



Introduction to the Integration of Animal Tracking and Remote Sensing

Part 2: Integration of Animal Tracking and Remote Sensing Data

Juan Torres-Pérez (NASA), Justin Fain (BAERI), Sativa Cruz (BAERI)
Invited Speakers: Morgan Gilmour (NASA), Claire Teitelbaum (USGS/Univ. of Georgia)

Training Learning Objectives

By the end of this training attendees will be able to:

1. Identify the types of animal tracking tags and sensors that are commonly used in animal tracking.
2. Identify the types of remote sensing data and products that can be used for species distribution models and step-selection functions.
3. Recognize the process for integrating remote sensing and animal tracking data in species distribution models and step selection functions to facilitate an understanding of animal movements in relation to their environment.
4. Recognize key takeaways from examples of terrestrial and marine applications that inform and characterize animals' habitats.



Prerequisites

- [Fundamentals of Remote Sensing](#)

Training Outline

Part 1

Introduction to
Animal Tracking
and Remote
Sensing at NASA

May 20, 2025

12:00 - 13:30 EDT
(UTC-4)

Part 2

Integration of
Animal Tracking
and Remote
Sensing Data

May 22, 2025

12:00 - 13:30 EDT
(UTC-4)

Homework

Opens May 22, 2025 – Due June 5, 2025 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



Part 2 – Trainers

Juan Torres-Pérez

Research Scientist
NASA Ames



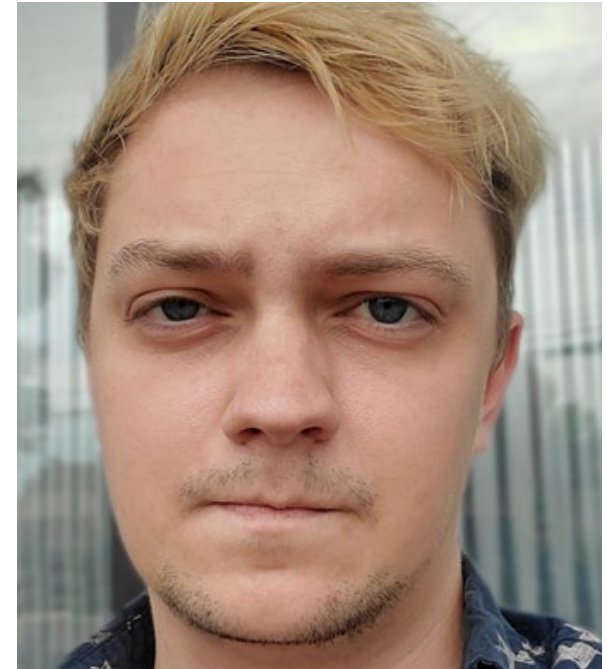
Sativa Cruz

Research Scientist
BAERI/NASA Ames



Justin Fain

Research Scientist
BAERI/NASA Ames



Integration of Animal Tracking and Remote Sensing Data – Guest Instructors

Dr. Morgan Gilmour

Research Scientist

NASA Ames Research Center



Dr. Claire Teitelbaum

Assistant Unit Leader

USGS

University of Georgia



Part 2 - Learning Objectives

By the end of this session, attendees will be able to:

1. Identify steps in the process for accessing animal tracking data in **species distribution models** to facilitate an understanding of animal movements in relation to their environment.
2. Identify steps in the process for accessing animal tracking data in **step selection functions** to facilitate an understanding of animal movements in relation to their environment.
3. Recognize key takeaways from examples of **terrestrial applications that inform and characterize animals' habitats.**
4. Recognize key takeaways from examples of **marine applications that inform and characterize animals' habitats.**



How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

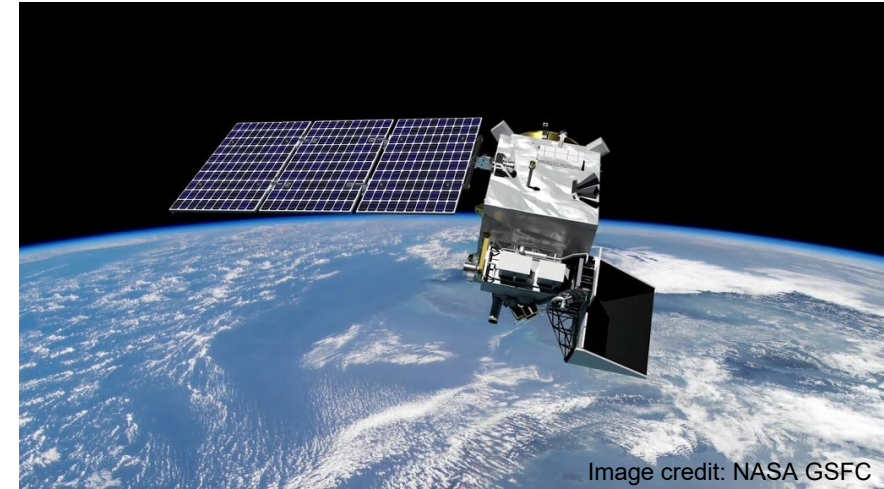




Section 1: Integration of Animal Tracking & Remote Sensing: A Marine Case Study on Tracking Frigatebirds at Palmyra Atoll

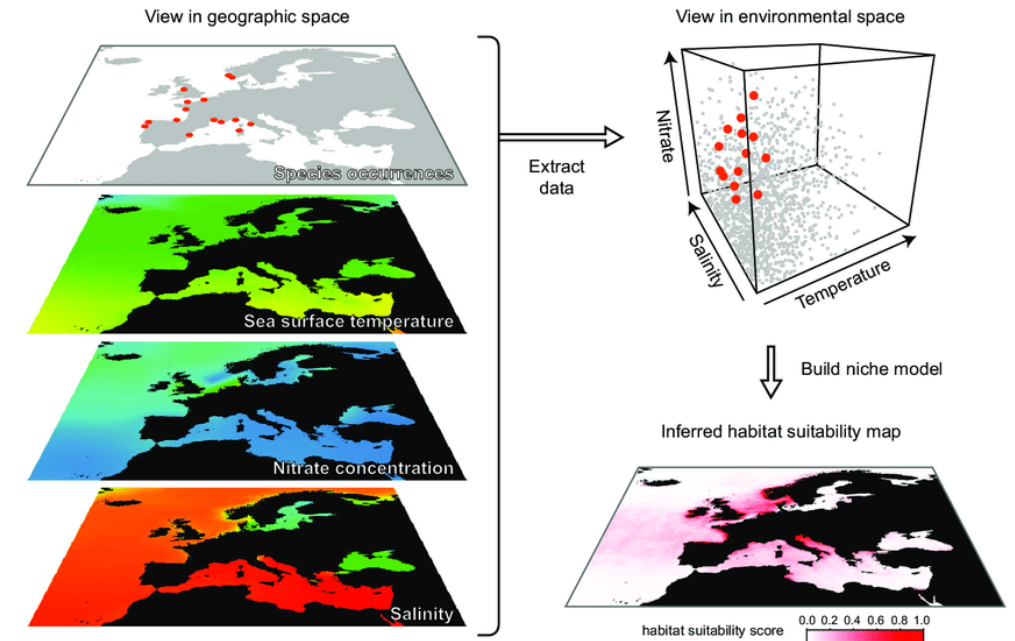
Remote Sensing Data Considerations

- Determine which **environmental covariates** you're interested in
 - A literature search can help understand what variables were important and/or of interest in other study regions, or for similar or related species
- Determine the **temporal resolution** best suited for your species, habitat, and research question
 - Finescale data (e.g., hourly, daily) may not be available in all regions
 - Regions/seasons with high cloud cover can generate a lot of NA's in the data, so using coarser resolutions may help
 - Consider the scale of each variable; some may not change much on an hourly basis (e.g., temperature) and may also not change much across a small horizontal scale
- Record the **spatiotemporal resolution** of the environmental data so that you can report it later.



Recap: Characterizing Animals' Habitats via Species Distribution Models

- Species Distribution Models (SDM)
 - Help us understand the likelihood of animals' presence in different habitat types
 - Asks the question: **How did the environment differ between where the animal did and did NOT go?**
 - Result: Habitat suitability map
- Steps
 - Prepare animal tracks
 - Define presence/absence points
 - Download environmental covariates
 - Model
 - Binary response variable (present/absent) predicted by environmental covariates



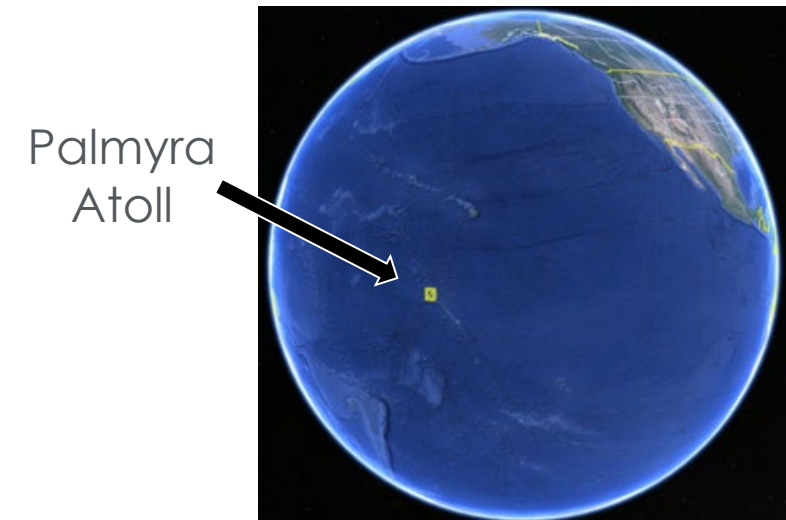
Marcelino & Verbruggen 2015 *J. Phycol*



Tracking Dataset: Great Frigatebirds at Palmyra Atoll

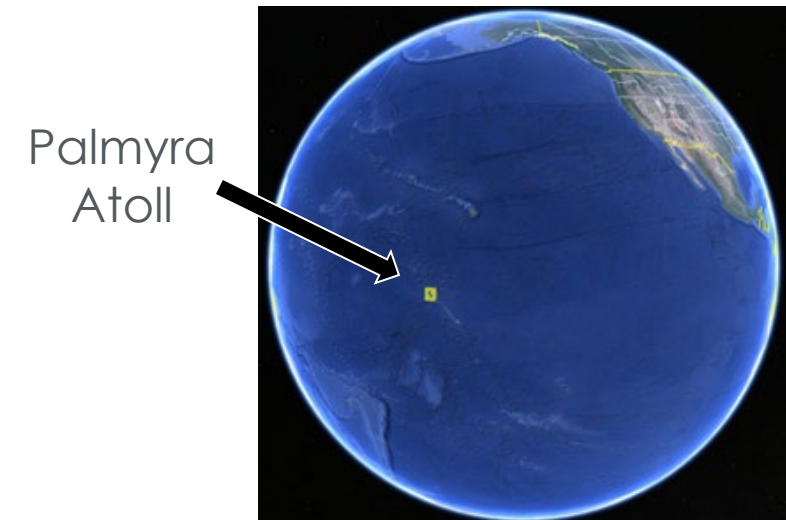
Dataset details

- Species: Great frigatebird (*Fregata minor*)
- Tag type: GPS
- Sample size: 7 birds
- Dates: June 2022 - March 2023
- Original tracking project objective: Quantify movement within & outside marine protected area
 - Project results published here:
<https://doi.org/10.1111/gcb.70138>
 - Dataset available here:
<https://doi.org/10.24431/rw1k8ez>



Tracking Dataset: Great Frigatebirds at Palmyra Atoll

- **Ecological context**
 - Frigatebirds are seabirds: They nest on islands and search the ocean for food like fish & squid.
 - Frigatebirds are central-place foragers: They need to forage in the ocean and return to their nest regularly to feed their growing chick.
- SDM can help answer the question: What is the ocean like where frigatebirds travel and forage?



Tracking Data: Great Frigatebirds at Palmyra Atoll

- Data prep
 - Basic cleaning steps
 - Remove NA's in locations (GPS data, so not many NA's)
 - Apply speed filter (25 m/s [90 km/hr])
 - Calculate distance to nest & filter for points >5 km away

```
> # Show dataframe
> glimpse(frigatebird.tracks)
Rows: 135,316
Columns: 5
$ Timestamp      <dtm> 2022-06-04 19:40:08, 2022-06-04 19:45:07, 2022-06-04 19:50:11, 2022-06-04 1...
$ LocationLong    <dbl> -162.0737, -162.0736, -162.0736, -162.0737, -162.0736, -162.0736, -162.0736,...
$ LocationLat     <dbl> 5.879910, 5.879928, 5.879931, 5.879917, 5.879932, 5.879929, 5.879933, 5.8799...
$ TagLocalIdentifier <chr> "eobs_9829", "eobs_9829", "eobs_9829", "eobs_9829", "eobs_9829", "eobs_9829"...
$ Island          <chr> "Palmyra", "Palmyra", "Palmyra", "Palmyra", "Palmyra", "Palmyra", "Palmyra",...
```



Tracking Data: Great Frigatebirds at Palmyra Atoll

- Data prep: Apply speed filter

```
# Apply speed filter ----

# First, calculate Inter-point distances (unit=seconds)
frigatebird.tracks$InterPtDist<-trakR::InterpointDist(tracks = frigatebird.tracks,
                                                       ID = "TagLocalIdentifier",
                                                       lat = "LocationLat",
                                                       lon = "LocationLong")

# Second, calculate Inter-point time (unit=meters)
frigatebird.tracks$InterPtTime<-trakR::InterpointTime(tracks = frigatebird.tracks,
                                                       ID = "TagLocalIdentifier",
                                                       DateTime = "Timestamp")

# Third, calculate Inter-point speed (unit=km/hr)
frigatebird.tracks$Speed<-trakR::Speed(Dist = frigatebird.tracks$InterPtDist,
                                       Time = frigatebird.tracks$InterPtTime)

# Fourth, filter out points based on speed threshold
# 25 m/s (90 kmphr; speed filter from: Weimerskirch & Prudor 2019
# https://doi.org/10.1038/s41598-019-41481-x)
frigatebird.tracks<-frigatebird.tracks %>%
  filter(Speed<90)
#
```



Tracking Data: Great Frigatebirds at Palmyra Atoll

- Data prep: Keep points > 5 km from nesting island
 - This is because seabirds spend many hours sitting on their nests, and this doesn't tell us anything about oceanographic habitat

```
# Calculate distance to nest island ----

# Define nest island location
palmyra<-data.frame(LocationLong=-162.072567,
                    LocationLat=5.879722,
                    Island="Palmyra")

frigatebird.tracks$Dist2Island<-trakR::AddDist2Colony(tracks = frigatebird.tracks,
                                                    dataLat = "LocationLat",
                                                    dataLon = "LocationLong",
                                                    CaptureSitesData = palmyra,
                                                    SiteName = "Island",
                                                    capLat = "LocationLat",
                                                    capLon = "LocationLong")

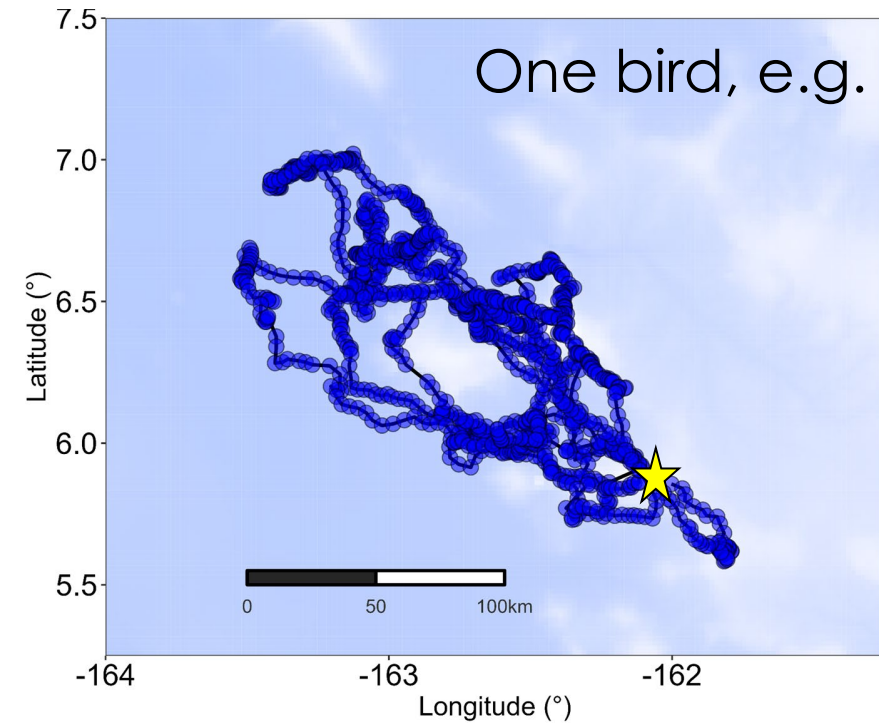
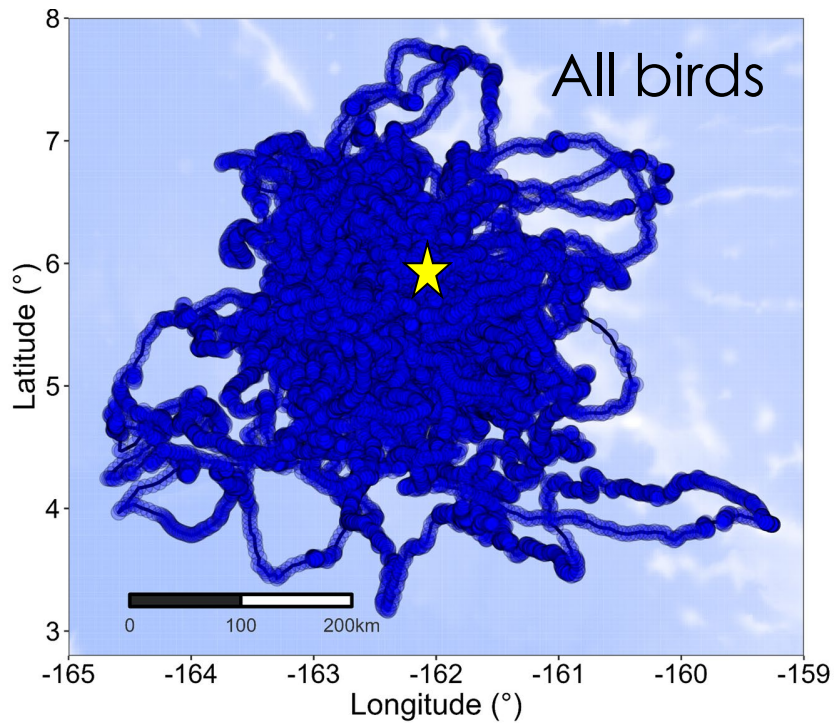
# Filter locations >5 km from Palmyra for analyses
frigatebird.tracks<-frigatebird.tracks %>%
  filter(Dist2Island > 5)

#
```



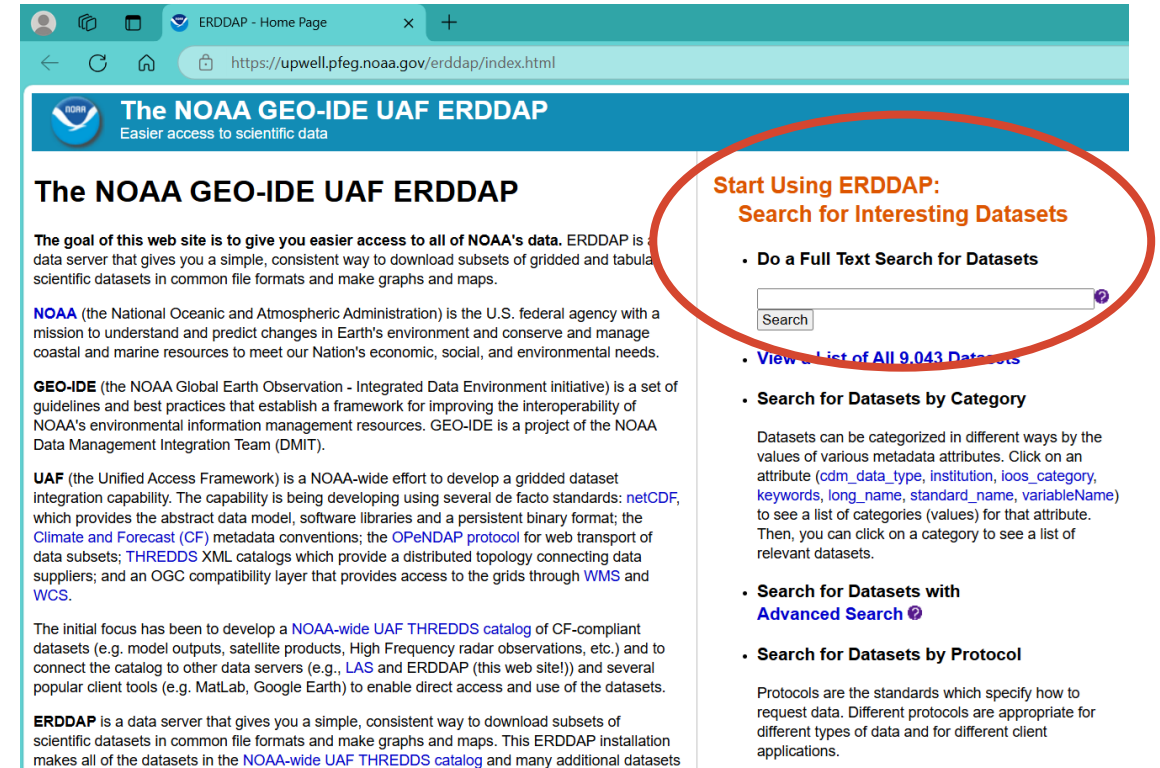
Tracking Data: Great Frigatebirds at Palmyra Atoll

- Data prep
 - Visualize tracking data: Does it look as you expected?



Download Remote Sensing Data via R: ERDDAP

- R-pkg: `rerddapXtracto`
 - Can extract data for single points along the track (function: `rextracto`) or over a whole grid (function `rextracto_3D`)
- How it works:
 - ERDDAP: Environmental Research Division Data Access Program
 - Provides standardized way to access and download data from many sources
 - We use NOAA's ERDDAP here, but you can substitute other ERDDAP platforms



Download Remote Sensing Data via R: ERDDAP

- Example: “chlorophyll” search

The screenshot shows the NOAA GEO-IDE UAF ERDDAP search interface. The browser address bar displays the URL: <https://upwell.pfeg.noaa.gov/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=chlorophyll>. The page header includes the NOAA logo and the text "The NOAA GEO-IDE UAF ERDDAP" with the tagline "Easier access to scientific data". A search bar contains the text "chlorophyll" and a "Search" button. Below the search bar, it states "171 matching datasets, with the most relevant ones listed first. (Or, refine this search with [Advanced Search](#))".

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	W M S	Source Data Files	Access-ible	Title	Sum-mary	FGDC, ISO, Metadata	Back-ground Info	RSS	E mail	Institution	Dataset ID
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (1 Day Composite)	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchla1day
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (1 Day Composite), Lon0360	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchla1day_Lon0360
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (3 Day Composite)	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchla3day
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (3 Day Composite), Lon0360	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchla3day_Lon0360
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (8 Day Composite)	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchla8day
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (8 Day Composite), Lon0360	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchla8day_Lon0360
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (Monthly Composite)	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchlamday
data			graph	M	files	public	Chlorophyll a, North Pacific, NOAA VIIRS, 750m resolution, 2015-present (Monthly Composite), Lon0360	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdVHNchlamday_Lon0360
data			graph	M	files	public	Chlorophyll-a, Aqua MODIS, NPP, 0.0125°, West US, EXPERIMENTAL, 2002-present (1 Day Composite)	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdMWchla1day
data			graph	M	files	public	Chlorophyll-a, Aqua MODIS, NPP, 0.0125°, West US, EXPERIMENTAL, 2002-present (1 Day Composite), Lon+/-180	?	F I M	background	RSS	✉	NOAA NMFS SWFSC ERD	erdMWchla1day_LonPM180



Download Remote Sensing Data via R: ERDDAP

- View the metadata for your chosen dataset via rerddap function “info”
 - Does this match the spatiotemporal extent of your tracking data?


```
> ## Chlorophyll ----  
> CHL<-rerddap::info("erdMBchlamday_LonPM180")  
> CHL  
<ERDDAP info> erdMBchlamday_LonPM180  
Base URL: https://upwell.pfeg.noaa.gov/erddap  
Dataset Type: griddap  
Dimensions (range):  
  time: (2008-01-16T12:00:00Z, 2025-03-16T12:00:00Z)  
  altitude: (0.0, 0.0)  
  latitude: (-45.0, 65.0)  
  longitude: (-180.0, 179.975)  
Variables:  
  chlorophyll:  
    Units: mg m-3  
> |
```



Download Remote Sensing Data via R: ERDDAP

Download steps

1. Determine spatiotemporal extent of data to download
2. Download grid of environmental data
3. Append environmental data to each frigatebird location (next section)

```
# Download environmental variables via ERDDAP   
## Data prep ----  
  
# Step 1: Determine spatial extent of frigatebird tracks  
extent_to_download<-data.frame(Longitude=c(min(frigatebird.tracks$LocationLong),  
                                             max(frigatebird.tracks$LocationLong)),  
                                Latitude=c(min(frigatebird.tracks$LocationLat),  
                                           max(frigatebird.tracks$LocationLat)))  
  
# Step 2: Determine temporal extent of frigatebird tracks  
dates_to_download<-data.frame(min_date=min(frigatebird.tracks$Timestamp),  
                              max_date=max(frigatebird.tracks$Timestamp))  
  
# Step 3: Set location to hold downloaded data  
out_folder<-"C:/Users/Desktop/Frigatebird_evars/"  
  
# Set cache to out_folder  
rerddap::cache_setup(full_path = out_folder,temp_dir = FALSE)
```



Download Remote Sensing Data via R: ERDDAP

- Download reminders
 - Set `cache_remove=FALSE` to save file for later, if desired (will save as .nc file)
 - Resulting dataframe can be converted to tidy-data (helpful for ggplot, e.g.)

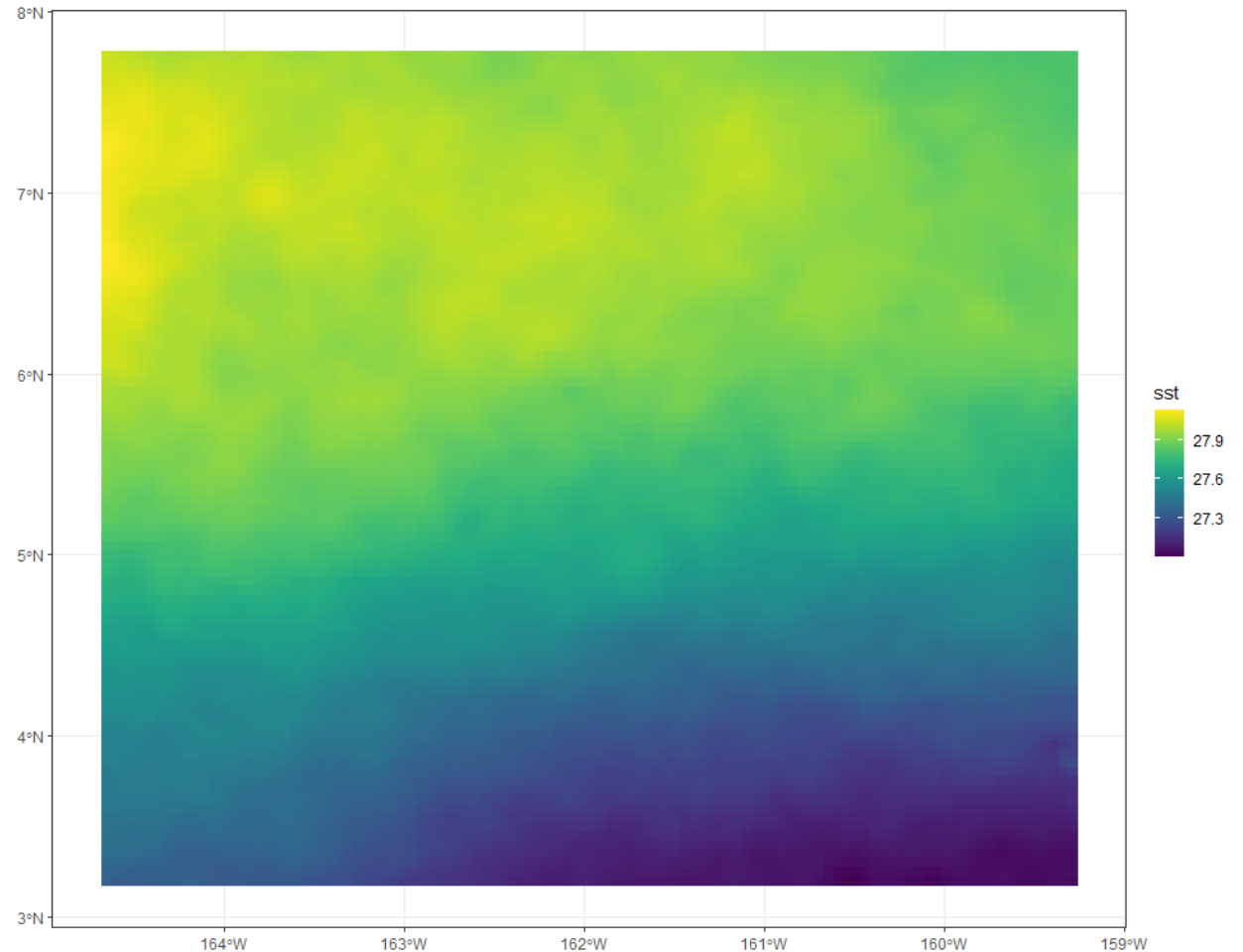
```
▼ # Sea surface temperature ----  
SST<-rerddap::info("jplMURSST41mday")  
SST  
  
# Download data  
sst<-rerddapXtracto::rxtracto_3D(dataInfo = SST,  
                                parameter = "sst",  
                                xcoord = c(min(extent_to_download$Longitude),  
                                           max(extent_to_download$Longitude)),  
                                ycoord = c(min(extent_to_download$Latitude),  
                                           max(extent_to_download$Latitude)),  
                                tcoord = c(dates_to_download$min_date,  
                                           dates_to_download$max_date),  
                                # zcoord = c(0,0),  
                                verbose = TRUE,  
                                cache_remove = FALSE)  
  
# Plot to verify download was successful  
rerddapXtracto::plotBBox(sst)  
  
# Convert to tidy format (dataframe)  
sst_tidy<-rerddapXtracto::tidy_grid(sst)
```



Download Remote Sensing Data via R: ERDDAP

- Download reminders
 - Several rerddapXtracto functions also enable plotting (e.g., plotBBox)

```
# Plot to verify download was successful  
rerddapXtracto::plotBBox(sst)
```



Download Remote Sensing Data via R: R-pkg marmap

- Download bathymetry directly from the NOAA ETOPO 2022 database (via National Centers for Environmental Information)
 - Citation for bathymetry dataset: <https://www.doi.org/10.25921/fd45-gt74>
- Reminders
 - Downloads as a grid
 - Use keep = TRUE to save file for later (if desired)
 - Resulting dataframe can be converted to tidy-data (helpful for ggplot, e.g.)
 - If downloading data in the Pacific (across the dateline) use antimeridian = TRUE

```
## Download bathymetry via marmap package ----  
bathymetry<-marmap::getNOAA.bathy(lon1 = max(extent_to_download$Longitude),  
                                   lon2 = min(extent_to_download$Longitude),  
                                   lat1 = min(extent_to_download$Latitude),  
                                   lat2 = max(extent_to_download$Latitude),  
                                   antimeridian = TRUE,  
                                   resolution = 4, #units=arc-minutes  
                                   keep = TRUE,  
                                   path = out_folder)  
#
```



Append Remote Sensing Data to Animal Tracks

- Read in .nc files

```
# Append environmental covariates to tracking data ----  
## Read in .nc files ----  
  
library(ncdf4)  
  
# List all the chlorophyll files in your out_folder, e.g.  
files<-list.files(path=out_folder,  
                  pattern="chl_a",  
                  full.names=TRUE)  
  
# Open the chlorophyll files  
chl_a.nc<-nc_open(files)  
# Confirm that there's data  
ncdf4::ncvar_get(chl_a.nc,varid = "chlorophyll")  
  
# Create a raster "stack" of the chlorophyll data. Each layer is a date.  
dat_chl_a<-lapply(files,function(x)raster::stack(x,varname="chlorophyll"))  
dat_chl_a<-raster::stack(dat_chl_a)  
#
```



Append Remote Sensing Data to Animal Tracks

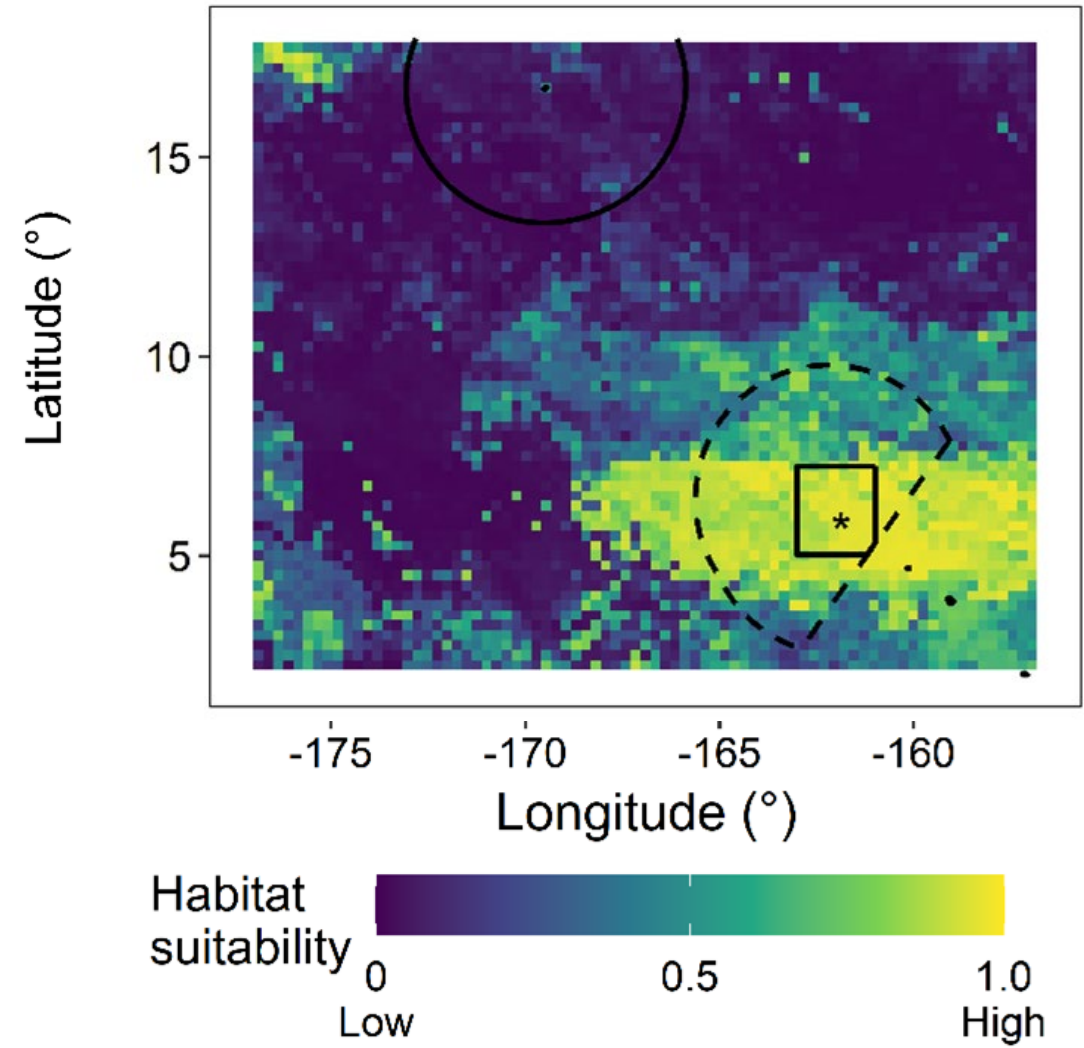
- See code demo



Species Distribution Model

Basic Steps

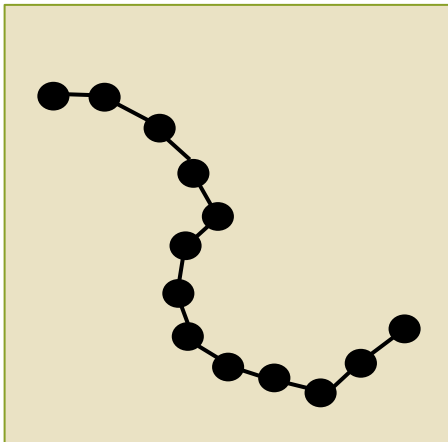
1. Simulate pseudo-absences: Select points where animals did NOT go
2. Predict species occurrence with statistical model
 - a. Species presence (or absence) = environmental covariate + environmental covariate etc.
3. Assess resulting model
 - a. Evaluate results statistically
 - b. Plot
 - c. Evaluate results within context of species' behaviors, known habitats



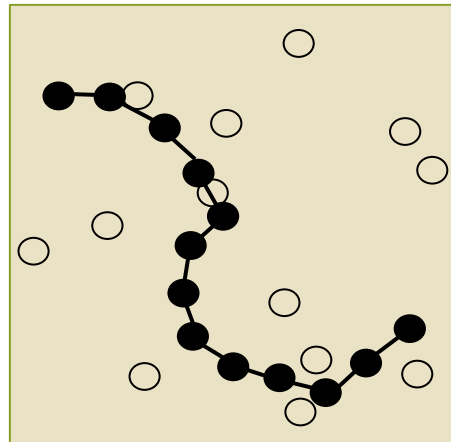
Species Distribution Model: Simulate Pseudo-Absences

- Pseudo-absence: A location where an animal did NOT go
- Needed to form binary response variable in SDM (presence, absence)
- Can be simulated a few ways:
 - Randomly-sampled points (background sampling)
 - Chosen from distribution of turn angles and transit speeds from tracking dataset (random walk)
 - Chosen from state-space model parameters

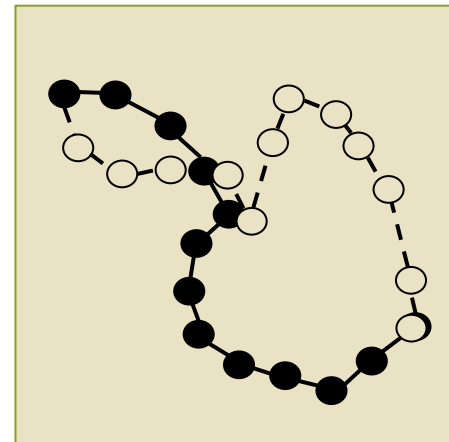
Original track



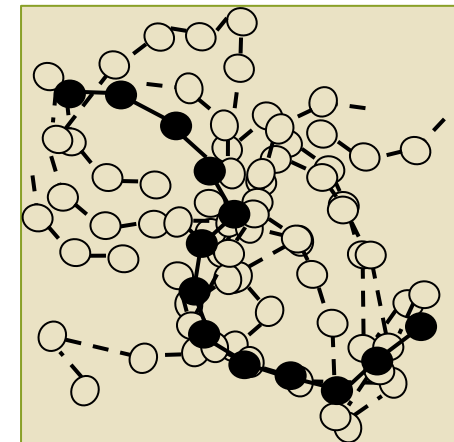
Background sampling



Random walk



State-space Model



Species Distribution Model: Predict Habitat

- A few options to model species-environment relationships
 - **Generalized linear model (GLMM)**
 - Parametric
 - Estimates linear relationships
 - **Generalized additive mixed model (GAMM)**
 - Semi-parametric
 - Smoothers used to represent non-linear relationships
 - **Boosted regression tree**
 - Non-parametric
 - Boosting optimizes the partition of variance



Species Distribution Model: Predict Habitat

- Code demo



Species Distribution Model: Evaluation

Approaches to assess model fit (there are many!)

1. Evaluate model explanatory power
 - a. R^2
2. Evaluate model predictive skill
 - a. Area Under the receiver characteristic Curve (AUC)
 - b. True Test Statistic
 - c. Cross-validation
3. Understand similarity of presence/absence points
 - a. Bhattacharyya's coefficient
4. Examine relative importance of variables (environmental predictors)





Section 2: Integration of Animal Tracking & Remote Sensing: A Terrestrial Case Study on Tracking Deer

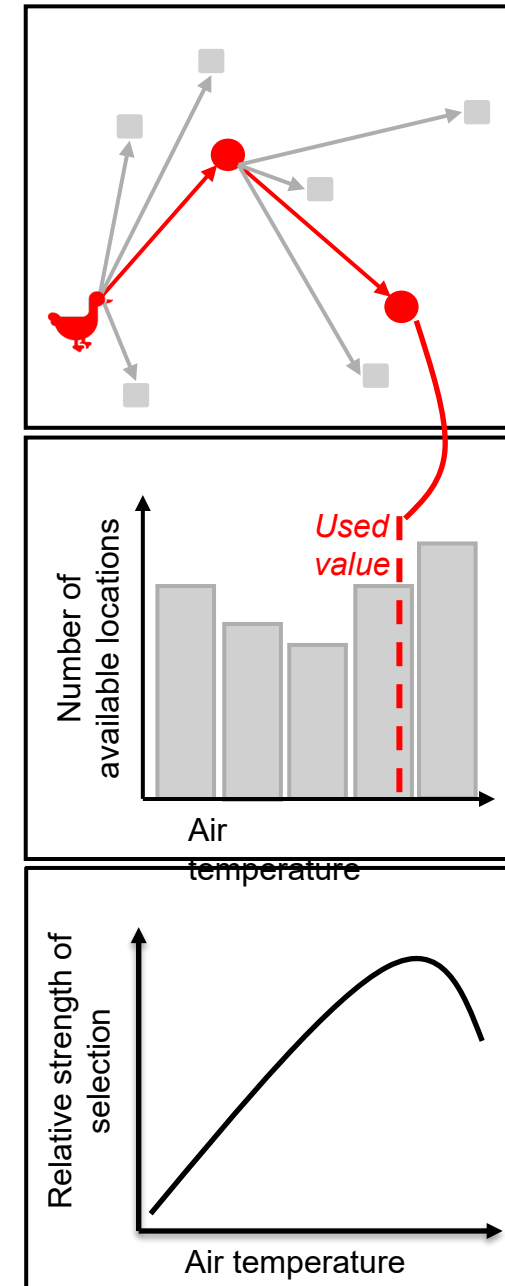
Tracking Dataset: Red Deer

- Source: amt R-package
- Verein für Wildtierforschung Dresden und Göttingen e.V.
- 826 relocations of one red deer from northern Germany
 - 6-hour data
- March 2008 - April 2009
 - No winter data



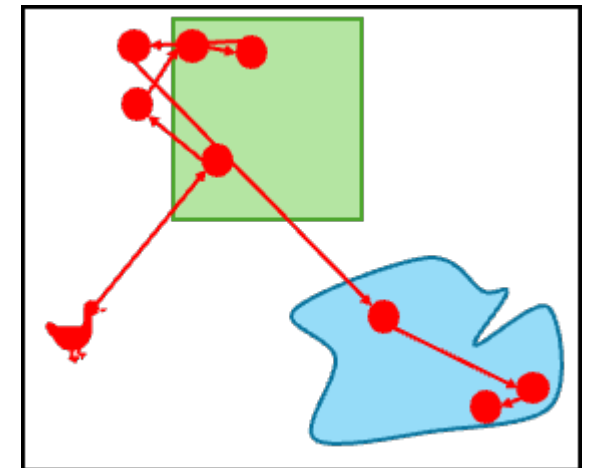
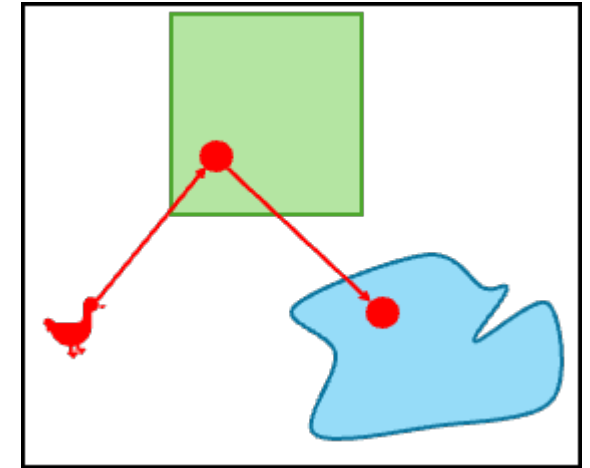
Step-Selection Functions

- Similar conceptually and statistically to SDMs
- Key differences
 - Specific way of defining “used” and “available” locations
 - Require regularly sampled locations
 - Analysis is at the level of an individual movement “step”
 - Remote sensing data can easily be time-matched
- Steps
 - Regularly sampled animal tracks
 - Define presence/absence points **by simulating alternative “steps” based on step lengths and turn angles**
 - Model
 - Binary response variable (case/control) predicted by environmental covariates using **conditional logistic regression**



Tracking Data

- Data must be regularly sampled
 - Within some **tolerance**
 - Gaps are okay: analyze **bursts**
 - Generally compatible: GPS, Argos, etc. (active)
 - Generally not compatible: MOTUS, RFID (passive)
- **Temporal resolution:** what questions can you answer?
 - Daily step: local dispersal/relocation
 - Hourly step: functional movements (foraging, etc.)
 - Minute step: fine-scale habitat use
- Temporal and **spatial scale** are often related
 - What environmental conditions represent a *daily* location?
- **Multiple individuals** can be analyzed separately or together
 - Together: population-level inference
 - Separately: individual differences in habitat use



Download Remote Sensing Data via NASA Earthdata

1. Navigate to <https://search.earthdata.nasa.gov/search>

The screenshot displays the NASA Earthdata Search interface. The browser address bar shows the URL search.earthdata.nasa.gov/search. The page header includes the NASA logo, "EARTHDATA SEARCH", and a "Find a DAAC" dropdown. A search bar on the left contains the text "Search for collections or topics". Below the search bar is a "Browse Portals" section and a "Filter Collections" sidebar. The sidebar includes filters for Features (Available in Earthdata Cloud, Customizable, Map Imagery), Keywords, Platforms, Instruments, Organizations, Projects, Processing Levels, Data Format, Tiling System, Horizontal Data Resolution, and Latency. The main content area displays "10,176 Matching Collections" and "Showing 20 of 10,176 matching collections". The results are sorted by "Usage" and viewed as a "List". The first three results are:

- SENTINEL-1A_SLC**: 1,887,641 Granules, 2014-04-03 ongoing. Sentinel-1A slant-range product. GEOSS · SENTINEL-1A_SLC v1 - ASF.
- Aqua AIRS-MODIS 1-km Matchup Indexes V1 (Aqua_AIRS_MODIS1km_IND) at GES_DISC**: 1,657,164 Granules, 2002-08-31 ongoing. This dataset includes Aqua AIRS to MODIS 1-km collocation index product, within the framework of the Multidecadal Satellite Record of Water Vapor... GEOSS · Aqua_AIRS_MODIS1km_IND v1 - NASA/GSFC/SED/ESD/GCDC/GESDI...
- AIRS-CloudSat cloud mask and radar reflectivities collocation indexes V4.0 (AIRS_CPR_IND) at GES_DISC**: 507,049 Granules, 2006-06-15 ongoing. Version 4.1 is the current version of the data set. Previous versions are no longer available and have been superseded by Version 4.1. This is AIRS-... GEOSS · AIRS_CPR_IND v4.0 - NASA/GSFC/SED/ESD/GCDC/GESDISC

The fourth result is **SENTINEL-1B_SLC**: 789,393 Granules, 2016-04-25 to 2021-12-24. Sentinel-1B slant-range product. GEOSS · SENTINEL-1B_SLC v1 - ASF. The page also includes a "Subscriptions" section at the bottom. The footer shows the version "v25.1.4-4", search time "2.0s", and links to NASA Official, FOIA, NASA Privacy Policy, and USA.gov. A note at the bottom right states "Earthdata Access: A Section 508 accessible alternative".



Download Remote Sensing Data via NASA Earthdata

2. Enter search terms (vegetation, sea surface temperature, land cover, etc.)

The screenshot displays the NASA Earthdata Search web application. A red box highlights the search input area on the left, where 'NDVI' has been entered. Below the search bar are icons for calendar, map, and filters, and a 'Browse Portals' button. A second red box highlights the 'Filter Collections' sidebar on the right, which includes sections for 'Available in Earthdata Cloud', 'Keywords', 'Platforms', 'Instruments', 'Organizations', 'Projects', 'Processing Levels', 'Data Format', 'Tiling System', 'Horizontal Data Resolution', 'Latency', and 'Additional Filters'. The main content area shows '10,176 Matching Collections' with a list of results including 'SENTINEL-1A_SLC', 'Aqua AIRS-MODIS 1-km Matchup Indexes V1 (Aqua_AIRS_MODIS1km_IND) at GES_DISC', and 'AIRS-CloudSat cloud mask and radar reflectivities collocation indexes V4.0 (AIRS_CPR_IND) at GES_DISC'. A map of the Indian Ocean region is visible on the right side of the interface.



Download Remote Sensing Data via NASA Earthdata

3. Select desired product

The screenshot shows the NASA Earthdata Search interface. The search query is 'NDVI'. The results show 176 matching collections. The first collection, 'MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061', is highlighted with a red circle. This collection has 169,020 granules and is ongoing since 2000-02-18. It is described as 'The Terra Moderate Resolution Imaging Spectroradiometer (MODIS) Vegetation Indices (MOD13Q1) Version 6.1 data are generated every 16 da...'. The second collection, 'MODIS/Aqua Vegetation Indices 16-Day L3 Global 1km SIN Grid V061', has 152,408 granules and is ongoing since 2002-07-04. It is described as 'The MYD13A2 Version 6.1 product provides Vegetation Index (VI) values at a per pixel basis at 1 kilometer (km) spatial resolution. There are two primar...'. The left sidebar contains filters for Features, Keywords, Platforms, and Instruments. The top navigation bar includes the NASA logo, 'EARTHDATA SEARCH', and a 'Find a DAAC' dropdown.

search.earthdata.nasa.gov/search?q=NDVI

EARTHDATA SEARCH Find a DAAC

NDVI

176 Matching Collections

Showing 20 of 176 matching collections Sort: Usage View: List

MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061

169,020 Granules 2000-02-18 ongoing

The Terra Moderate Resolution Imaging Spectroradiometer (MODIS) Vegetation Indices (MOD13Q1) Version 6.1 data are generated every 16 da...

GEOSS • MOD13Q1 v061 - LP DAAC

MODIS/Aqua Vegetation Indices 16-Day L3 Global 1km SIN Grid V061

152,408 Granules 2002-07-04 ongoing

The MYD13A2 Version 6.1 product provides Vegetation Index (VI) values at a per pixel basis at 1 kilometer (km) spatial resolution. There are two primar...

GEOSS • MYD13A2 v061 - LP DAAC

Filter Collections

Features

- ☐ Available in Earthdata Cloud
- ☐ Customizable
- ☐ Map Imagery

Keywords

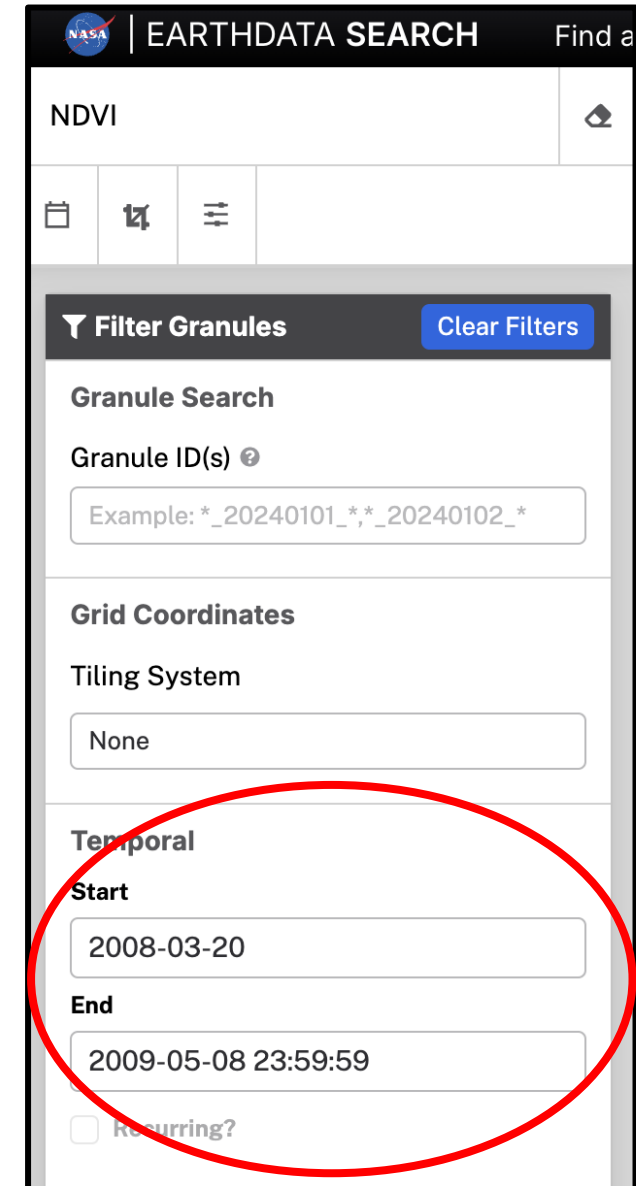
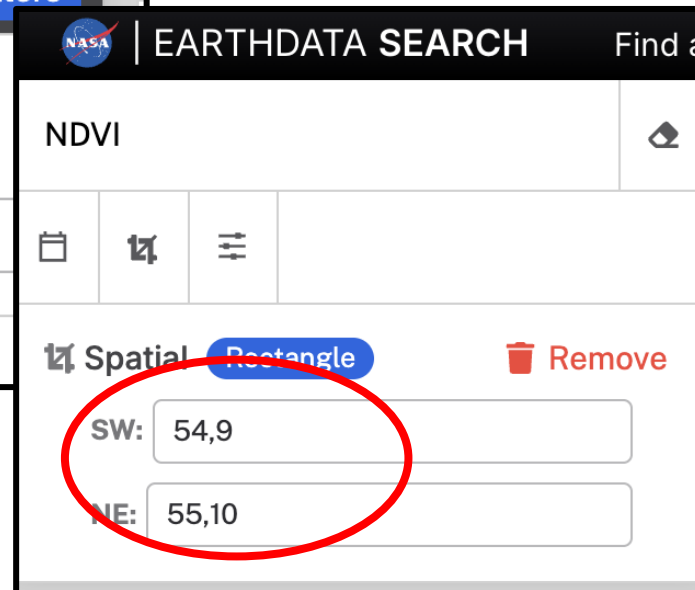
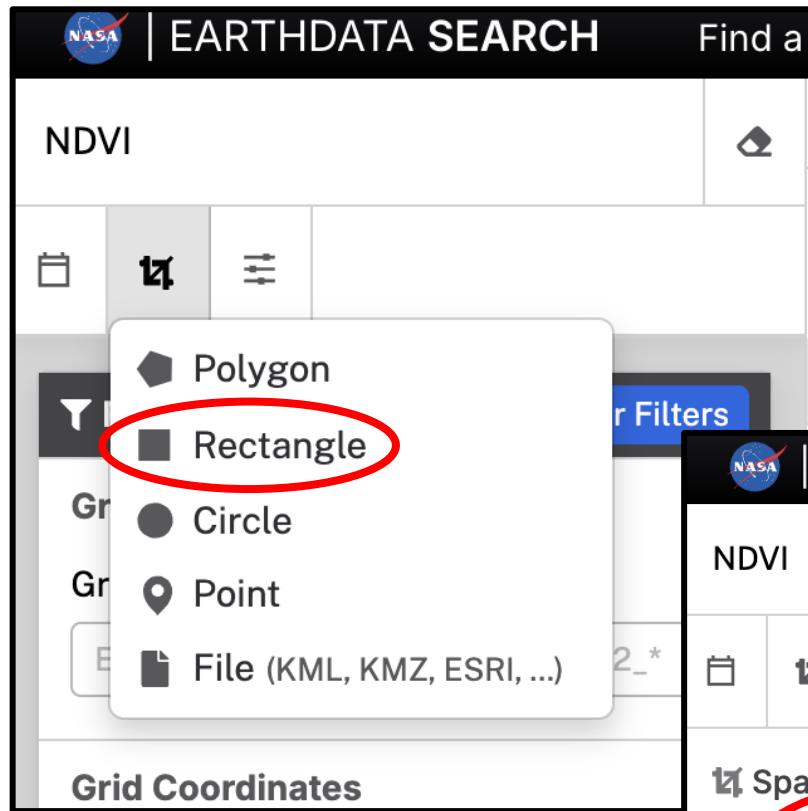
Platforms

Instruments



Download Remote Sensing Data via NASA Earthdata


4. Filter by spatial and temporal extent



Download Remote Sensing Data via NASA Earthdata

5. Check map and number of granules

MOD13Q1.A2009033.h18v03.0
61.2021121043211



START 2009-02-02 00:00:00

END 2009-02-17 23:59:59

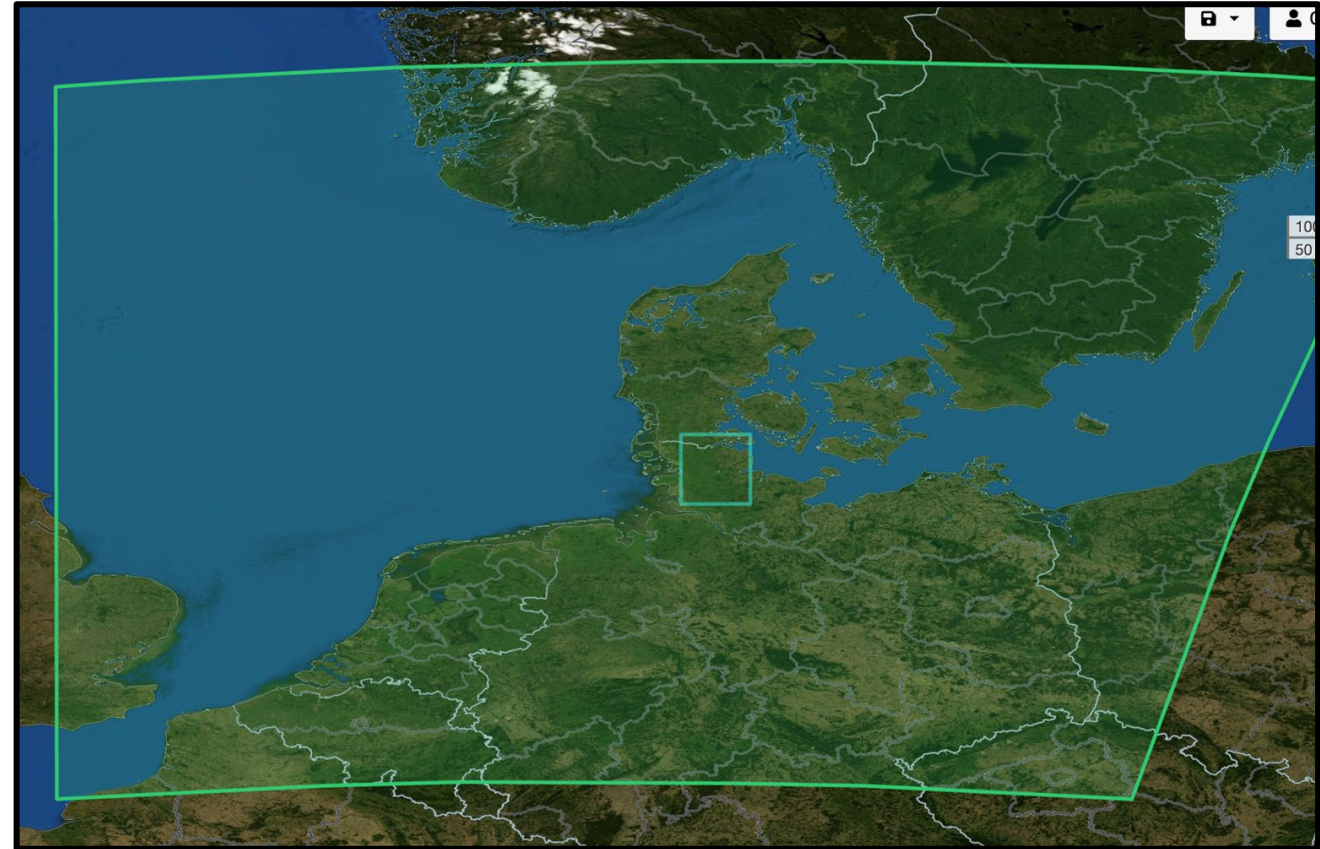
+

↓

Search Time: 0.6s


+ Add

↓ Download All 27

A satellite map showing the North Atlantic Ocean and parts of Europe and North America. A large green rectangular bounding box is drawn over the map, covering the North Atlantic and parts of Europe and North America. A smaller green square is also visible on the map, located in the North Atlantic.

NASA ARSET – Introduction to the Integration of Animal Tracking and Remote Sensing

40

The NASA ARSET logo, which features a stylized globe with a satellite orbiting it, and the text "NASA ARSET" below it.

6. Follow download instructions

Option 1: use the Earthdata Download tool (<https://nasa.github.io/earthdata-download/>)

Option 2: use command-line tools (“Download Script” tab)

Download Status

This page will automatically update as your orders are processed. The Download Status page can be accessed later by visiting <https://search.earthdata.nasa.gov/downloads/1038664454> or the [Download Status and History](#) page.

MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061

STATUS

Complete (100%)

Updated: 04-16-2025 09:46:42 am

ACCESS METHOD

Download

GRANULES

27 Granules

Download your data directly from the links below, or use the provided download script.

Download Files

AWS S3 Access

Download Script

Browse Imagery

Retrieved 27 files for 27 granules

100%

Download Files

Copy

Save

Expand

<https://data.lpdaac.earthdatacloud.nasa.gov/lp-prod-protected/MOD13Q1.061/MOD13Q1.A2009113.h18v03.061.2021131114445/MOD13Q1.061.h18v03.061.2021131114445.tif>

<https://data.lpdaac.earthdatacloud.nasa.gov/lp-prod-protected/MOD13Q1.061/MOD13Q1.A2009097.h18v03.061.2021126174407/MOD13Q1.061.h18v03.061.2021126174407.tif>

<https://data.lpdaac.earthdatacloud.nasa.gov/lp-prod-protected/MOD13Q1.061/MOD13Q1.A2009081.h18v03.061.2021124190515/MOD13Q1.061.h18v03.061.2021124190515.tif>

The screenshot shows the EarthData Search interface. At the top, there's a header with the NASA logo, 'EARTHDATA SEARCH', and a search bar. Below the header, the main content area displays a project named 'Untitled Project' with a pencil icon. The project details show '27 Granules', '1 Collection', and '3.4 GB'. The project name is 'MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061'. Below the project name, it shows '27 Granules' and 'Est. Size 3.4 GB'. There is a gear icon and a link labeled 'Edit Options'. A red circle highlights the 'Edit Options' link and the 'Download Data' button at the bottom.

Find a DAA

Untitled Project

27 Granules 1 Collection 3.4 GB

MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V061

27 Granules Est. Size 3.4 GB

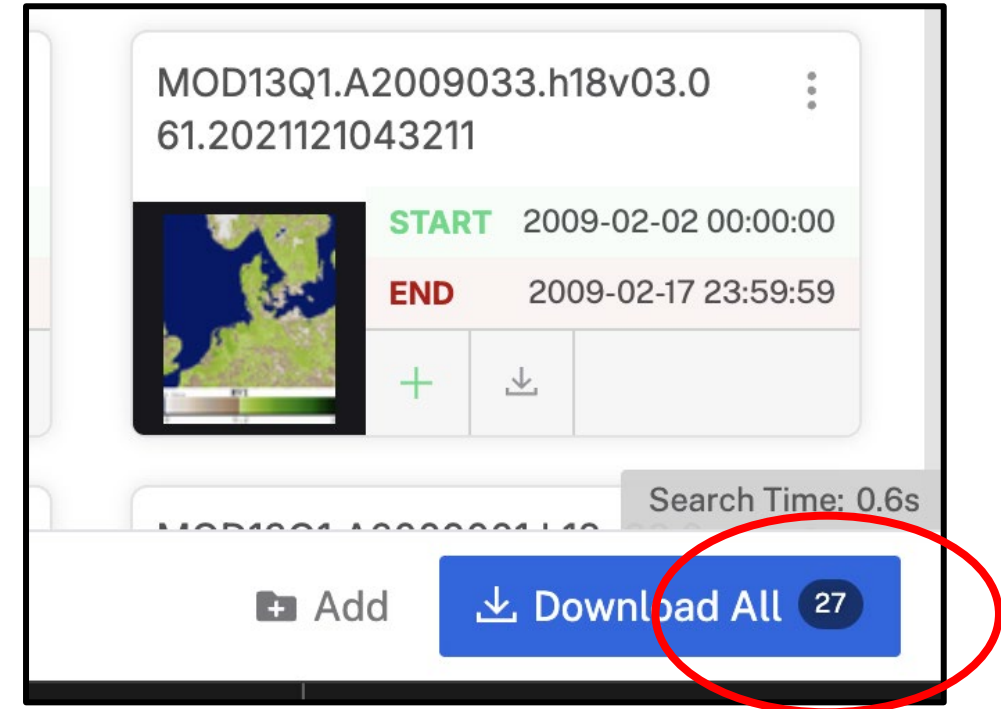
[Edit Options](#)

Click "Edit Options" above to customize the output for each project.

Download Data

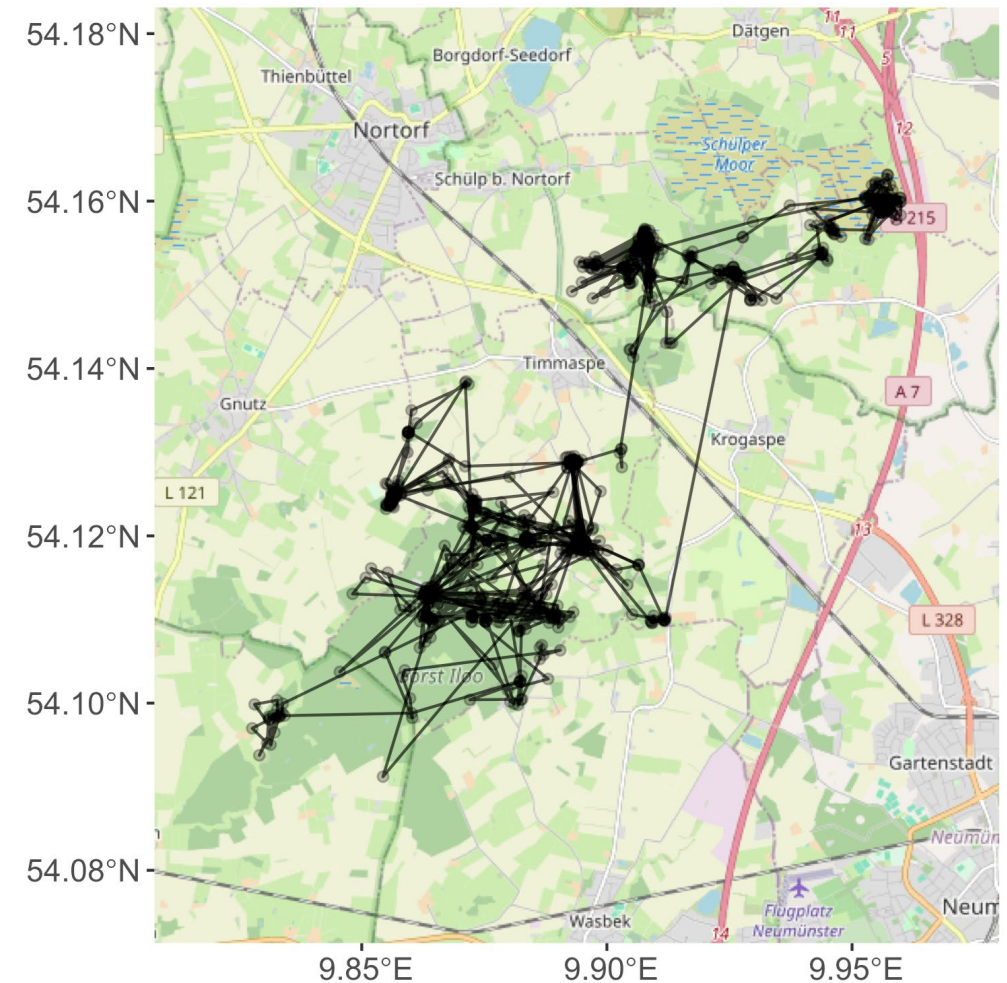
A Note on Post-Processing Spatial Data

- Many products will include multiple granules
 - Locations
 - Dates/times
- Many granules will include multiple layers
 - Variables
 - QA/QC
- Put your GIS skills to use!
 - Mosaicking to combine spatial tiles
 - Stacking to combine temporal tiles
 - Cropping to include only needed area
- **Always check original documentation!**
 - What does each layer mean?
 - Rescaling values



Conduct Step Selection Analysis

1. Clean telemetry data
2. Process telemetry data to **regular steps** and identify **bursts**
3. Simulate alternative **(control) steps**
 - a. model distributions of step lengths and turning angles
4. Identify spatial and temporal extent of data
5. Download and process desired environmental (remote sensing) data
6. Extract environmental data
 - a. At step end points
 - b. At step starting points
 - c. Along trajectories
7. Perform **conditional logistic regression**
8. Inference and mapping
 - a. Relative strength of selection: primary metric



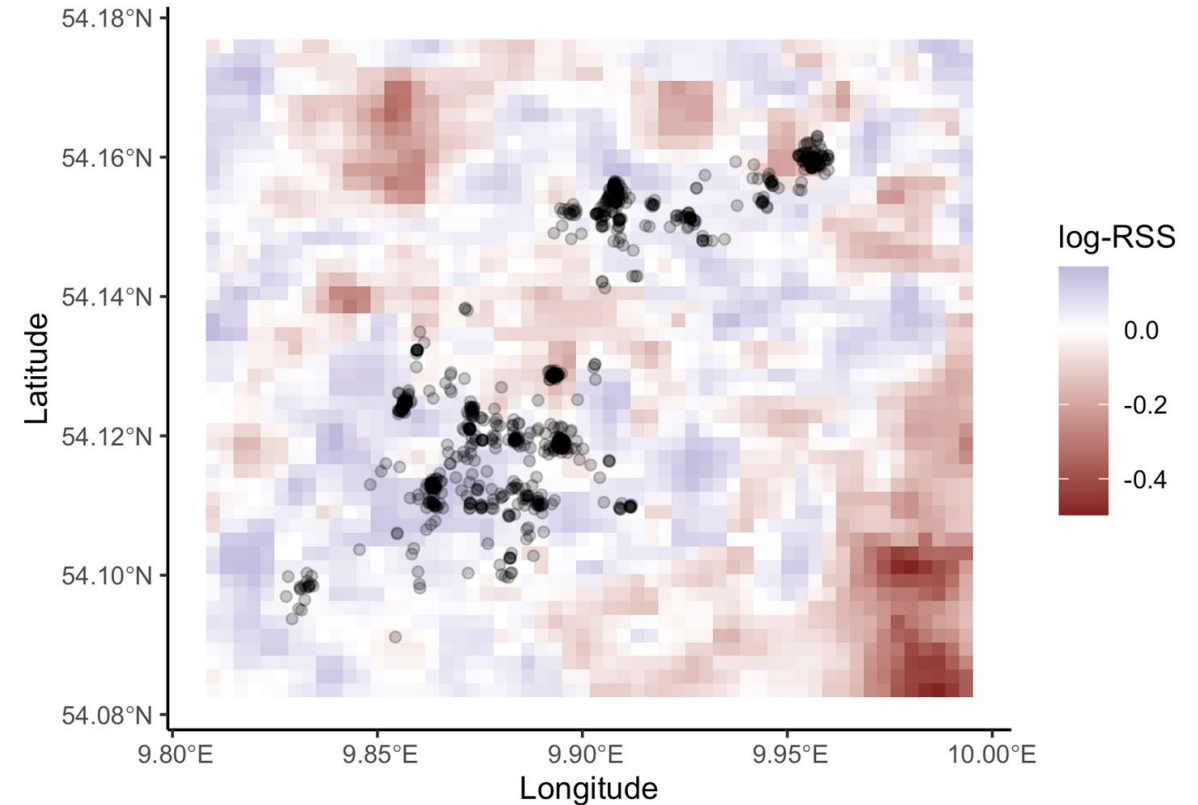
Conduct Step Selection Analysis

- See code demo



Model Interpretation

- **Relative strength of selection (RSS):** what does this mean?
 - NOT probability of use
 - Requires defining reference conditions: average, home range, etc.
 - For a single variable: average change in the space use probability...as we change the covariate of interest...while averaging over possible values of other covariates
- SSFs: available environment changes across space and time
 - Simulation methods can help





Resources

Resources

- Animal telemetry concepts
 - Animals as sensors: Ellis-Soto, D., Wikelski, M., & Jetz, W. (2023). Animal-borne sensors as a biologically informed lens on a changing climate. *Nature Climate Change*, 13(10), 1042-1054. <https://doi.org/10.1038/s41558-023-01781-7>
- Remote sensing resources:
 - Earthdata Search: <https://search.earthdata.nasa.gov/search>
 - rerddapXtracto R package: <https://cran.r-project.org/web/packages/rerddapXtracto/index.html>
- Additional analysis platforms
 - Movebank Env-DATA system: <https://www.movebank.org/cms/movebank-content/env-data>
 - MoveApps: <https://www.moveapps.org/>



Resources

SSFs

- The “original” step-selection paper: Fortin, D., Beyer, H. L., Boyce, M. S., Smith, D. W., Duchesne, T., & Mao, J. S. (2005). Wolves influence elk movements: behavior shapes a trophic cascade in Yellowstone National Park. *Ecology*, 86(5), 1320-1330. <https://doi.org/10.1890/04-0953>
- amt R package: <https://cran.r-project.org/web/packages/amt/>
 - Step-selection vignette: https://cran.r-project.org/web/packages/amt/vignettes/p4_SSF.html



Resources

Species Distribution Models

- SDM code in this training based on: Hazen et al. (2021). Where did they not go? Considerations for generating pseudo-absences for telemetry-based habitat models. *Movement Ecology* 9:5. <https://www.doi.org/10.1186/s40462-021-00240-2>
 - SDM & pseudo-absence code here: <https://github.com/elhazen/PA-paper>
- Additional suggestions
 - R-pkg. aniMotum: Jonsen et al. (2023). aniMotum, an R package for animal movement data: Rapid quality control, behavioural estimation and simulation. *Methods in Ecology and Evolution* 14: 806-816. <https://doi.org/10.1111/2041-210X.14060> and code here: <https://ianjonsen.github.io/aniMotum/index.html>
 - Great discussion of SDMs: Braun et al. (2023). Building use-inspired species distribution models: Using multiple data types to examine and improve model performance. *Ecological Applications*



Summary of Part 2

- When integrating animal tracking and remote sensing data, it is very important to consider:
 - The environmental variables that affect the presence/absence of the animal species of interest.
 - The spatiotemporal resolution of the remote sensing data.
- Species Distribution Models help us understand the likelihood of the presence of a particular animal species depending on the habitat type.
- The selection of a particular Species Distribution Model will depend on the research question and available datasets.



Homework and Certificates

- **Homework:**
 - One homework assignment
 - Opens on 5/22/2025
 - Access from the [training webpage](#)
 - Answers must be submitted via Google Forms
 - **Due by 5/6/2025**
- **Certificate of Completion:**
 - Attend this live webinar (attendance is recorded automatically)
 - Complete the homework assignment by the deadline
 - You will receive a certificate via email approximately two months after completion of the course.



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Thank You!

