Remote Sensing and Animal Movement

Animal Movement Workshop

Beijing, China

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Outline

1. Remote Sensing
2. Case Studies: Remote Sensing Data in Animal Movement Research
3. Downloading Remote Sensing Products
4. Manipulating Remote Sensing Data in R
5. Practical Exercise

Earth Observation & Remote Sensing

Earth Observation (EO)

- It is the act the gathering of information about Earth. It encompasses numerous techniques and approaches, one of which is remote sensing.

Remote Sensing (RS)

- Obtaining information about objects, areas, or phenomena from a distance, **without direct physical contact** with it, typically from aircraft/drones or satellites.

In Situ Observation/Data

- Data or observations **collected directly** in

contact with the objects of interest

- Can typically be independently validated

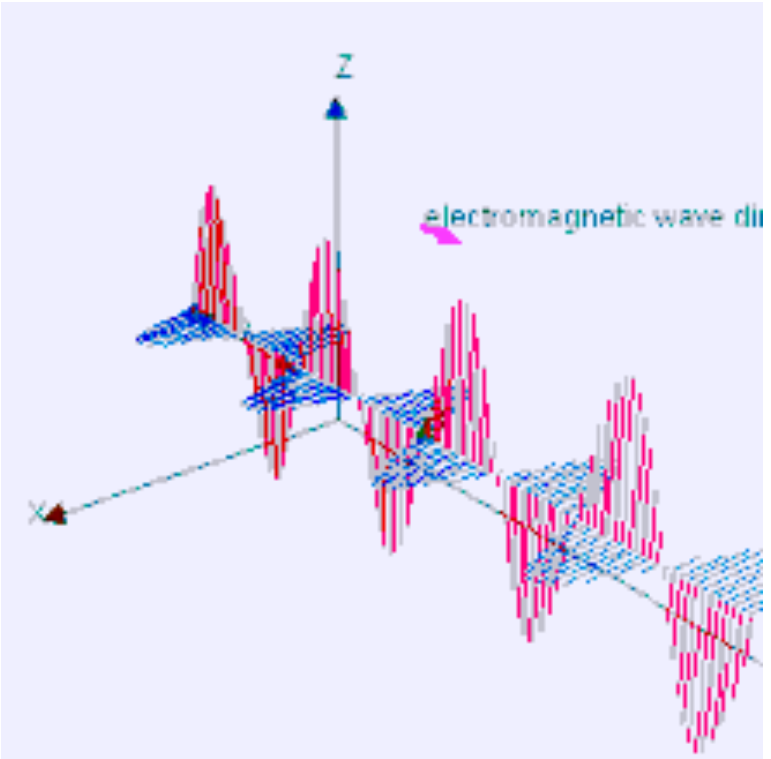
by remote sensing data

Ines and Elham (2024)

Remote Sensing: What data are we sensing?

The most common type of data: **Electro-magnetic radiation**

It is a synchronized oscillation of electric and magnetic fields.



Wave-Particle Duality

Wavelength: the distance between successive peaks of the wave

Frequency: the number of oscillations per second.

The speed of light (c) = wavelength (λ) * frequency (ν)

In the vacuum: ~300 million (3 x 10^8) meters per second.

Ines and Elham (2024)

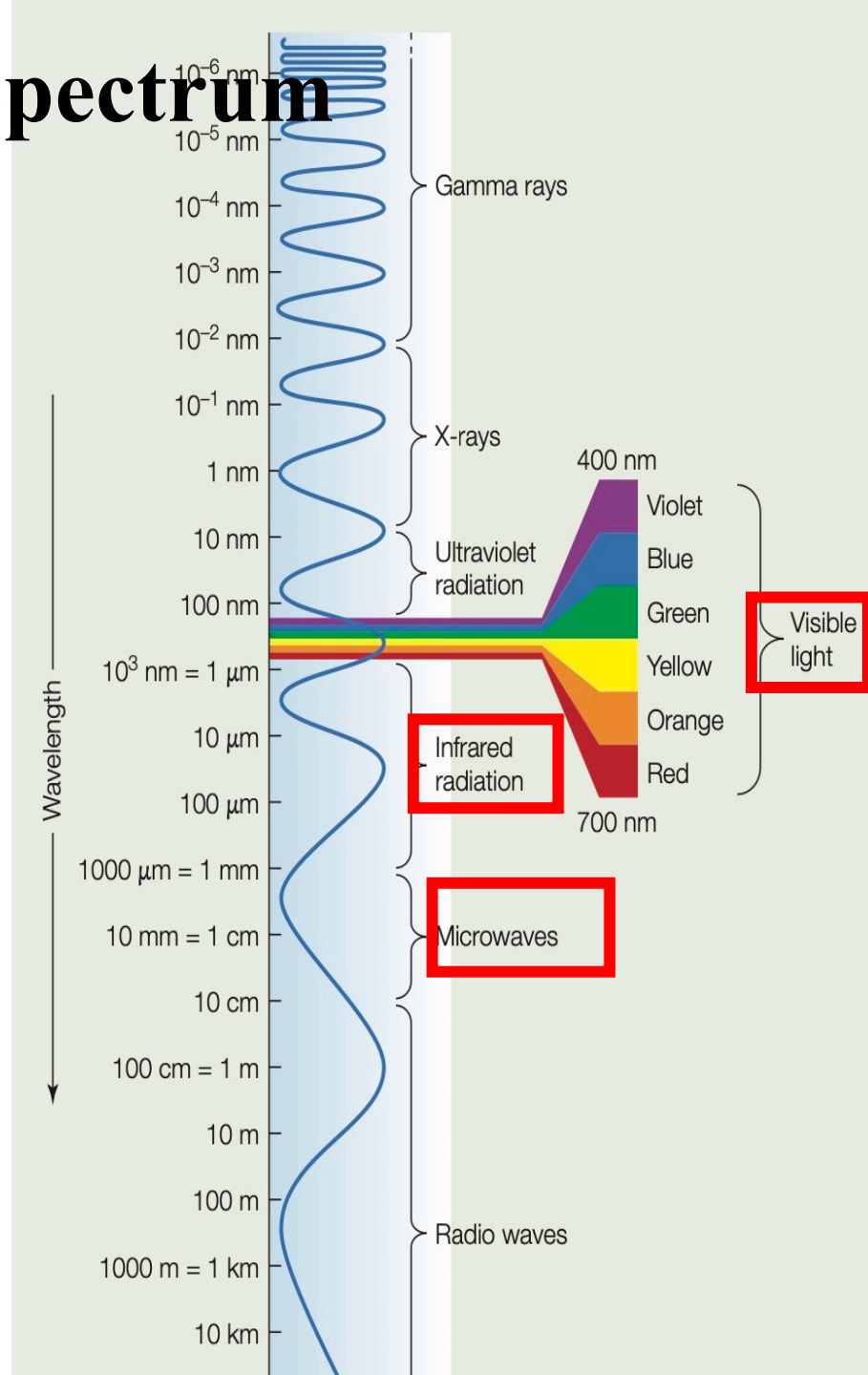
Wavelength of Electro-magnetic (EM) Spectrum

Different types of sensors can detect at different specific wavelengths.
1000 nm = 1 μm, 1000 μm = 1 mm, 1000 mm = 1cm

1. **Visible Light (VIS):** 400 ~ 700 nm

2. **Infra-Red (IR):** 700 nm ~ a few hundred μm
- **Near Infra-Red (NIR):** 700-1,000 nm
  - Vegetation (calculate NDVI), land cover classification, water bodies..
- **Short Wave-Infra-Red (SWIR):** 1 ~ 3 μm
  - Moisture monitoring (soil / vegetation), minerals identification…
- **Thermal Infrared (TIR):** 9 ~ 15 μm
  - captures radiation emitted by objects (temperature)
  - can penetrate smoke and thin clouds
  - measure the surface temperature, heat loss, body temperature, wildfire

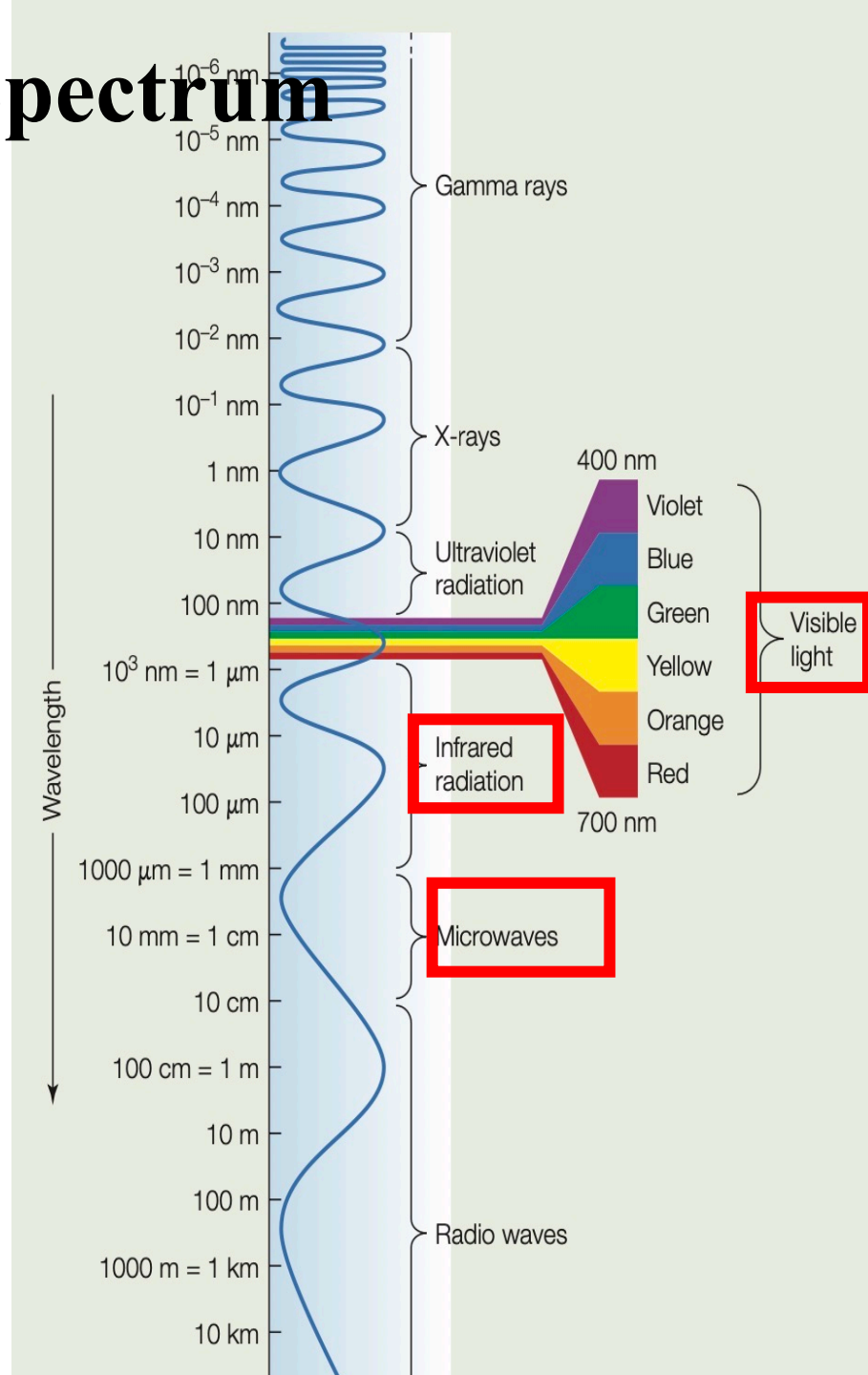
3. **Microwave Radiation**: 1mm ~ 1m
   - High penetration: can penetrate cloud cover; all weather, day and night
   - Weather, climate monitoring, surface roughness, GPS and satellite communication
   - **Passive microwave:** low spatial resolution (res: >9km)
   - **Active microwave:** res <100 m



Wavelength of Electro-magnetic (EM) Spectrum

The longer the wavelength, the lower the energy.

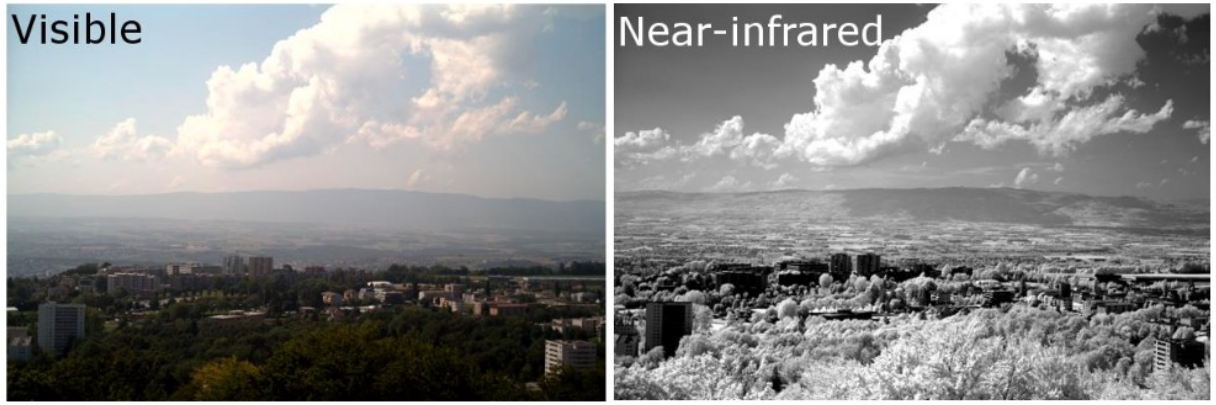
Consequently, the spatial resolution of remote sensing images (passive sensor) becomes coarser.



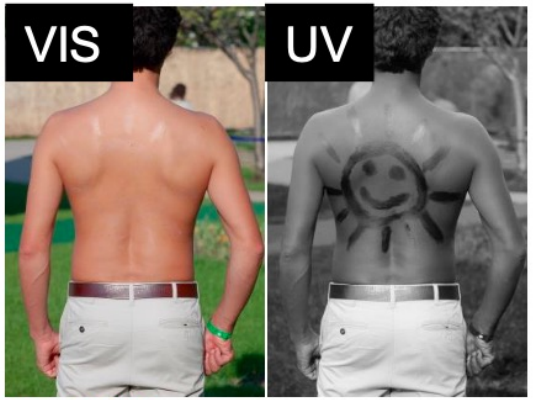
Example

argosfp7project

argostp7project



EPFL



source

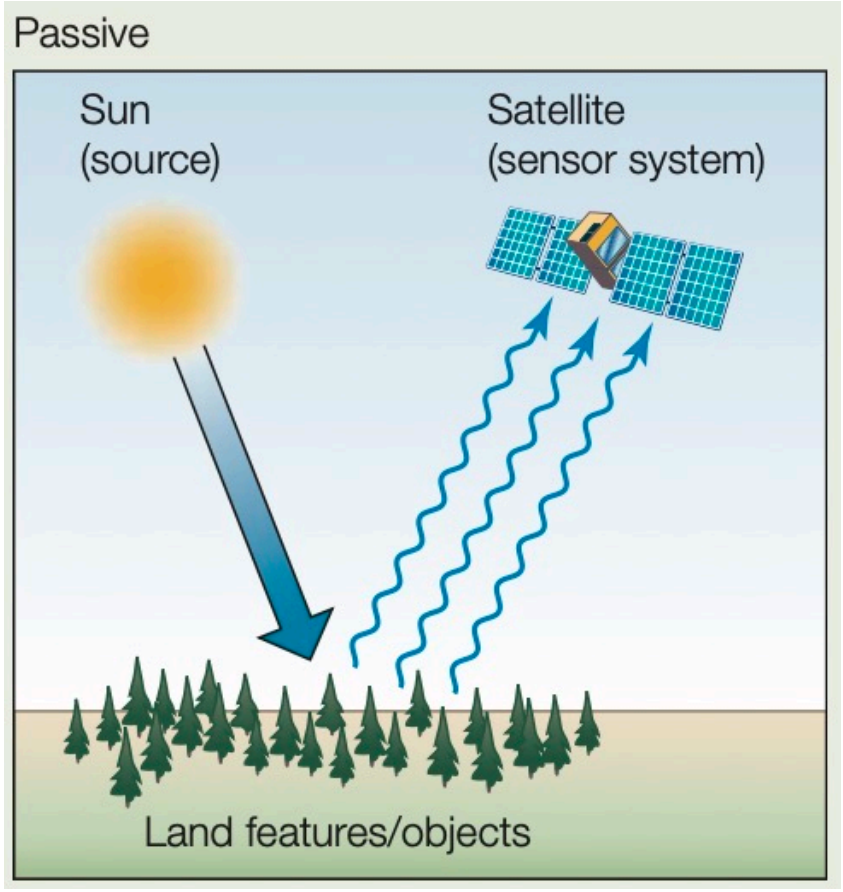
Ines and Elham (2024)

Different wavelength domains require different types of sensors to be measured

Feature	Optical Remote Sensing	Thermal Remote Sensing	Radar Remote Sensing
Wavelength Range	Visible, NIR, SWIR sensors (400 nm to 3,000nm)	Thermal Infrared (TIR) sensors (3 μm to 14 μm)	Microwave (1mm to 30 cm, or even 1m)
Source of Radiation	Sunlight (Passive)	Earth (Passive)	Earth (passive) and Microwave signals (active)
Weather Dependence	Affected by clouds, haze, darkness (ineffective in night)	Affected by clouds and weather conditions	All-weather, day and night capability
Spatial Resolution	Generally higher	Generally coarser than optical	Generally coarser (passive sensor), higher in active sensor
Penetration Ability	Limited (surface)	Limited to surface temperatures	Penetrate vegetation, soil..
Application	Vegetation, agriculture, land cover, water quality	Surface temperature, geothermal activity	Topography, soil moisture, vegetation structure…
Platform	Satellites (e.g., Sentinel-2, Landsat), Aircraft, Drones	Satellites (e.g., Landsat 8, MODIS, ASTER), Aircraft	Satellites (e.g., Sentinel-1, RADARSAT), Aircraft
Data	Easier to interpret	Moderate complexity	Complex to process
Sensors	Multispectral and hyperspectral sensors	Thermal infrared sensors (e.g., TIRS, MODIS, ASTER)	Synthetic Aperture Radar (SAR), Real Aperture Radar

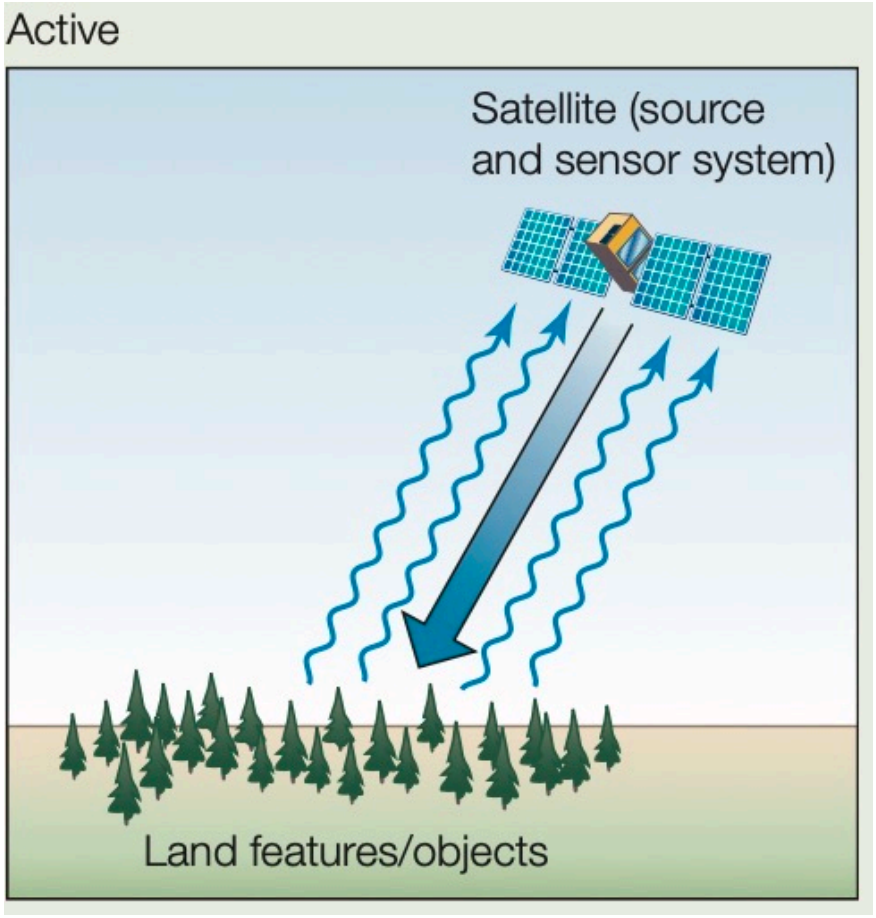
Where does EM radiation come from?

PASSIVE
Measure whatever comes to you
Source: Sun / Earth/ Atmosphere



Example:
Digital Camera,
Optical sensor

ACTIVE
Emit a radiation and measure what is coming back
Source: part of the remote sensor system



Example:
LiDAR,
Radar,
Digital Camera
With flash

Image Credit: Dipen Sahajramani, M,Tech Geomatics & Remote Sensing, Center for Environmental Planning and Technology University (2019)
https://www.quora.com/What-are-the-components-of-a-remote-sensing-satellite

Where is the radiation PASSIVE sensors measure coming from?

Reflected Sunlight:

VIS, NIR, SWIR: 400 ~ 2500 nm

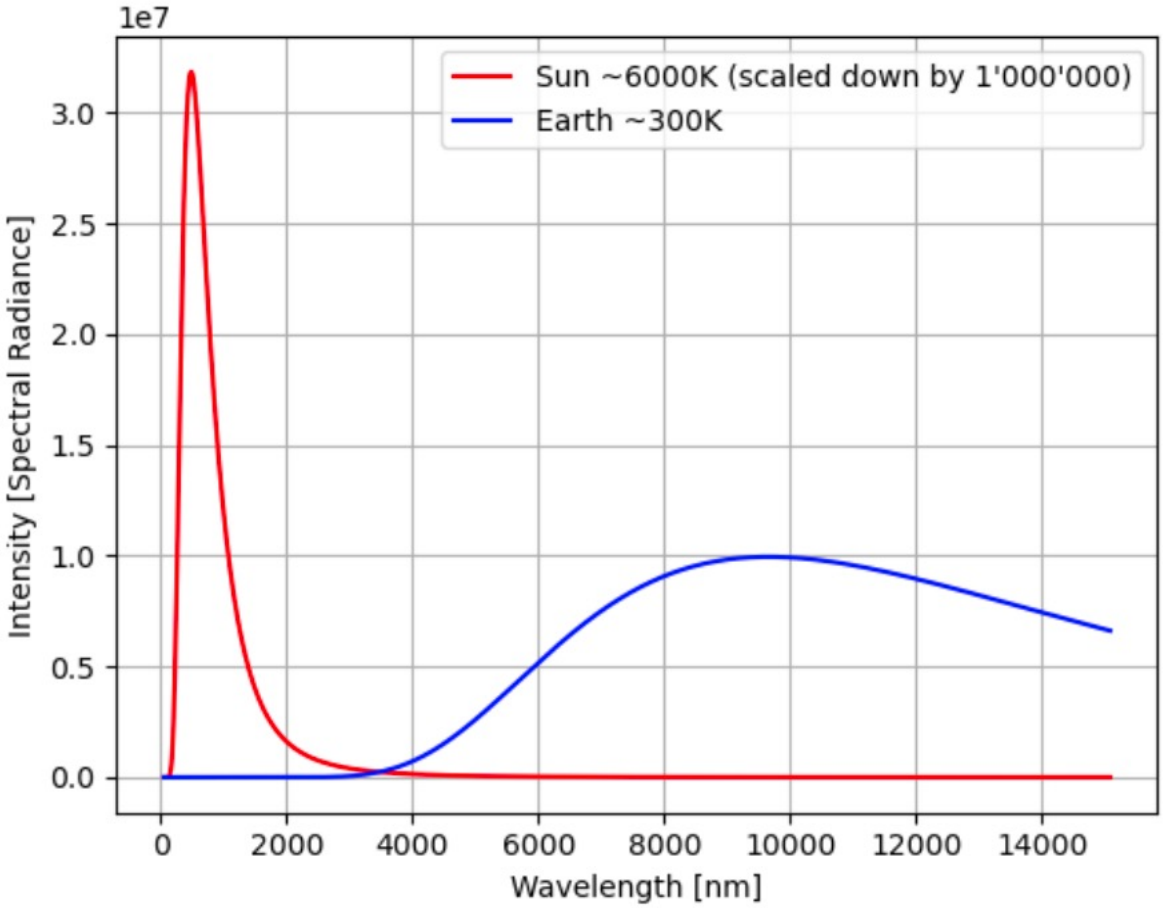
Optical remote sensing

Earth:

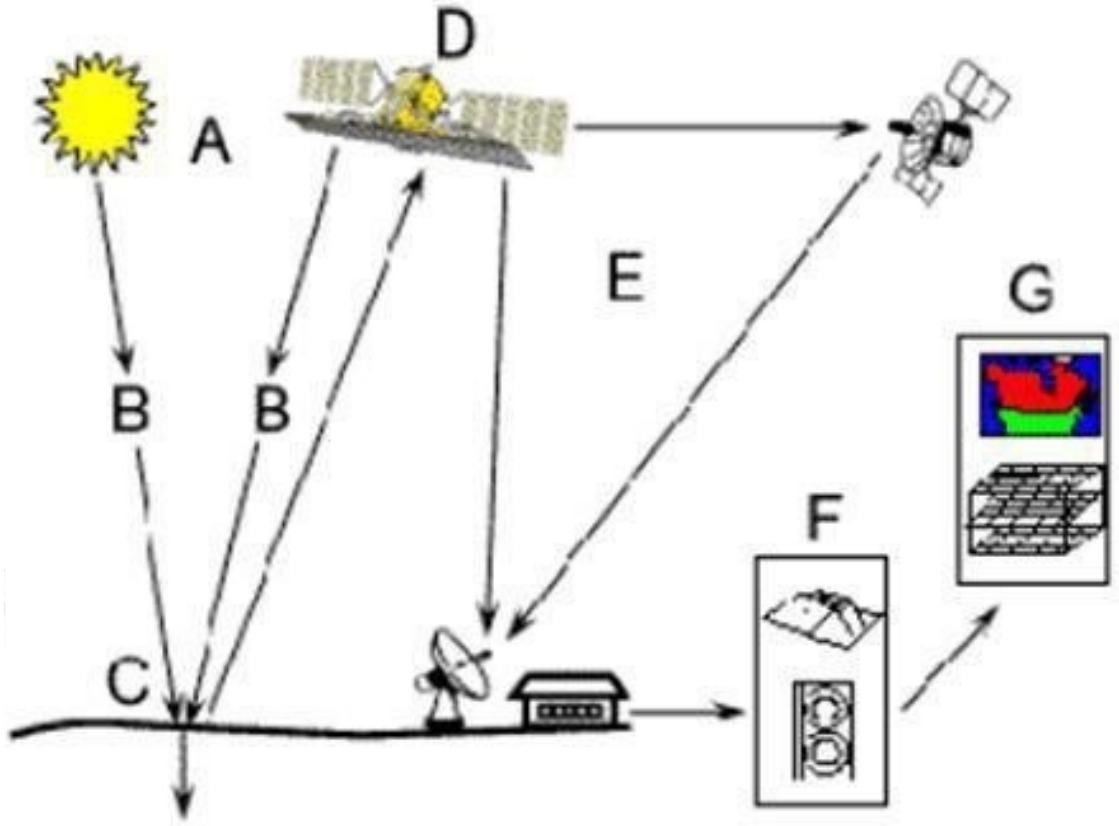
MWIR, LWIR (TIR): > 4000 nm

- These temperatures on Earth can reach a few 100°Celsius (e.g., Lava 1,200°C)

Thermal remote sensing



Component of remote sensing system



A: Energy source or illumination
B: Interaction with the atmosphere

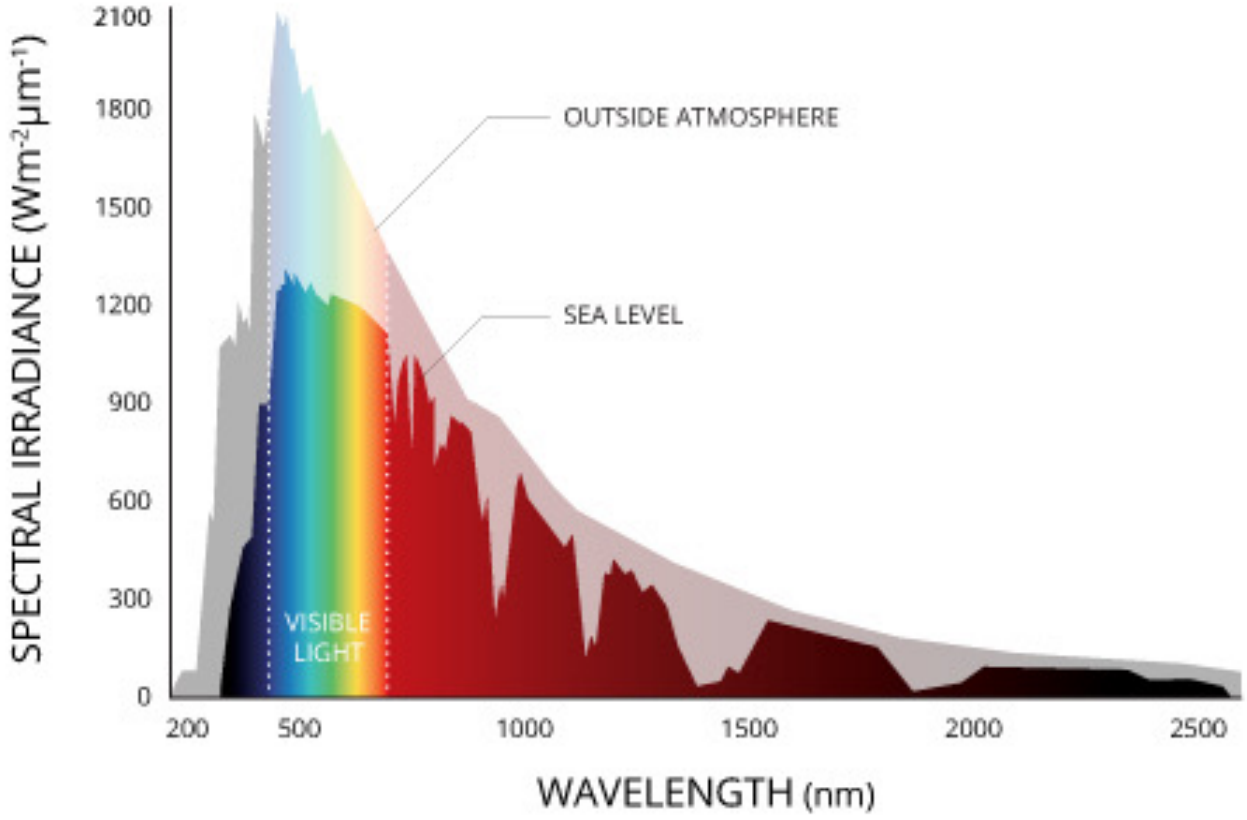


Image Credit: Dipen Sahajramani, M,Tech Geomatics & Remote Sensing, Center for Environmental Planning and Technology University (2019)
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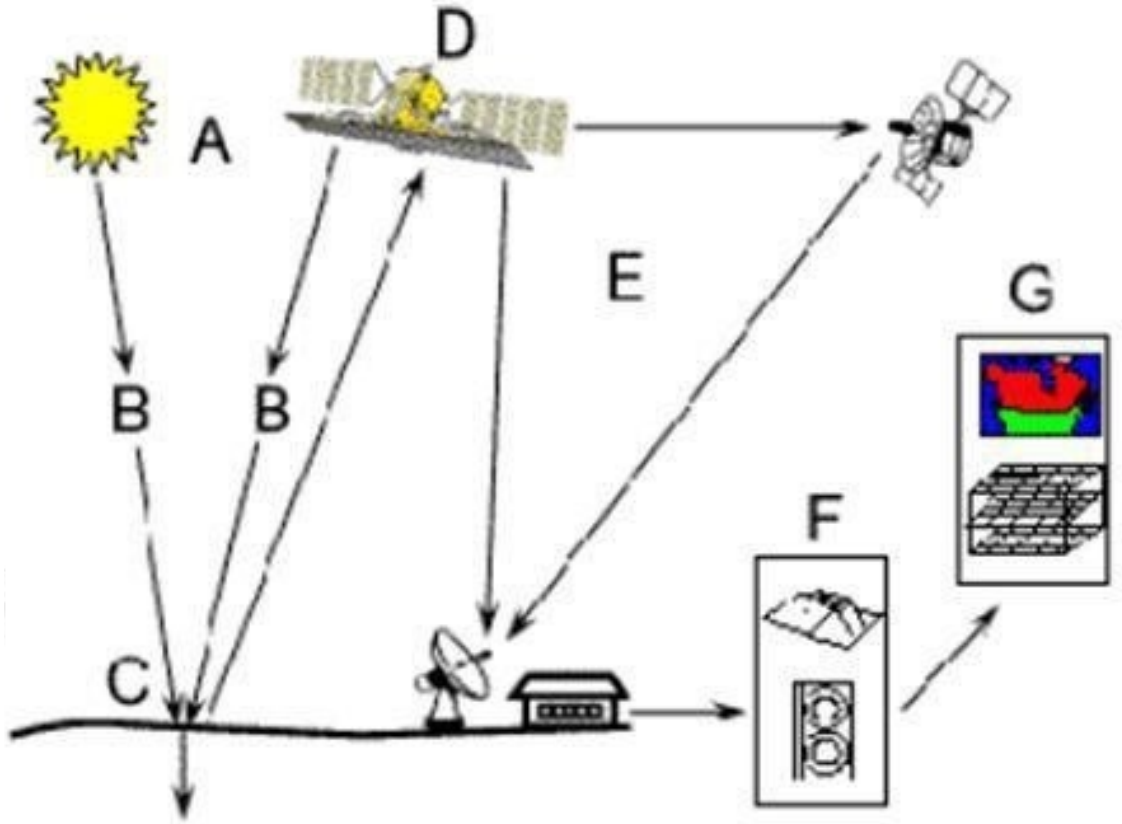
Component of remote sensing system



A: Energy source or illumination
B: Interaction with the atmosphere
C: Interaction with the target

Spectral Signatures

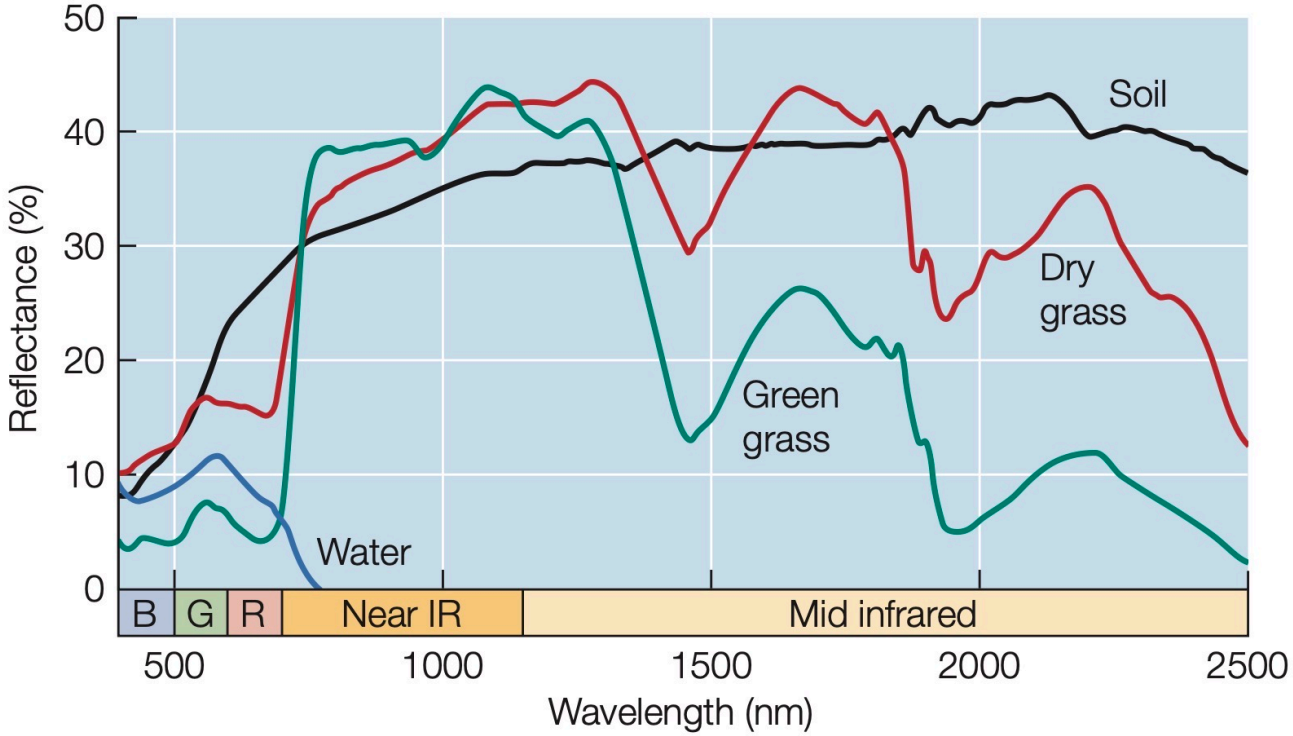


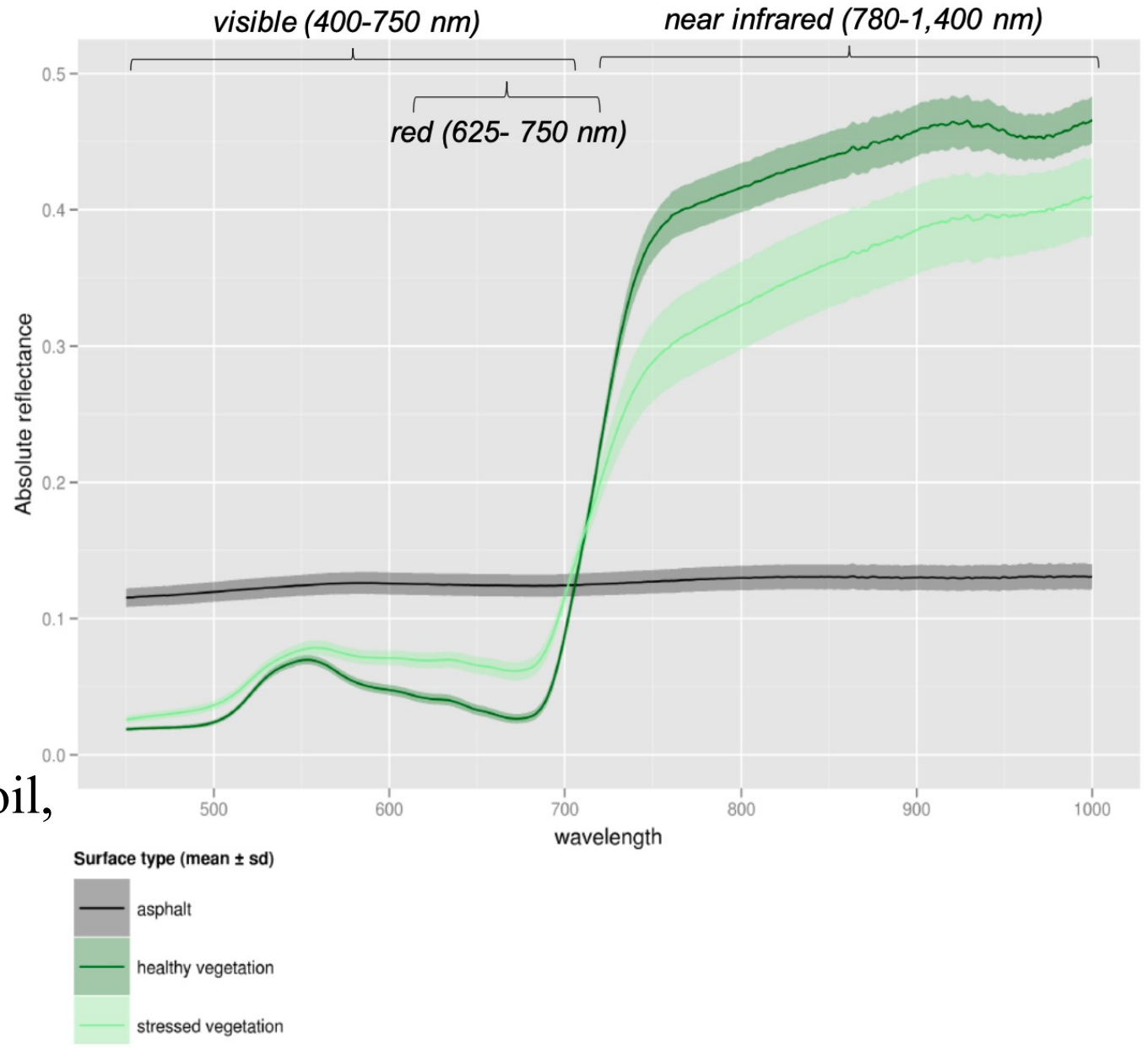
Image Credit: Dipen Sahajramani, M,Tech Geomatics & Remote Sensing, Center for Environmer
https://www.quora.com/What-are-the-components-of-a-remote-sensing-satellite

Normalized Difference Vegetation Index (NDVI)

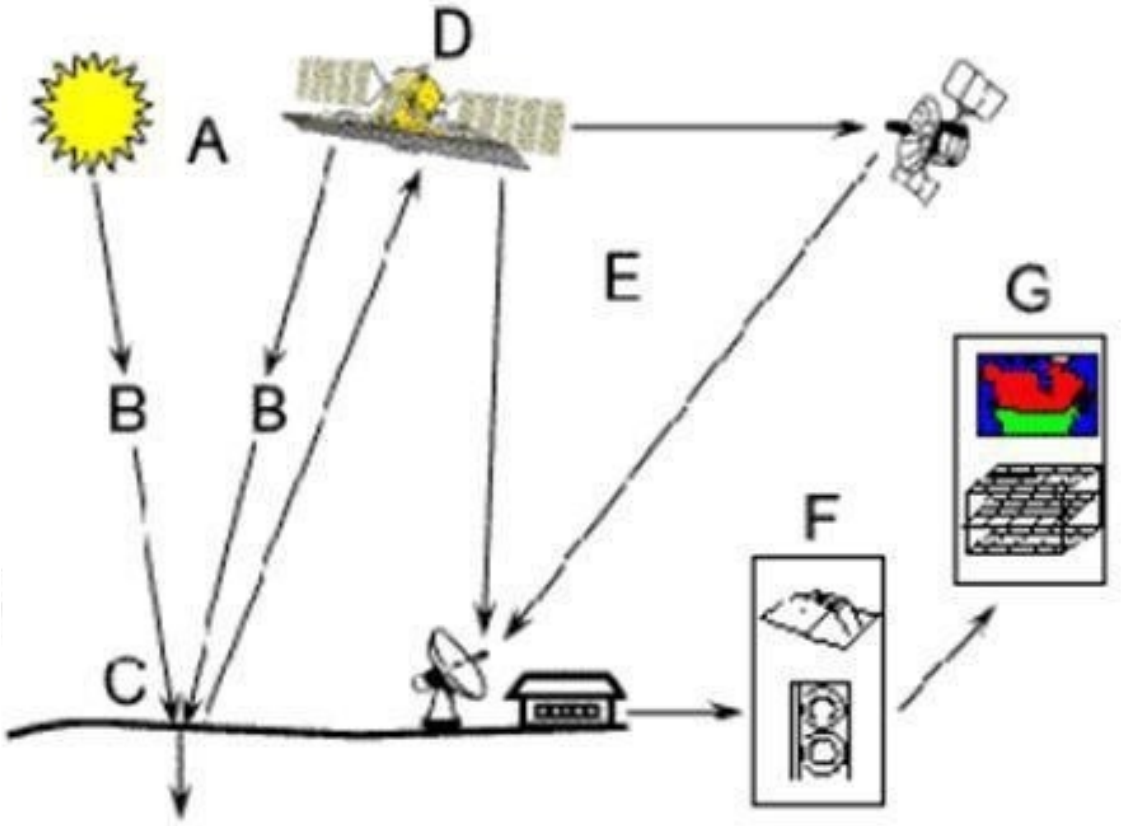
- The amount of vegetation and the health condition on the land surface.
- Green Vegetation & Bare Soils
- Healthy Plants & Aging Plants

$$NDVI = \frac{(nir - red)}{(nir + red)}$$

- Range: 0 ~ 1
- 0: non-vegetated materials, such as bared soil, concrete, or snow
- Negative values are often found over water



Component of remote sensing system



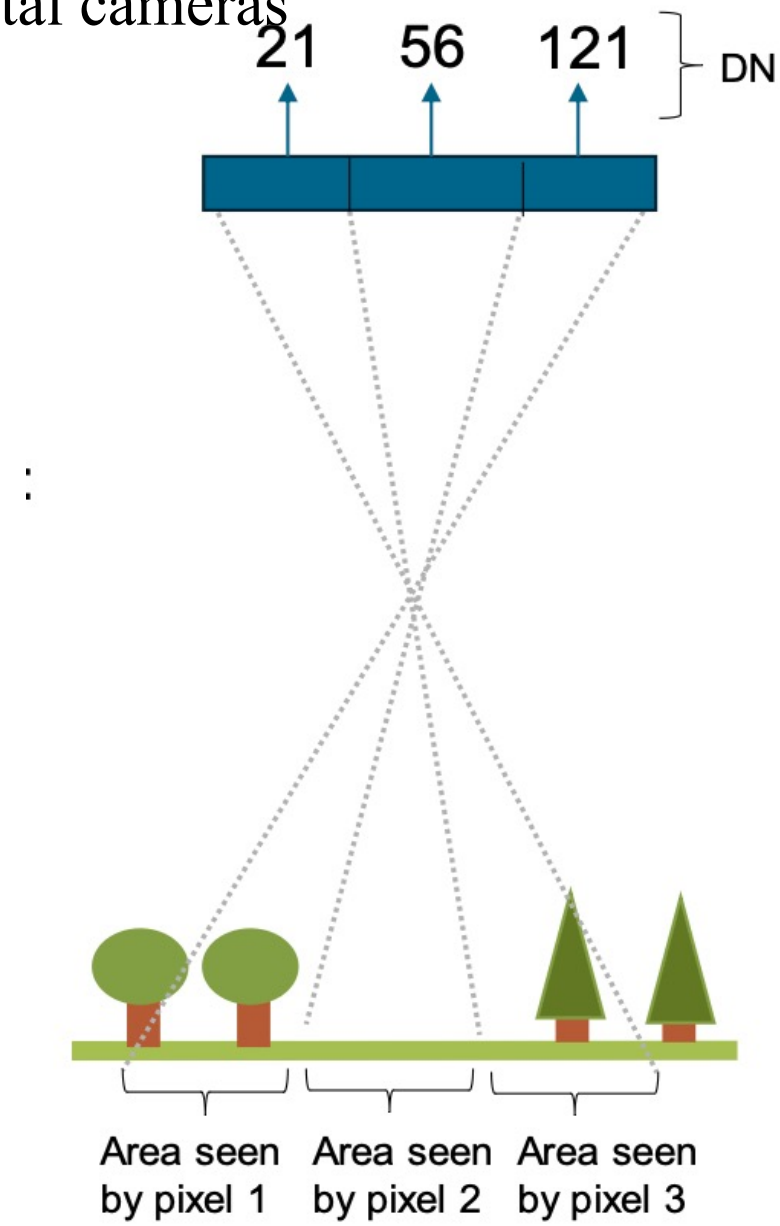
A: Energy source or illumination
B: Interaction with the atmosphere
C: Interaction with the target
D: Recording of energy by the sensor
E: Transmission, Reception and Processing
F: Interpretation & Analysis
G: Application

Image Credit: Dipen Sahajramani, M,Tech Geomatics & Remote Sensing, Center for Environmental Planning and Technology University (2019)
https://www.quora.com/What-are-the-components-of-a-remote-sensing-satellite

How are we measuring?

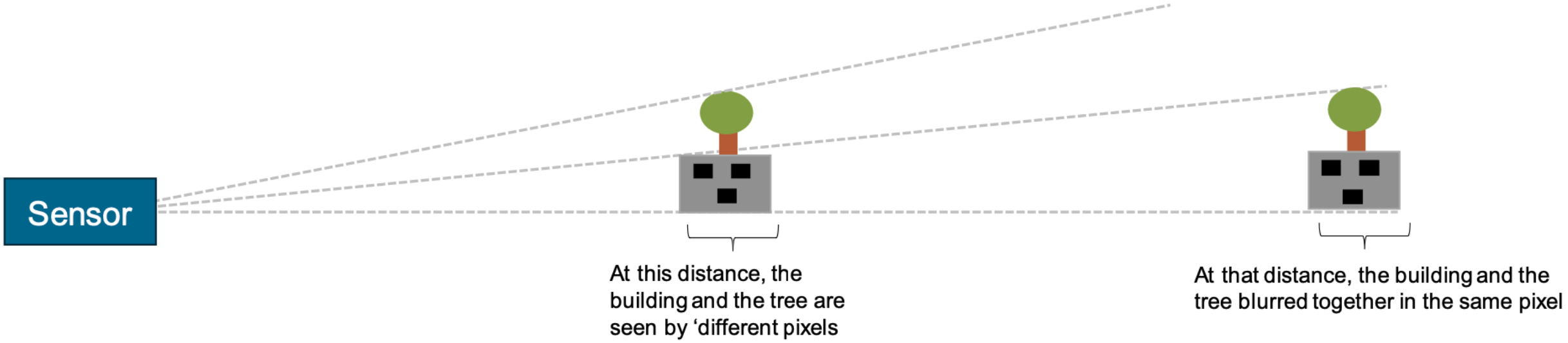
In the VIS-SWIR domain (optical remote sensing), sensors are ‘digital cameras’

1. **Detection**
2. **Counting**
   The photons at specific wavelengths from the given directions over a certain time
   Number of photons per second per solid angle per area per wavelength.
3. **DN Conversion**
   The intensity of the detected light
4. **Calibration**
   Observed radiance at the Top of Atmosphere (TOA) (the raw data)
5. **Inversion Process**
   Obtain information, such as surface reflectance, temperature, vegetation indices, gas concentration



Noted:

- Each Pixel corresponds to an '**angle**' - not directly a size
  - depends on the sensor characteristics
- If several objects are covered by the same pixel, they will be 'mixed' or 'blurred' together by that pixel



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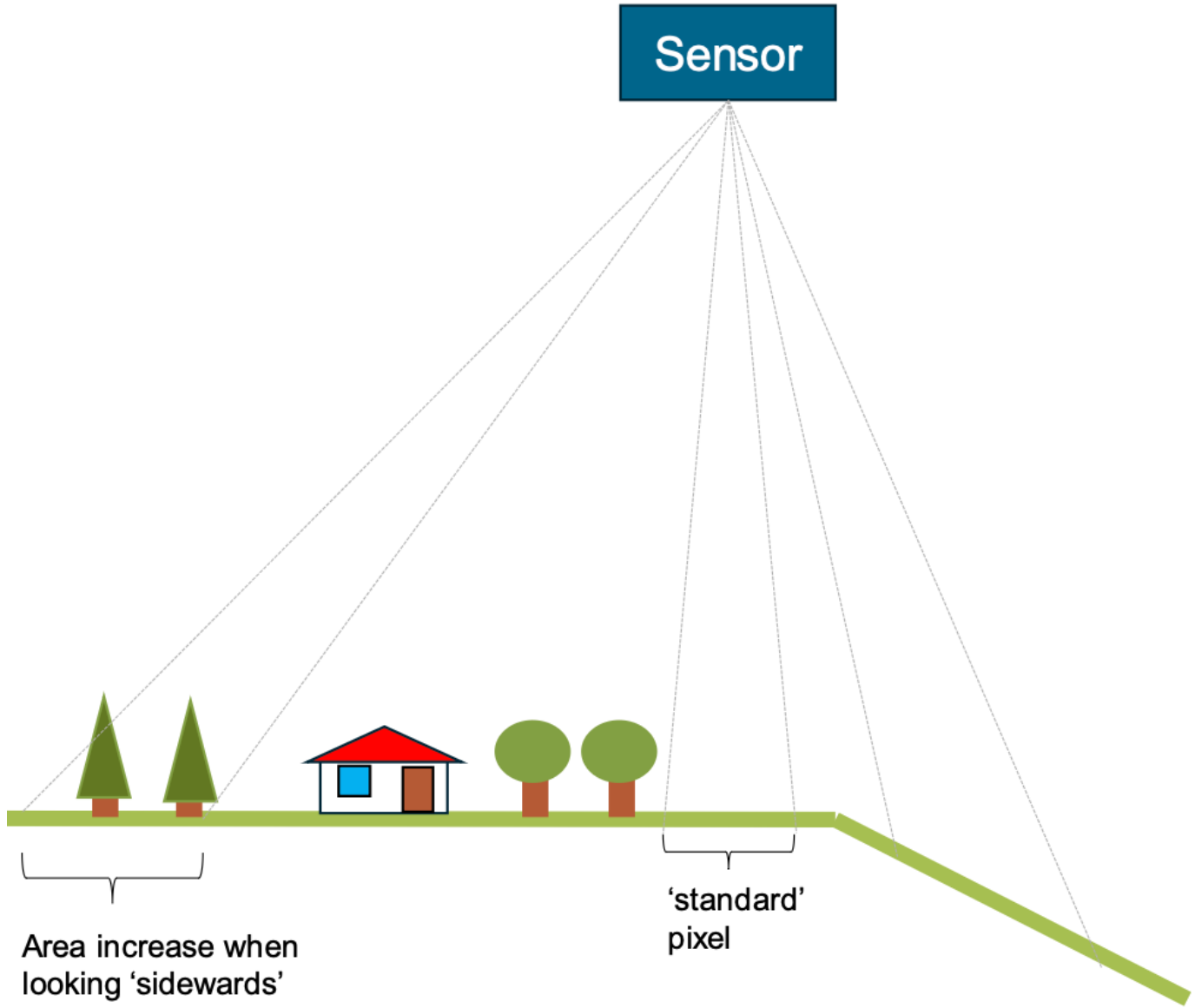
Resolution of Satelite Images

- Spatial Resolution
- Spectral Resolution
- Temporal Resolution

Spatial Resolution

- Sensor itself
- Location of the pixel
  - edge & center
- Sensor orientation (angle)
- Shape of the terrain



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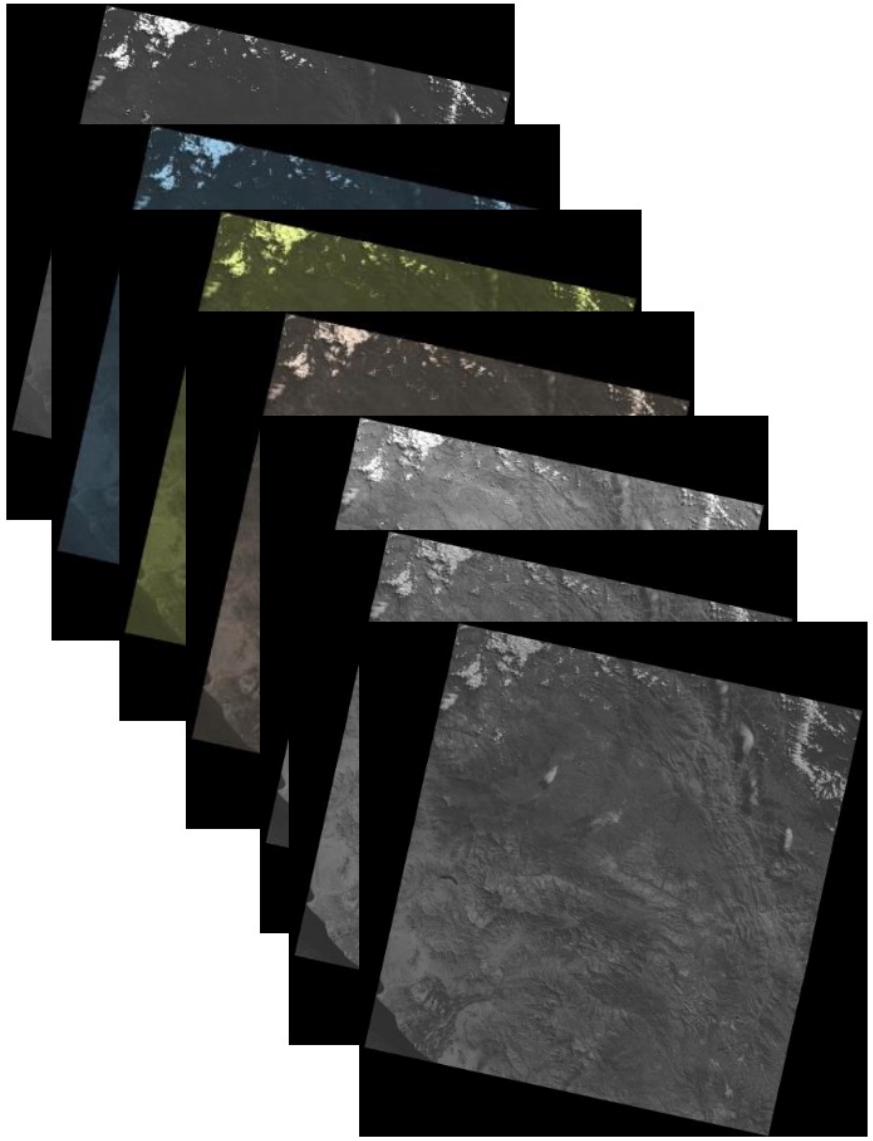
Spectral Resolution

distinguish between different wavelengths and divide the spectrum into separate bands

Remote sensing imagery is composed of multiple layers (bands). It captures light over a specific wavelength interval: blue, green, red, near-infrared (NIR) band.

- **Multispectral Sensor:**
  - 3~10 bands, such as Landsat and Sentinel-2

- **Hyperspectral Sensor:**
  - hundreds of bands covering very narrow wavelength intervals
  - Identify vegetation species, and minerals
  - AVIRIS (Airborne Visible/Infrared Imaging Spectrometer)



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Temporal Resolution

How often can the sensor capture data from the same area?

- **Satellite's orbit and revisit frequency**

Polar orbits: from the North Pole to the South Pole

- Earth: rotates east-west
- **Footprint**: the specific area observed by the satellite sensor at any moment

Swath (a strip of data): Each orbit captures a swath of the Earth's surface during a single pass.

Global Coverage: Due to the Earth's rotation, each satellite orbit shifts slightly westward. Over time, the satellite can cover the entire Earth's surface.

Revisit Time: The time it takes for the satellite to pass over the same spot again.

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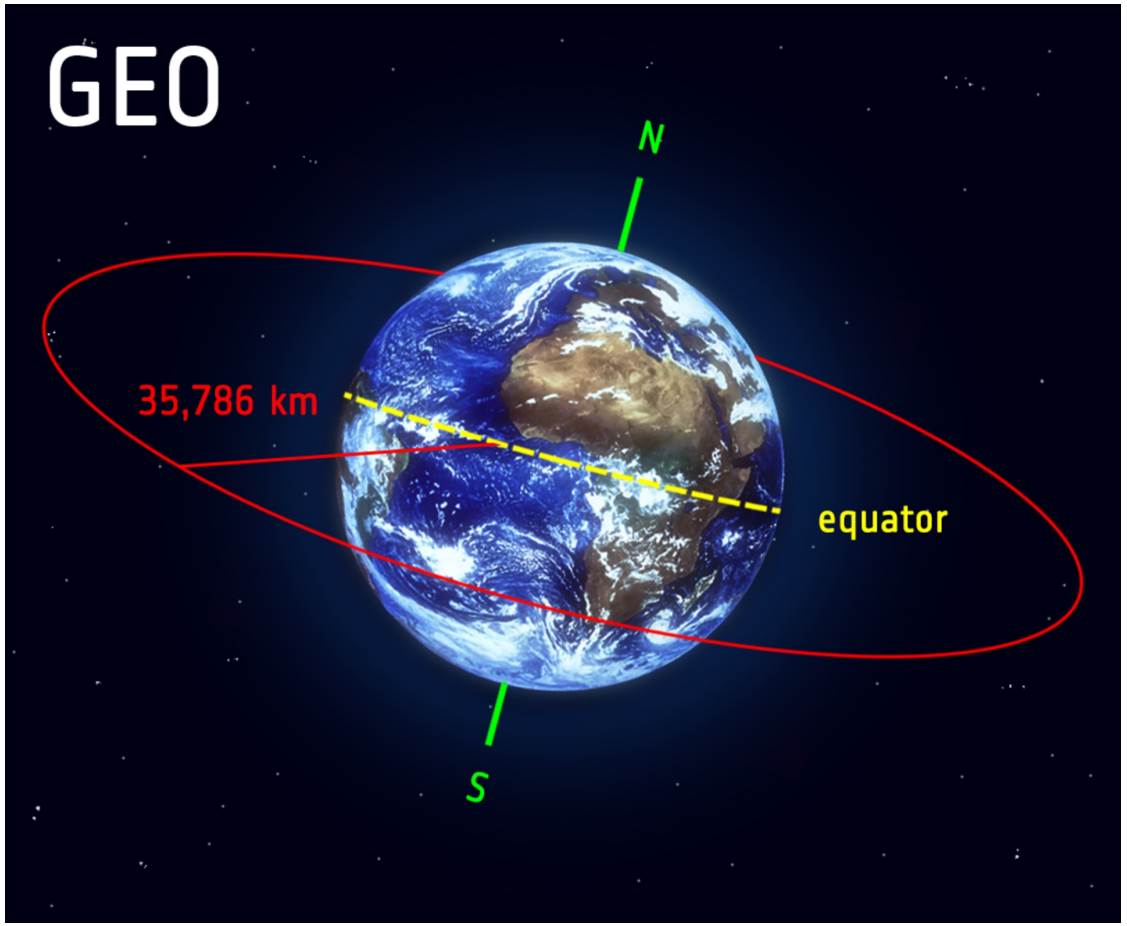
Geostationary Orbit

Above the Earth's equator (~35000 km)

Fixed position relative to Earth

- is about 24 hours
- continuous observation of the same area
    - constant, real-time data



Weather forecasting

Communications

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Trade-off

- Spatial resolution & Temporal resolution
- Spectral resolution & Spatial resolution

Basic Information on Polar-orbiting satellite or sensors

Satellite	Spatial Resolution	Temporal Resolution	Launch Date
Landsat 8	15m, 30m, 100m	16 days	February 11, 2013
Landsat 9			September 27, 2021
MODIS (Terra + Aqua)	250m, 500m, 1000m	1 to 2 days	Terra: December 18, 1999; Aqua: May 4, 2002
VIIRS	375m, 750m	12 hours	Suomi NPP: October 28, 2011; NOAA-20: November 18, 2017
AVHRR	1100m	<1 day	First launched in 1978 (TIROS-N); NOAA-19: February 6, 2009
Sentinel-2	10m, 20m, 60m	5 days	Sentinel-2A: June 23, 2015; Sentinel-2B: March 7, 2017
Ikonos	0.8m, 3.2m	<3 days	September 24, 1999
SPOT-7	1.5m, 6m	1 day	June 30, 2014

Other satellite data: Sentinel-1 (Radar), Sentinel-3, WorldView-3, GeoEye-1, ALOS…

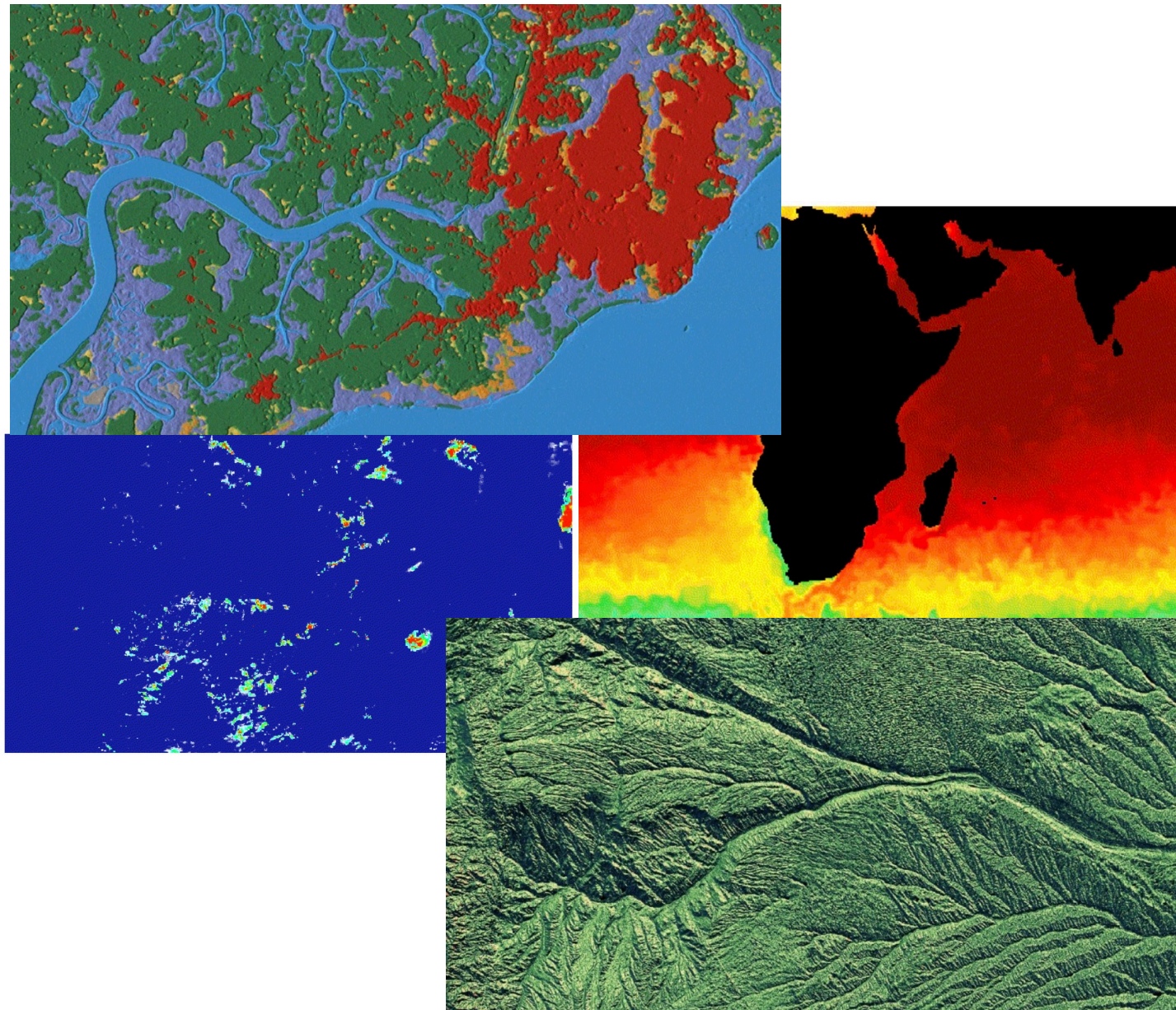
Types of Remotely Sensed Imagery

- **Satellite Imagery**
  - Passive remote sensing
    - Landsat, MODIS
  - Active remote sensing
    - Synthetic Aperture Radar (SAR), Microwave
- **Aerial Photography**
- **Airborne LiDAR (Light Detection and Ranging)**
  - Active remote sensing
  - 3-D information: Topographic Mapping, Digital Elevation Models (DEMs)
  - Forestry: Tree Height, canopy structure and carbon stock

…

Remote Sensing Products

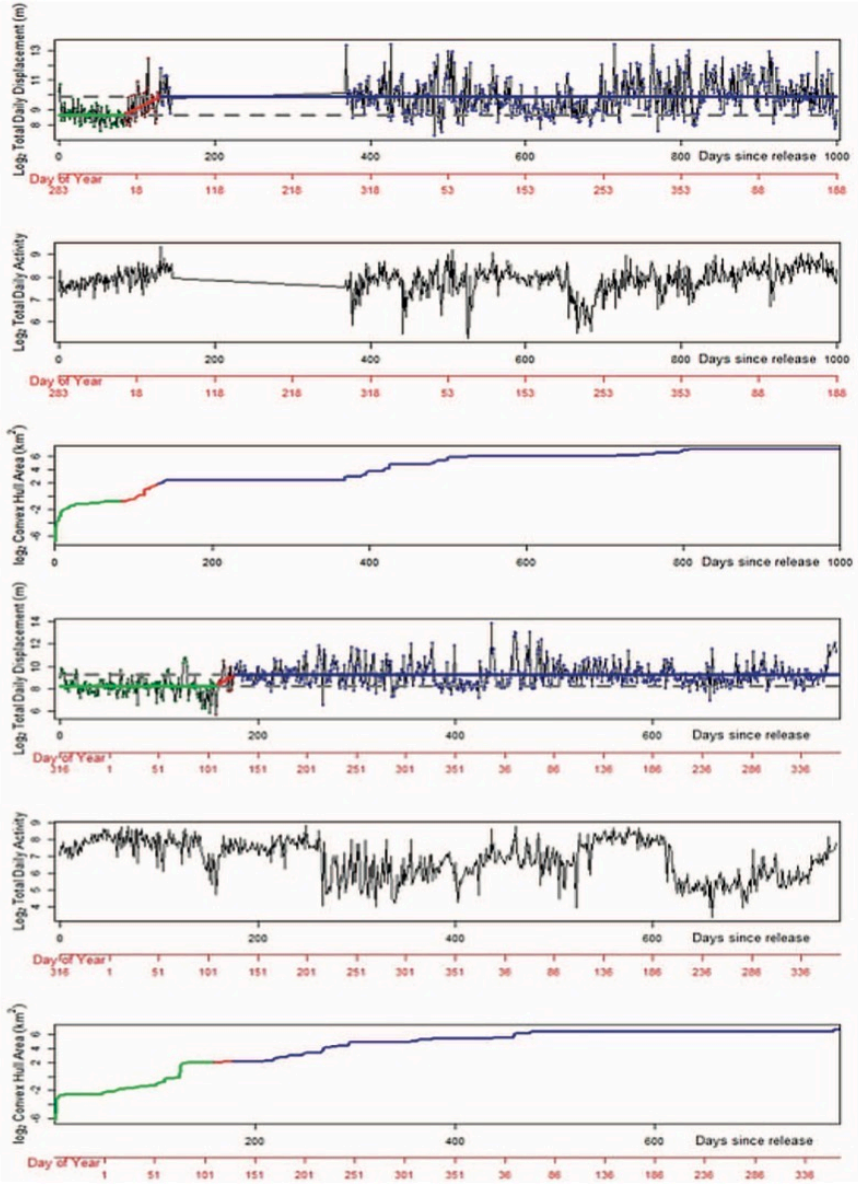
- Elevation
- NDVI
- Topographic Indices
- Temperature
- Snow Cover/ Ice Cover
- Weather Conditions
- Human Footprint Index
- Land Cover Classification
- Soil Moisture
- …

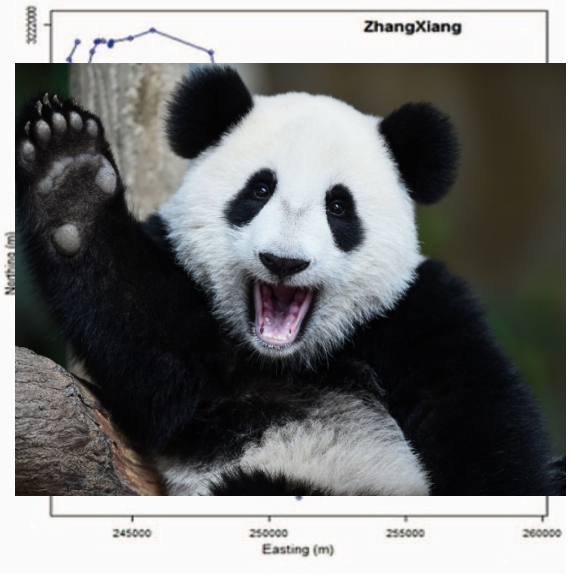


Case Studies:
Remote Sensing Data in Animal Movement Research

- Reintroduced Giant Panda & Elevation
- Puma Cougar & Terrain Steepness
- Mongolian Gazelle & NDVI & Snow Cover
- Tropical Armadillos & Temperature & Landcover Type
- Terrestrial Mammals & Human Footprint Index
- Migrating Turkey Vulture & Weather Data
- Caribou & Snow Cover/Ice condition

Reintroduced Giant Panda





BioOne COMPLETE

Movement and activity of reintroduced giant pandas

Authors: Ke He, Qiang Dai, Andrew Foss-Grant, Eliezer Gurarie, William F. Fagan, et. al.

Source: Ursus, 29(2) : 163-174

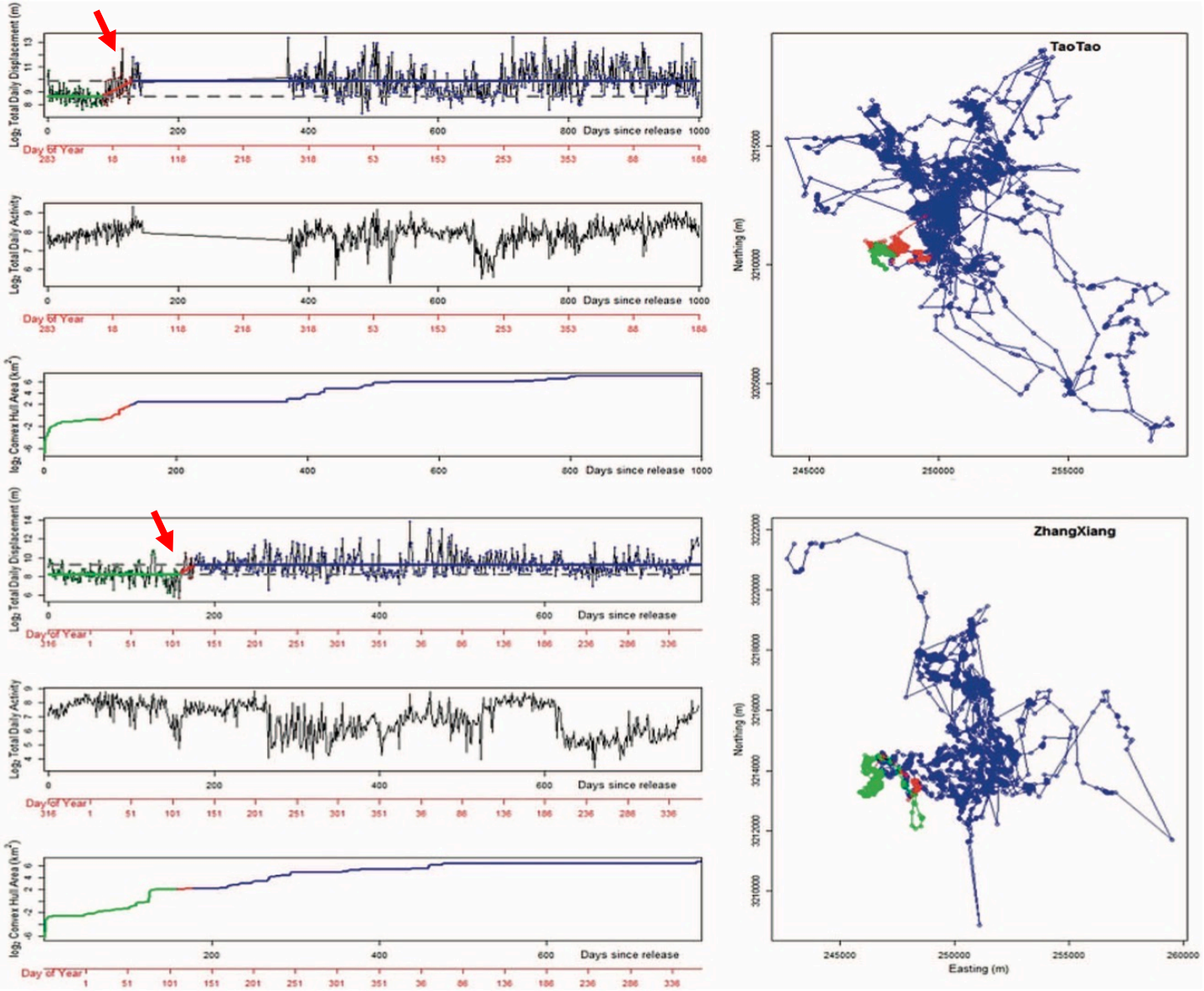
Published By: International Association for Bear Research and Management

URL: https://doi.org/10.2192/URSUS-D-17-00030.1

Identify post-release adjustment behavior periods

- Captive-bred giant pandas
- Introduced to the wild (Liziping National Nature Reserve)

Reintroduced Giant Panda

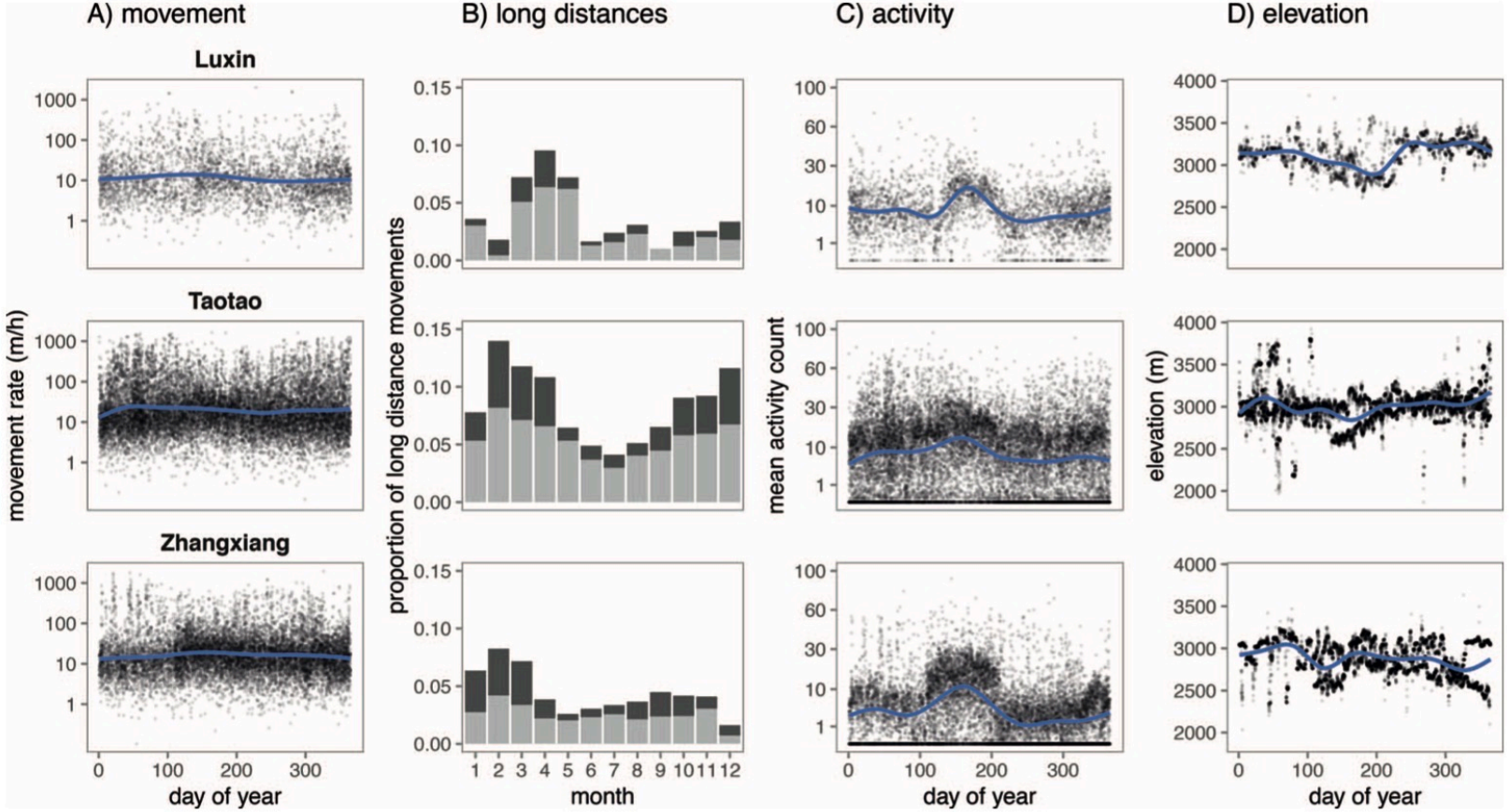


GPS collars data: (2011~ 2016)

- Total daily displacement (log)
- Summed activity counts
- Convex hull areas (log)

Green:
the period before the first change point
Red:
the period between change points
Blue:
the period after the second change point

Reintroduced Giant Panda & Elevation



Post-adjustment movement of more than 1 year

Seasonal migration?

Combined the movement data with Digital Elevation Model (DEM)

- Movement rate
- Proportion of long-distance movement
- Activity rate

No elevational (vertical) seasonal migration,
Stay at a similar elevation year-around

Compare this with the published behaviour of wild giant pandas (migrate from low-elevation (<2000 m) to high-elevation habitats for summer months (elevation change ~800 m)

Seasonal migration between elevations in the giant panda population is not an innate behaviour

Wild Mountain Cat & Terrain Steepness

How does the steepness in a complex landscape affect the mountain cat's incline locomotion?

Balance energy and locomotor efficiency?

Dunford *et al. Movement Ecology* (2020) 8:34
https://doi.org/10.1186/s40462-020-00215-9

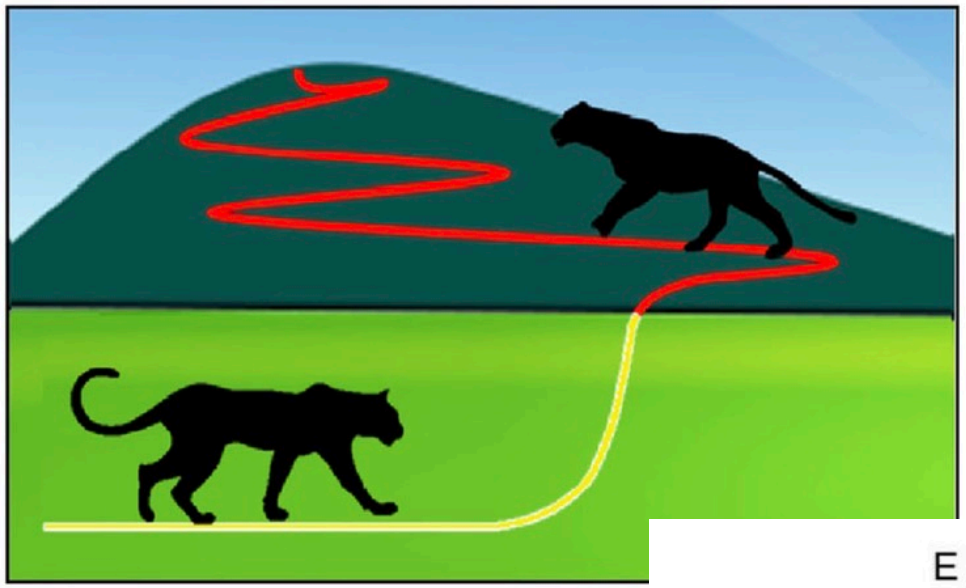
Movement Ecology

RESEARCH Open Access

Surviving in steep terrain: a lab-to-field assessment of locomotor costs for wild mountain lions (*Puma concolor*)

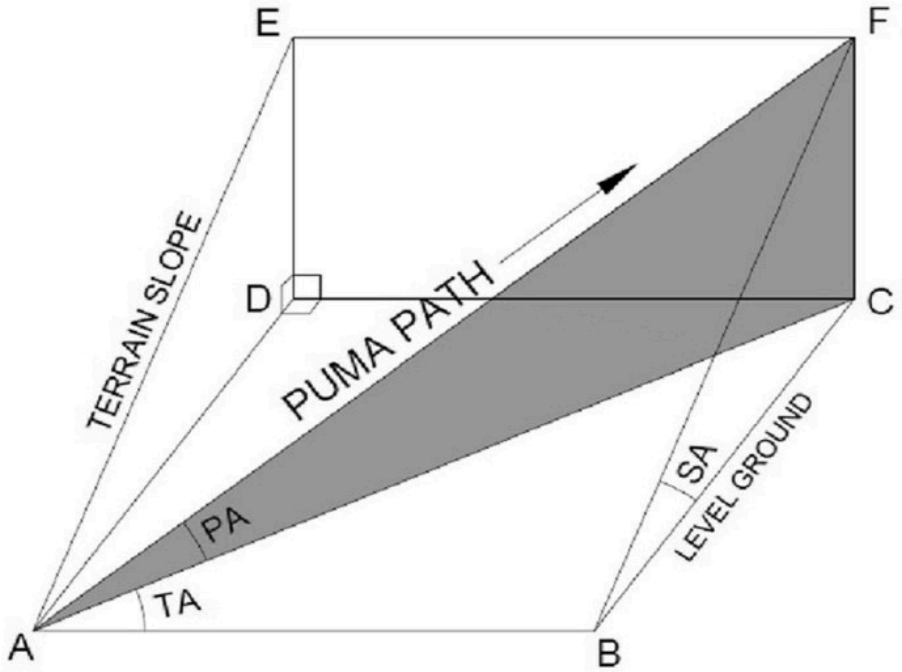
Carolyn E. Dunford[1], Nikki J. Marks[1], Christopher C. Wilmers[2], Caleb M. Bryce[3], Barry Nickel[2], Lisa L. Wolfe[4], D. Michael Scantlebury[1*] and Terrie M. Williams[5*]

Wild Mountain Cat & Terrain Steepness



Santa Cruz Mountains
(California, USA)
4 individuals

Code	Measurement
AC	*GPS distance*
AF	*Path distance*
CF	*Elevation gain*
∠FAC	*Path angle (PA)*
∠FBC	*Topographical slope angle (SA)*
∠CAB	*Traverse angle (TA)*



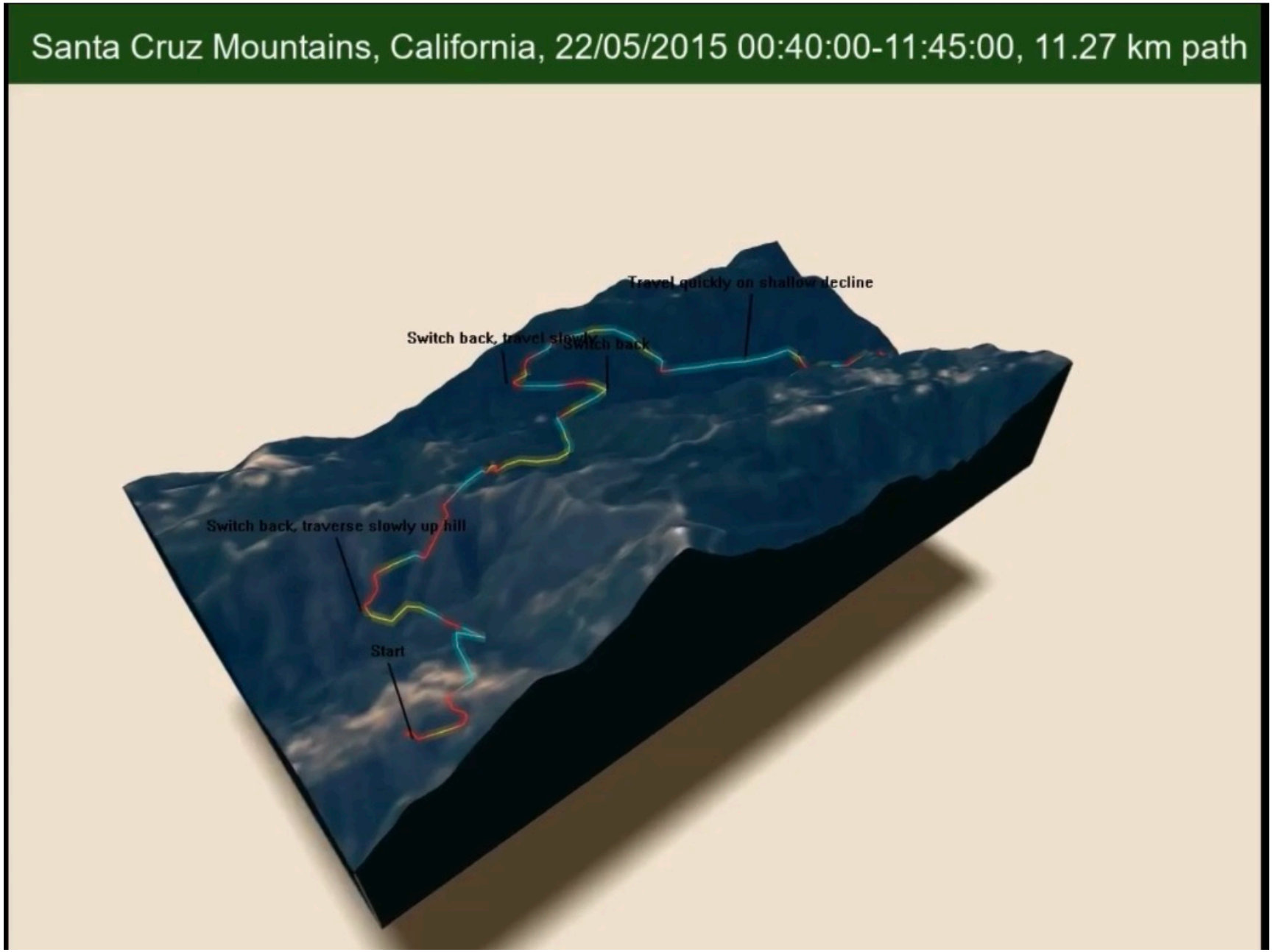
GPS location data

- GPS-derived speed
- Accelerometer-derived speed

Digital Elevation Model (DEM)

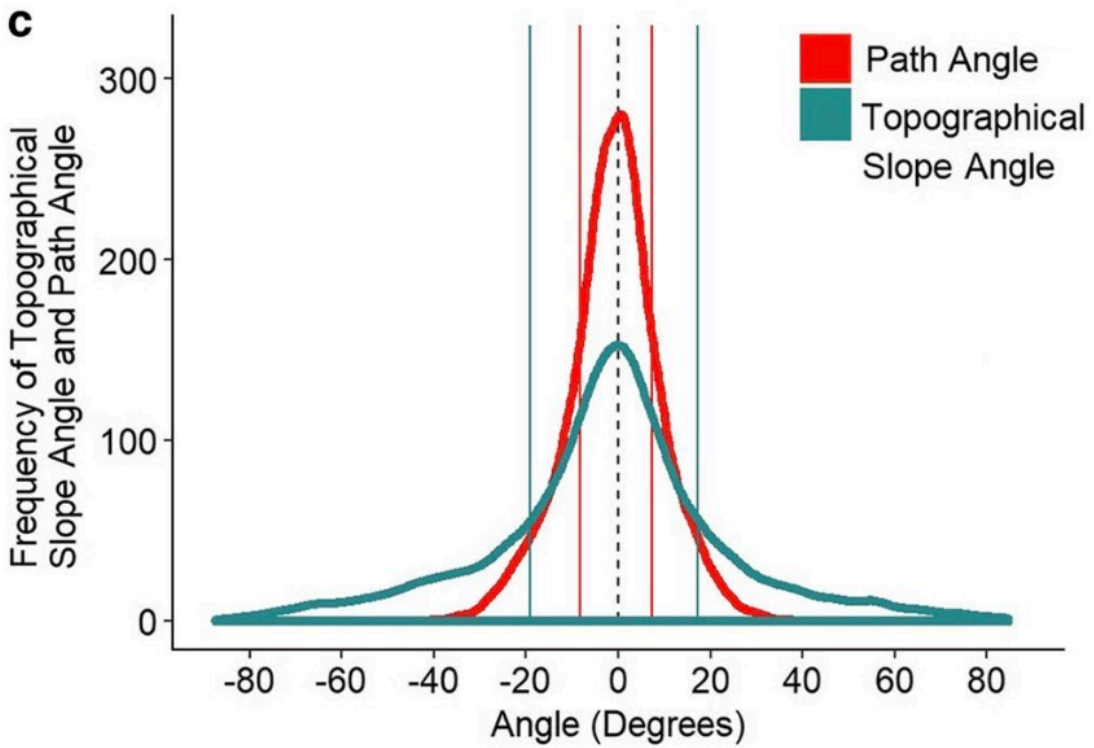
Locomotor costs

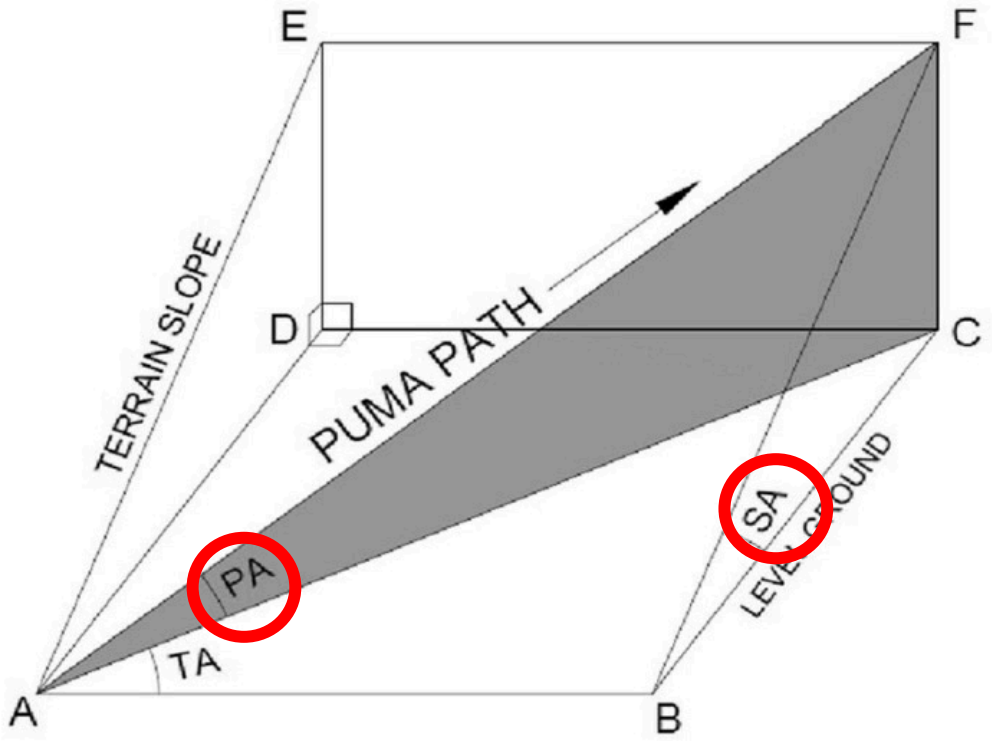
- The rate of oxygen consumption
- Laboratory:
- captive pumas on levels and motorized treadmills at different speeds, incline angle



https://movementecologyjournal.biomedcentral.com/articles/10.1186/s40462-020-00215-9

Wild Mountain Cat & Terrain Steepness

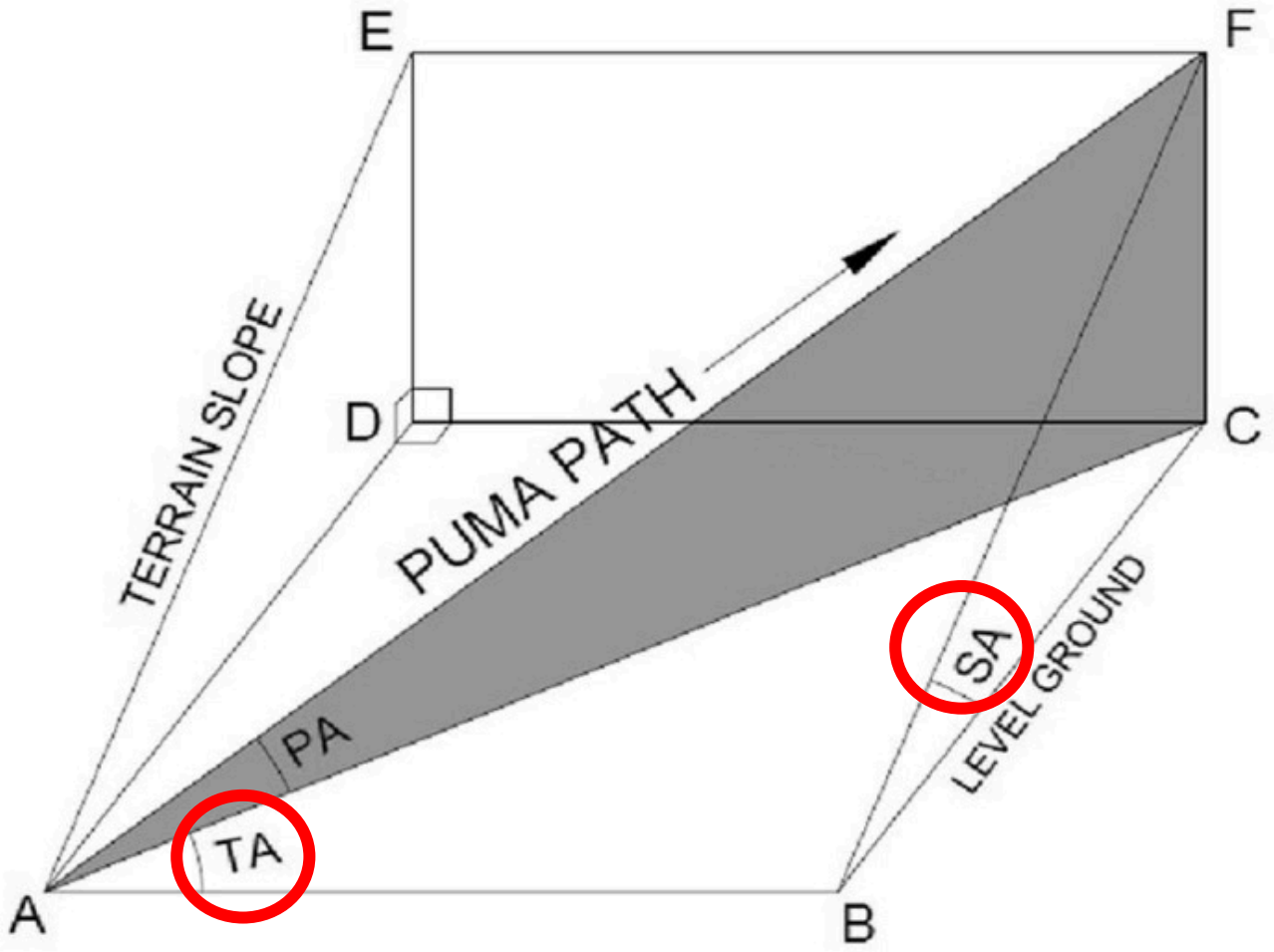


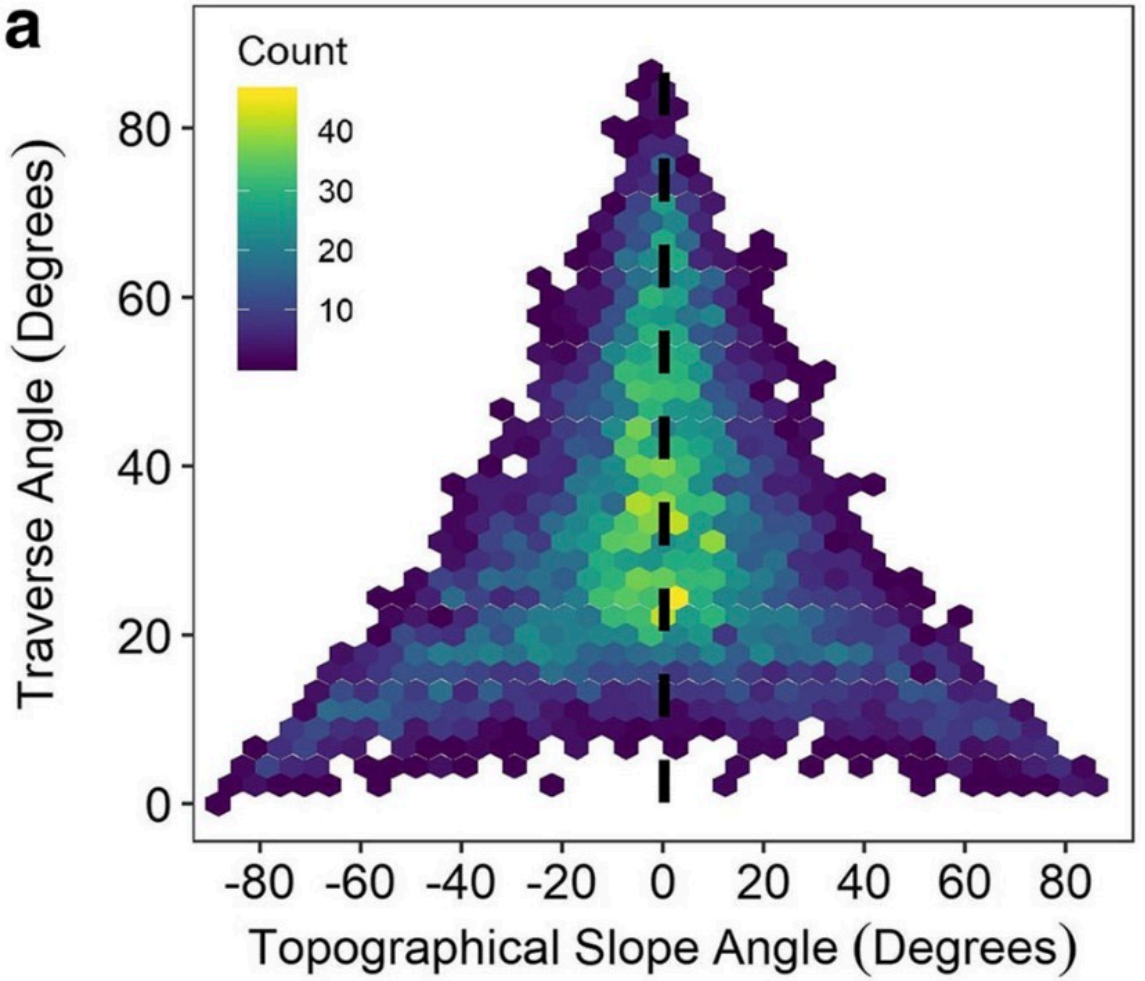


The solid line shows the mean for incline and decline.
The dashed line is zero degrees.

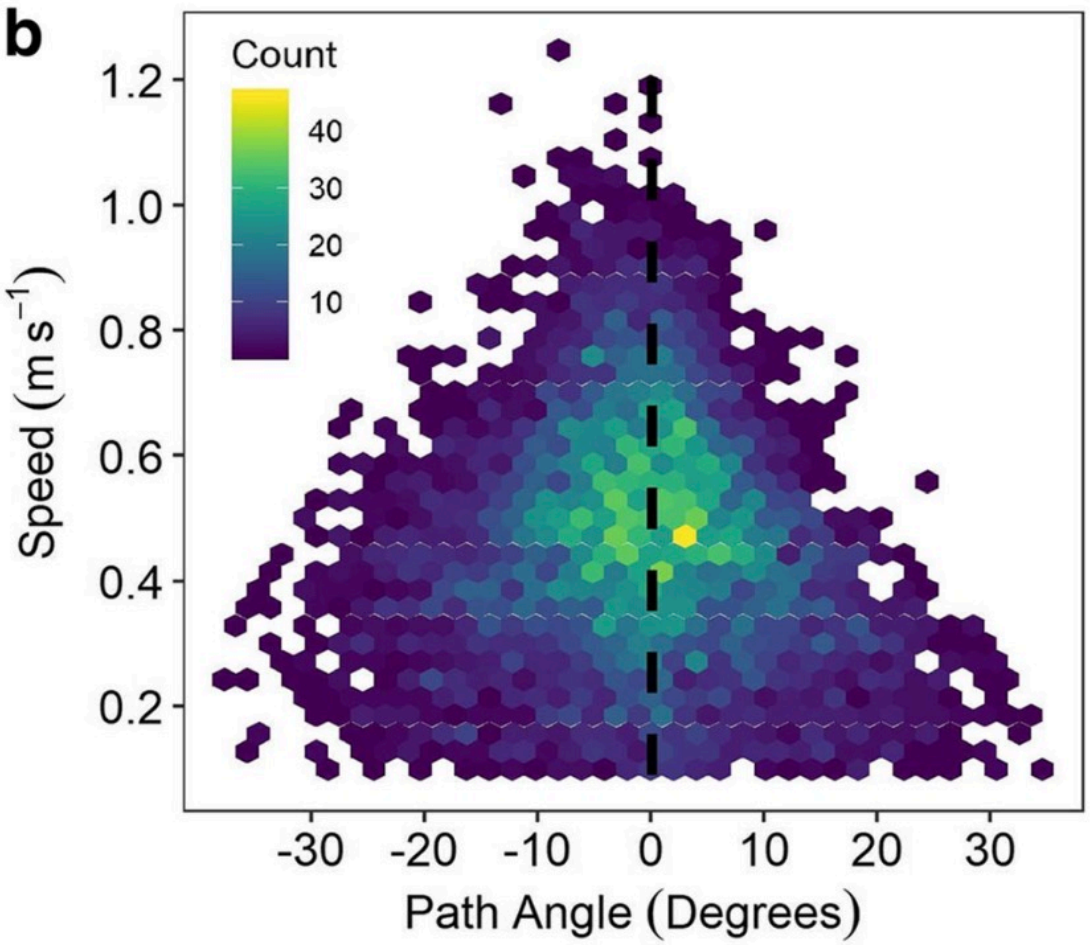
Choose to traverse and choose a shallower path angle;
Avoid climbing steep slopes up and down directly;

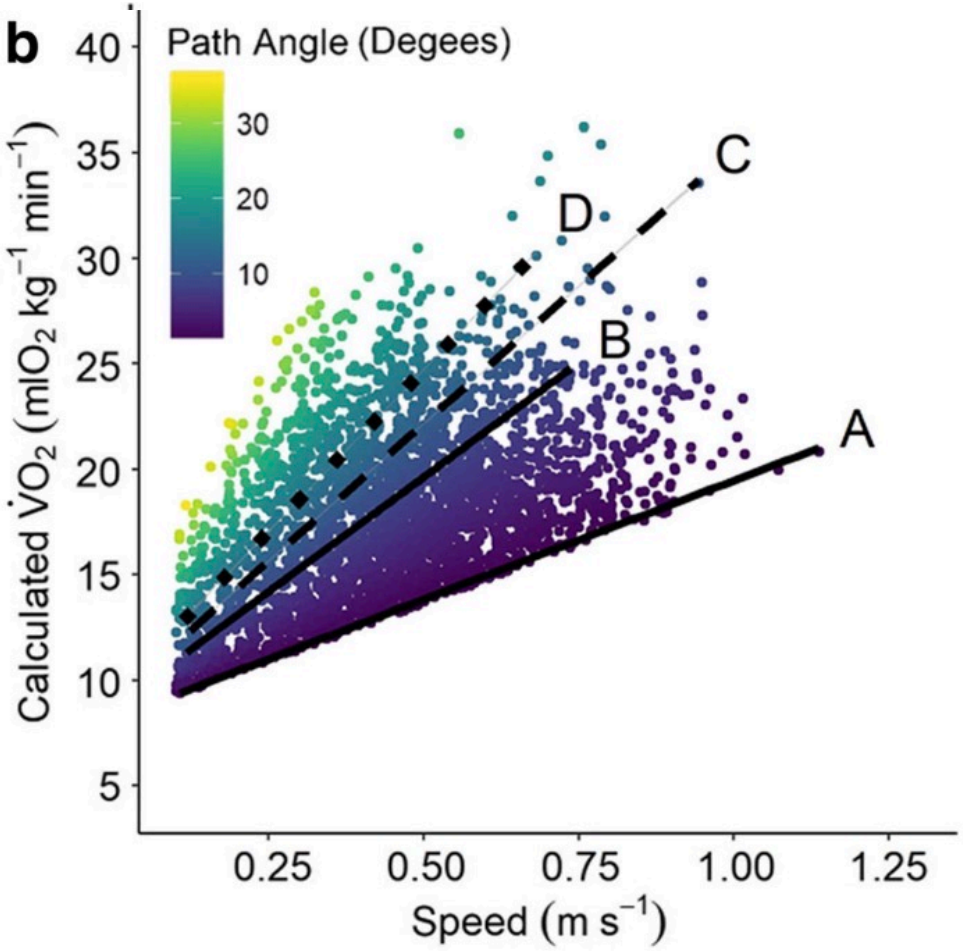
Wild Mountain Cat & Terrain Steepness





Avoid directly climbing up and down (the traverse angle decreased)

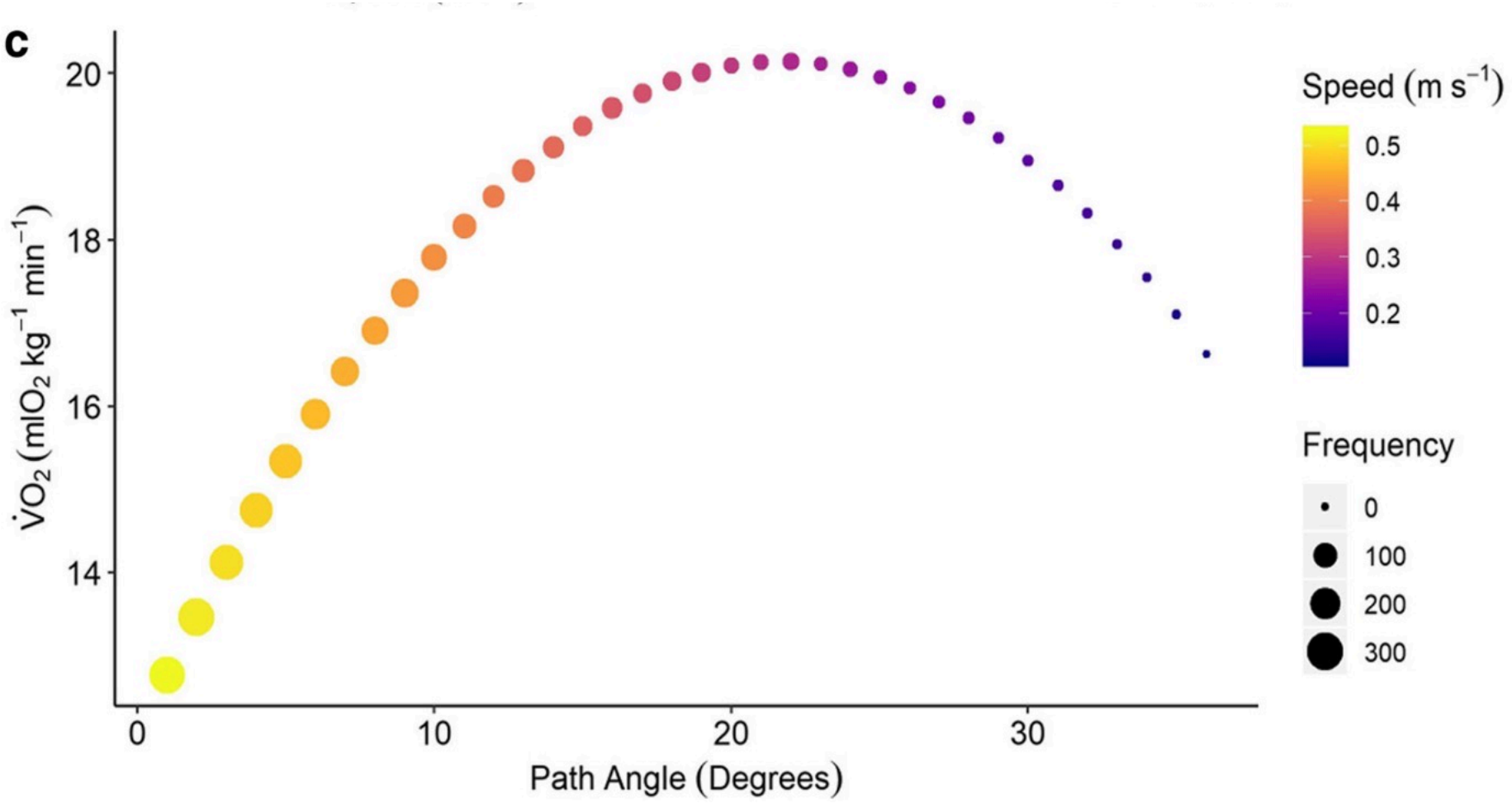




Wild mountain cats move slower on steep slopes and faster on gentle ones.

The result from the laboratory:
At the same speed, mountain cat uses more energy walking on a treadmill slope than flat ground.

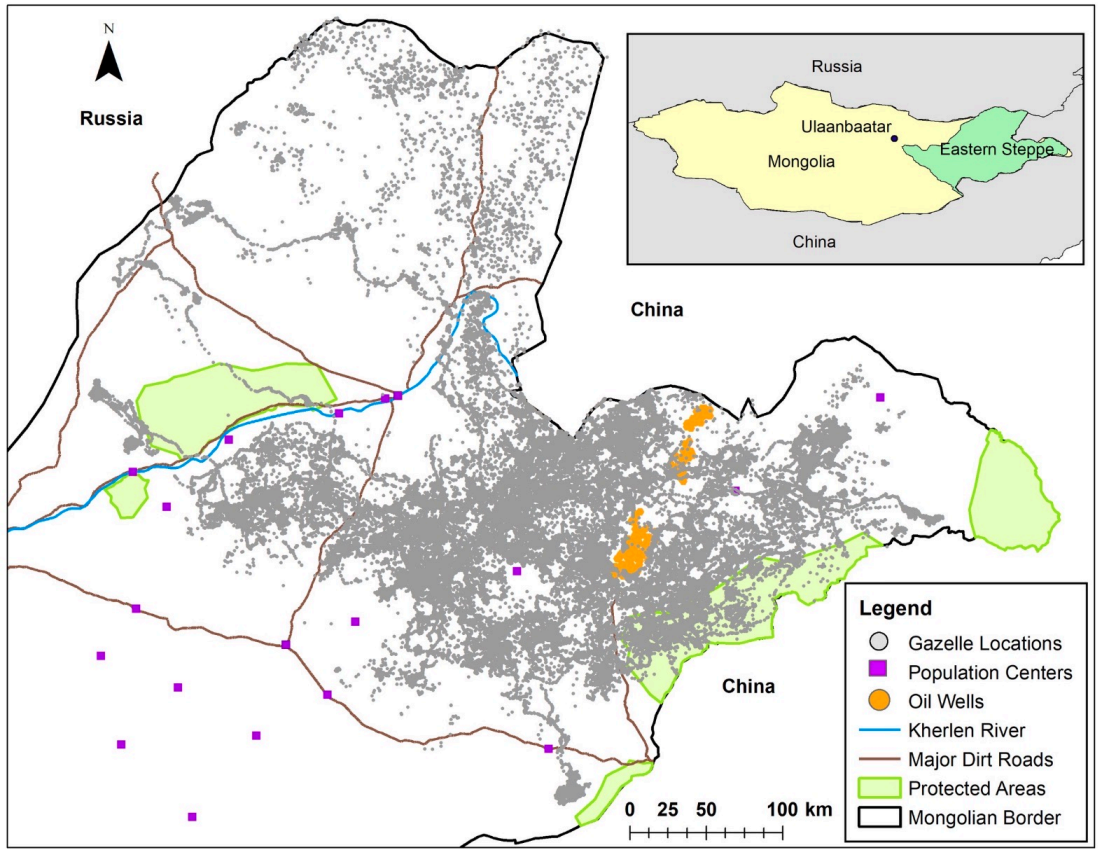
Puma traversed steep slopes and walk slowly to save energy.



As long as pumas climb the steepest slopes slowly, they use **less oxygen** compared to climbing moderate slopes at faster speeds.

Pumas showed a trade-off between speed, distance, and energy cost by changing their incline and decline paths.

Mongolian Gazelle & Snow Cover & NDVI



How are the movement paths chosen by individual Mongolian gazelles affected by Snow Cover and NDVI?

~ resource availability

PLOS ONE

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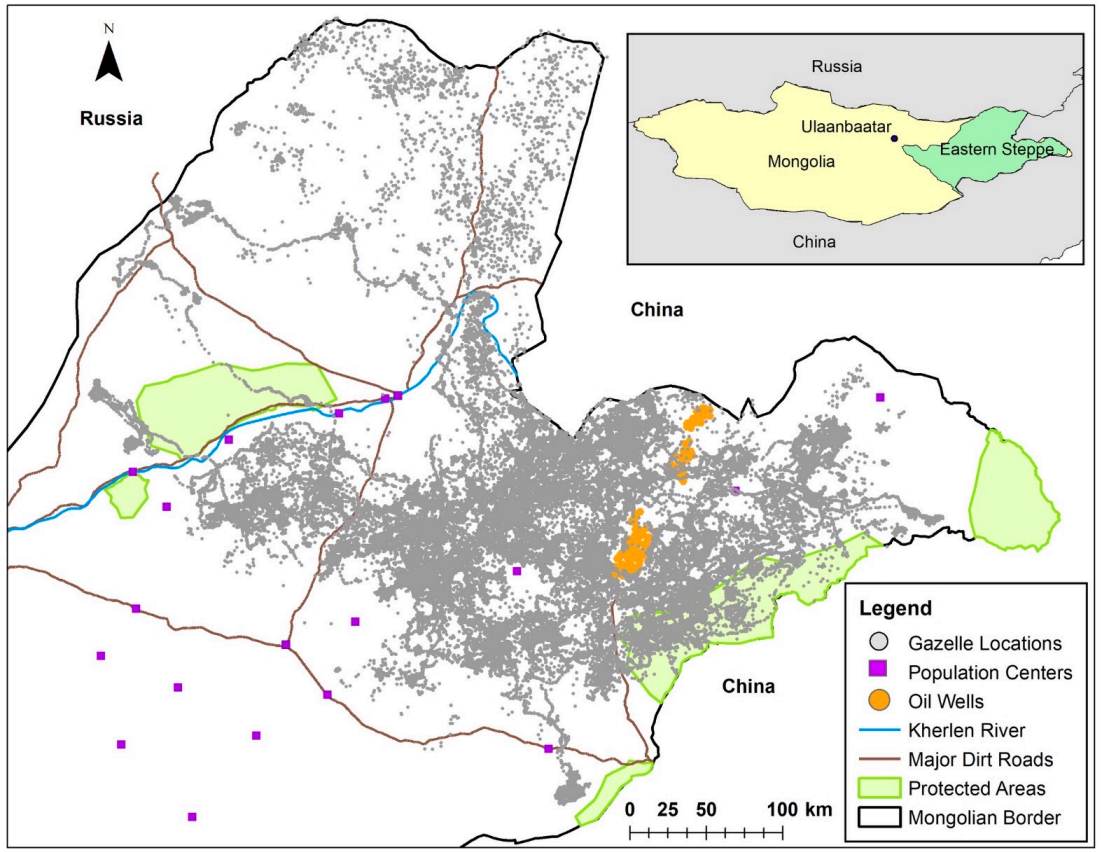
RESEARCH ARTICLE

Resource selection of a nomadic ungulate in a dynamic landscape

Theresa S. M. Stratmann, Nandintsetseg Dejid, Justin M. Calabrese, William F. Fagan, Christen H. Fleming, Kirk A. Olson, Thomas Mueller

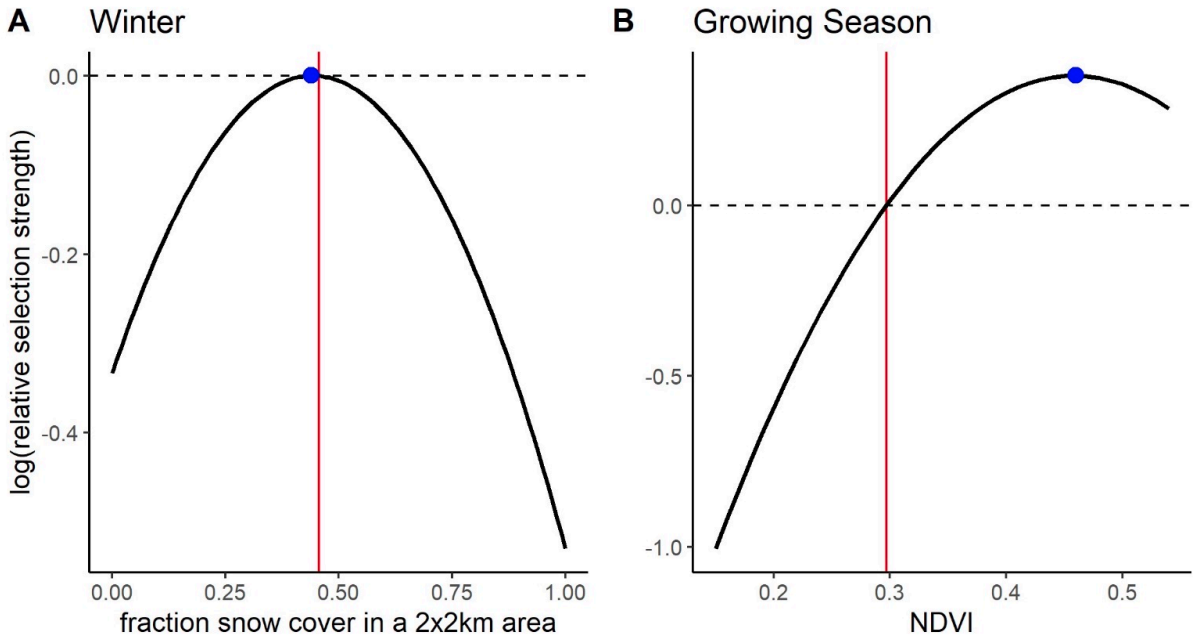
Published: February 12, 2021 • https://doi.org/10.1371/journal.pone.0246809

Mongolian Gazelle & Snow Cover &NDVI



How the movement path of individual Mongolian gazelles selected affected by Snow Cover and NDVI

- **GPS collars** (per hour) for 33 individuals
- **Snow cover index** (500 m Terra MODIS data)
- Normalized difference vegetation index (**NDVI**) (250 m ~)



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Population-level: intermediate snow cover; above average NDVI,

Tropical Armadillos & Temperature & Landcover Type

Pantanal wetlands (grey area) in South America

Euphractus sexcinctus
Six-banded armadillos

Tolypeutes matacus
Southern three-banded armadillos

How does the air temperature affect the **variation in activity patterns** and **habitat selection** by two tropical armadillos species (imperfect homeotherms)?

Contents lists available at ScienceDirect

Animal Behaviour

journal homepage: www.elsevier.com/locate/anbehav

Effects of air temperature on habitat selection and activity patterns of two tropical imperfect homeotherms

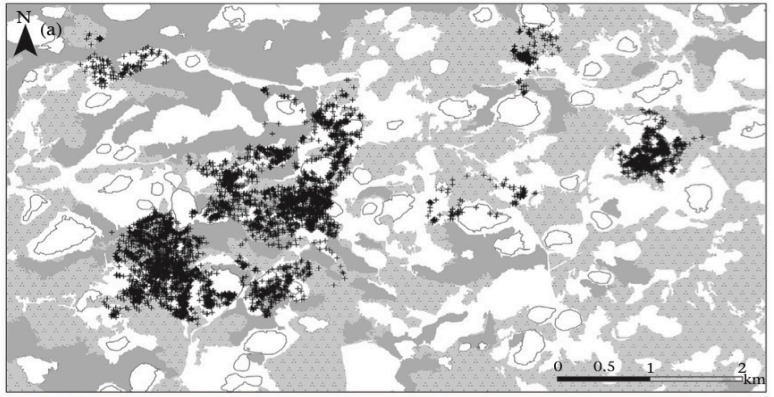
Nina Attias [a,*], Luiz Gustavo Rodrigues Oliveira-Santos [a], William F. Fagan [b], Guilherme Mourão [c]

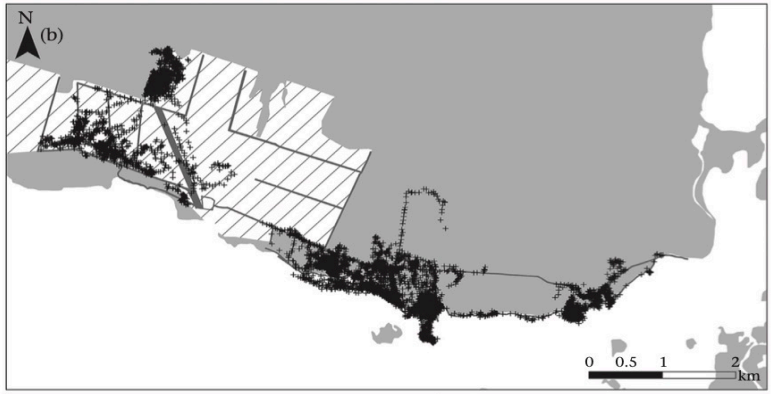
[a] Ecology Department, Federal University of Mato Grosso Do Sul, Campo Grande, MS, Brazil
[b] Biology Department, University of Maryland, College Park, MD, U.S.A.
[c] Embrapa Pantanal, Corumbá, MS, Brazil

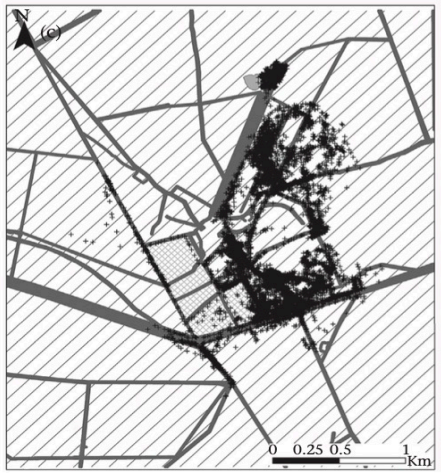
Tropical Armadillos & Temperature & Landcover Type

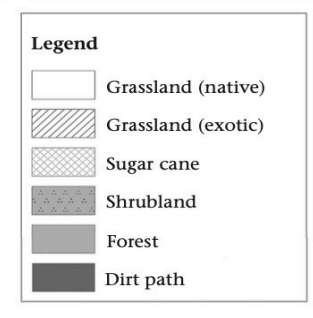
Euphractus sexcinctus
Six-banded armadillos

Tolypeutes matacus
Southern three-banded armadillos









Data:

GPS location data (5 min)

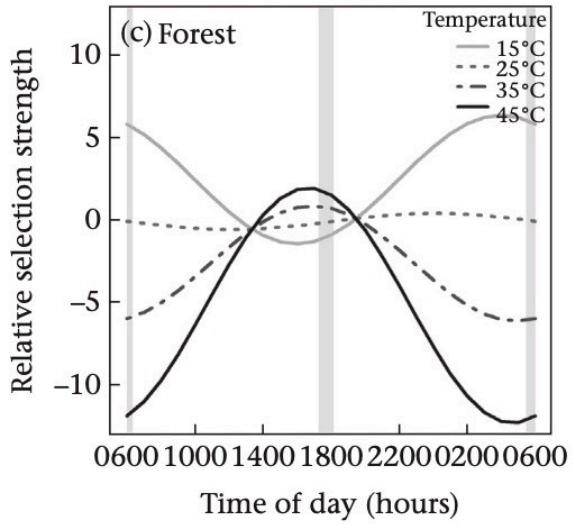
Landcover type

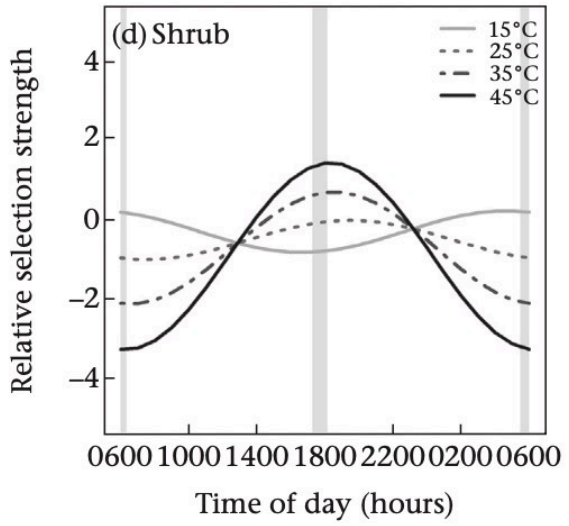
Forest, grassland, shrubland, and sugarcane plantation (RapidEye satellite imagery)

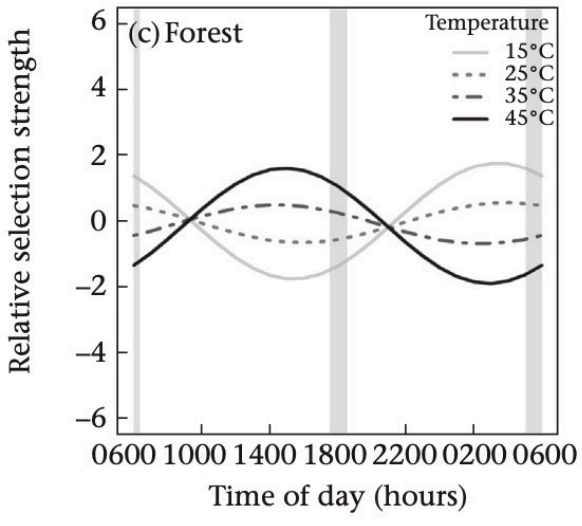
Temperature

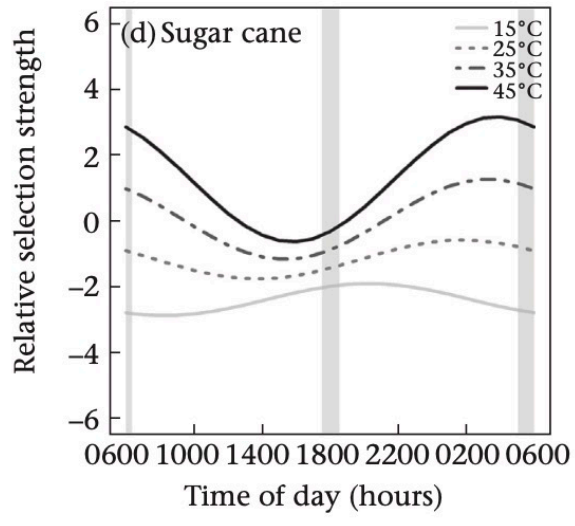
Measured hourly in automatic stations in each site

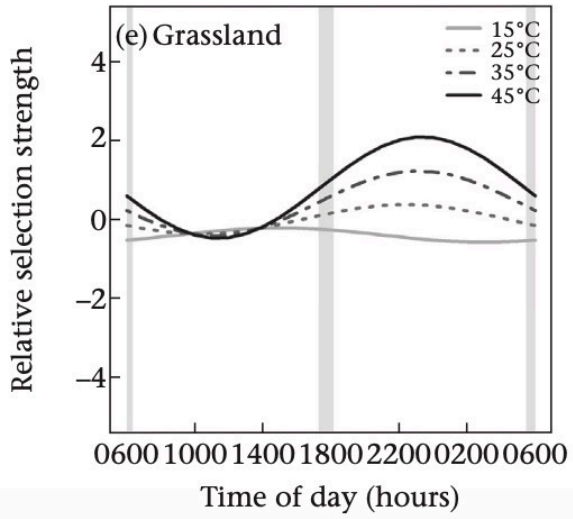
Selection strength of forest, shrublands and grasslands at 4 air temperature scenarios





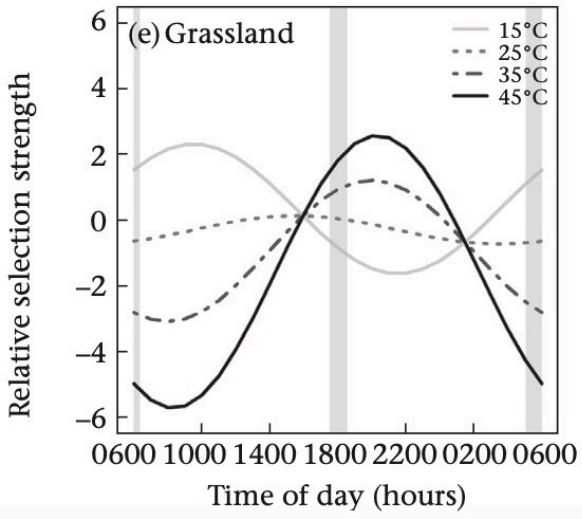






Six-banded armadillos

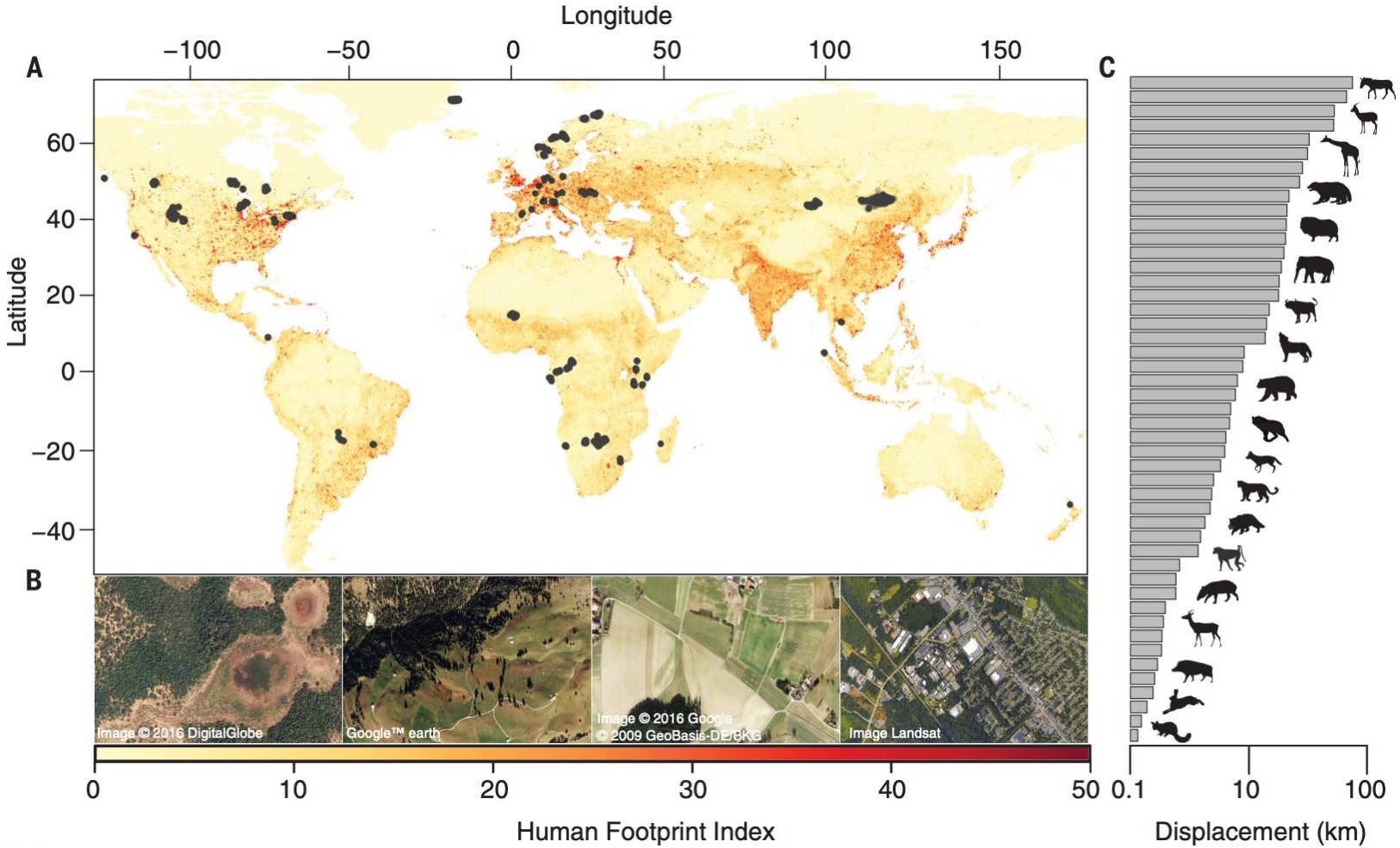
Forest:
Close to 35 / 45 °C(upper limit) during the warmest hours of the afternoon
< 15°C (thermoneutral zone), during the nighttime or early morning
Shrubland is similar to forest
Grassland: higher than 25 ~45 °C



Southern three-banded armadillos

Forest:
45°C during the daytime;
15°C during the nighttime;
Sugar cane plantations:
>35°C in the nighttime
Grassland:
>35 °C in the nighttime
<15°C in the daytime

Terrestrial Mammals & Human Footprint Index

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HOME > SCIENCE > VOL. 359, NO. 6374 > MOVING IN THE ANTHROPOCENE: GLOBAL REDUCTIONS IN TERRESTRIAL MAMMALIAN MOVEMENTS

REPORT

Moving in the Anthropocene: Global reductions in terrestrial mammalian movements

MARLEE A. TUCKER, KATRIN BÖHNING-GAESE, WILLIAM F. FAGAN, JOHN M. FRYXELL, BRAM VAN MOORTER, SUSAN C. ALBERTS, ABDULLAHI H. ALI, ANDREW M. ALLEN, NINA ATTIAS, [...], AND THOMAS MUELLER +105 authors Authors Info & Affiliations

SCIENCE · 26 Jan 2018 · Vol 359, Issue 6374 · pp. 466-469 · DOI: 10.1126/science.aam9712

Data:

GPS location data

803 individuals from 57 mammal species from 1998 to 2015

Displacement distance

between subsequent GPS locations at different time scales (1 hour to 10 days)

Human footprint index

Global terrestrial Human Footprint maps for 1993 and 2009 (1km) (Log10)
Range from 0 (natural environments) to 50 (high-density built environments)

NDVI

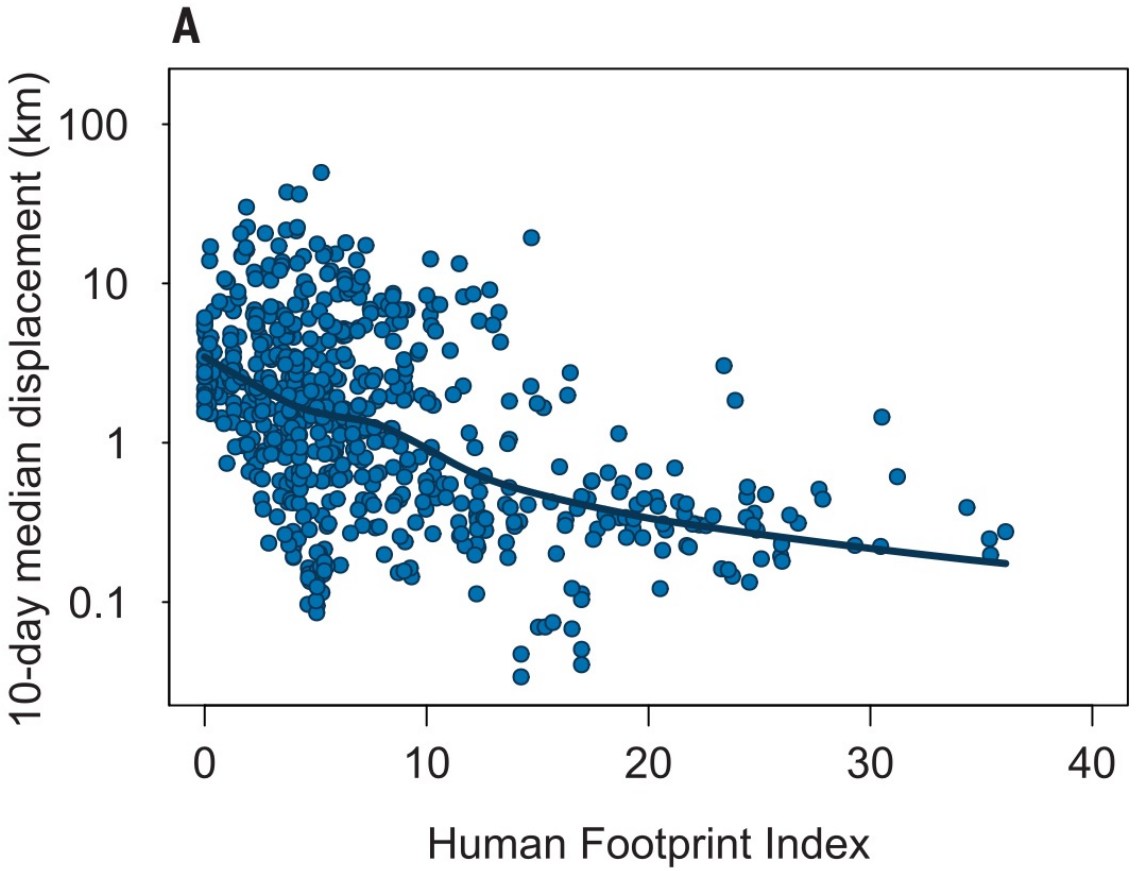
Movebank Env-DATA system

Body Mass

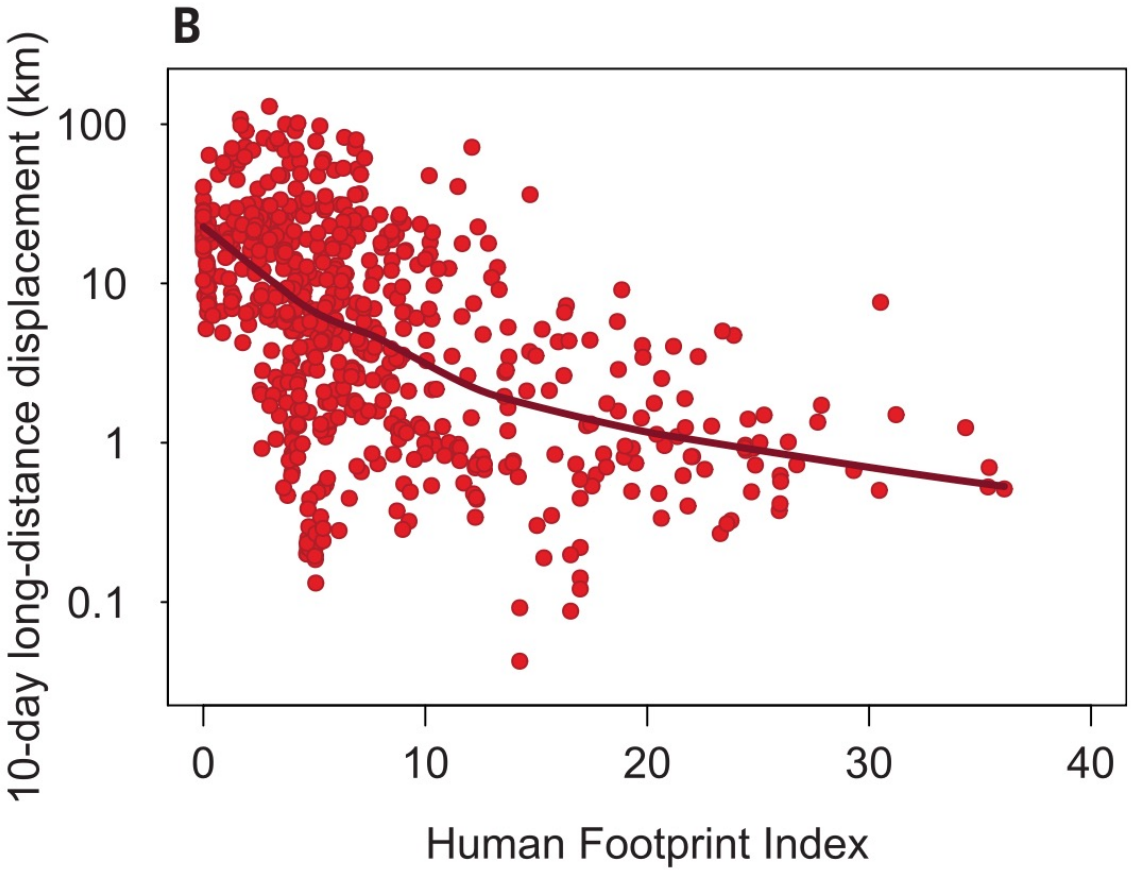
Species-level- PanTHERIA database

Mammalian displacement in relation to the Human Footprint Index

Median displacements



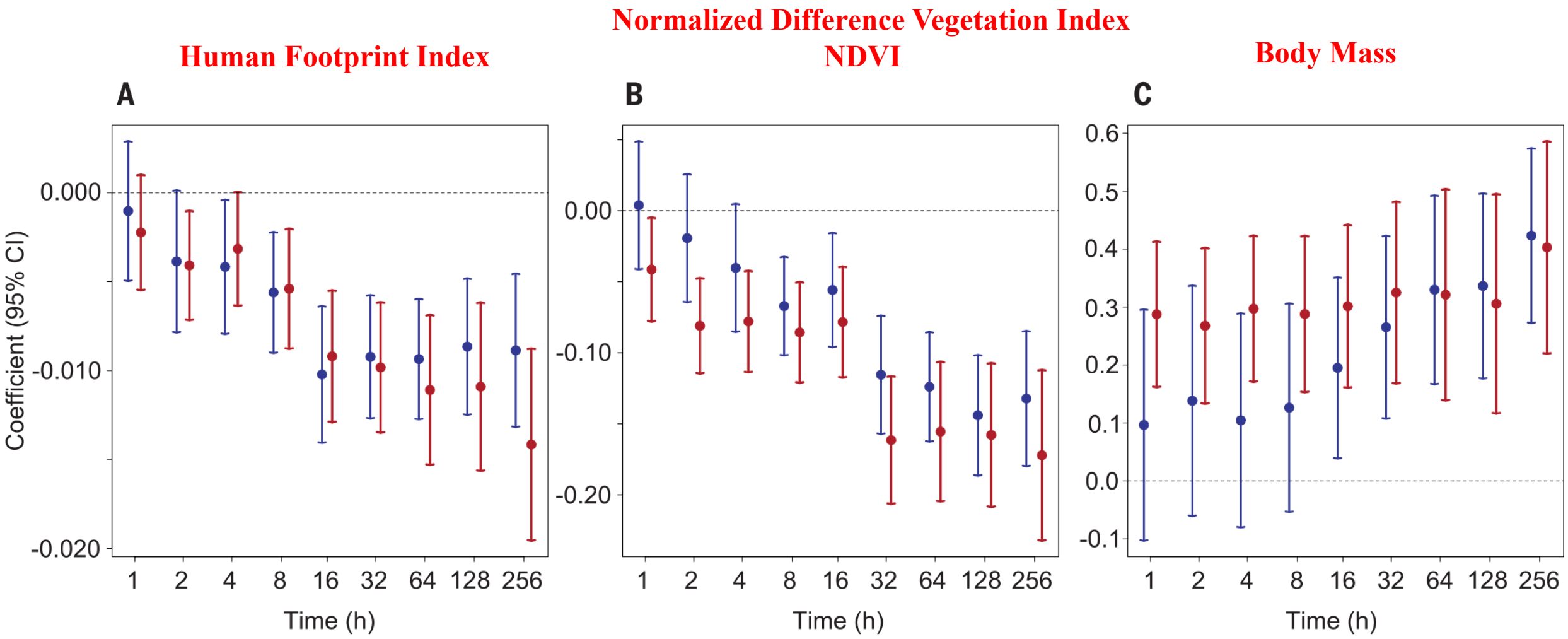
Long-distance (0.95 quantile) displacements



Strong negative effects

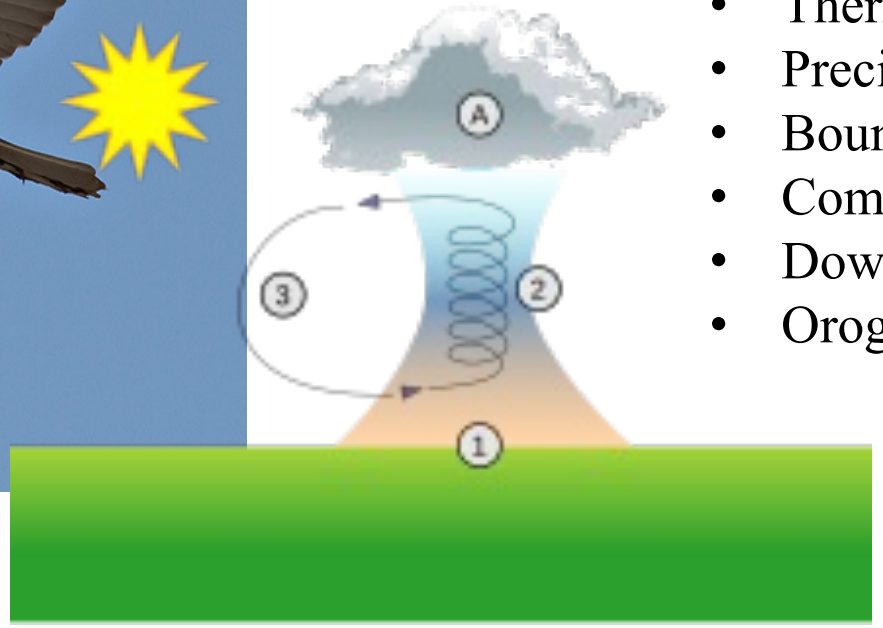
Move less: high human activity and sufficient food resources and lower body mass

Blue: median
Red: long distance



Migrating Turkey Vulture & Weather Data

- Was the decision to stopover a response to changes in local weather conditions?



Data:

GPS location data

174 migration of 34 individuals from 2006 to 2019

Local weather data

Movebank Env-data annotation

- Thermal updraft velocity
- Precipitation fraction
- Boundary level height
- Component of wind
- Downward shortwave radiation
- Orographic updraft velocity

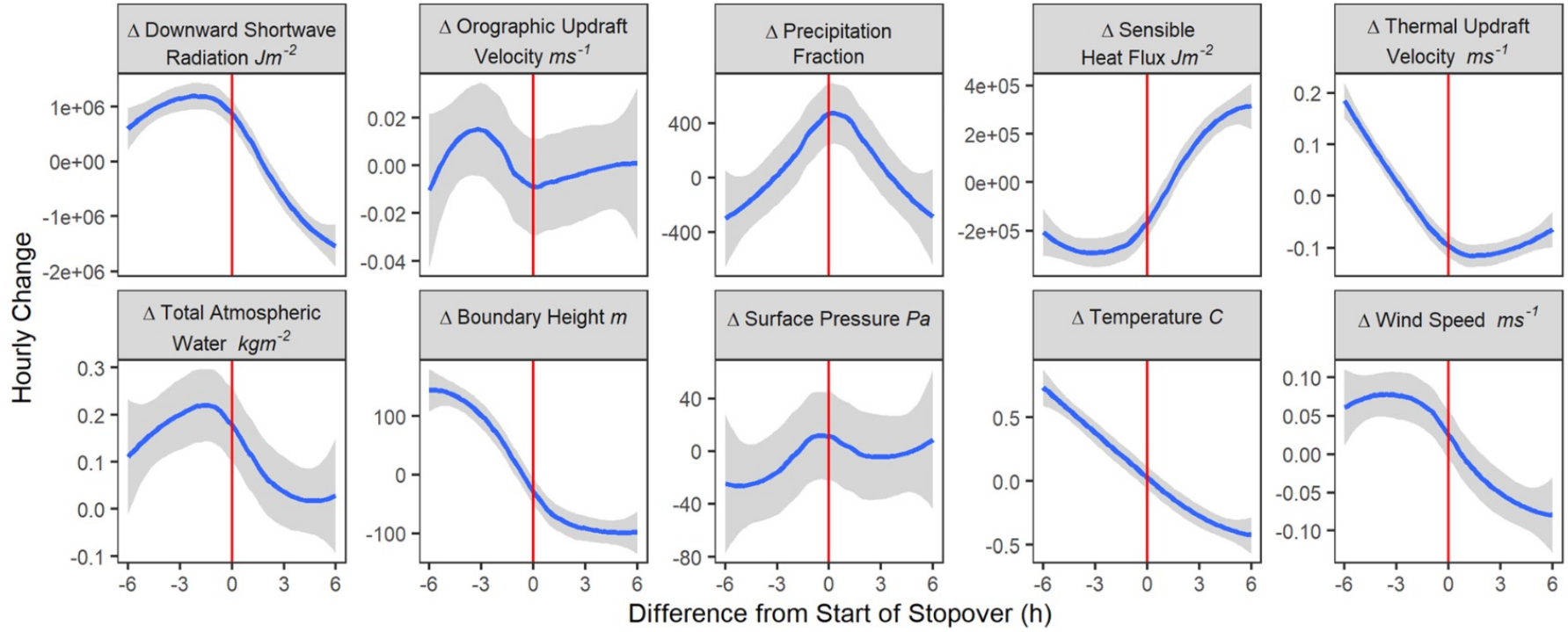
Mallon *et al. Movement Ecology* (2021) 9:39
https://doi.org/10.1186/s40462-021-00274-6

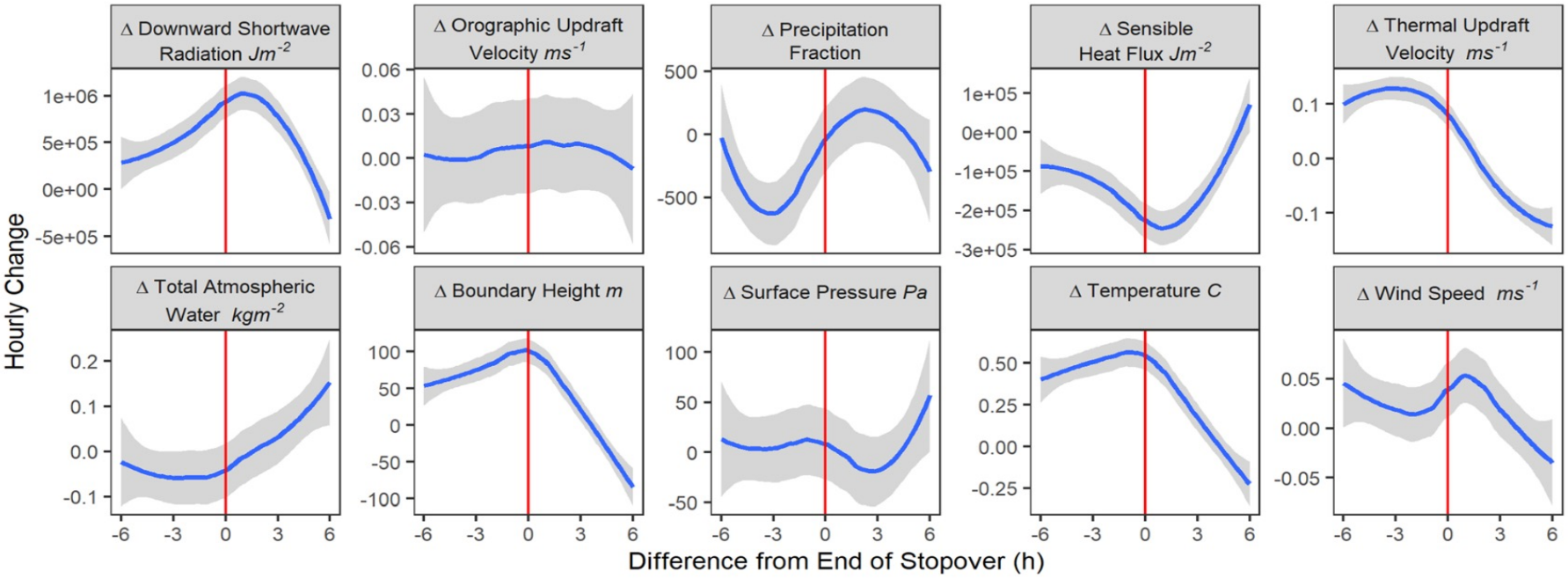
Movement Ecology

RESEARCH Open Access

Inclement weather forces stopovers and prevents migratory progress for obligate soaring migrants

Julie M. Mallon[1*], Keith L. Bildstein[2] and William F. Fagan[1]





Y-axis: average hourly change of the variable;
Grey: confidence interval 95%

Start of stopovers

Peak (within 1 hour)

- Precipitation Fraction
- Downward Shortwave radiation
- Total atmospheric water…

Declining

- Thermal updraft velocity
- Boundary height
- Temperature, wind speed

End of stopovers

Peak (within 1 hour)

- Boundary height
- Temperature

Other peaks (within 3 hours)

Generalized mixed-effects model

Variable	β	SE	z	*p*-value
Intercept	-1.7332	0.1082	-4.759	< 0.001
Precipitation Fraction	-3.7785	0.1235	-2.348	0.0189
Thermal Updraft Velocity	9.2448	0.1050	2.231	0.0257
Temperature	2.9703	0.1224	3.306	< 0.001

Diurnal Patterns:

- Temperature
- Thermal updraft velocity
- The boundary layer

Affected by precipitation: disrupt updrafts

Most Frequent Time:

Take-off (resume) migration (morning)

- Rapid changes in temperature and solar radiation, the development of thermals (rising air currents)

Start stopover (afternoon)

- The decline in thermal strength

Caribou & Snow Cover/Ice condition

Downloading Remote Sensing Products

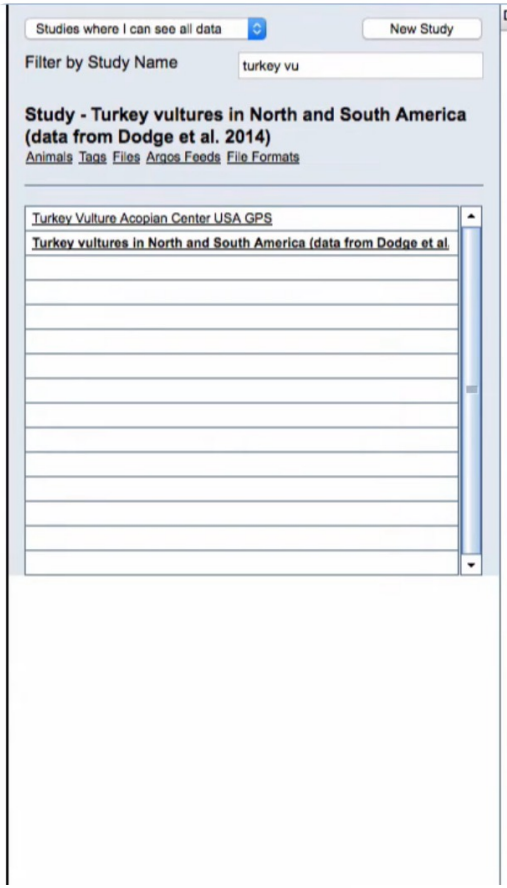
- Envi-data from Movebank
- NASA Platforms
- Google Earth Engine
- GSClouds

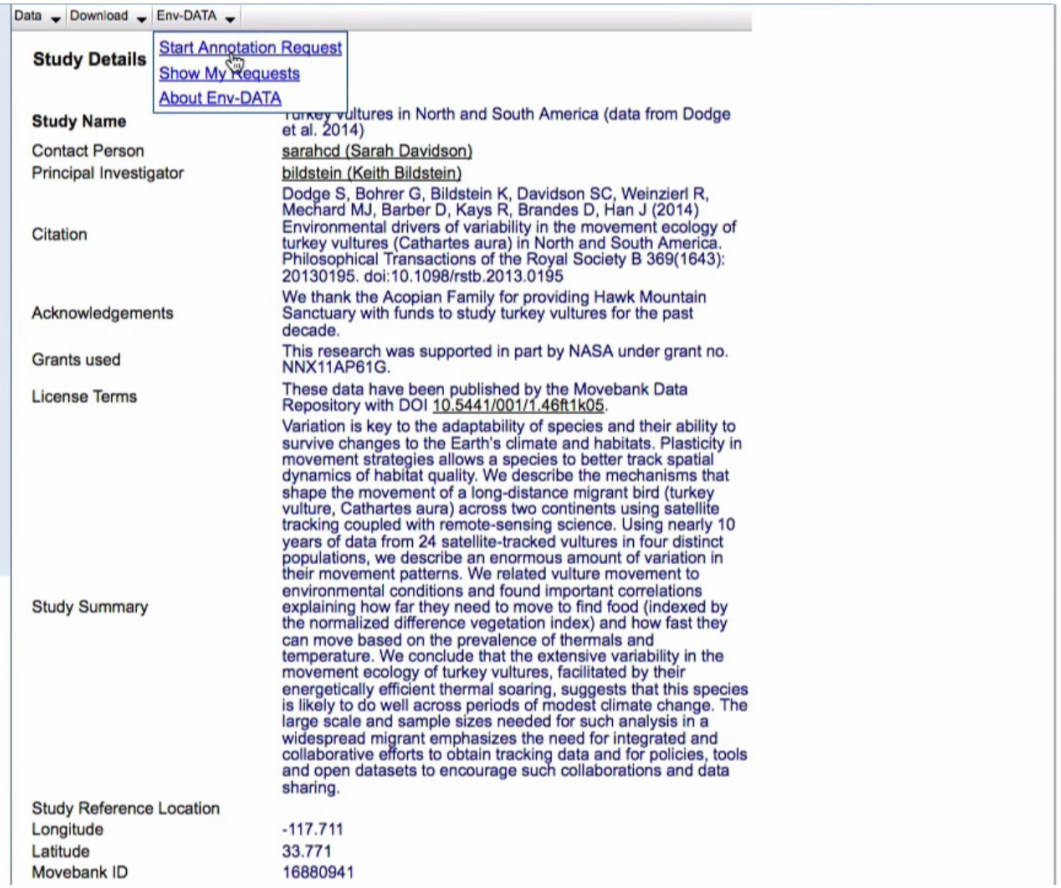
Movebank – Envi-data

The Env-DATA Track Annotation Service

Tutorial about how to use Env-DATA System in Movebank

Datasets	Data description	Data provider	Temporal coverage	Geographic coverage	Temporal resolution	Spatial resolution	Status
ASTER Global DEM V3	Topography	US Geological Survey	–	83°N–83°S 180°E–180°W	–		
Derived wind variables for flight	Thermal and orographic uplift	Calculated derived variables, based on ECMWF or NARR and DEMs	1979–present	89.463°N–89.463°S 180°E–180°W	1-3		
ECMWF Global Atmospheric Reanalysis (ERA5)	Weather, atmosphere, hydrology	European Centre for Medium-Range Weather Forecasts (ECMWF)	1959–present	89.463°N–89.463°S 180°E–180°W	hou		
ETOPO1 Global Relief Model	Topography and bathymetry	National Oceanic and Atmospheric Administration (NOAA)	1940–2008	90°N–90°S 180°E–180°W	–		
GlobCover	Land cover and land-use type	European Space Agency (ESA)	2004–2006, 2009	90°N–65°S 180°E–180°W	–		
MODIS Ocean	Sea surface temperature and other ocean	NASA Goddard Space Flight Center Ocean Biology	2002–present	90°N–90°S 180°E–	Dai day, monthly	4 km	Active





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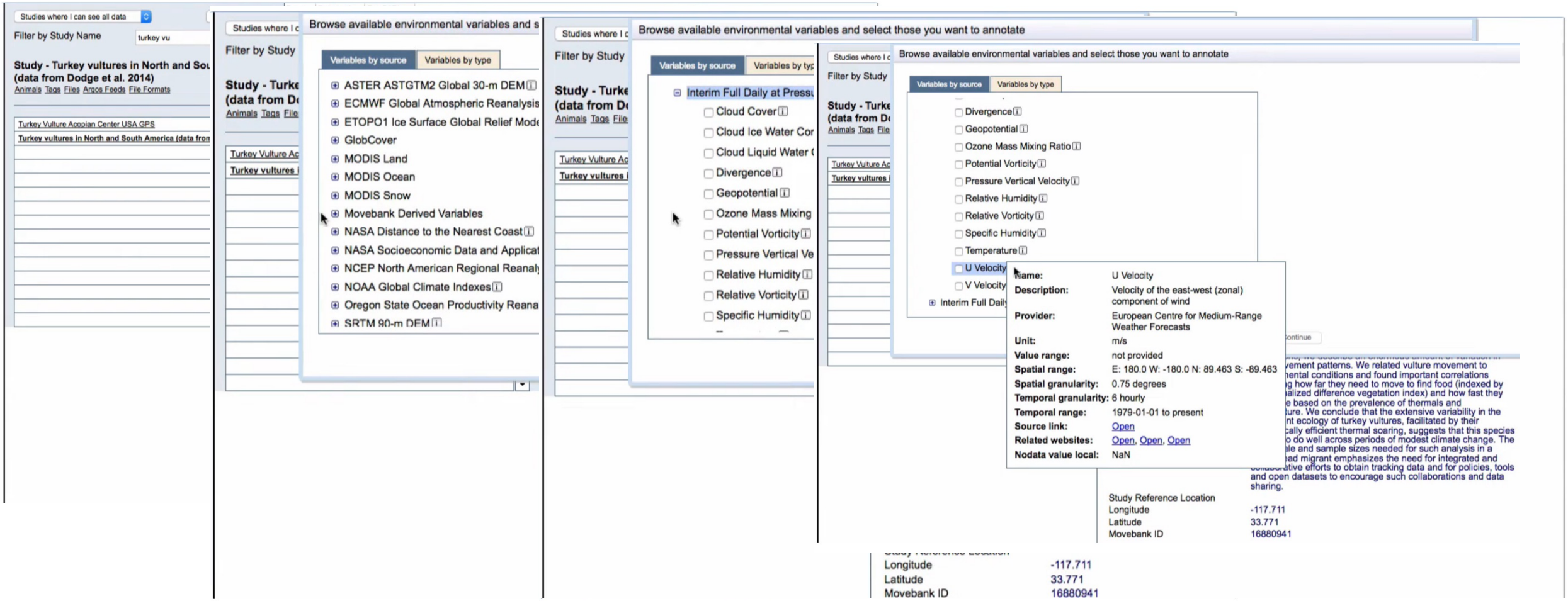

Movebank – Envi-data

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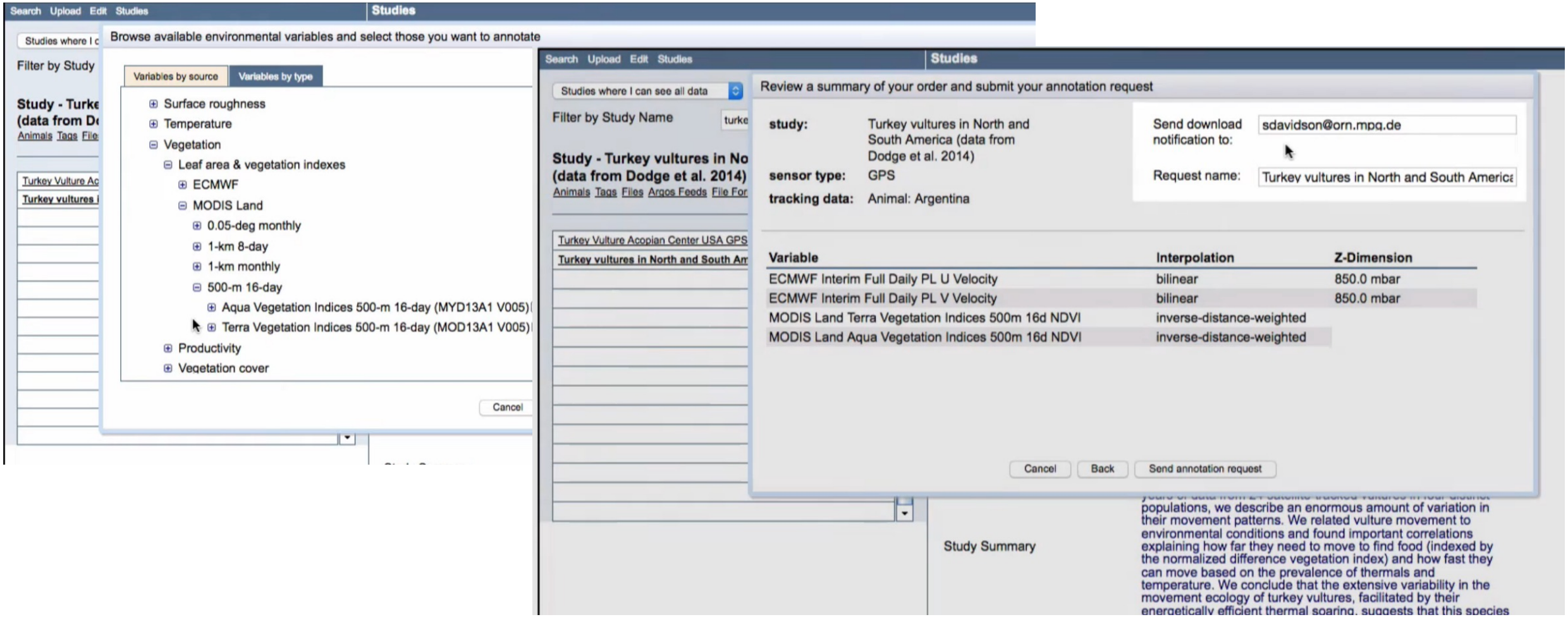
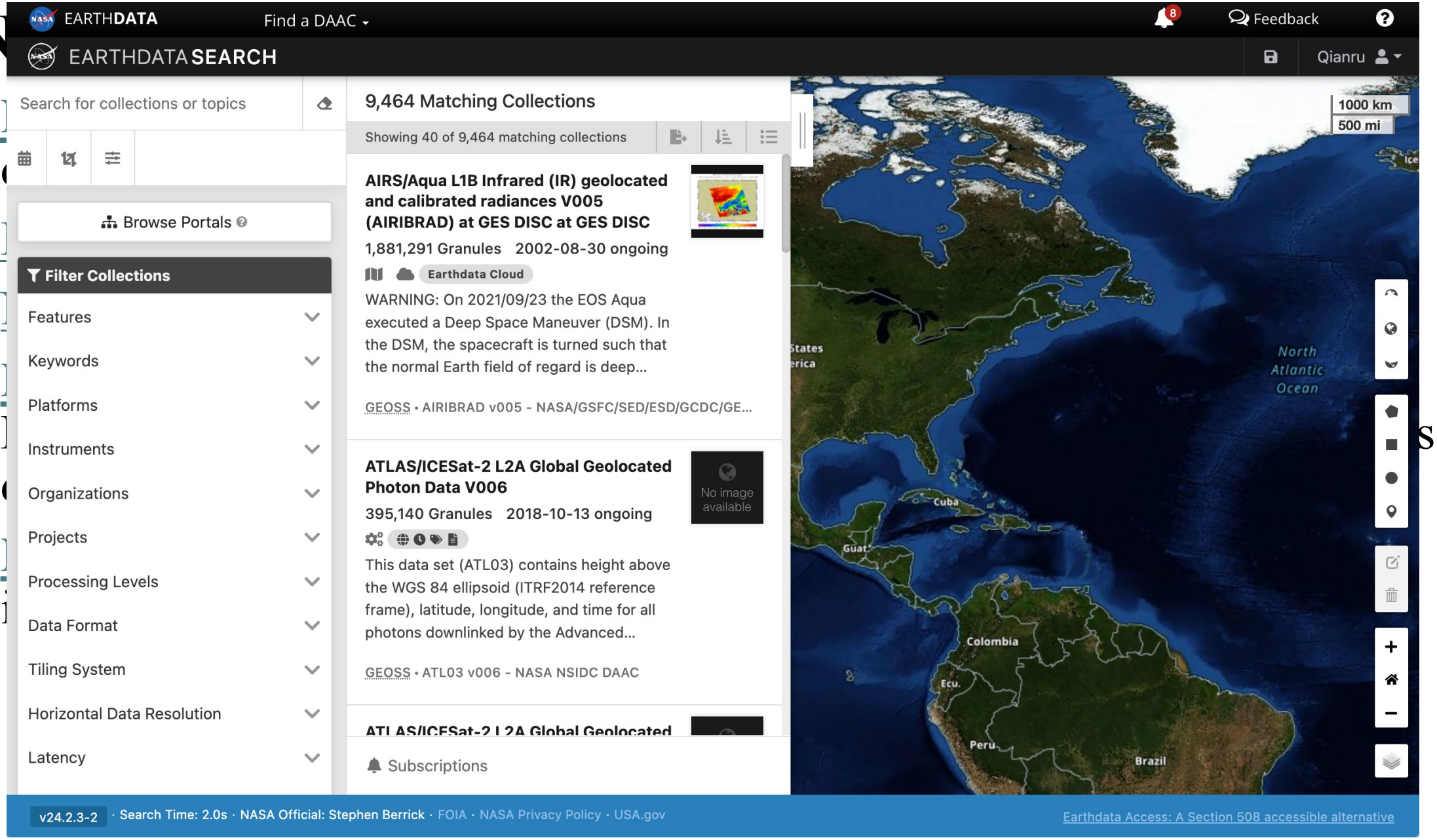


NASA Platforms

- **NASA Earthdata** - free and comprehensive access platform;
- LP DAACs (Land Processes Distributed Active Archive Center)
- NSIDC (National Snow and Ice Data Center)
- **NASA AppEEARS** (Application for Extracting and Exploring Analysis Ready Samples) – **The most user-friendly**; quick extraction; ready-to-use data samples, no reprojection, obtain tiff directly
- **NASA Worldview** – quickly visualize global, full-resolution satellite imagery; real-time imagery; no registration required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Qianru
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Showing 40 of 9,464 matching collections
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Filter Collections
Features
Keywords
Platforms
Instruments
Organizations
Projects
Processing Levels
Data Format
Tiling System
Horizontal Data Resolution
Latency
AIRS/Aqua L1B Infrared (IR) geolocated and calibrated radiances V005 (AIRIBRAD) at GES DISC at GES DISC
1,881,291 Granules 2002-08-30 ongoing
Earthdata Cloud
WARNING: On 2021/09/23 the EOS Aqua executed a Deep Space Maneuver (DSM). In the DSM, the spacecraft is turned such that the normal Earth field of regard is deep...
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ATLAS/ICESat-2 L2A Global Geolocated Photon Data V006
No image available
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This data set (ATL03) contains height above the WGS 84 ellipsoid (ITRF2014 reference frame), latitude, longitude, and time for all photons downlinked by the Advanced...
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Earthdata Access: A Section 508 accessible alternative

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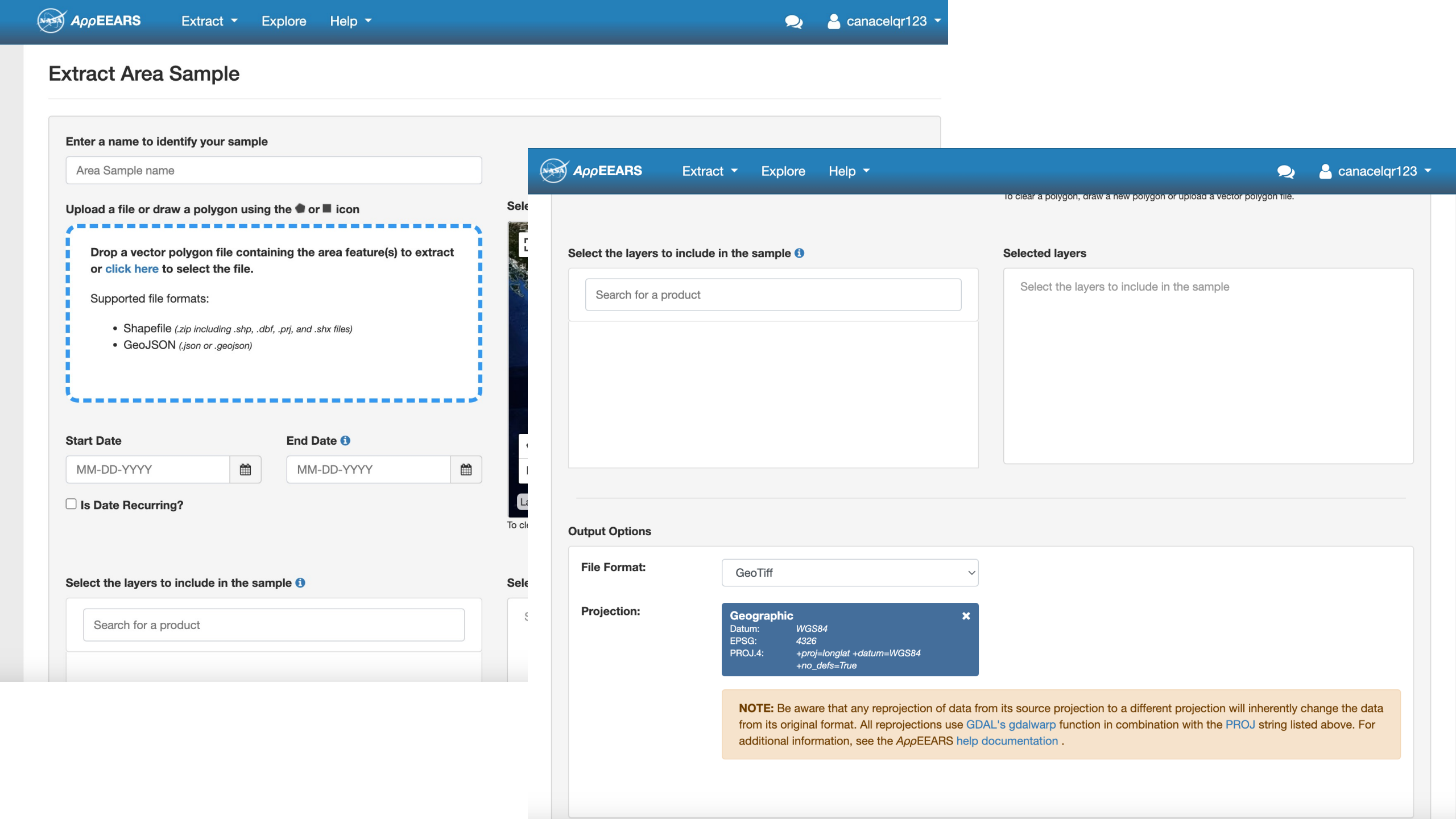
AppEEARS
Extract
Explore
Help
canacelqr123
Extract Area Sample
Enter a name to identify your sample
Area Sample name
Upload a file or draw a polygon using the ⬟ or ■ icon
Drop a vector polygon file containing the area feature(s) to extract or click here to select the file.
Supported file formats:
Shapefile (.zip including .shp, .dbf, .prj, and .shx files)
GeoJSON (.json or .geojson)
Start Date
End Date
MM-DD-YYYY
MM-DD-YYYY
Is Date Recurring?
Select the layers to include in the sample
Search for a product
AppEEARS
Extract
Explore
Help
canacelqr123
To clear a polygon, draw a new polygon or upload a vector polygon file.
Select the layers to include in the sample
Search for a product
Selected layers
Select the layers to include in the sample
Output Options
File Format:
GeoTiff
Projection:
Geographic
Datum: WGS84
EPSG: 4326
PROJ.4: +proj=longlat +datum=WGS84 +no_defs=True
NOTE: Be aware that any reprojection of data from its source projection to a different projection will inherently change the data from its original format. All reprojections use GDAL's gdalwarp function in combination with the PROJ string listed above. For additional information, see the AppEEARS help documentation .

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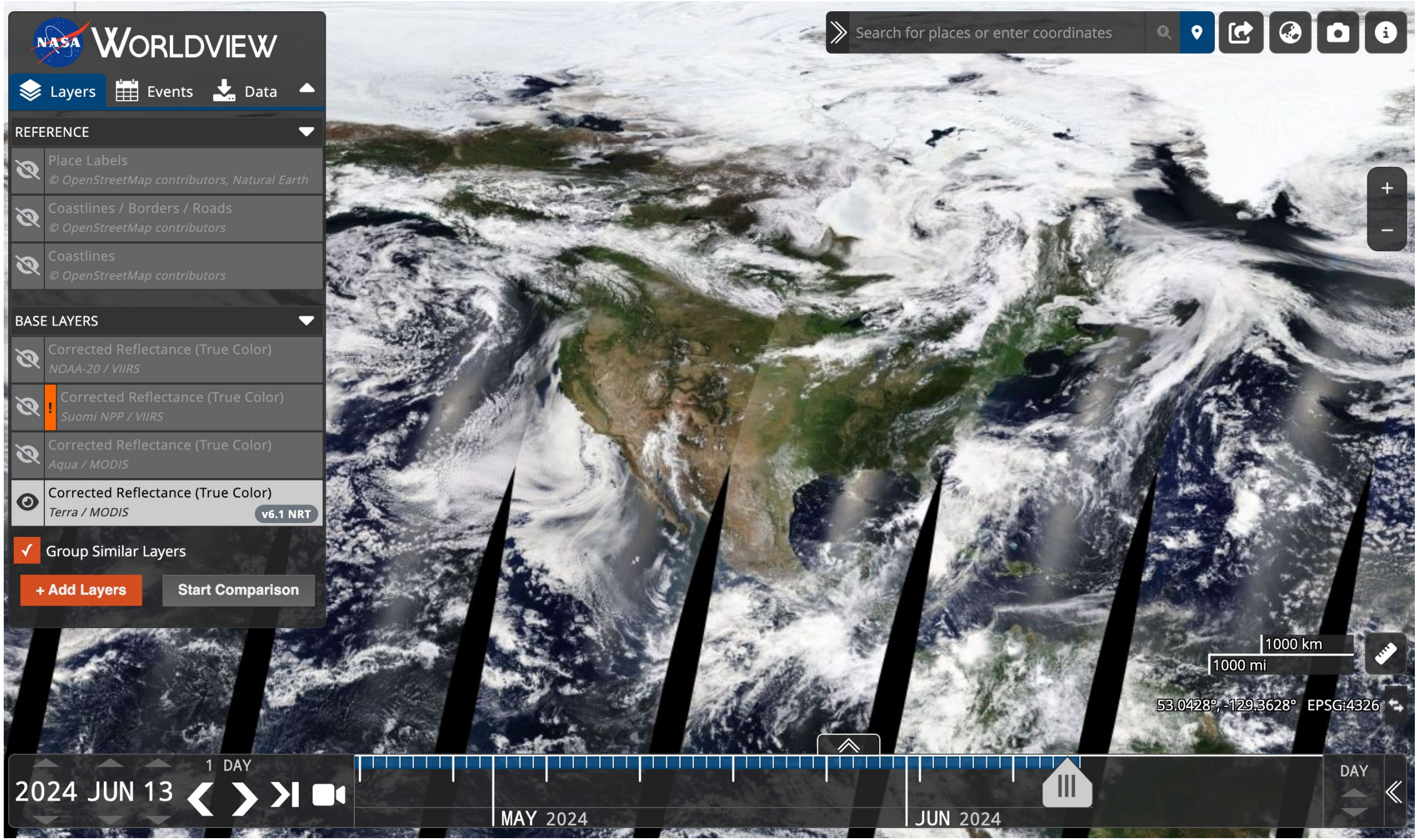
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Coastlines
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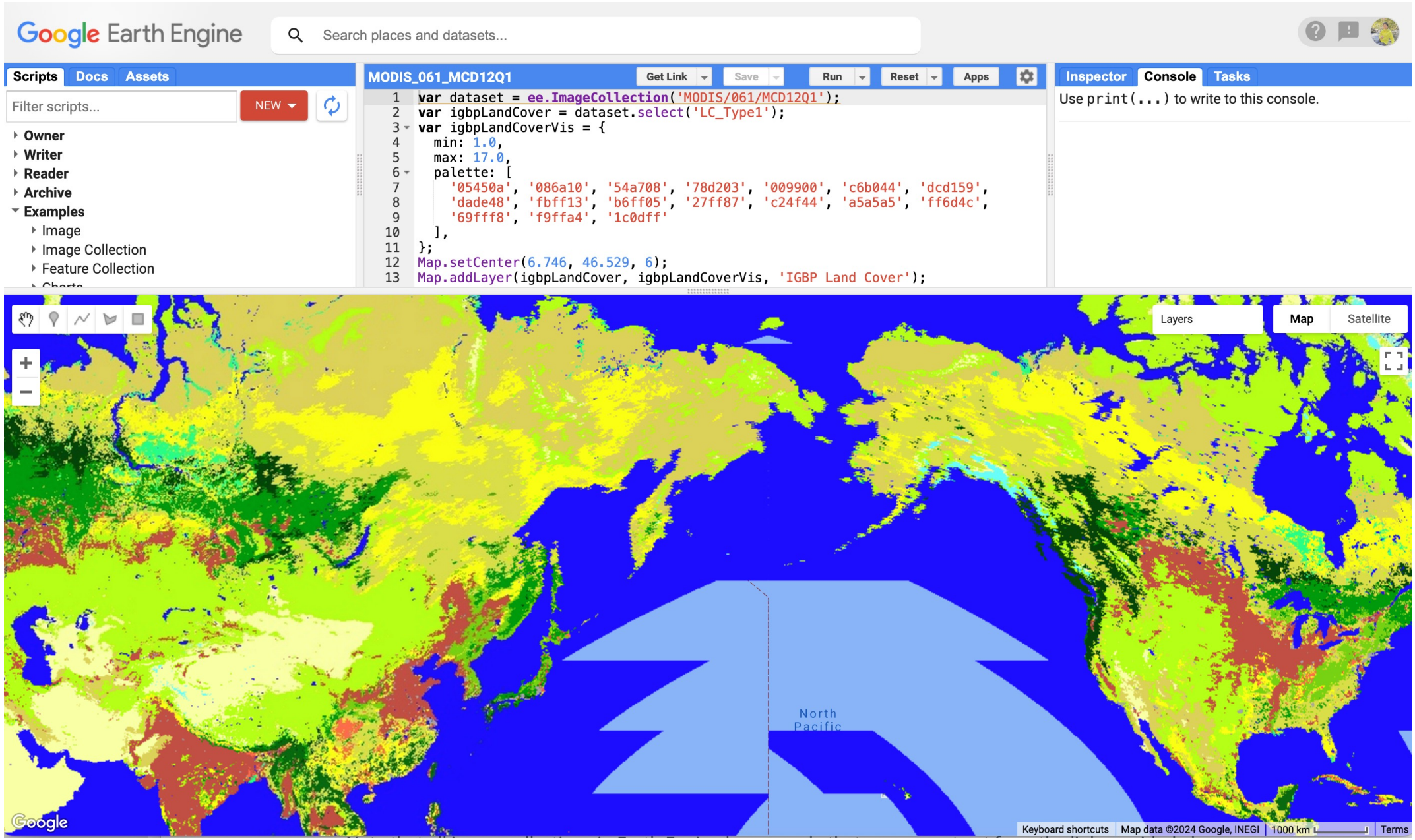
NOAA-20 / VIIRS
Corrected Reflectance (True Color)
Suomi NPP / VIIRS
Corrected Reflectance (True Color)
Aqua / MODIS
Corrected Reflectance (True Color)
Terra / MODIS
v6.1 NRT
Group Similar Layers
+ Add Layers
Start Comparison
Search for places or enter coordinates
1000 km
1000 mi
53.0428°, -129.3628° EPSG:4326
1 DAY
2024 JUN 13
MAY 2024
JUN 2024
DAY

Google Earth Engine

- Cloud-based platform for global scale environmental data analysis
- Different kinds of satellite imagery and dataset
- Powerful computational capabilities for data processing
- No need to worry about local storage
- Javascript/ python

- Tutorial:
- https://calekochenour.github.io/remote-sensing-textbook/03-beginner/chapter08-normalized-difference-vegetation-index.html


Google Earth Engine
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Scripts
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Assets
Filter scripts...
NEW
Owner
Writer
Reader
Archive
Examples
Image
Image Collection
Feature Collection
MODIS_061_MCD12Q1
Get Link
Save
Run
Reset
Apps
1 var dataset = ee.ImageCollection('MODIS/061/MCD12Q1');
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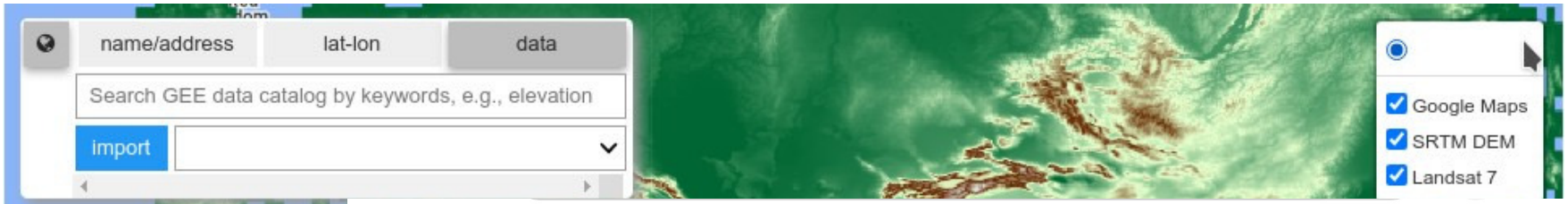
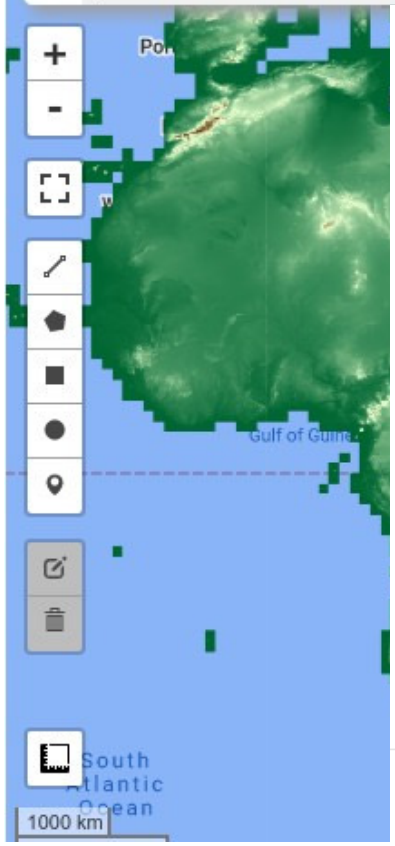
3 var igbpLandCoverVis = {
4 min: 1.0,
5 max: 17.0,
6 palette: [
7 '05450a', '086a10', '54a708', '78d203', '009900', 'c6b044', 'dcd159',
8 'dade48', 'fbff13', 'b6ff05', '27ff87', 'c24f44', 'a5a5a5', 'ff6d4c',
9 '69fff8', 'f9ffa4', '1c0dff'
10],
11 };
12 Map.setCenter(6.746, 46.529, 6);
13 Map.addLayer(igbpLandCover, igbpLandCoverVis, 'IGBP Land Cover');
Inspector
Console
Tasks
Use print(...) to write to this console.
Layers
Map
Satellite
North Pacific
Google
Keyboard shortcuts
Map data ©2024 Google, INEGI
1000 km
Terms

Google Earth Engine

- Geemap (GEE Python API)
- analyze and visualize earth engine datasets in a jupyter environments





Open G

@giswqs · 3.27万位

Dr. Qiusheng Wu is

twitter.com/giswqs

已订阅

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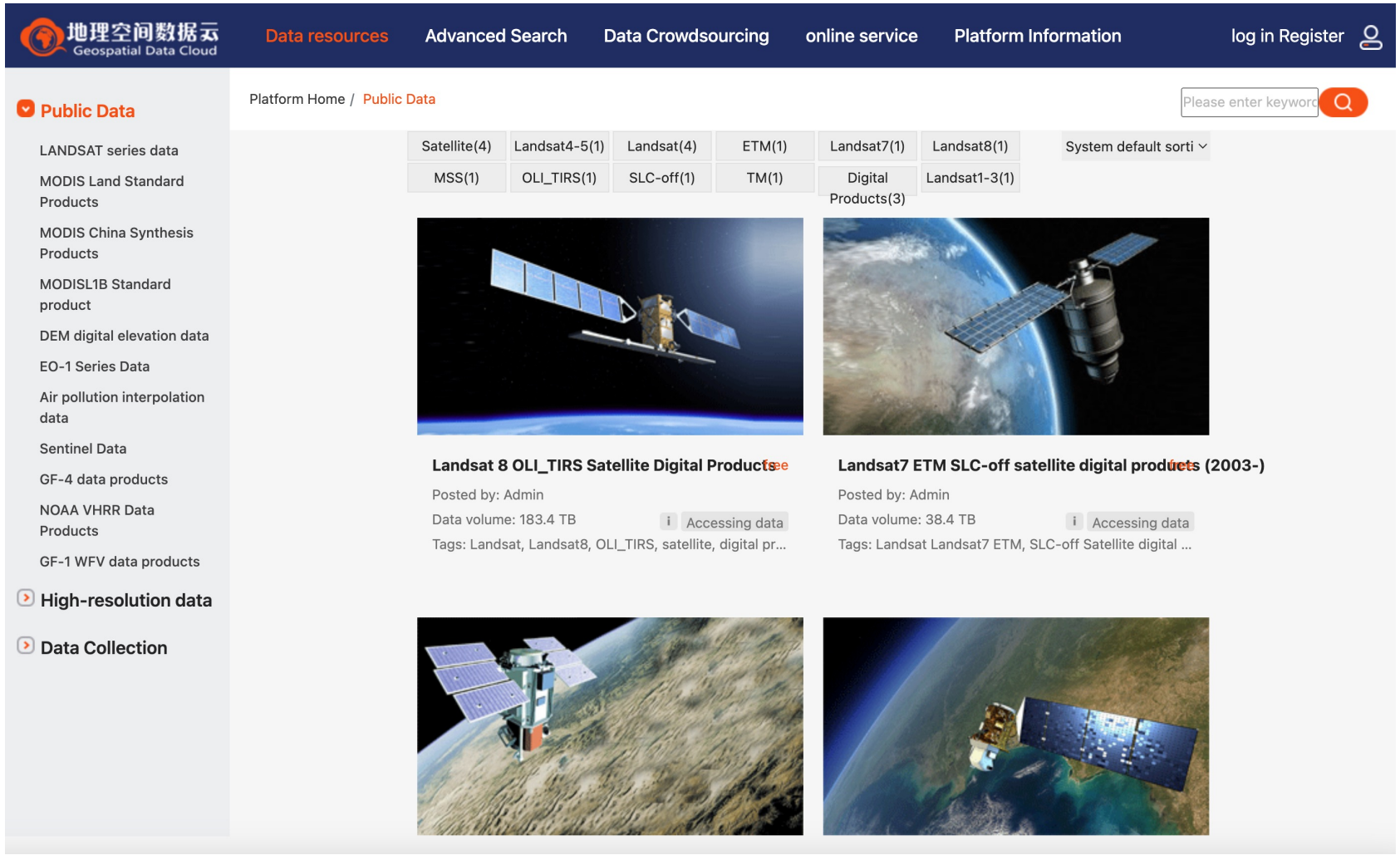
geemap for interactive mapping with GEE

GEE
inter
Open
The vi
Engine

GSCloud (地理空间数据云)

- Easy to obtain high-resolution imagery data in China
- Ready to use data
- …



R packages: load Environmental Data

Data type	Source	R Package	Uses
Daily raster data	MODIS	**MODIStsp,**	Moderate spatial, high temporal resolution
Daily raster data	AVHRR	**luna**	High temporal, low spatial resolution
Various raster data	GEE	**rgee**	Various, including cloud computation
Historical climate projections	ERA5	**ecmwfr**	High temporal (hourly!), modeled + observed
Future climate projections	ClimateNA	**climatenaR**	Monthly projections with IPCC SSPs
…….			

R packages: process raster data

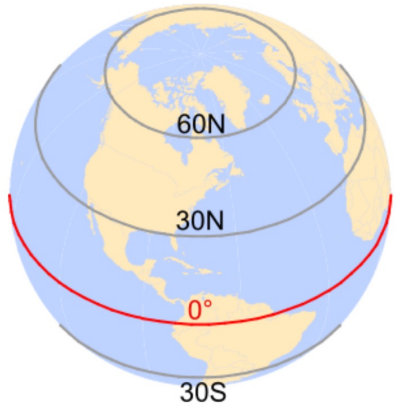
- sf
- sp
- Terra
- Raster
- Ncdf4
- …

Coordinate System

- Geographic coordinate system
- Projected coordinate system

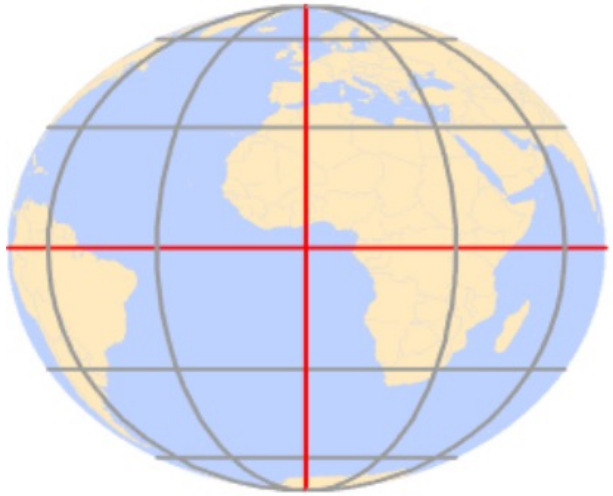
Geographic Coordinate System (GCS)

- A reference system for identifying locations on the **curved** surface of the earth.
- The location is measured in angular units from the center of the earth relative to two planes: the equator and the prime meridian.
- use longitude and latitude

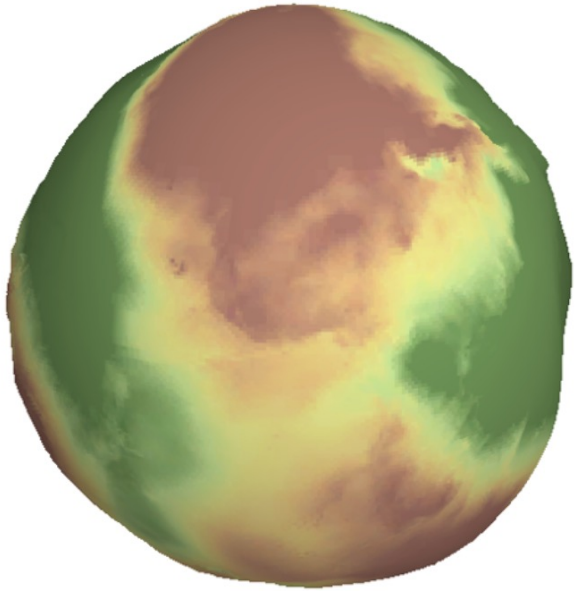


North and East are assigned a positive (+) sign and South and West are assigned a negative (-) sign

- The GCS is defined by ellipsoid, geoid and datum.



- Simple mathematical model of the earth's surface
- The equatorial axis is roughly 21 km longer than polar axis.



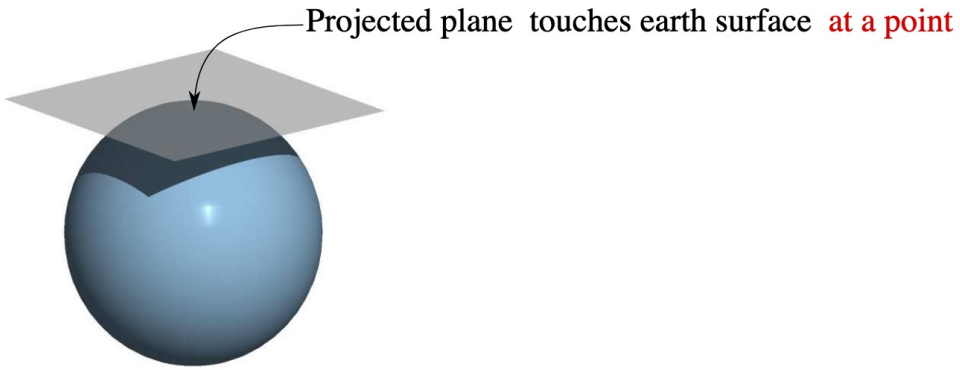
- Irregular shape; Closer to the Earth’s true shape (locational calculation)
- Distance from the earth’ s center to the water's surface
- Constantly changing (gravitational field & hot and fluid core)

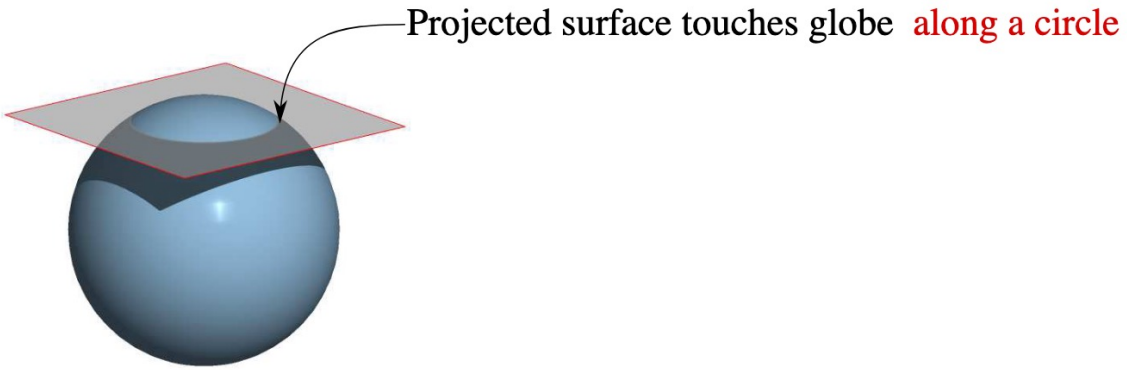
- Datum: align the ellipsoid to the geoid; map the earth's surface feather to the ellipsoid
- For example: World Geodetic System 1984 (WGS 84) for the global use

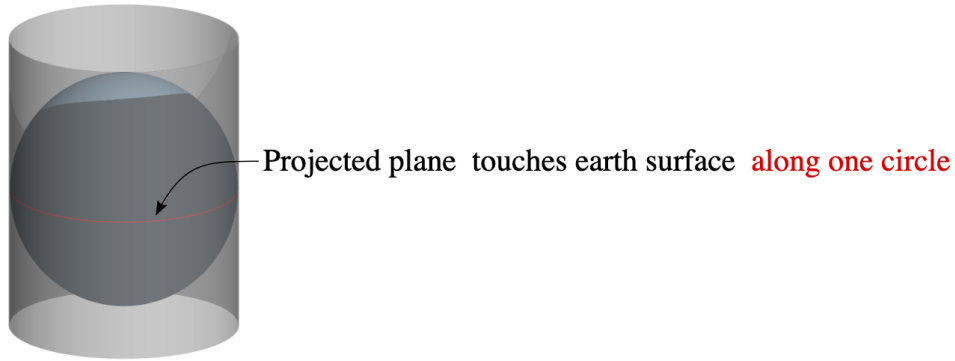
A Geographic Coordinate System (GCS) is defined by the ellipsoid model aligned with the geoid

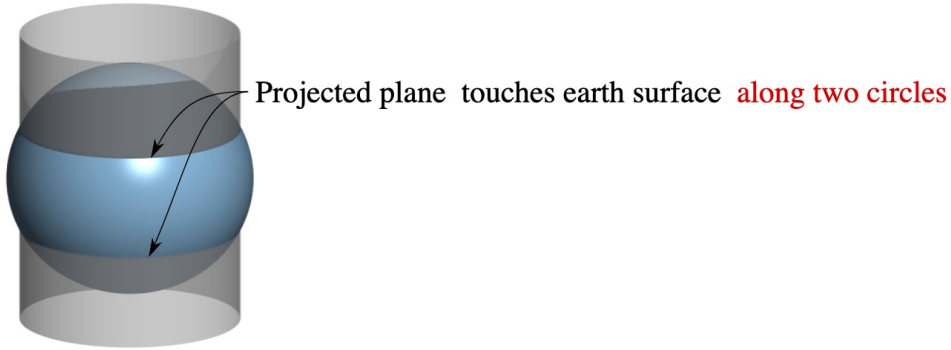
Projected Coordinate System (GCS)

- identify locations and measure feathers on a **flat** map
- an origin, an x-axis, a y-axis, and a linear unit of measure (such as meter, km)



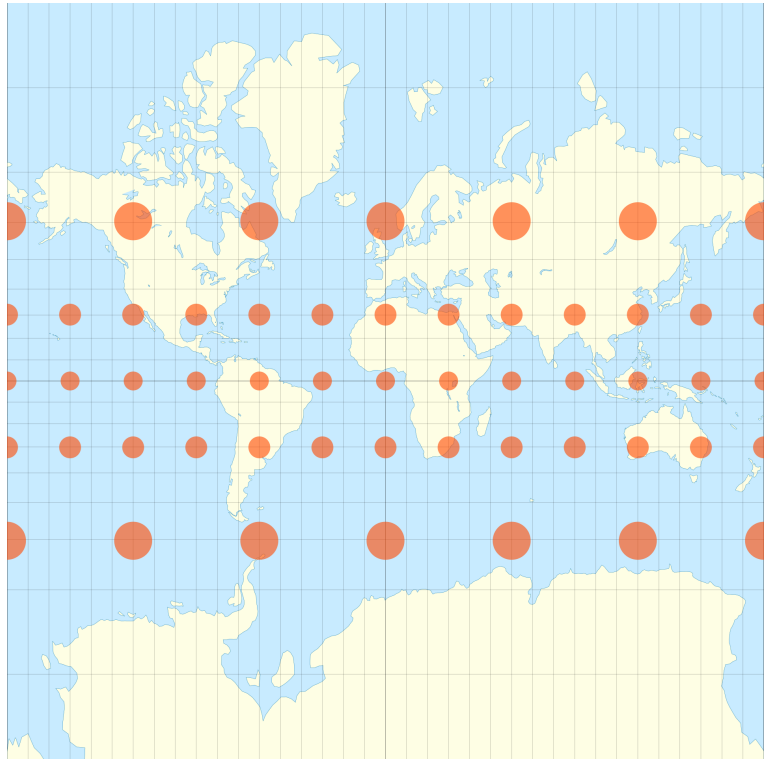


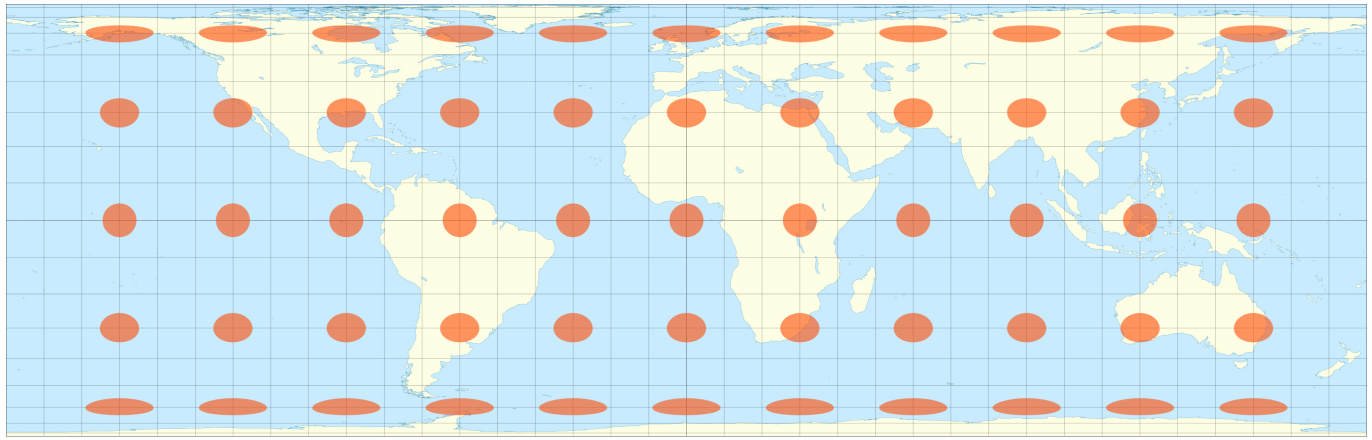




Types of Projection

- **Conformal Projection:** preserves local angles and shapes but distorts areas and lengths
  - Mercator Projection:
  - Universal Transverse Mercator (UTM)
- **Equal-Area Projections:** preserves local areas, but not shape
  - Lambert Projection



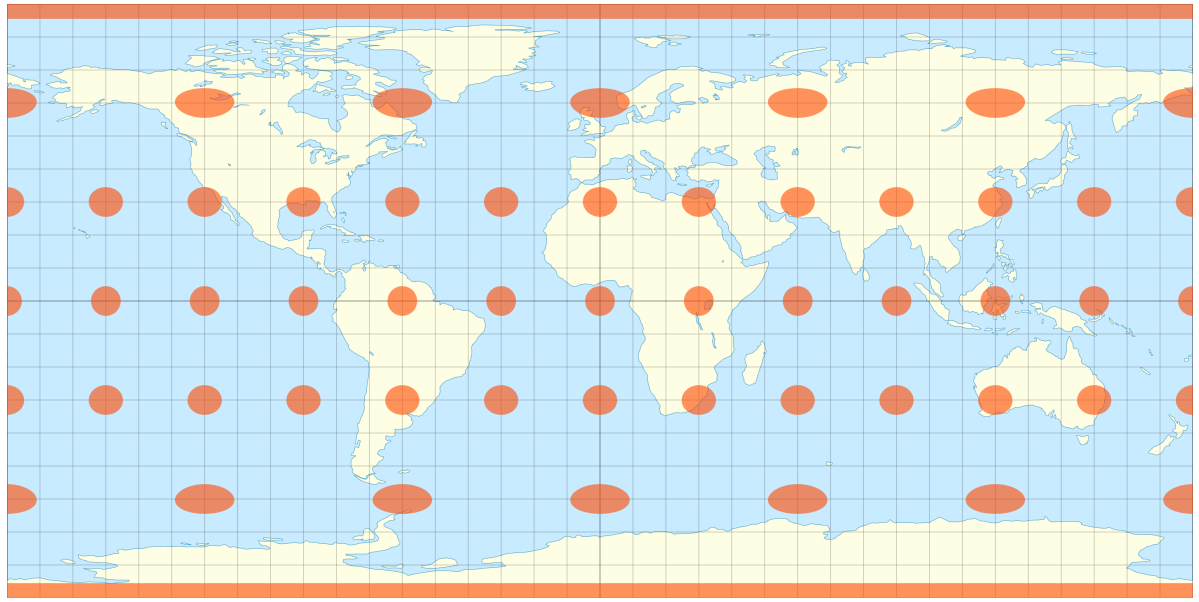


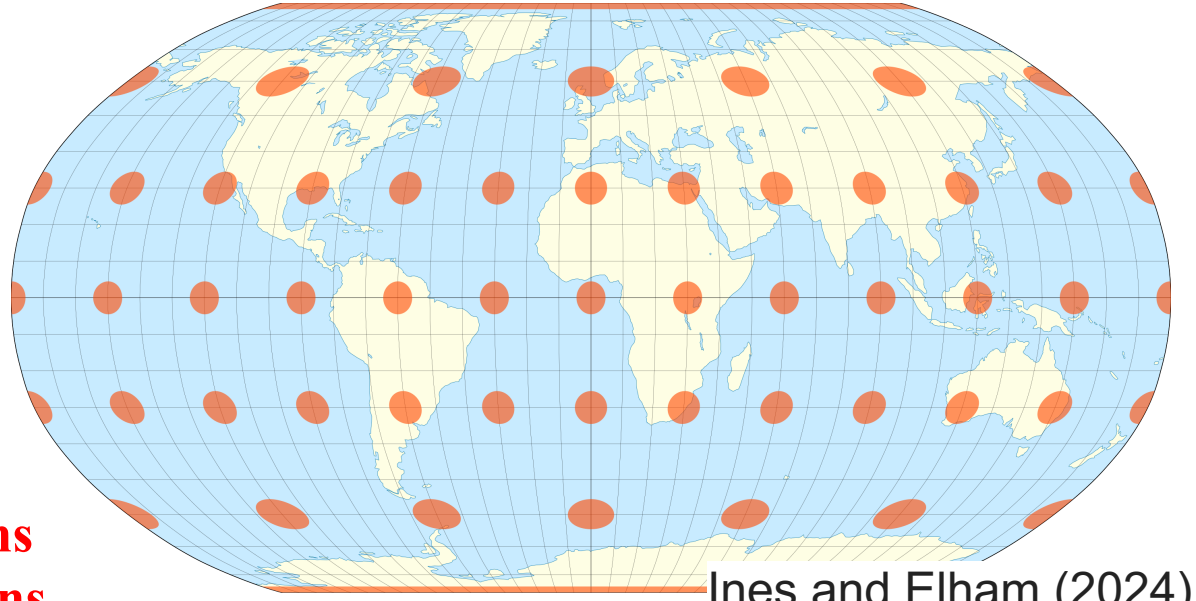
Ines and Elham (2024)

Types of Projection

- **Conformal Projection:** preserves local angles and shapes but distorts areas and lengths
  - Mercator Projection:
  - Universal Transverse Mercator (UTM)
- **Equal-Area Projections:** preserves local areas, but not shape
  - Lambert Projection
- **Equidistance:** maintain scale (distance) along one or more lines
  - Equirectangular Projection
- **Compromise Projection:** balance shape, area and distance
  - Robinson Projection

Different data providers might use different projections
You might need to convert between different projections



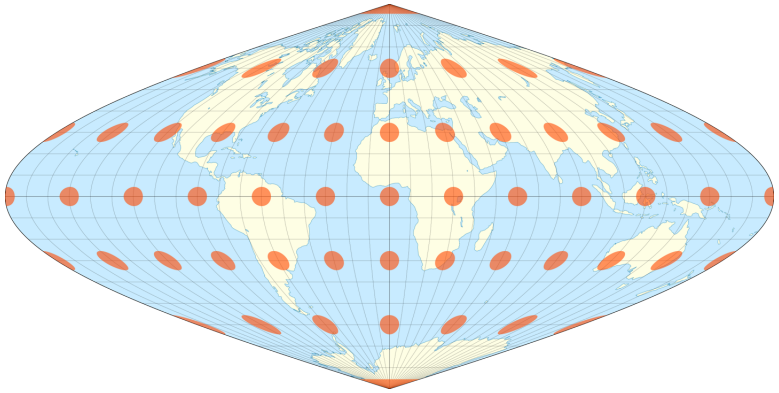


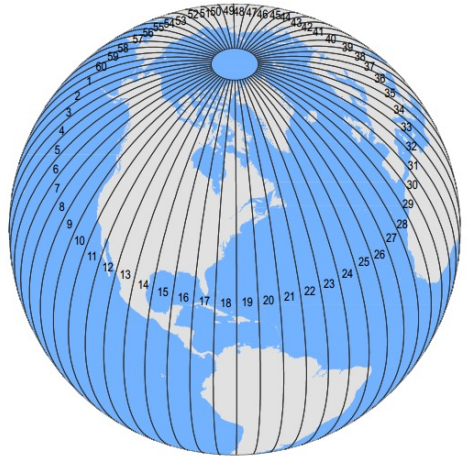
Ines and Elham (2024)

Pre-processing Remote Sensing Imagery

Once you download the satellite images from NASA Earth Data, for example MODIS data

- Convert HDF to TIFF
- Reproject
- convert Sinusoidal Projection (preserve area) to Geographic Coordinate Systems (lat/lon) (not a projection) to define the locations on the Earth's surface
- convert to Universal Transverse Mercator (UTM) (conformal, cylindrical projection) for regional mapping, providing high accuracy for distances and directions within each zone.





Reprojection

- gdal
- need operate system – Download the Anaconda Installer
- Install GDAL

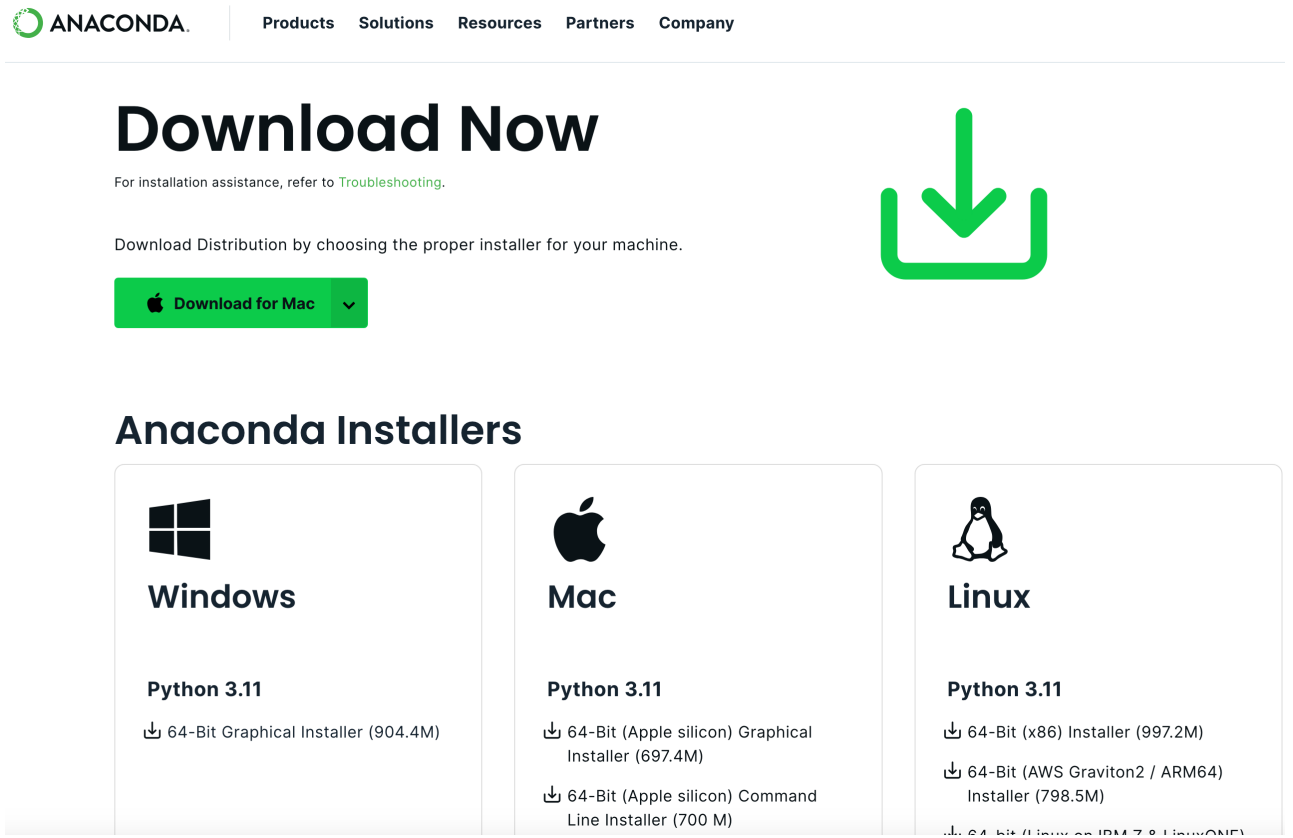
Command to convert to TIFF

- gdal_translate
  - gdal_translate -of GTiff

Option 1:

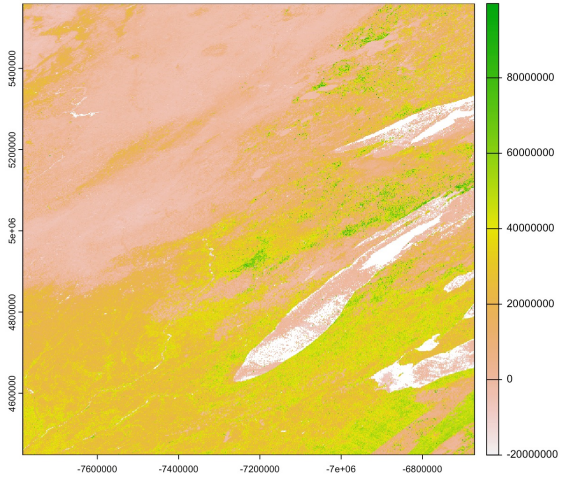
Command to convert it to WGS84

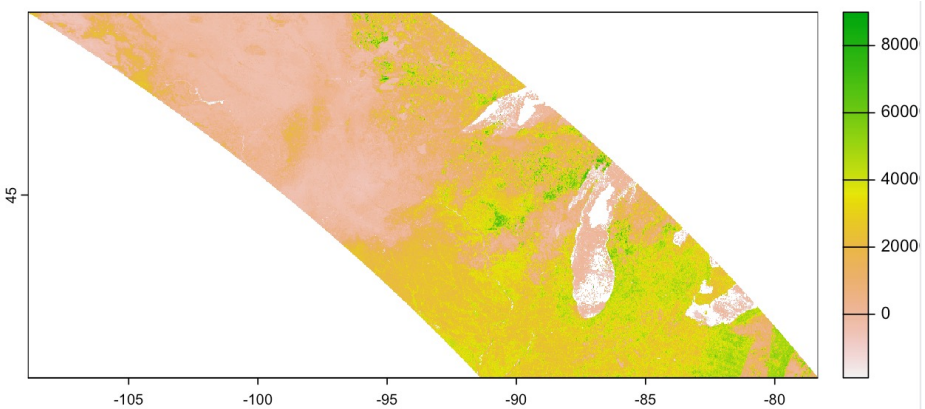
- gdalwarp
  - gdalwarp -t_srs EPSG:4326



Option 2: Use Terra::project in R

- r <- rast(input_tiff)
- r_wgs84 <- project(r, "+proj=longlat +datum=WGS84 +no_defs")
- writeRaster(r_wgs84, filename=output_tiff, overwrite=TRUE)






```
> r
class       : SpatRaster
dimensions  : 4800, 4800, 1  (nrow, ncol, nlyr)
resolution  : 231.6564, 231.6564  (x, y)
extent      : -7783654, -6671703, 4447802, 5559753  (xmin, xmax, ymin, yma
x)
coord. ref. : +proj=sinu +lon_0=0 +x_0=0 +y_0=0 +R=6371007.181 +units=m +n
o_defs
source      : output_NDVI.tif
name        : 250m 16 days NDVI
> r_wgs84
class       : SpatRaster
dimensions  : 2110, 6452, 1  (nrow, ncol, nlyr)
resolution  : 0.004739082, 0.004739082  (x, y)
extent      : -108.9007, -78.32411, 40.00054, 50  (xmin, xmax, ymin, ymax)
coord. ref. : +proj=longlat +datum=WGS84 +no_defs
source(s)   : memory
name        : 250m 16 days NDVI
min value   :         -20000000
max value   :          94500000
```

Practical Exercise

Examples of Remote Sensing Data for Animal Movement Analyses

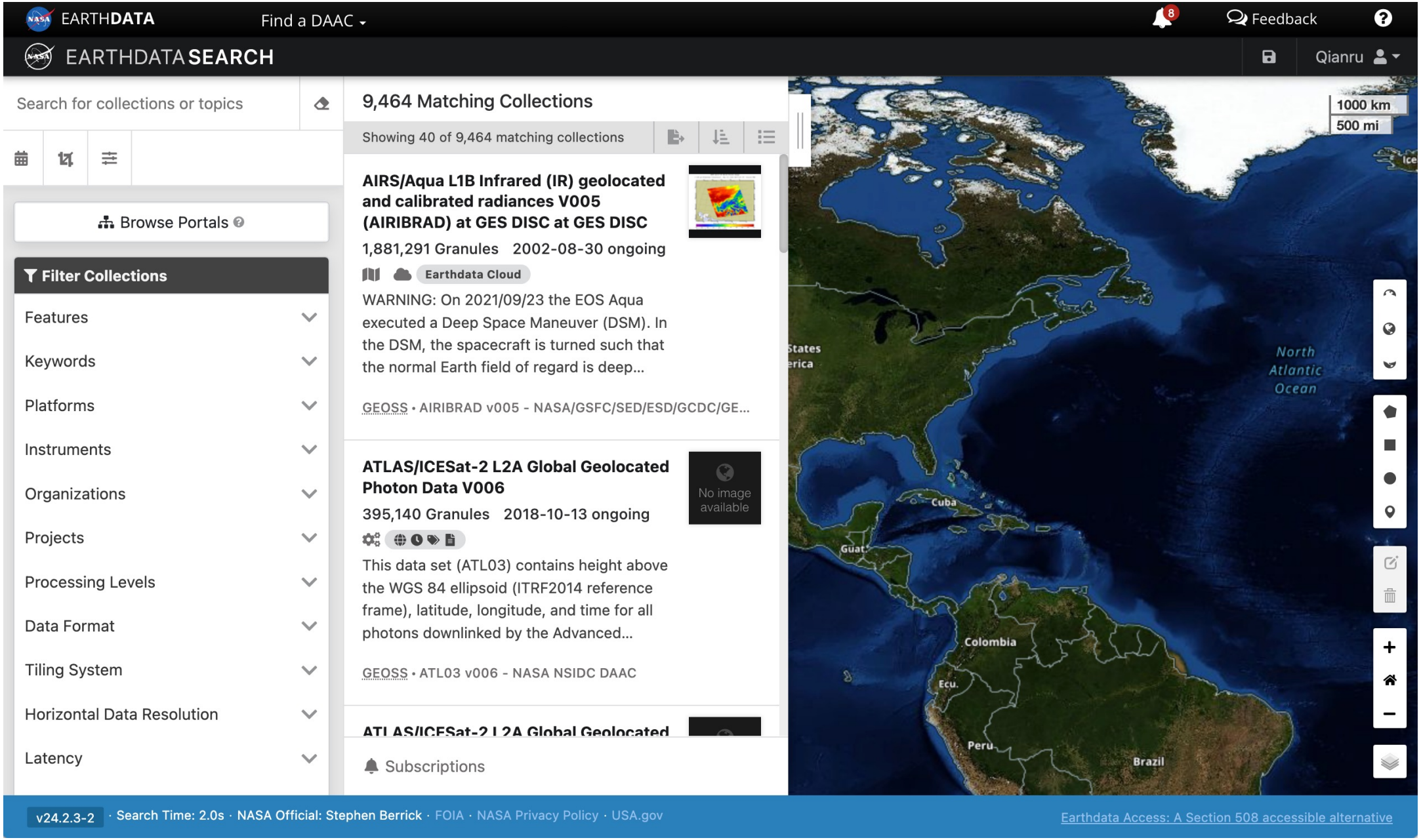
Q&A

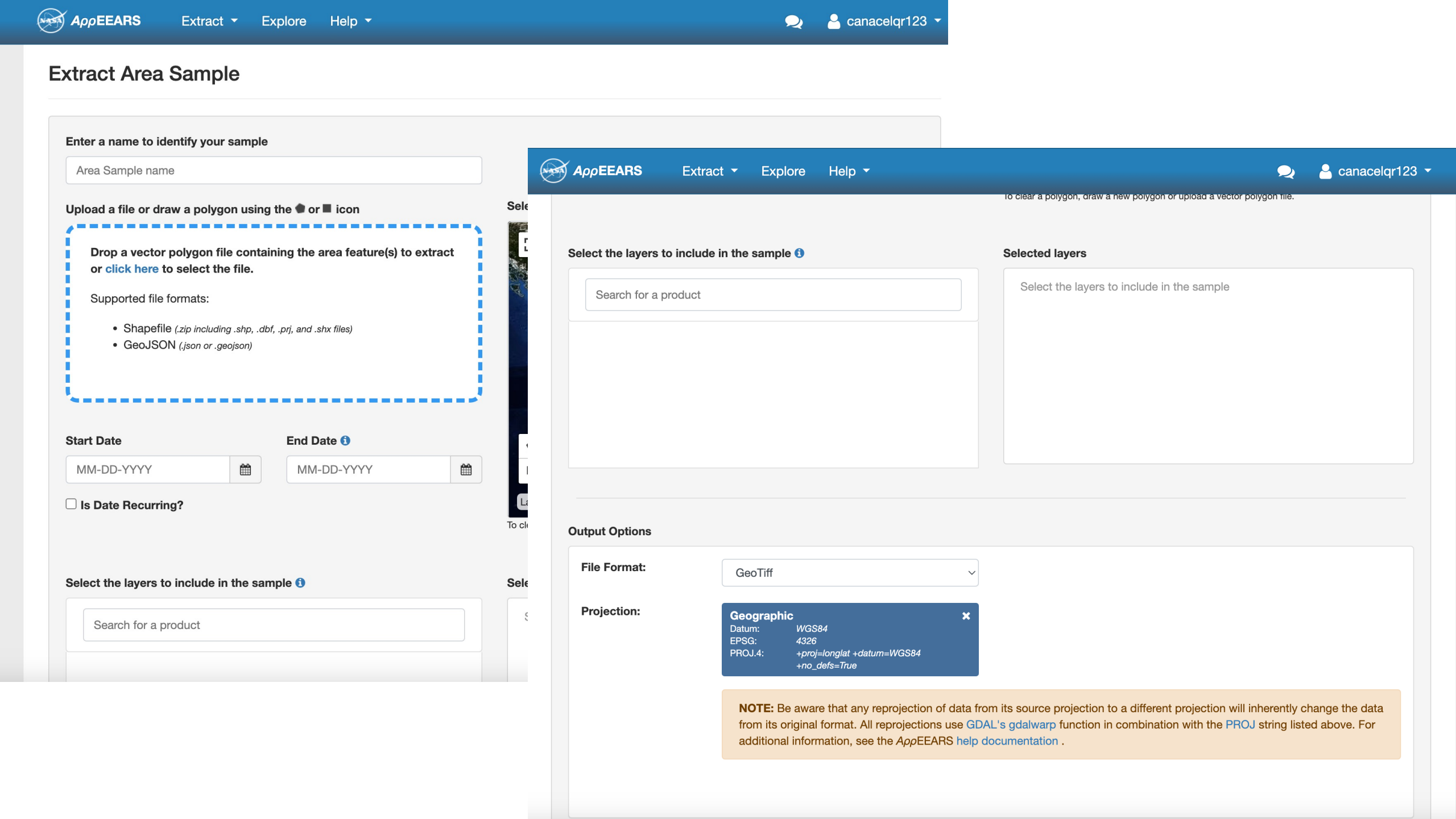
Thank you!

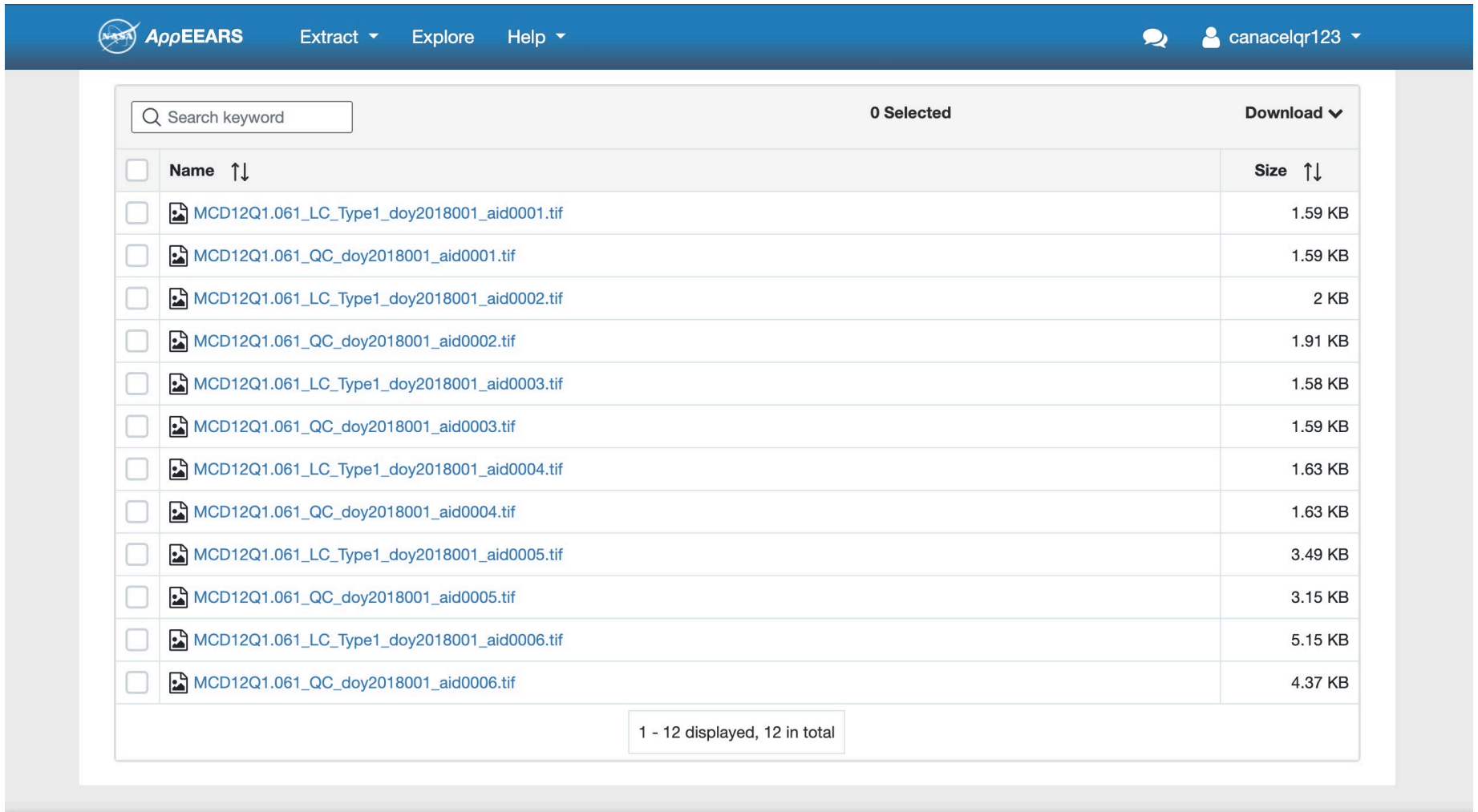
Extract environmental data by points/ spatial boundaries

```
//===online GEE code to extract landsat images based on a spatial rectangle
// image collection can be changed to sentinel 2, and loaded bands can be changed to optical reflectance bands



var batch = require('users/fitoprincipe/geetools:batch')

// Create a geometry representing an export region.
var roi = ee.Geometry.Rectangle([115.466827,-28.6914,147.7908,-36.4878]);

//time range
var start_date = 2018+'-01-01';
var end_date  = (2018)+'-01-31';
var dateFilter = ee.Filter.date(start_date, end_date);

// Load the Landsat ImageCollection.
var l7 = ee.ImageCollection('LANDSAT/LE07/C02/T1_L2').select('ST_B6','QA_PIXEL').filter(dateFilter).filterBounds(roi);
print(l7)

//export to the folder 'test'
batch.Download.ImageCollection.toDrive(l7, 'test',
                {scale: 30,
                 type: 'float'})
```

```
var table = ee.FeatureCollection("projects/ee-aolin/assets/SURFRAD");

 var landsat = ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')

  // function to map over the FeatureCollection
  var mapfunc = function(feat) {
    // get feature geometry
    var geom = feat.geometry();
    // filter the image collection with the geom of a feature
    var l8sr_pt = landsat.filterBounds(geom);
    // make an empty list to store the features
    var newfc = ee.List([]);
    // function to iterate over the ImageCollection
    var addProp = function(img, fc) {
      // the initial value is the empty list
      fc = ee.List(fc);
      // get the date as string
      var date = img.date().format();
      // extract the value in the feature
      var val = img.reduceRegion(ee.Reducer.first(),geom,30);
      // add the date to the property
      var feat2 = feat.set('date', date);
      // add the extracted band values to the properties
      var newfeat = feat2.setMulti(val);
      // add the value to the list
      return fc.add(newfeat);
    };
    var newfeat = ee.FeatureCollection(ee.List(l8sr_pt.iterate(addProp, newfc)));
    return newfeat;
  };

  var newft = table.map(mapfunc).flatten();

  Export.table.toDrive(newft,
  "export_Points_surf_landsat8", //task name
  "export_Points", //folder name in your drive
  "export_Points_surf_landsat8"); //filename
```


EARTHDATA
Find a DAAC
8
Feedback
EARTHDATA SEARCH
Qianru
Search for collections or topics
9,464 Matching Collections
Showing 40 of 9,464 matching collections
Browse Portals
Filter Collections
Features
Keywords
Platforms
Instruments
Organizations
Projects
Processing Levels
Data Format
Tiling System
Horizontal Data Resolution
Latency
AIRS/Aqua L1B Infrared (IR) geolocated and calibrated radiances V005 (AIRIBRAD) at GES DISC at GES DISC
1,881,291 Granules 2002-08-30 ongoing
Earthdata Cloud
WARNING: On 2021/09/23 the EOS Aqua executed a Deep Space Maneuver (DSM). In the DSM, the spacecraft is turned such that the normal Earth field of regard is deep...
GEOSS • AIRIBRAD v005 - NASA/GSFC/SED/ESD/GCDC/GE...
ATLAS/ICESat-2 L2A Global Geolocated Photon Data V006
No image available
395,140 Granules 2018-10-13 ongoing
This data set (ATL03) contains height above the WGS 84 ellipsoid (ITRF2014 reference frame), latitude, longitude, and time for all photons downlinked by the Advanced...
GEOSS • ATL03 v006 - NASA NSIDC DAAC
Subscriptions
1000 km
500 mi
North Atlantic Ocean
Cuba
Colombia
Peru
Brazil
v24.2.3-2 · Search Time: 2.0s · NASA Official: Stephen Berrick · FOIA · NASA Privacy Policy · USA.gov
Earthdata Access: A Section 508 accessible alternative


AppEEARS
Extract
Explore
Help
canacelqr123
Extract Area Sample
Enter a name to identify your sample
Area Sample name
Upload a file or draw a polygon using the ⬟ or ■ icon
Drop a vector polygon file containing the area feature(s) to extract or click here to select the file.
Supported file formats:
Shapefile (.zip including .shp, .dbf, .prj, and .shx files)
GeoJSON (.json or .geojson)
Start Date
End Date
MM-DD-YYYY
MM-DD-YYYY
Is Date Recurring?
Select the layers to include in the sample
Search for a product
AppEEARS
Extract
Explore
Help
canacelqr123
To clear a polygon, draw a new polygon or upload a vector polygon file.
Select the layers to include in the sample
Search for a product
Selected layers
Select the layers to include in the sample
Output Options
File Format:
GeoTiff
Projection:
Geographic
Datum: WGS84
EPSG: 4326
PROJ.4: +proj=longlat +datum=WGS84 +no_defs=True
NOTE: Be aware that any reprojection of data from its source projection to a different projection will inherently change the data from its original format. All reprojections use GDAL's gdalwarp function in combination with the PROJ string listed above. For additional information, see the AppEEARS help documentation .


AppEEARS
Extract
Explore
Help
canacelqr123
Search keyword
0 Selected
Download
Name
Size
MCD12Q1.061_LC_Type1_doy2018001_aid0001.tif 1.59 KB
MCD12Q1.061_QC_doy2018001_aid0001.tif 1.59 KB
MCD12Q1.061_LC_Type1_doy2018001_aid0002.tif 2 KB
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MCD12Q1.061_QC_doy2018001_aid0005.tif 3.15 KB
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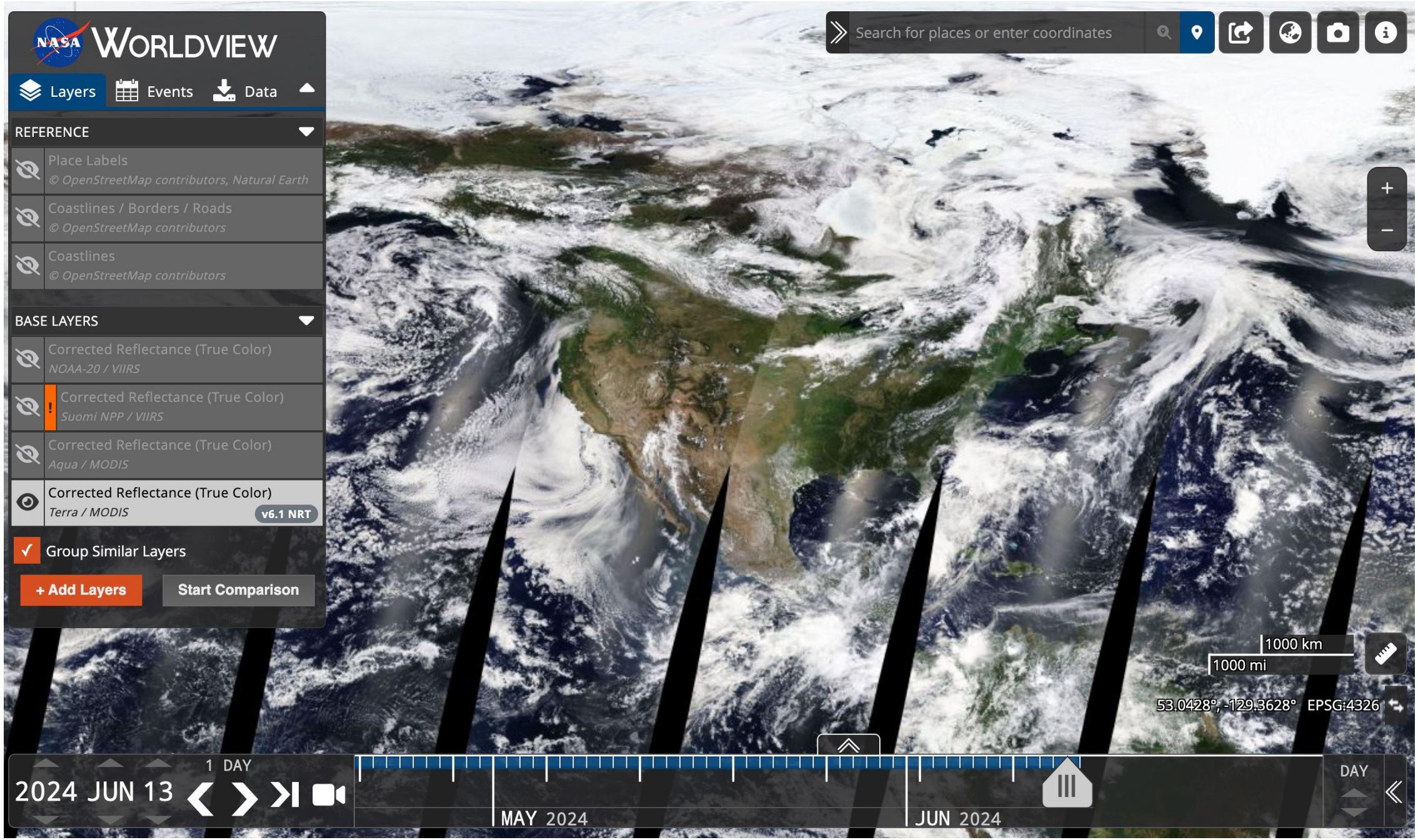
MCD12Q1.061_QC_doy2018001_aid0006.tif 4.37 KB
1 - 12 displayed, 12 in total


NASA WORLDVIEW
Layers
Events
Data
REFERENCE
Place Labels
© OpenStreetMap contributors, Natural Earth
Coastlines / Borders / Roads
© OpenStreetMap contributors
Coastlines
© OpenStreetMap contributors
BASE LAYERS
Corrected Reflectance (True Color)
NOAA-20 / VIIRS
Corrected Reflectance (True Color)
Suomi NPP / VIIRS
Corrected Reflectance (True Color)
Aqua / MODIS
Corrected Reflectance (True Color)
Terra / MODIS
v6.1 NRT
Group Similar Layers
+ Add Layers
Start Comparison
Search for places or enter coordinates
1000 km
1000 mi
53.0428°, -129.3628° EPSG:4326
1 DAY
2024 JUN 13
MAY 2024
JUN 2024
DAY

Google Earth Engine

Search places and datasets...

Scripts | Docs | Assets

Filter scripts... NEW

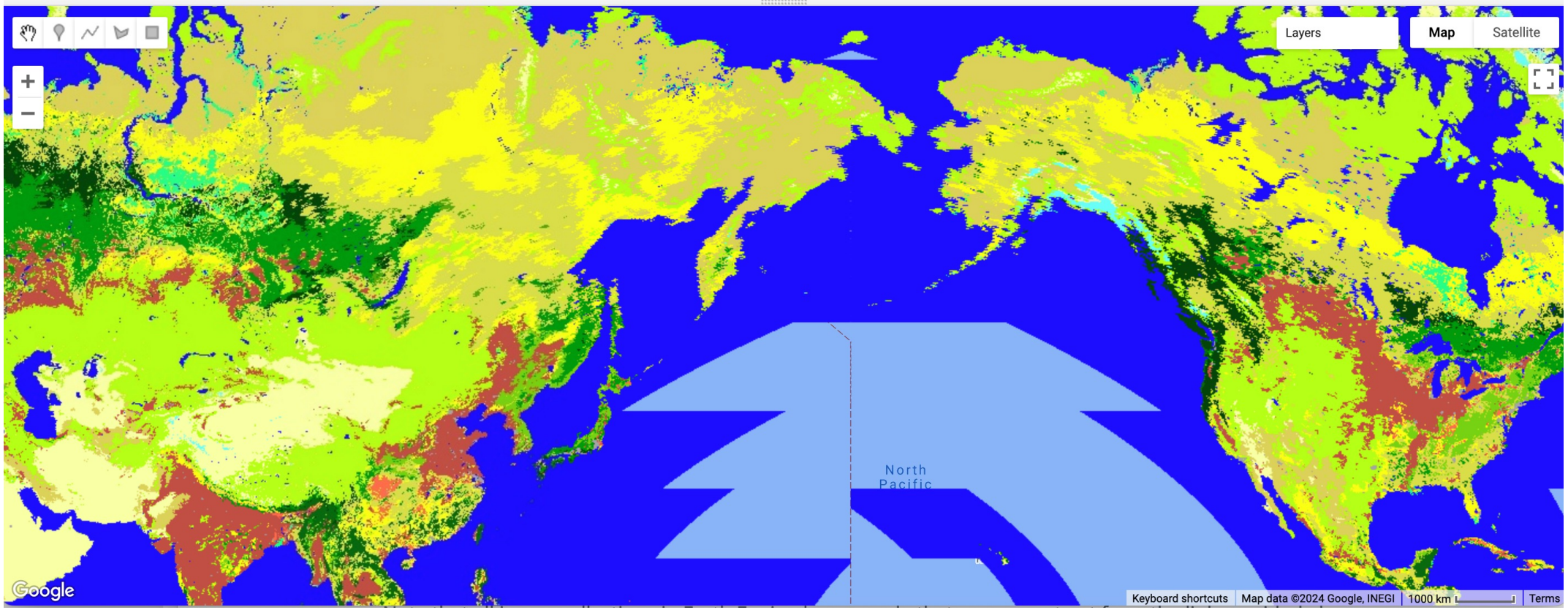
- Owner
- Writer
- Reader
- Archive
- Examples
  - Image
  - Image Collection
  - Feature Collection

MODIS_061_MCD12Q1 | Get Link | Save | Run | Reset | Apps

```
1  var dataset = ee.ImageCollection('MODIS/061/MCD12Q1');
2  var igbpLandCover = dataset.select('LC_Type1');
3  var igbpLandCoverVis = {
4    min: 1.0,
5    max: 17.0,
6    palette: [
7      '05450a', '086a10', '54a708', '78d203', '009900', 'c6b044', 'dcd159',
8      'dade48', 'fbff13', 'b6ff05', '27ff87', 'c24f44', 'a5a5a5', 'ff6d4c',
9      '69fff8', 'f9ffa4', '1c0dff'
10   ],
11 };
12 Map.setCenter(6.746, 46.529, 6);
13 Map.addLayer(igbpLandCover, igbpLandCoverVis, 'IGBP Land Cover');
```

Inspector | Console | Tasks

Use `print(...)` to write to this console.



Public Data
LANDSAT series data
MODIS Land Standard Products
MODIS China Synthesis Products
MODISL1B Standard product
DEM digital elevation data
EO-1 Series Data
Air pollution interpolation data
Sentinel Data
GF-4 data products
NOAA VHRR Data Products
GF-1 WFV data products
High-resolution data
Data Collection

Platform Home / Public Data

Please enter keyword

Satellite(4) | Landsat4-5(1) | Landsat(4) | ETM(1) | Landsat7(1) | Landsat8(1) | System default sorti
MSS(1) | OLI_TIRS(1) | SLC-off(1) | TM(1) | Digital Products(3) | Landsat1-3(1)

Landsat 8 OLI_TIRS Satellite Digital Products free

Posted by: Admin

Data volume: 183.4 TB

Accessing data

Tags: Landsat, Landsat8, OLI_TIRS, satellite, digital pr...

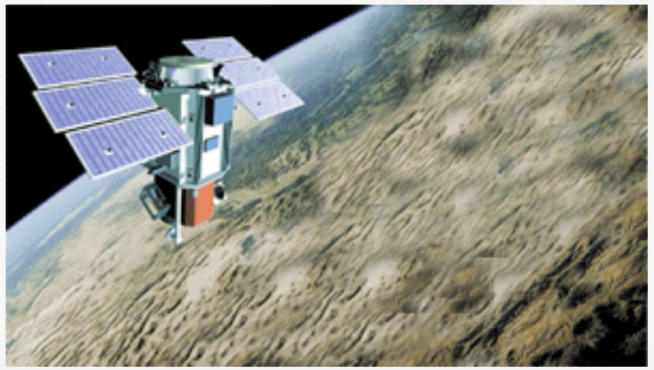
Landsat7 ETM SLC-off satellite digital products (2003-) free

Posted by: Admin

Data volume: 38.4 TB

Accessing data

Tags: Landsat Landsat7 ETM, SLC-off Satellite digital ...



Available Products

Select a dataset below to list the products that are

- ✓ Aqua MODIS
- ASTER GDEM
- Combined MODIS
- DAYMET
- ECOSTRESS
- EMIT
- Global WELD
- GPW
- Harmonized Landsat and Sentinel-2
- Landsat ARD
- MEaSUREs LSTE
- NASADEM
- NOAA-20 VIIRS
- NPS Historical Water Balance, Daily
- NPS Historical Water Balance, Monthly
- SMAP
- SRTM
- Suomi NPP VIIRS
- Terra MODIS

rsio

1

1

Image Corrections

- **Georeferencing:** associating each image pixel to a specific Earth location, placing it in a geographic coordinate system for easier spatial analysis and data integration with other data.

- **Ortho-rectification:** correcting remote sensing images so all pixels cover uniform, equal “quadratic” areas on the ground. It removes distortions caused by the sensor’s perspective, terrain relief, and the curvature of the earth.