Identifying Population Tipping Points Through Imagery Super-resolution

Christian Che-Castaldo[1], Mathew Schwaller[2] & Heather Lynch[2]

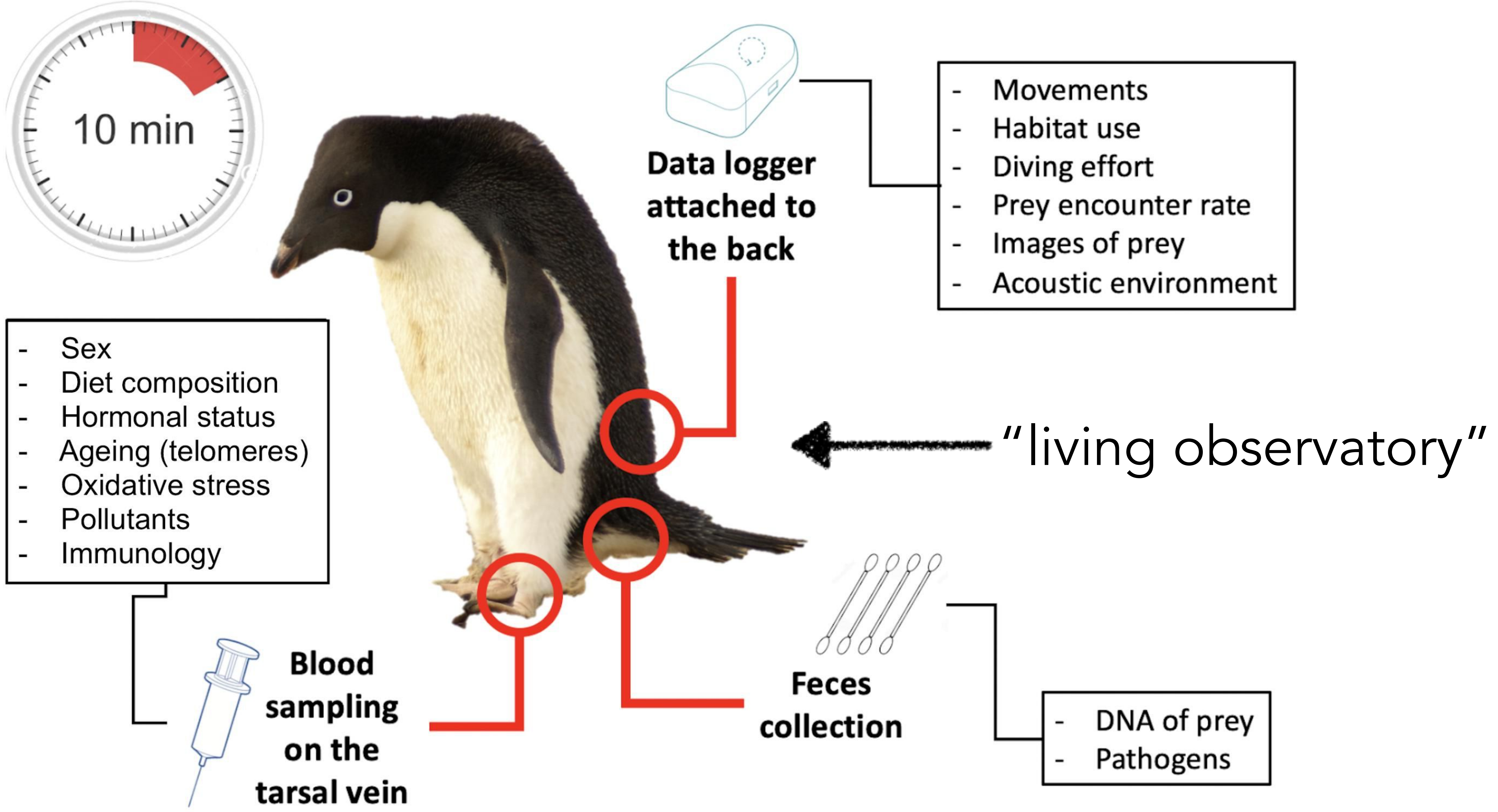
2 Stony Brook University

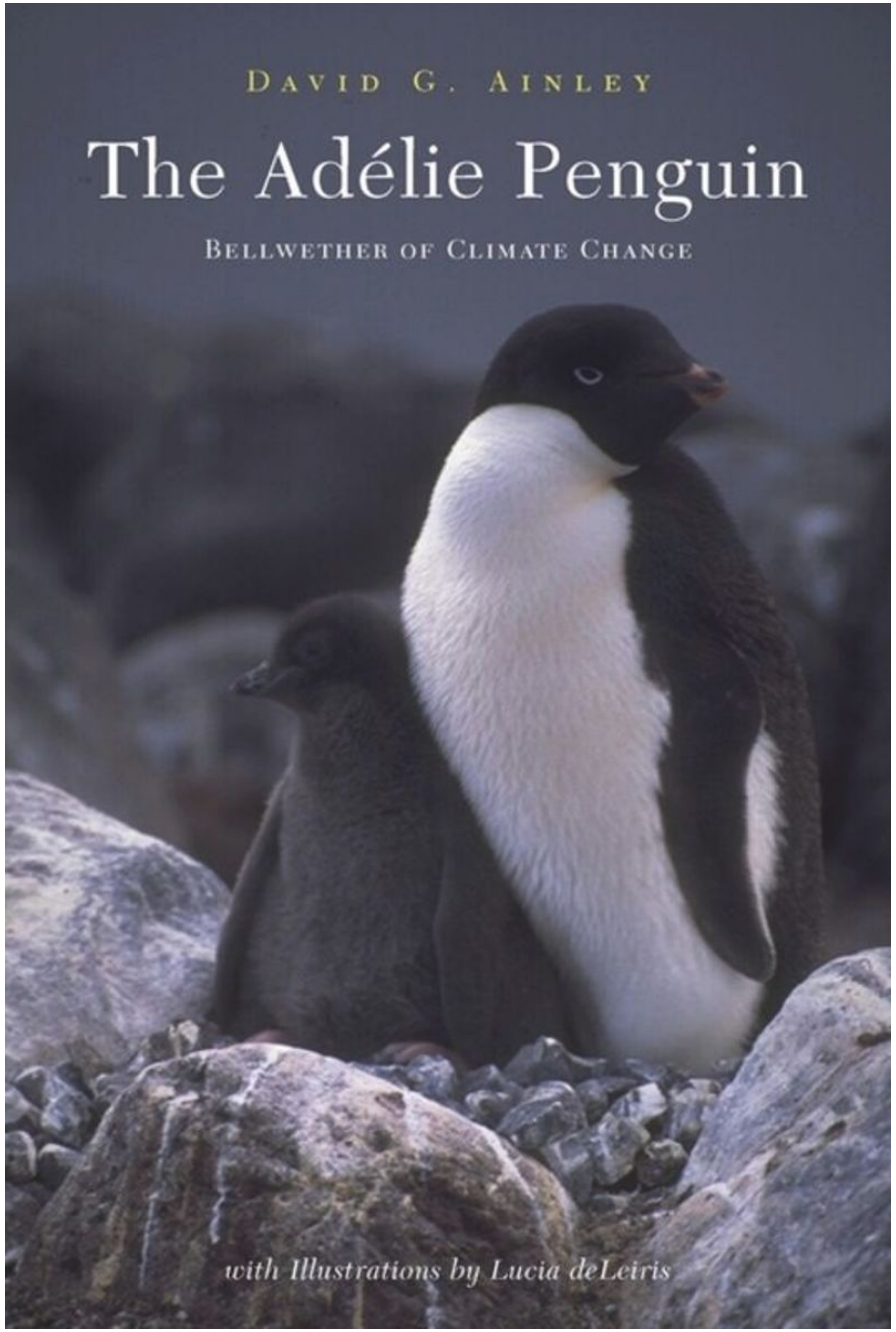
INSTITUTE FOR ADVANCED COMPUTATIONAL SCIENCE

USGS science for a changing world 1

Adélies as sentinel species

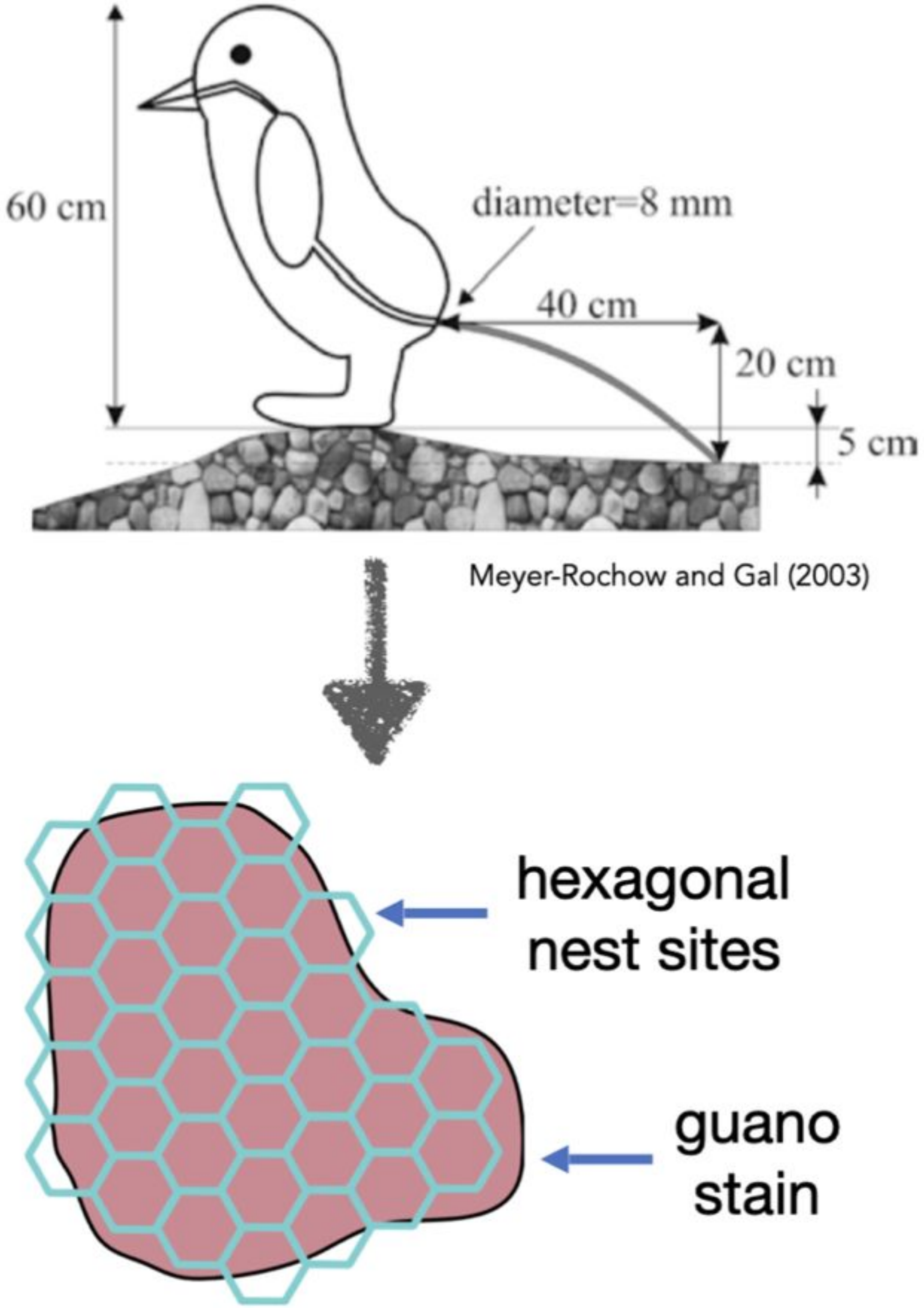
Dependent on both terrestrial and marine habitat
Sensitive to multiple stressors, especially climate change
Respond to changes occurring in marine food chain
Indicator for Southern Ocean ecosystem health
From individuals to population-level…





(Bestley et al., Frontiers in Ecology and Evolution, 2020)


Antarctic Danger Islands penguin breeding colony
© Tom Hart


60 cm
diameter=8 mm
40 cm
20 cm
5 cm
Meyer-Rochow and Gal (2003)
hexagonal
nest sites
guano
stain

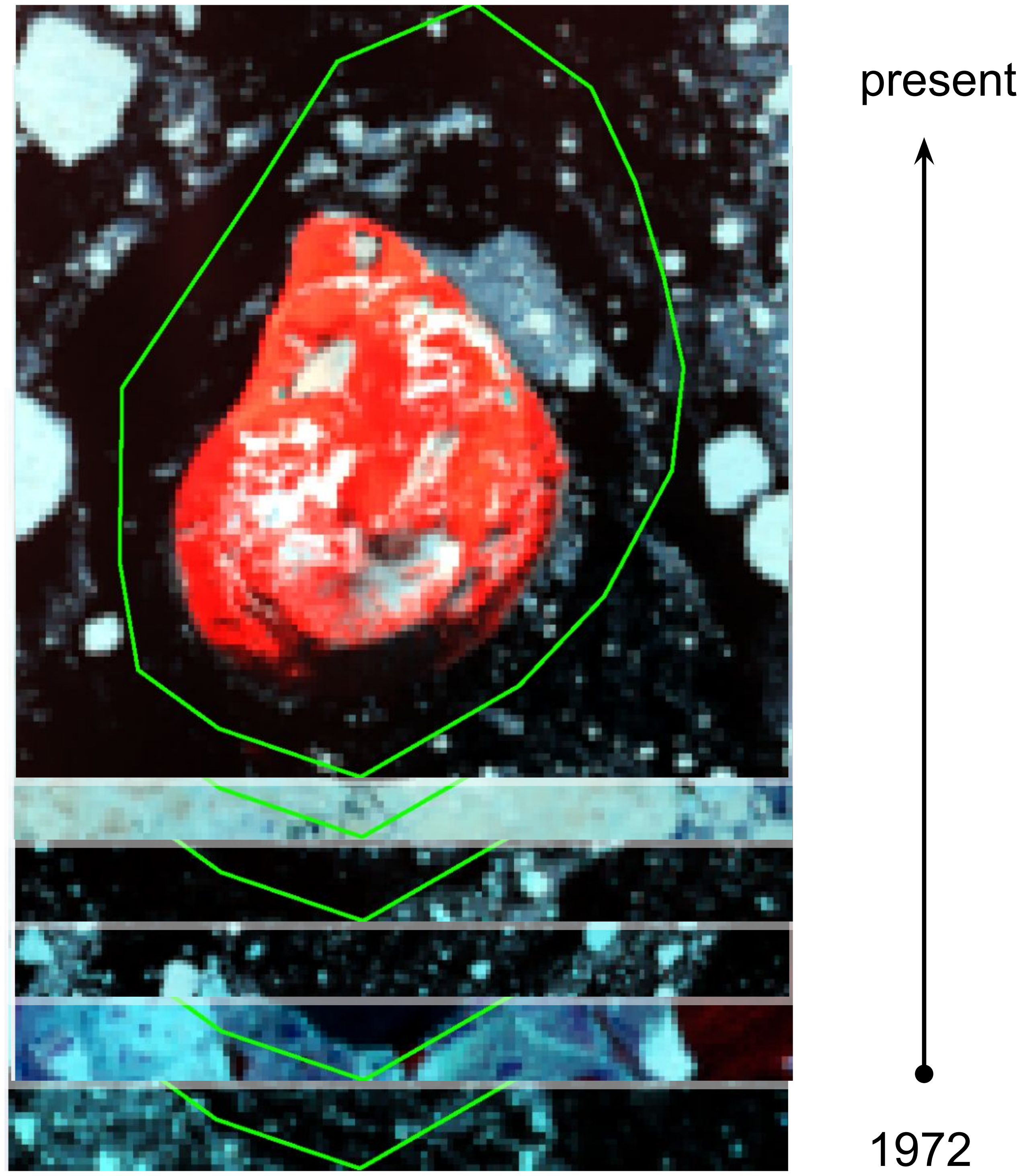
Identifying population tipping points through imagery super-resolution

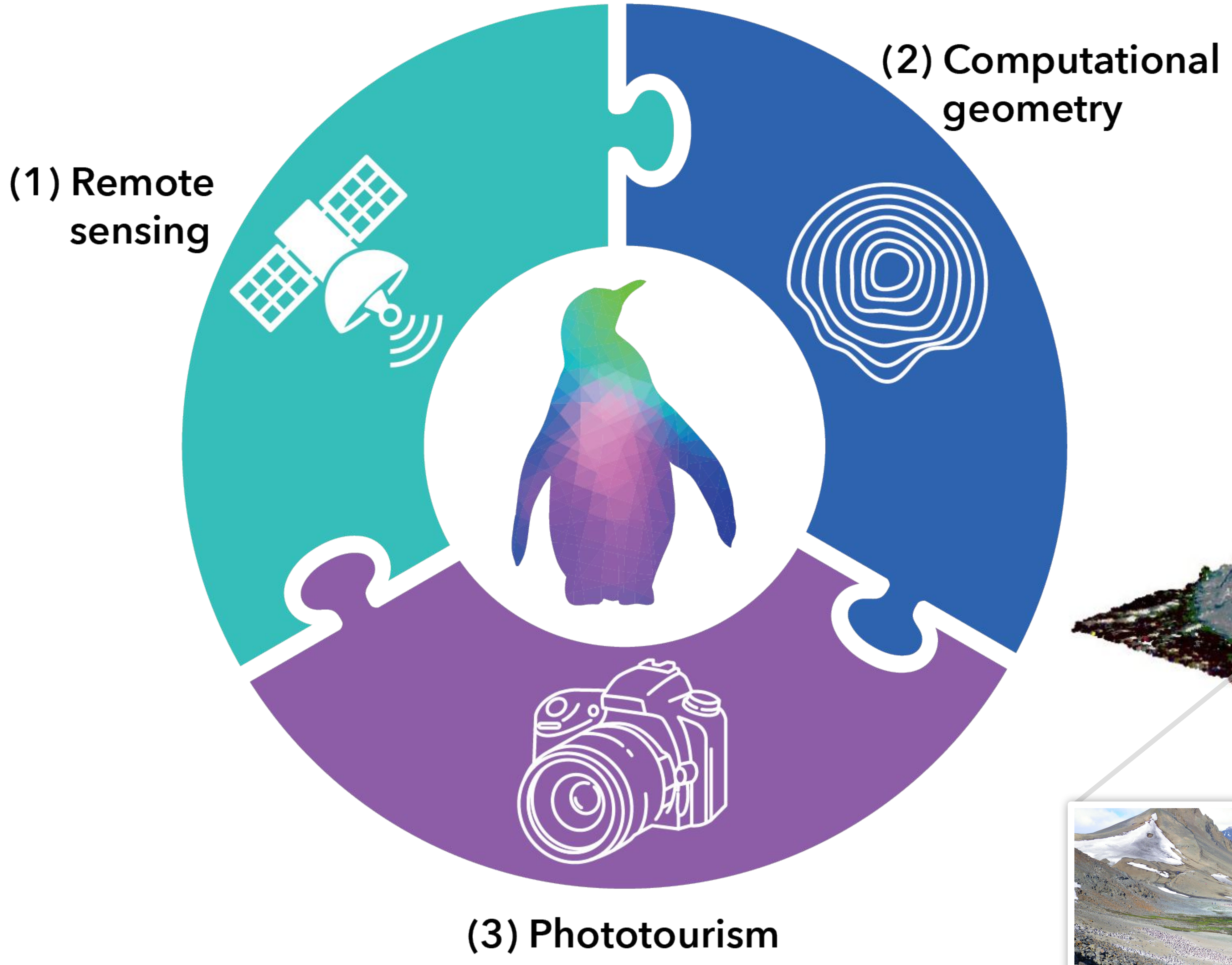
Heather J. Lynch[1], Christian Che-Castaldo[1], Dimitris Samaras[1]
Stony Brook University

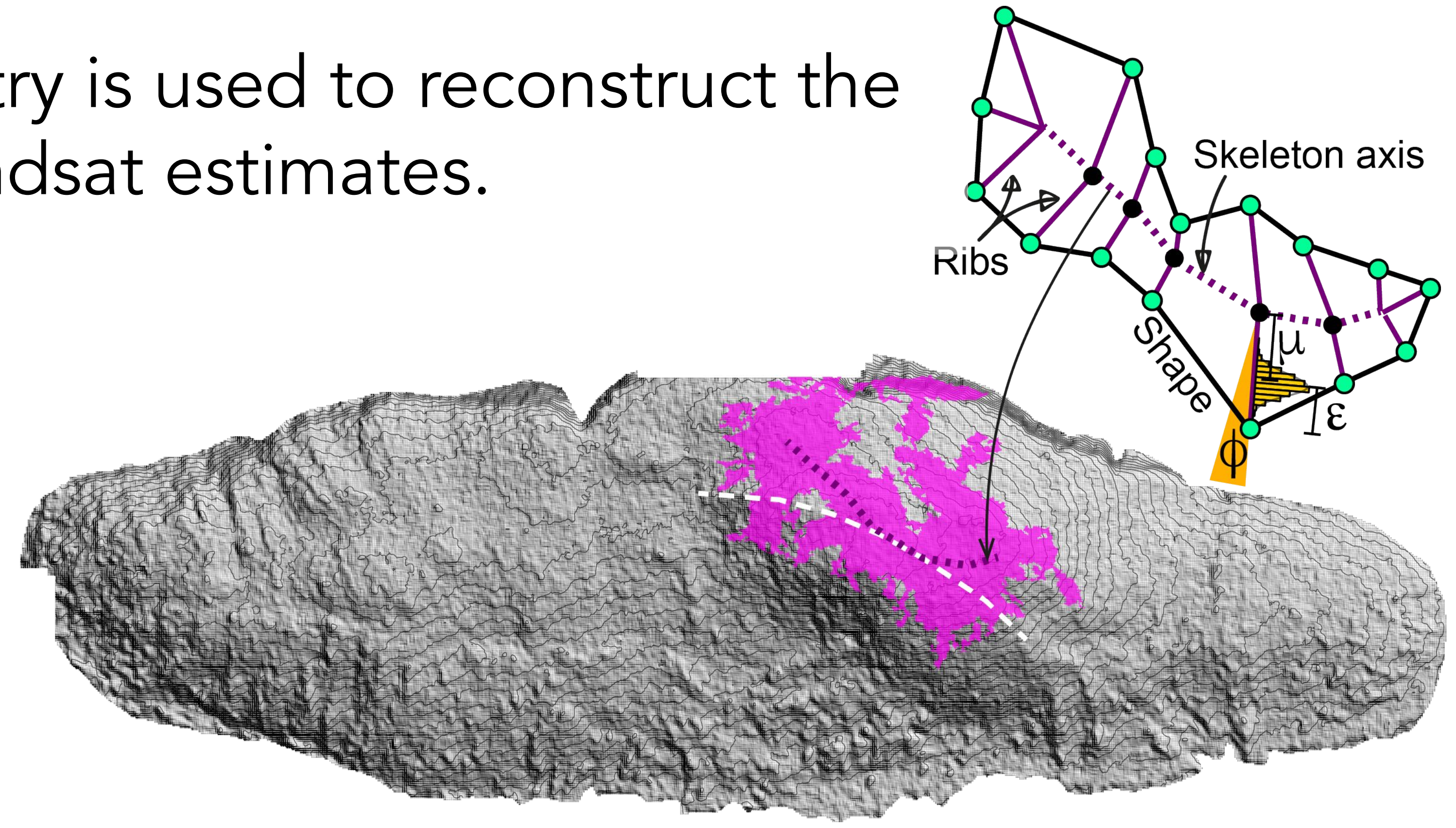
Matt Schwaller
NASA

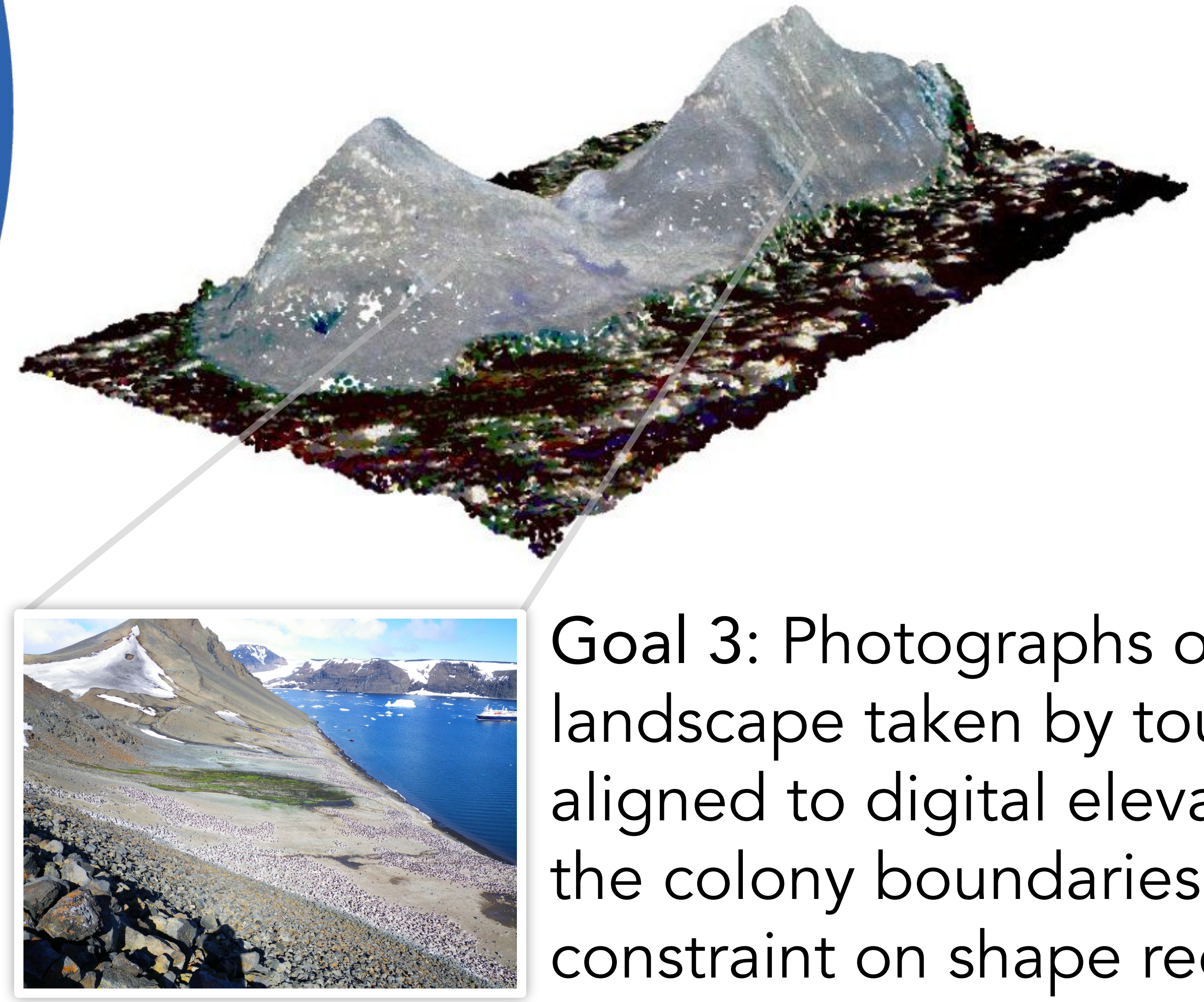
Goal 1: Landsat images over penguin colonies are georegistered and stacked for assessing super-resolution methodologies.

Goal 2: Computational geometry is used to reconstruct the most likely shape given the Landsat estimates.







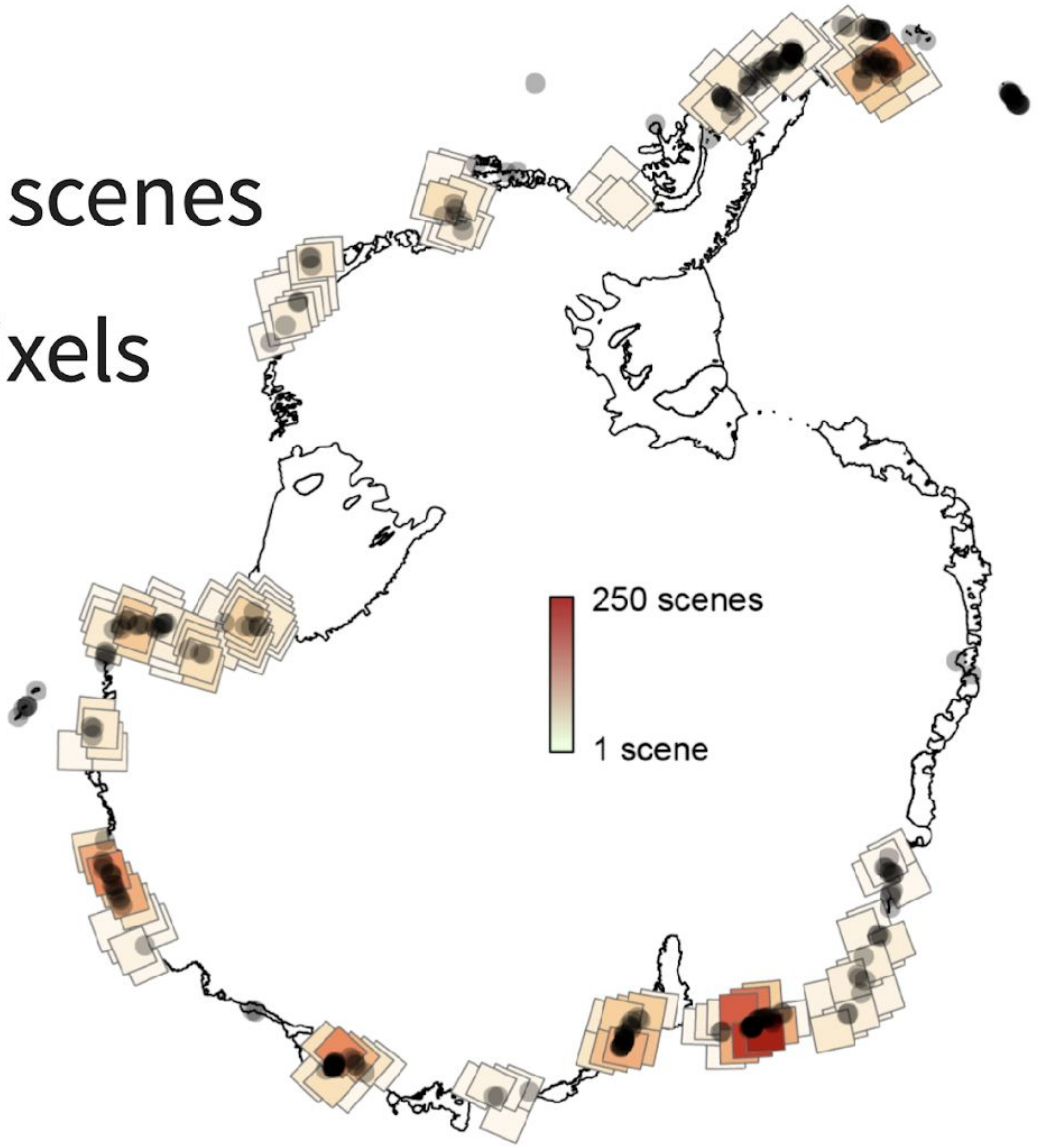


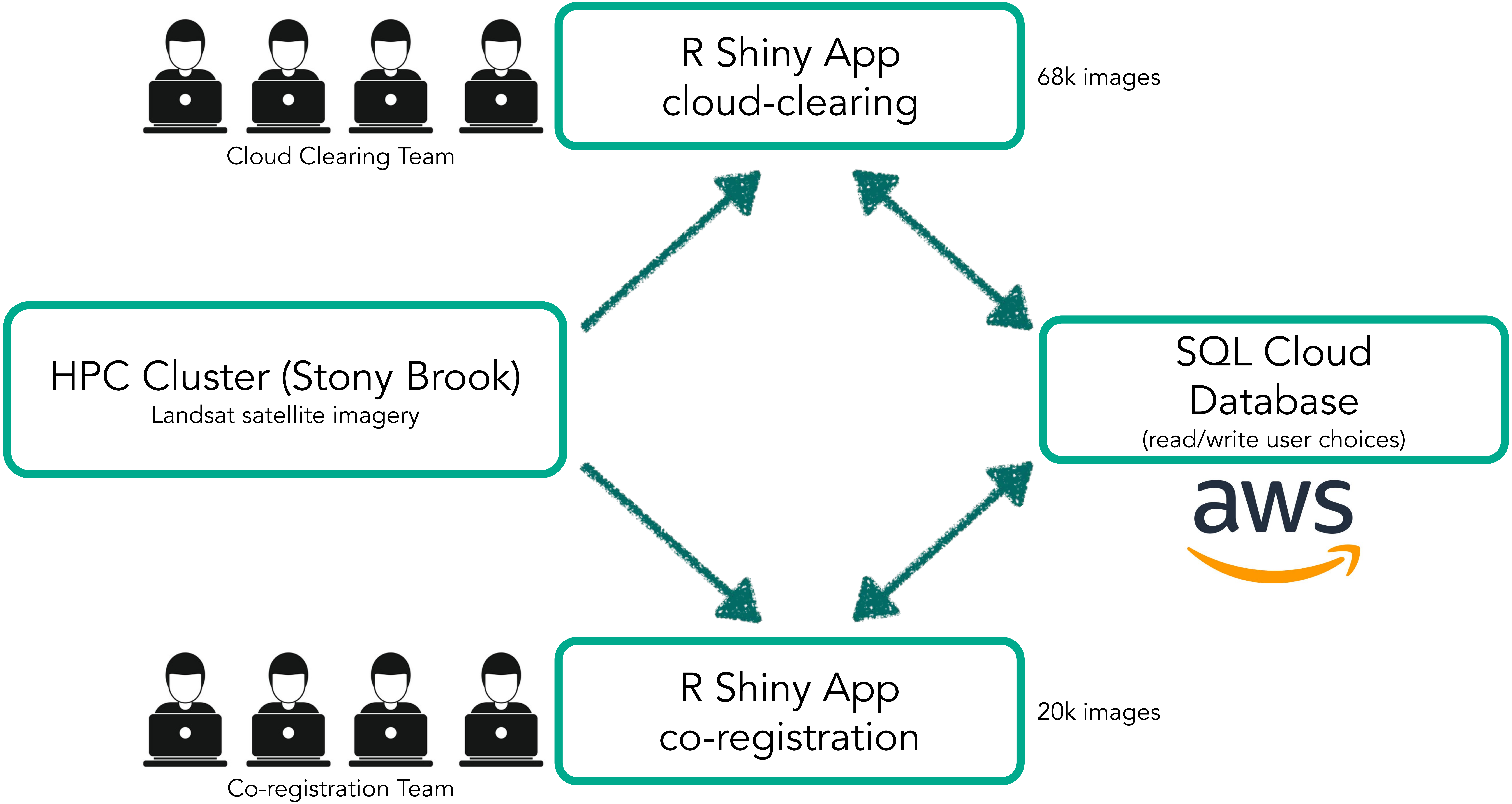
Goal 3: Photographs of the Antarctic landscape taken by tourists can be aligned to digital elevation models and the colony boundaries extracted as a constraint on shape reconstruction.

Penguin Guano Data Pipleline

PURPOSE: Build a reproducible ecological data pipeline for penguin guano so our research team can:

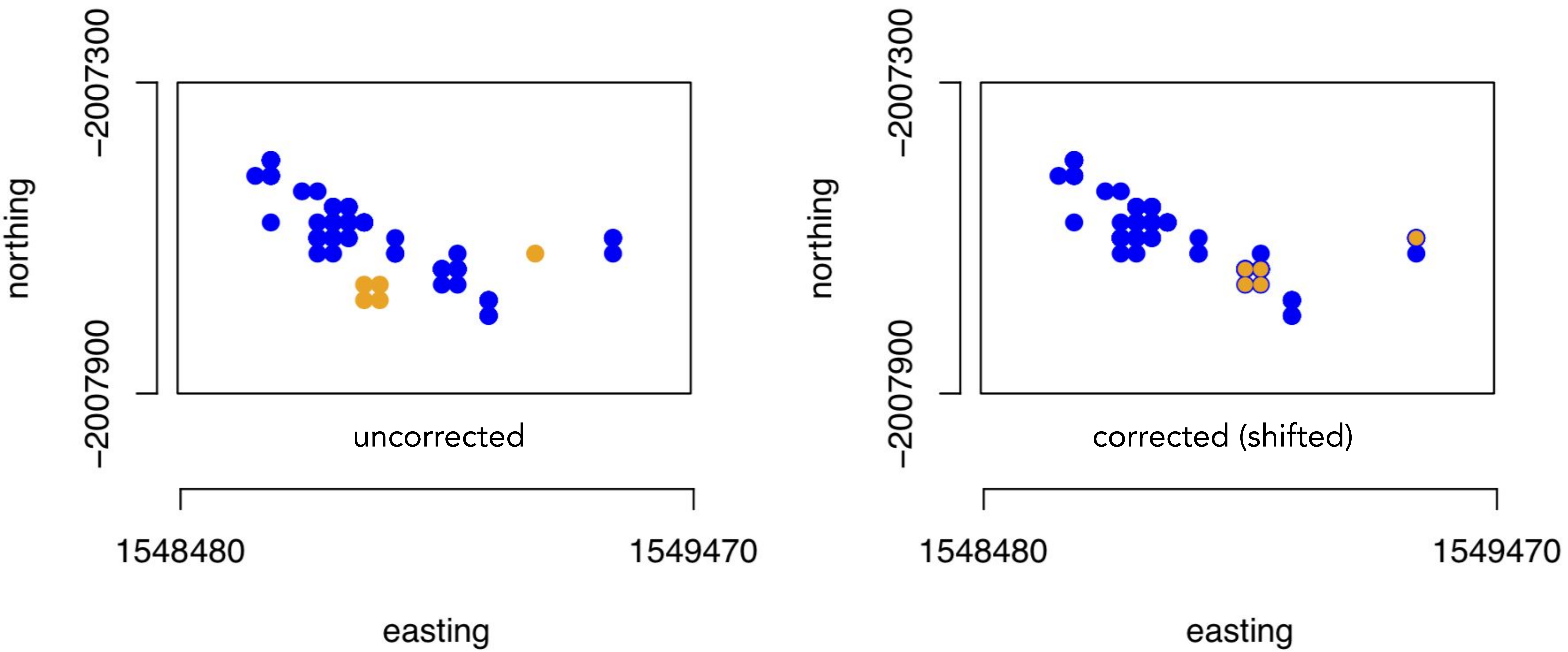
- Acquire and **cloud clear** ~68,000 Landsat scenes
- **Co-register** cleared scenes → stackable pixels
- **Improve** existing DEM and feature data
- Machine learning → **classify** guano



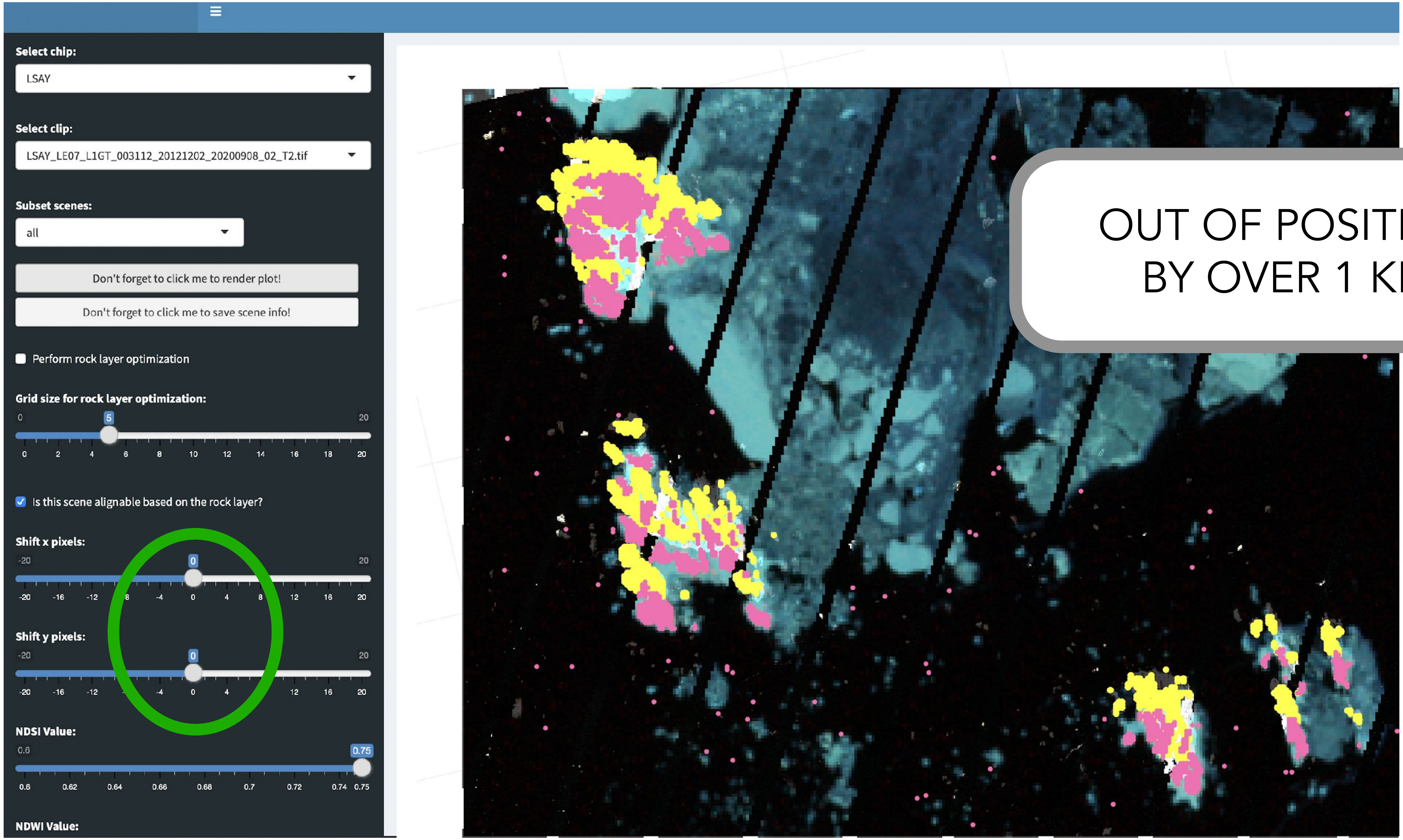


R Shiny App
cloud-clearing
68k images
Cloud Clearing Team
HPC Cluster (Stony Brook)
Landsat satellite imagery
SQL Cloud
Database
(read/write user choices)
aws
R Shiny App
co-registration
20k images
Co-registration Team

Scene alignment: Use sunlit rock as a ground control point to geo-register Landsat scenes to one another to study per-pixel change over time

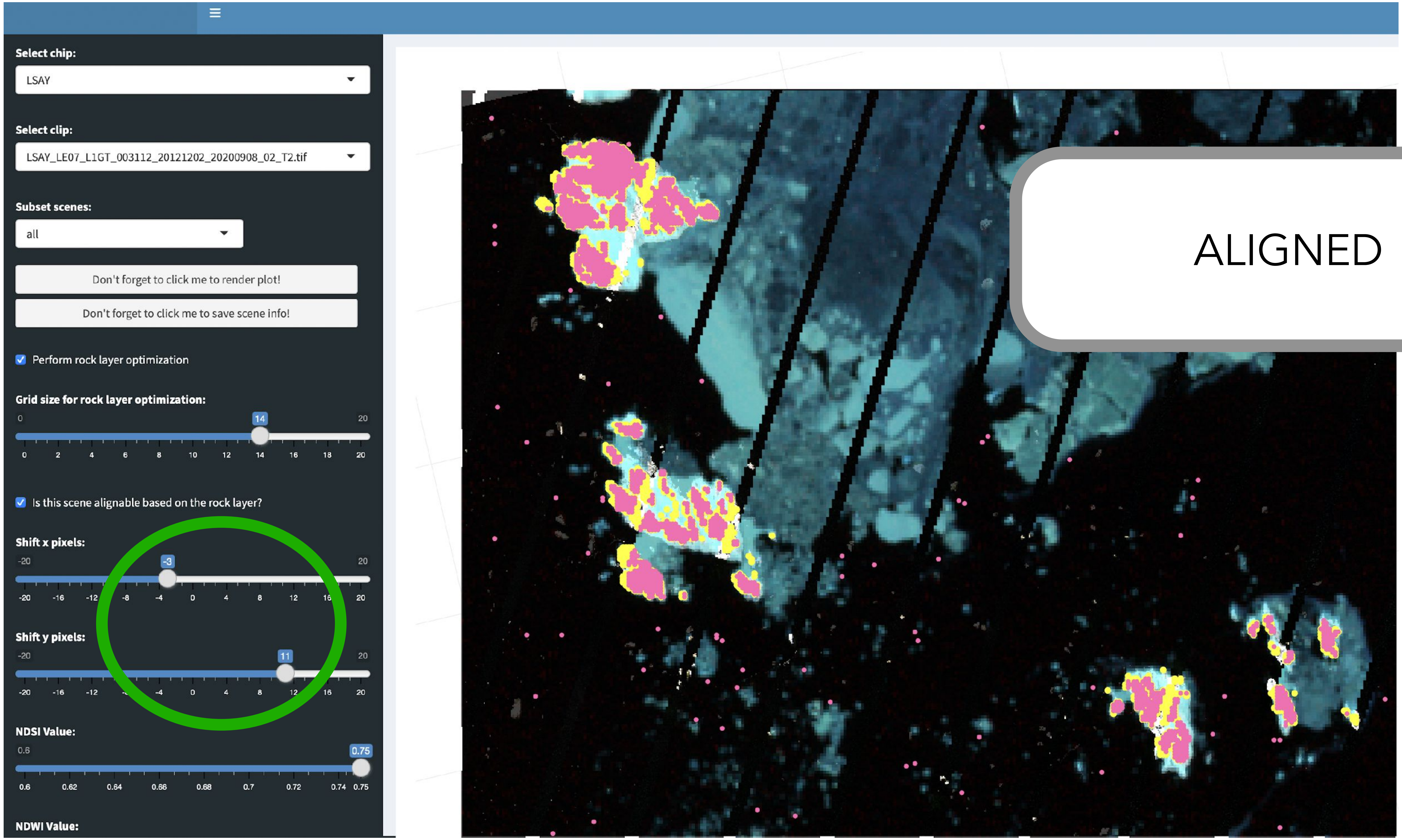


R SHINY GEOREGISTRATION APP



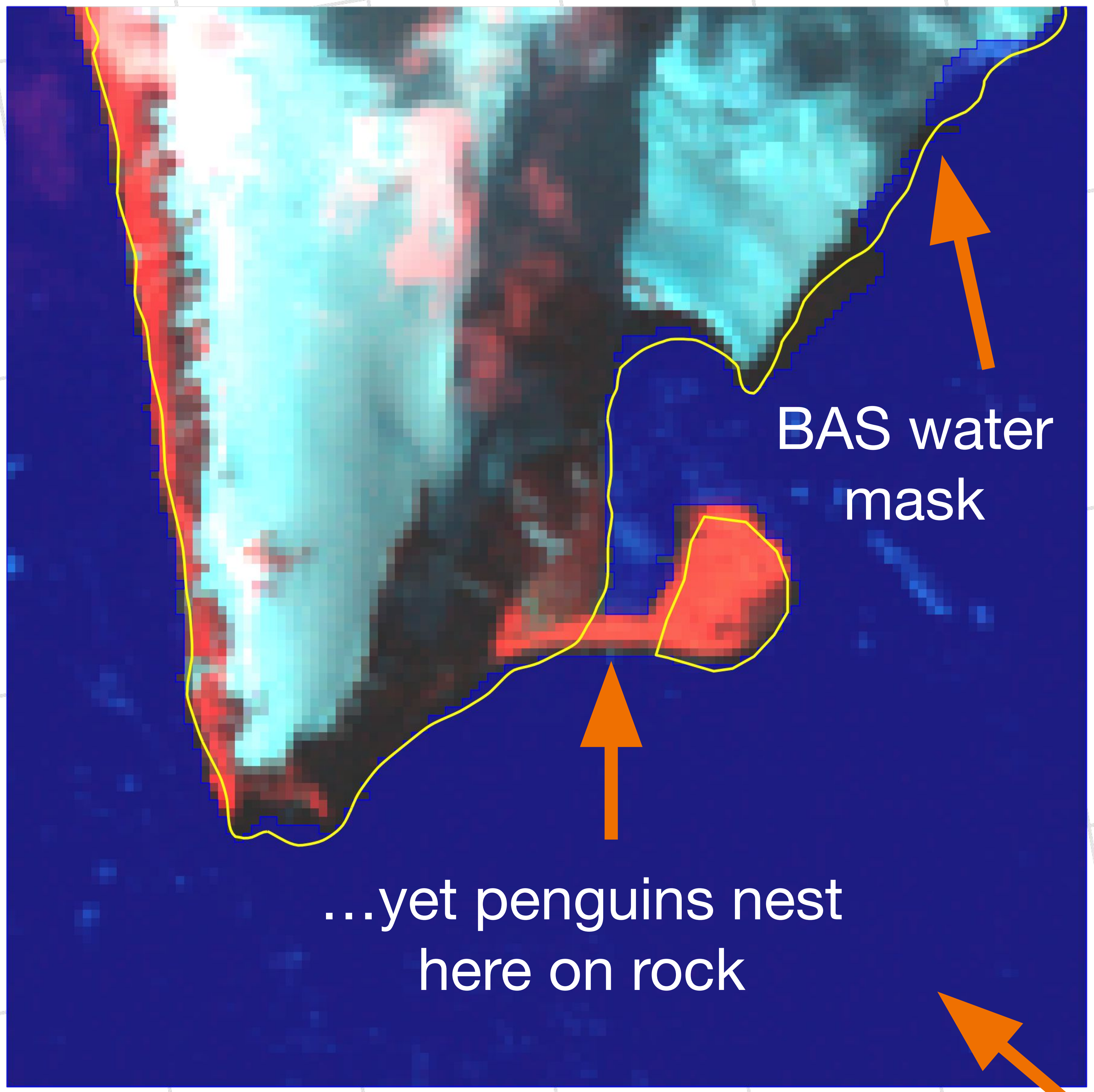
OUT OF POSITION
BY OVER 1 KM

R SHINY GEOREGISTRATION APP



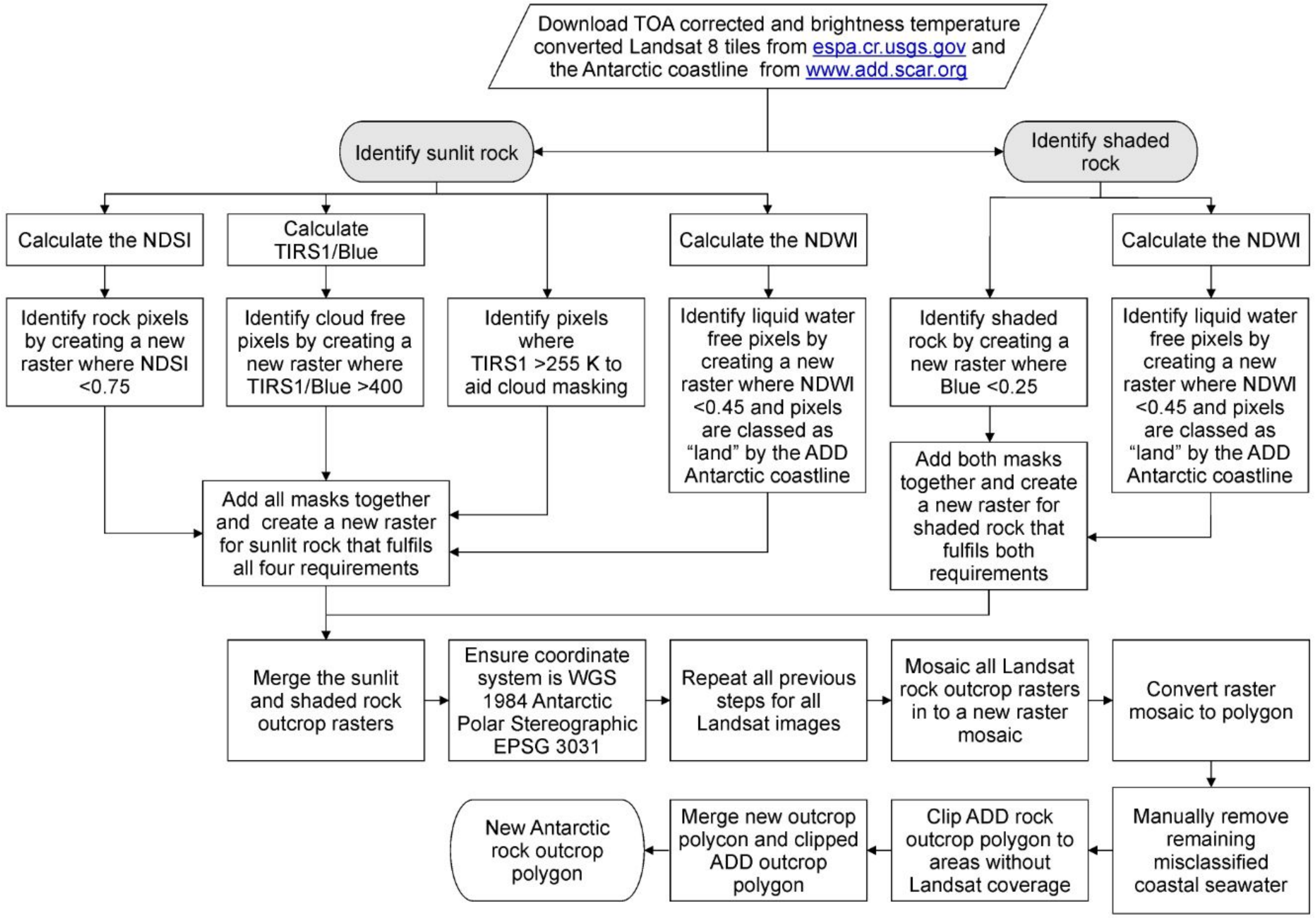
ALIGNED

Landsat to improve topographical features: Use mosaics of Landsat images to produce highly accurate water masks to ground DEMs and identify all rock pixels



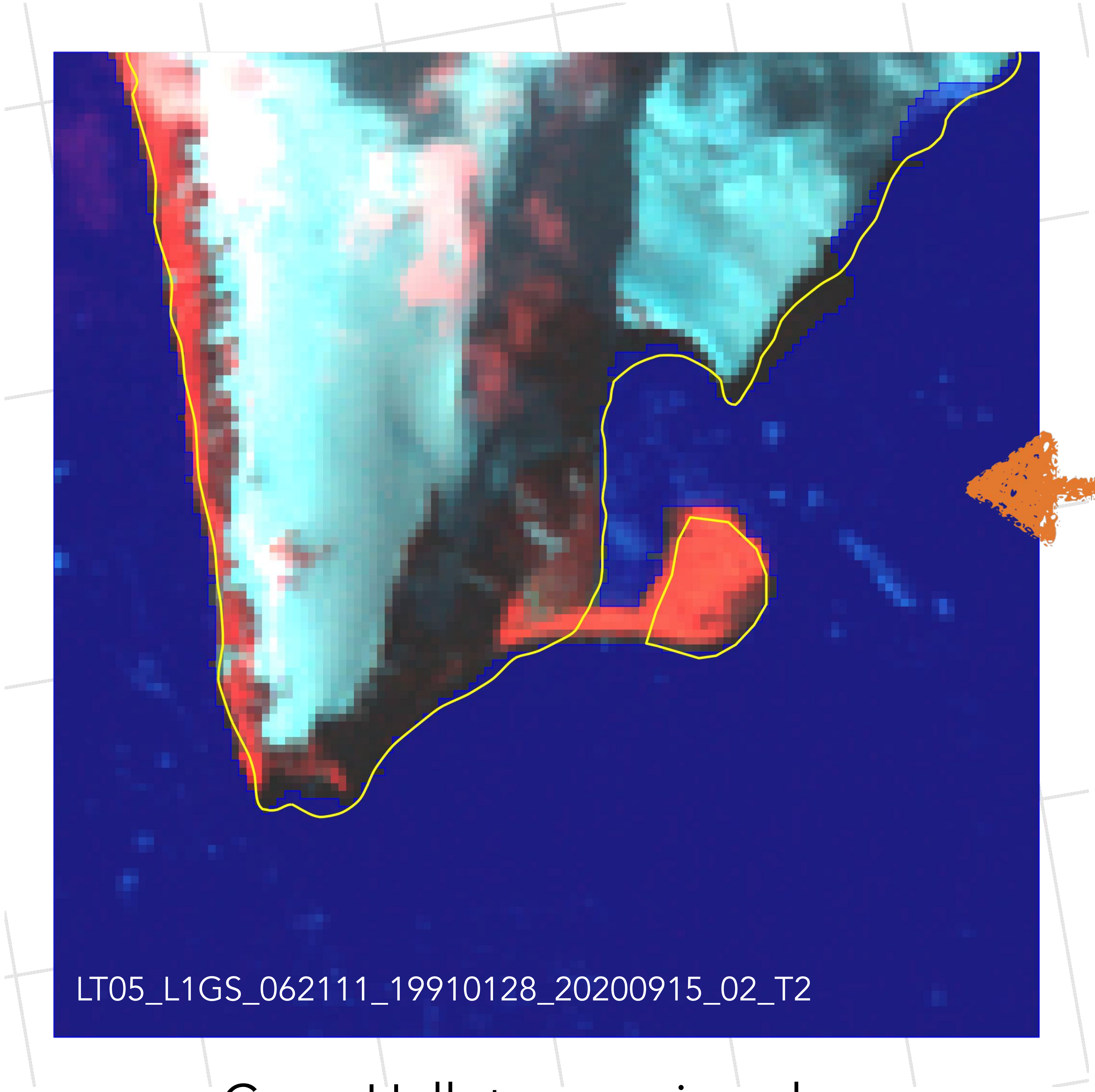
Cape Hallet penguin colony

An automated methodology for differentiating rock from snow, clouds and sea in Antarctica from Landsat 8 imagery: a new rock outcrop map and area estimation for the

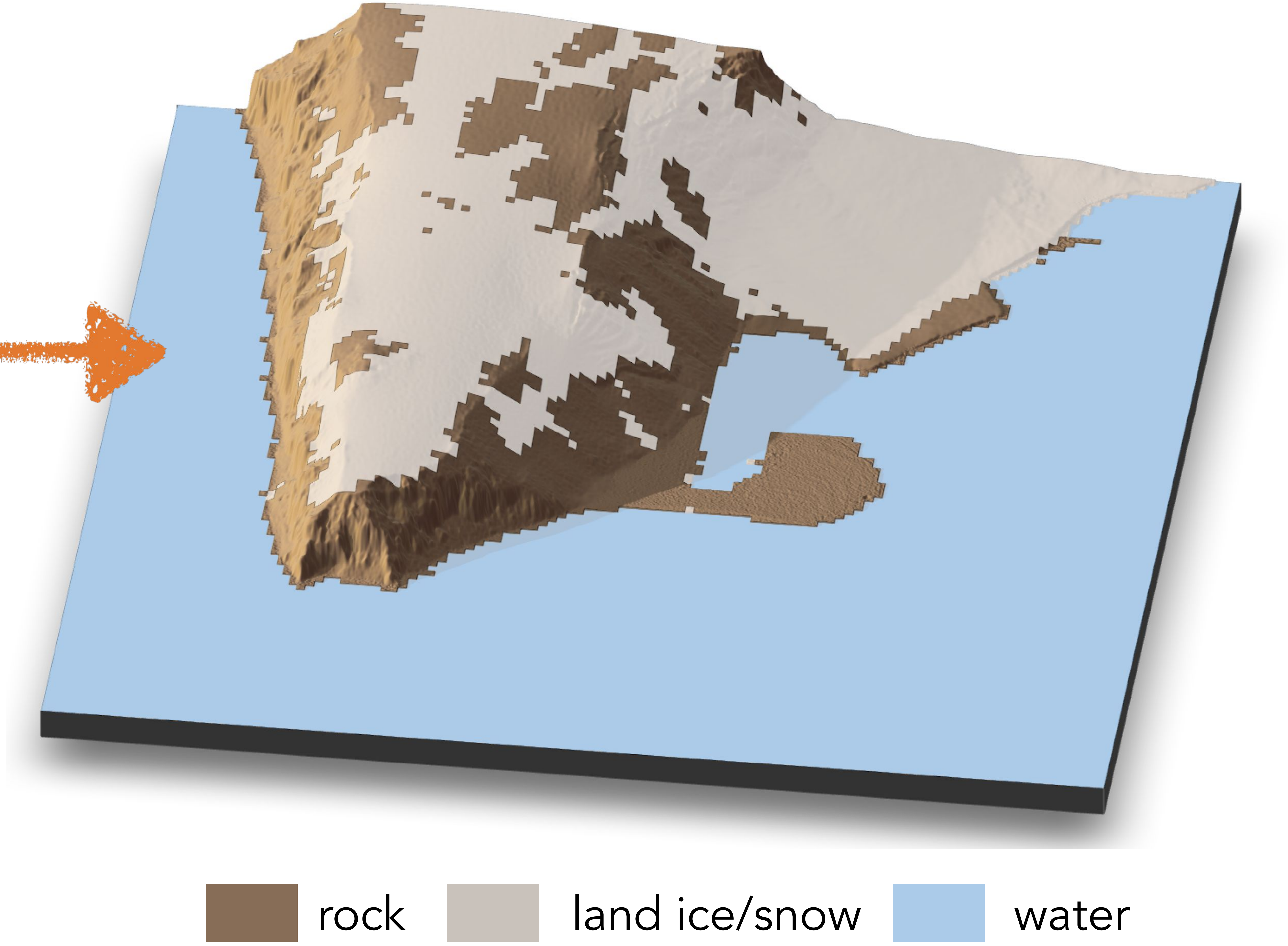


water mask derived from Landsat 4578 mosaic

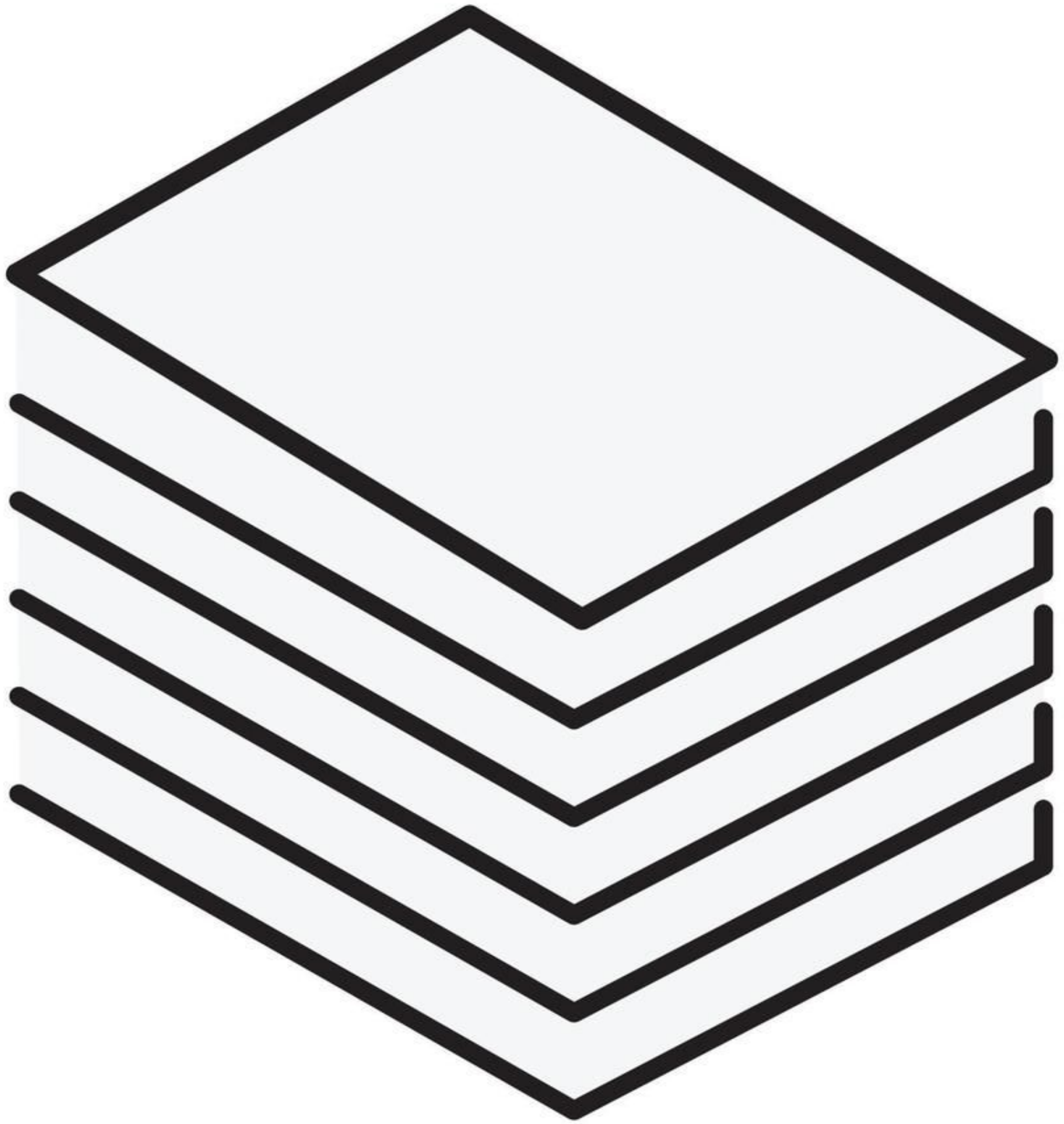
Landsat to improve topographical features: Use mosaics of Landsat images to produce highly accurate water masks to ground DEMs and identify all rock pixels



Cape Hallet penguin colony



16,115 Adélie colony Landsat images each containing 18 channels



- Spectral data (7 channels)
red, green, blue, NIR, SWIR1, SWIR2
- Spectral indices (3 channels)
NDWI, NDSI, NDMI
- Topographical data (5 channels)
elevation, slope, roughness, aspect
- Masks (3 channels)
ocean, rock, shade, bad pixel data

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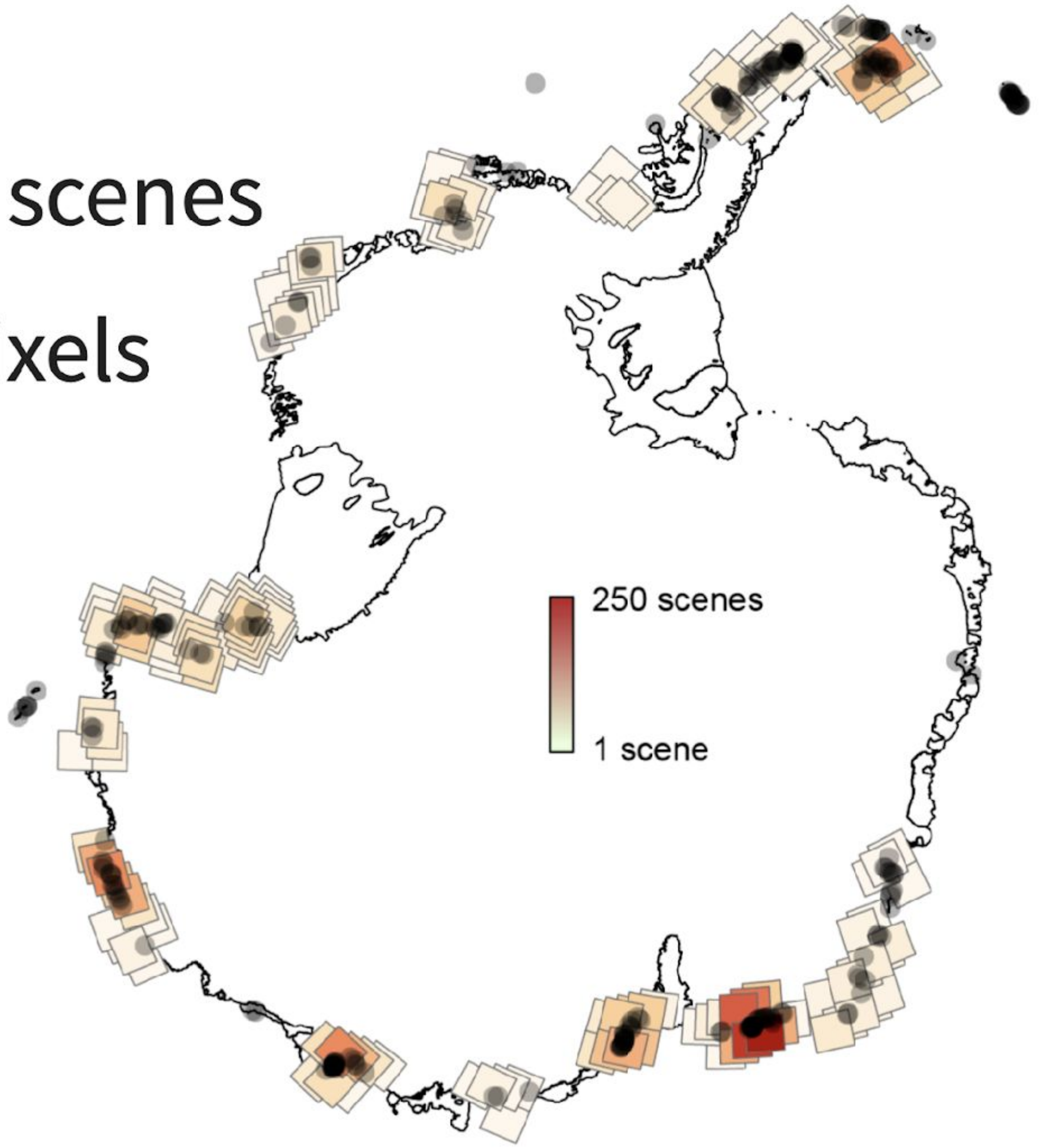


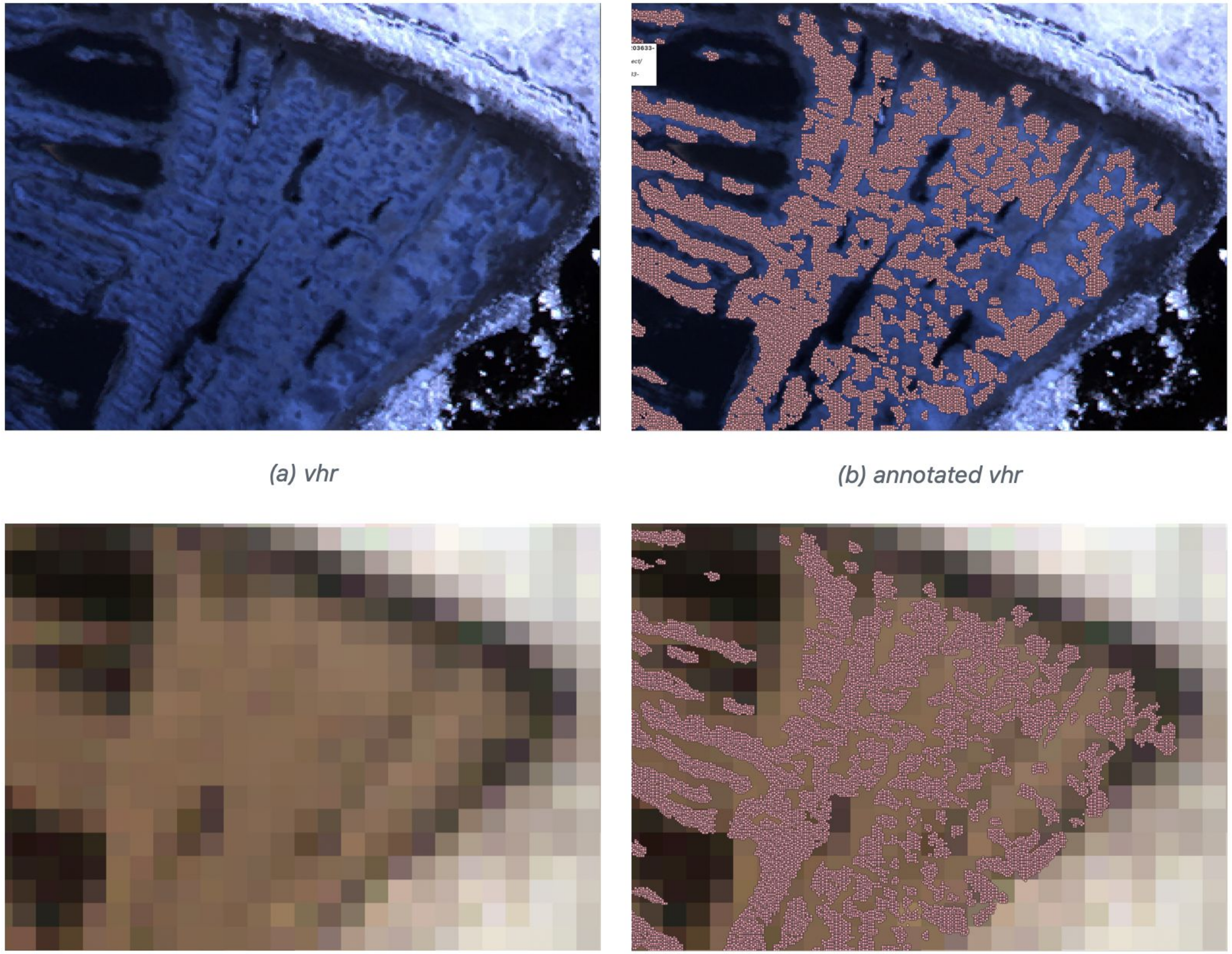

Lindsay Islands
(1989-2017)
Duke of York Island (1989 – 2017)
Hope Bay
(1987-2016)
Franklin Island West
(1984-2017)
Matt Schwaller NASA
Eden Rocks (1987-2017)
Cockburn Island (1999-2017)

Annotate VHR imagery for guano and pair with Landsat

Clare Flynn, Stony Brook University

Heather Lynch, Stony Brook University

annotate guano



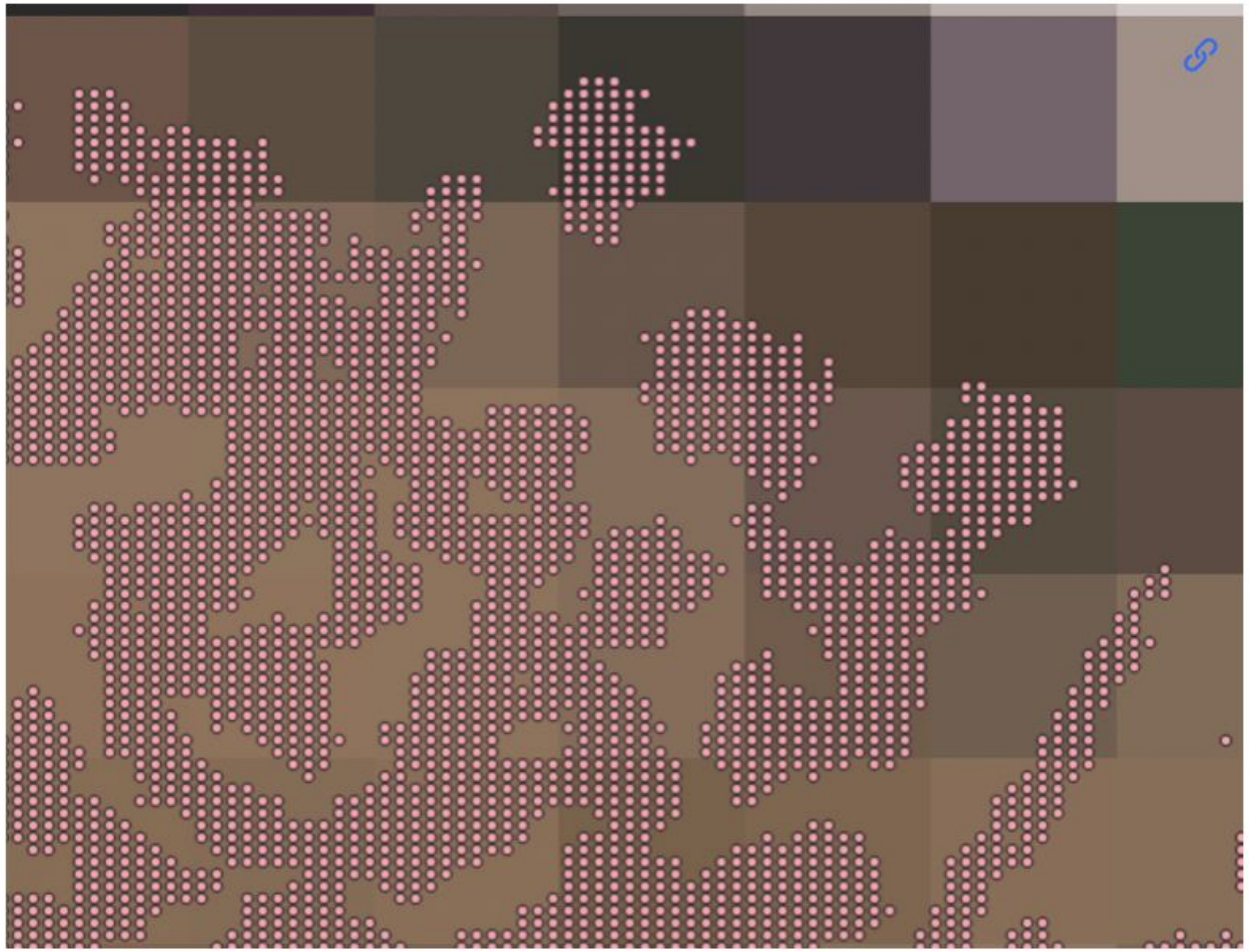
(a) vhr

(b) annotated vhr

(c) Landsat 8

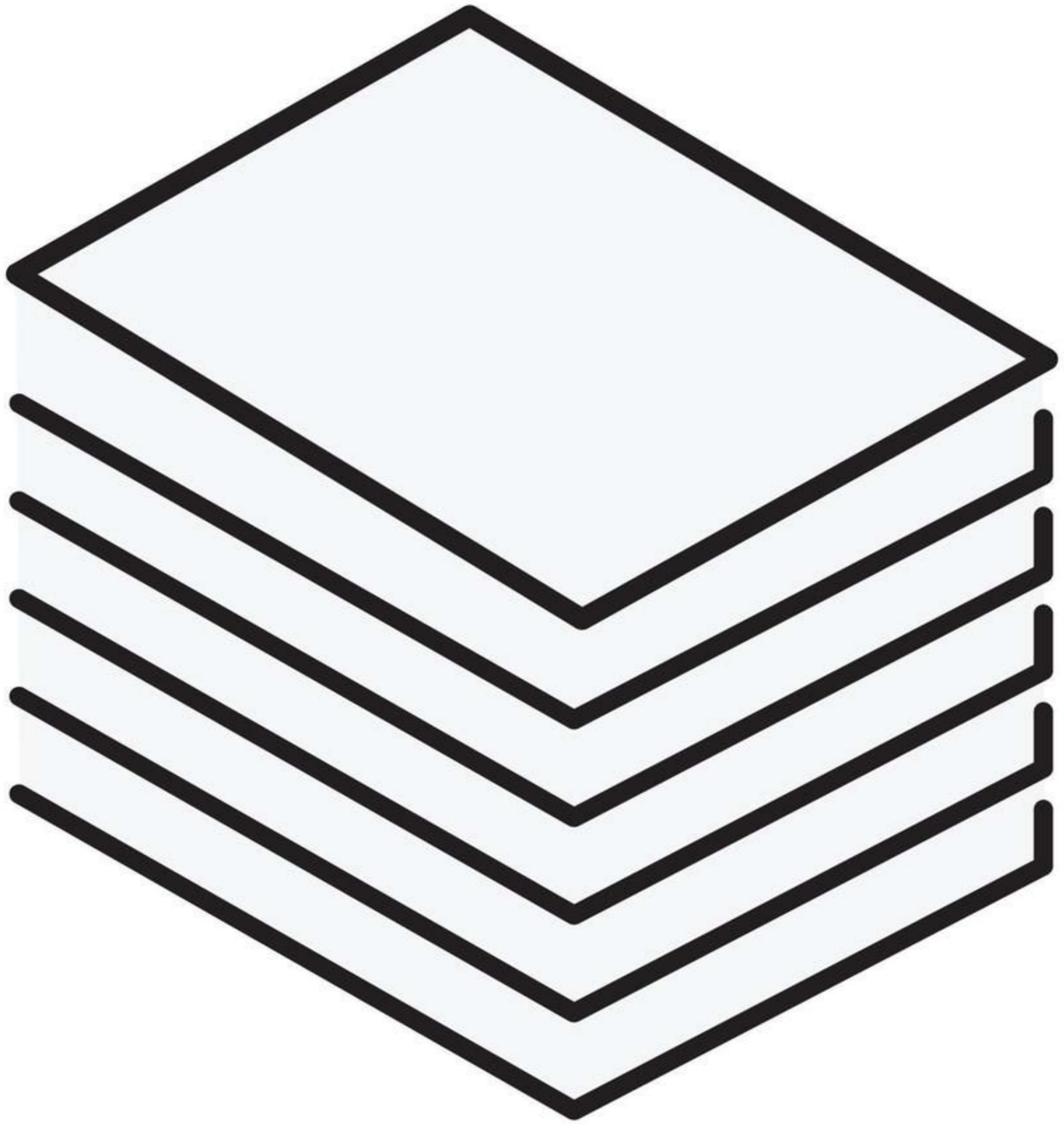
(d) Landsat 8 annotations added

Landsat labeled with percent guano per pixel



pink dots are annotated from vhr and transferred

194 Adélie colony Landsat images each containing 19 channels



- Percent guano transferred from VHR

- Spectral data (7 channels)
red, green, blue, NIR, SWIR1, SWIR2

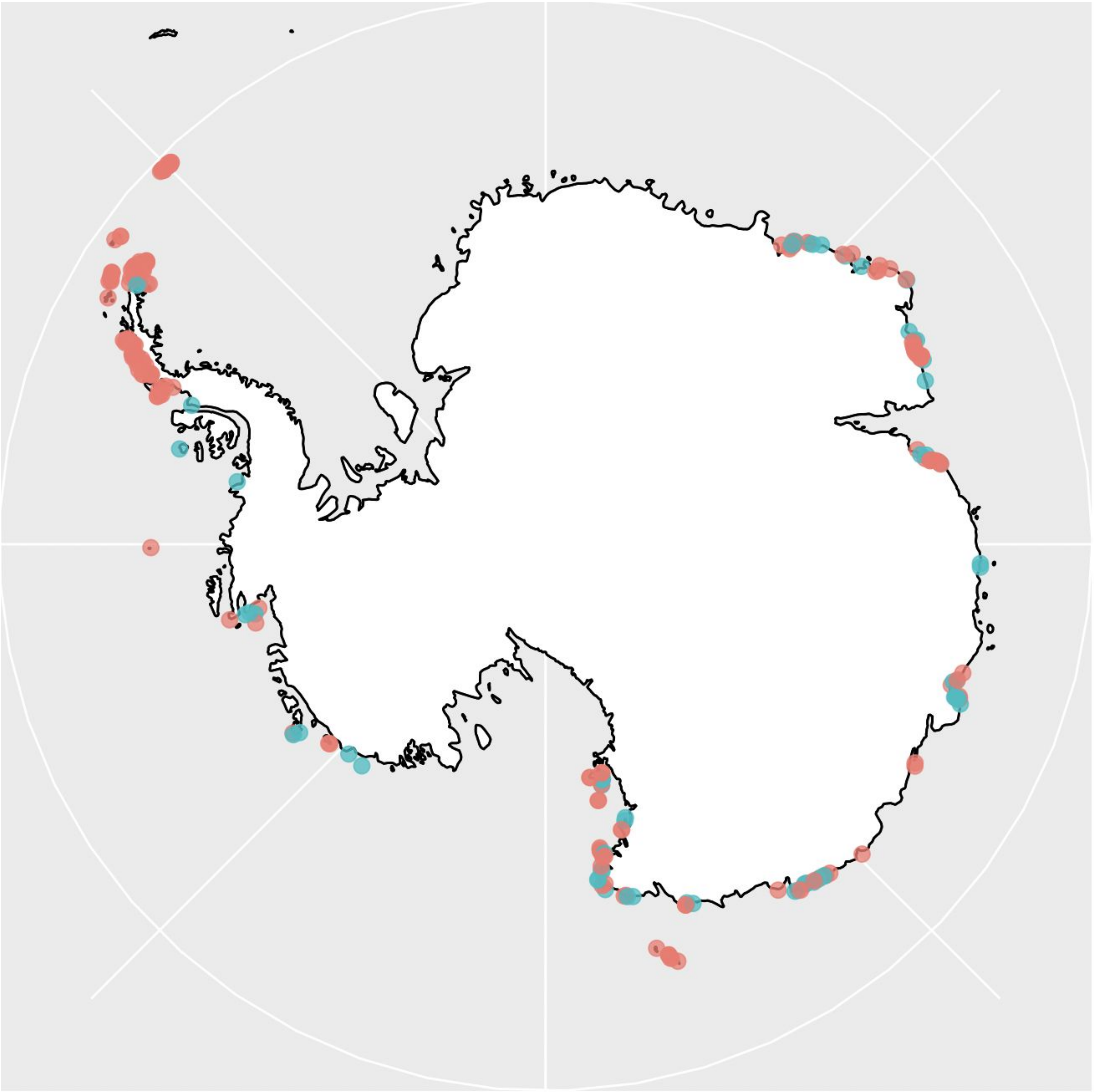
- Spectral indices (3 channels)
NDWI, NDSI, NDMI

- Topographical data (5 channels)
elevation, slope, roughness, aspect

- Masks (3 channels)
ocean, rock, shade, bad pixel data

Split data to test guano classification across colonies and seasons

		LANDSAT 7							LANDSAT 8				
		2003	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2018
AP	BEAG										4		
	DEVI					1					3		
	RHYO					1							
	VORT										1		
Eastern Antarctica (EA)	ADAM										2		
	AKAR					4					4		
	ALAS									7	4		
	AUST								1				
	BALA										1		
	BATT										2		
	BERK_SHLY_WHTY					1							
	CBAY										2		
	CHUN										3		
	CURZ					1							
	DAVI					1							
	DENI_MACK										3		
	FRAM		3		1								
	HASW		1								5		
	HINO				2								
	HOLL										3		
	JULE					1					2		
	KIDS										6		
	MALL										3		
	MAME_ONGU										1		
	MCDO							4			2		
	MIDG					1					2		
	ODBE					2							
	PGEO								2		4		
	PISL										3		
	SCUL									1	2		
	STEI										1		
	SVIS								1		1		
	TENM										4		
	TRYN						1				1		
	WATT										2		
	YTRE					1							
Ross Sea	ADAR					1					1		
	ARTH			1									
	BEAN	1											
	BRDM_BRDN_BRDS		2										
	BSON						3			4			
	BURK					2							
	CHAL										5		
	CHAR					1							
	COTT										2		
	CRUZ					1							
	EDWI									4			1
	HBAY										3		
	INEX					9					3		
	JONE										1		
	LOVI											1	
	LSAY										2		
	MAHE											1	
	NELL									2			
	NORF										7		
	POSS										4		
	SIMS										5		
	SVEN										4		
	UNGE										7		



to be predicted
annotated scenes

T-matrix: Binary Guano Classifier

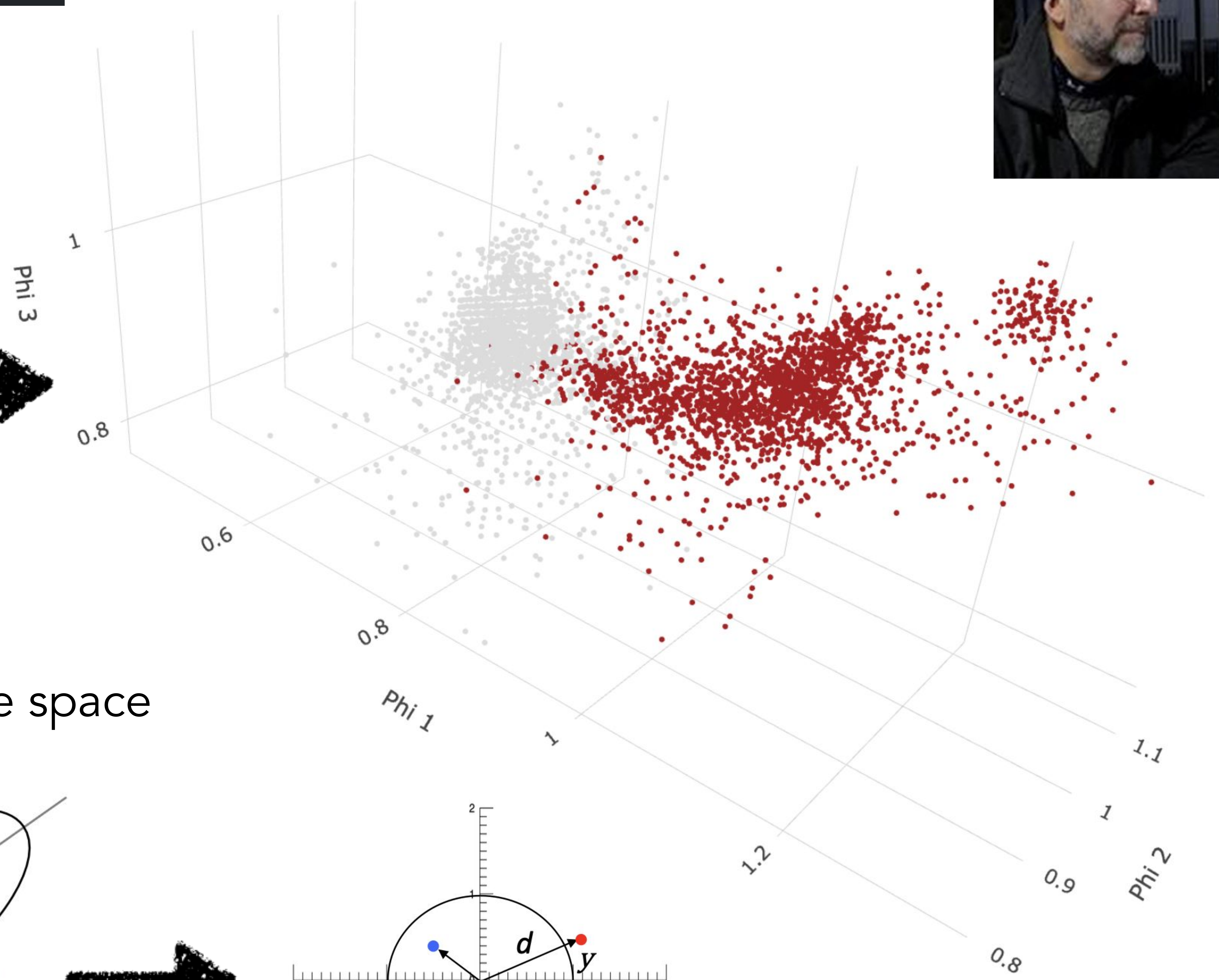
Matt Schwaller, NASA

		training data: colony	training data: not colony
classification	colony	a	c
classification	not colony	d	b

c = error of commission
d = error of omission

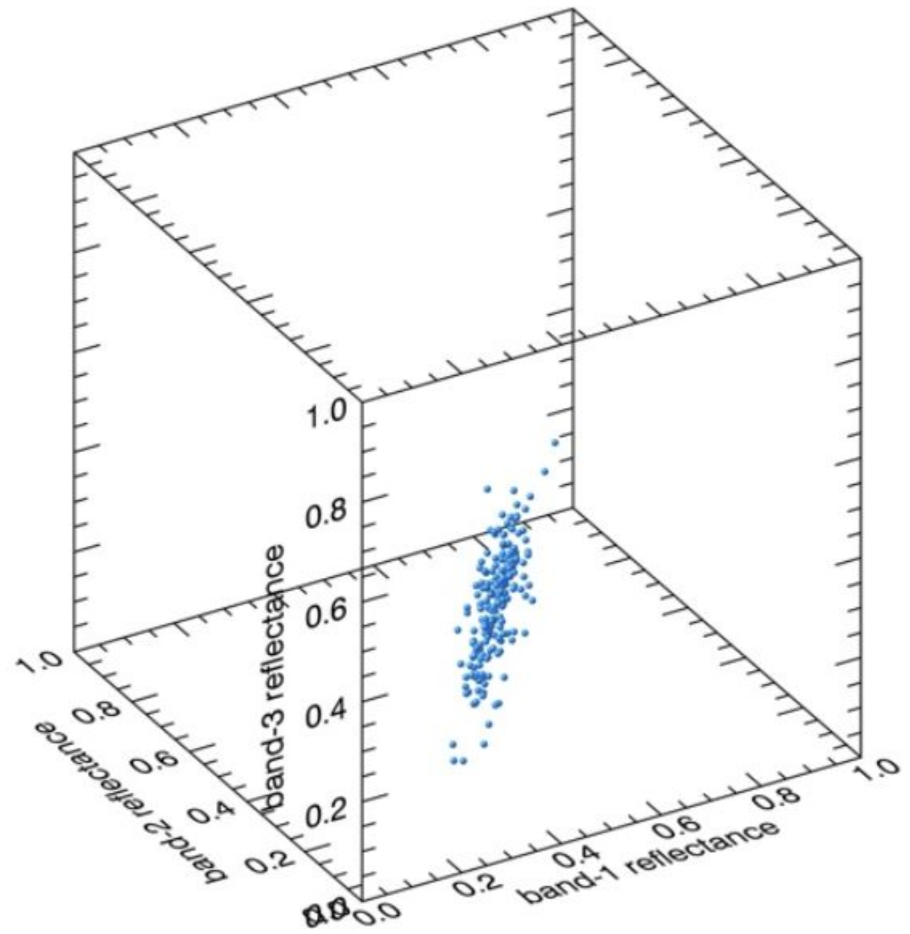
Tau is calculated as follows, with τ = 1 for a perfect classification.

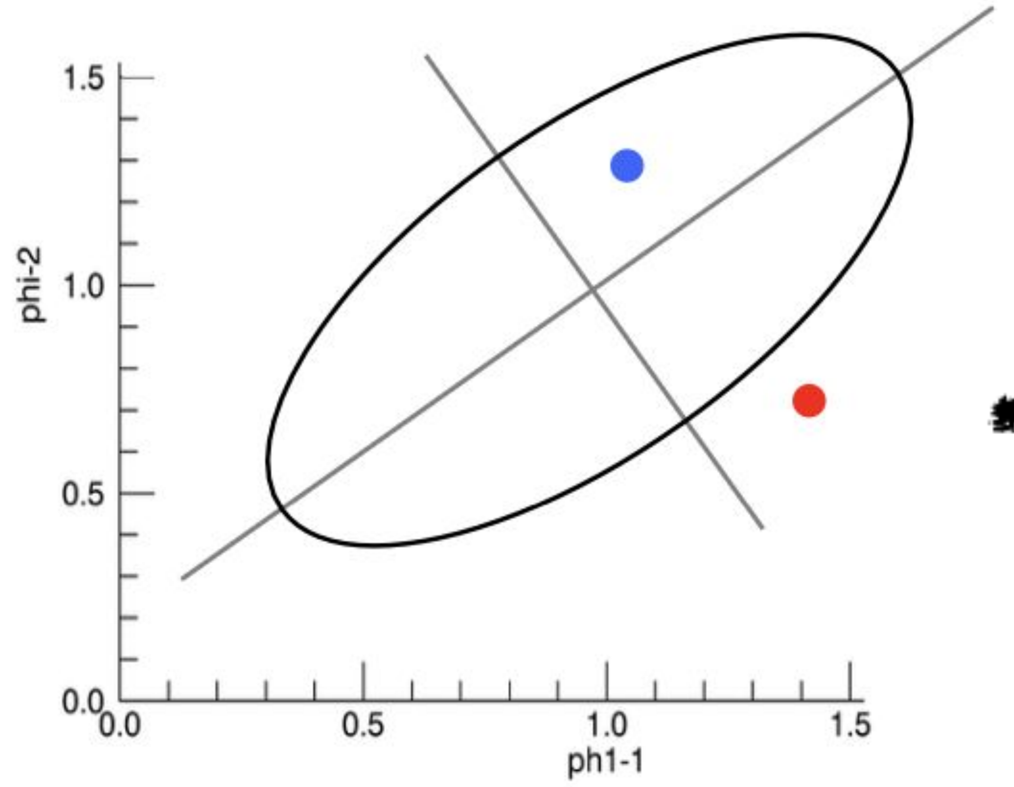
$$\tau = \frac{(ab-cd)}{\sqrt{(b+c)(d+a)(b+d)(c+a)}} \quad (10)$$

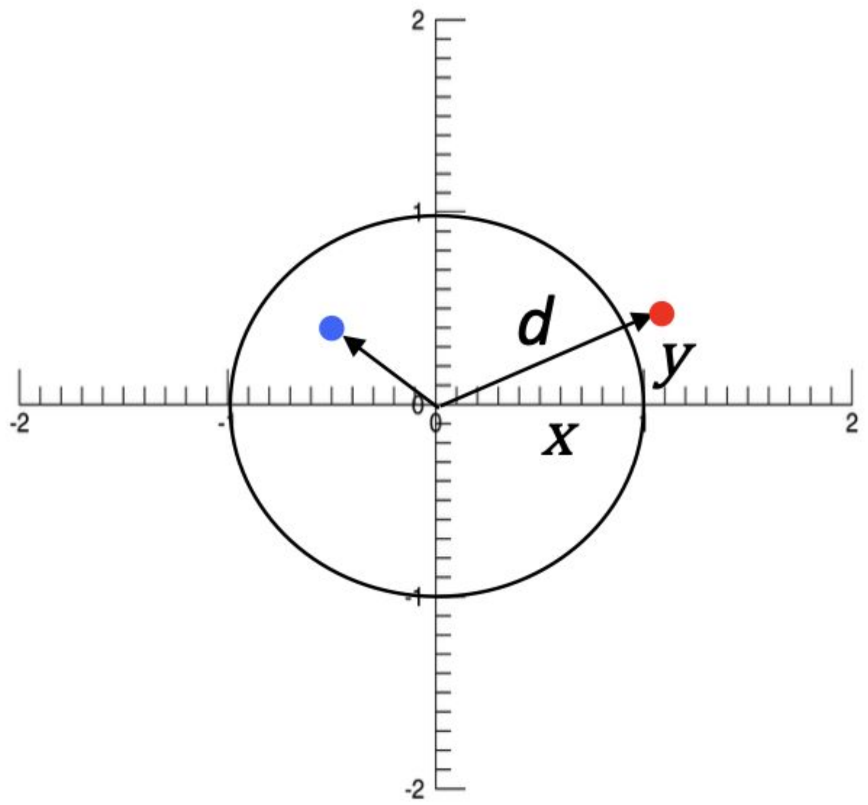


reflectance space

spherical coordinate space







transform observations back to unit circle

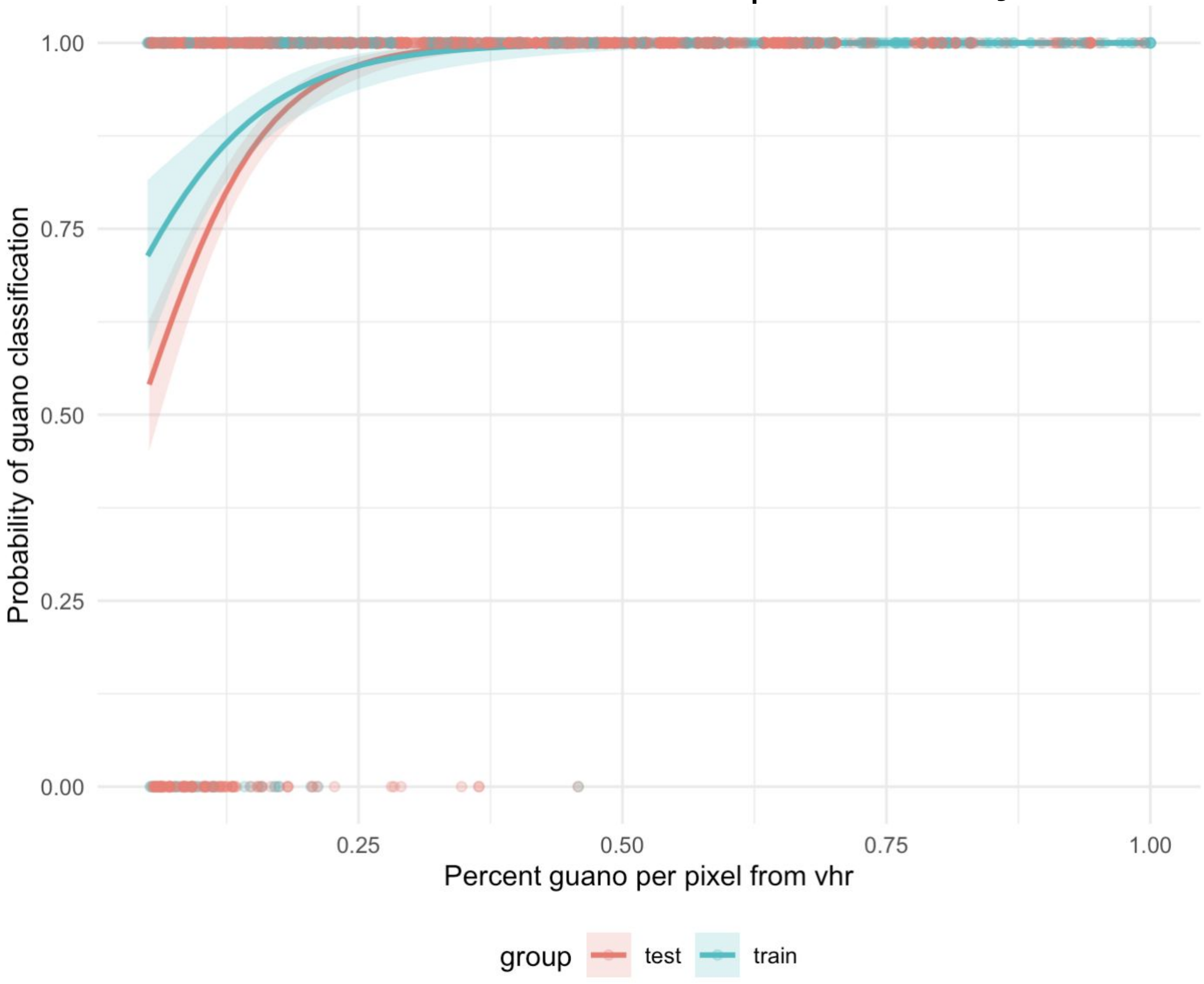
For non-shaded dry pixels containing >= 5% guano, which contain 83% of all guano in the Landsat 7 training-test set…

band order: swir1, swir2, red, nir, green, blue

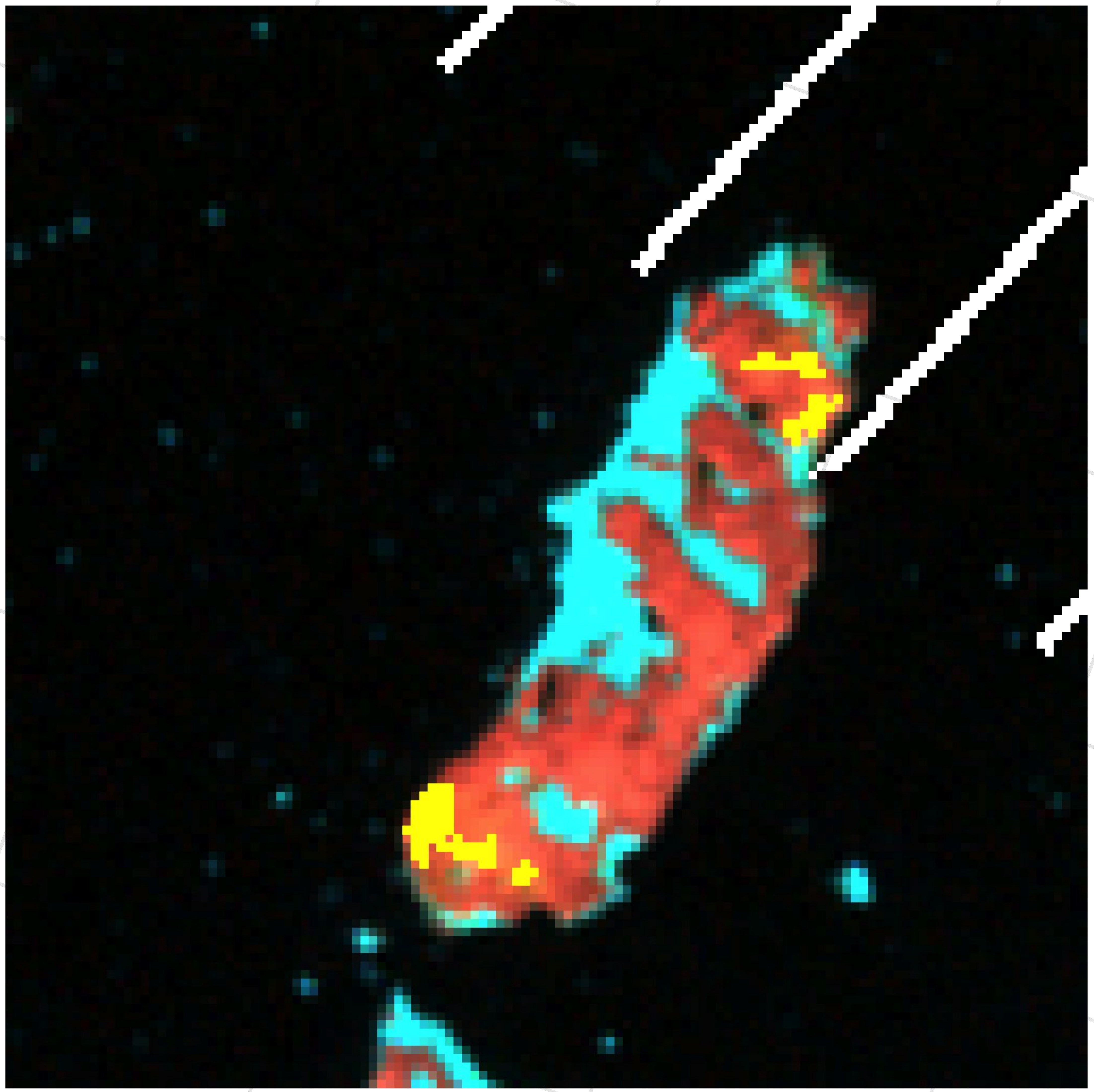
	Training set	Test set
Omission	5.6%	6.7%
Commission	3.0%	0.8%

<u>Test set omission using repeat visits: 3.4%</u>

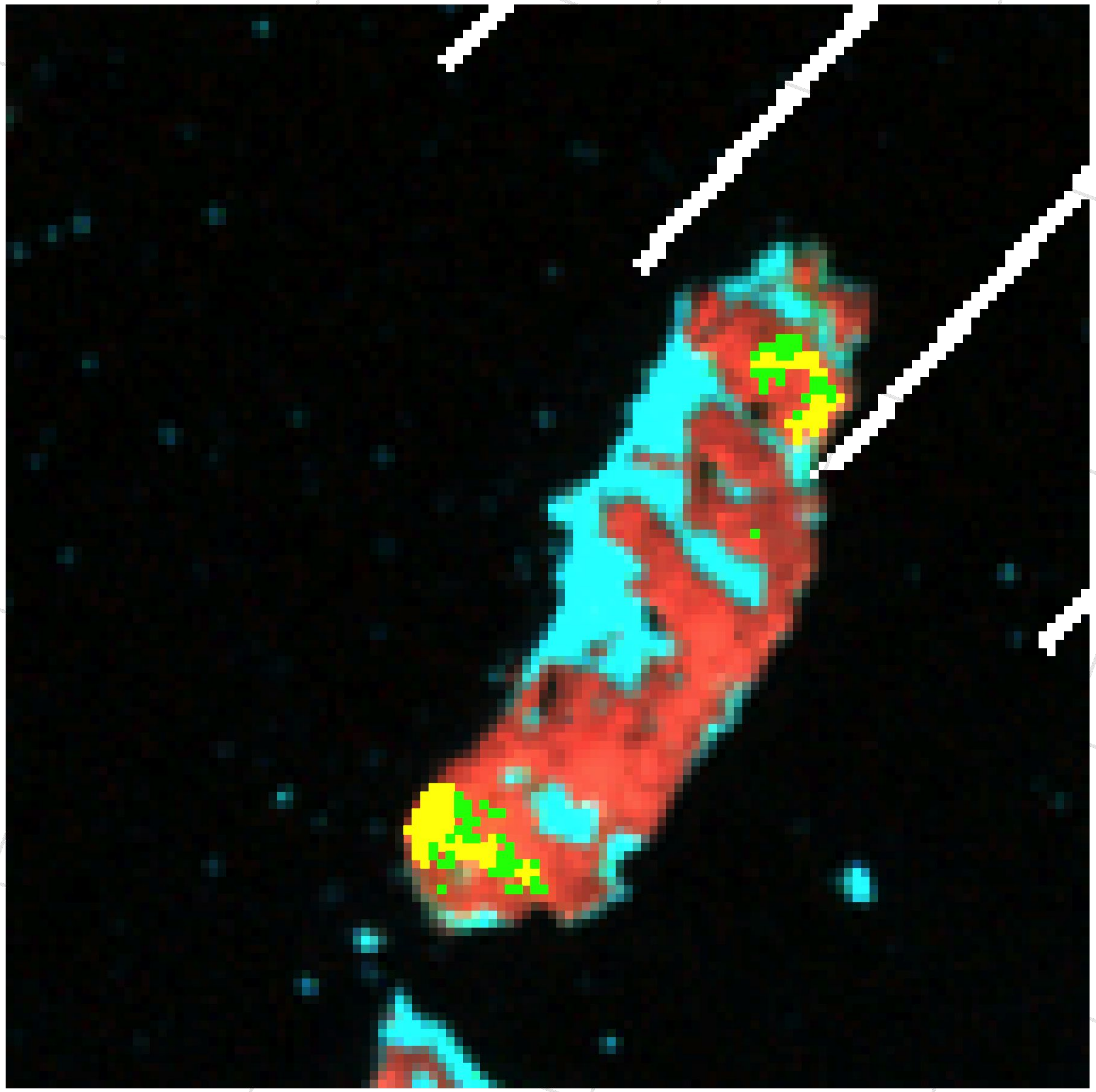
Guano detection probability



Odbert Island (-66.3742, 110.5421) January 2011



actual guano

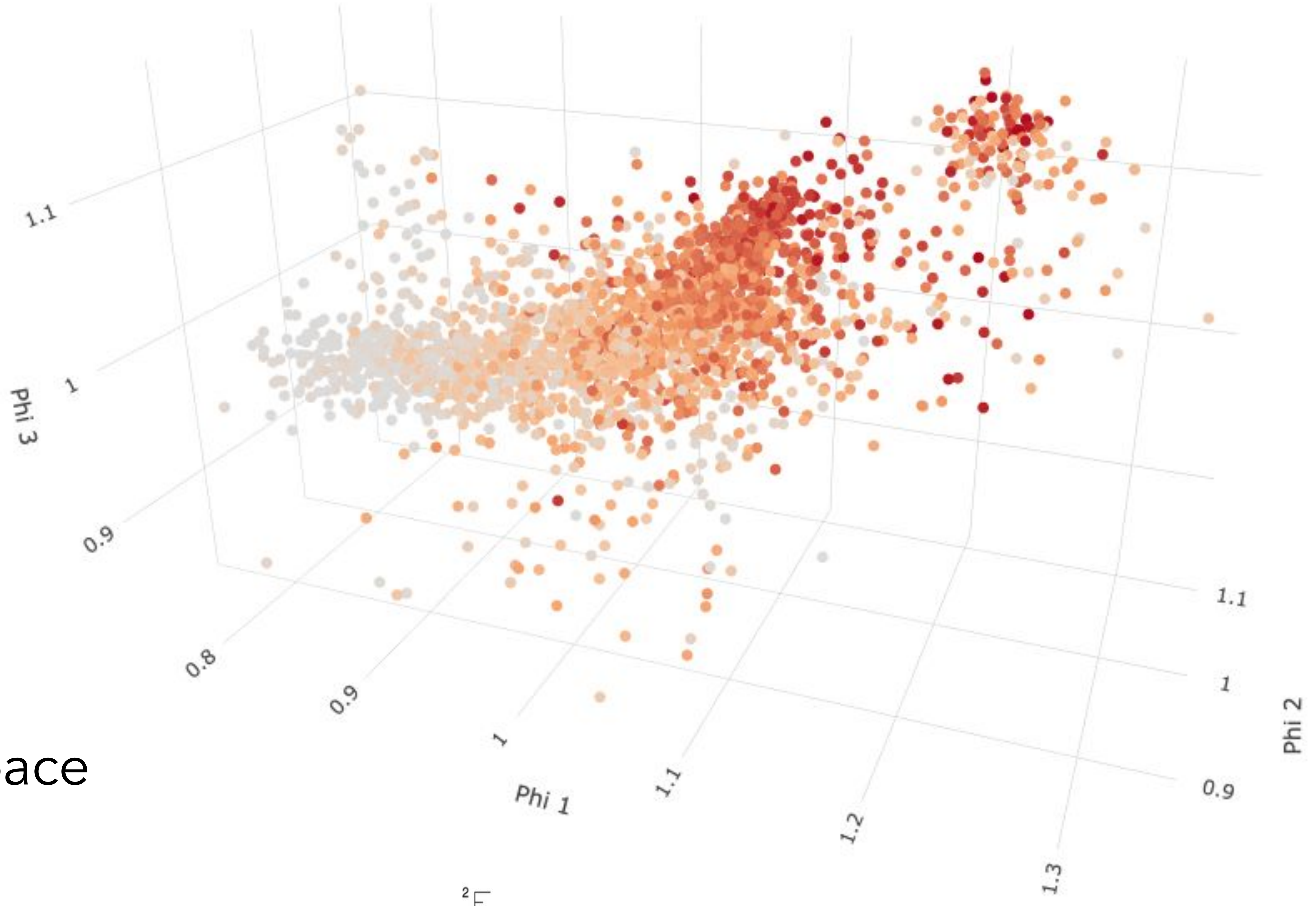


estimated guano
“commission”

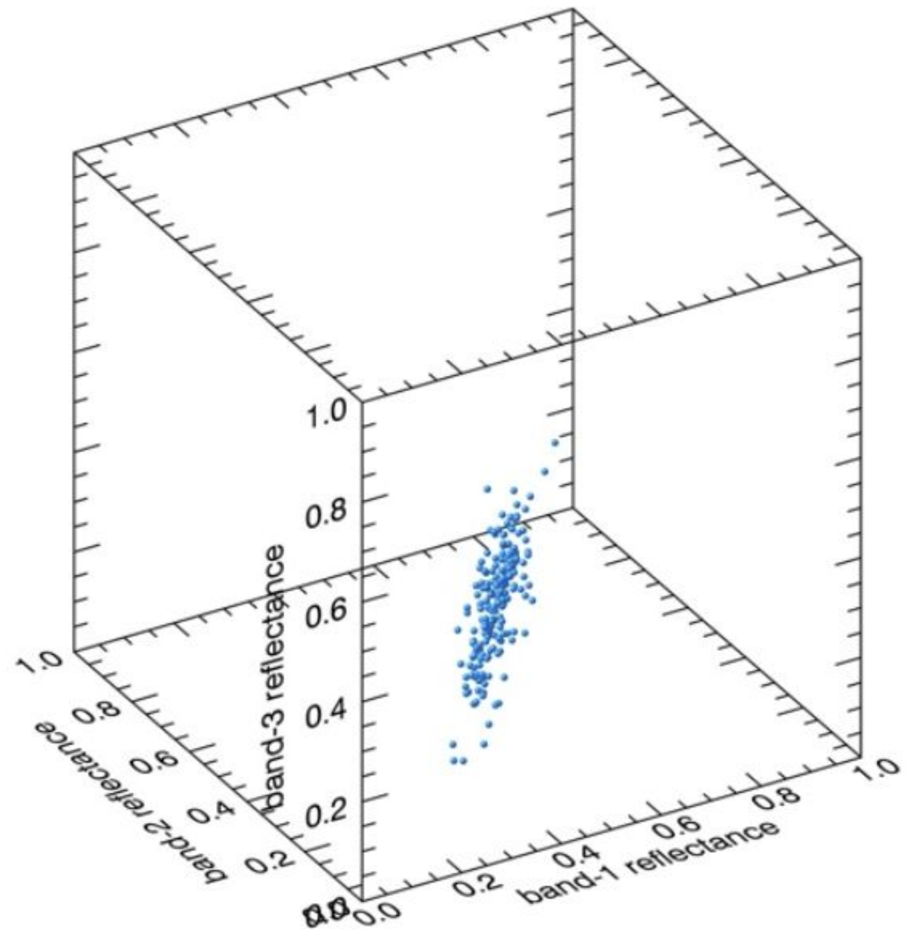
Odbert Island (-66.3742, 110.5421) January 2011

Super-resolution: Moving beyond the T-matrix

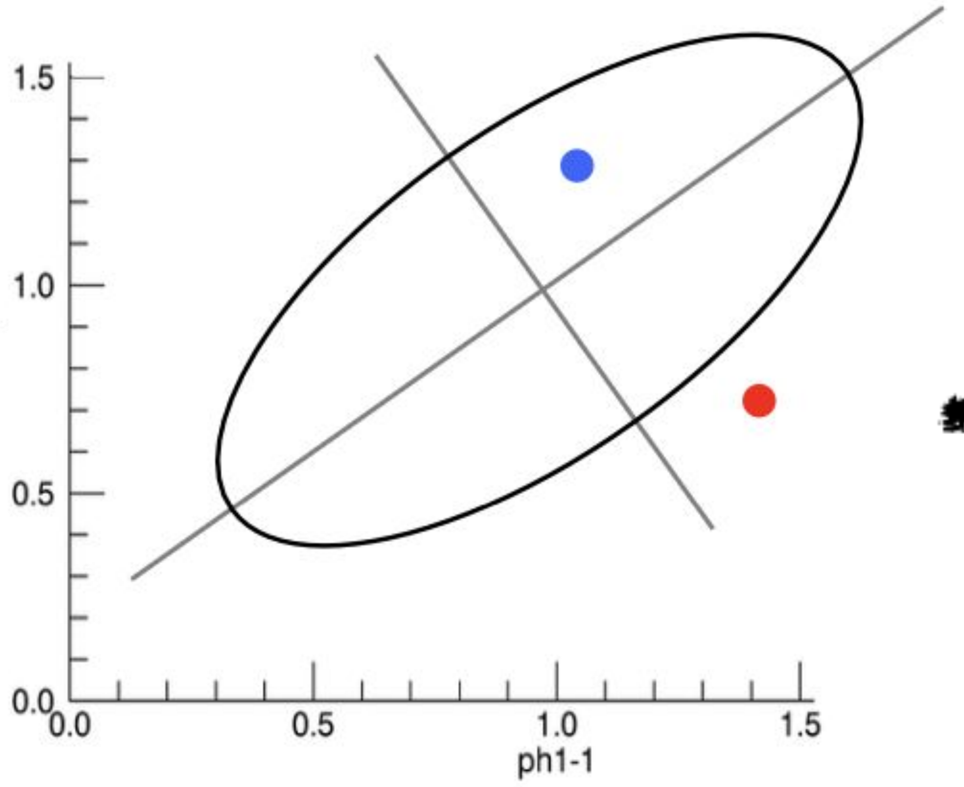
- Use phis or reflectances in shallow machine learning methods such as random forest, SVM etc.
- Spectral unmixing

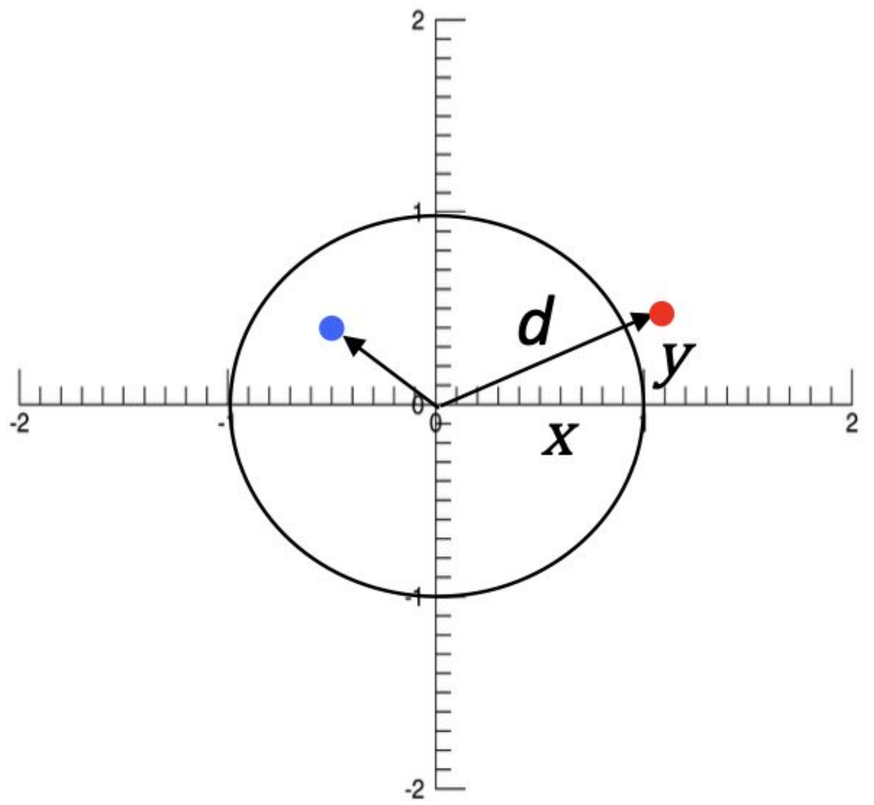


reflectance space



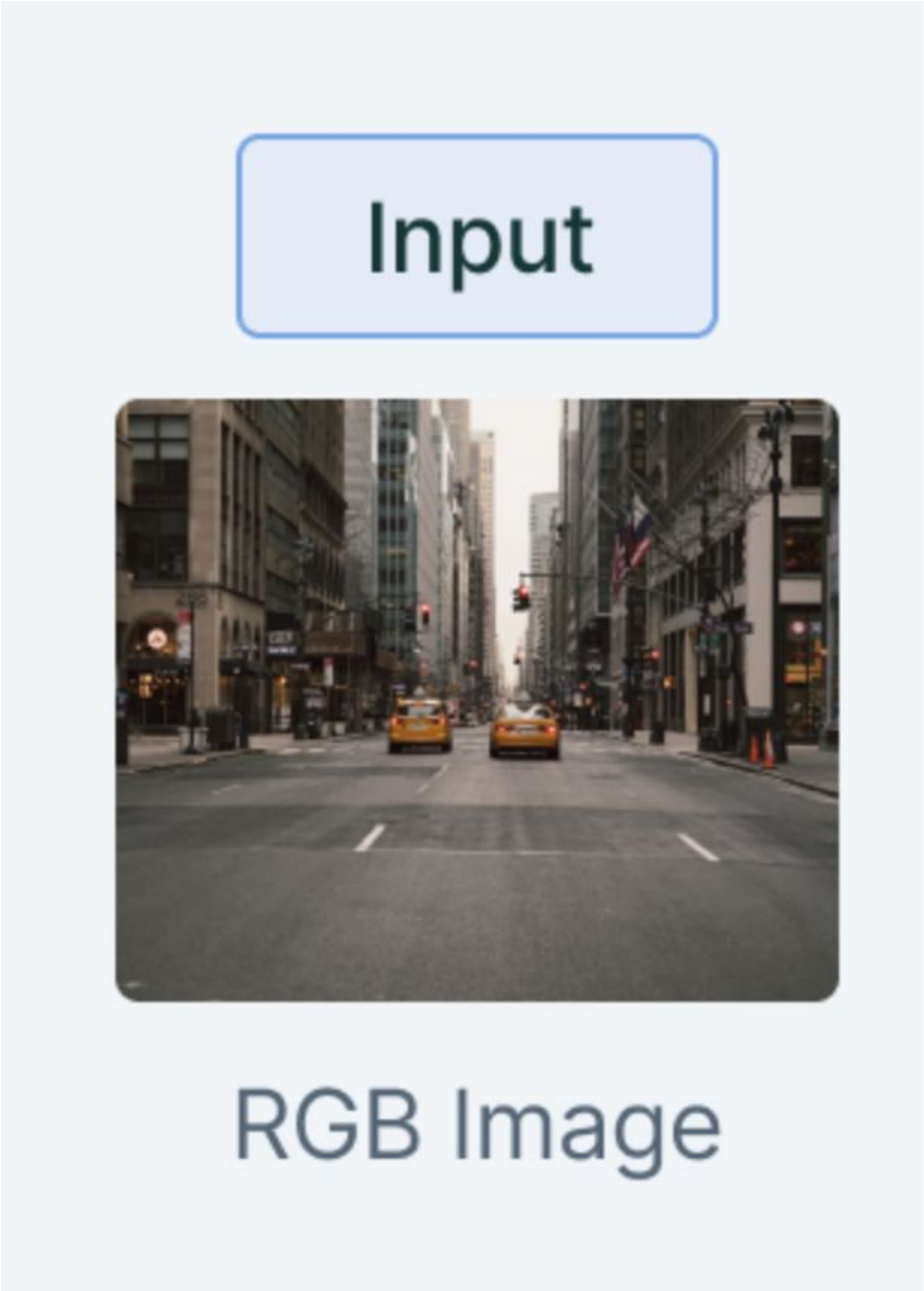
spherical coordinate space

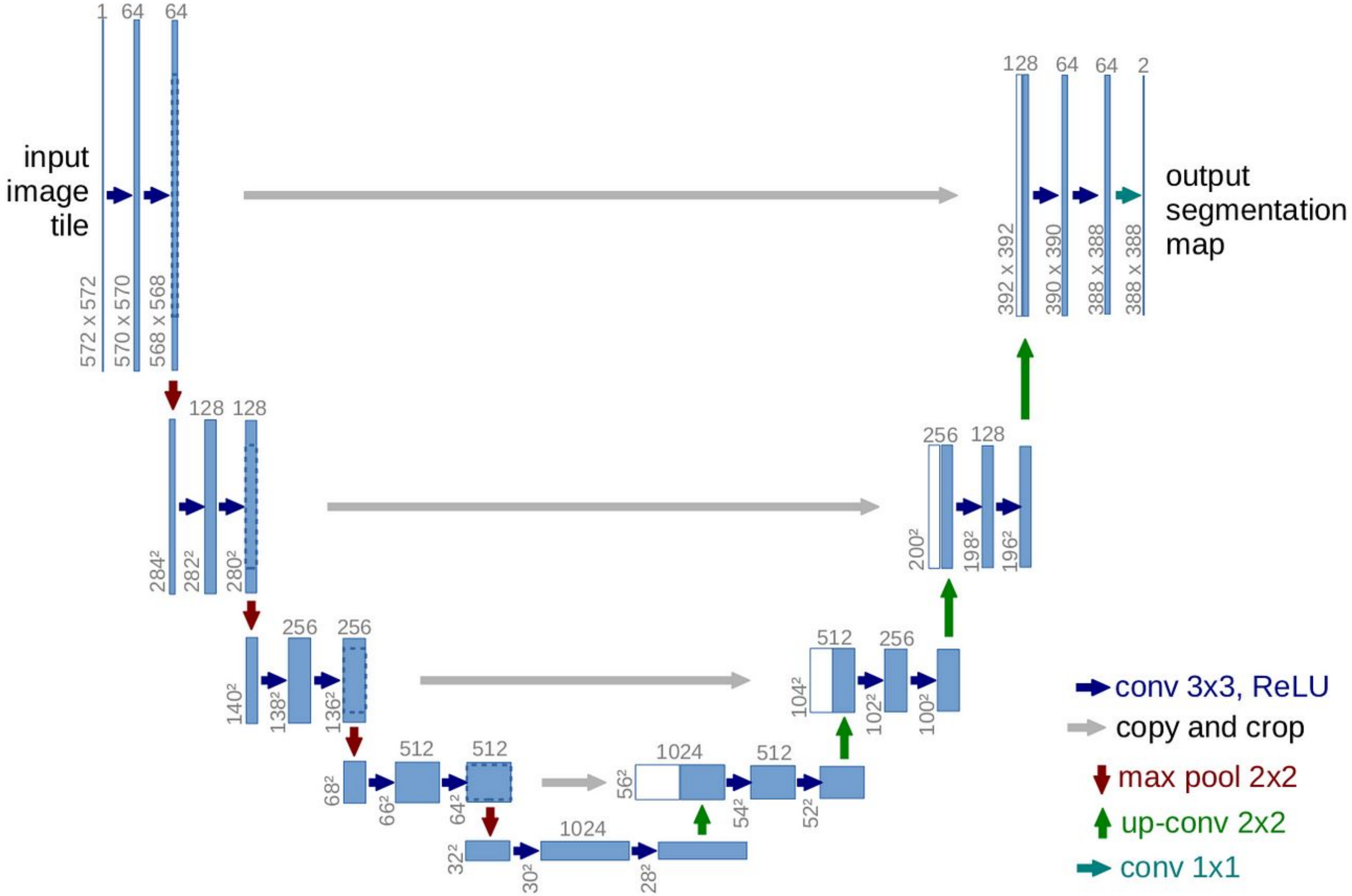


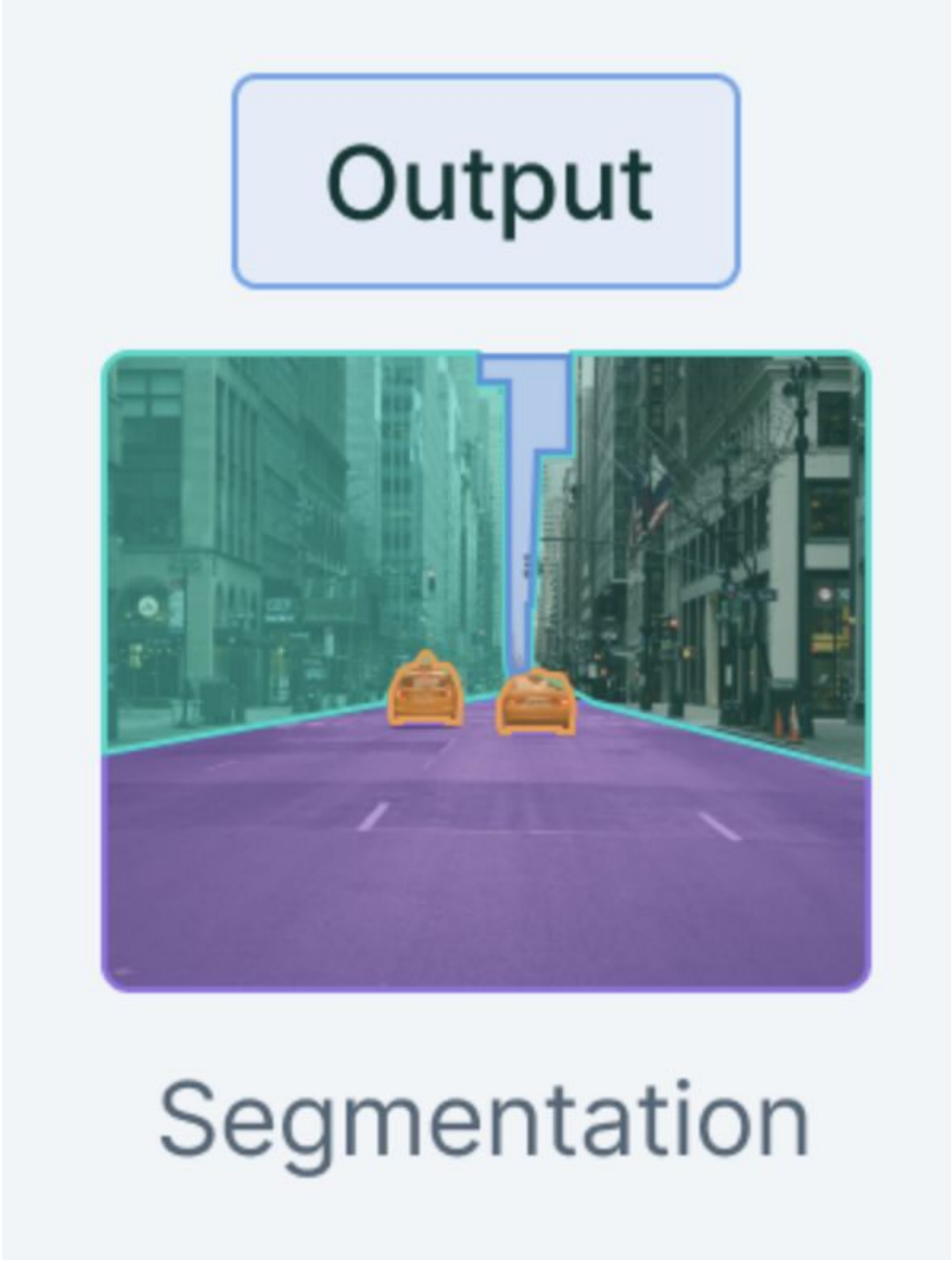


transform observations back to unit circle

U-Net CNN: Semantic segmentation with PyTorch







https://github.com/milesial/Pytorch-UNet

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Bilgecan Sen

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