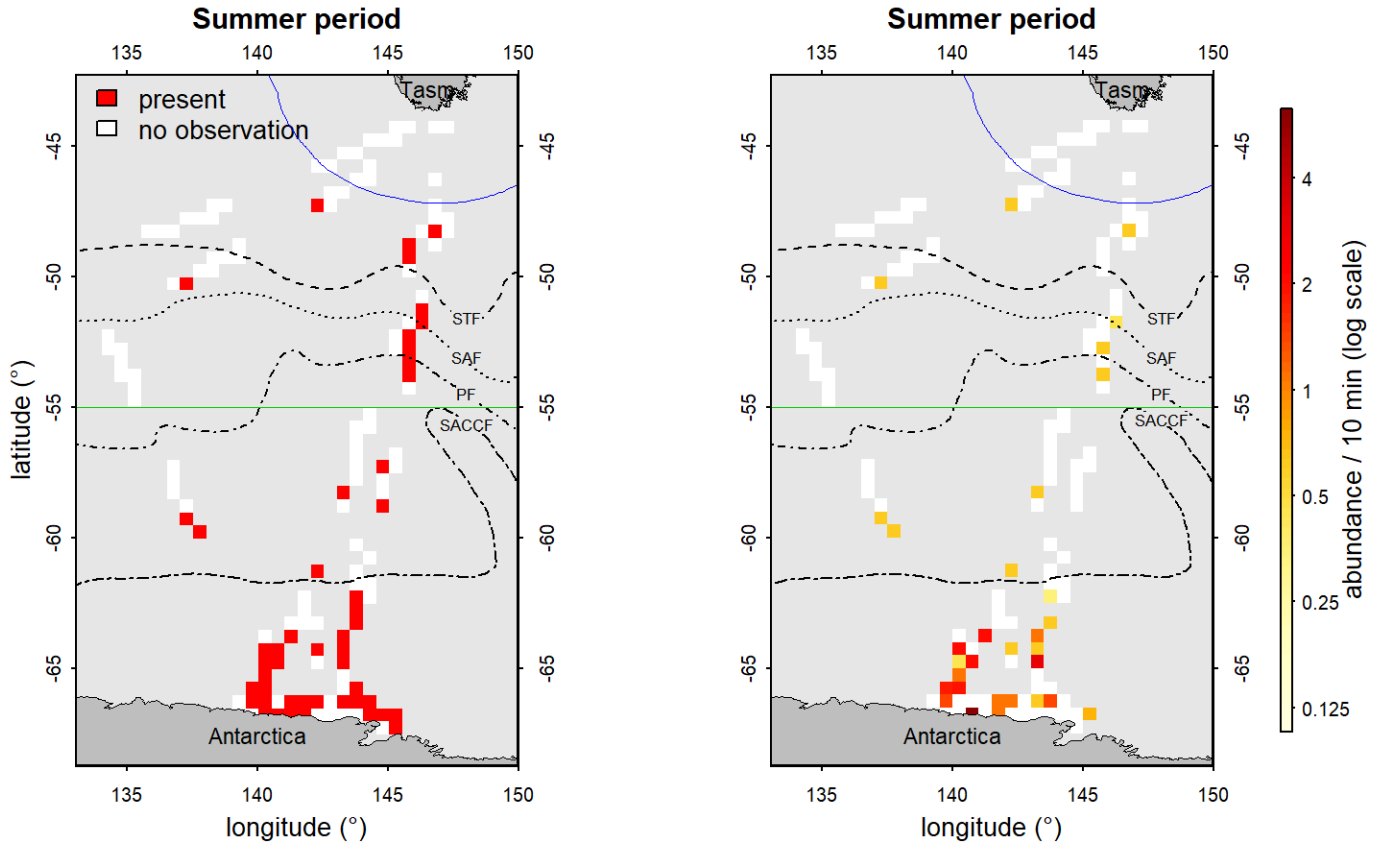


Figure 79 - Presence of Mottled Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Barau's Petrel *Pterodroma baraui* (EN)

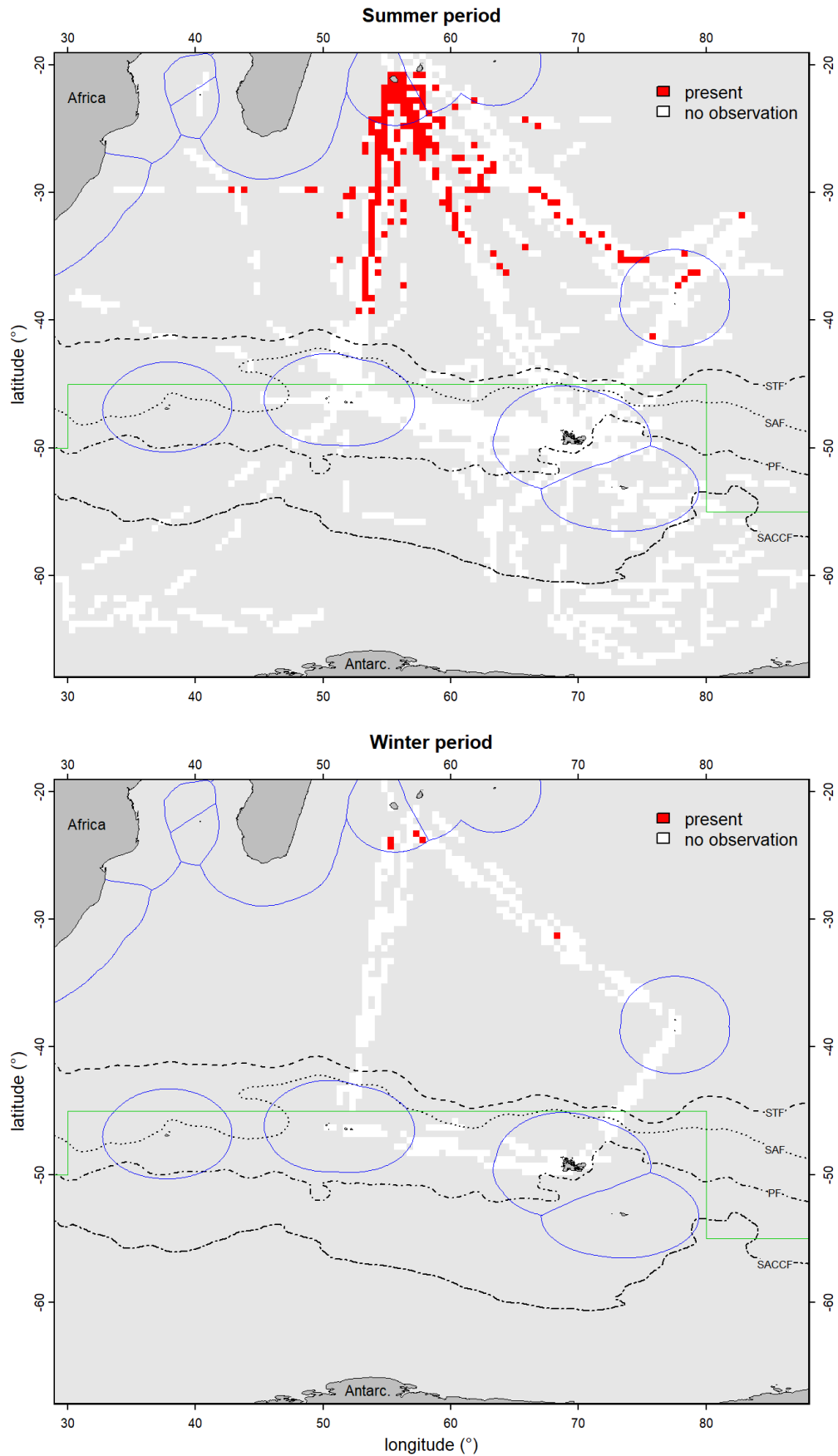


Figure 80 - Presence of Barau's Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

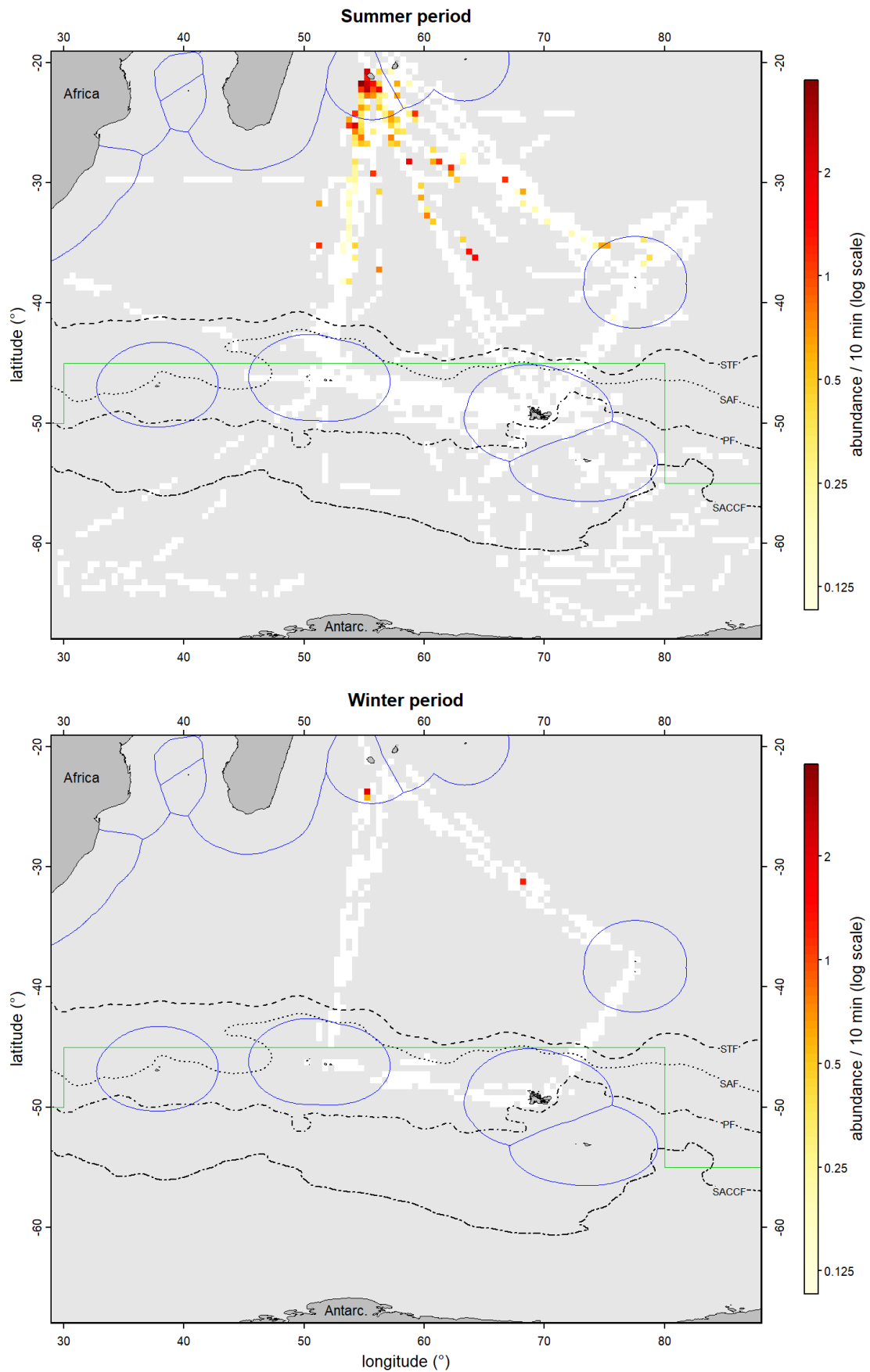


Figure 81 - Mean abundance of Barau's Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Great-winged Petrel *Pterodroma macroptera* (LC)

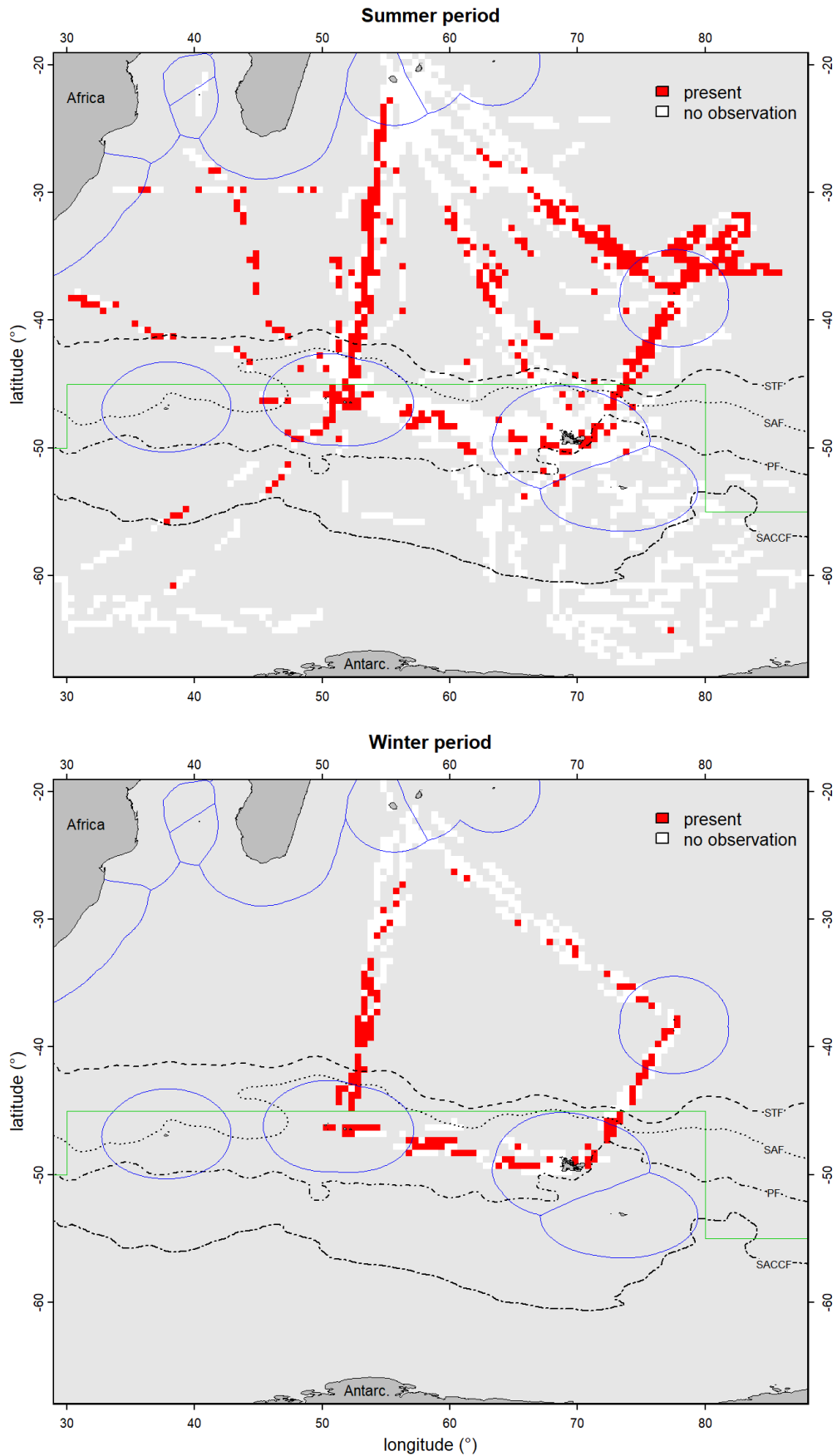


Figure 82 - Presence of Great-winged Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

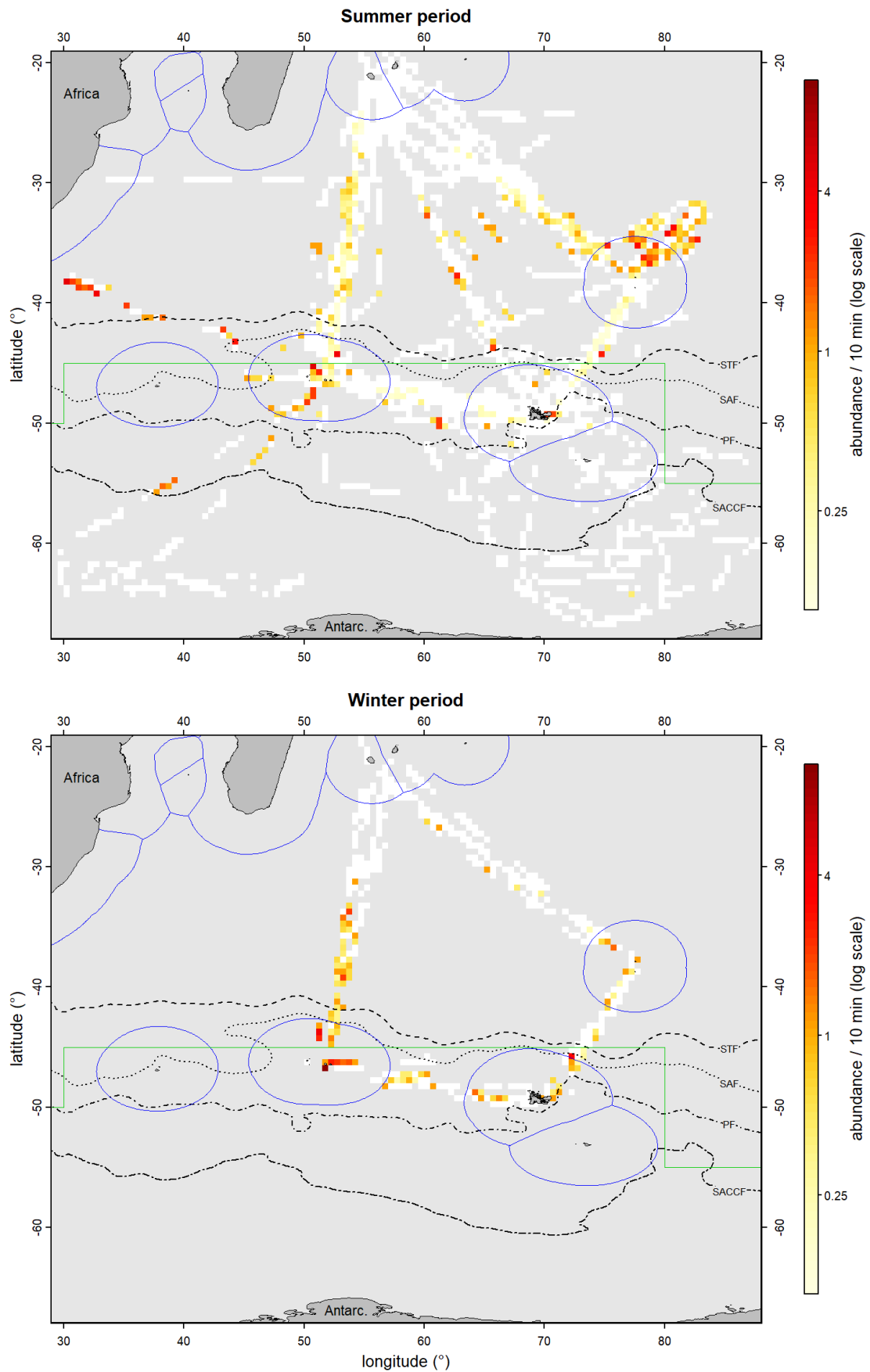


Figure 83 - Mean abundance of Great-winged Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

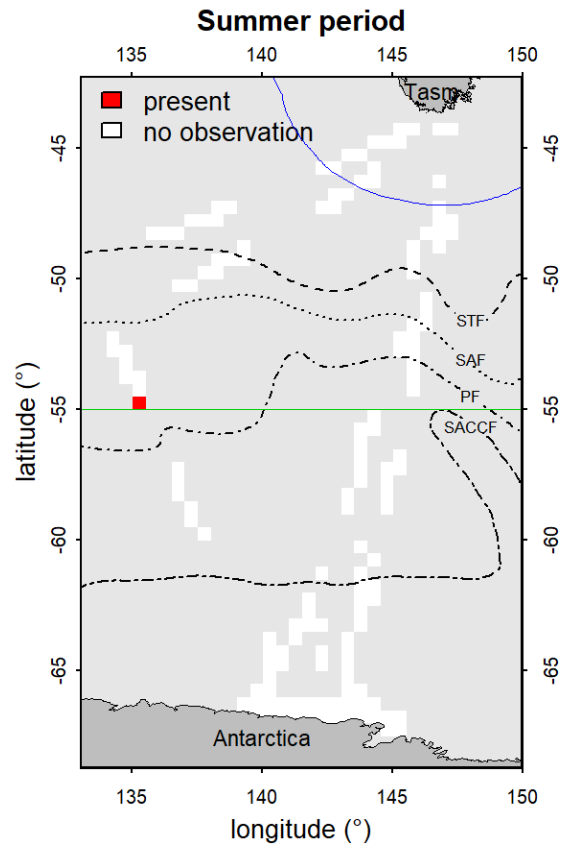


Figure 84 - Presence of Great-winged Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

White-headed Petrel *Pterodroma lessonii* (LC)

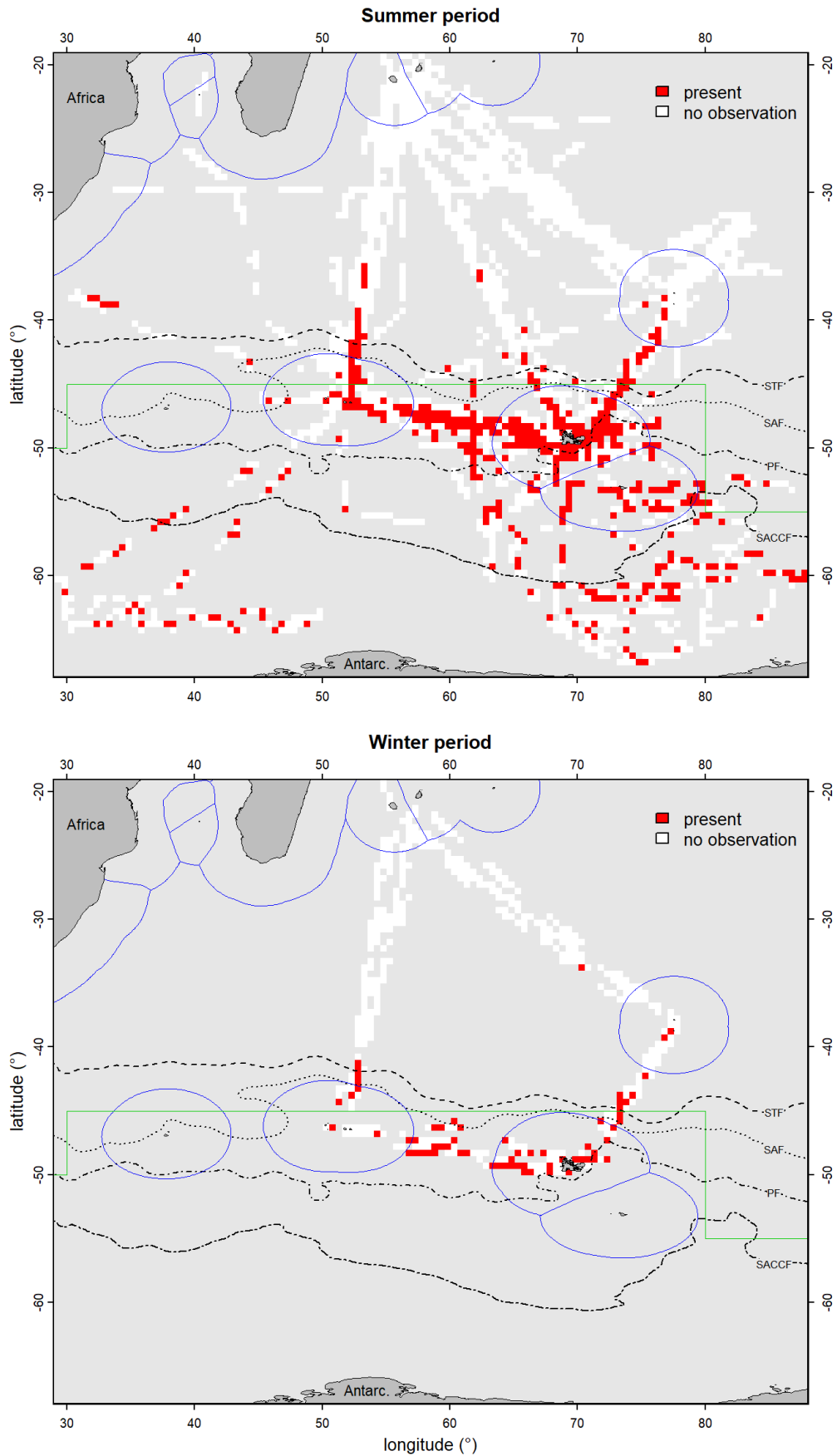


Figure 85 - Presence of White-headed Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

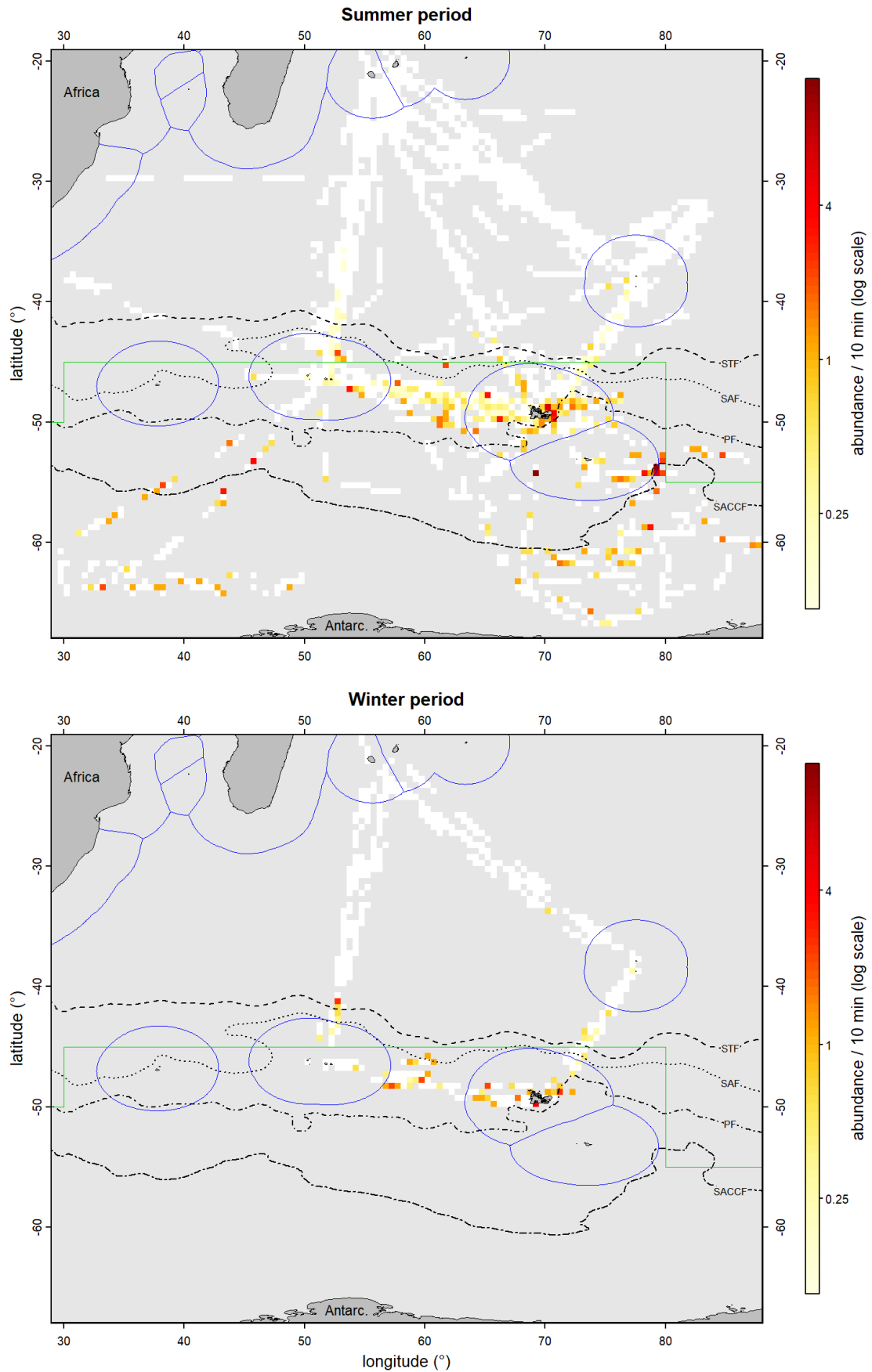


Figure 86 - Mean abundance of White-headed Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

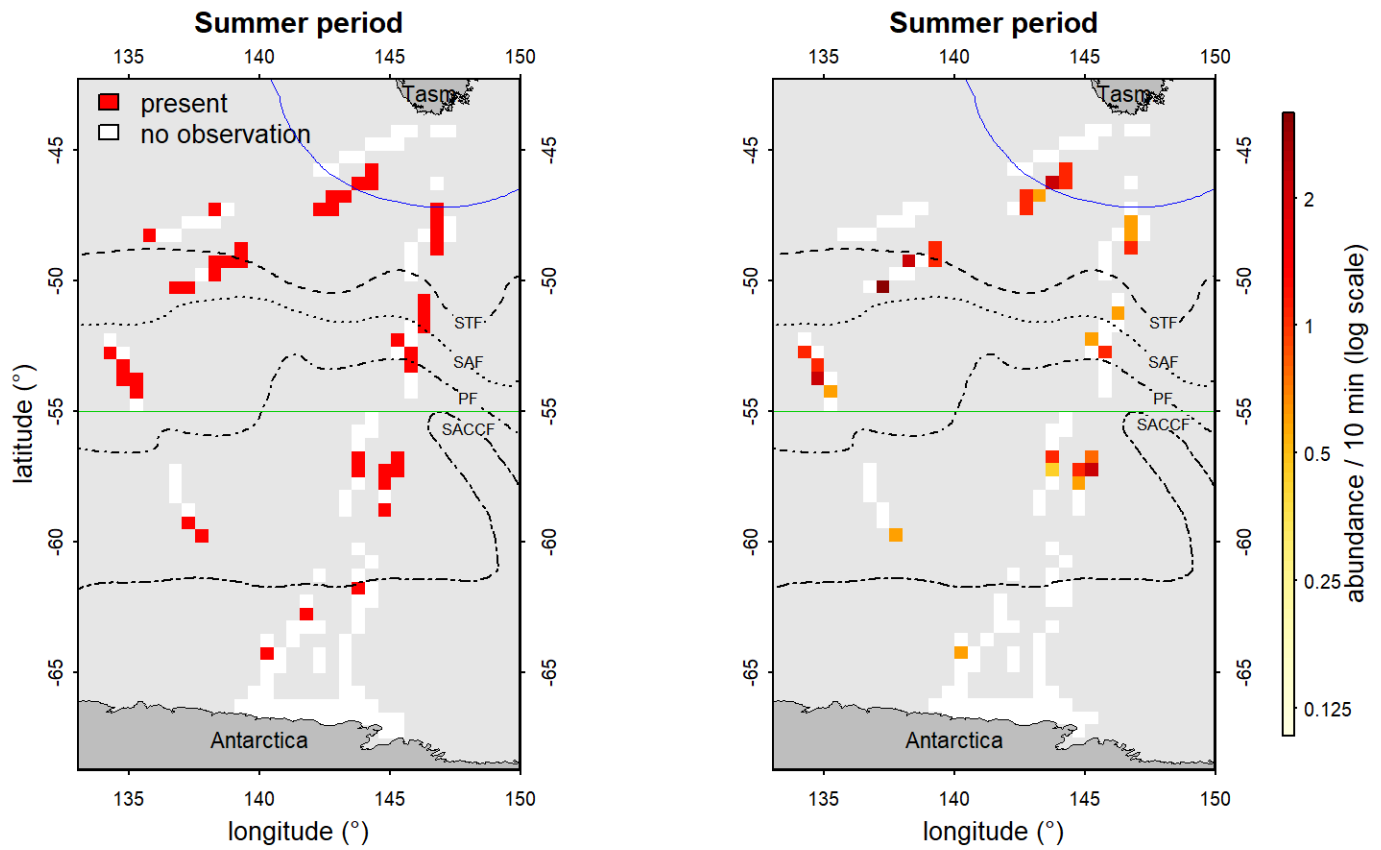


Figure 87 - Presence of White-headed Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Soft-plumaged Petrel *Pterodroma mollis* (LC)

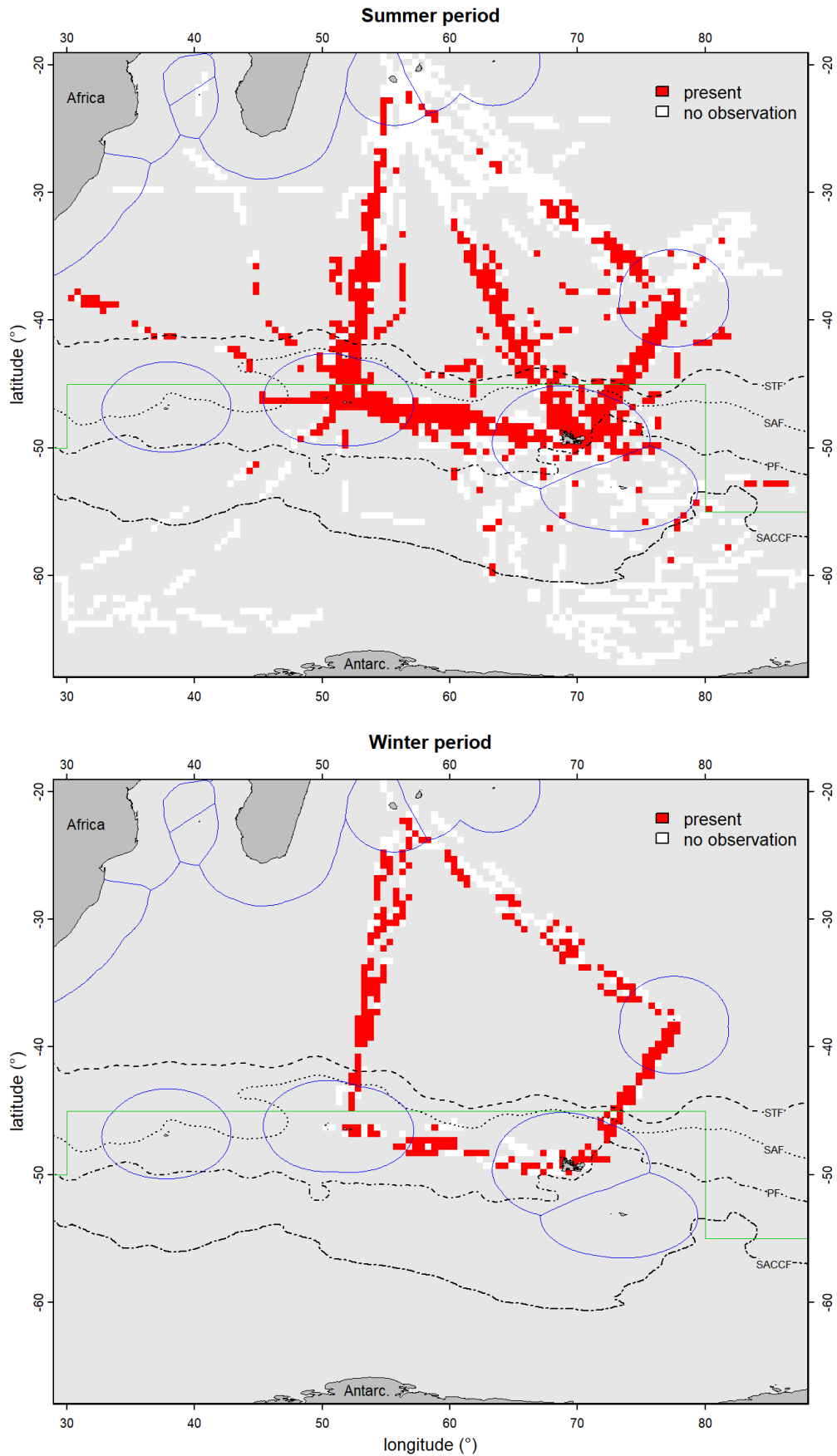


Figure 88 - Presence of Soft-plumaged Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

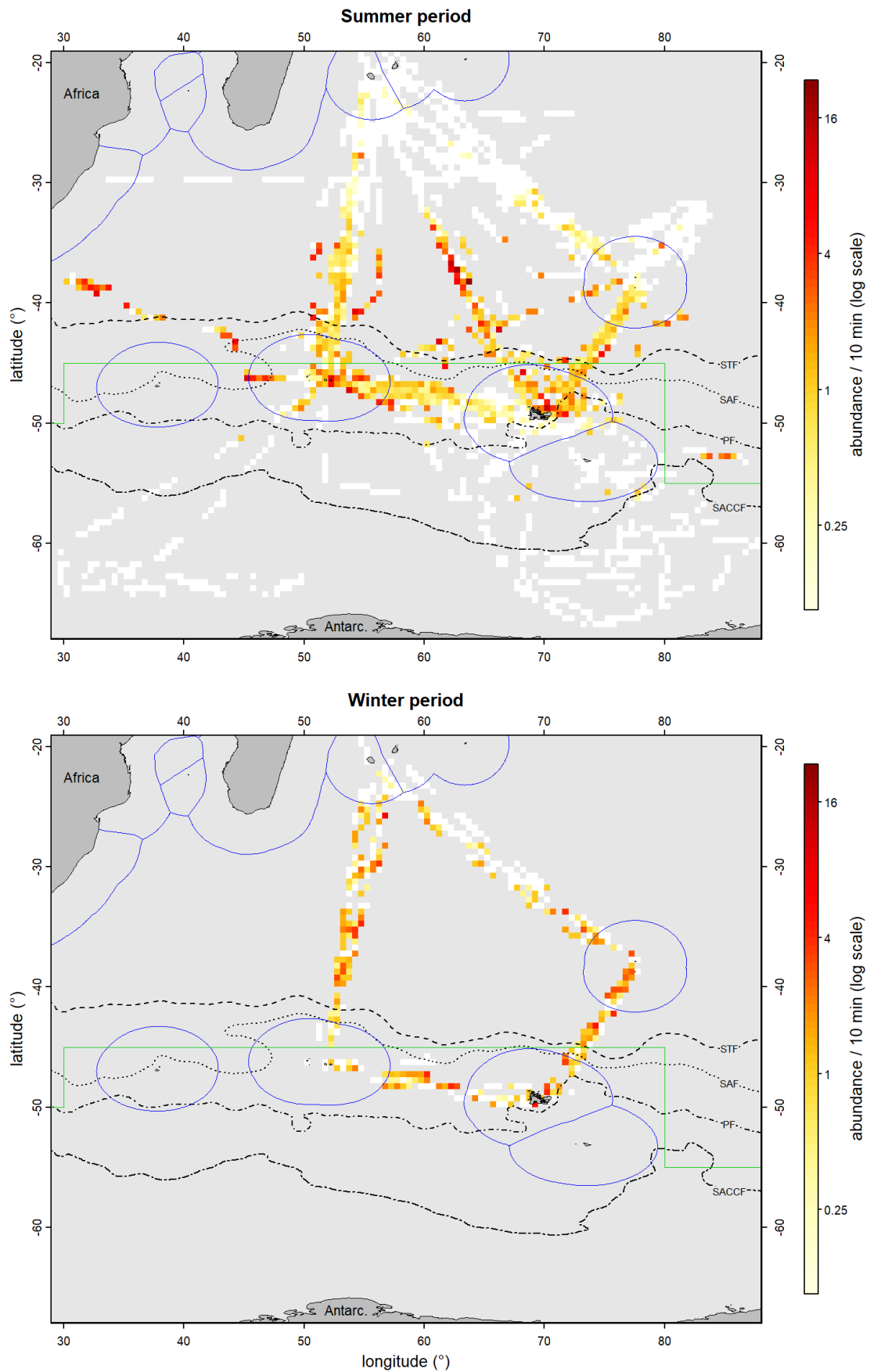


Figure 89 - Mean abundance of Soft-plumaged Petrel during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

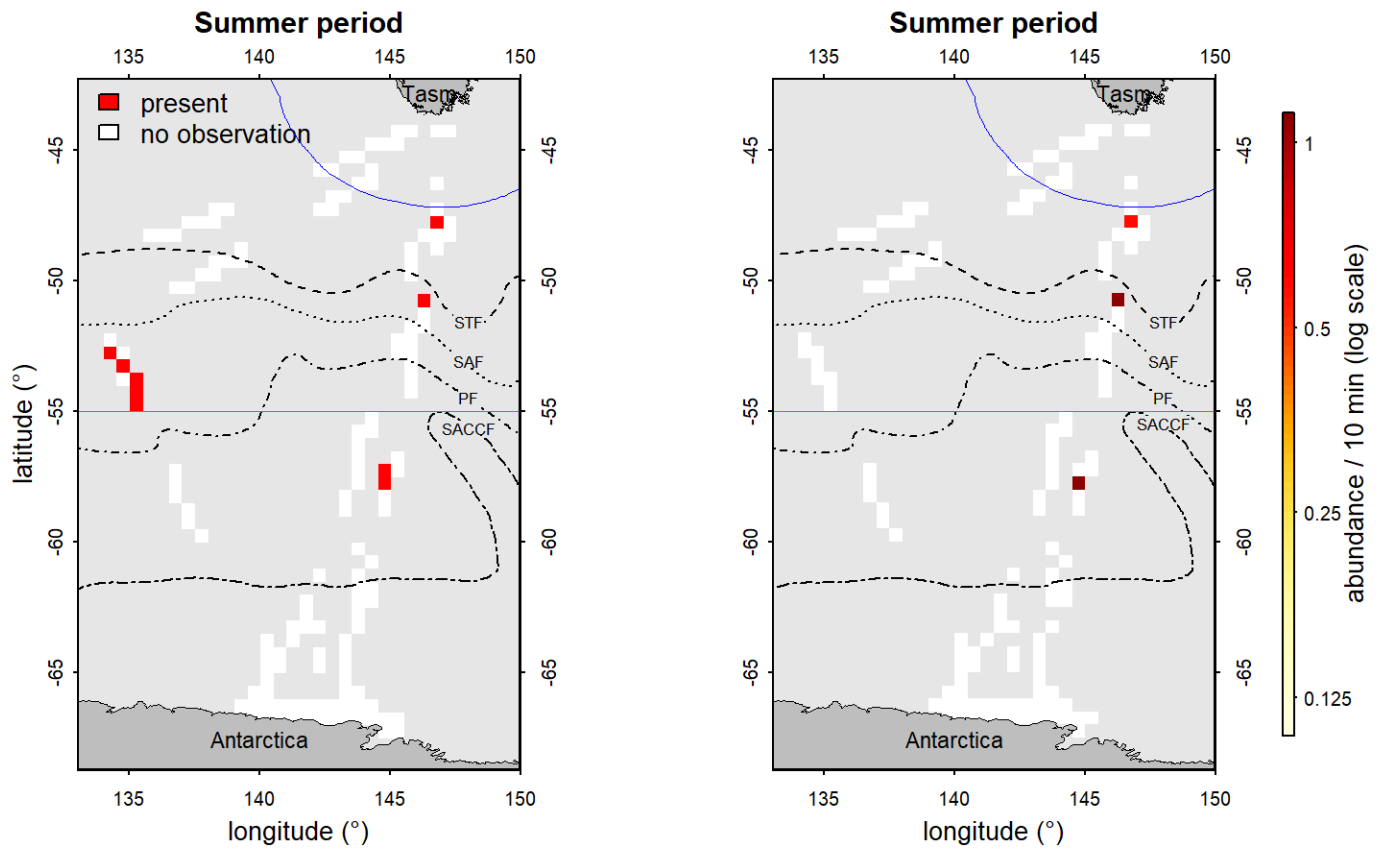


Figure 90 - Presence of Soft-plumaged Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Other large *Pterodroma cervicalis* / *P. incerta* / *P. arminjoniana* / *P. externa*
(VU/EN/VU/VU)

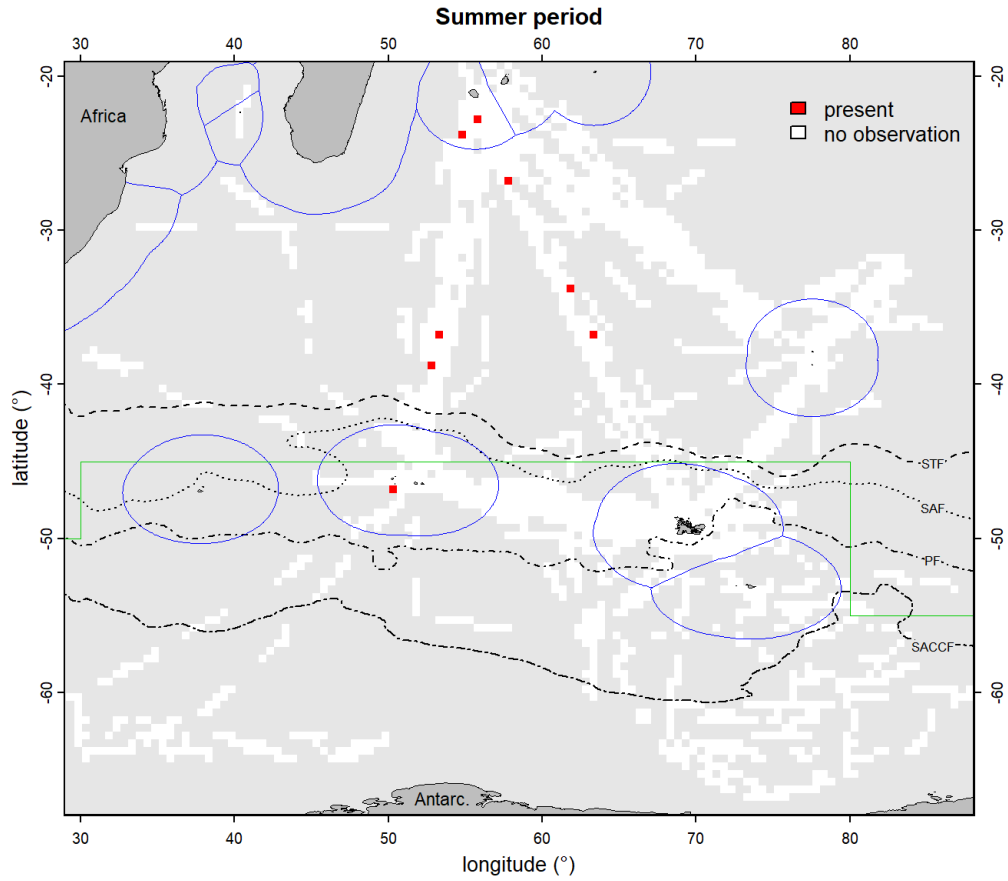


Figure 91 - Presence of other large *Pterodroma* in each 0.5°x0.5° square in the south-west Indian Ocean area

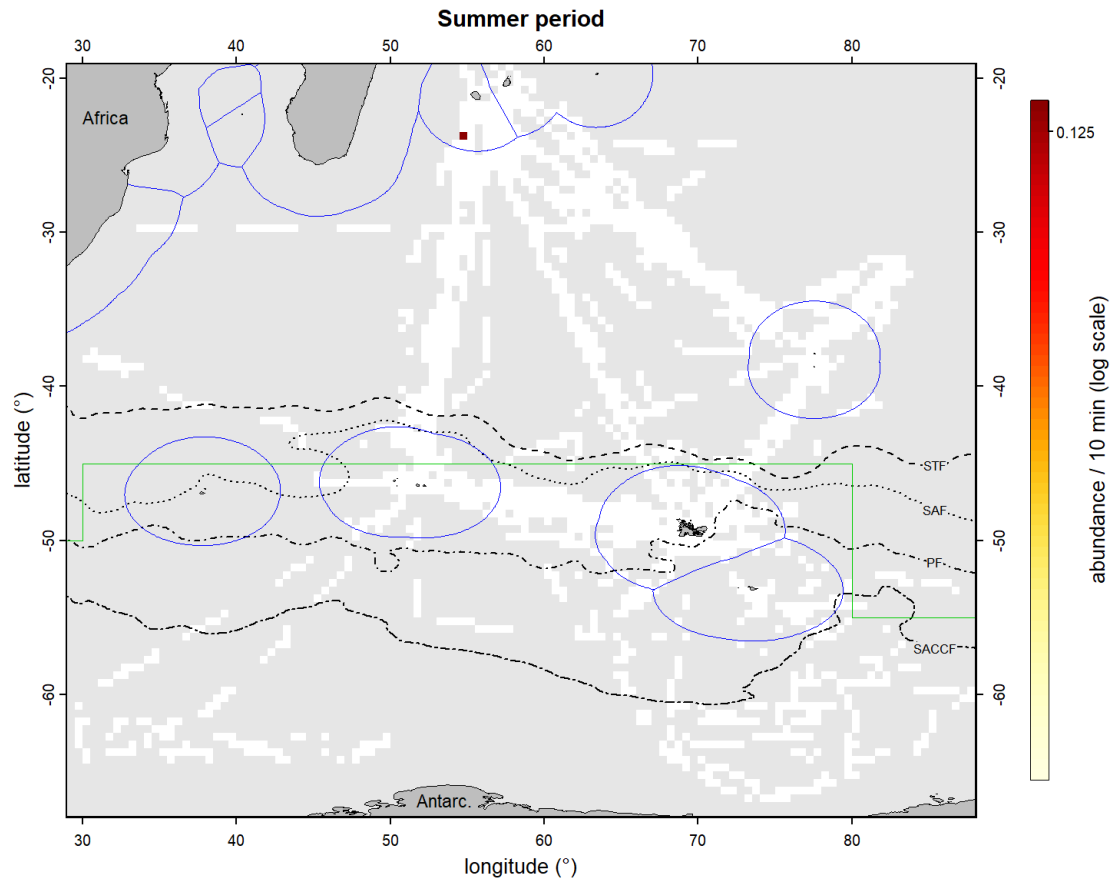


Figure 92 - Mean abundance of other large *Pterodroma* during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

White-chinned Petrel *Procellaria aequinoctialis* (VU)

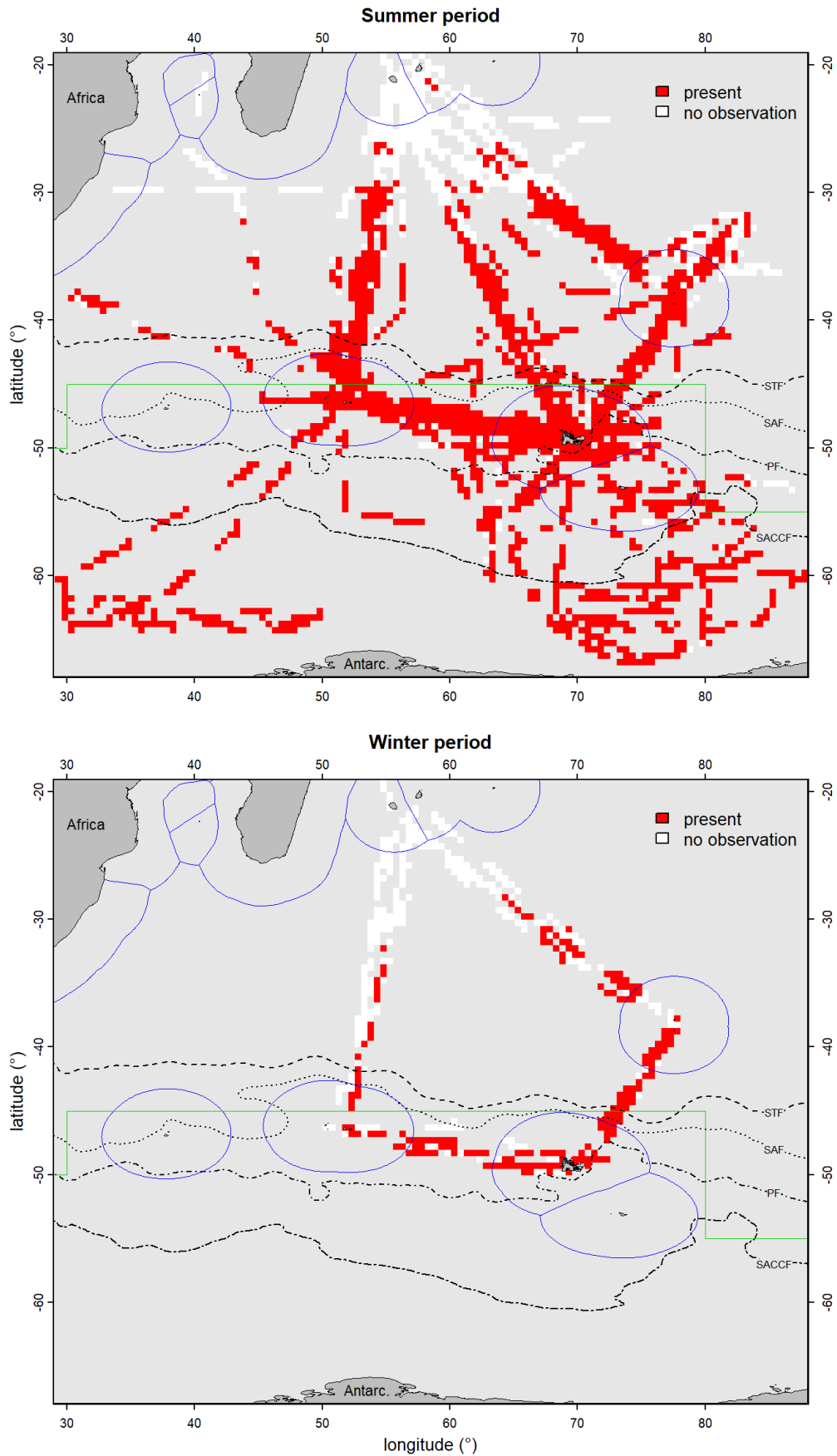


Figure 93 - Presence of White-chinned Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

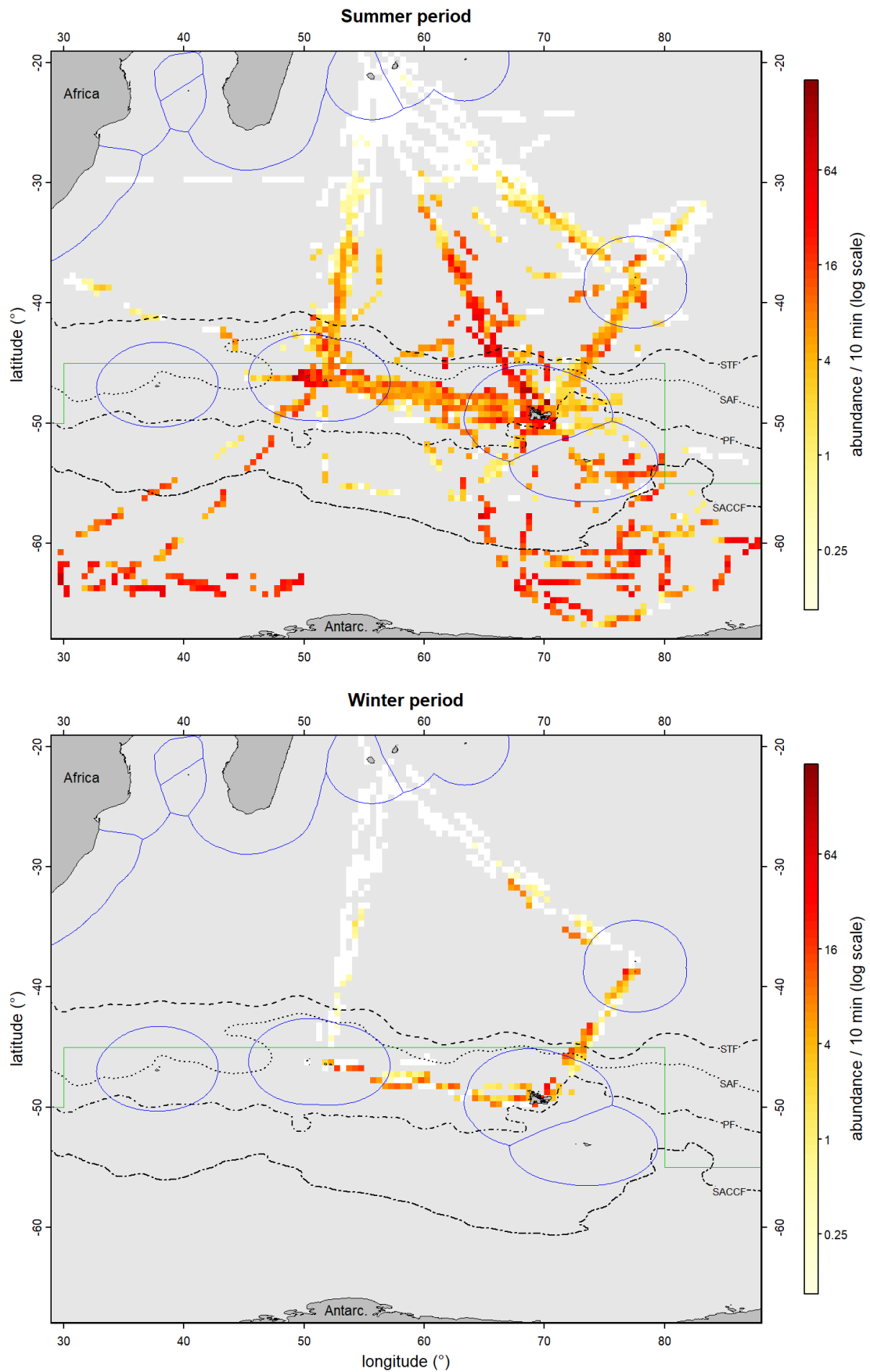


Figure 94 - Mean abundance of White-chinned Petrel during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

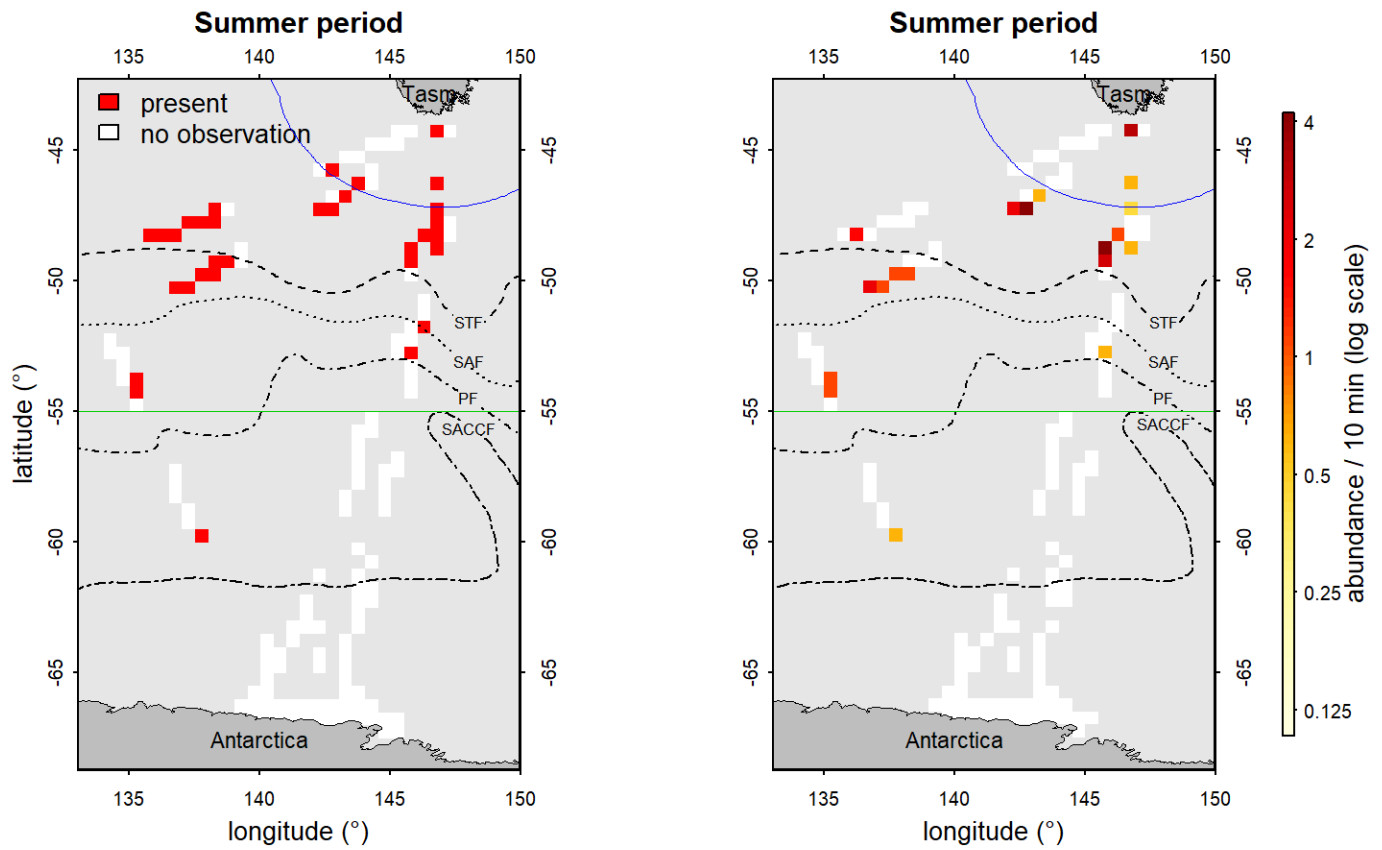


Figure 95 - Presence of White-chinned Petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Grey Petrel *Procellaria cinerea* (NT)

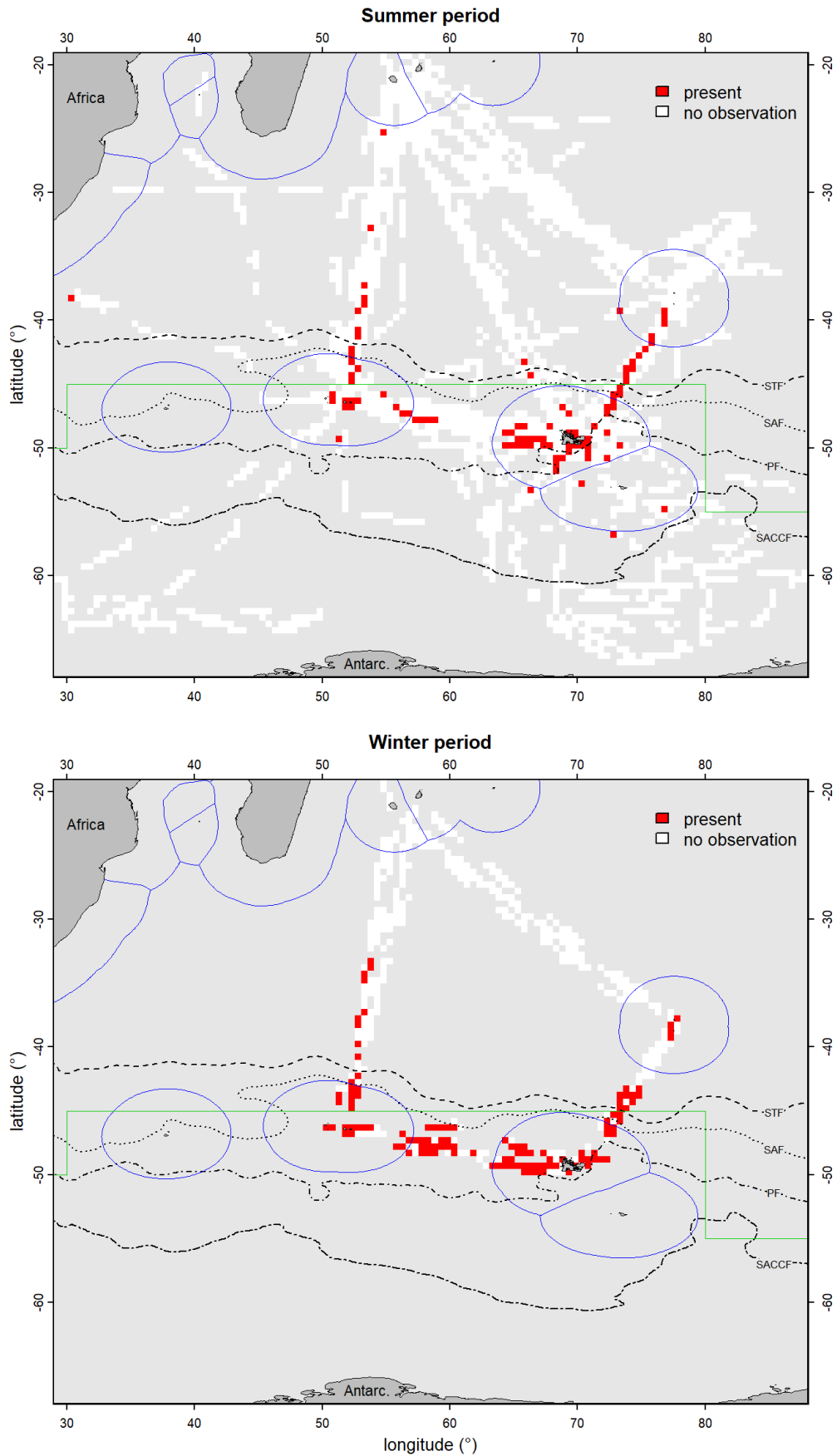


Figure 96 - Presence of Grey Petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

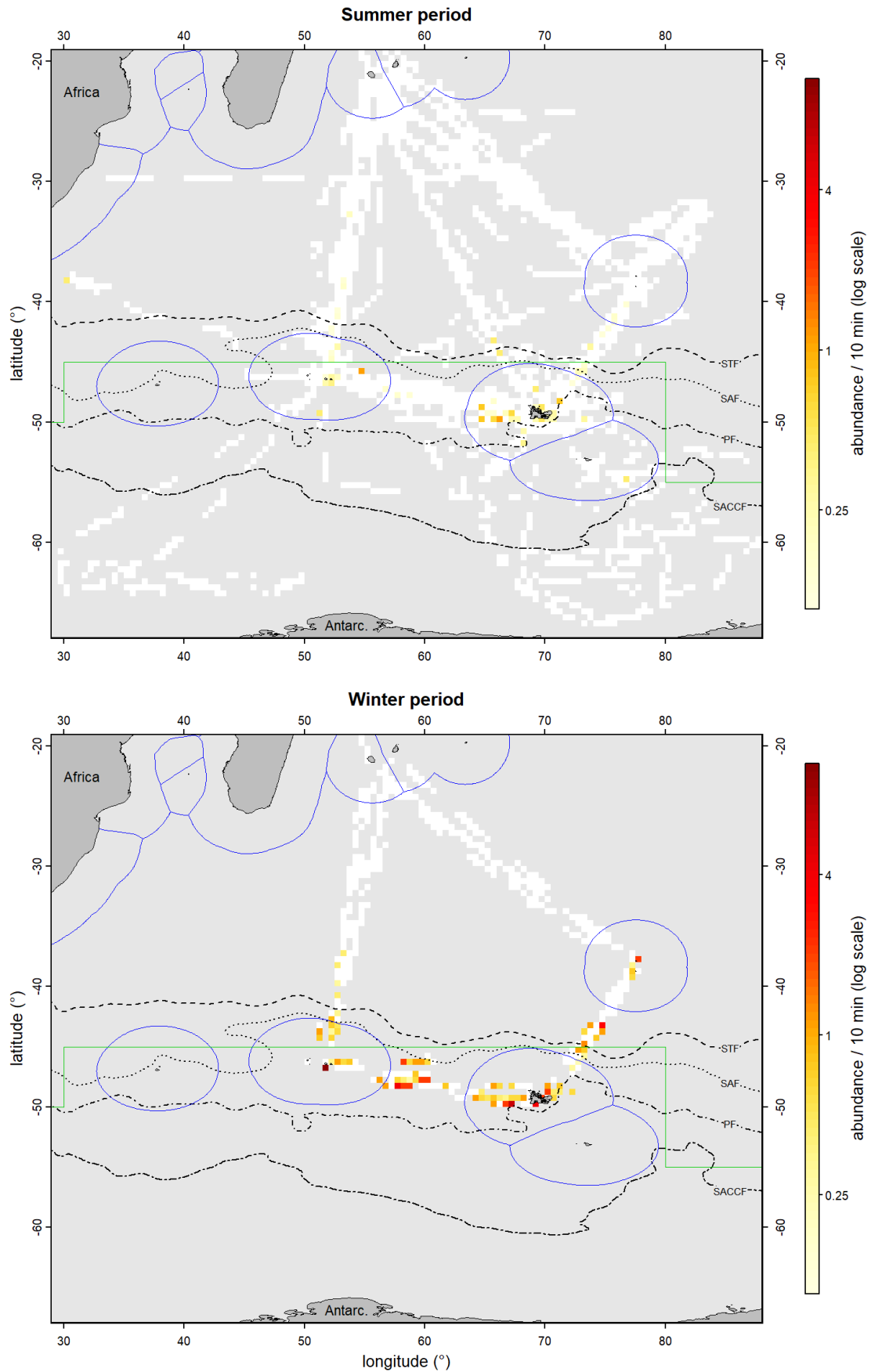


Figure 97 - Mean abundance of Grey Petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Cory's Shearwater *Calonectris diomedea* (LC)

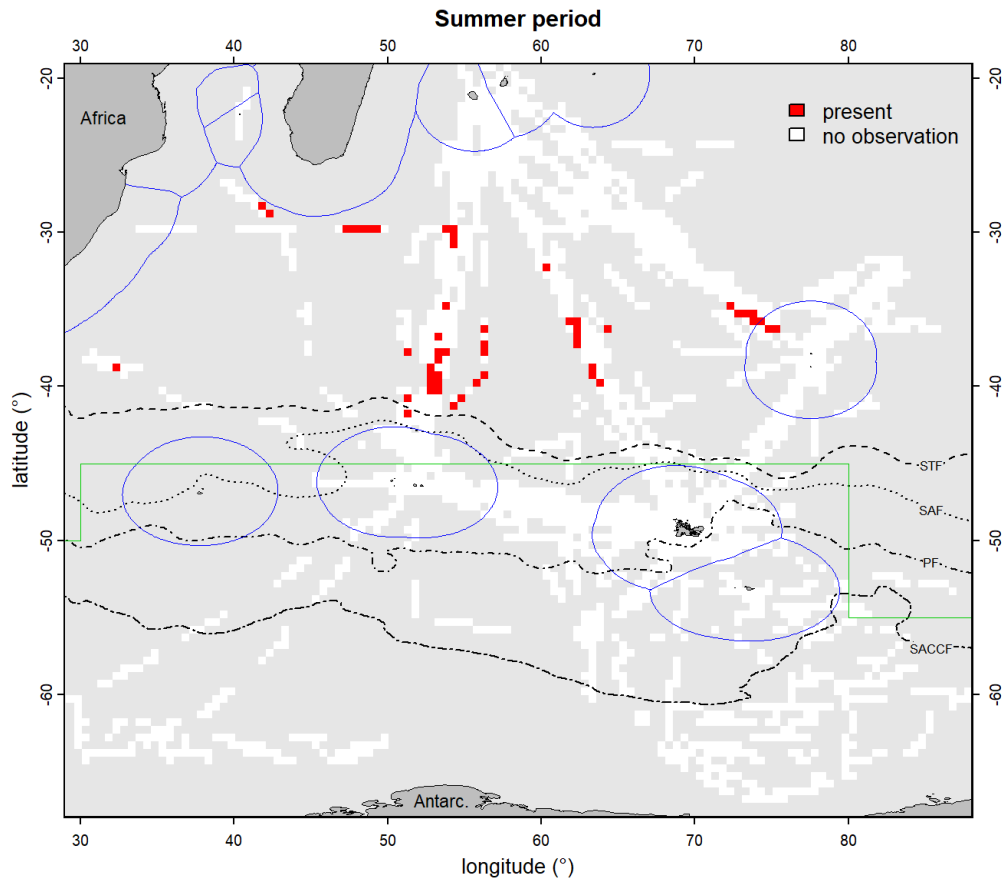


Figure 98 - Presence of Cory's Shearwater in each 0.5°x0.5° square in the south-west Indian Ocean area

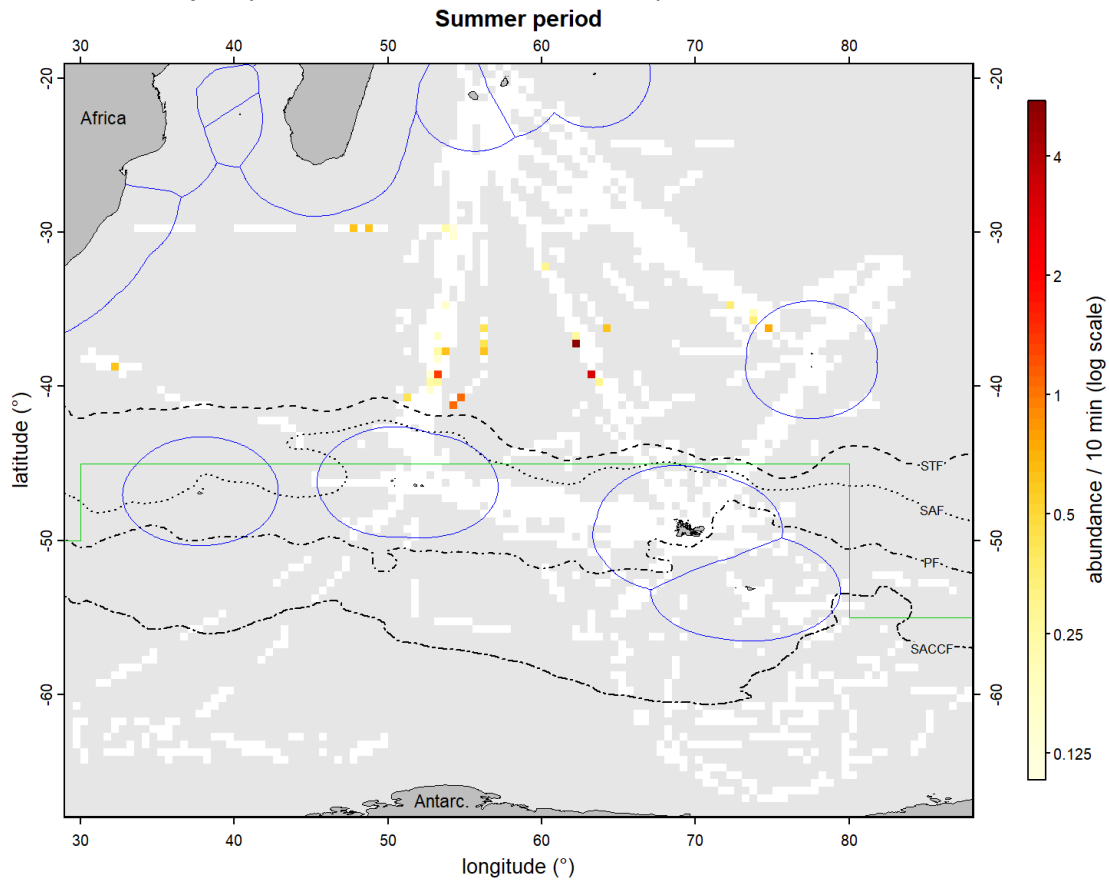


Figure 99 - Mean abundance of Cory's Shearwater during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Wedge-tailed Shearwater / Flesh-footed Shearwater *Ardenna pacifica* / *A. carneipes*
(LC/NT)

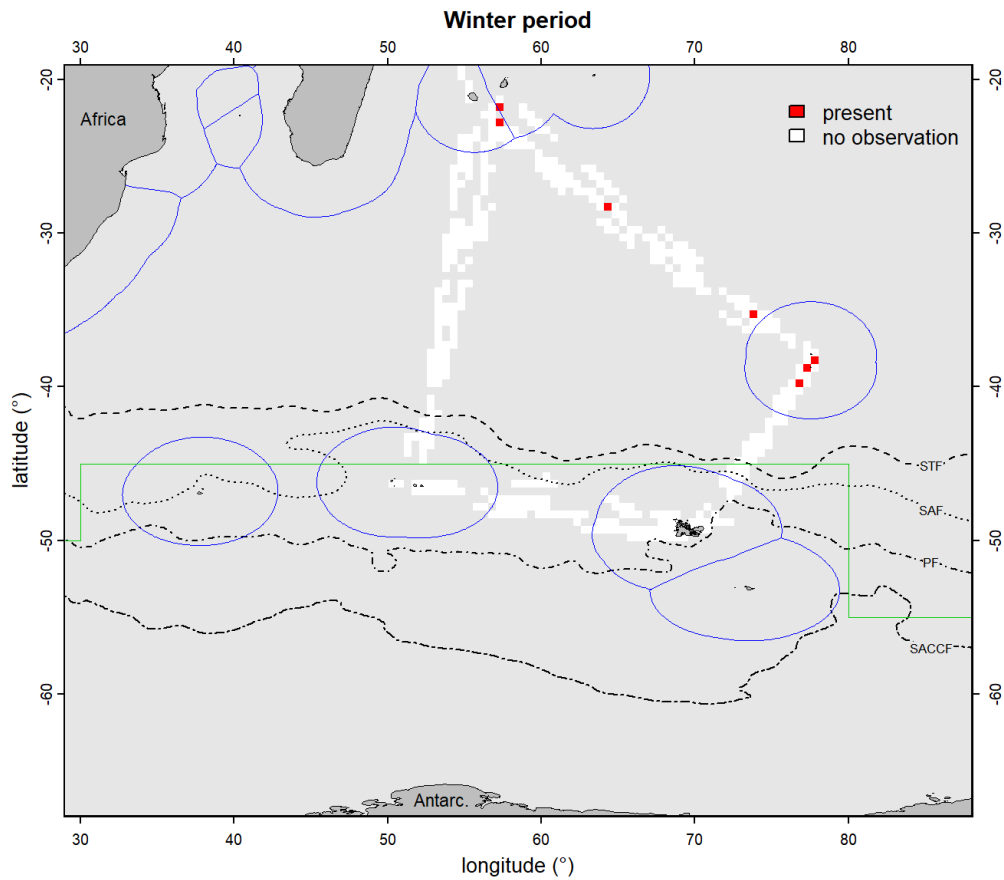
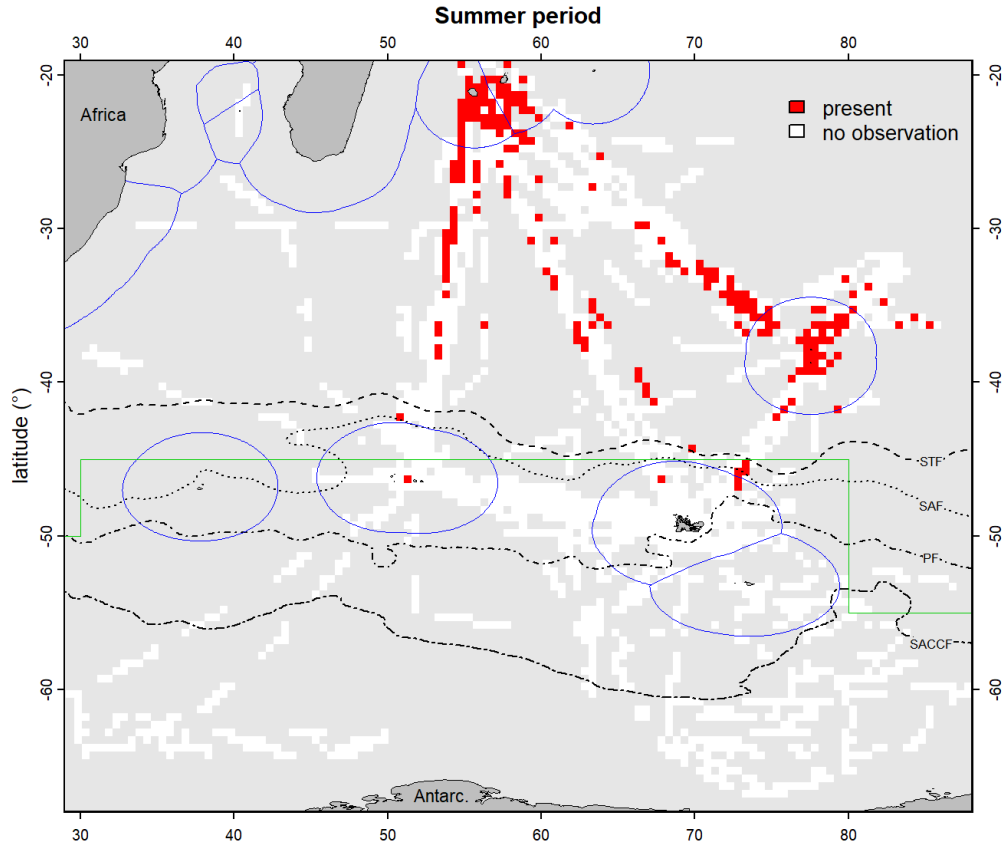


Figure 100 - Presence of Wedge-tailed Shearwater / Flesh-footed Shearwater in each 0.5°x0.5° square in the southwest Indian Ocean area

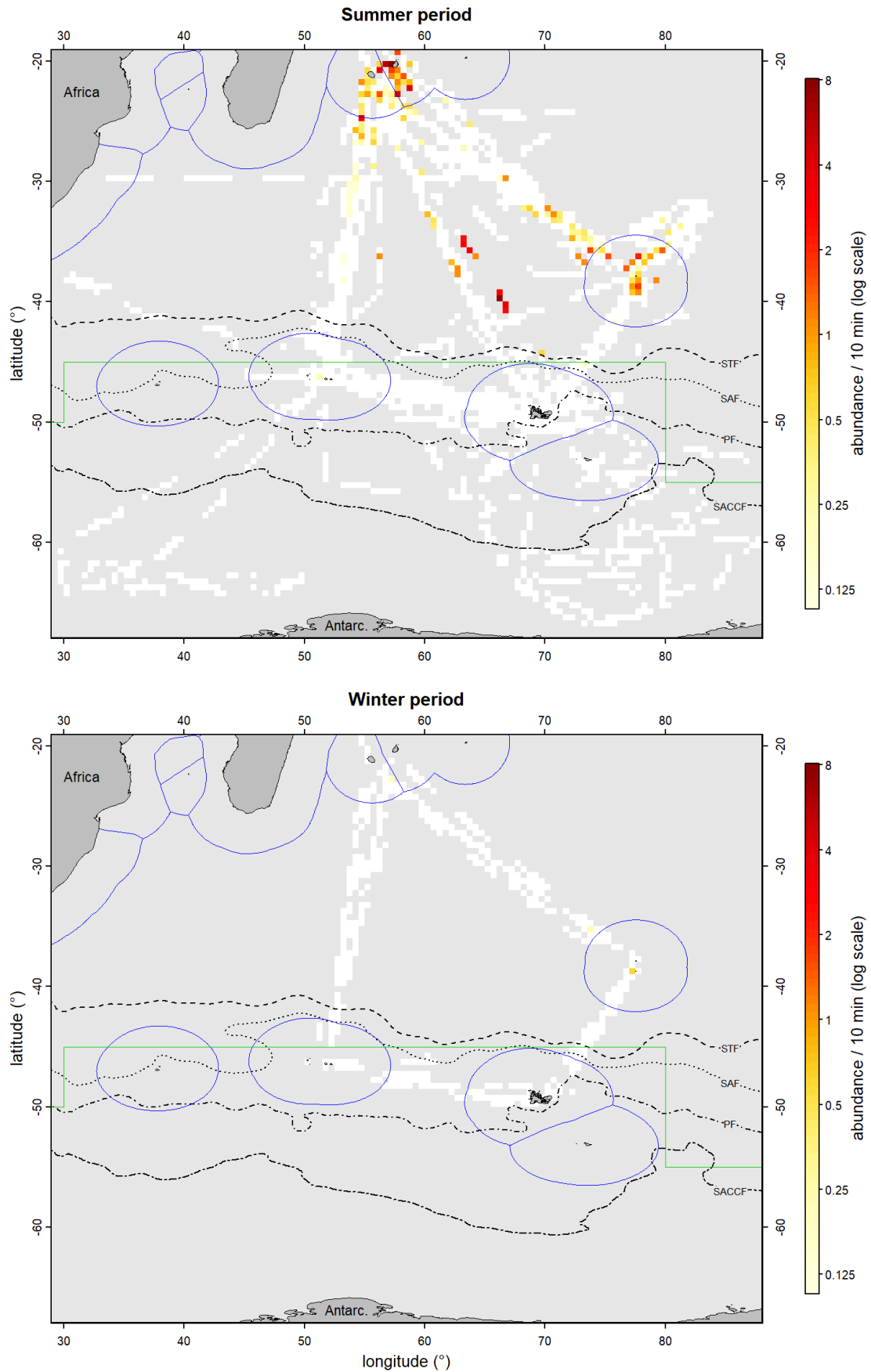


Figure 101 - Mean abundance of Wedge-tailed Shearwater / Flesh-footed Shearwater during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Great Shearwater *Ardenna gravis* (LC)

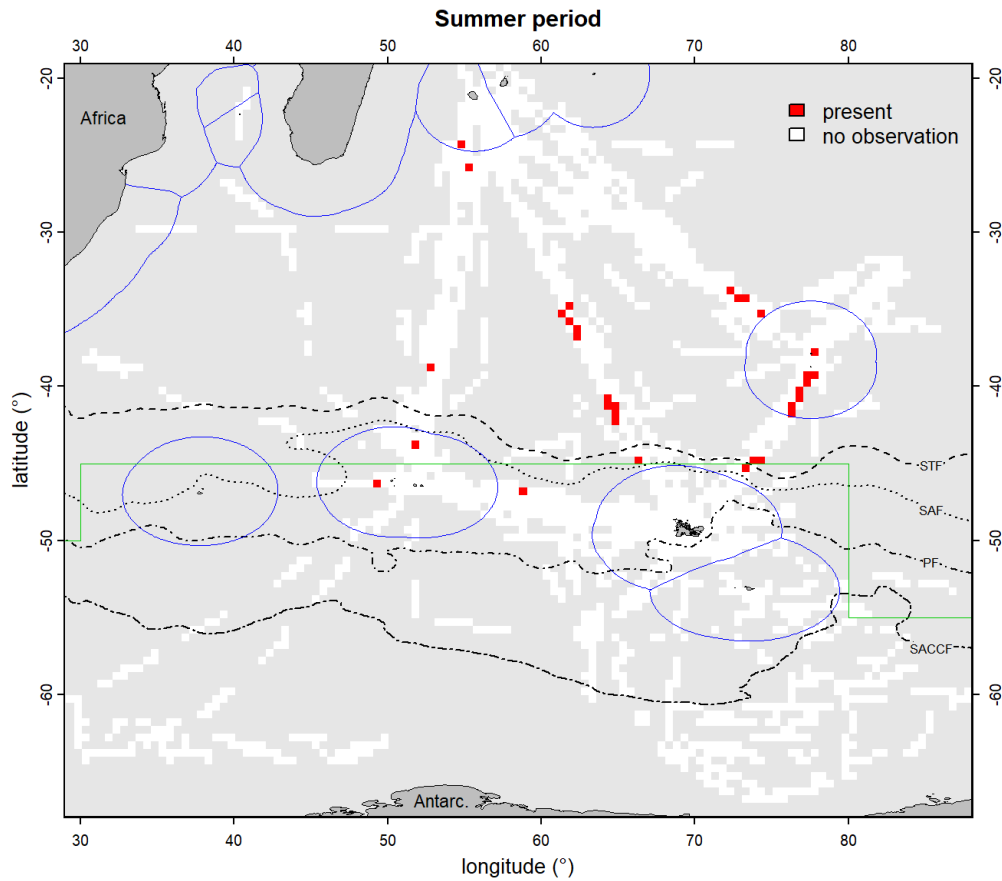


Figure 102 - Presence of Great Shearwater in each 0.5°x0.5° square in the south-west Indian Ocean area

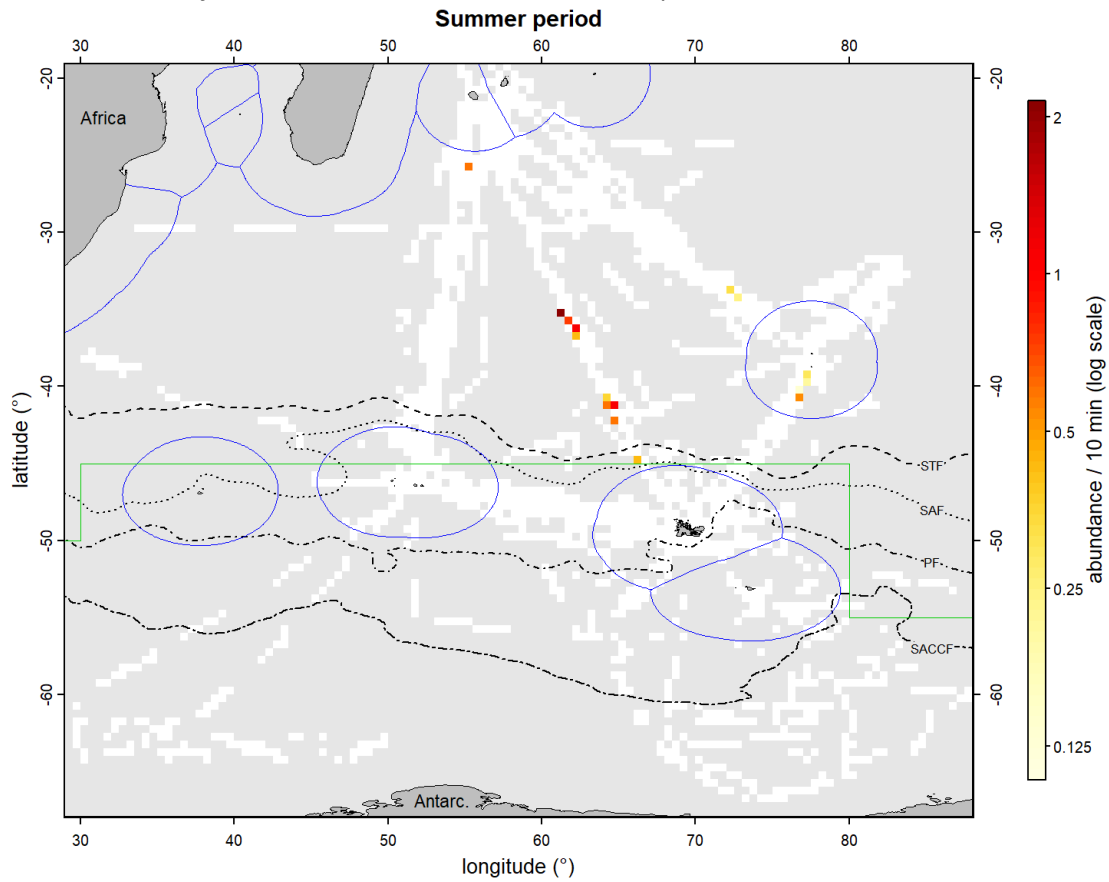


Figure 103 - Mean abundance of Great Shearwater during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Short-tailed Shearwater *Ardenna tenuirostris* (LC)

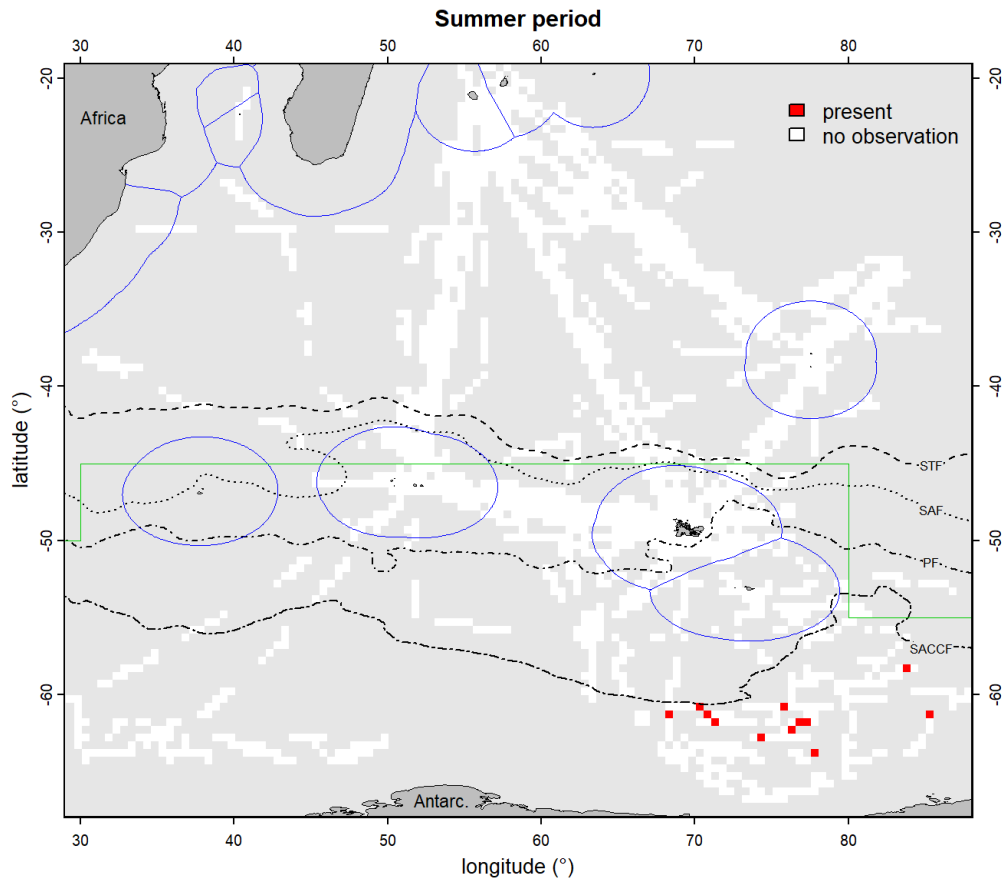


Figure 104 - Presence of Short-tailed Shearwater in each 0.5°x0.5° square in the south-west Indian Ocean area

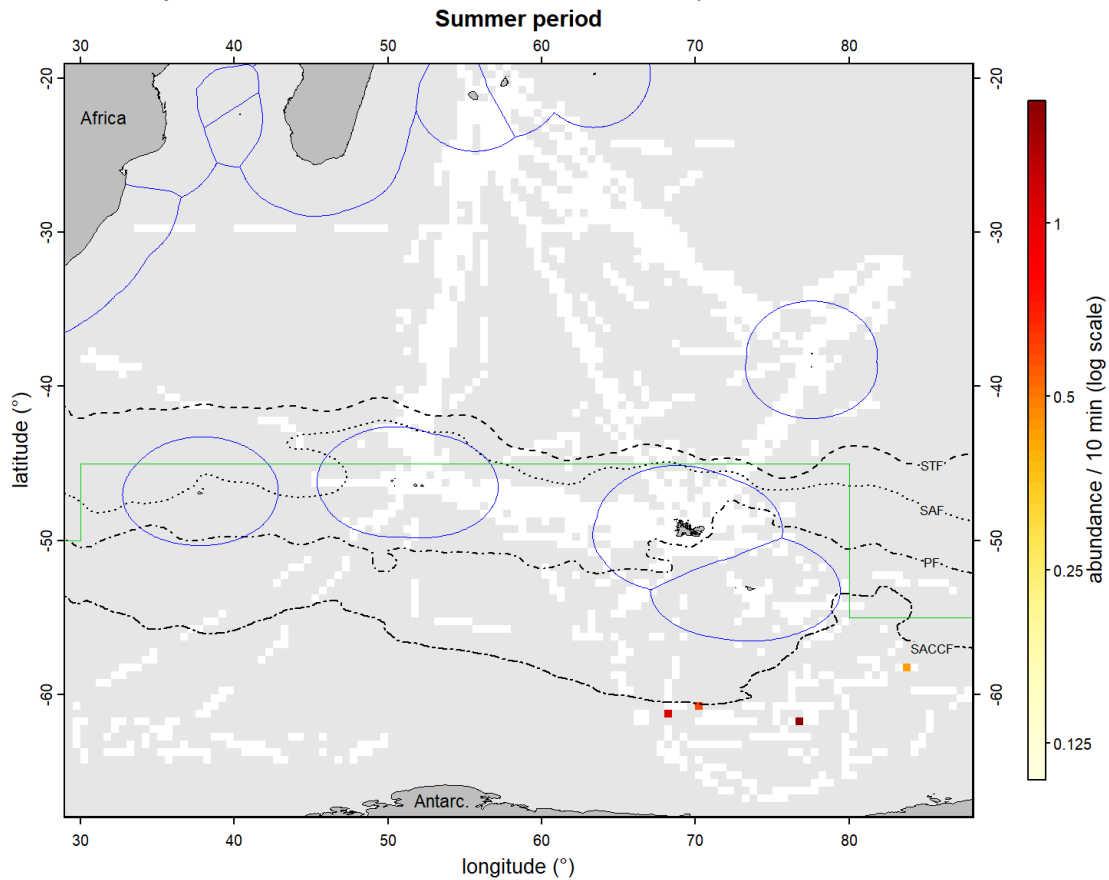


Figure 105 - Mean abundance of Short-tailed Shearwater during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

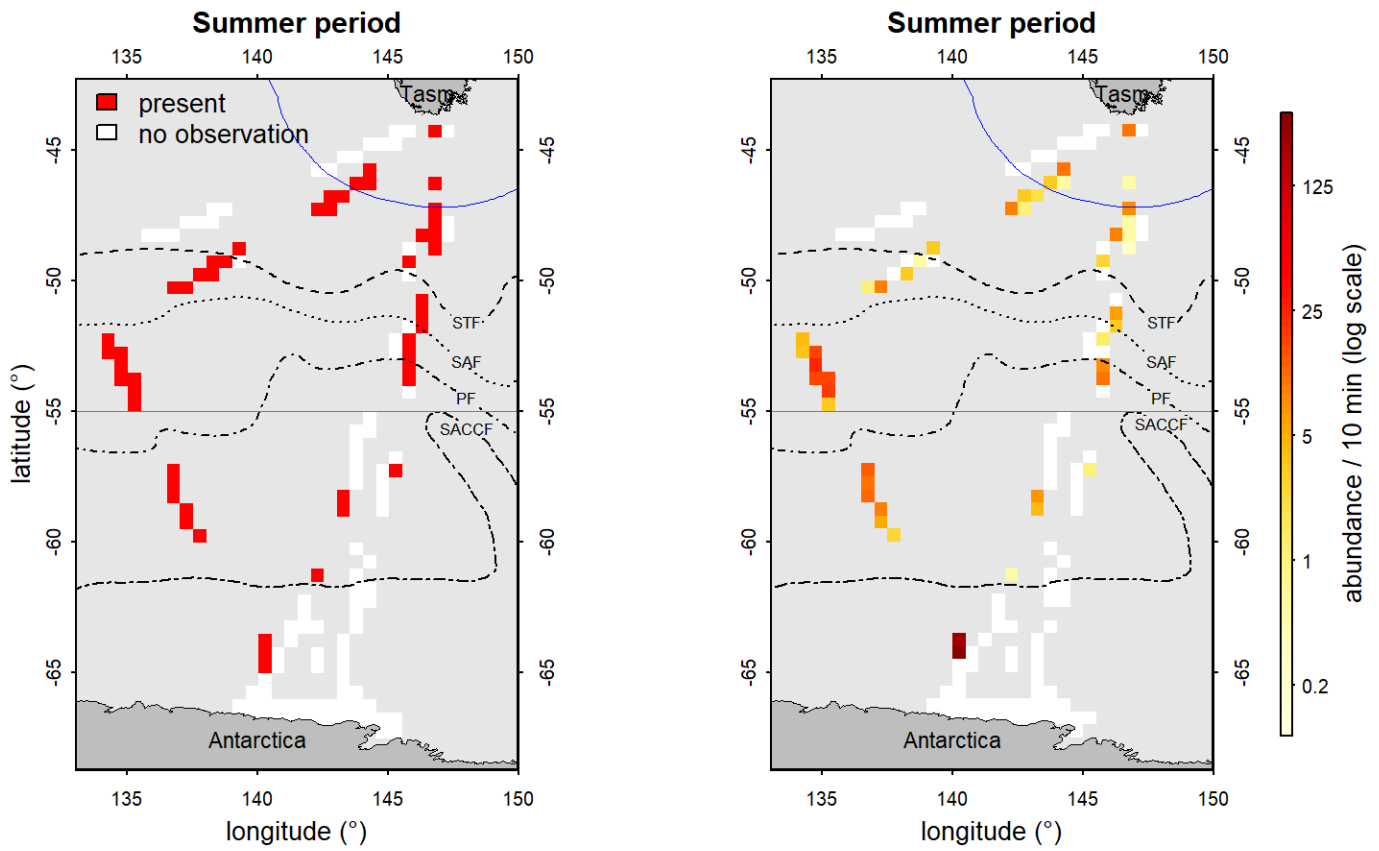


Figure 106 - Presence of Short-tailed Shearwater and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Sooty Shearwater *Ardenna grisea* (NT)

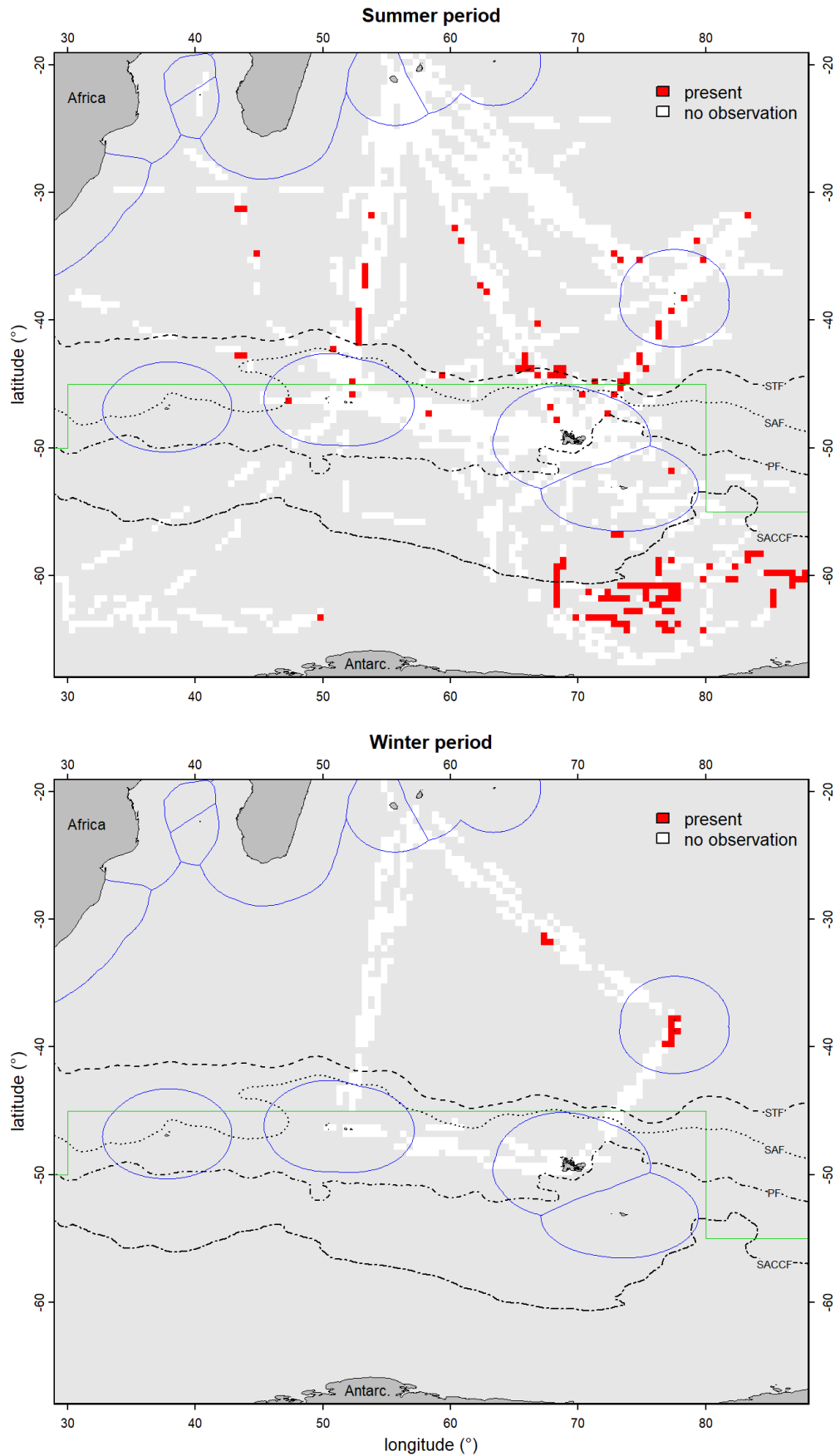


Figure 107 - Presence of Sooty Shearwater in each 0.5°x0.5° square in the south-west Indian Ocean area

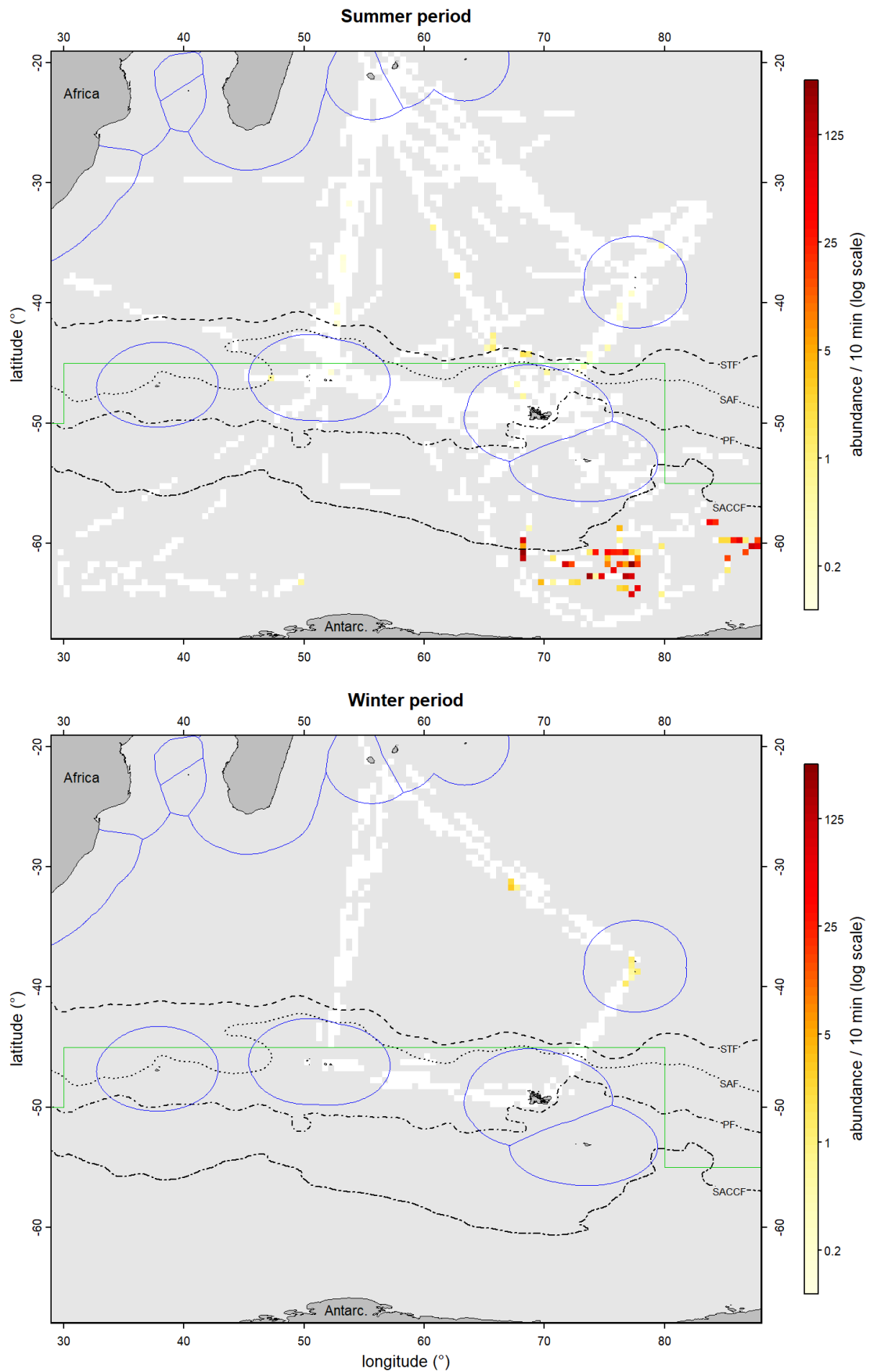


Figure 108 - Mean abundance of Sooty Shearwater during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

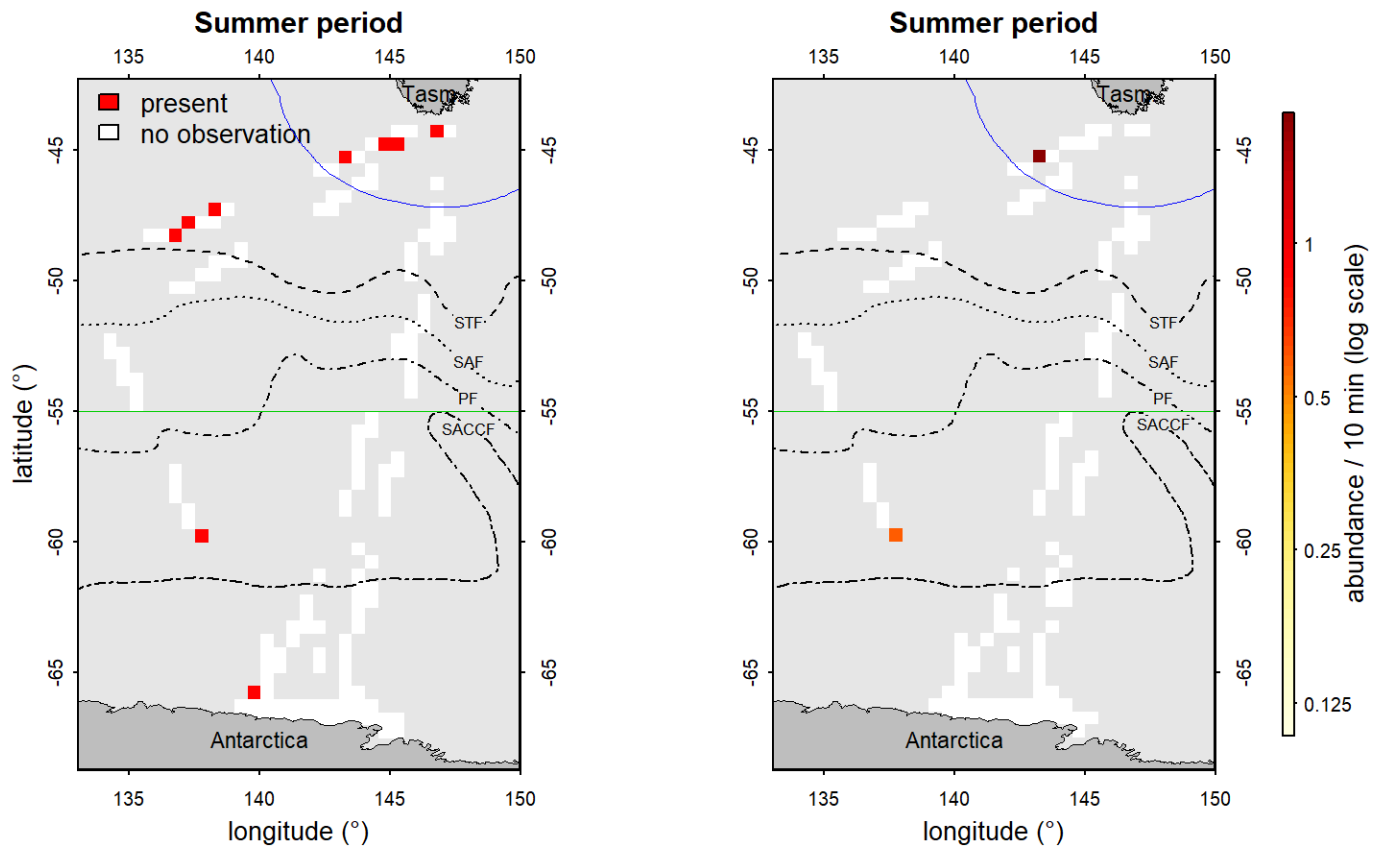


Figure 109 - Presence of Sooty Shearwater and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Little Shearwater / Baillon's Shearwater / Subantarctic shearwater *Puffinus assimilis* / *P. bailloni* / *P. elegans* (LC/LC/LC)

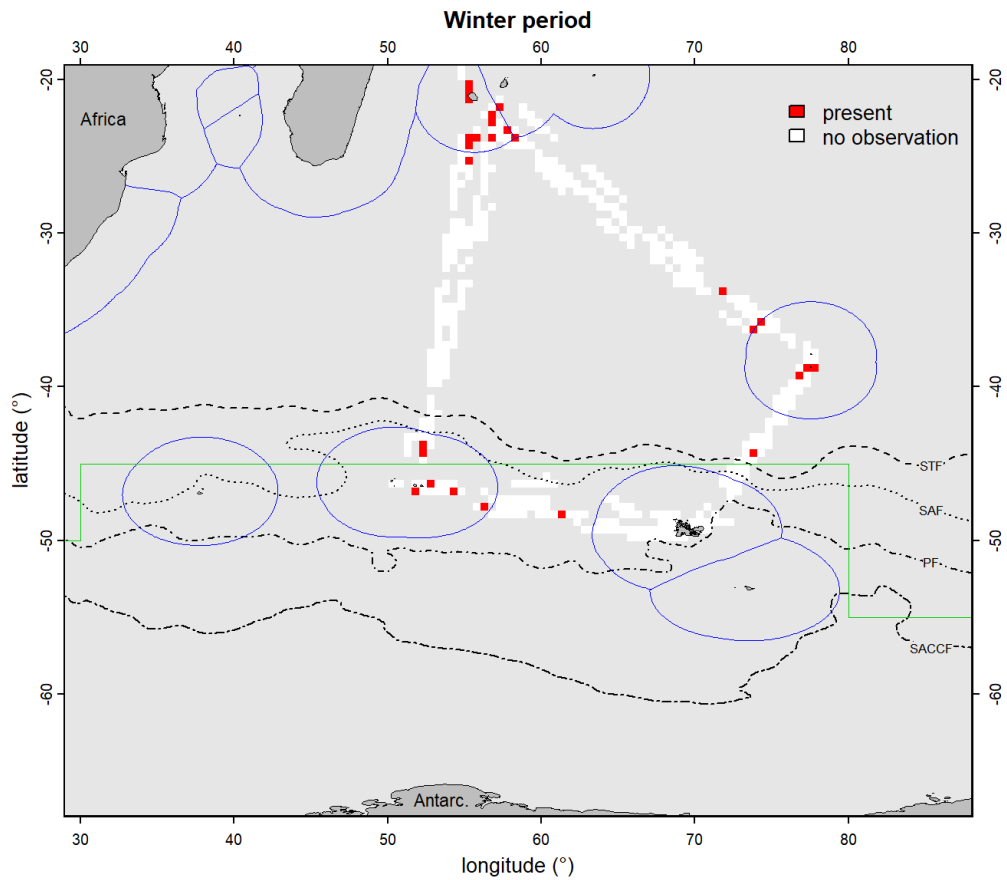
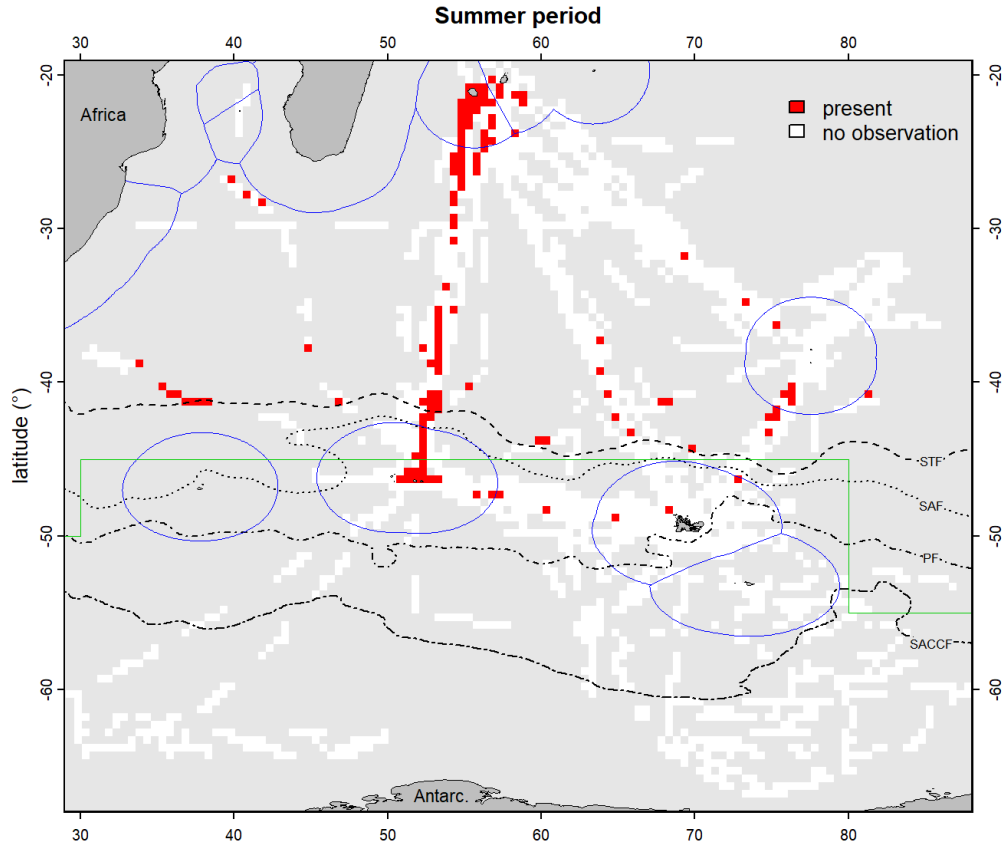


Figure 110 - Presence of Little Shearwater / Baillon's Shearwater / Subantarctic shearwater in each 0.5°x0.5° square in the south-west Indian Ocean area

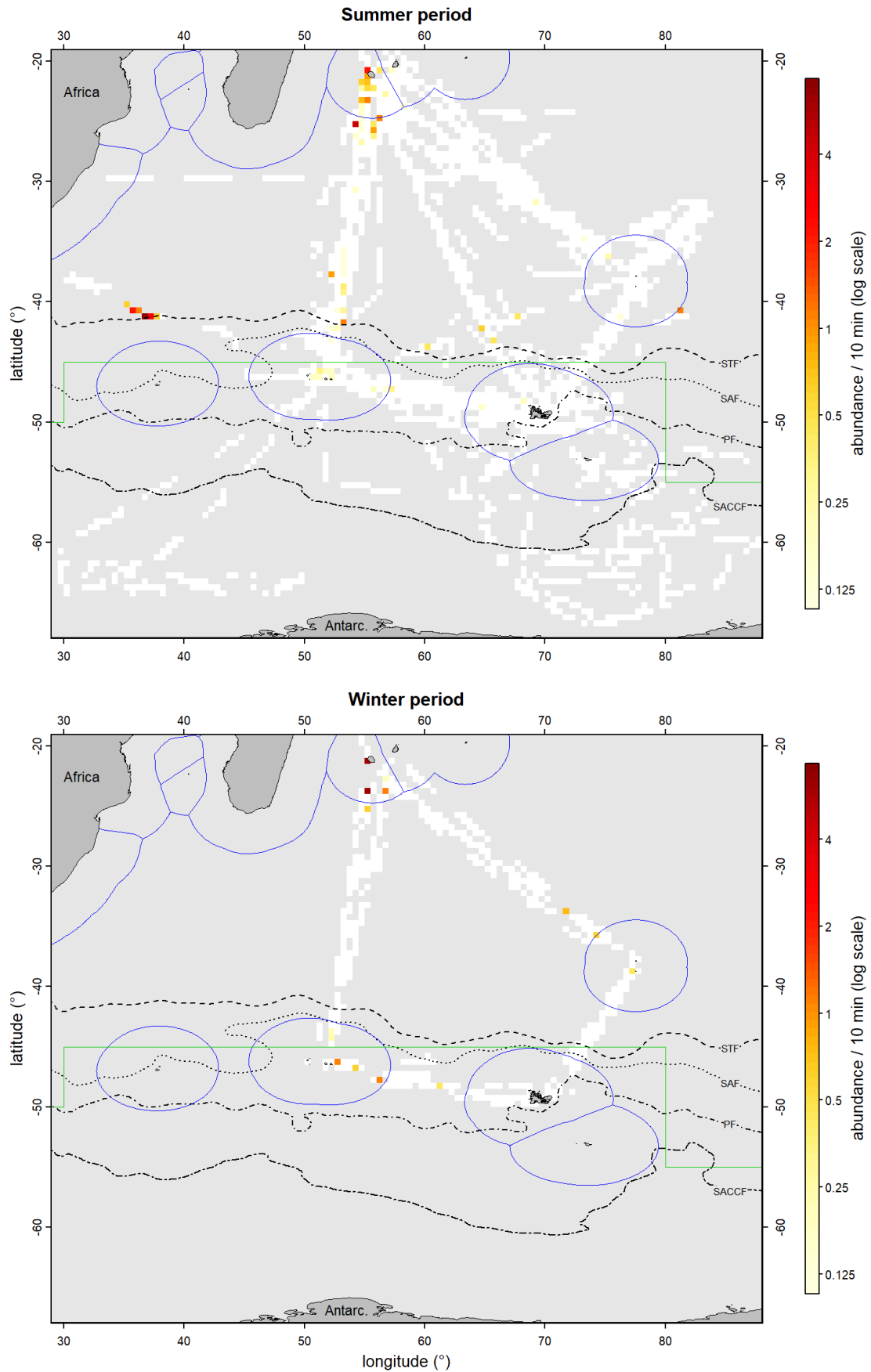


Figure 111 - Mean abundance of Little Shearwater / Baillon's Shearwater / Subantarctic shearwater during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

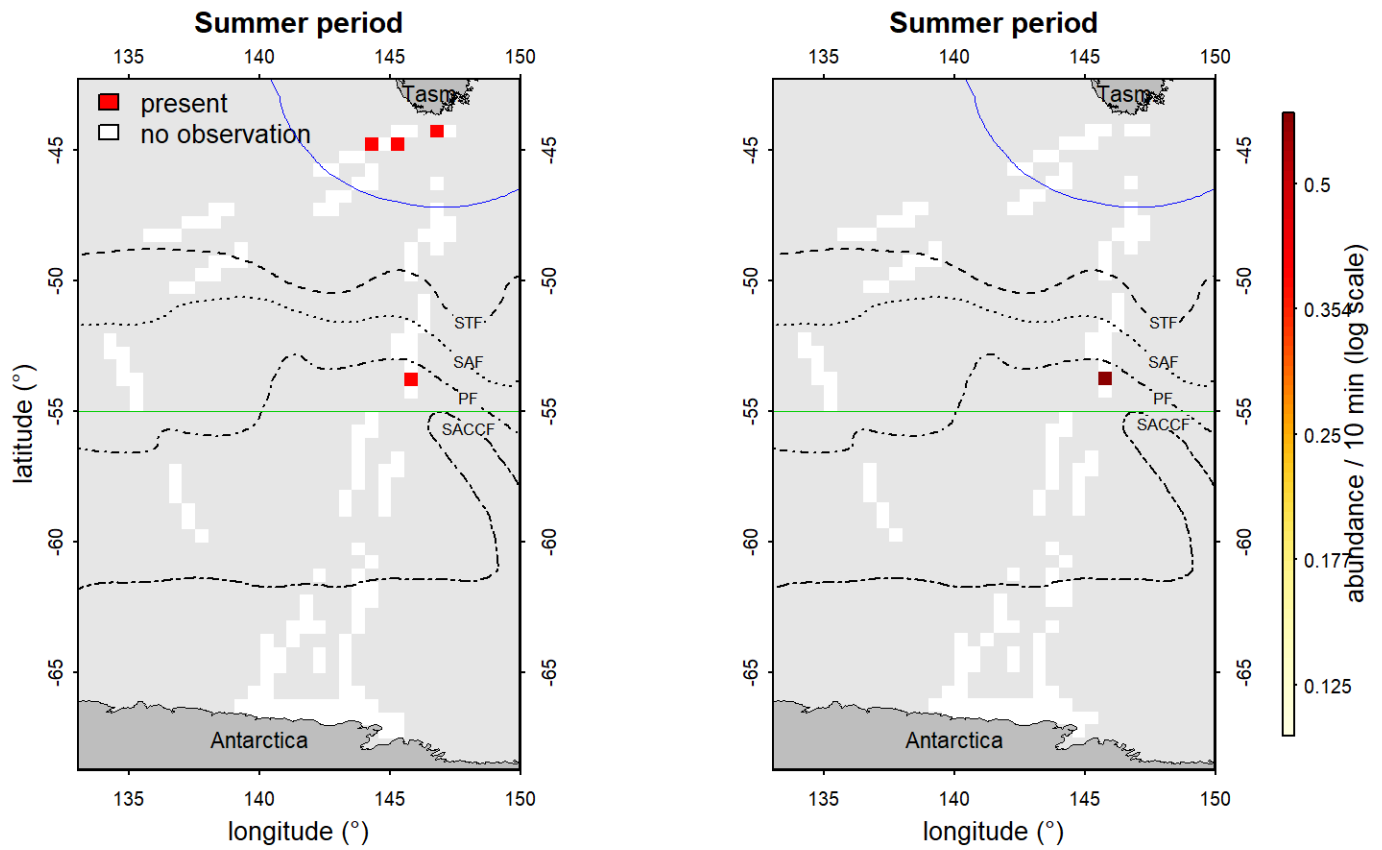


Figure 112 - Presence of Little Shearwater / Baillon's Shearwater / Subantarctic shearwater and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Wilson's Storm-petrel *Oceanites oceanicus* (LC)

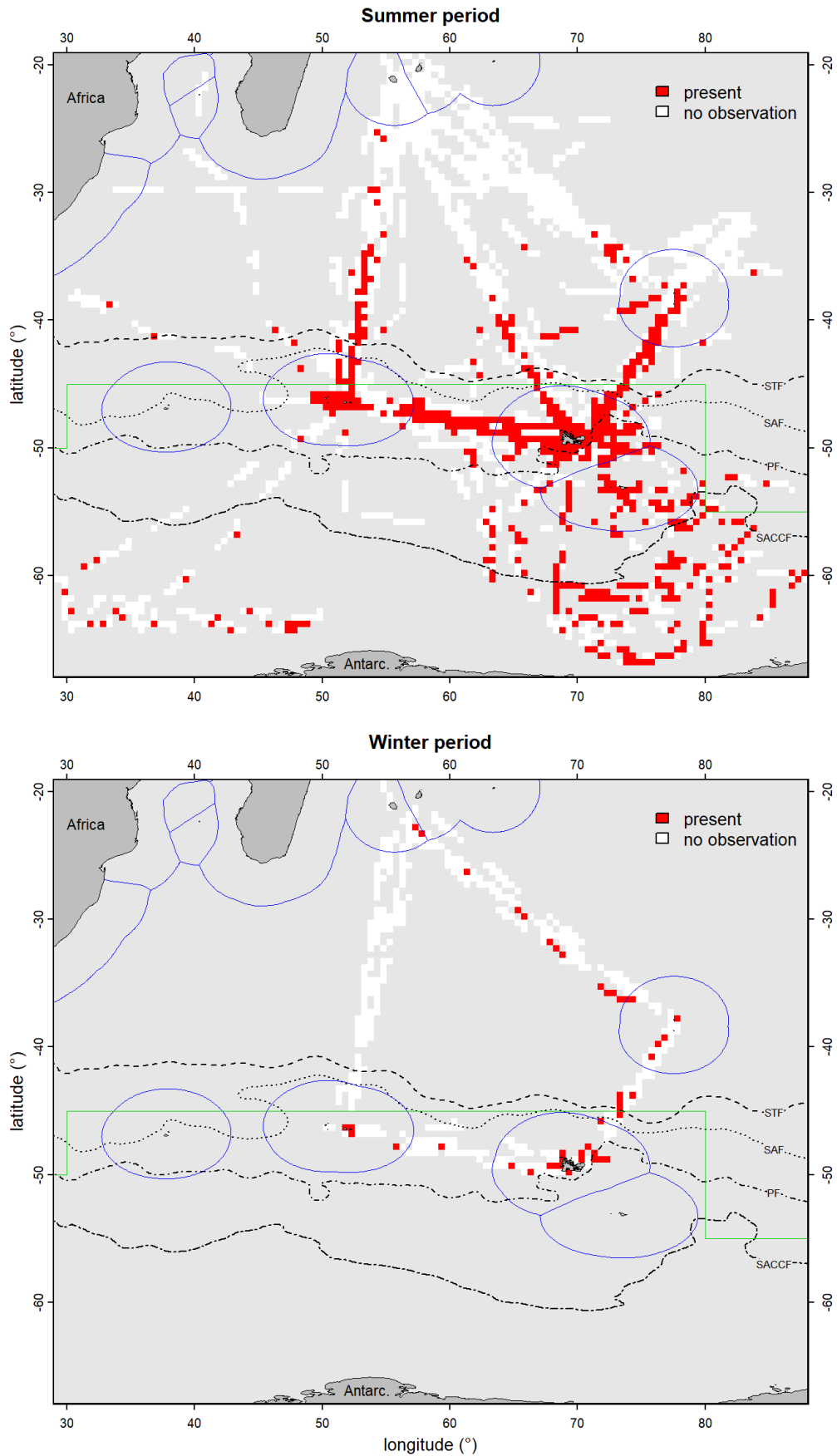


Figure 113 - Presence of Wilson's Storm-petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

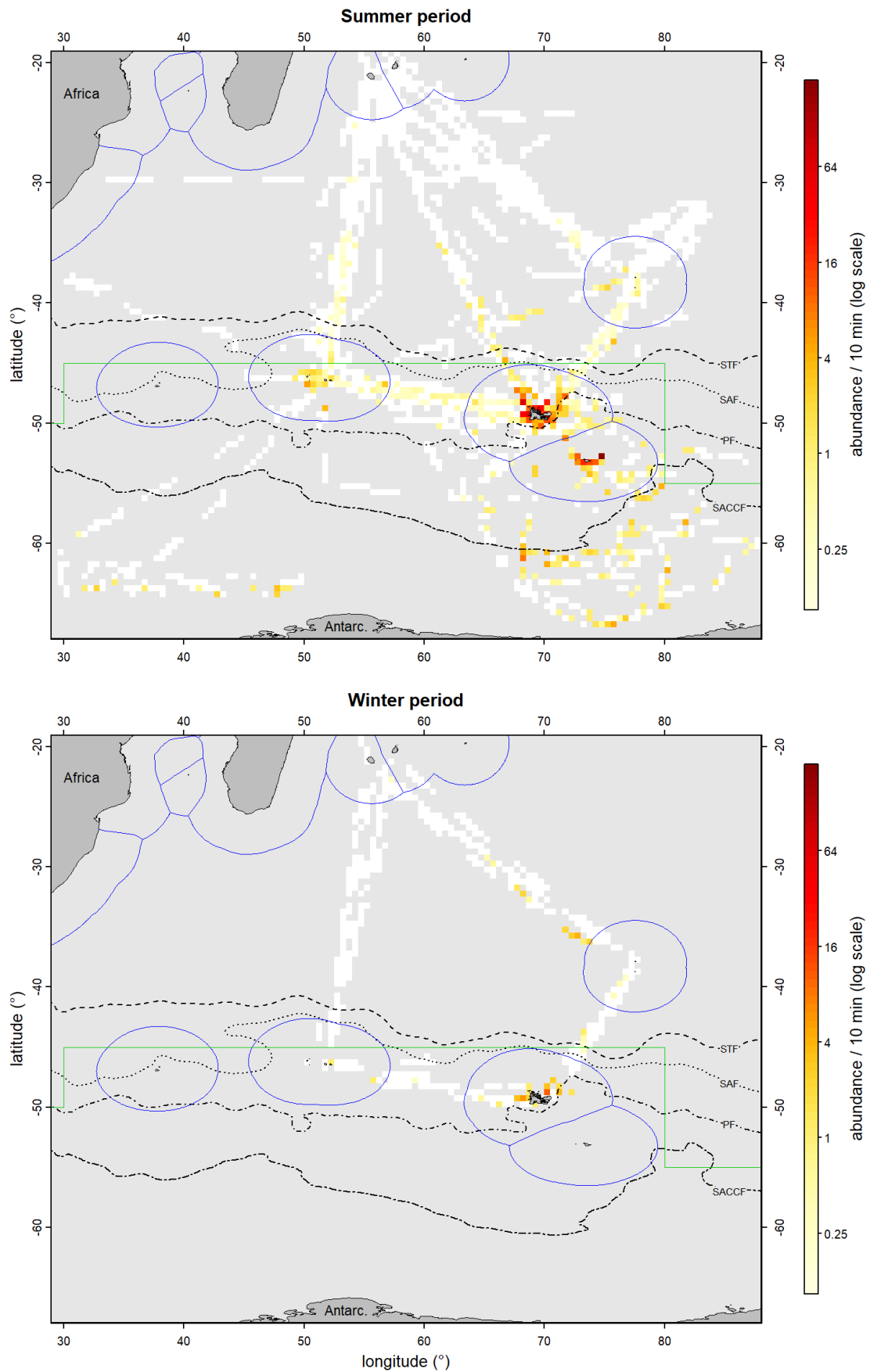


Figure 114 - Mean abundance of Wilson's Storm-petrel during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

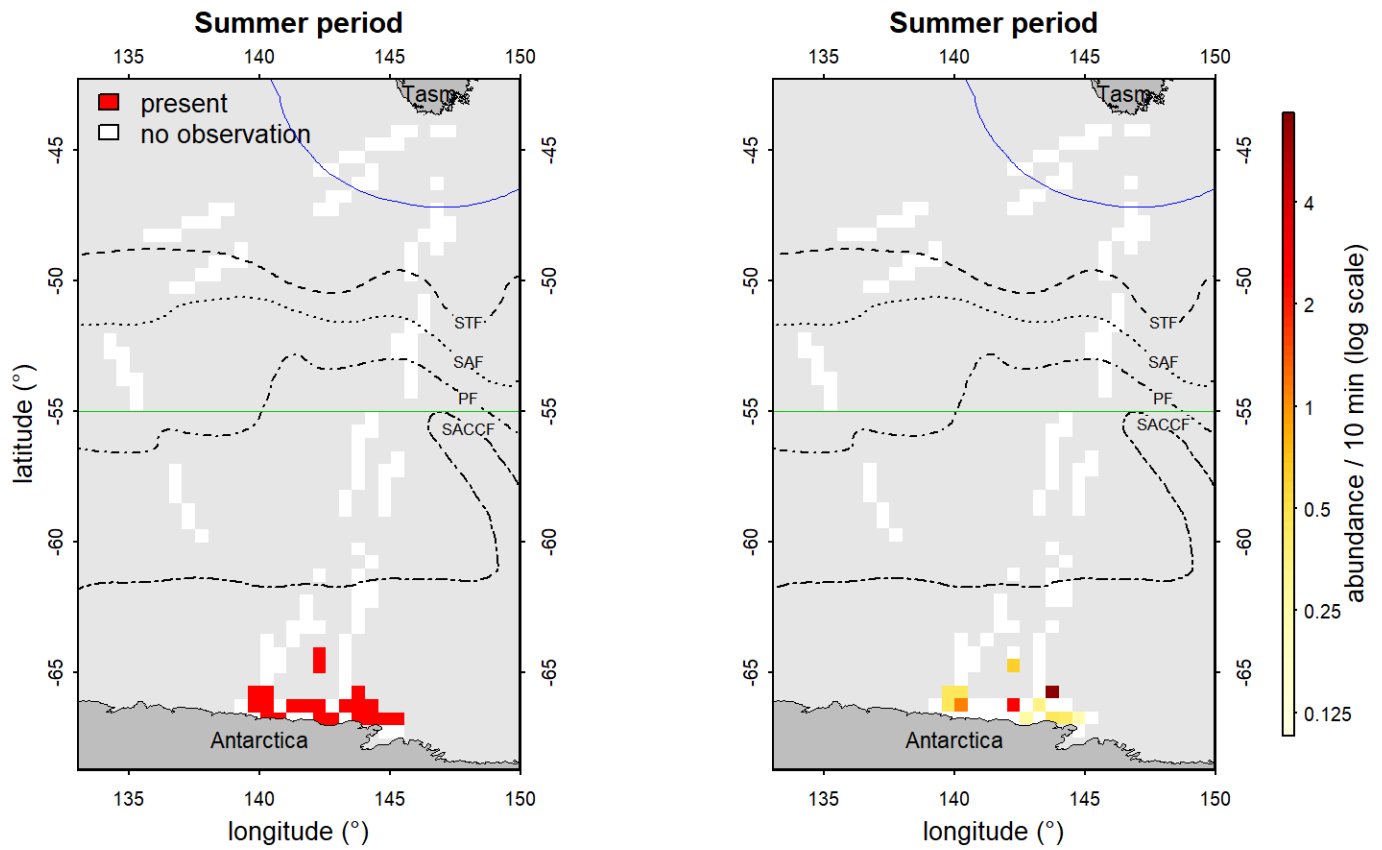


Figure 115 - Presence of Wilson's Storm-petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Grey-backed Storm-petrel *Garodia nereis* (LC)

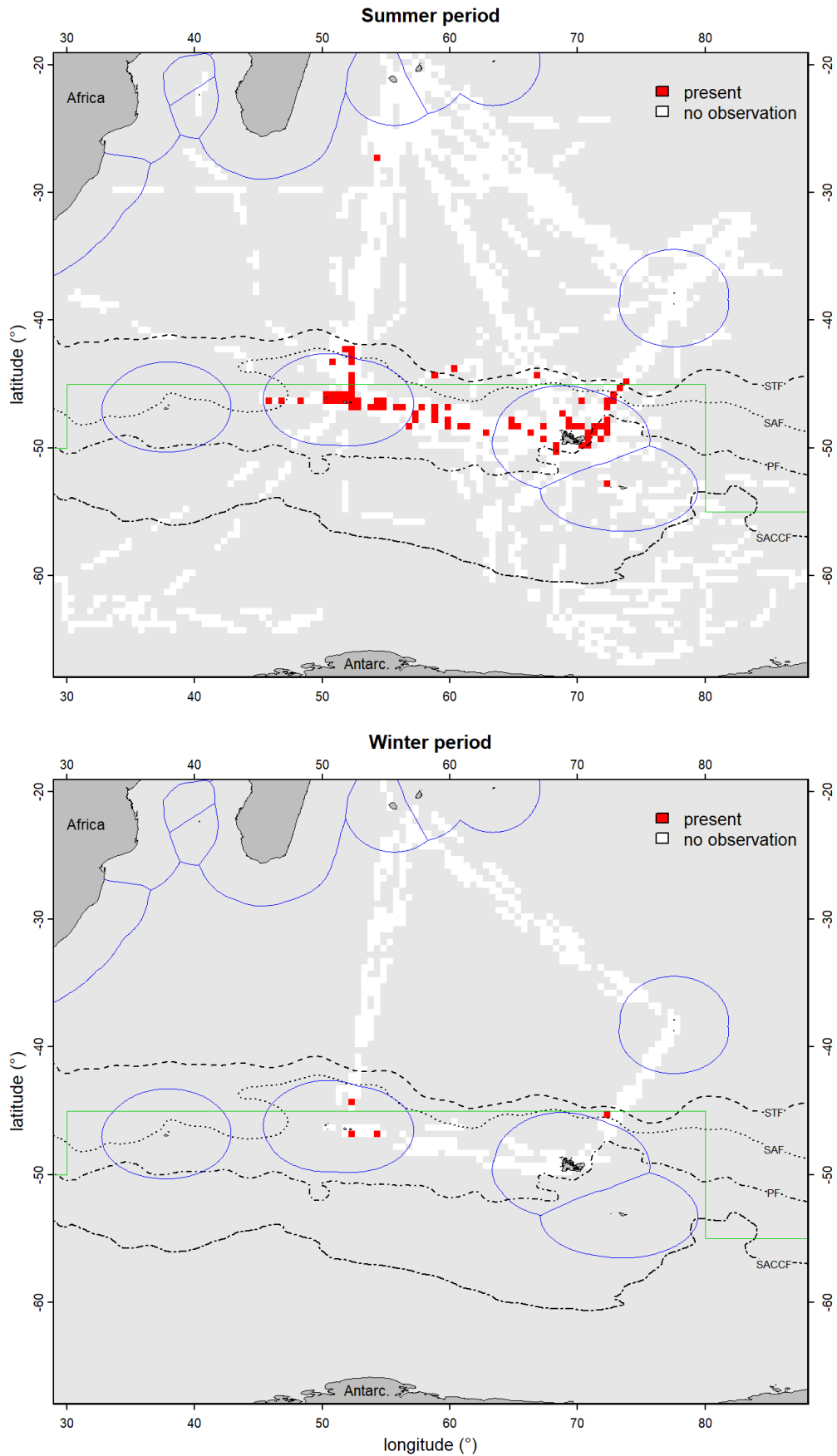


Figure 116 - Presence of Grey-backed Storm-petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

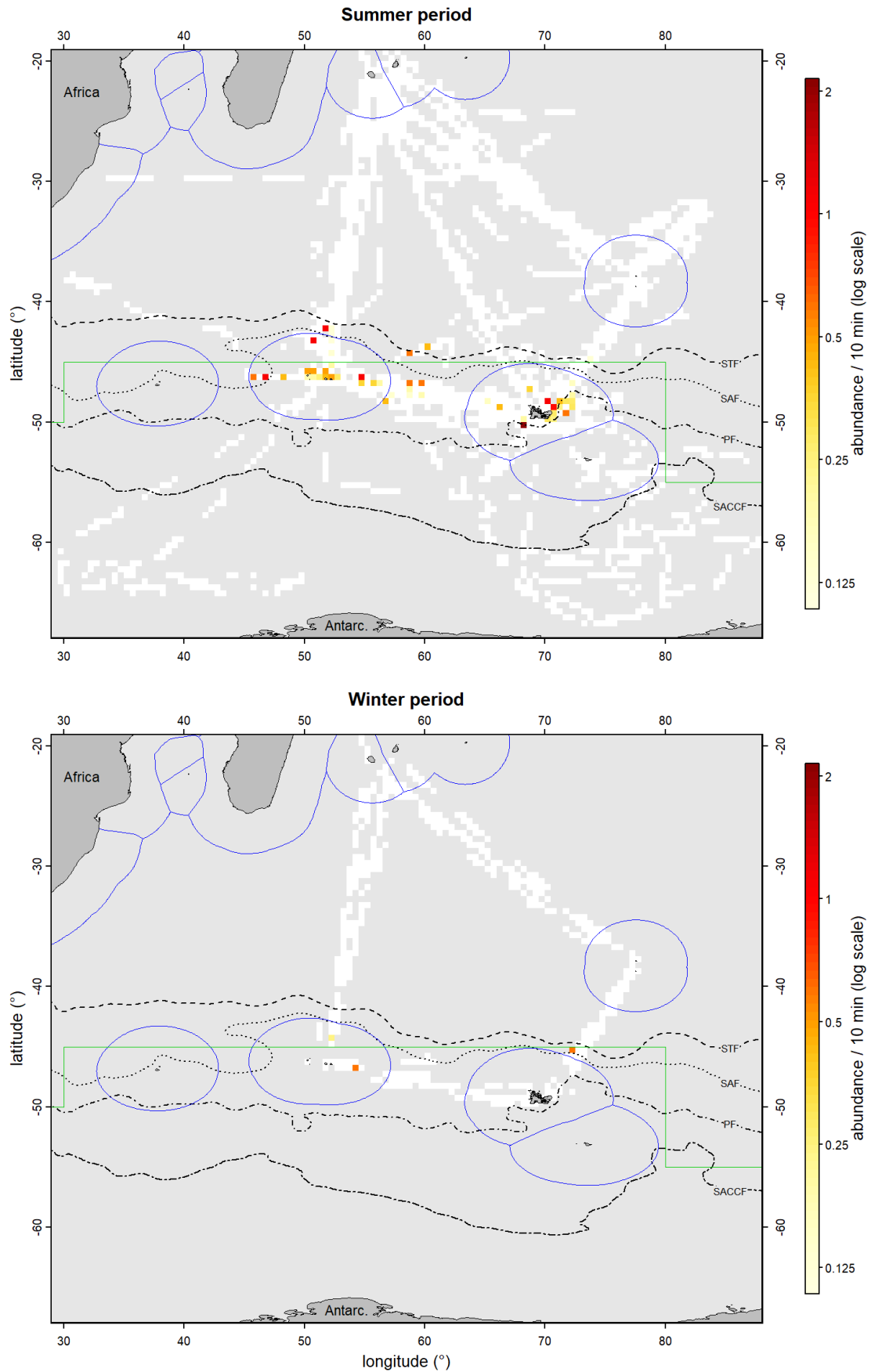


Figure 117 - Mean abundance of Grey-backed Storm-petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

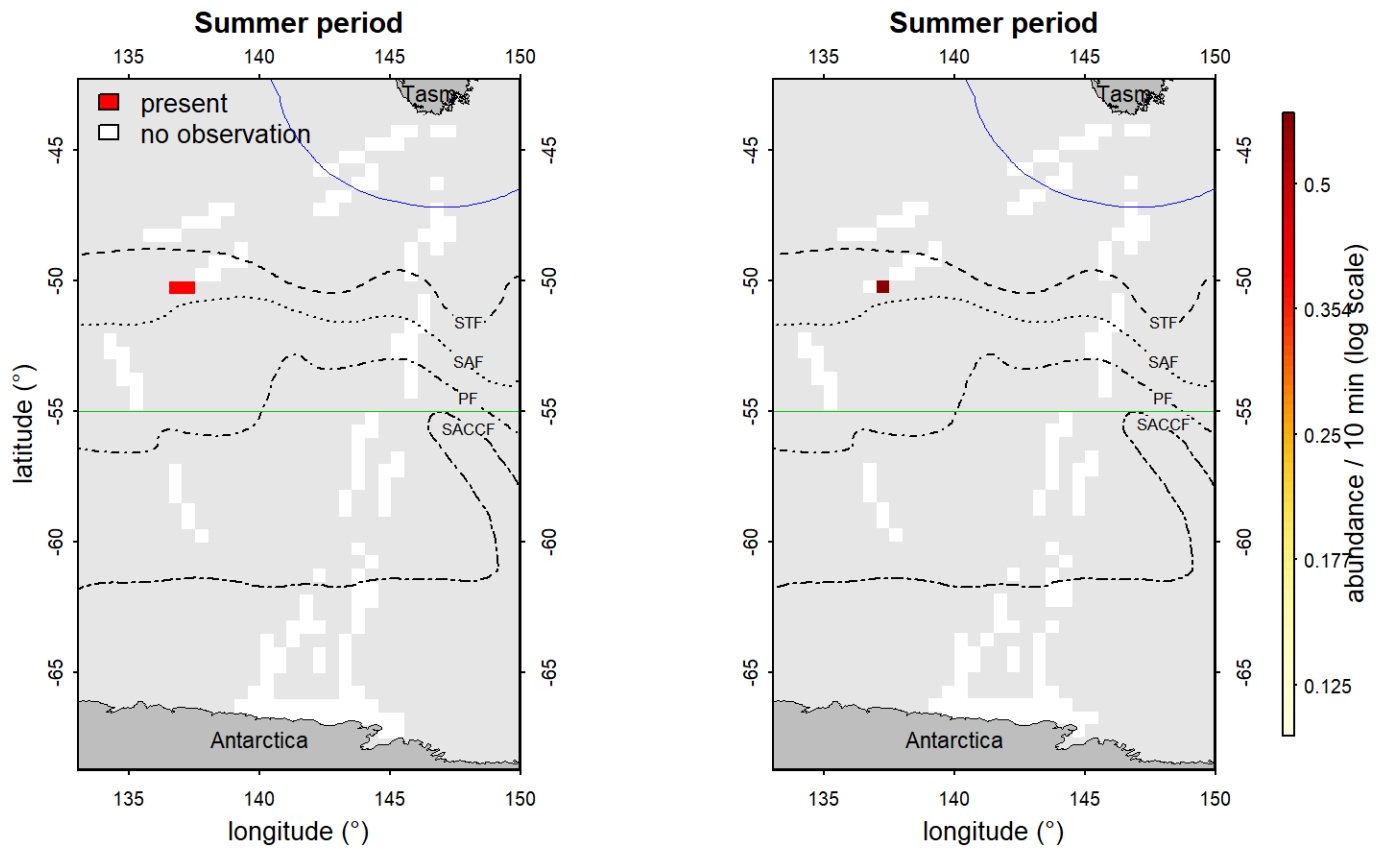


Figure 118 - Presence of Grey-backed Storm-petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

White-faced Storm-petrel *Pelagodroma marina* (LC)

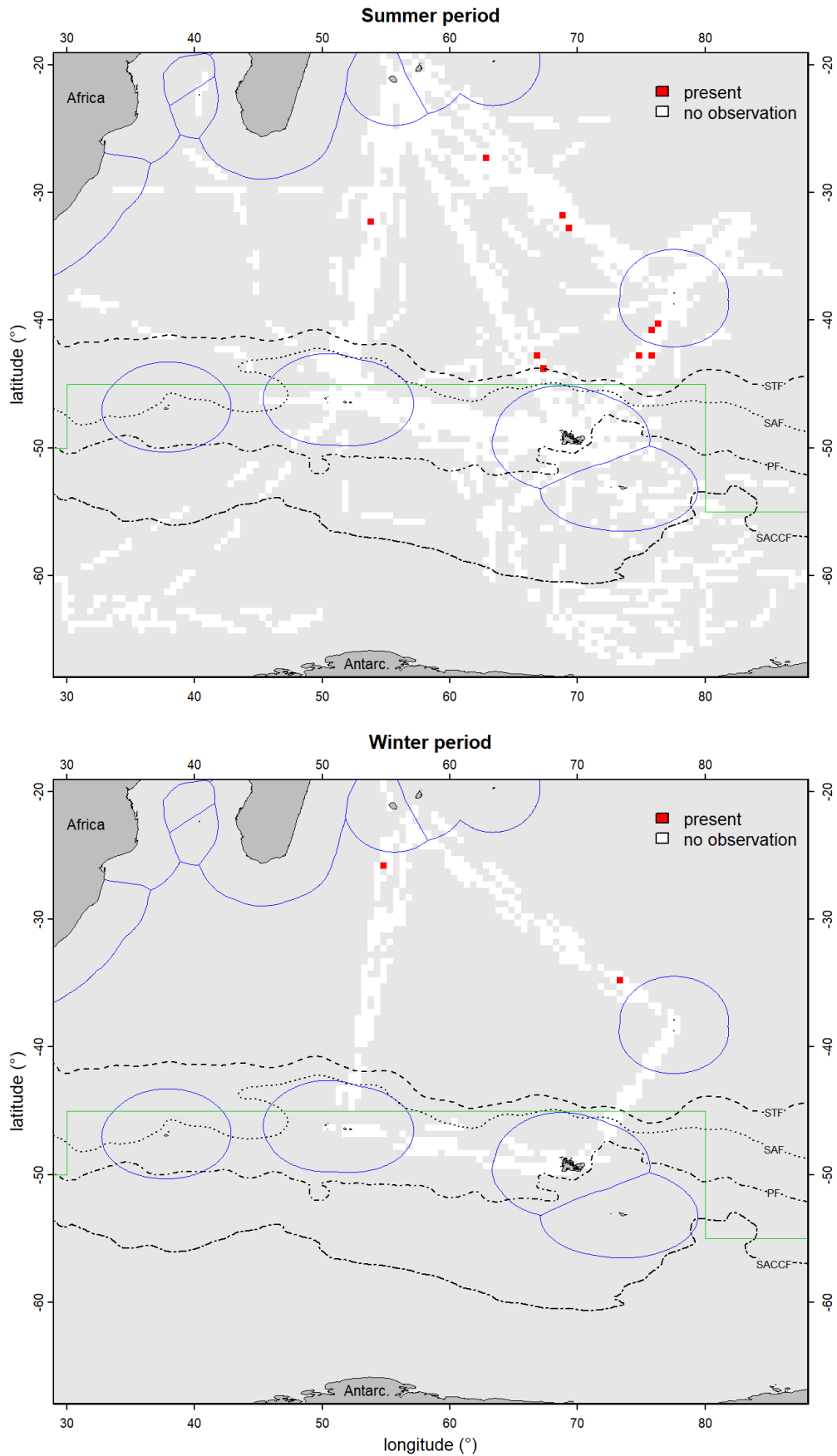


Figure 119 - Presence of White-faced Storm-petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

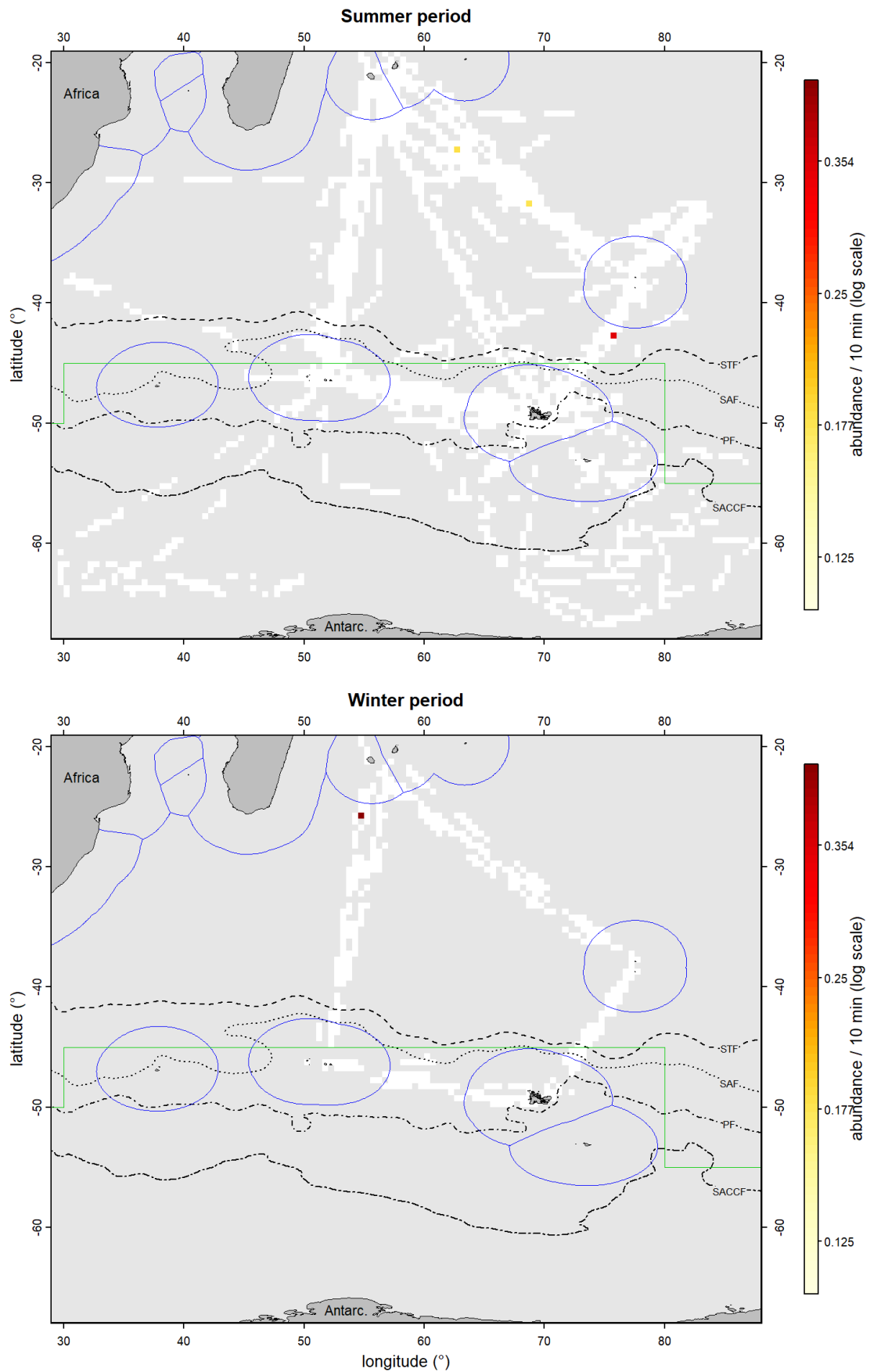


Figure 120 - Mean abundance of White-faced Storm-petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

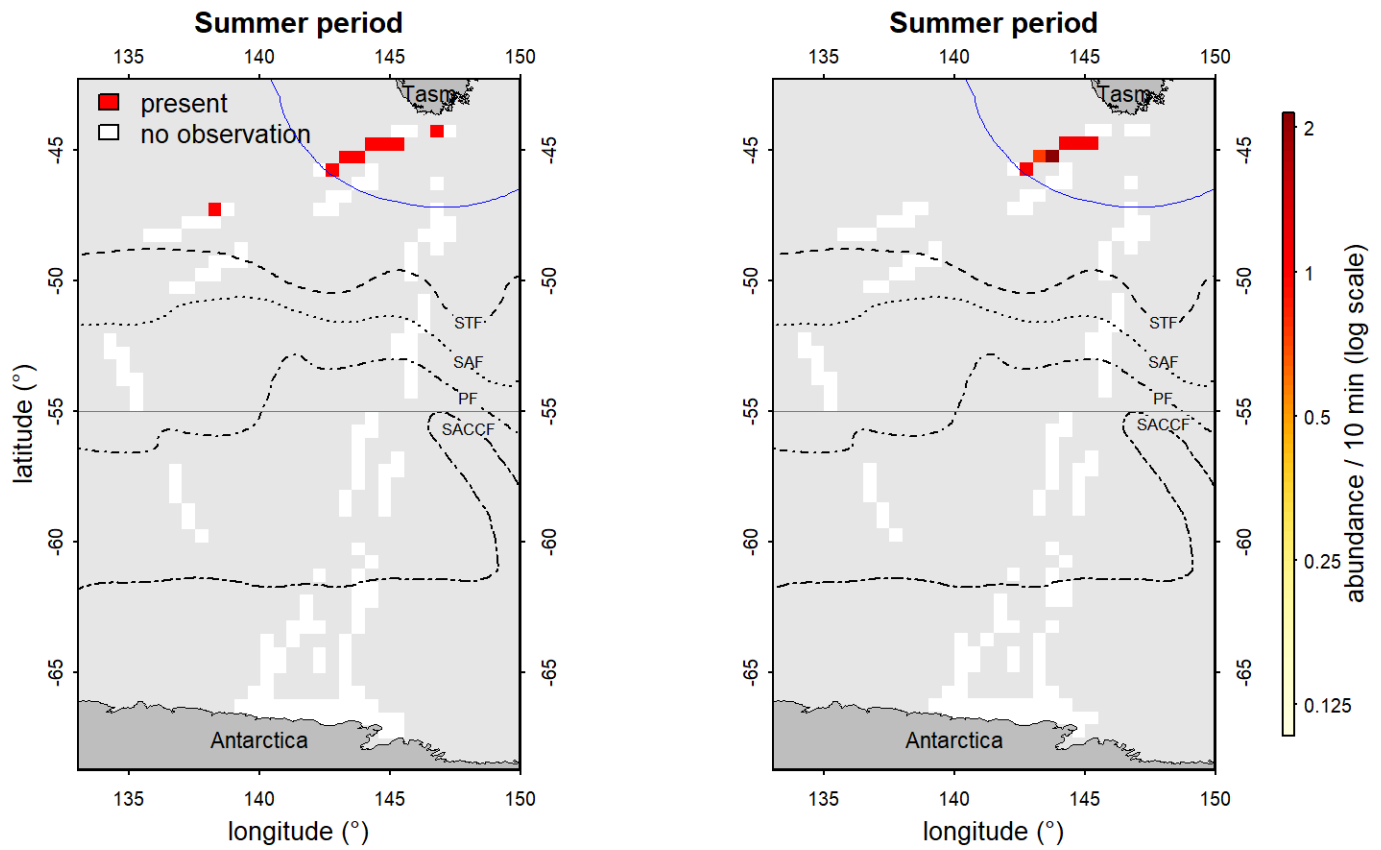


Figure 121 - Presence of White-faced Storm-petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

White-bellied Storm-petrel *Fregetta grallaria* (LC)

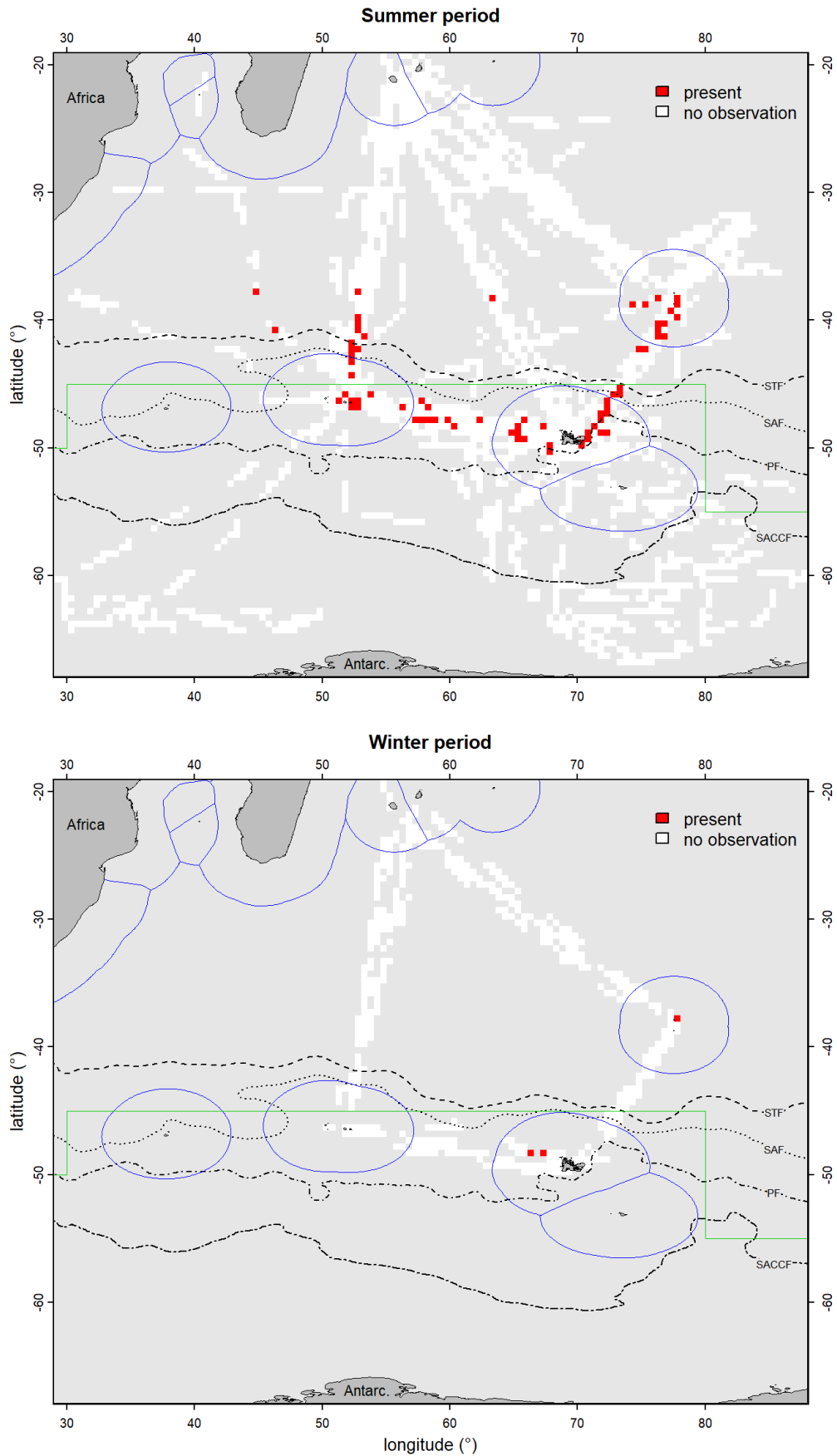


Figure 122 - Presence of White-bellied Storm-petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

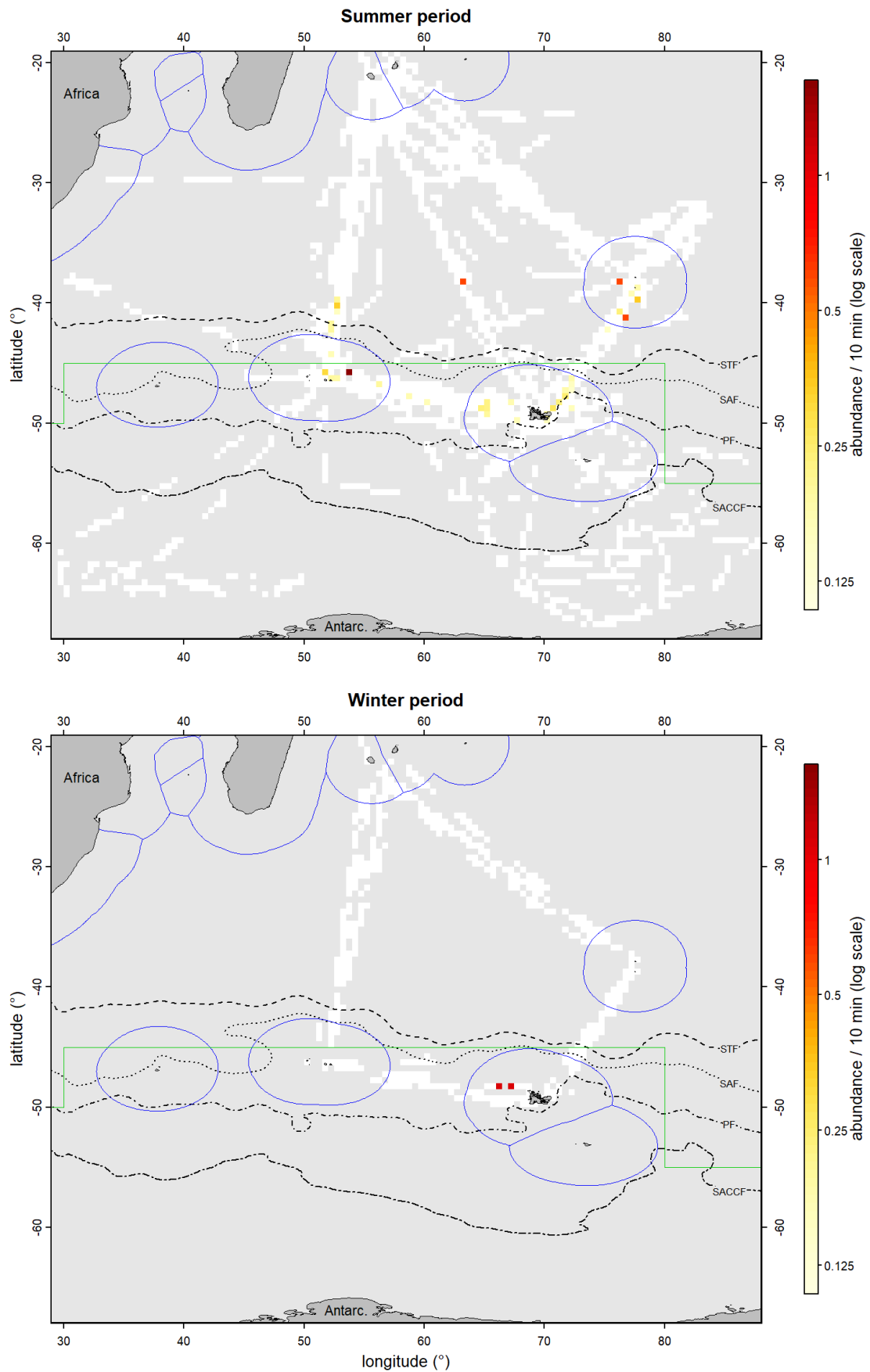


Figure 123 - Mean abundance of White-bellied Storm-petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

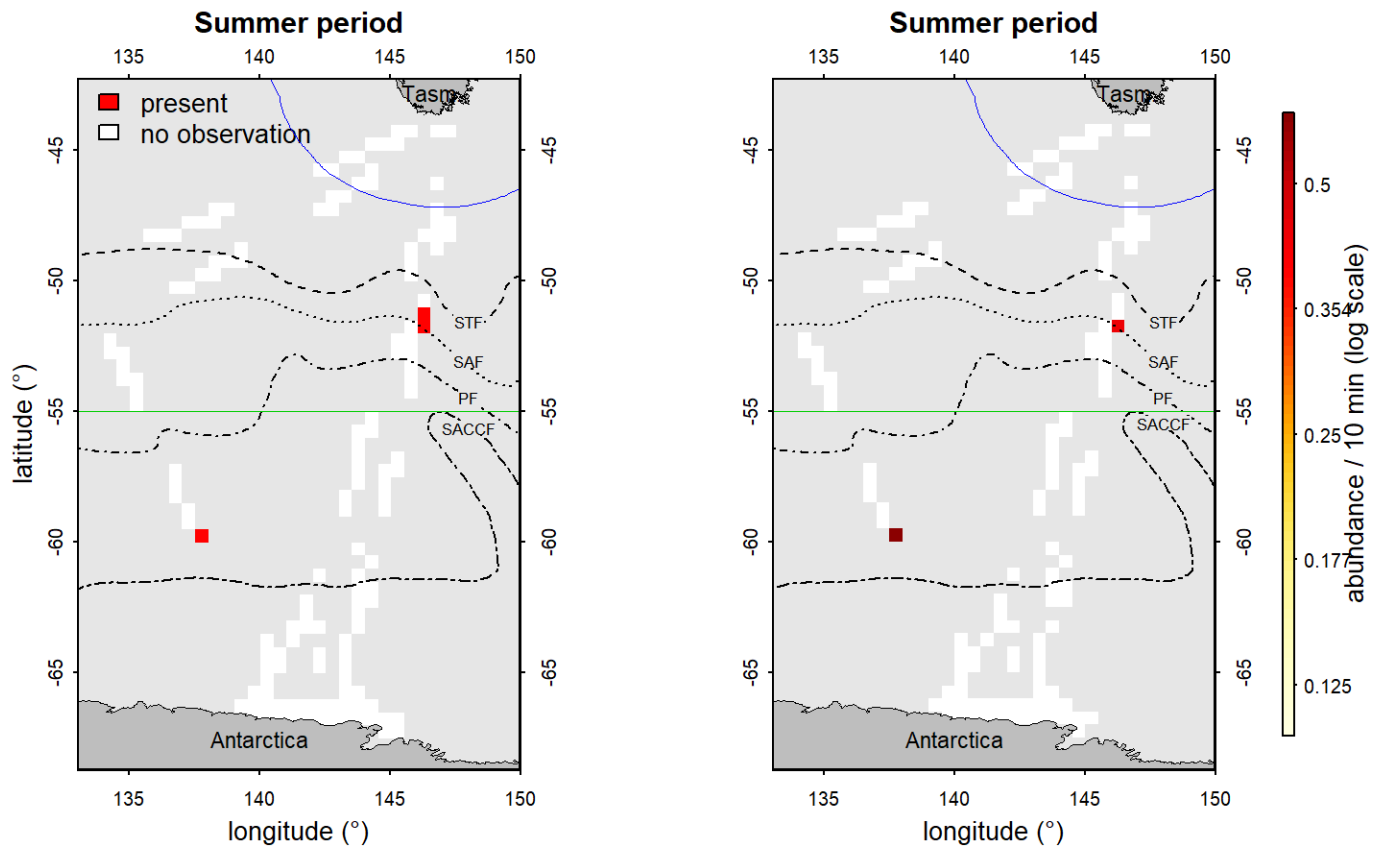


Figure 124 - Presence of White-bellied Storm-petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Black-bellied Storm-petrel *Fregetta tropica* (LC)

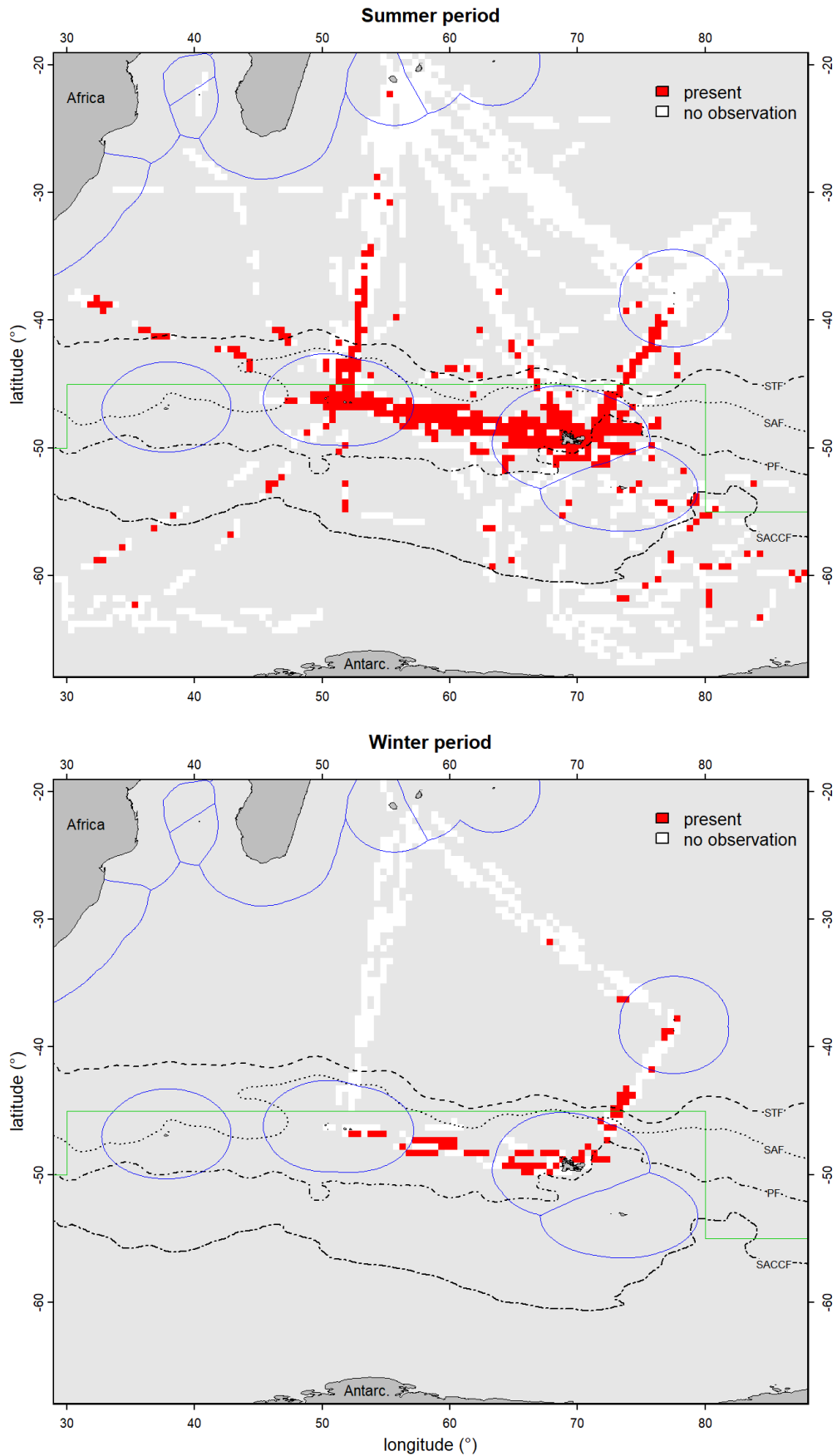


Figure 125 - Presence of Black-bellied Storm-petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

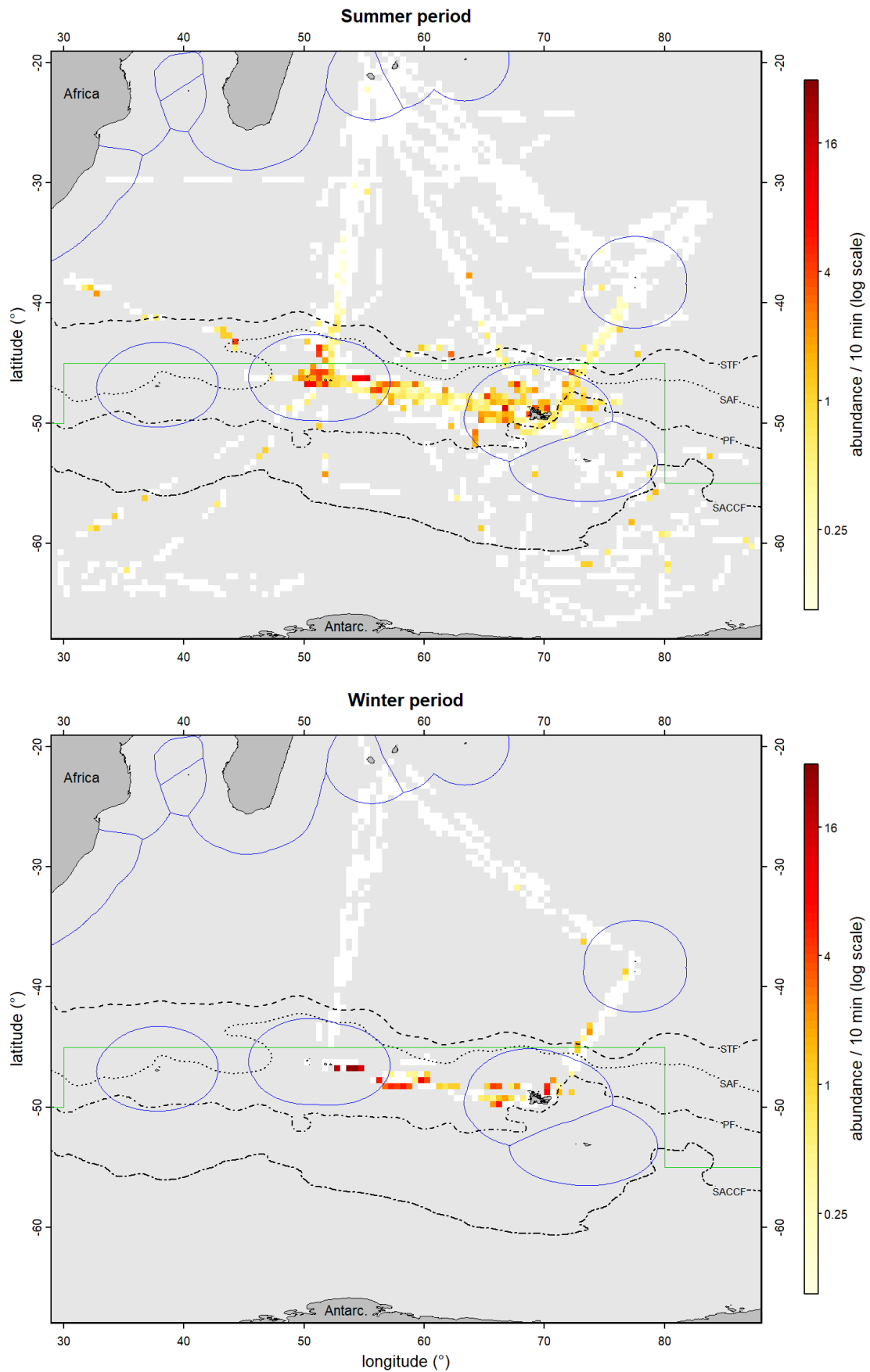


Figure 126 - Mean abundance of Black-bellied Storm-petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

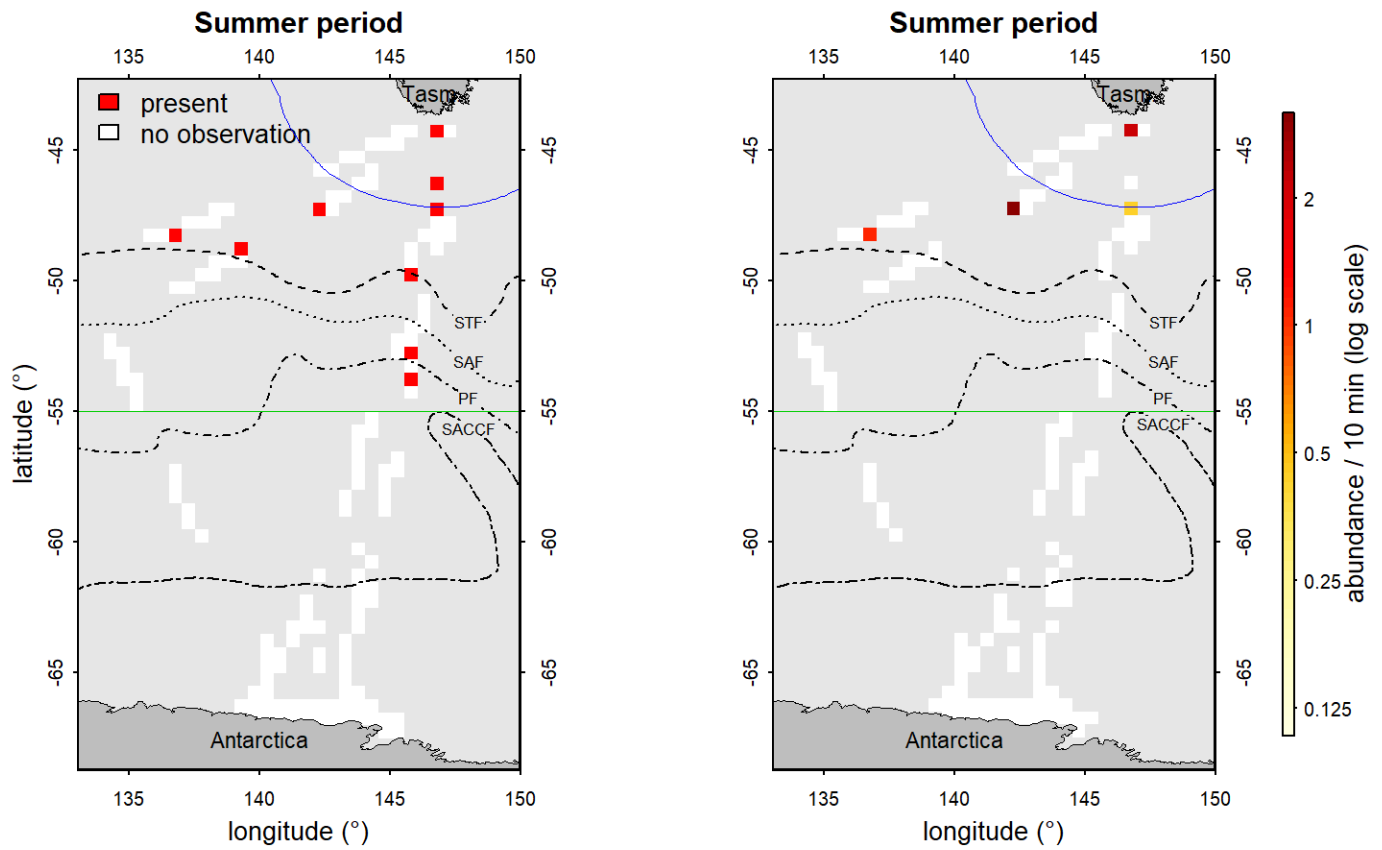


Figure 127 - Presence of Black-bellied Storm-petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

South Georgia Diving-petrel / Common Diving-petrel *Pelecanoides georgicus* / *P. urinatrix* (LC/LC)

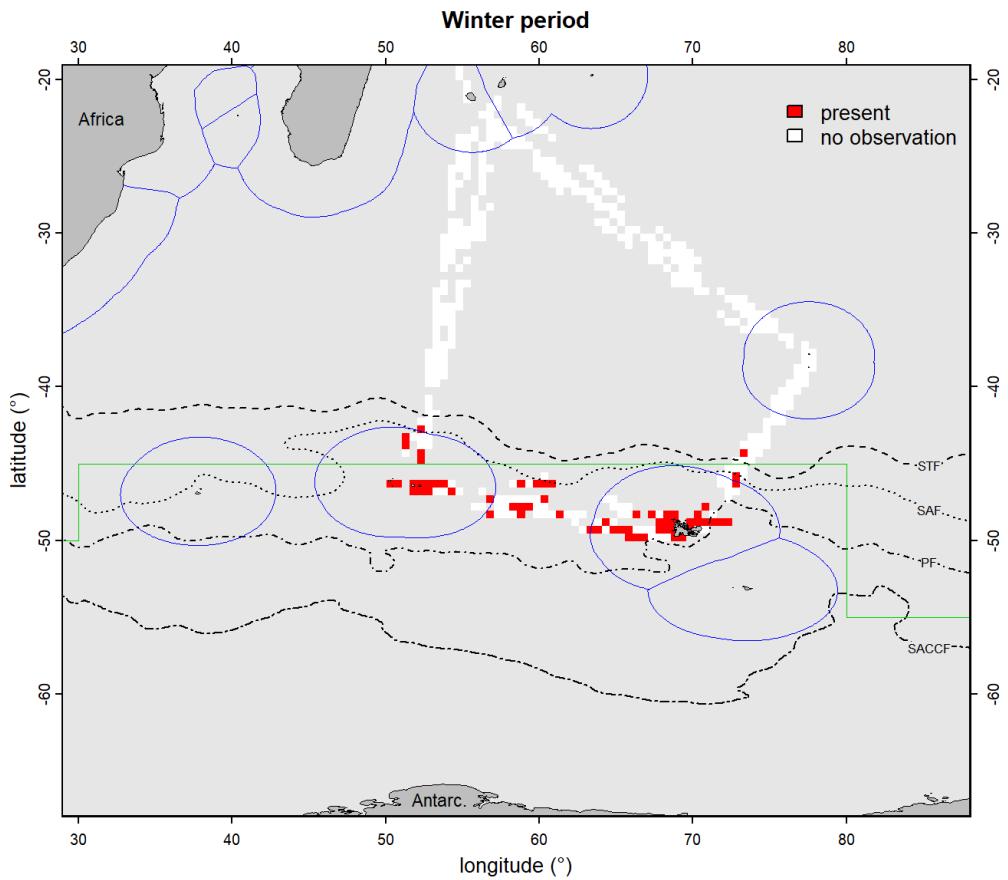
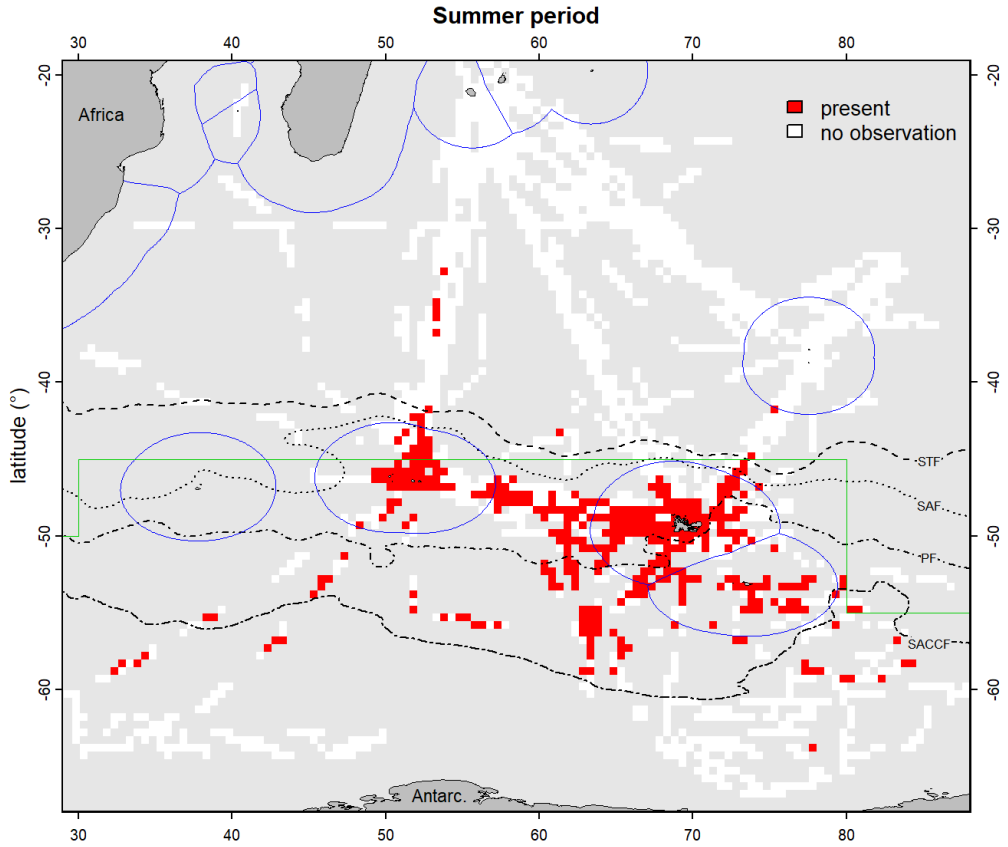


Figure 128 - Presence of South Georgia Diving-petrel / Common Diving-petrel in each 0.5°x0.5° square in the south-west Indian Ocean area

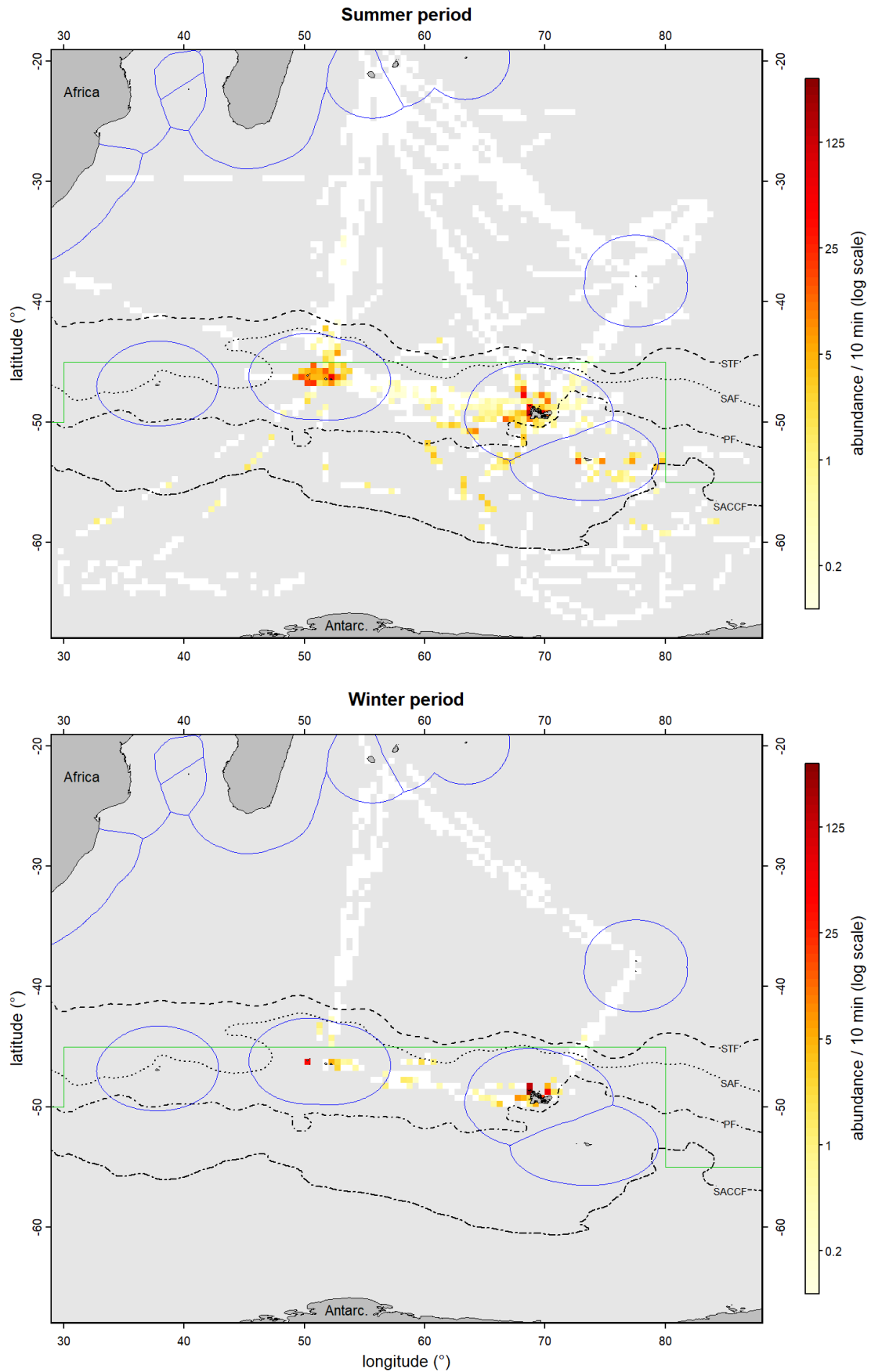


Figure 129 - Mean abundance of South Georgia Diving-petrel / Common Diving-petrel during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

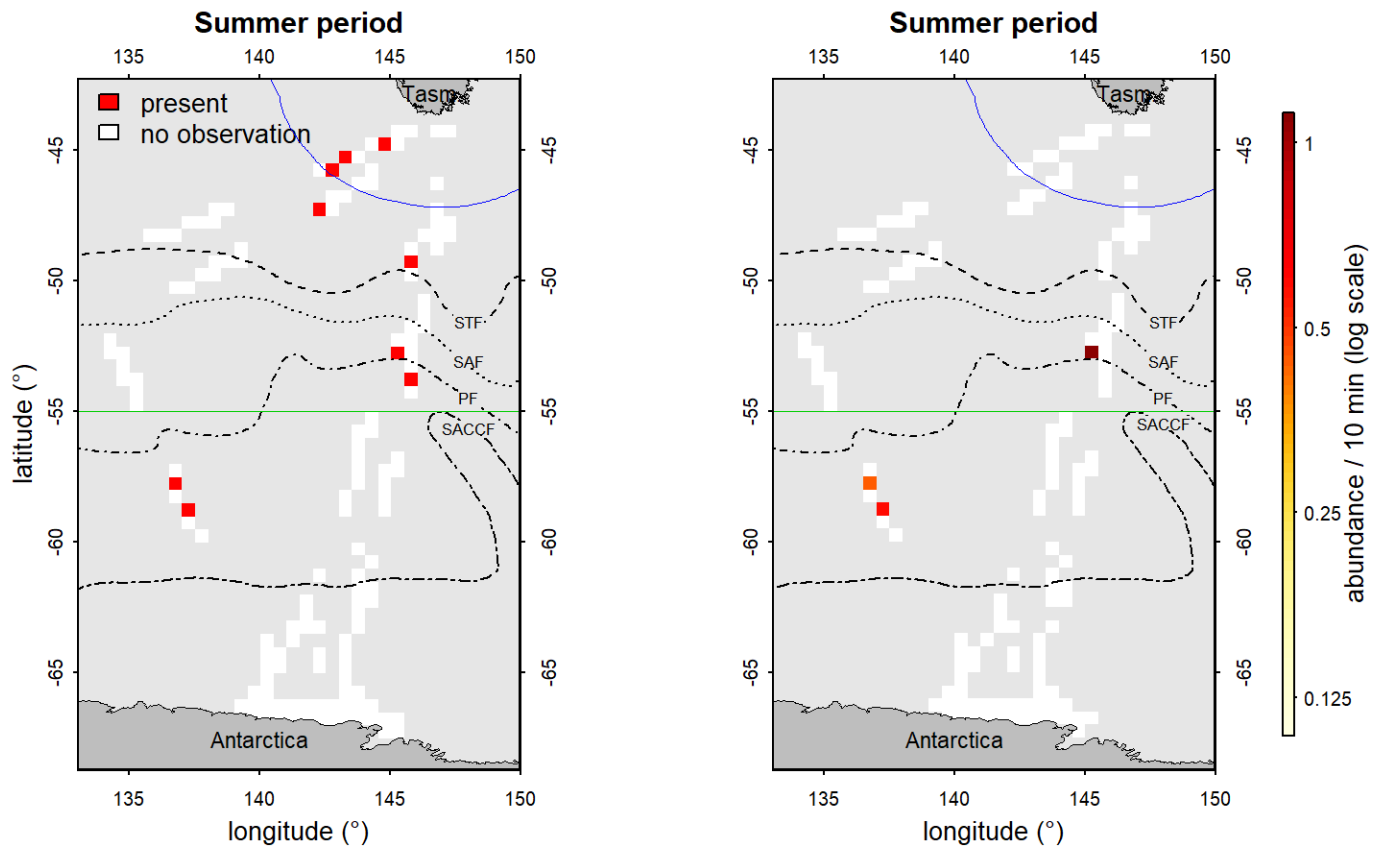


Figure 130 - Presence of South Georgia Diving-petrel / Common Diving-petrel and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Crozet Shag *Phalacrocorax melanogenis* (LC)

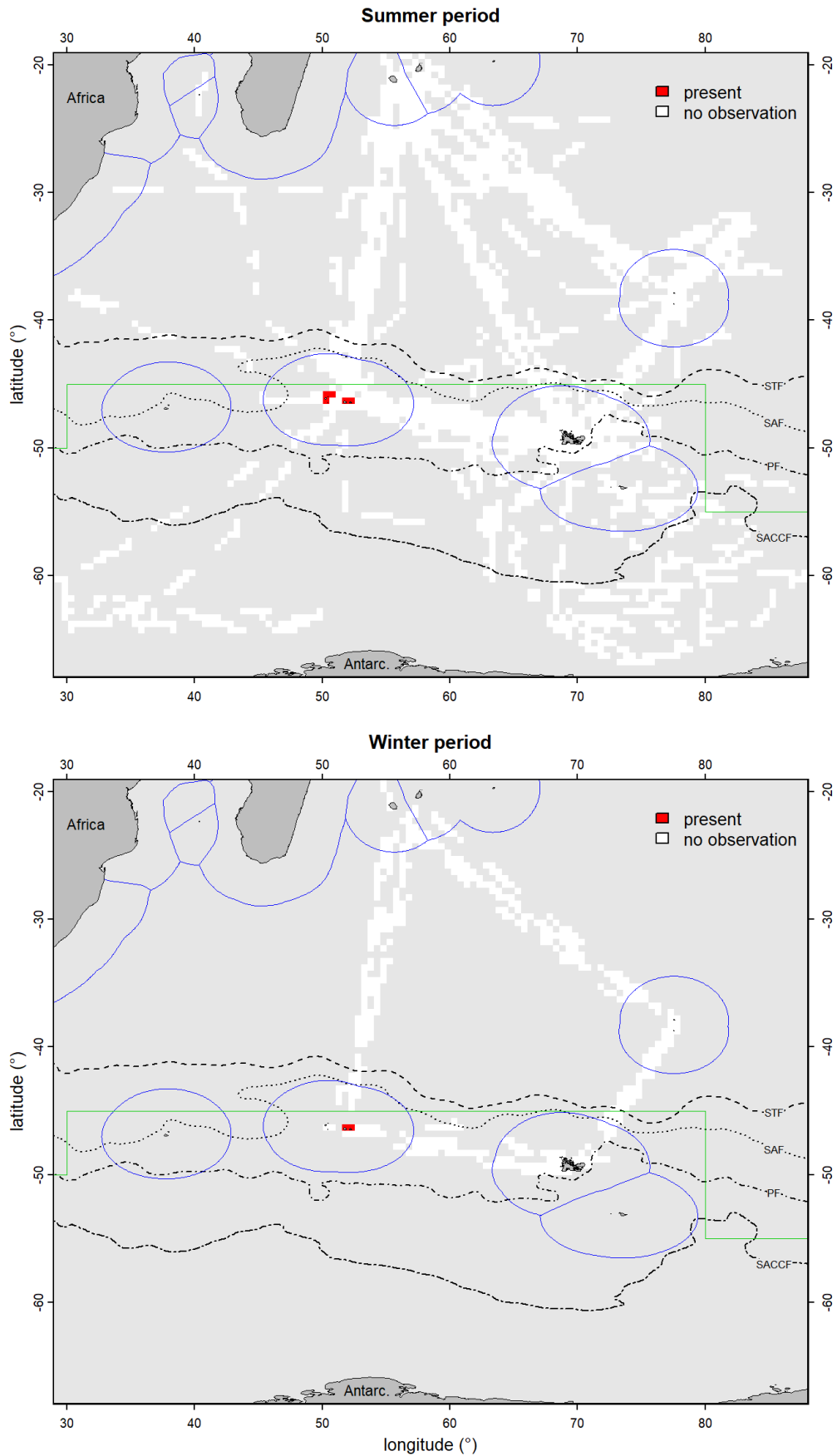


Figure 131 - Presence of Crozet Shag in each 0.5°x0.5° square in the south-west Indian Ocean area

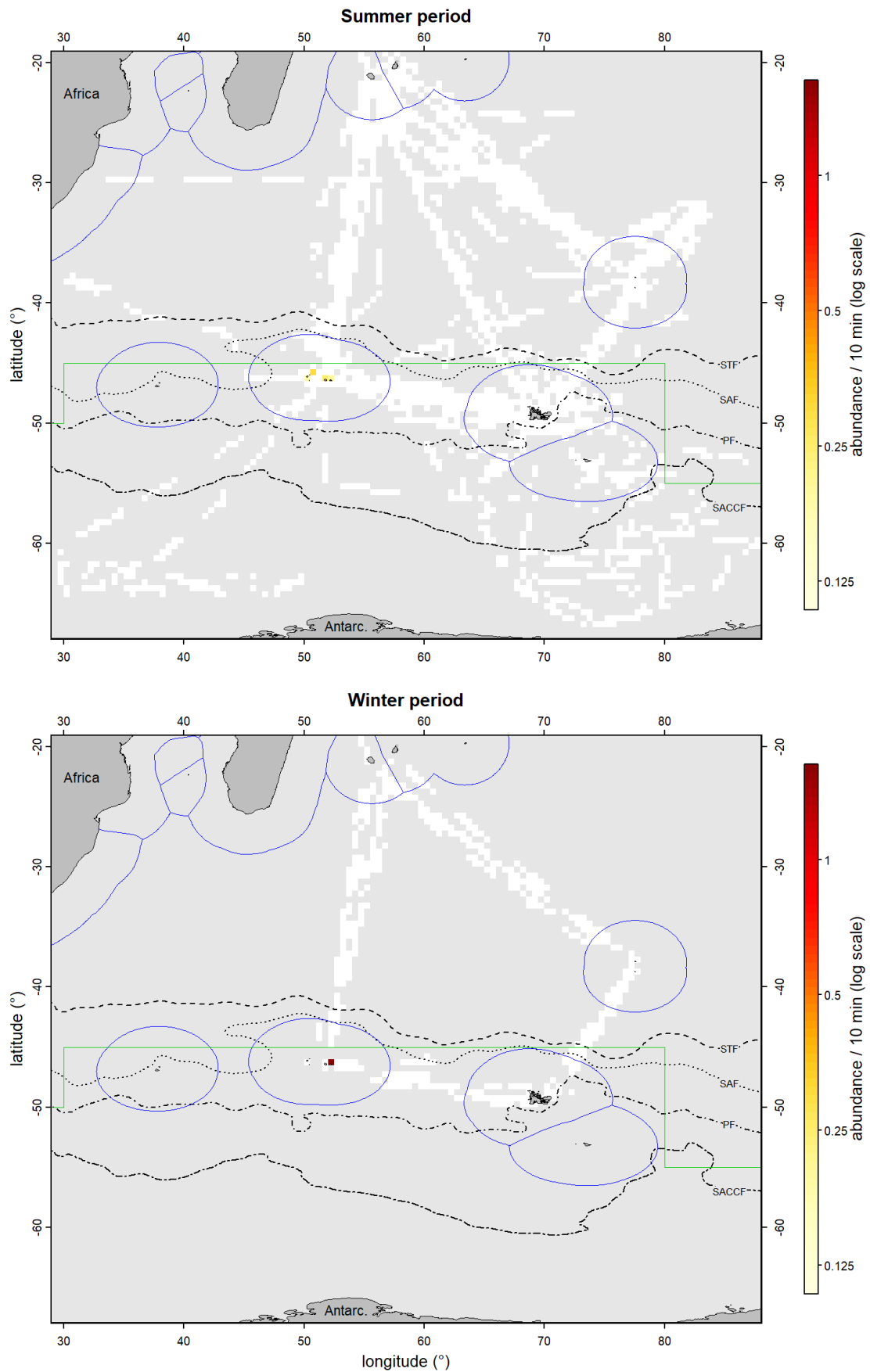


Figure 132 - Mean abundance of Crozet Shag during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Kerguelen Shag *Phalacrocorax verucosus* (LC)

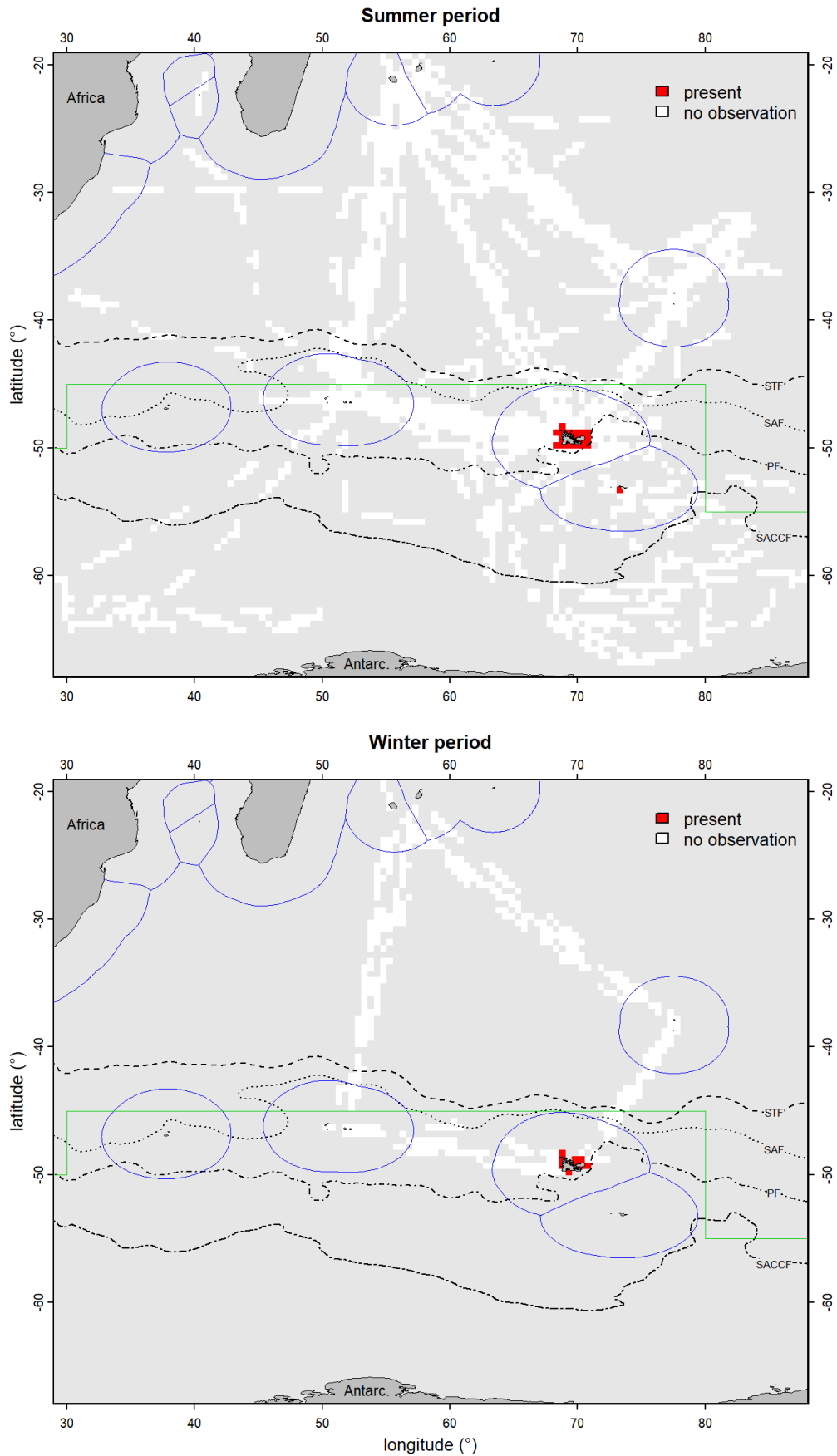


Figure 133 - Presence of Kerguelen Shag in each 0.5°x0.5° square in the south-west Indian Ocean area

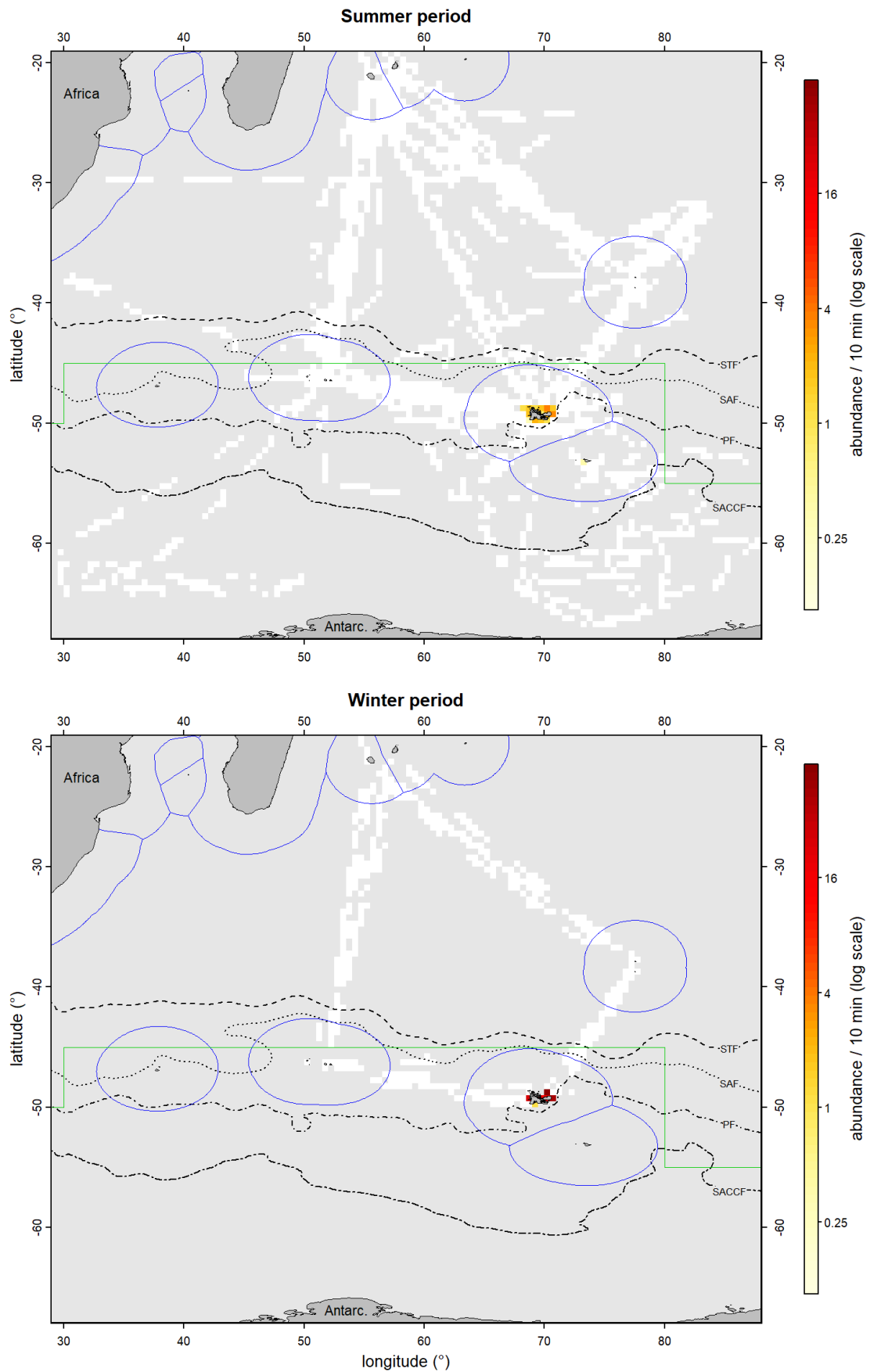


Figure 134 - Mean abundance of Kerguelen Shag during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Masked Booby *Sula dactylatra* (LC)

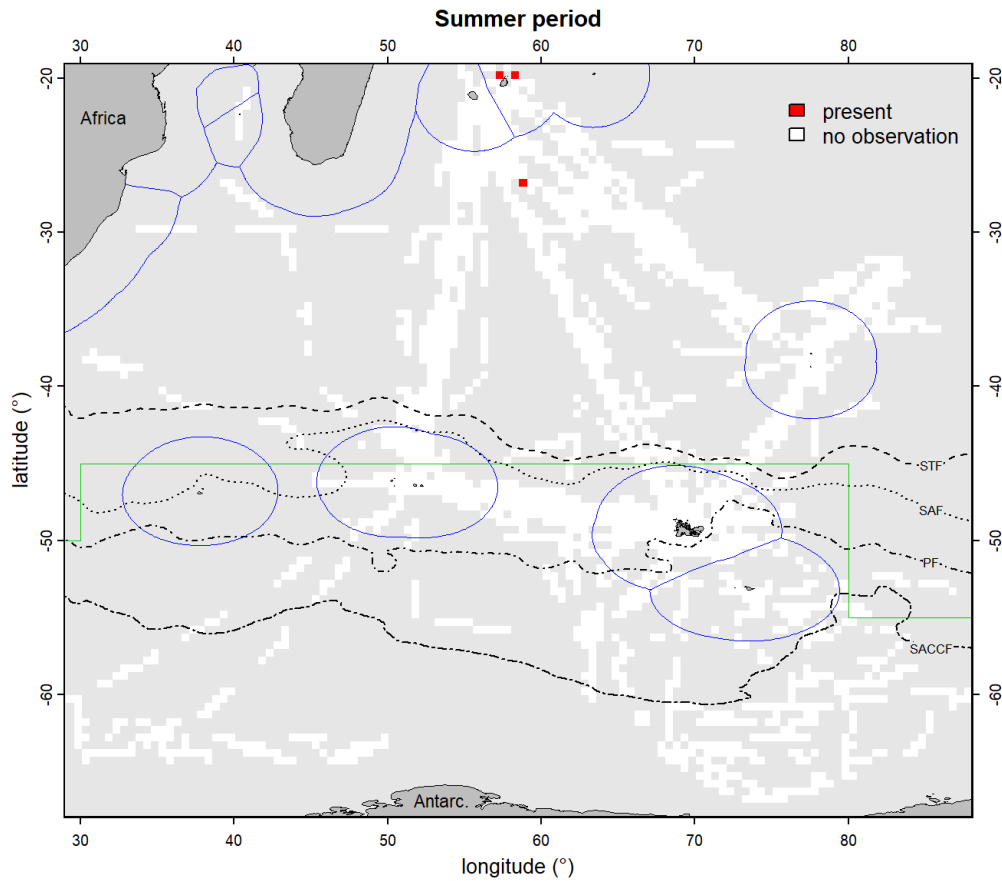


Figure 135 - Presence of Masked Booby in each 0.5°x0.5° square in the south-west Indian Ocean area

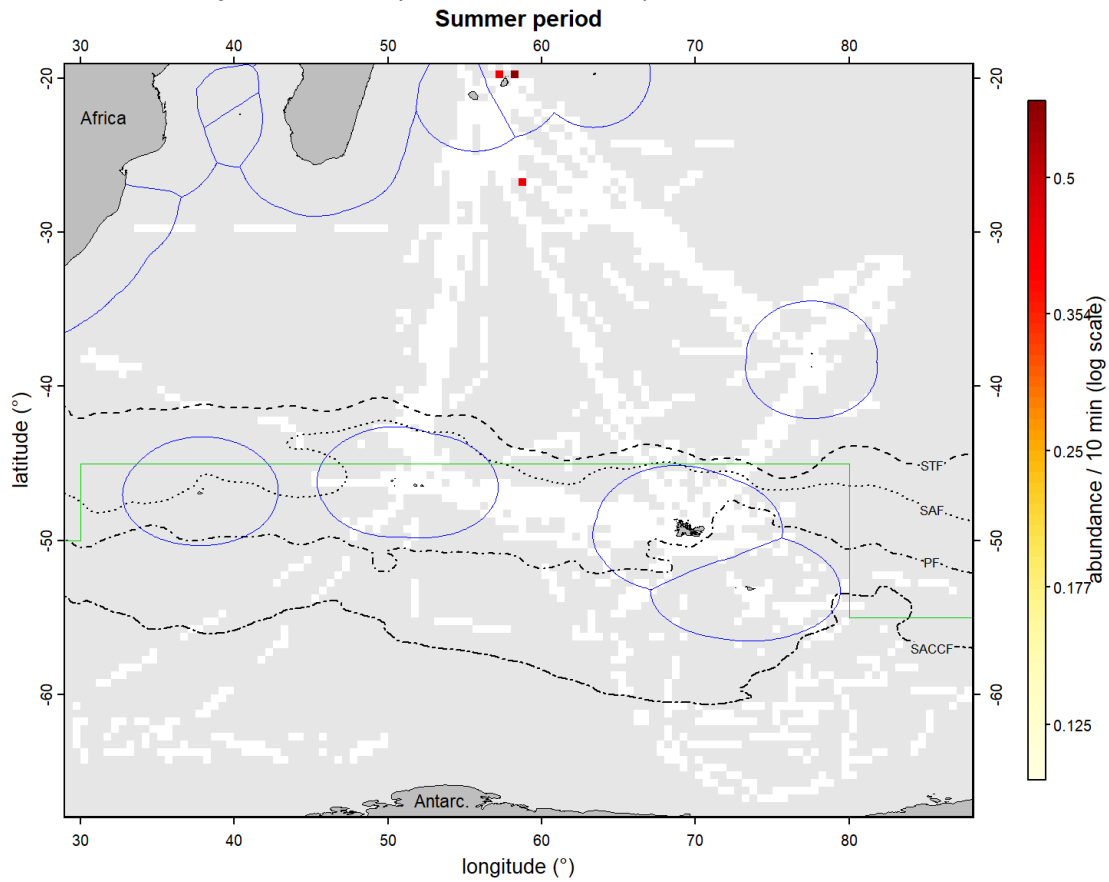


Figure 136 - Mean abundance of Masked Booby during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Red-footed Booby *Sula sula* (LC)

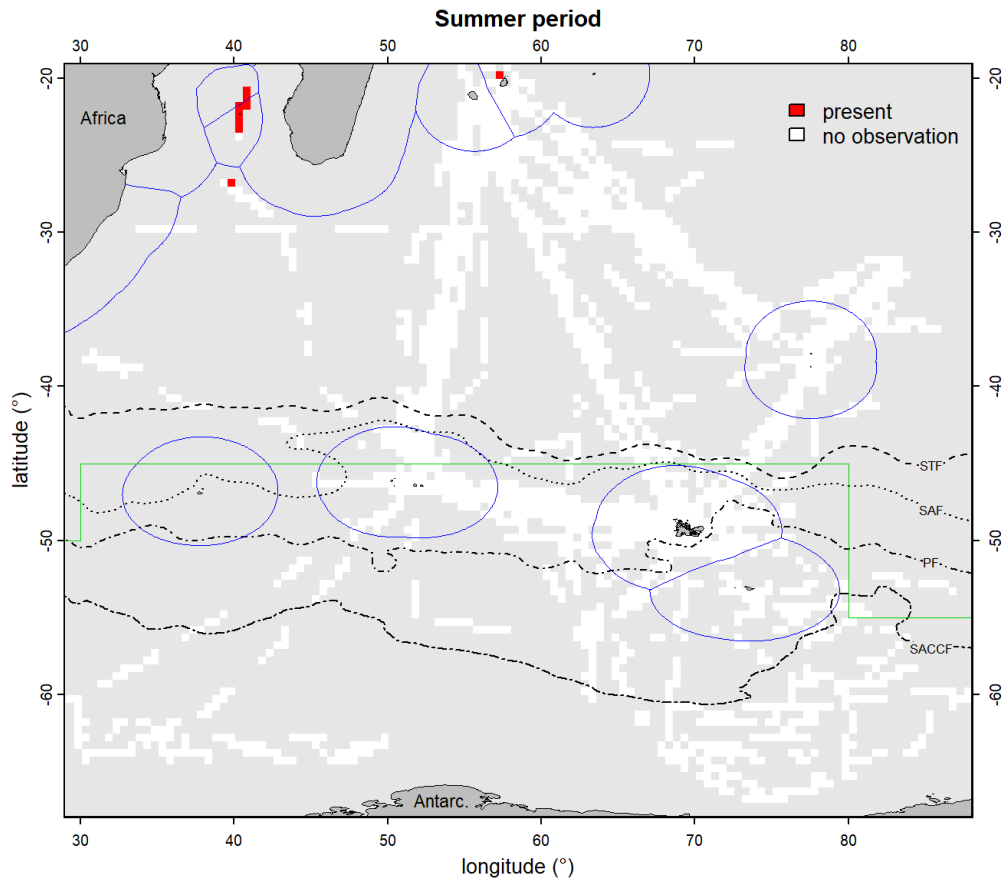


Figure 137 - Presence of Red-footed Booby in each 0.5°x0.5° square in the south-west Indian Ocean area

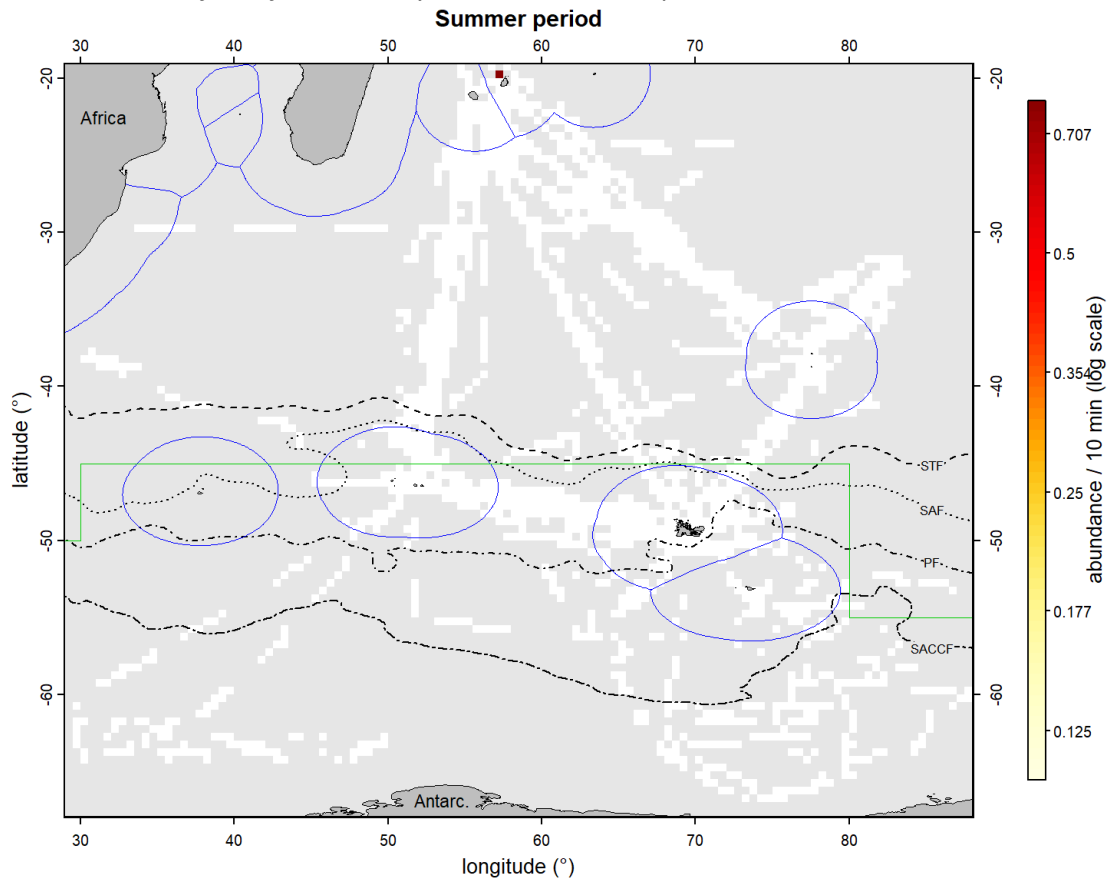


Figure 138 - Mean abundance of Red-footed Booby during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Australasian Gannet / Cape Gannet *Morus serrator* / *M. capensis* (LC/EN)

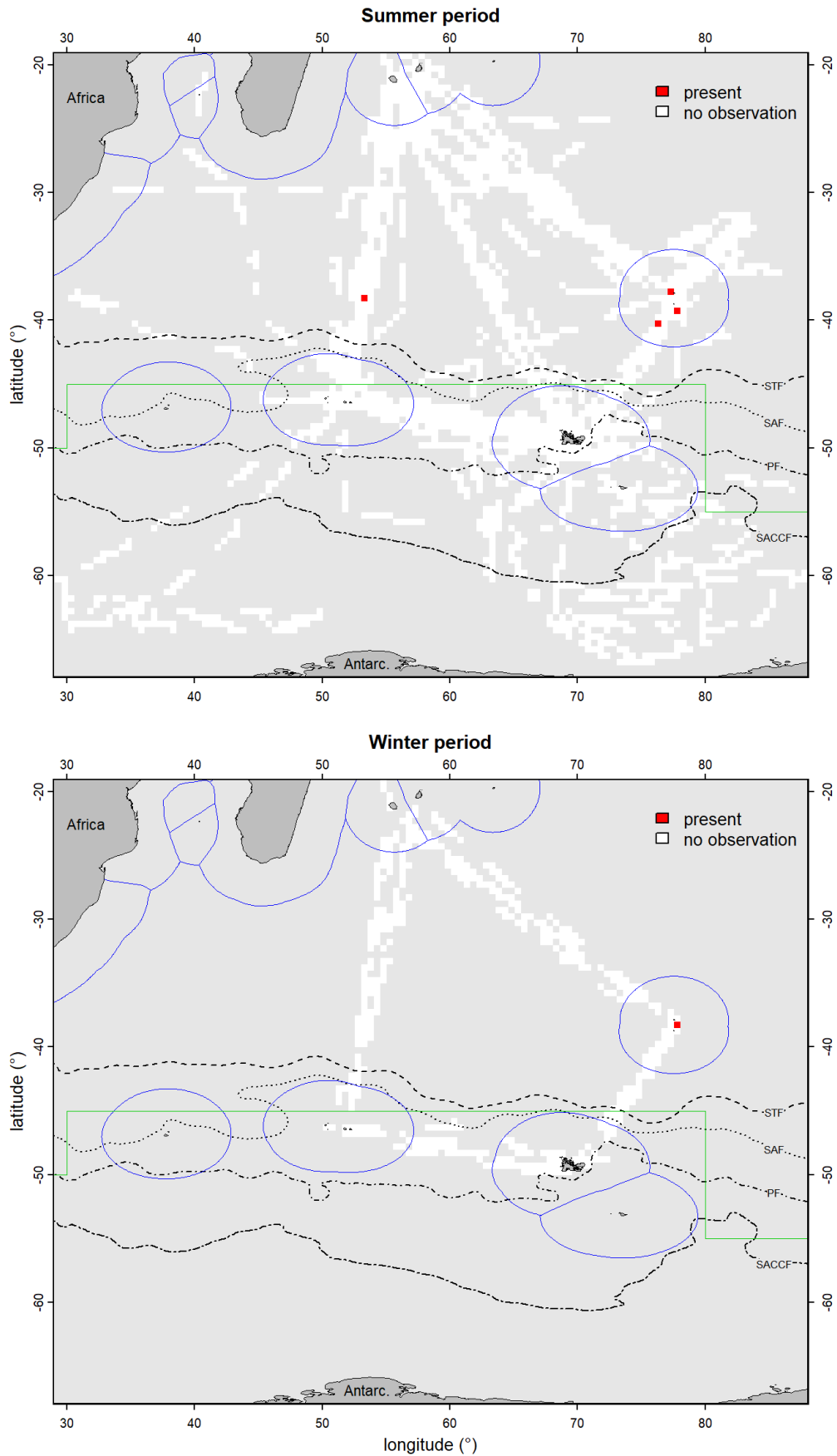


Figure 139 - Presence of Australasian Gannet / Cape Gannet in each 0.5°x0.5° square in the south-west Indian Ocean area

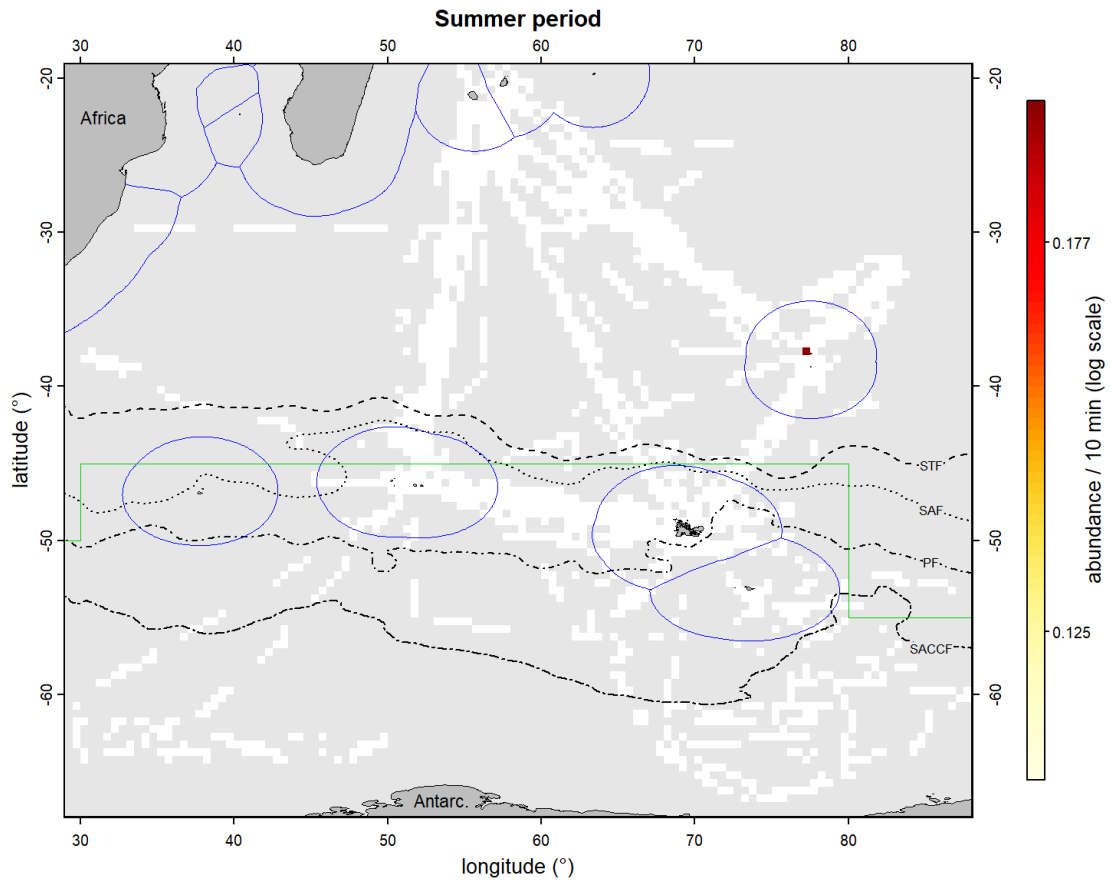


Figure 140 - Mean abundance of Australasian Gannet / Cape Gannet during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

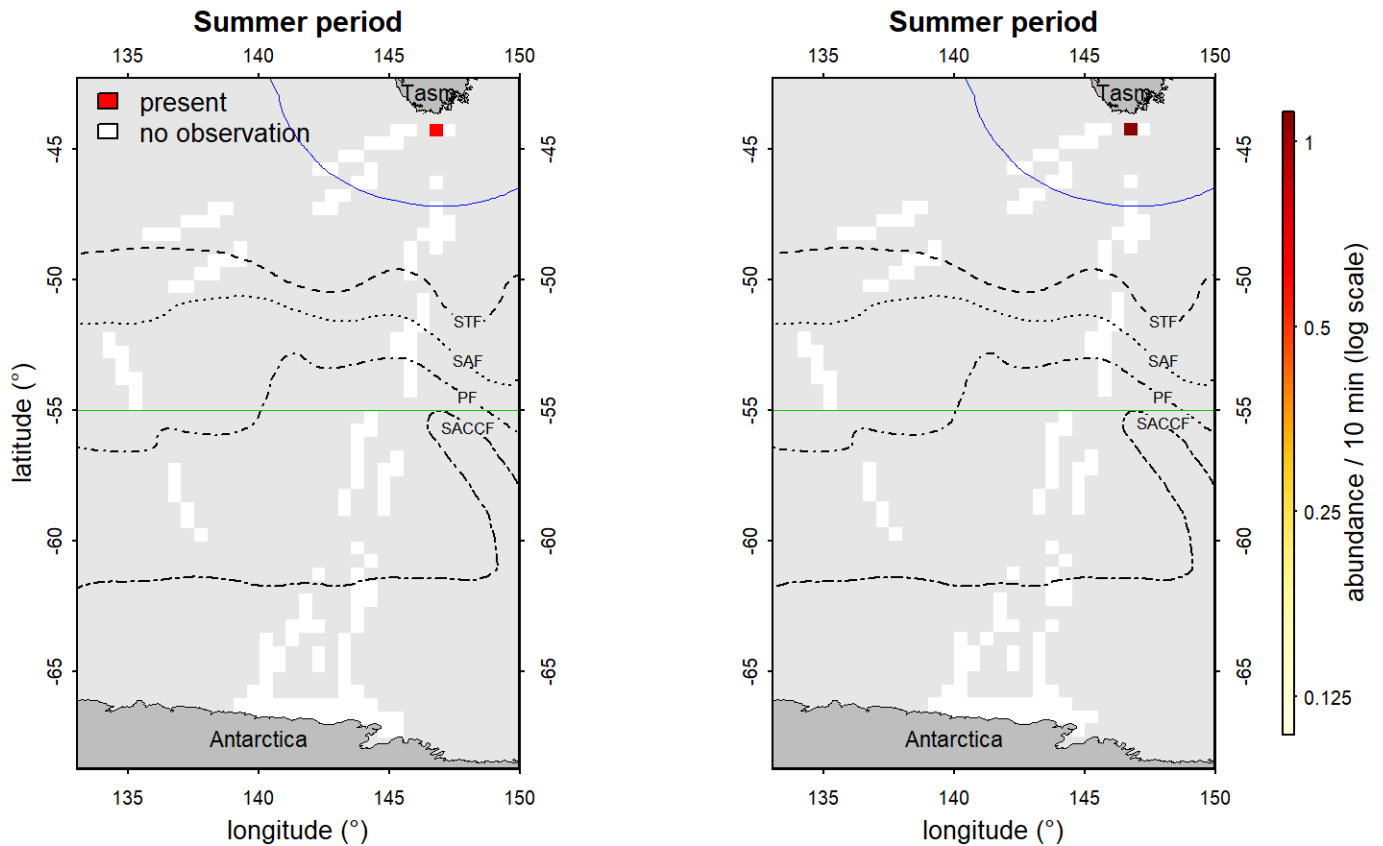


Figure 141 - Presence of Australasian Gannet / Cape Gannet and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

South Polar Skua *Catharacta maccormicki* (LC)

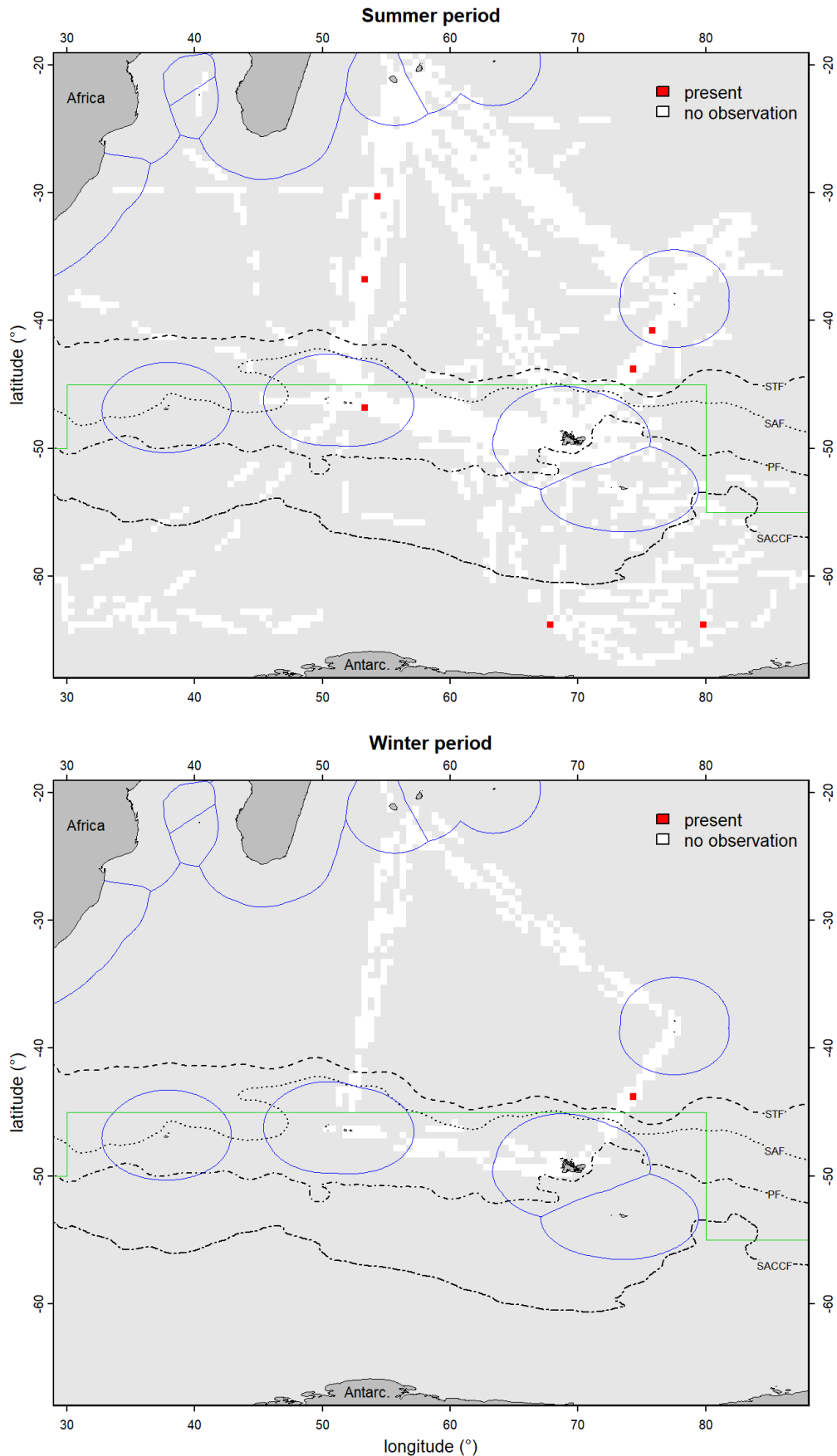


Figure 142 - Presence of South Polar Skua in each 0.5°x0.5° square in the south-west Indian Ocean area

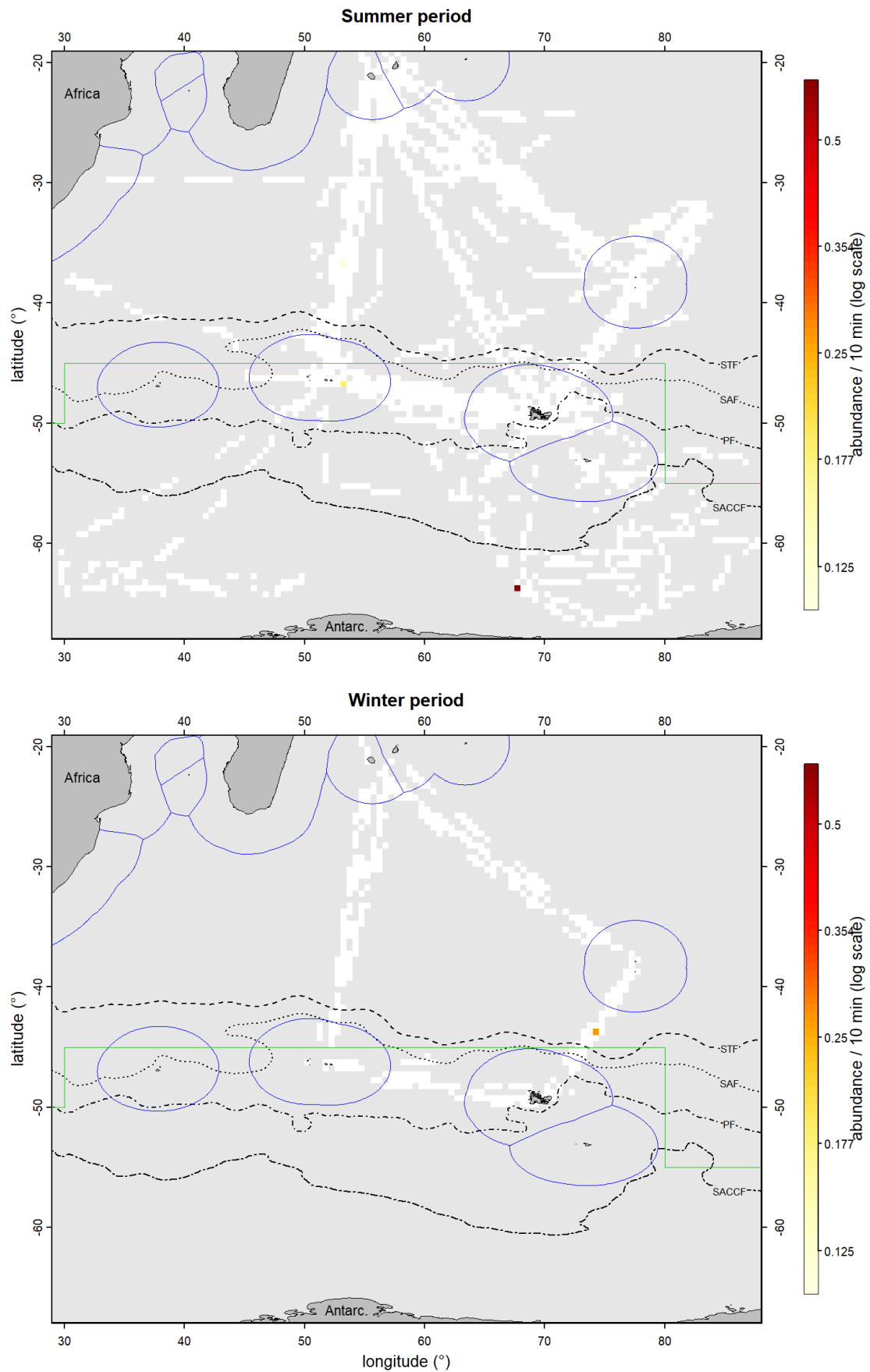


Figure 143 - Mean abundance of South Polar Skua during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

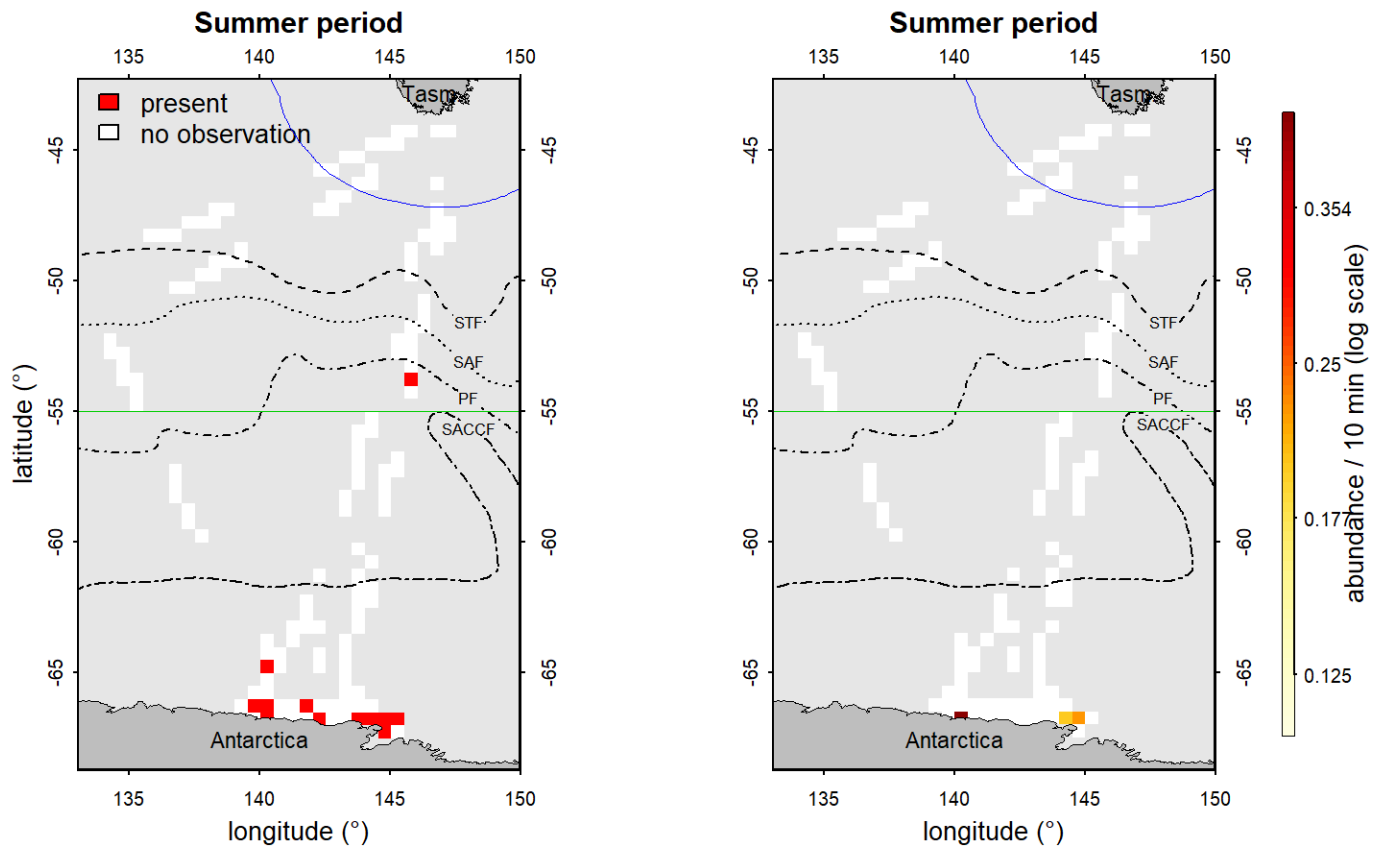


Figure 144 - Presence of South Polar Skua and mean abundance during 10-min counts in each 0.5°x0.5° square between Tasmania and Antarctica

Brown Skua *Catharacta antarctica lonnbergi* (LC)

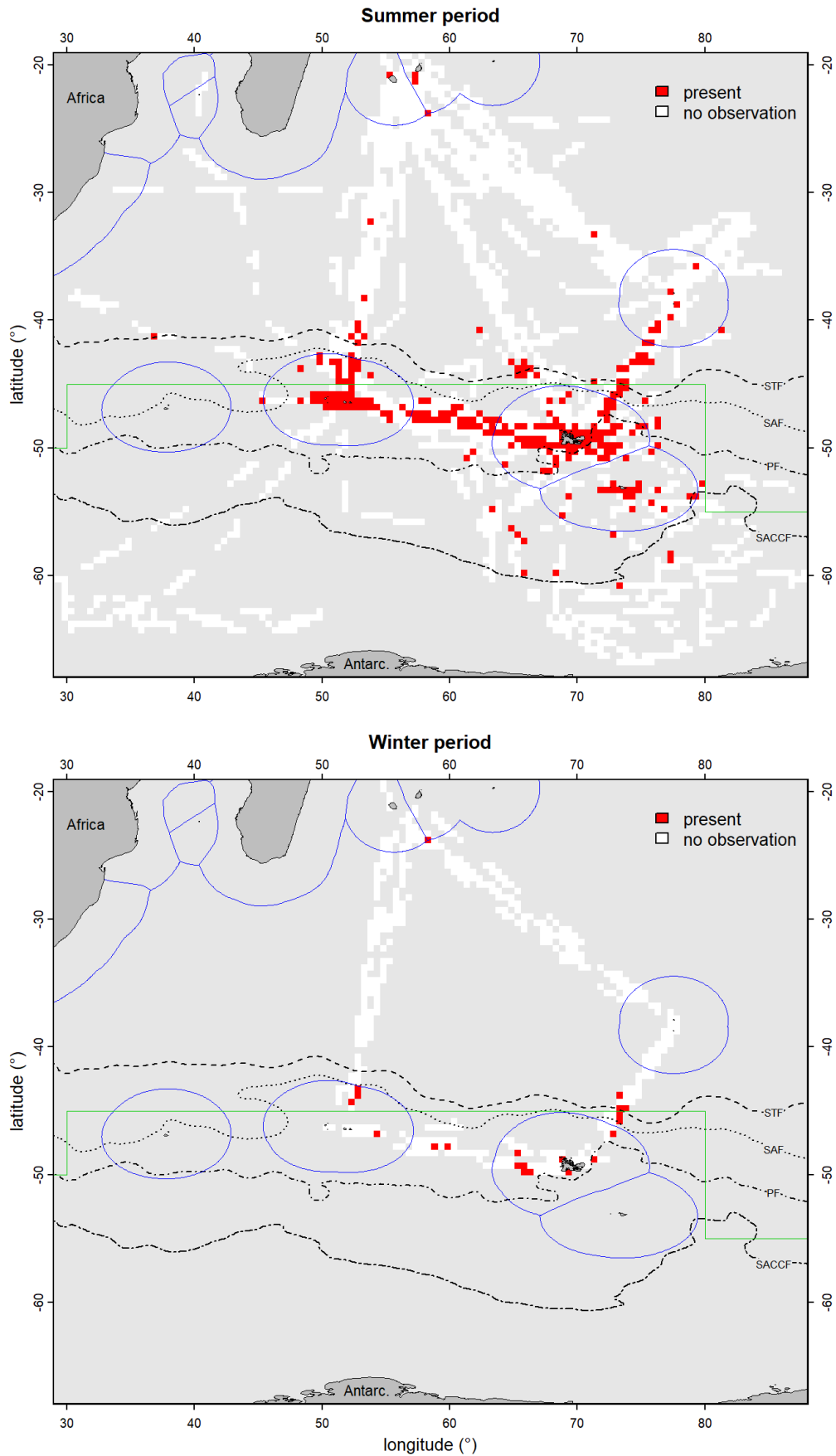


Figure 145 - Presence of Brown Skua in each 0.5°x0.5° square in the south-west Indian Ocean area

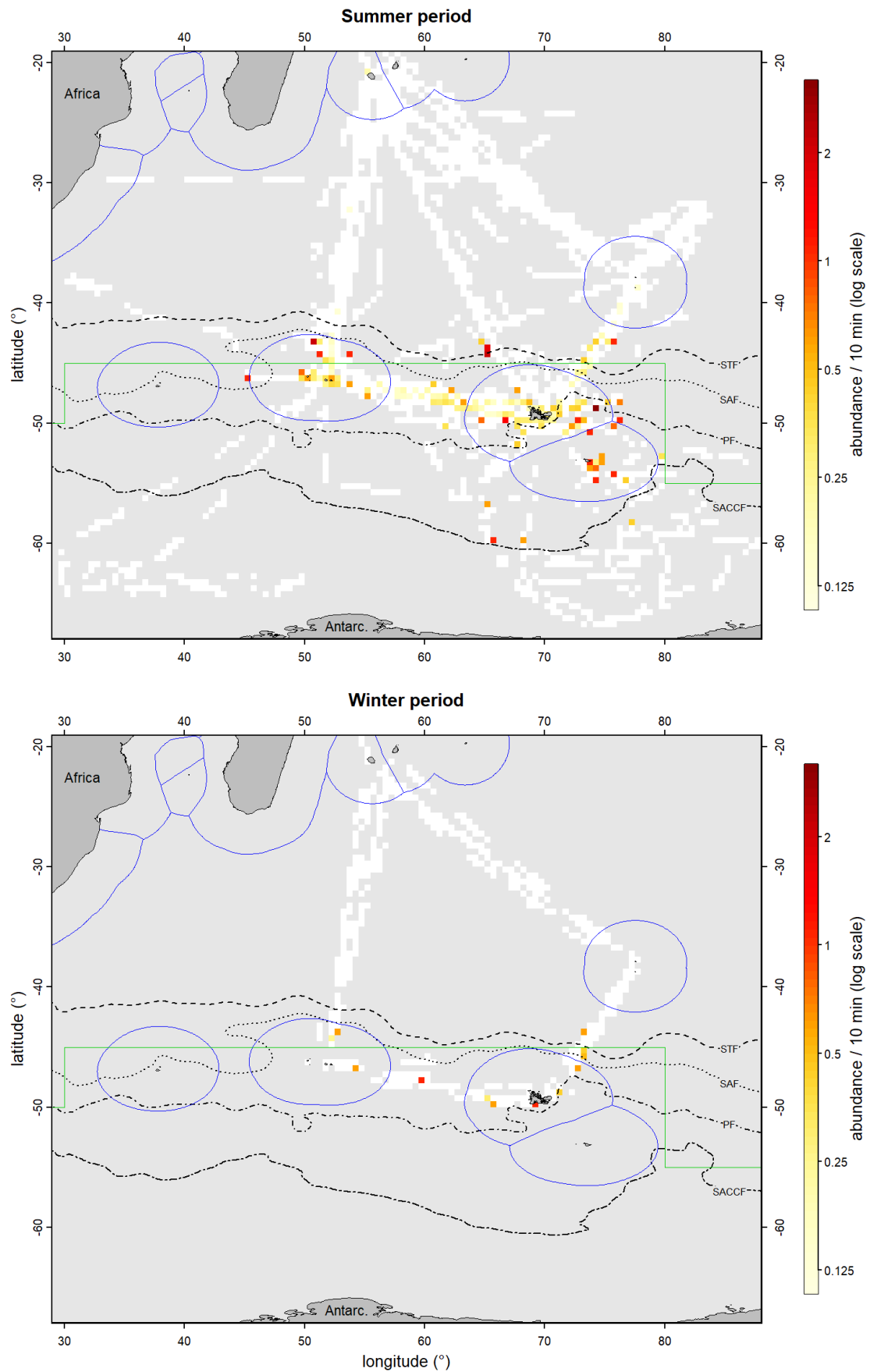


Figure 146 - Mean abundance of Brown Skua during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Long-tailed Jaeger *Stercorarius longicaudus* (LC)

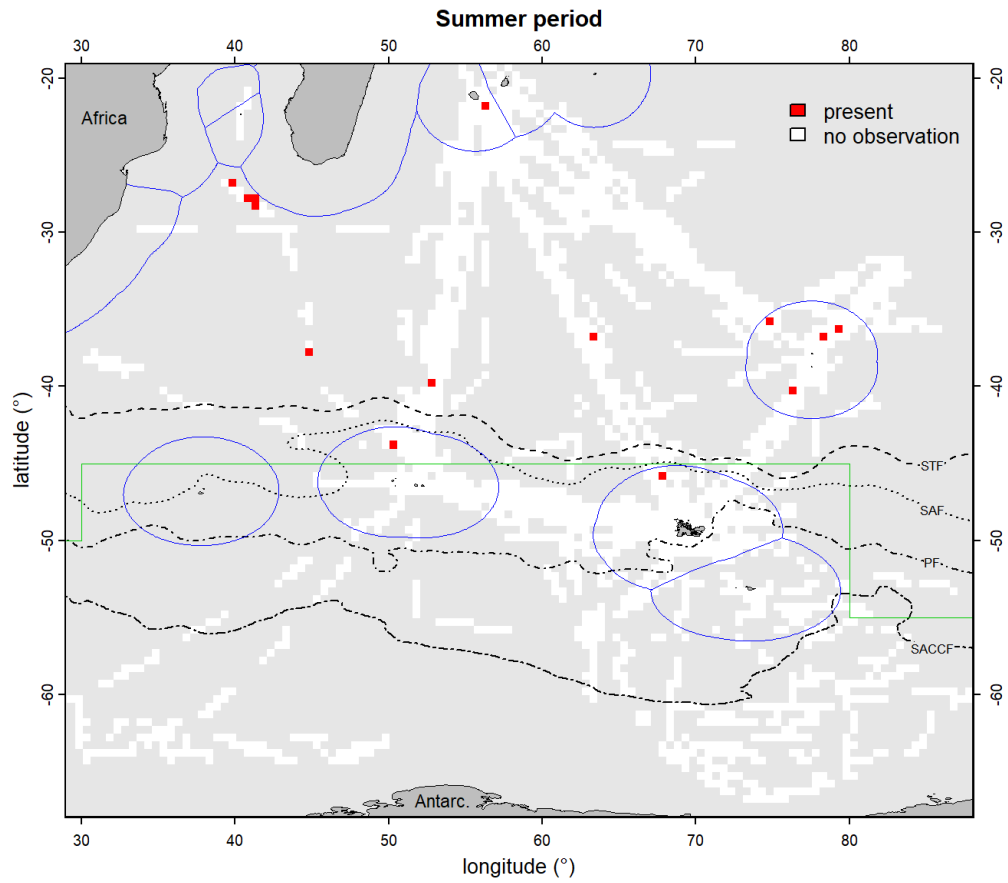


Figure 147 - Presence of Long-tailed Jaeger in each 0.5°x0.5° square in the south-west Indian Ocean area

Parasitic Jaeger *Stercorarius parasiticus* (LC)

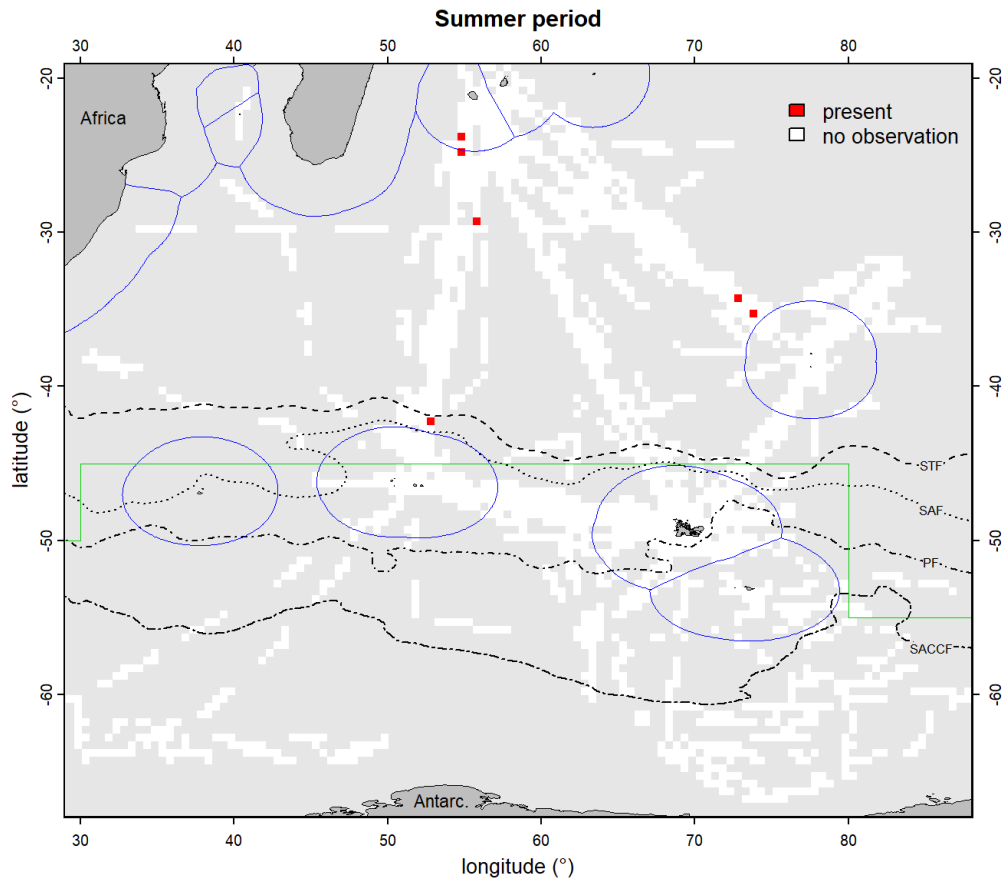


Figure 148 - Presence of Parasitic Jaeger in each 0.5°x0.5° square in the south-west Indian Ocean area

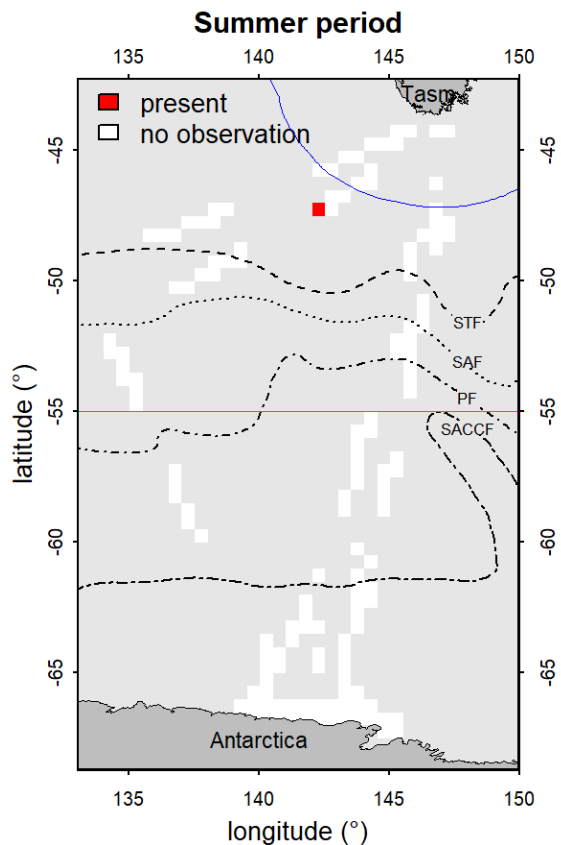


Figure 149 - Presence of Parasitic Jaeger in each 0.5°x0.5° square between Tasmania and Antarctica

Pomarine Jaeger *Stercorarius pomarinus* (LC)

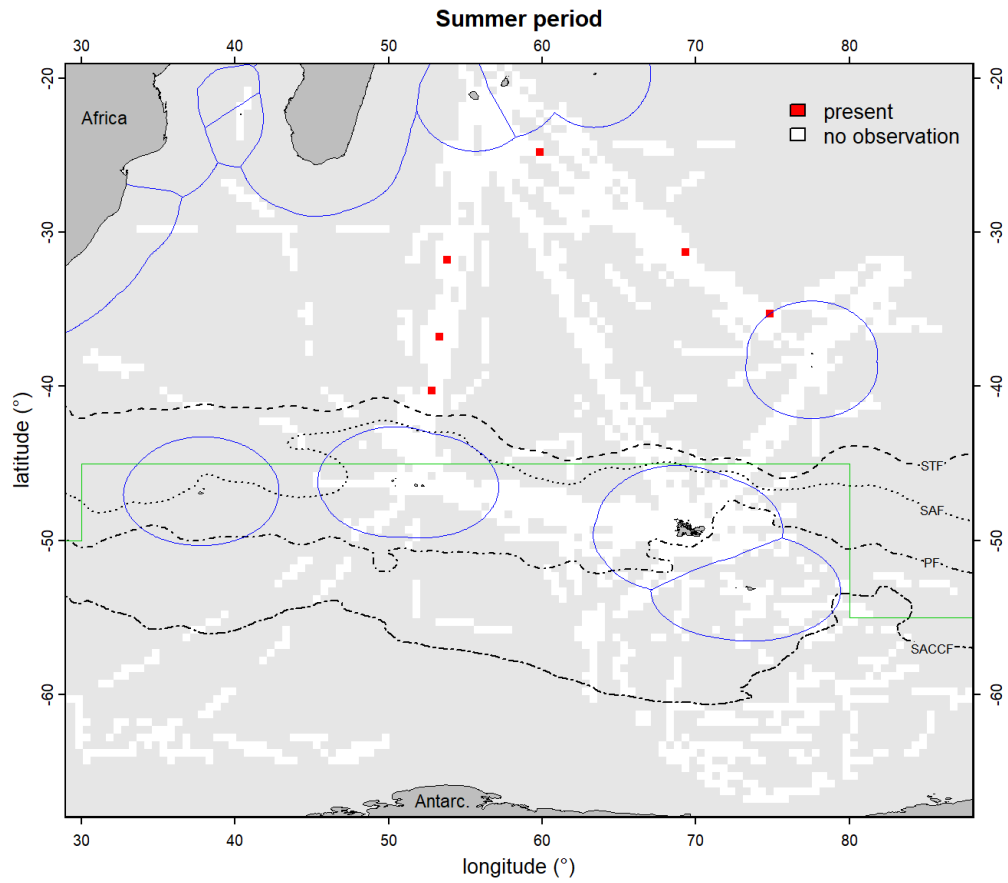


Figure 150 - Presence of Pomarine Jaeger in each 0.5°x0.5° square in the south-west Indian Ocean area

Kelp Gull *Larus dominicanus* (LC)

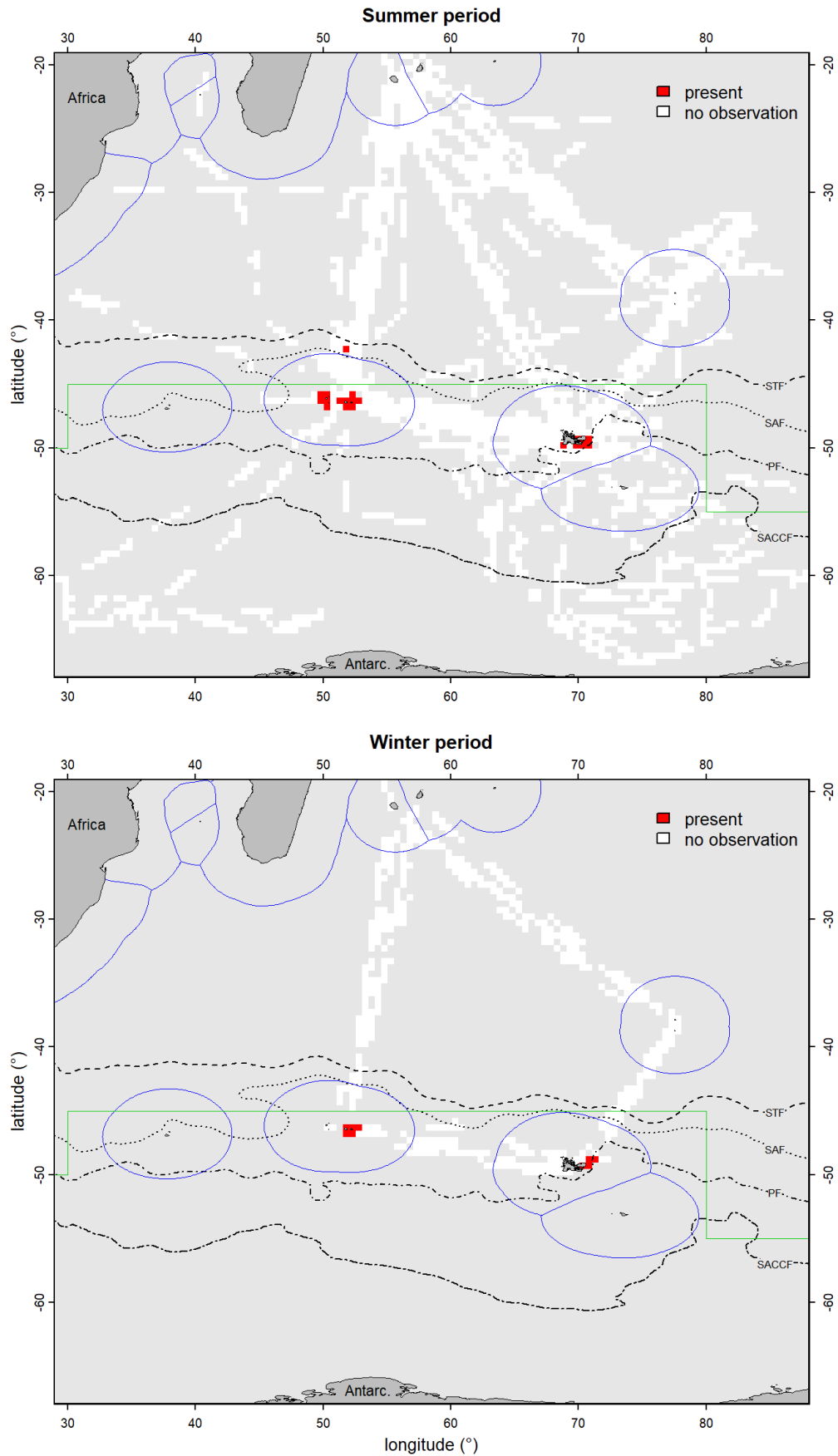


Figure 151 - Presence of Kelp Gull in each 0.5°x0.5° square in the south-west Indian Ocean area

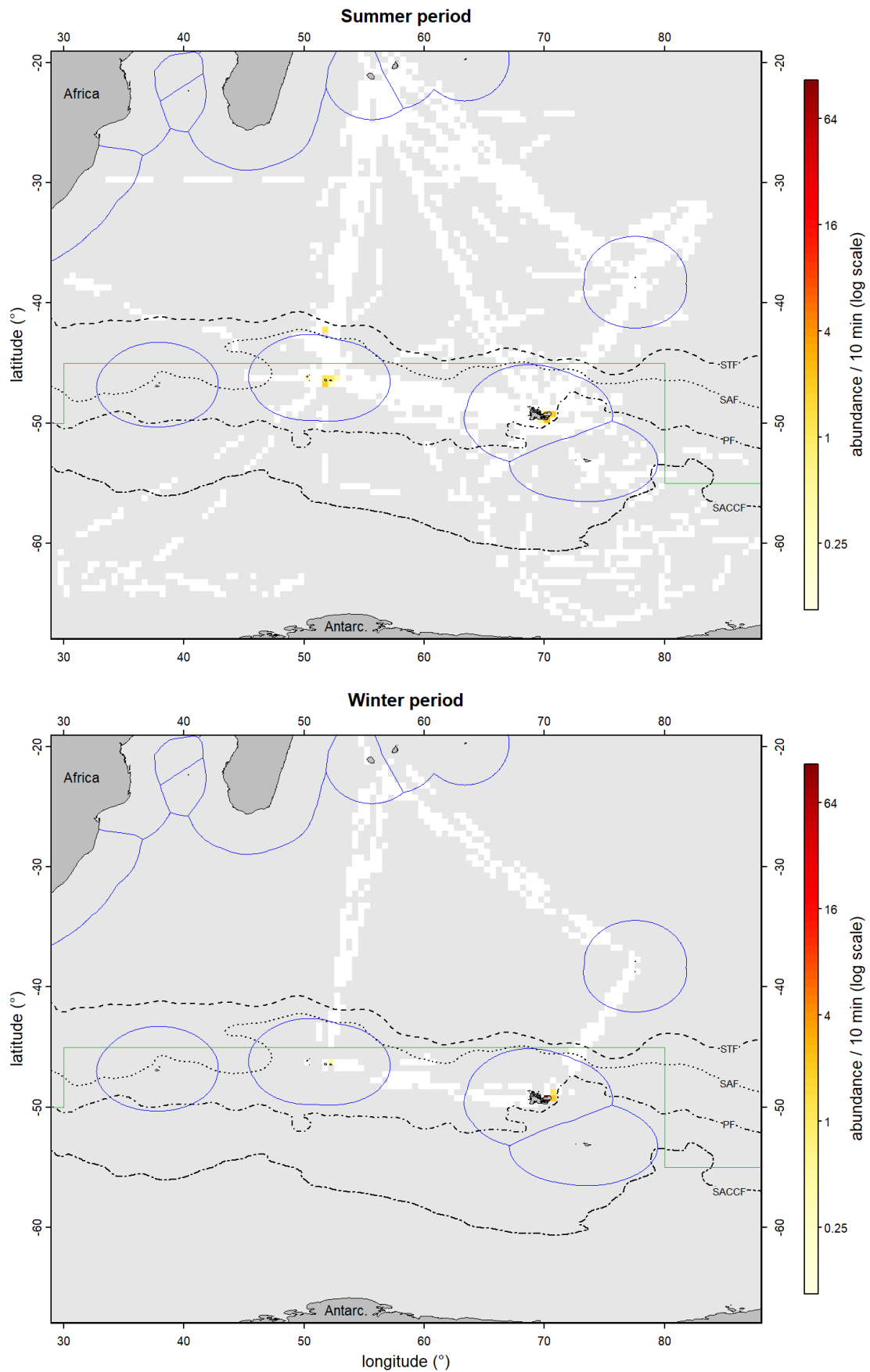


Figure 152 - Mean abundance of Kelp Gull during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Antarctic Tern / Arctic Tern *Sterna vittata* / *S. paradisaea* (LC/LC)

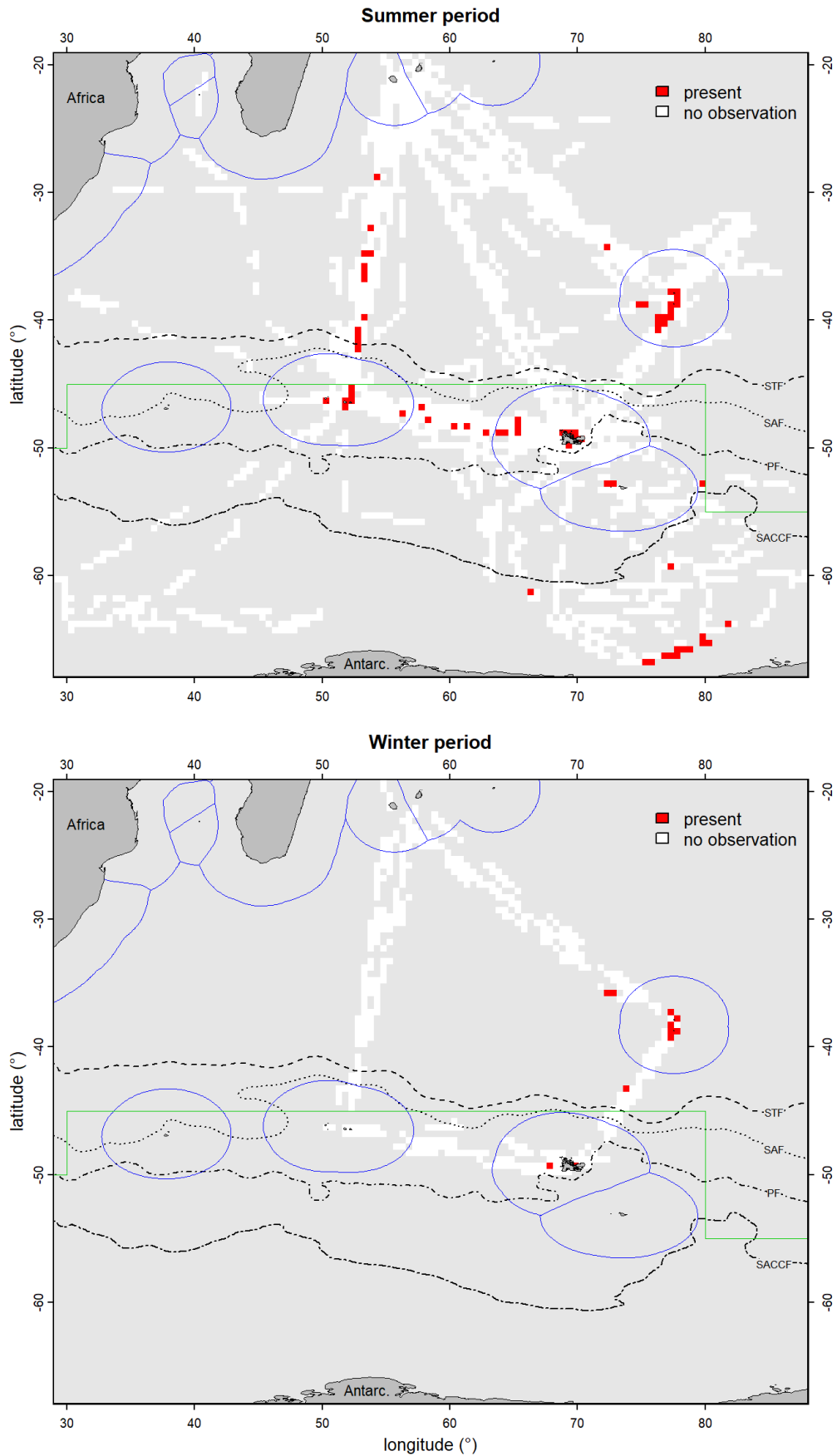


Figure 153 - Presence of Antarctic Tern / Arctic Tern in each 0.5°x0.5° square in the south-west Indian Ocean area

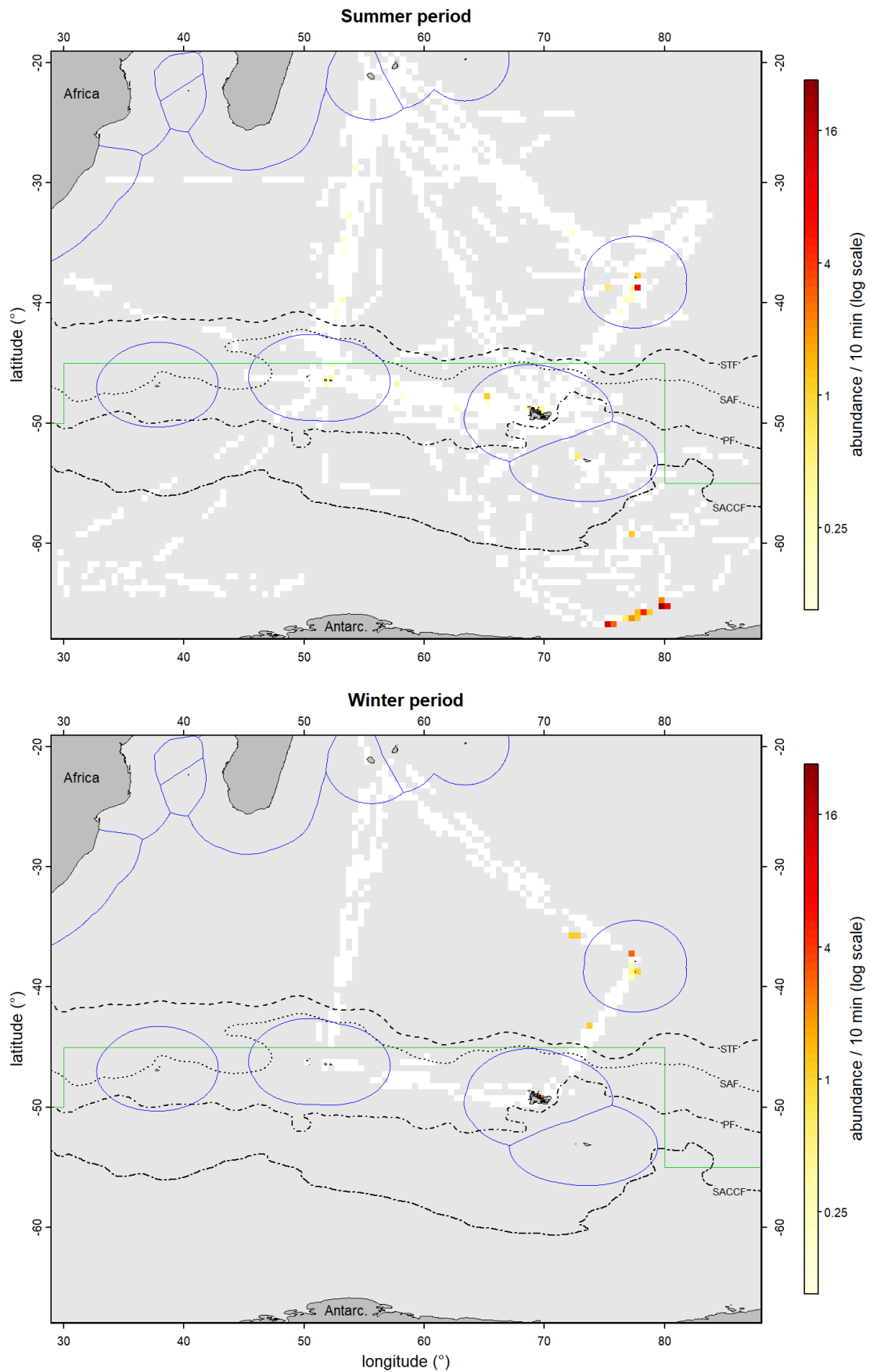


Figure 154 - Mean abundance of Antarctic Tern / Arctic Tern during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Kerguelen Tern *Sterna virgata* (NT)

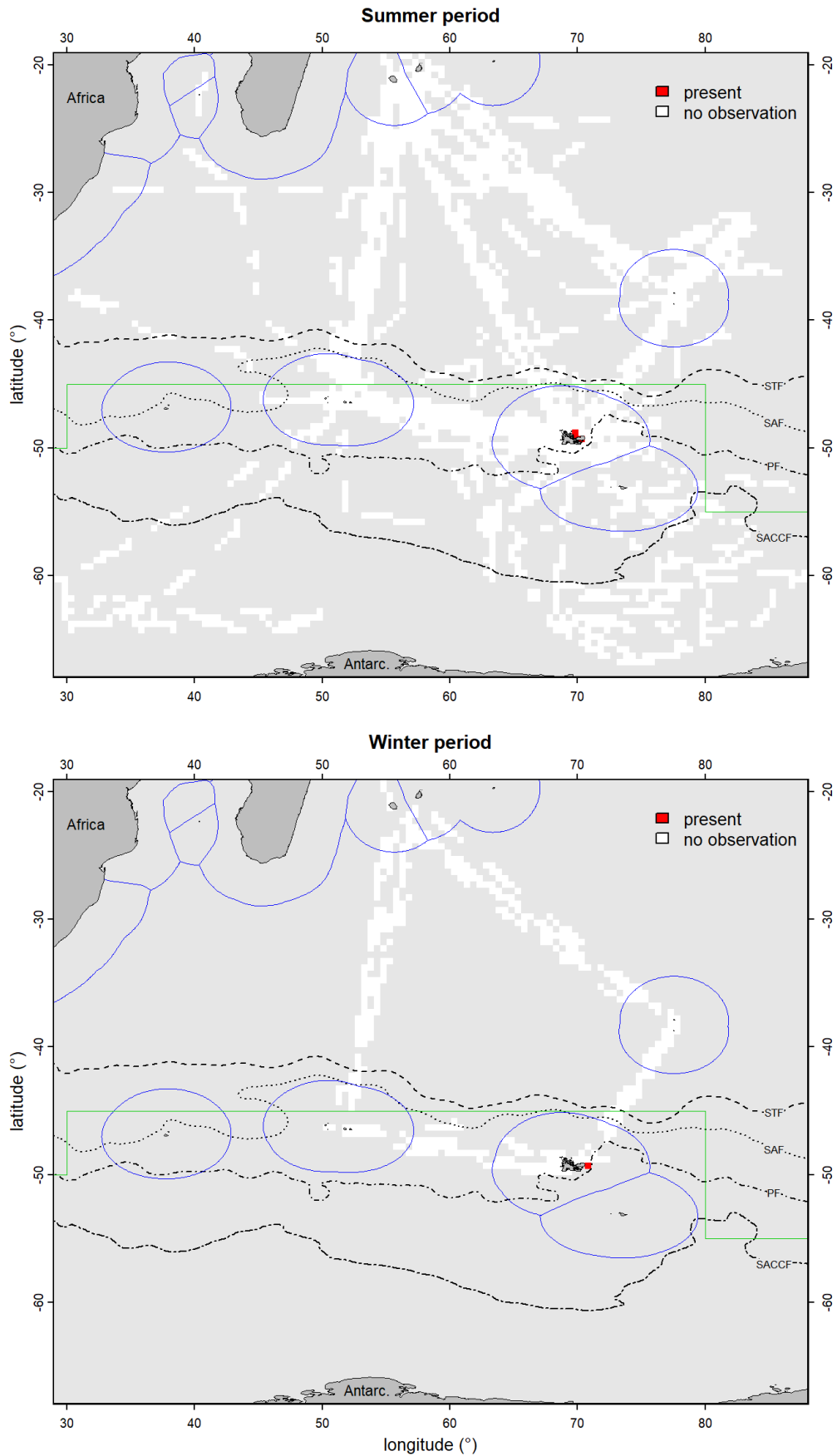


Figure 155 - Presence of Kerguelen Tern in each 0.5°x0.5° square in the south-west Indian Ocean area

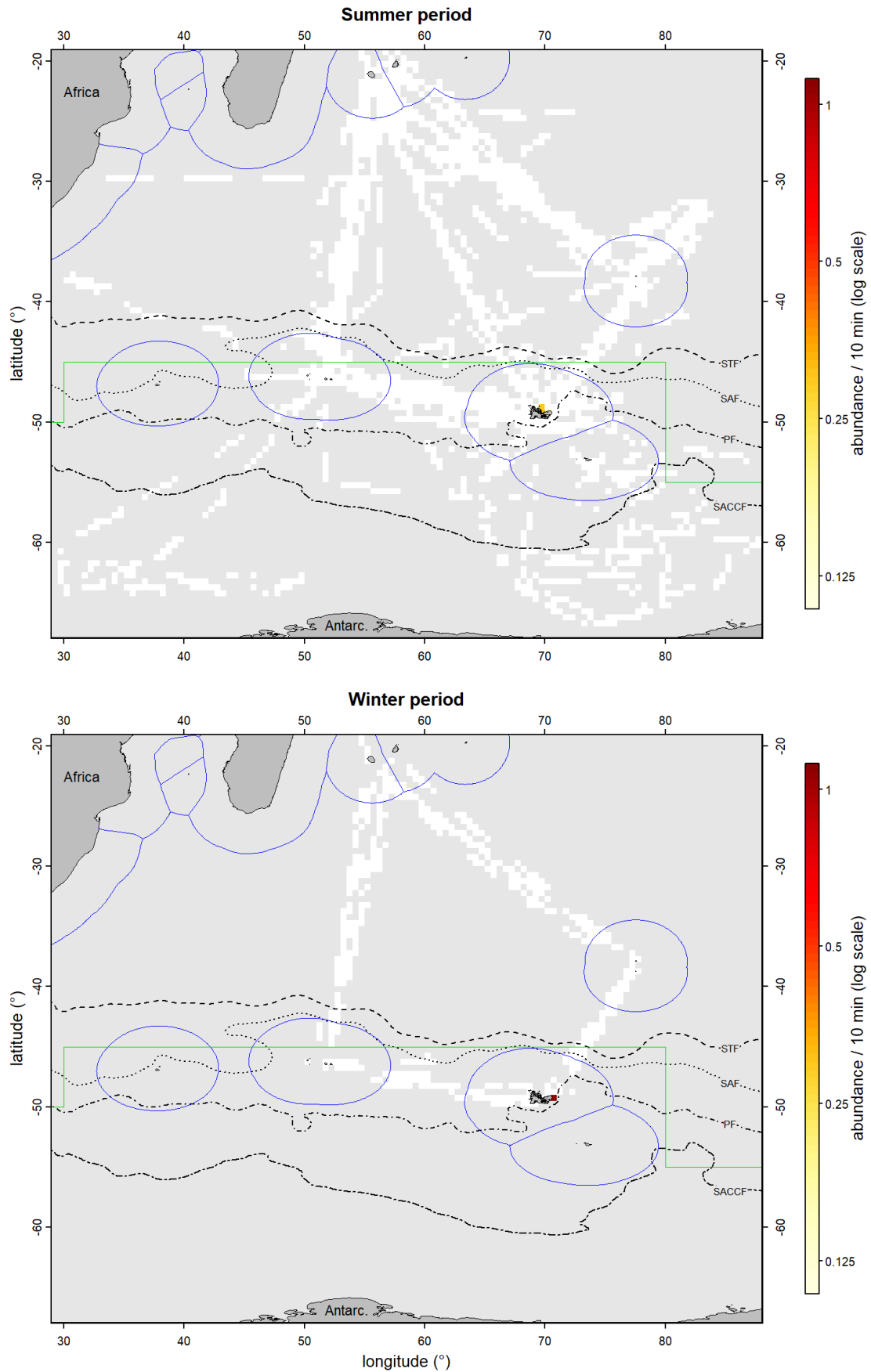


Figure 156 - Mean abundance of Kerguelen Tern during 10-min counts in each $0.5^{\circ} \times 0.5^{\circ}$ square in the south-west Indian Ocean area

Sooty Tern / Bridled Tern *Onychoprion fuscata* / *O. anaethetus* (LC/LC)

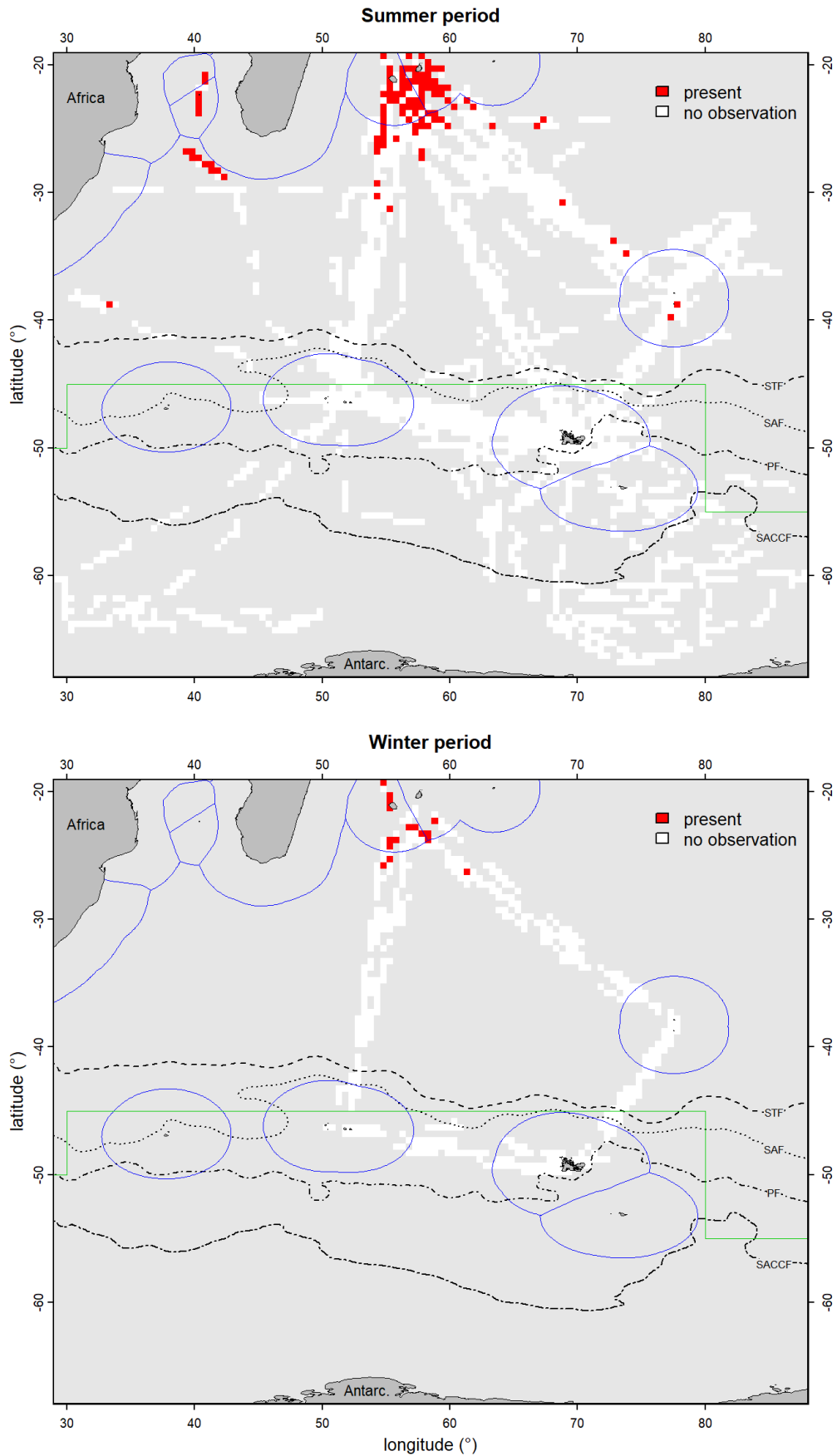


Figure 157 - Presence of Sooty Tern / Bridled Tern in each 0.5°x0.5° square in the south-west Indian Ocean area

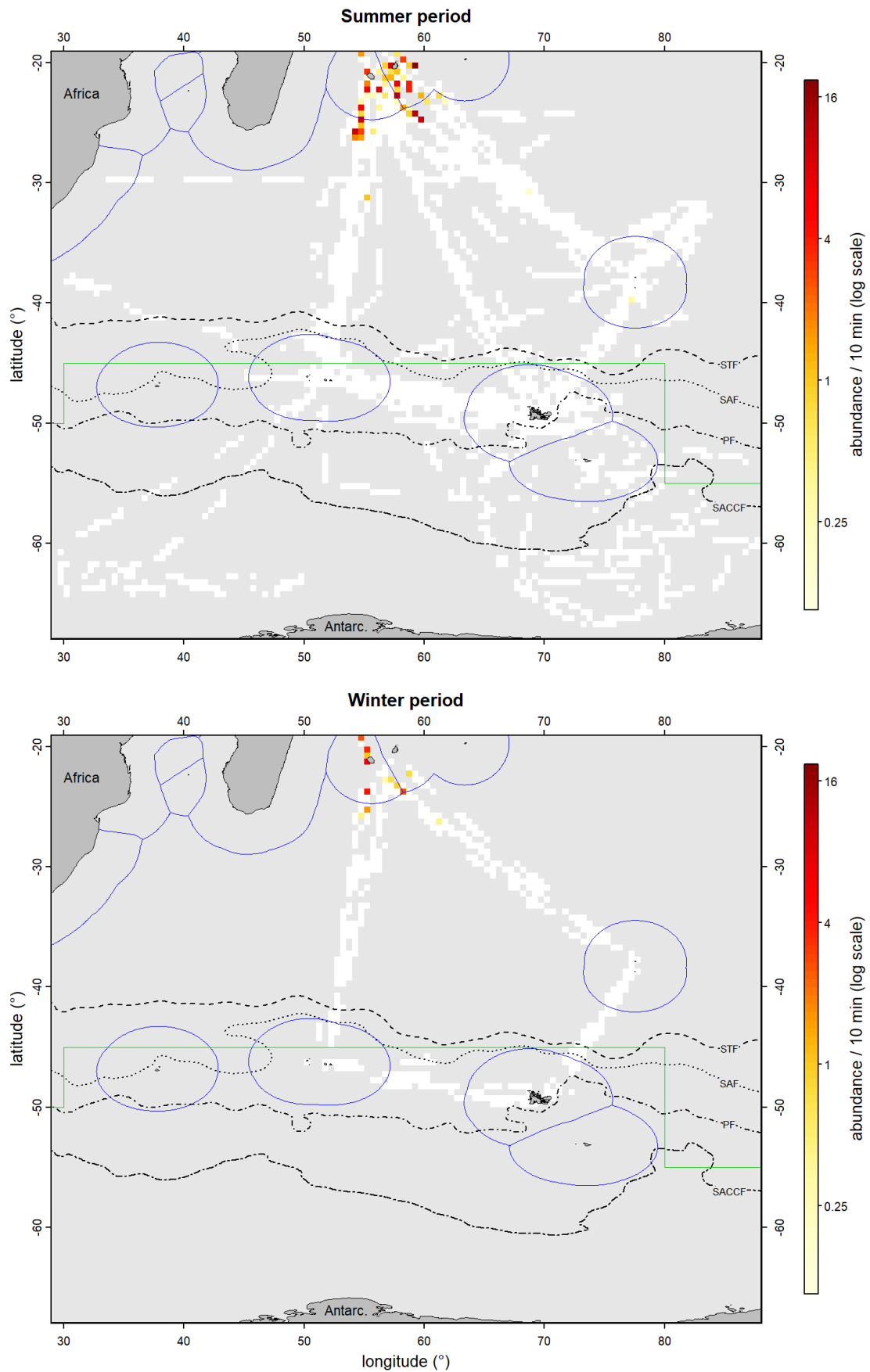


Figure 158 - Mean abundance of Sooty Tern / Bridled Tern during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Lesser Crested Tern / Greater Crested Tern *Thalasseus bengalensis* / *T. bergii* (LC/LC)

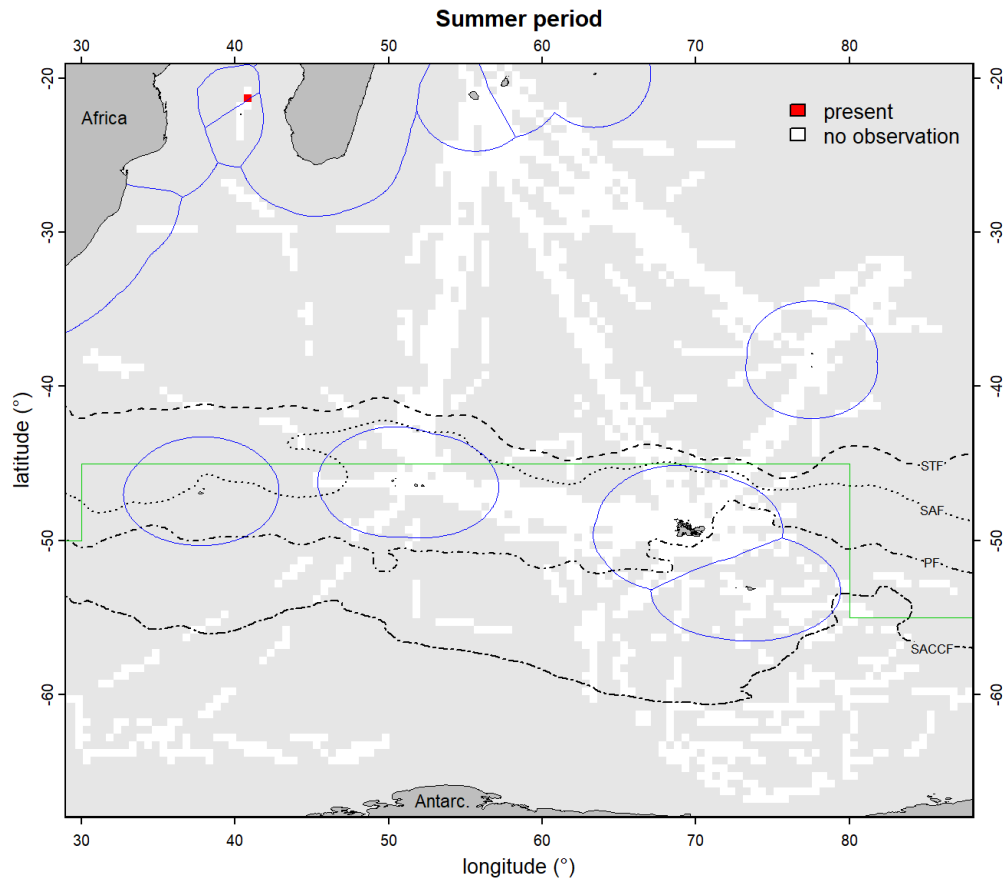


Figure 159 - Presence of Lesser Crested Tern / Greater Crested Tern in each 0.5°x0.5° square in the south-west Indian Ocean area

Black-naped Tern *Sterna sumatrana* (LC)

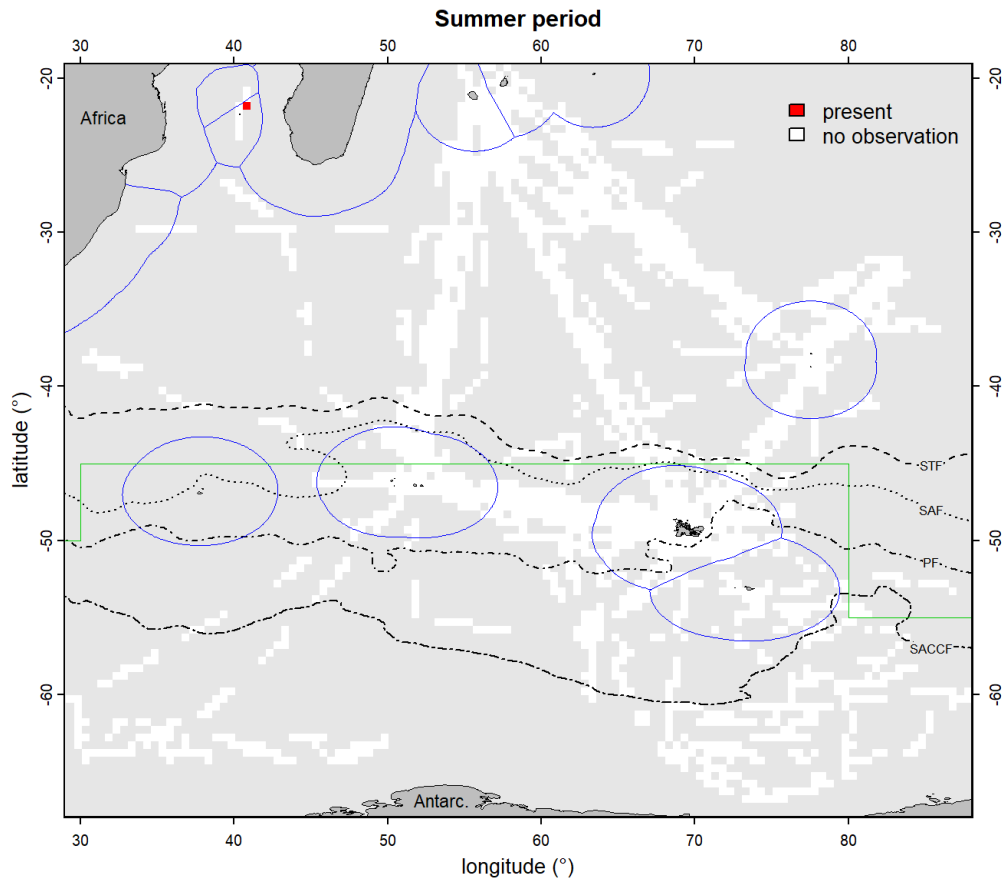


Figure 160 - Presence of Black-naped Tern in each 0.5°x0.5° square in the south-west Indian Ocean area

White Tern *Gygis alba* (LC)

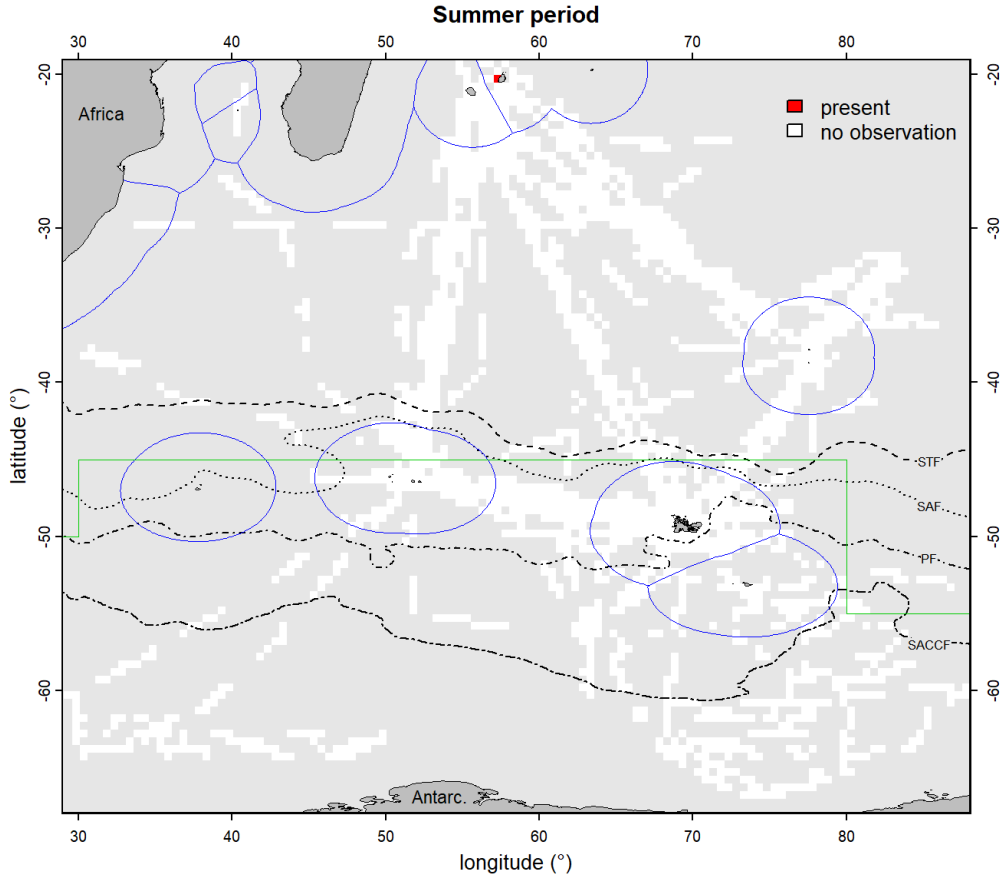


Figure 161 - Presence of White Tern in each 0.5°x0.5° square in the south-west Indian Ocean area

Brown Noddy / Lesser Noddy *Anous stolidus* / *A. tenuirostris* (LC/LC)

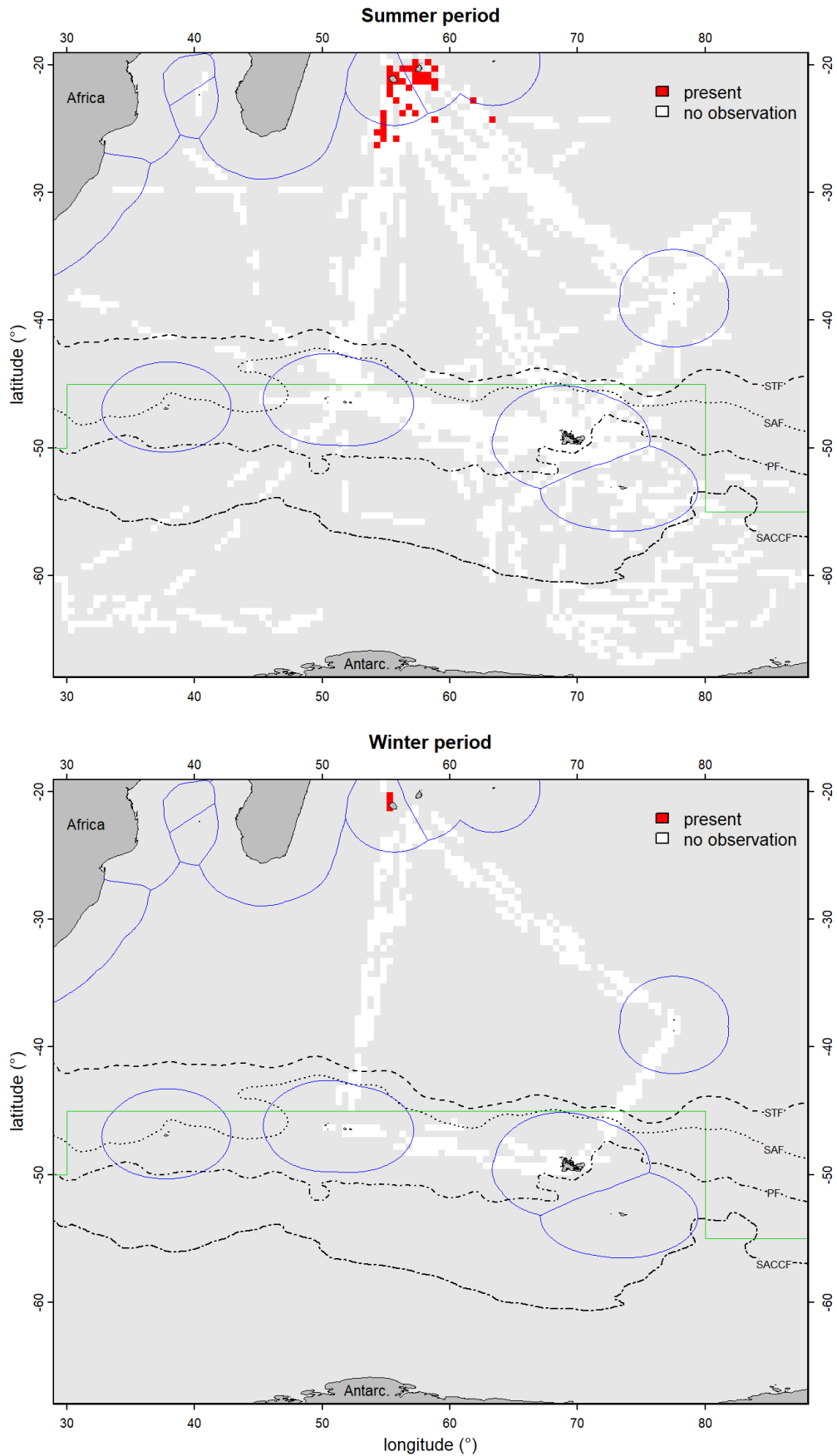


Figure 162 - Presence of Brown Noddy / Lesser Noddy in each 0.5°x0.5° square in the south-west Indian Ocean area

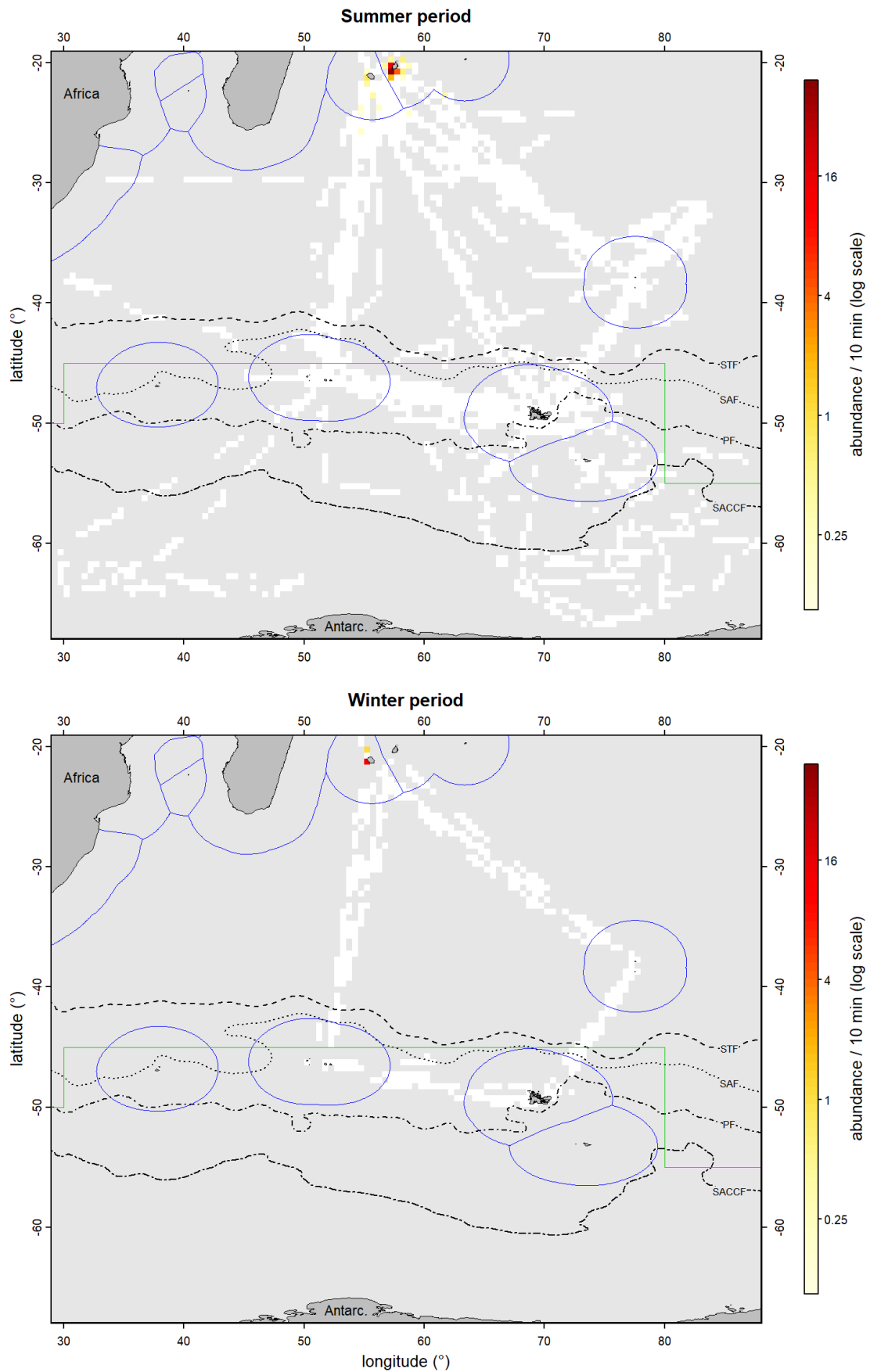


Figure 163 - Mean abundance of Brown Noddy / Lesser Noddy during 10-min counts in each 0.5°x0.5° square in the south-west Indian Ocean area

Red-tailed Tropicbird *Phaeton rubricauda* (LC)

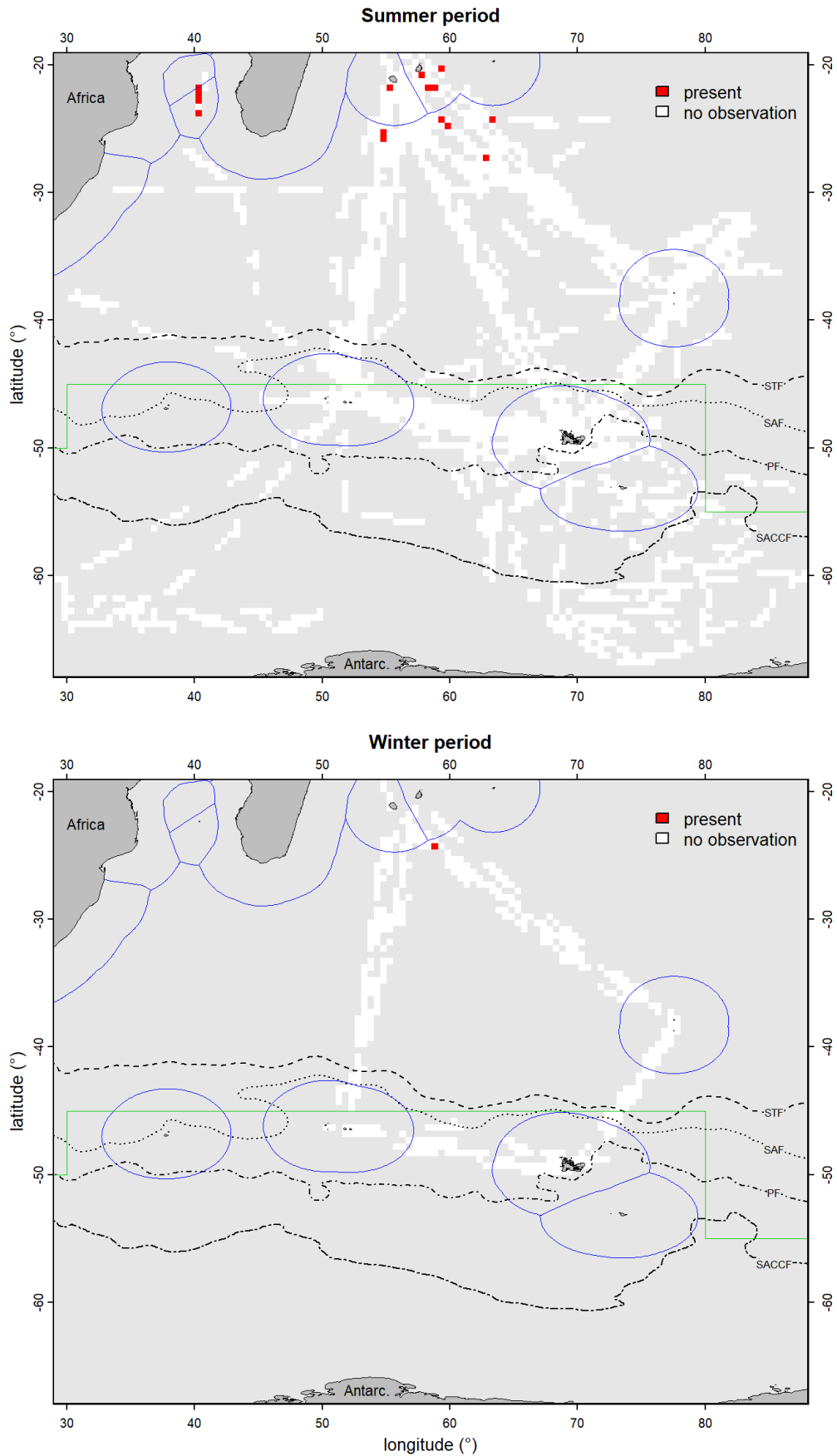


Figure 164 - Presence of Red-tailed Tropicbird in each 0.5°x0.5° square in the south-west Indian Ocean area

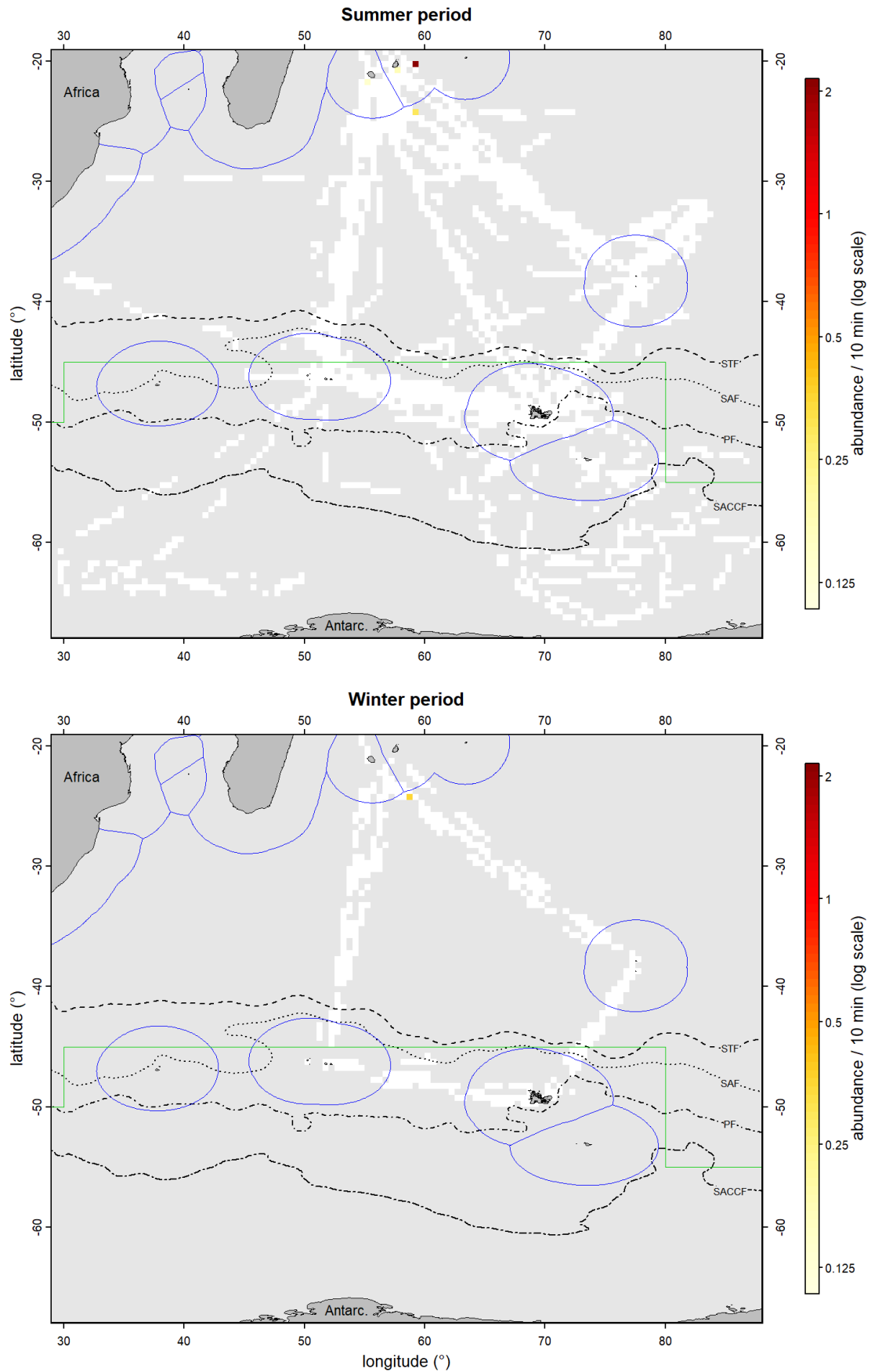


Figure 165 - Mean abundance of Red-tailed Tropicbird during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

White-tailed Tropicbird *Phaeton lepturus* (LC)

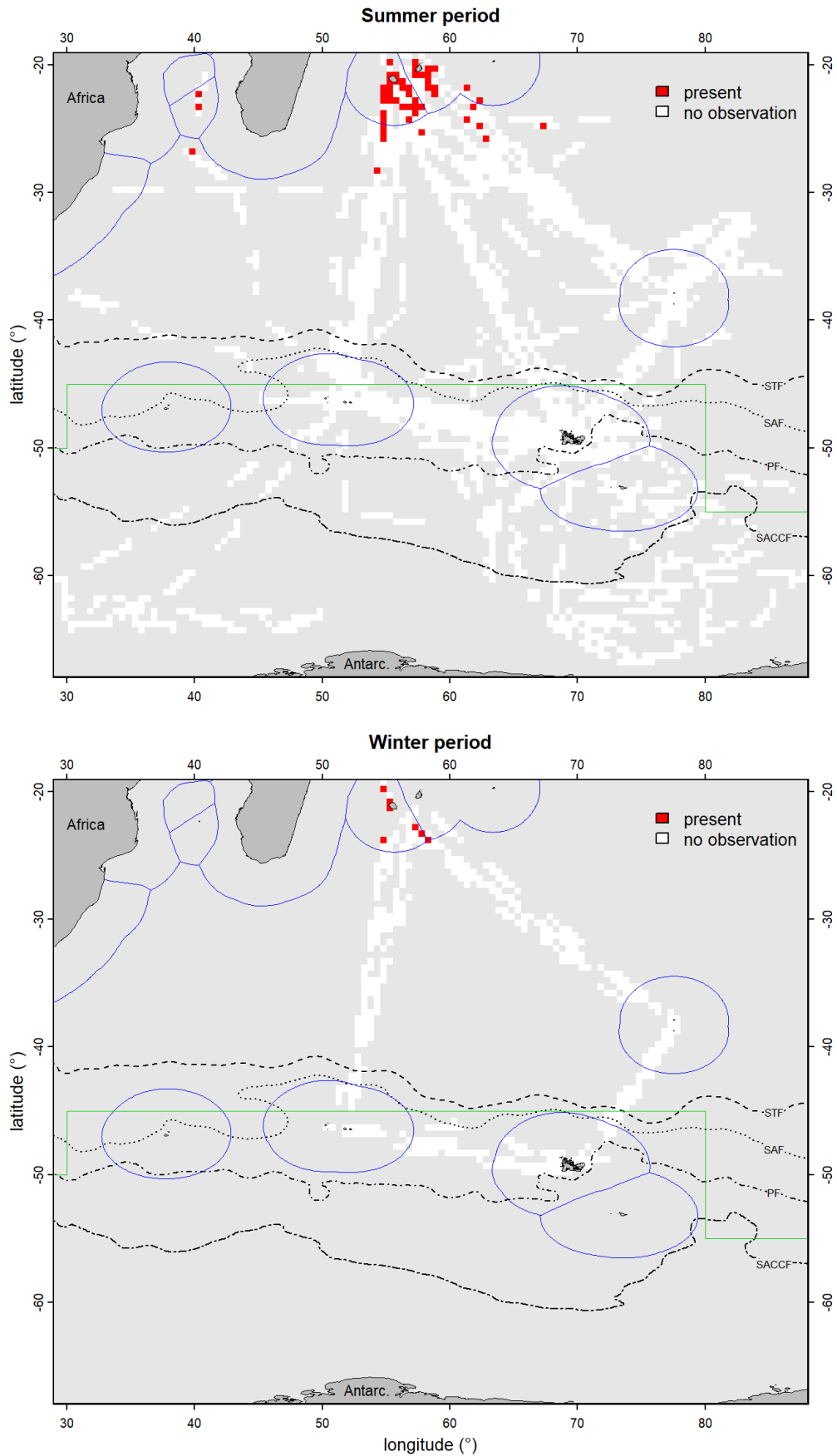


Figure 166 - Presence of White-tailed Tropicbird in each 0.5°x0.5° square in the south-west Indian Ocean area

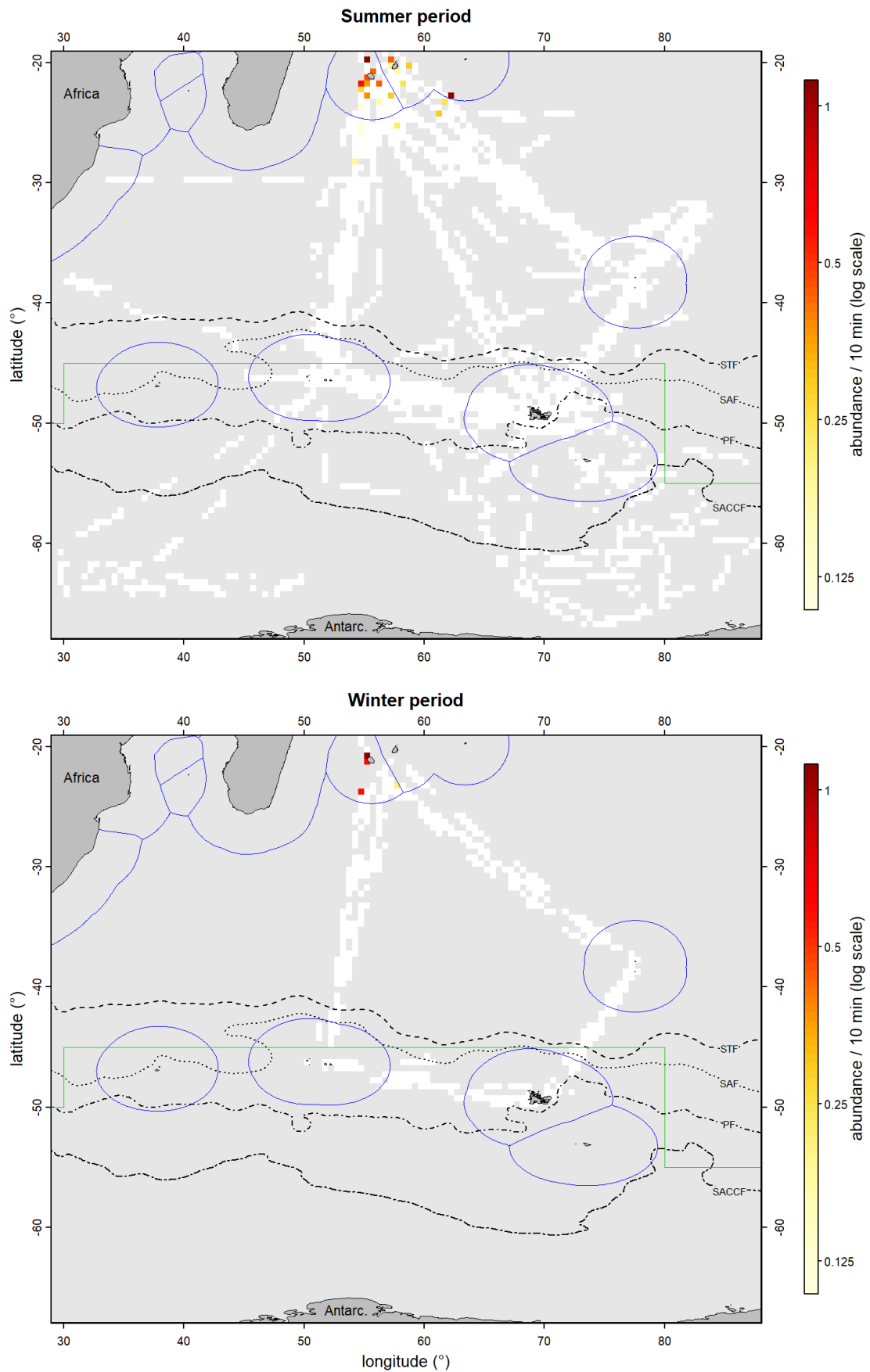


Figure 167 - Mean abundance of White-tailed Tropicbird during 10-min counts in each 0.5°x0.5° square in the southwest Indian Ocean area

Lesser Frigatebird / Great Frigatebird *Fregata ariel/minor* (LC)

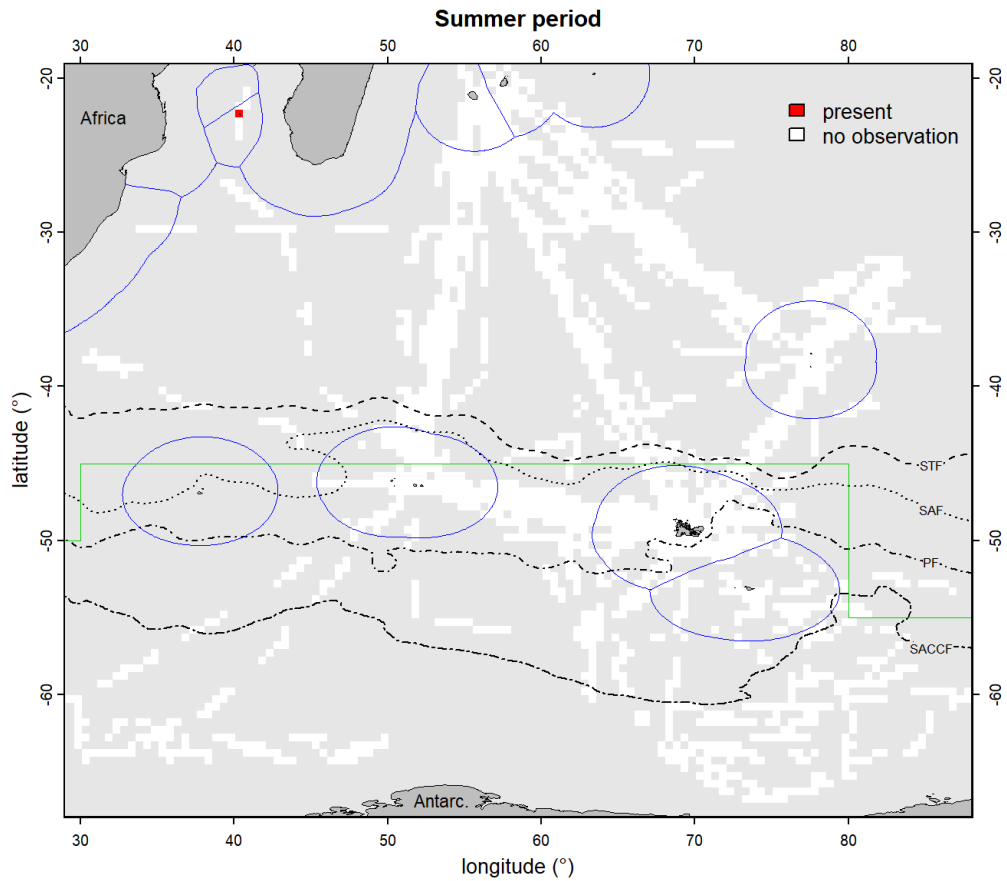


Figure 168 - Presence of Lesser Frigatebird / Great Frigatebird in each 0.5°x0.5° square in the south-west Indian Ocean area

Summary maps

The following maps display the abundance of seabirds – irrespective of the species – and their diversity in the South-West Indian Ocean and between Tasmania and Antarctica.

Abundance of seabirds

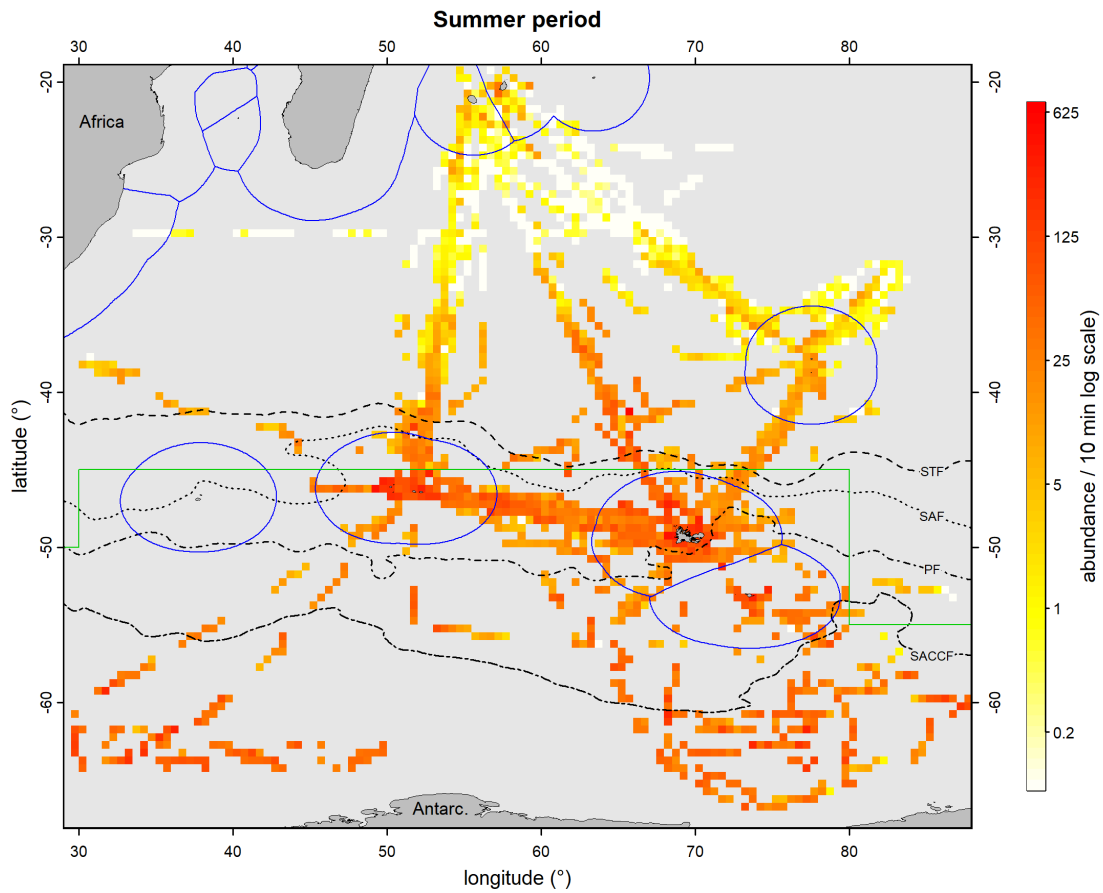


Figure 169 - Mean number of birds during a 10-min count in the south-west Indian Ocean area during the summer period

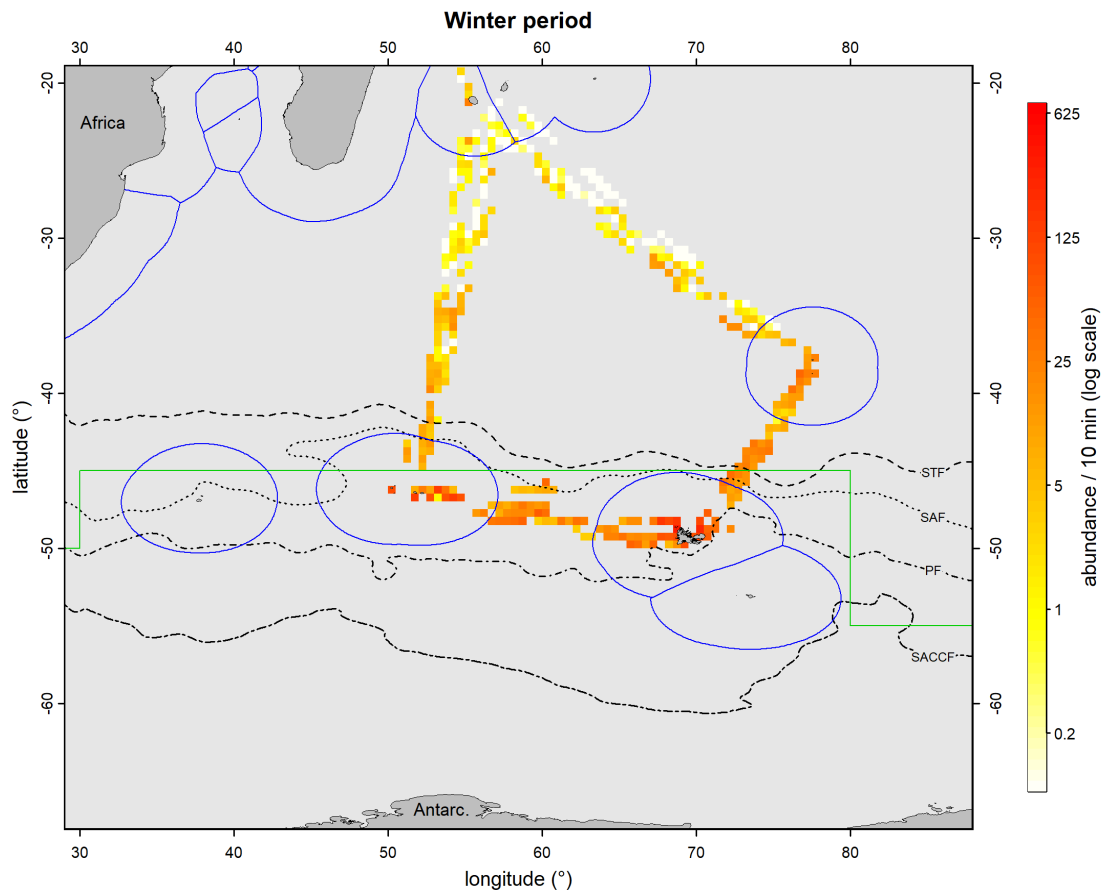


Figure 170 - Mean number of birds during a 10-min count in the south-west Indian Ocean area during the winter period

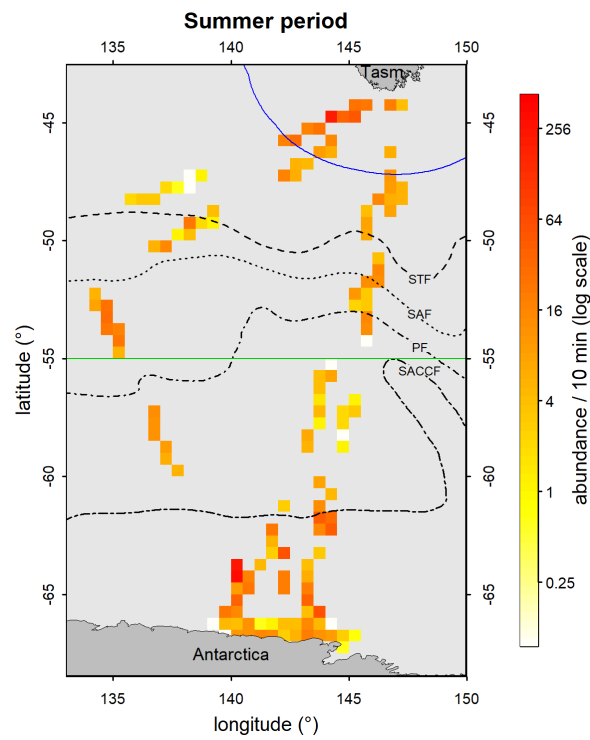


Figure 171 - Mean number of birds during a 10-min count between Tasmania and Antarctica

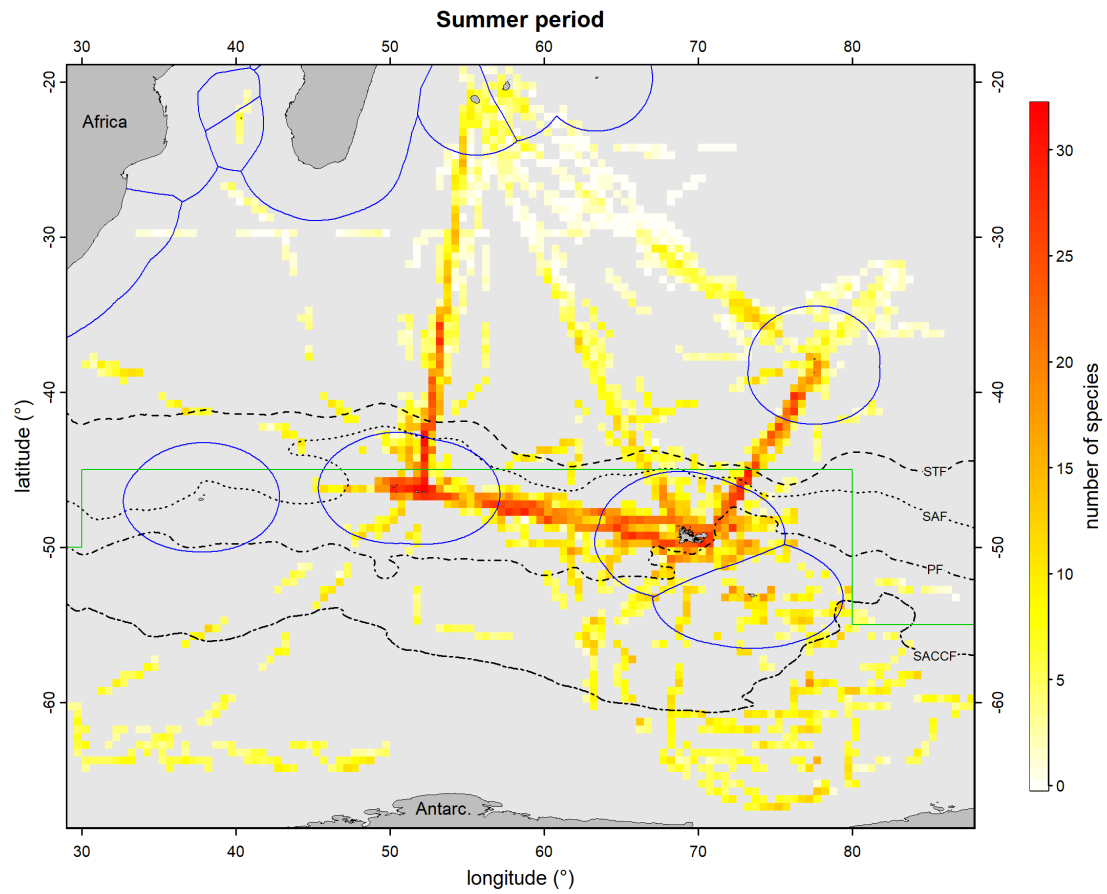


Figure 172 - Species richness in each 0.5°x0.5° square in the south-west Indian Ocean area during the summer period

Richness

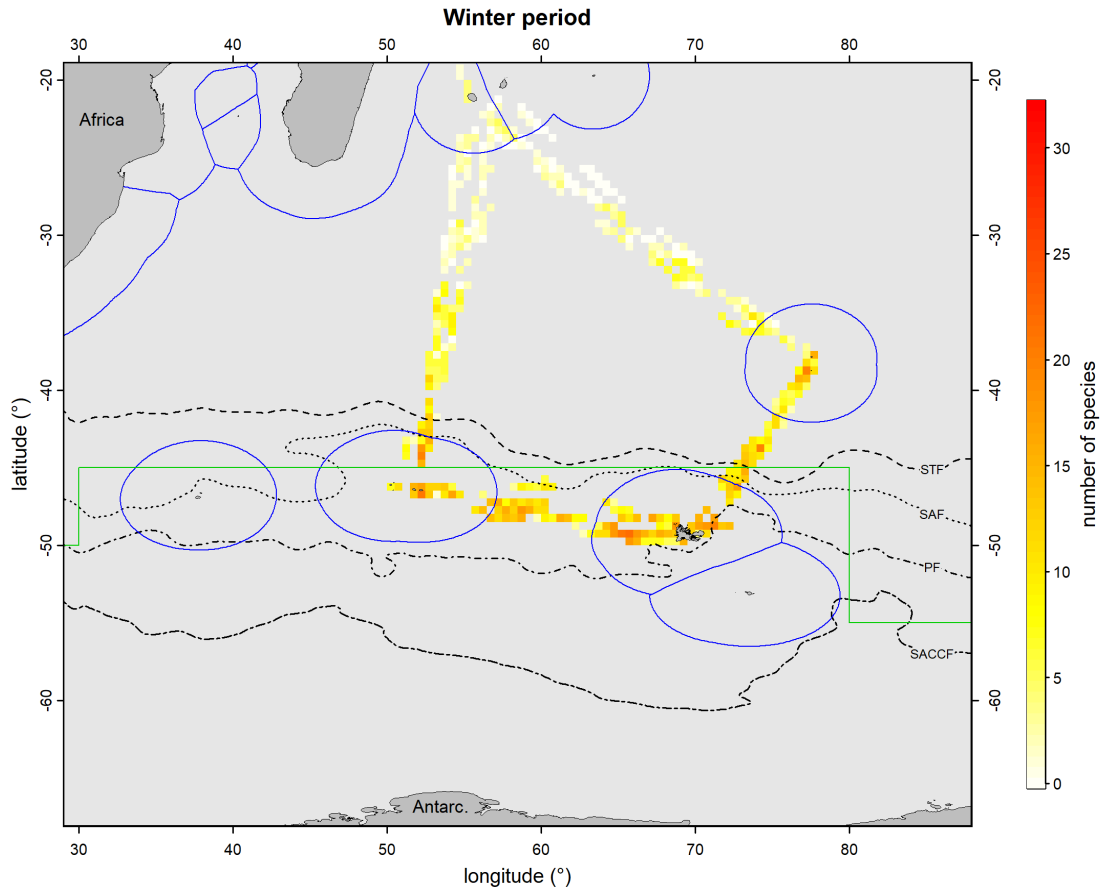


Figure 173 - Species richness in each $0.5^\circ \times 0.5^\circ$ square in the south-west Indian Ocean area during the winter period

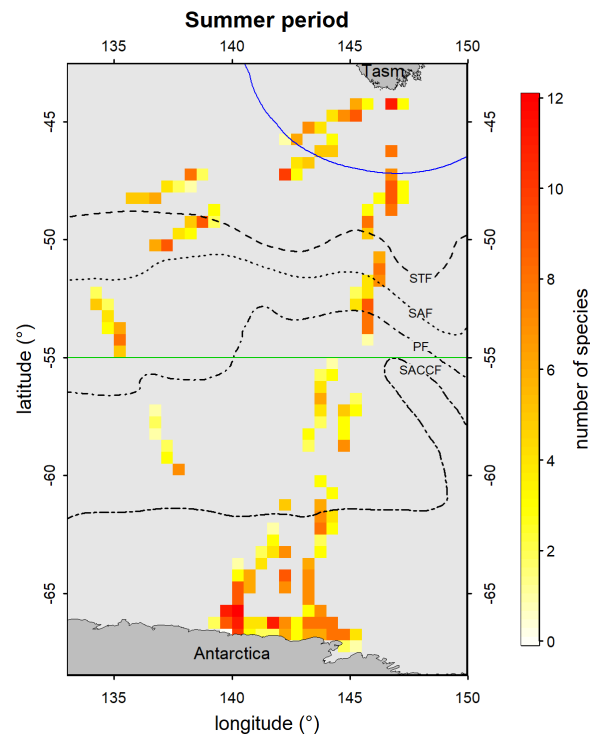


Figure 174 - Species richness in each $0.5^\circ \times 0.5^\circ$ square between Tasmania and Antarctica

Threatened species ratio

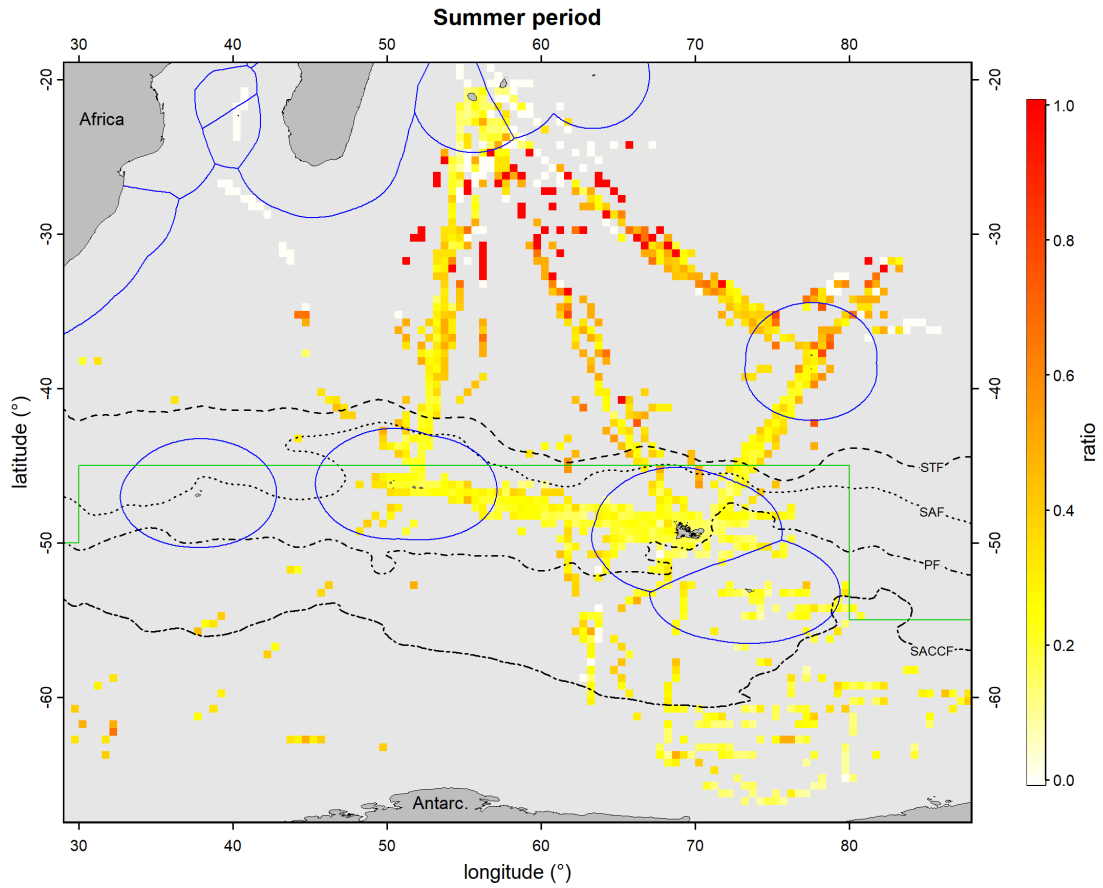


Figure 175 - Threatened species ratio in each 0.5°x0.5° square in the south-west Indian Ocean area during the summer period

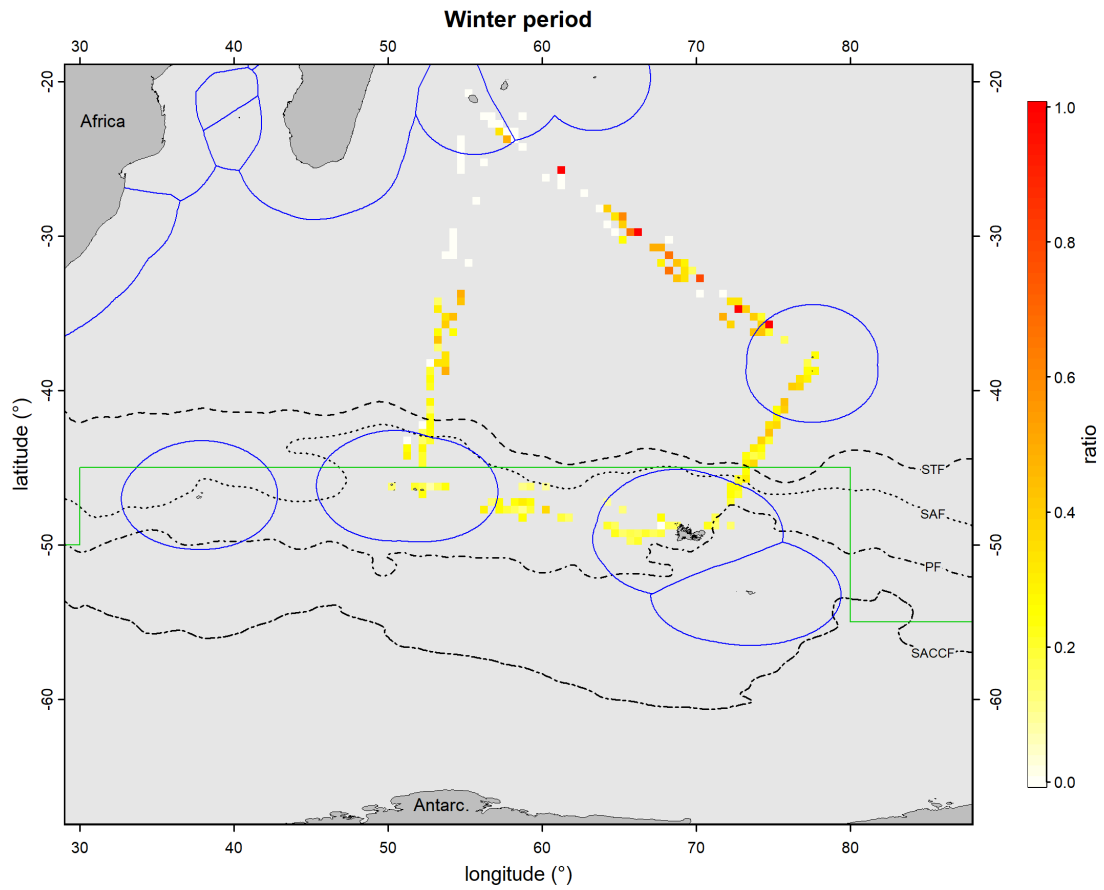


Figure 176 - Threatened species ratio in each 0.5°x0.5° square in the south-west Indian Ocean area during the winter period

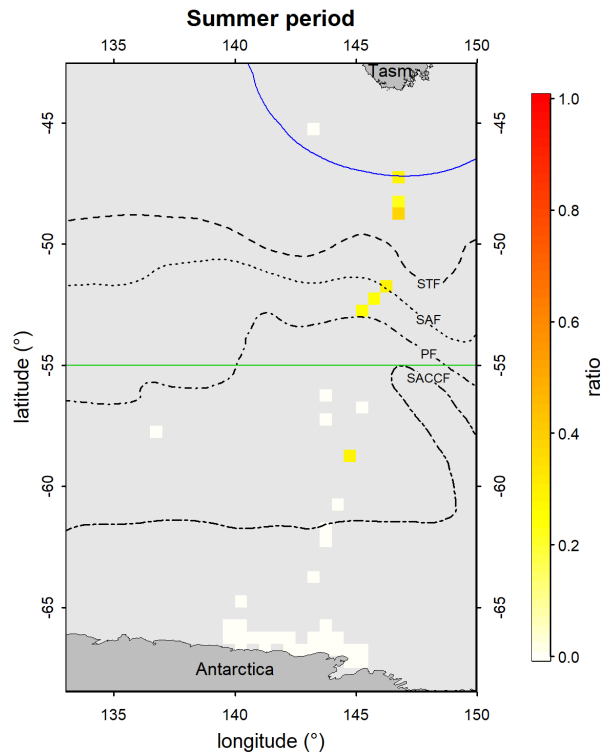


Figure 177 - Threatened species ratio in each 0.5°x0.5° square between Tasmania and Antarctica

Shannon's diversity index

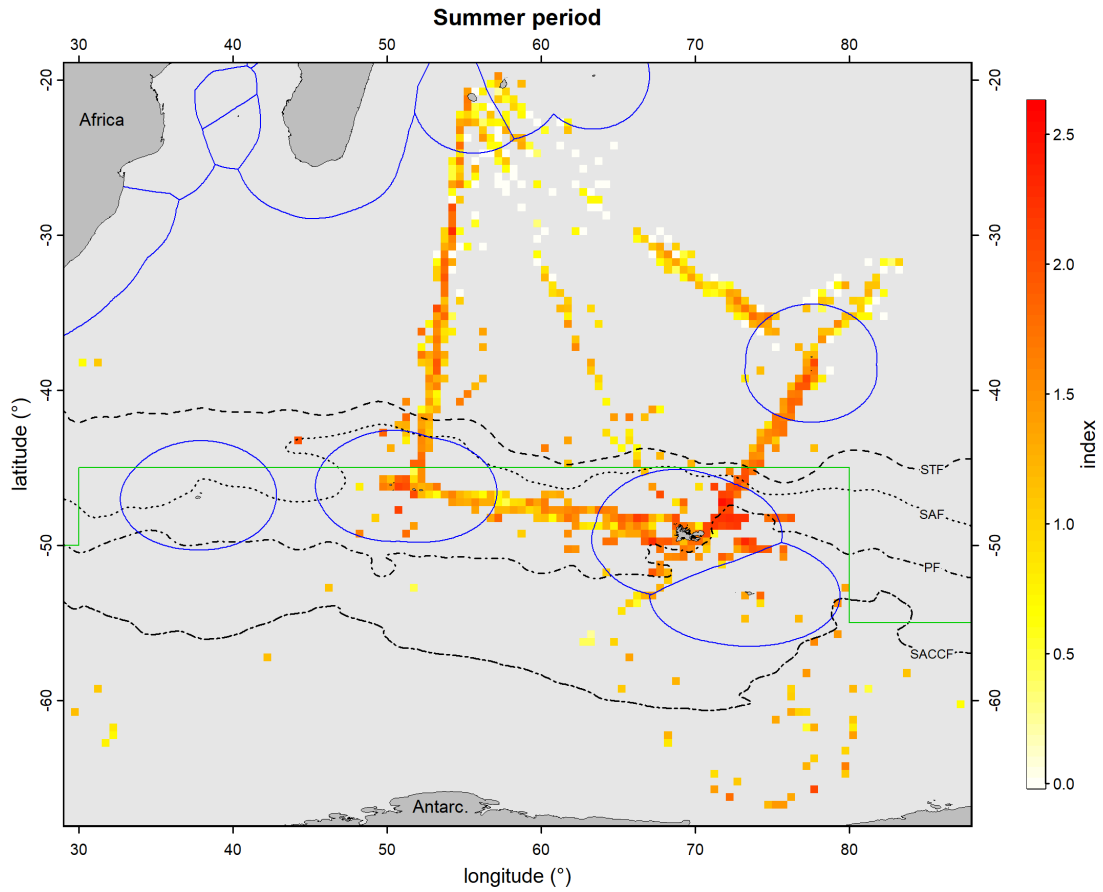


Figure 178 - Shannon's diversity index in each 0.5°x0.5° square in the south-west Indian Ocean area during the summer period

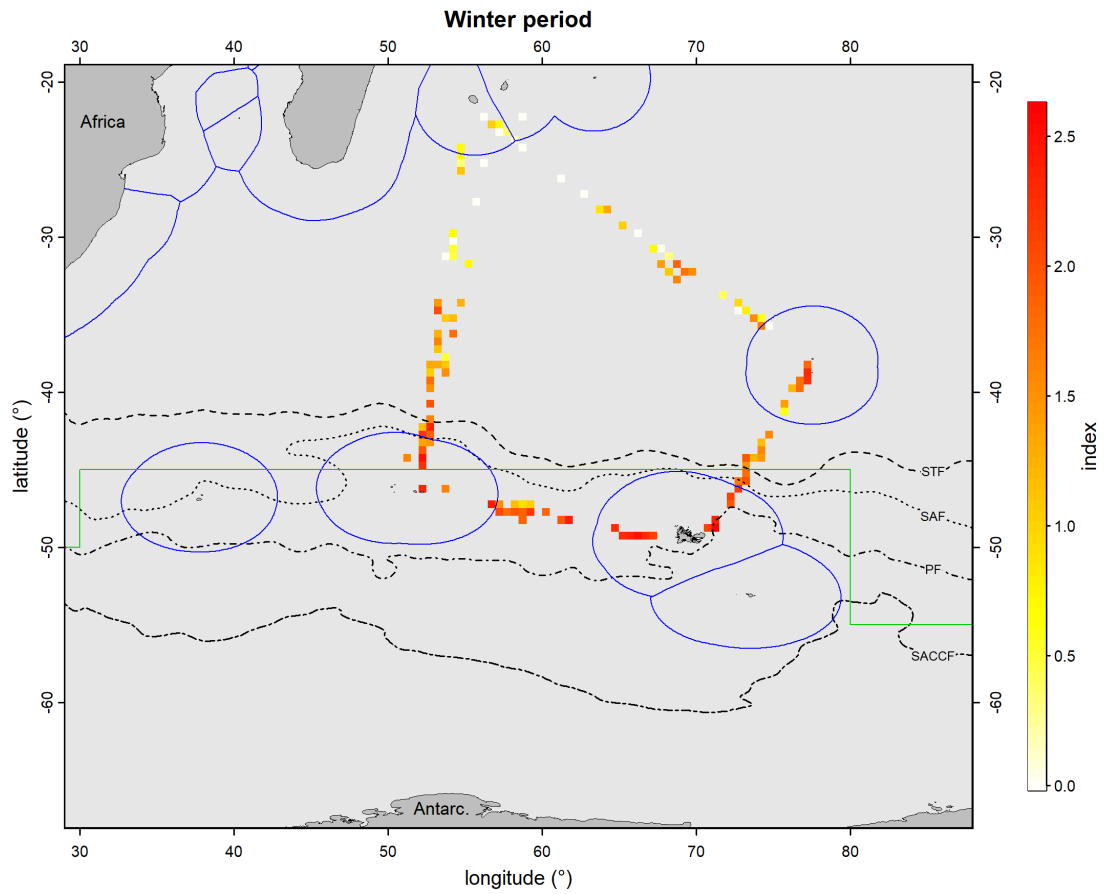


Figure 179 - Shannon's diversity index in each 0.5°x0.5° square in the south-west Indian Ocean area during the winter period

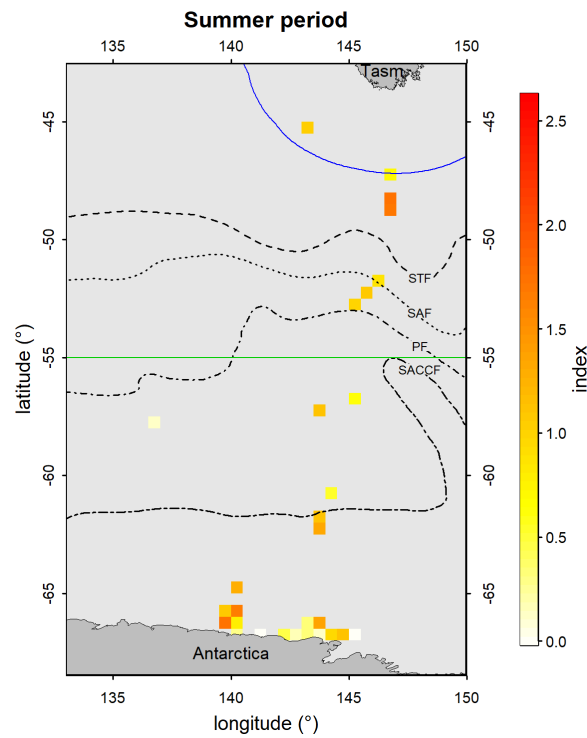


Figure 180 - Shannon's diversity index in each 0.5°x0.5° square between Tasmania and Antarctica

Simpson's diversity index

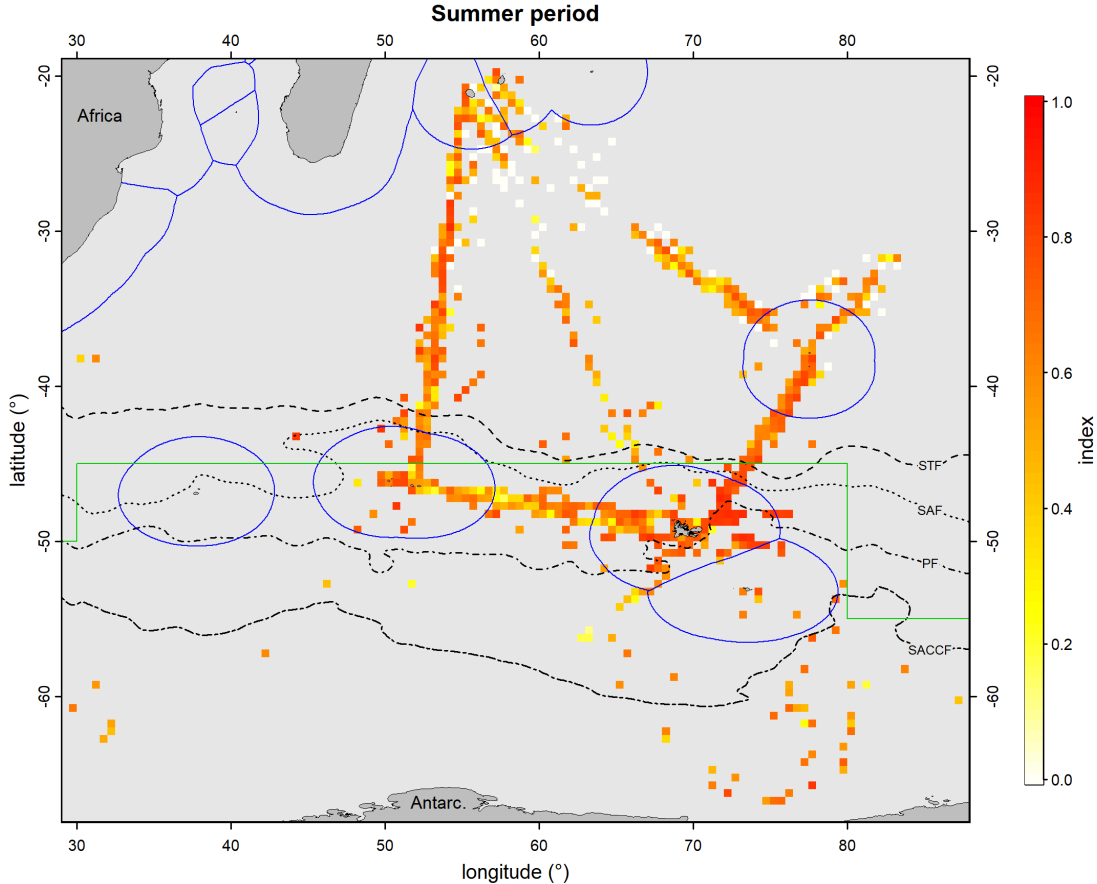


Figure 181 - Simpson's diversity index in each 0.5°x0.5° square in the south-west Indian Ocean area during the summer period

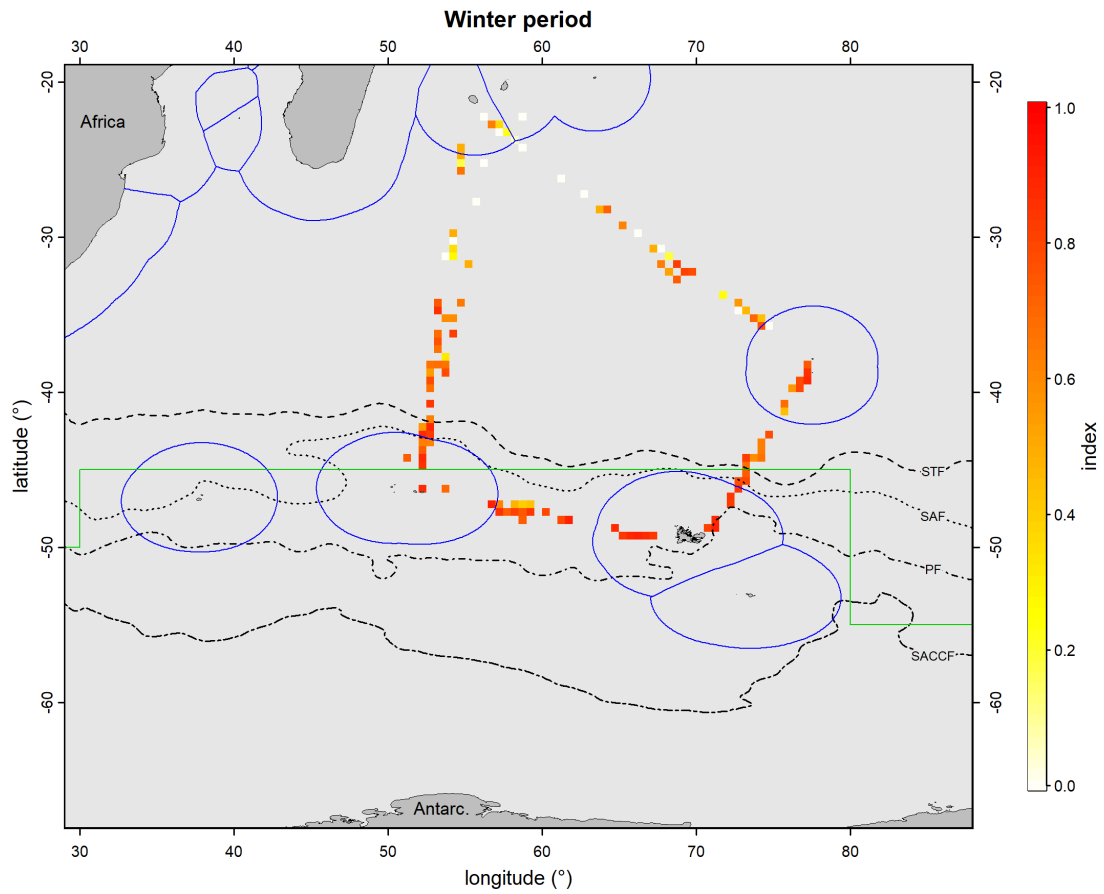


Figure 182 - Simpson index in each $0.5^\circ \times 0.5^\circ$ square in the south-west Indian Ocean area during the winter period

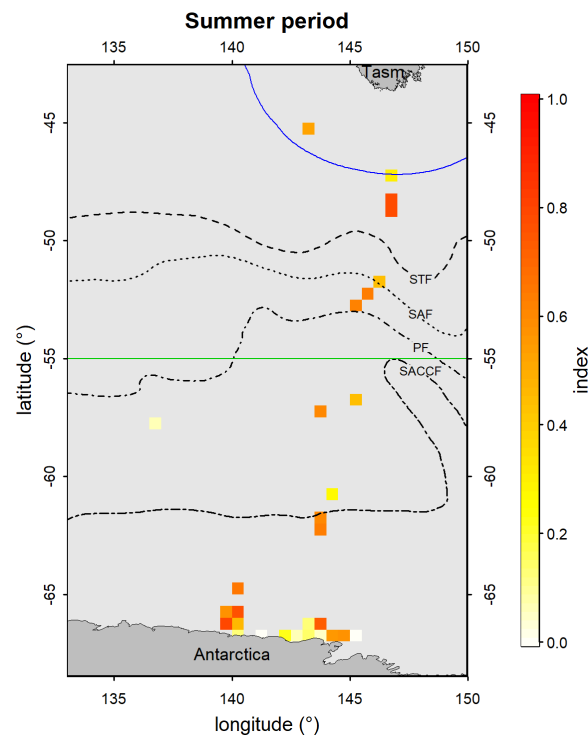


Figure 183 - Simpson's diversity index in each $0.5^\circ \times 0.5^\circ$ square between Tasmania and Antarctica

General patterns

The pattern illustrated in the abundance of seabirds (Fig. 169, 170, 171) and in the species richness, whatever the season for the western sector (South-West Indian Ocean), highlights a latitudinal gradient with an increase in richness towards the south. This latitudinal gradient is less visible in the eastern area (Fig. 171).

Abundance and diversity indices show the importance of the EEZ around the French and Australian islands in the use of the subtropical and subantarctic part of the Indian Ocean by seabirds. The proximity to the colonies and the presence of continental or insular shelves mainly explain this distribution. These remote overseas territories already provide huge marine protected areas (Heard Island and McDonald Islands Marine Reserve, French Southern Territories' National Nature Reserve, Tasmania's Marine Parks). Data from the present *Atlas* highlight their importance for the conservation of seabirds and their prey, which depends on the implementation of ambitious management plans and could be reinforced in the future by their extension.

Interestingly, the threatened species ratio (Fig. 175, 176, 177) shows the importance of waters outside the EEZ for species with conservation status concerns, whatever the season. These pelagic waters are indeed used by only a few subtropical and tropical species, but several are threatened (Amsterdam Albatross, Indian yellow-nosed Albatross, Sooty Albatross and Barau's Petrel). It stresses not only the importance of areas under state sovereignty, but also the importance of international waters for several threatened species.

Conclusions

This distribution *Atlas* update our knowledge of seabird distribution and species diversity in the Southern Indian Ocean, and could be a valuable tool for scientists and resource managers. The *Atlas* can be used : i) as a key reference point for ecological and ornithological studies, ii) to interpret and improve our understanding of the pelagic ecology of seabirds in the Southern Indian Ocean, iii) to provide distribution, abundance and diversity information for mitigating and assessing impacts of anthropogenic activities, iv) to develop area-specific information for Regional Fisheries Management Organizations and stakeholders, and v) to provide baseline information for assessing changes in seabird distribution, abundance and assemblage in the future (especially where data have been collected systematically and repeatedly in the same geographic areas).

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