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"Astro-Ecology": combining drones & astrophysics to help tackle biodiversity loss and climate change

How we are learning to turn our telescopes upside-down

Steve Longmore & Serge Wich

Owen McAree, Paul Fergus & Carl Chalmers; Simon Maskell & Yifan Zhou; Andy Symons

Maisie Rashman (Iain Steele), Simon Fox, James Crampton, Blessed Chianumba, Simon Pfeiffer, Ron Collins

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Astro-ecology: astrophysics meets conservation biology

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Staff @LJMU — Steve Longmore & Serge Wich — Staff @UoL

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PhD Masters Steve Longmore & Serge Wich Summer students

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Postdoctoral researchers Steve Longmore & Serge Wich

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Talk outline

1. Challenges we are trying to address
2. Background/timeline of the project
3. Long-term goals
4. Progress towards long-term goals
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Problem #1 → Biodiversity loss

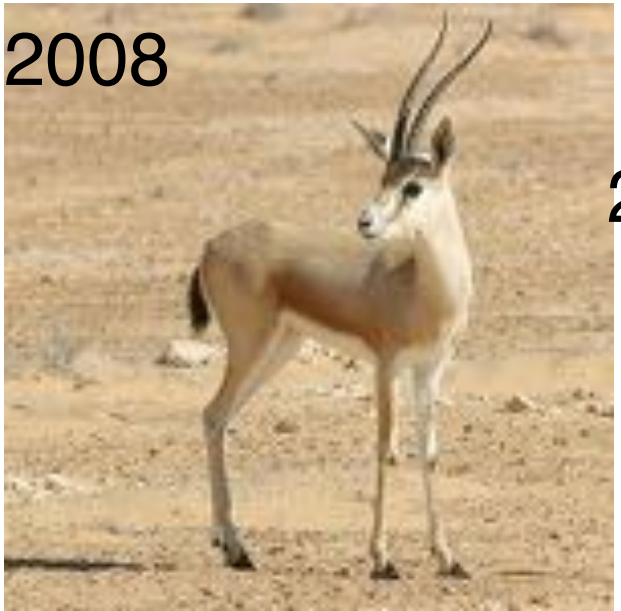

2000


2018


2009


2012


2008


2008


2011

Problem #1 → Biodiversity loss

By the end of today 5 species will have become extinct

Half as many wild animals in the world today as 30 years ago







Problem #1 → Biodiversity loss

By the end of today 5 species will have become

Half as m today as

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Problem #2 → Global Climate Change

Challenge #2 → Reduce CO_2 emission

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Traditional methods of counting animals/fires too inefficient

Problem: Fire/ecology management relies on good data. Data costly to get, hence mostly unavailable at the spatial and temporal resolutions that are required for conservation management.

Goal: Improve the efficiency of animal distribution and density data collection.

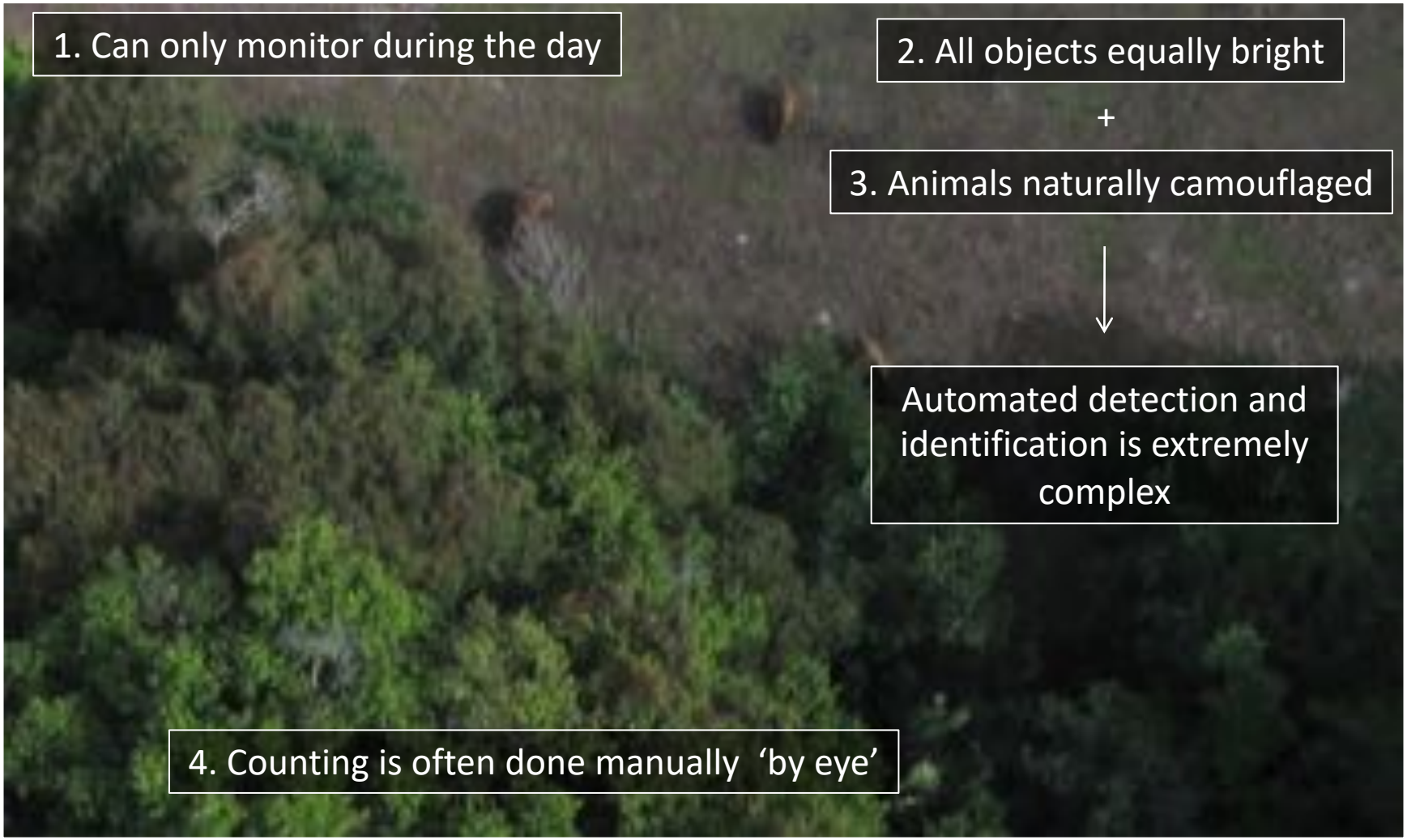
Use drones to survey large areas quickly

Explosion in use of drones for conservation* purposes

Easy to survey large areas quickly and efficiently

*and as a way to give your dog a different perspective on the world

Challenge to current efforts



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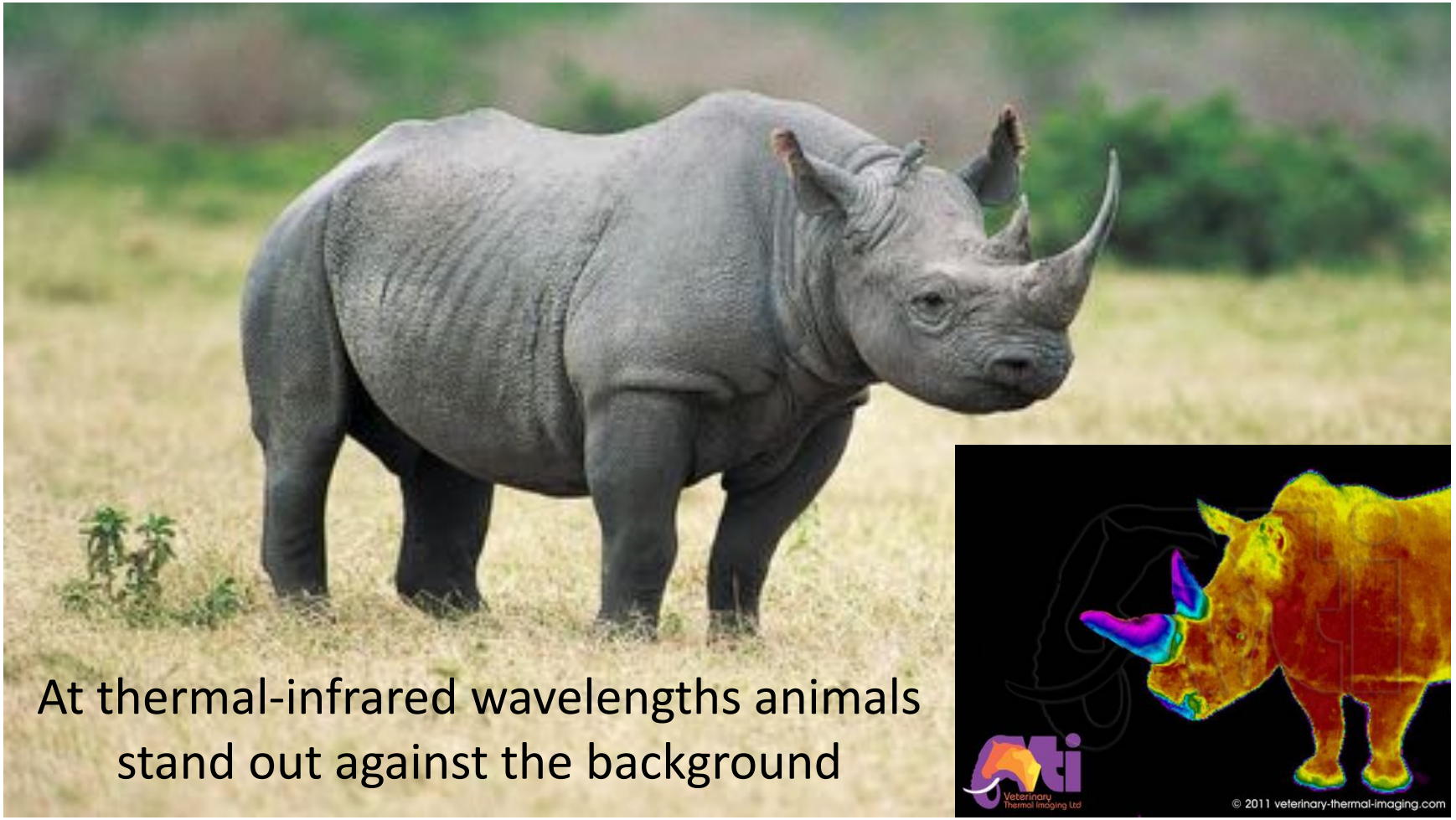
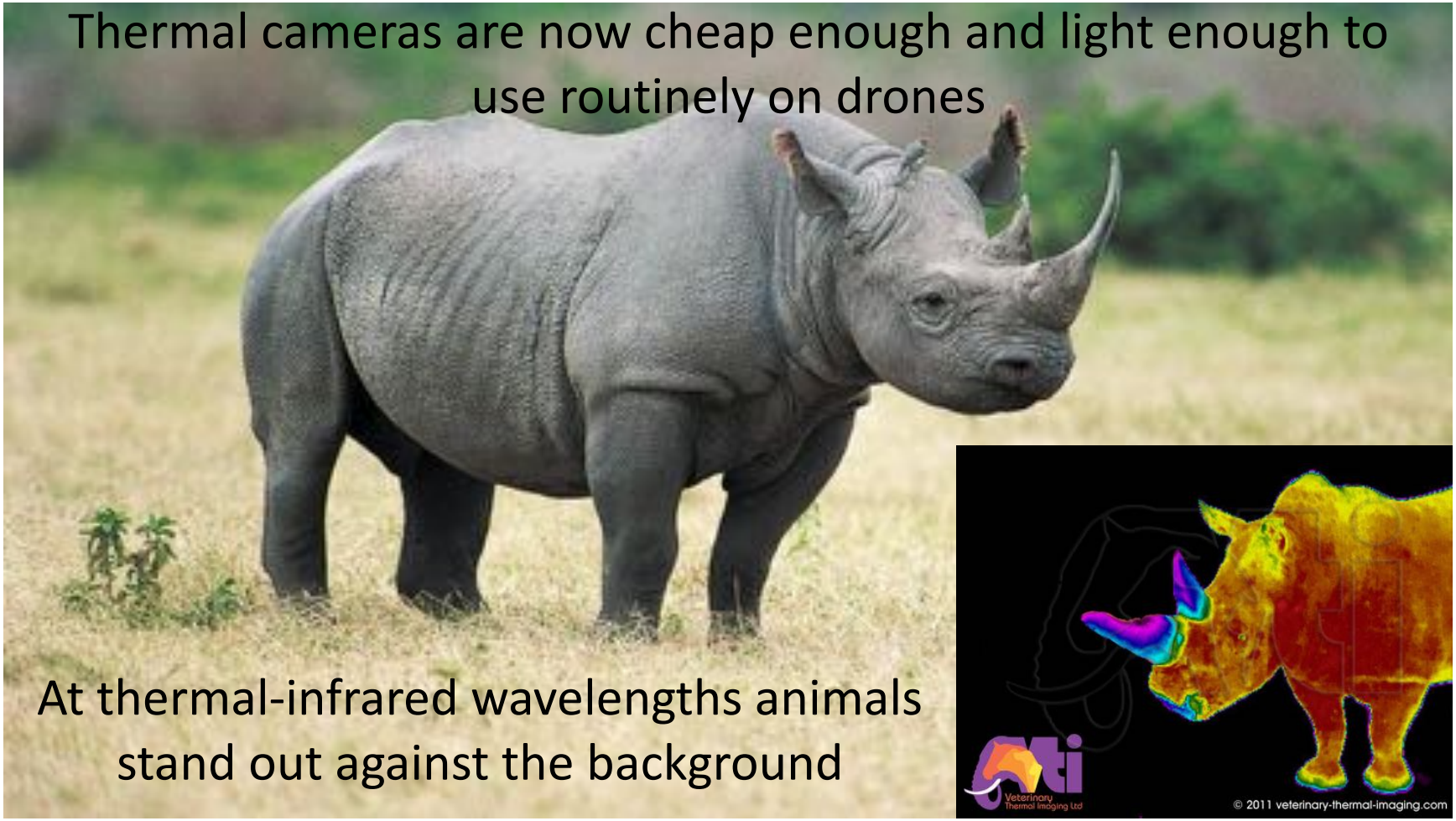
Seeing in the dark…

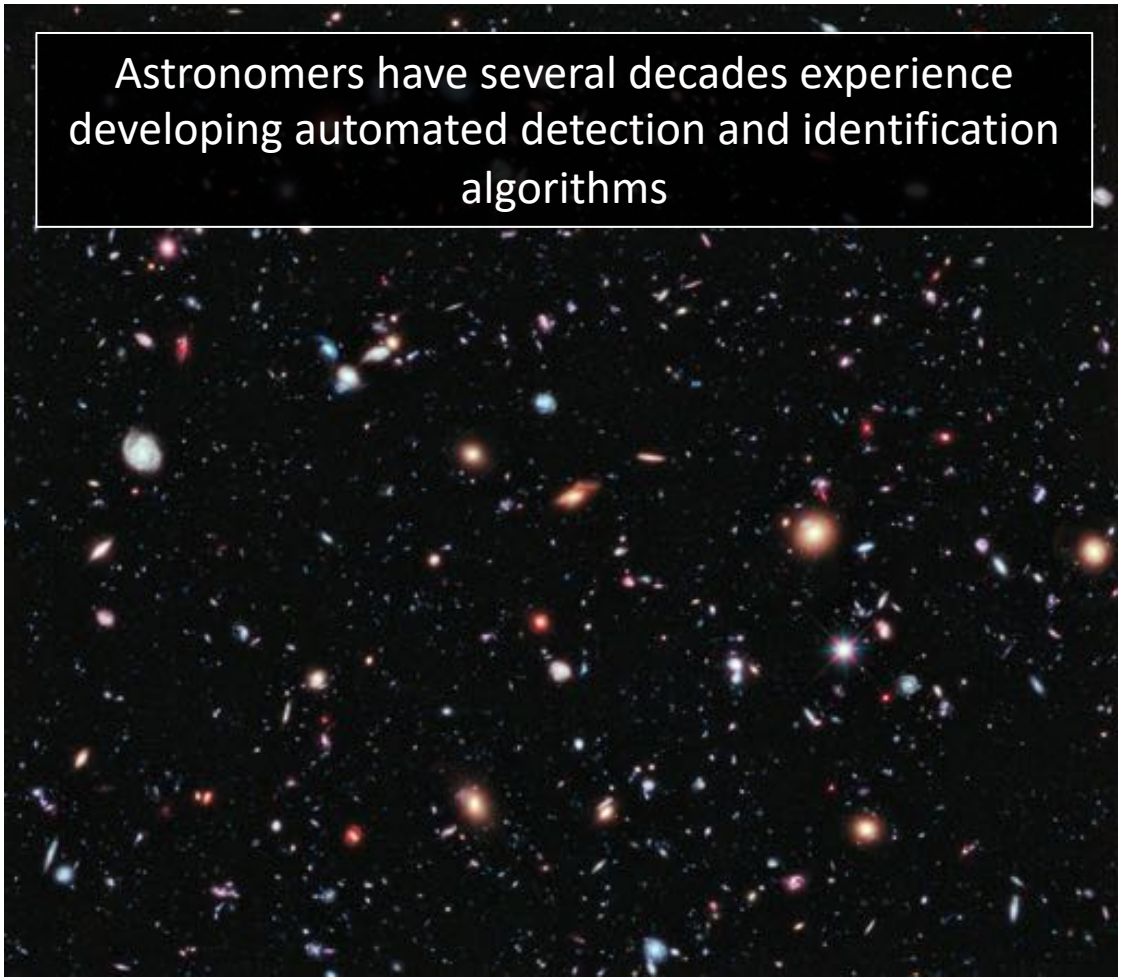


Seeing in the dark…

Thermal cameras are now cheap enough and light enough to use routinely on drones



Thermal “fingerprints” of stars, galaxies and … animals …



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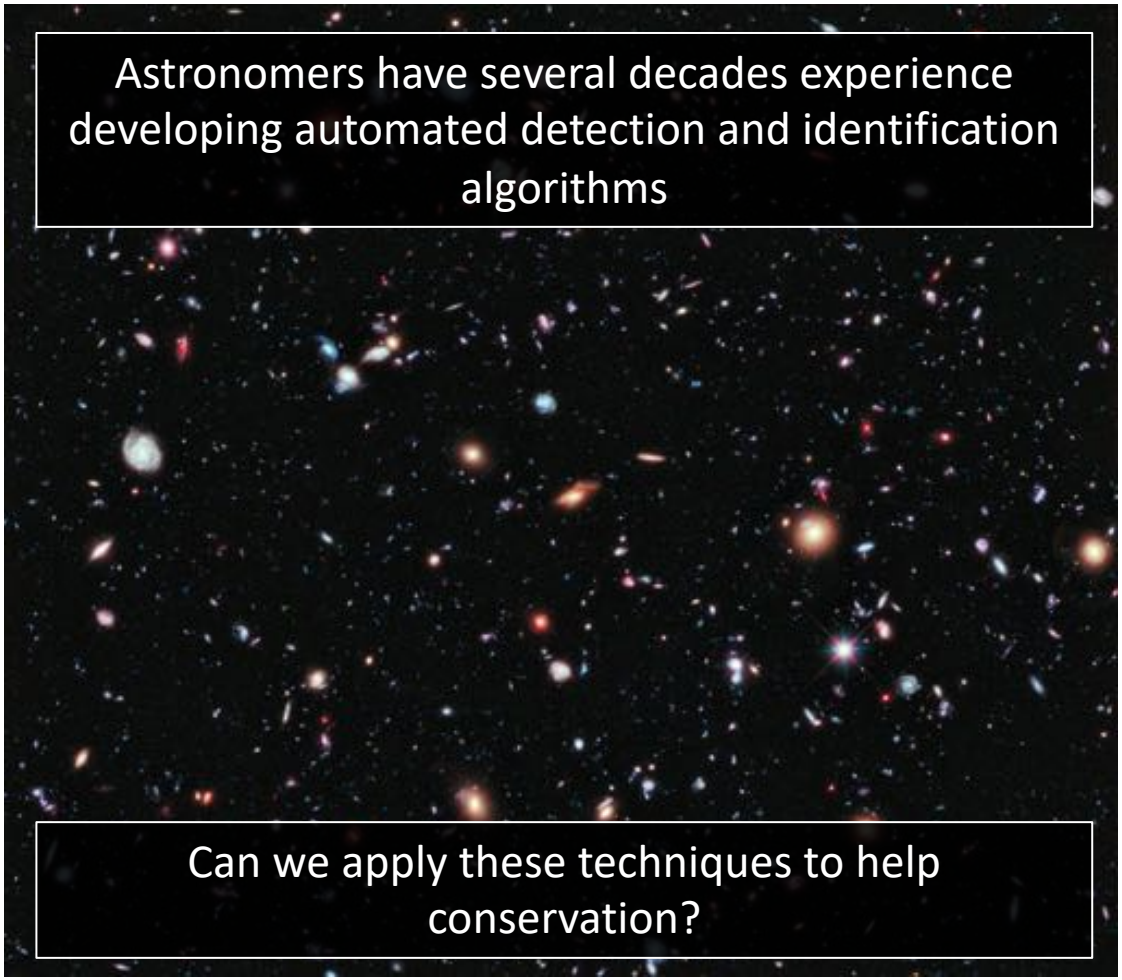
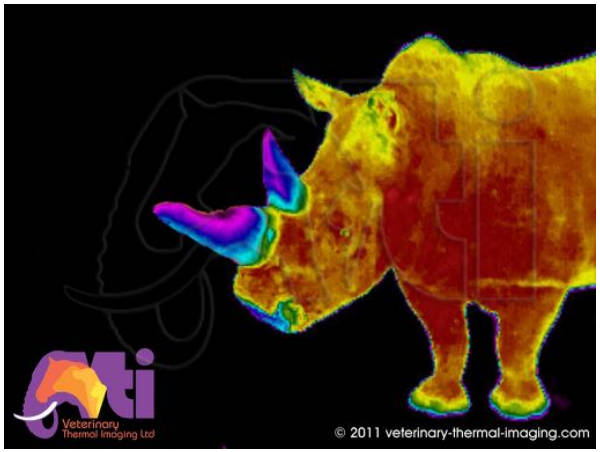
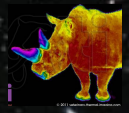


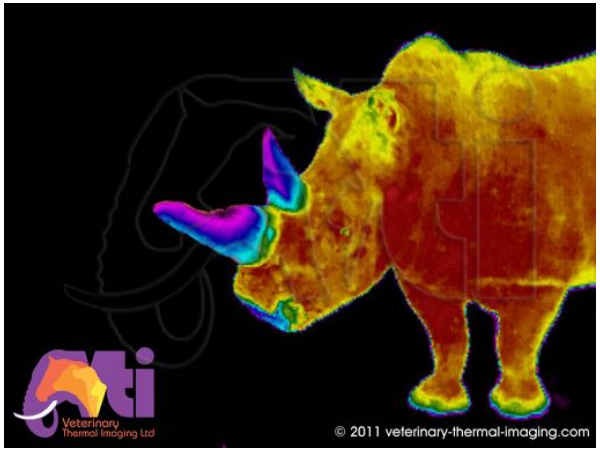


Thermal “fingerprints” of stars, galaxies and … animals …

Astronomers have several decades experience developing automated detection and identification algorithms



Can we apply these techniques to help conservation?



How to use this to try and help conservation efforts?

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2014 2015 2016 2017 2018 2019

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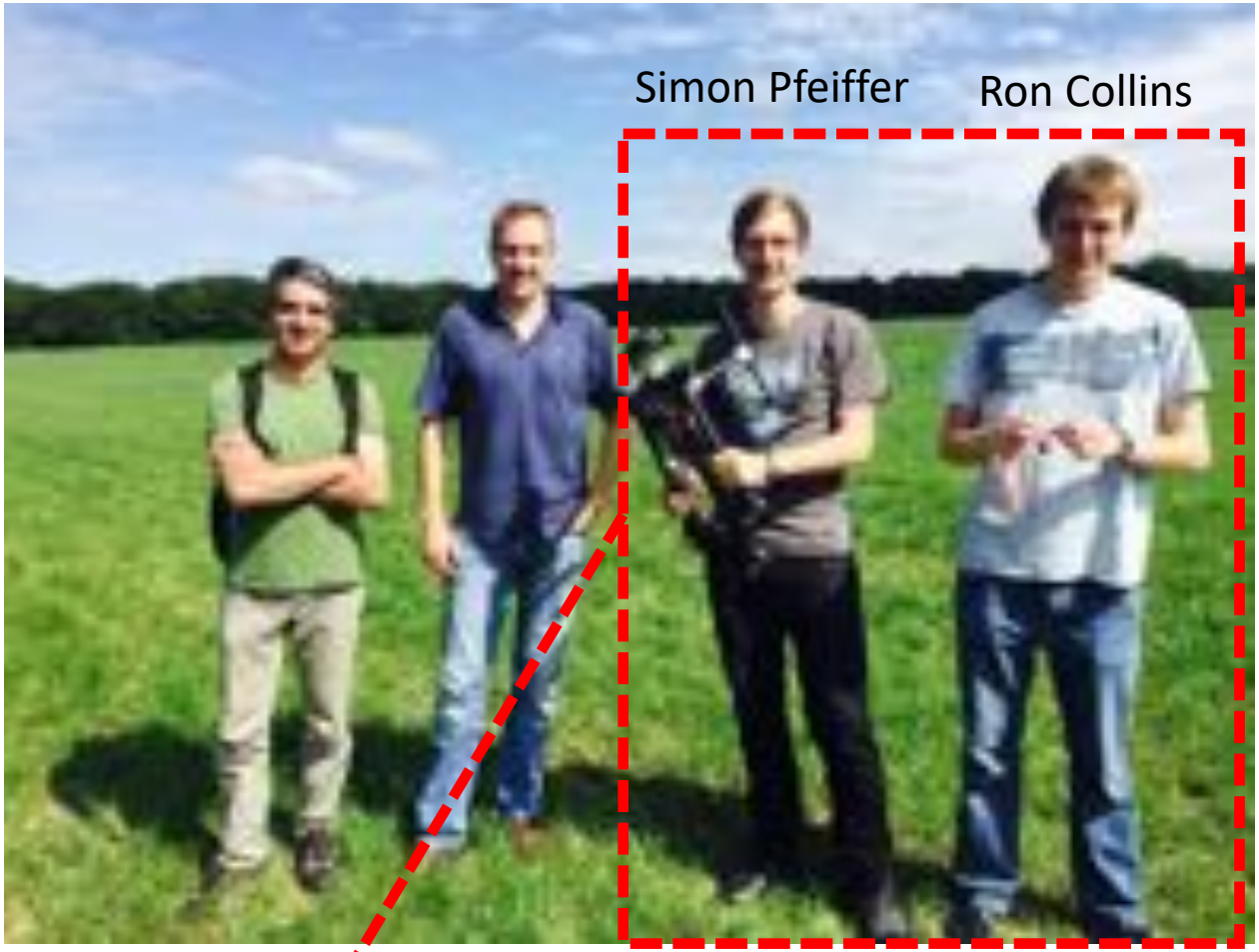

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Lift off!

Astronomy detection algorithms

+

Machine learning

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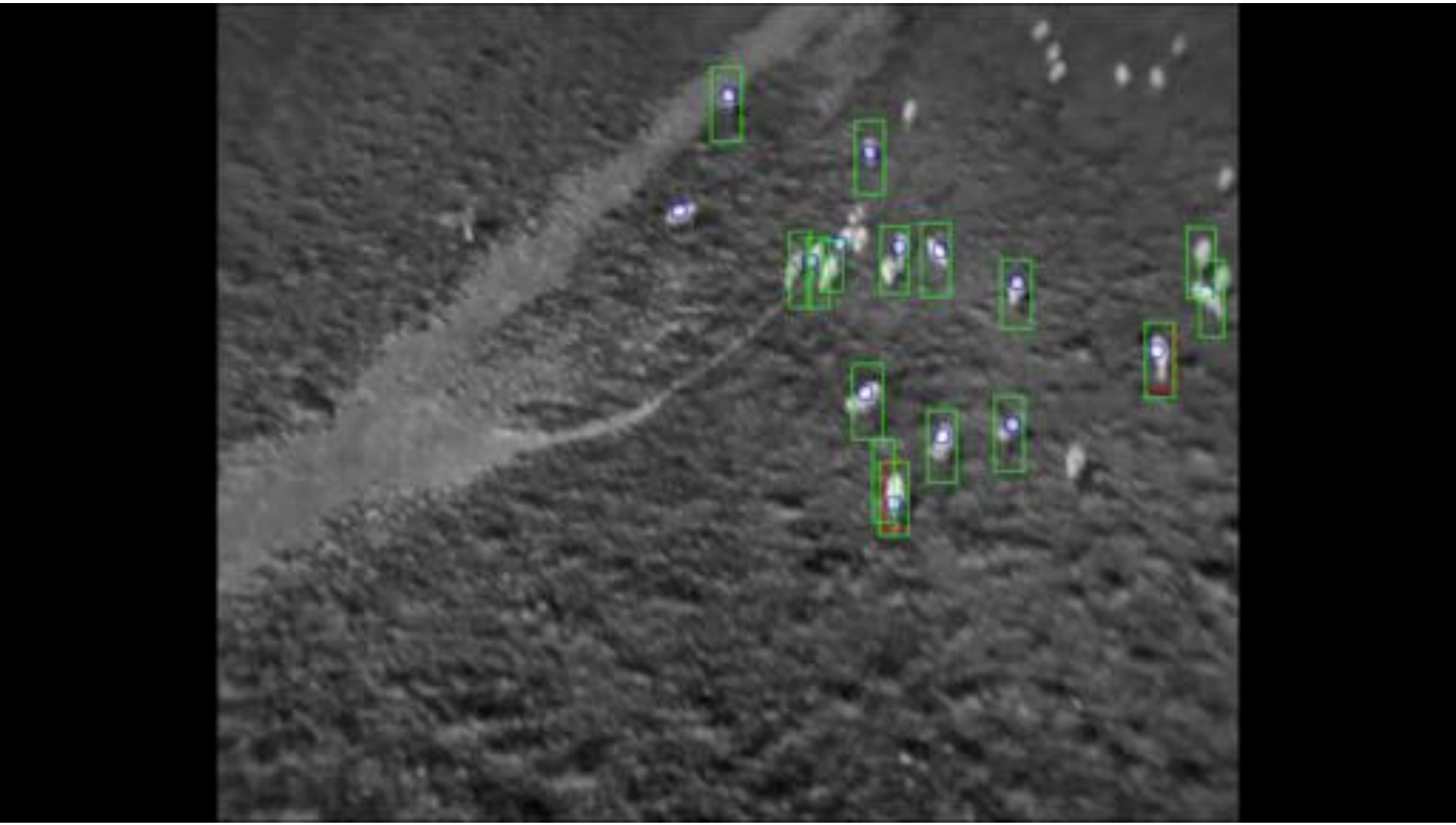
Lift off!



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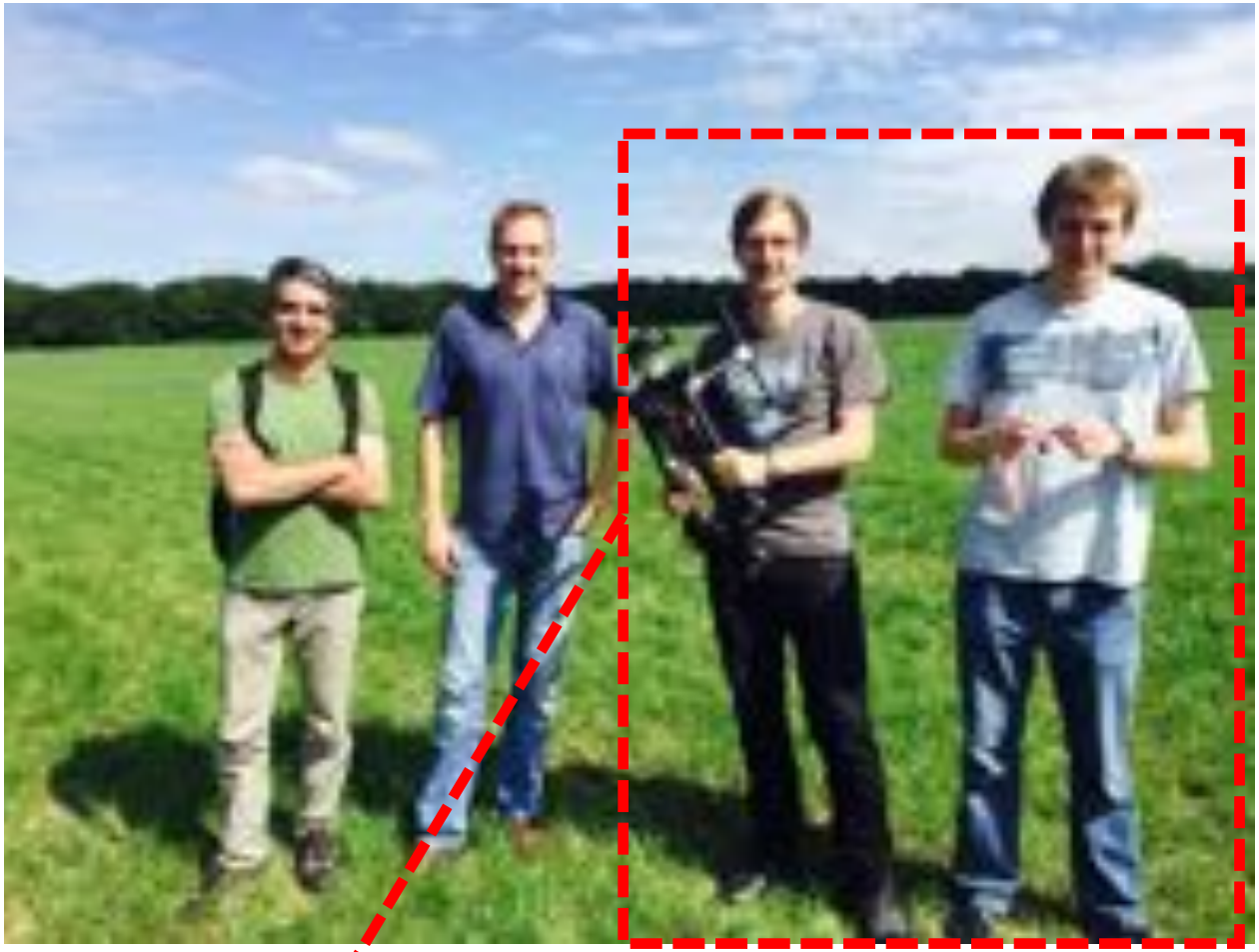

2014 2015 2016 2017 2018 2019

Building an astro-ecology group

Building an astro-ecology group

Research Spotlight Award (£25k)

2014 2015 2016 2017 2018 2019

Building an astro-ecology group

Maria de Juan Ovelar

Research Spotlight Award (£25k)

Hire part-time postdoctoral researcher for 11 months

Buy integrated thermal + optical camera

2014 2015 2016 2017 2018 2019

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Building an astro-ecology group

2014 2015 2016 2017 2018 2019

Building an astro-ecology group

Maisie Rashman

LJMU-funded
PhD student

2014 2015 2016 2017 2018 2019

Building an astro-ecology group

Claire Burke

PDRA funded through STFC 21st Challenges Grant

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Steve Longmore

Does this work on endangered animals?

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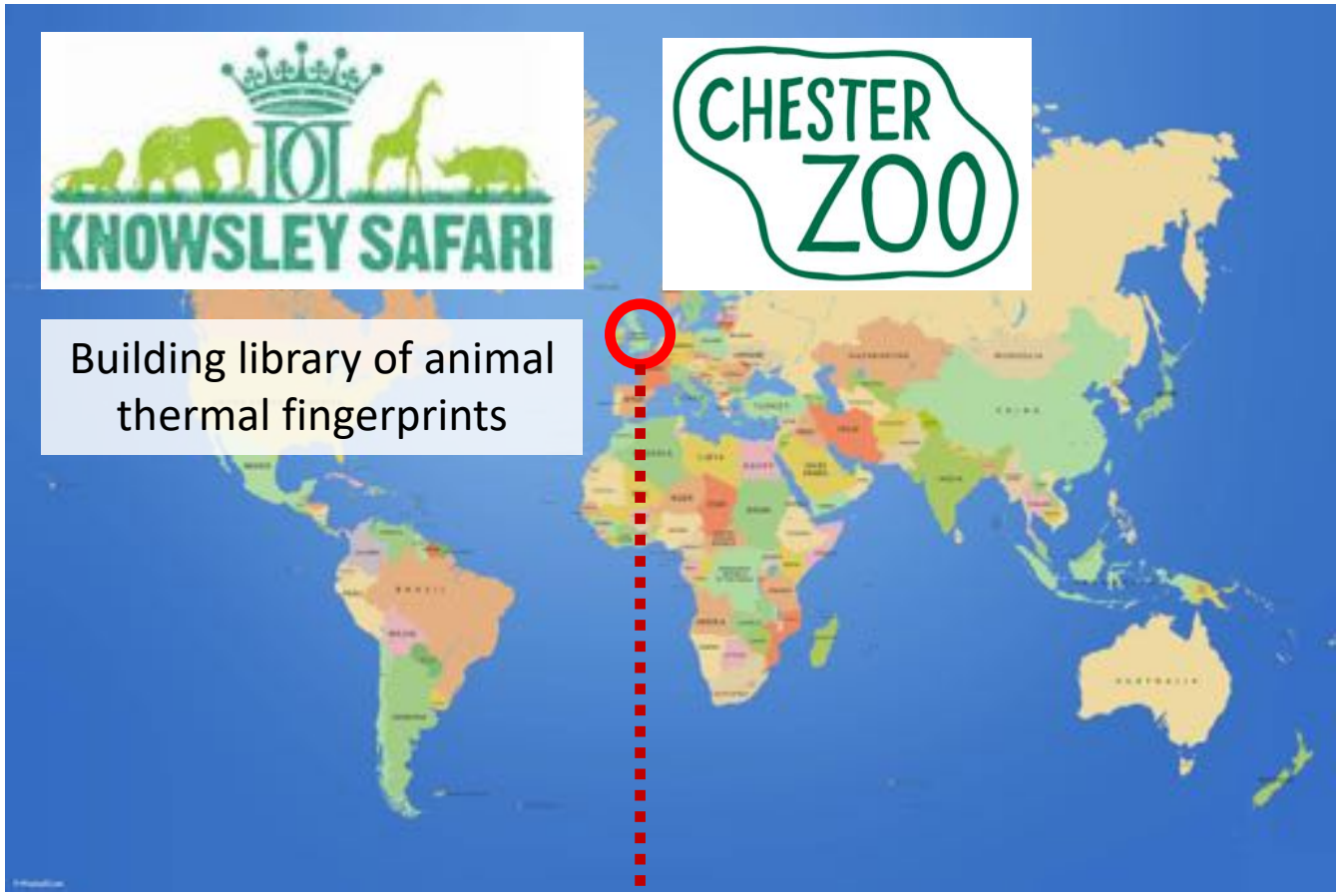

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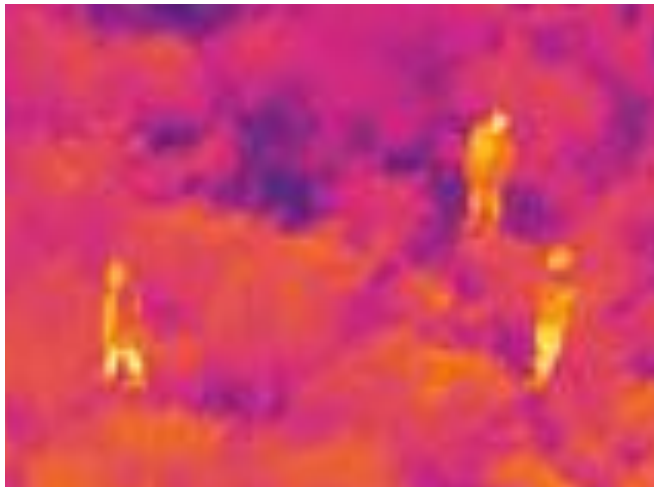
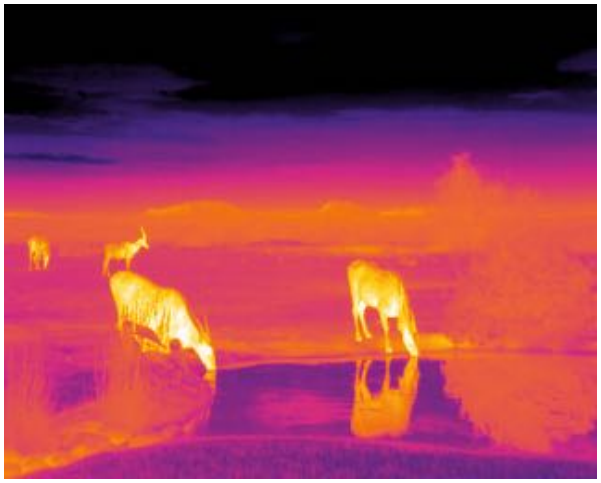
Building library of animal thermal fingerprints

KNOWSLEY SAFARI

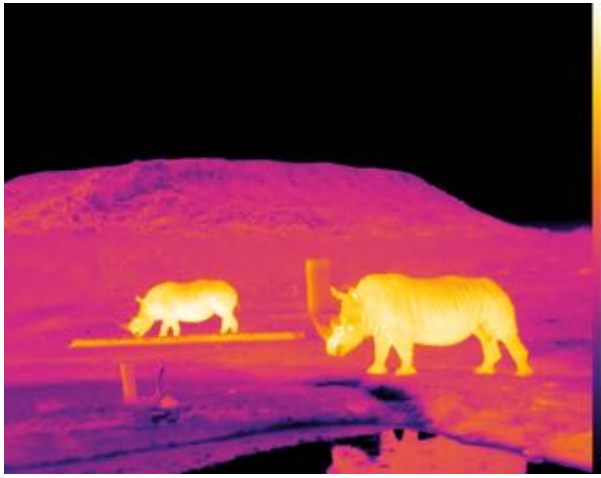
Human

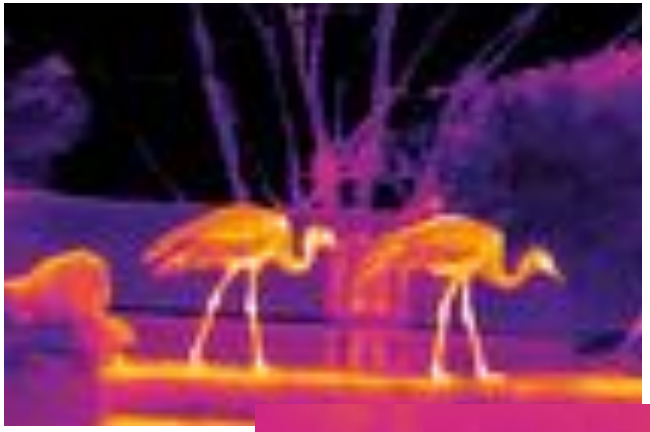


Eland



Rhinos

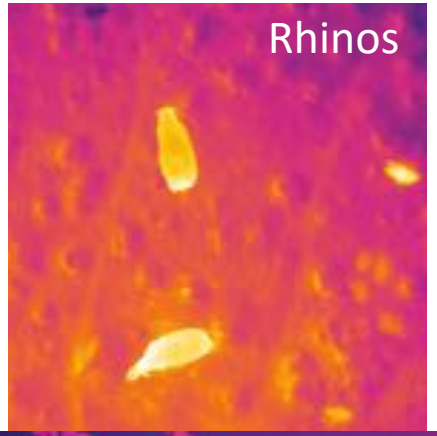


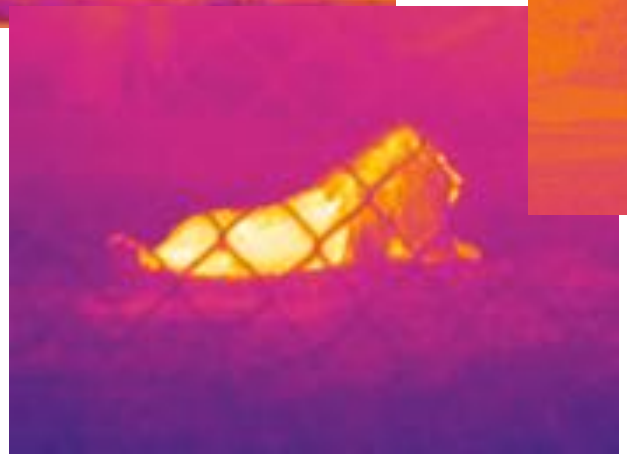


Blue crane

Giraffe

Rhinos





Lion

Elephants

First results

Pilot paper published in 2017.

Longmore et al., 2017, International Journal of Remote Sensing,

Associated press release → international media attention

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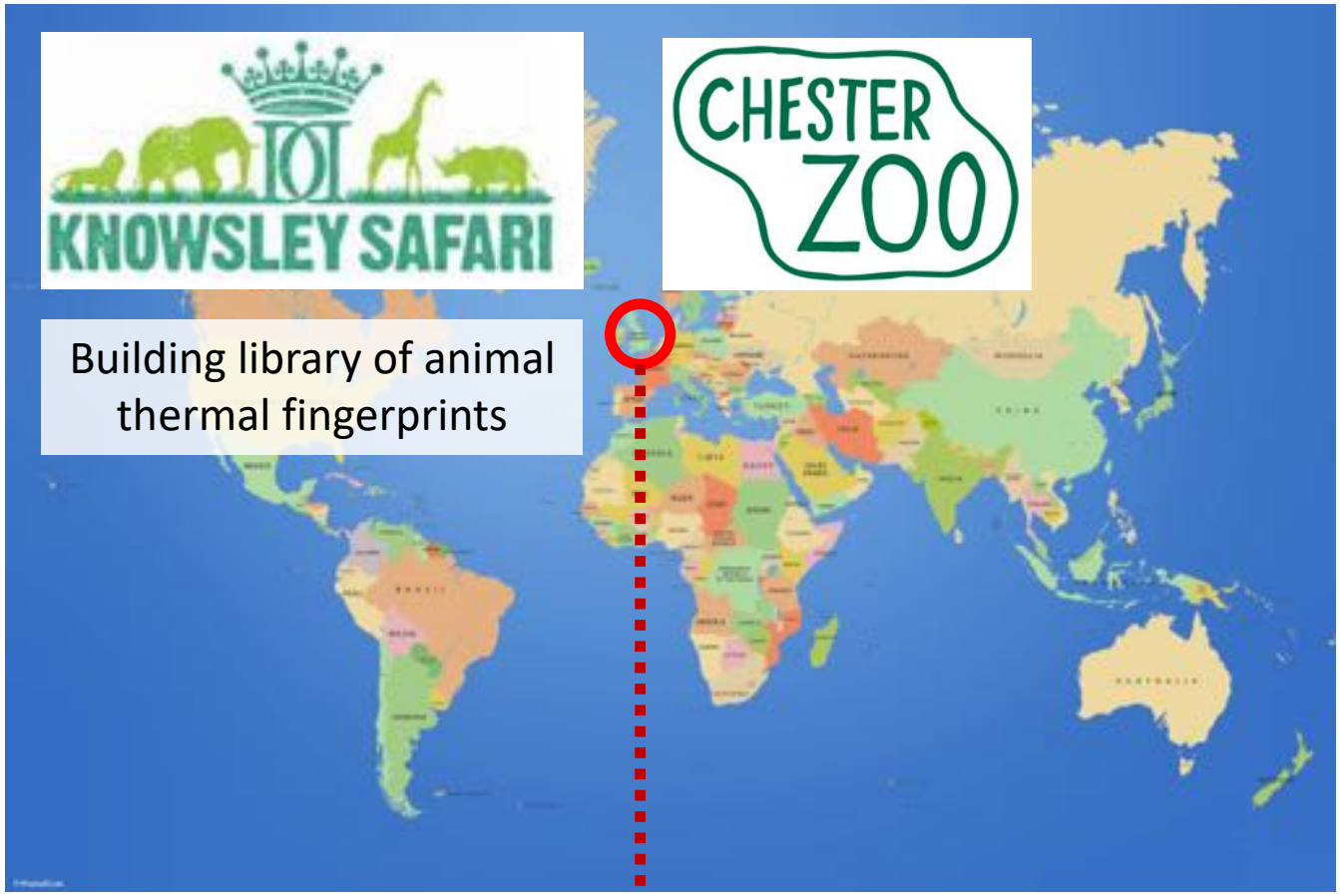
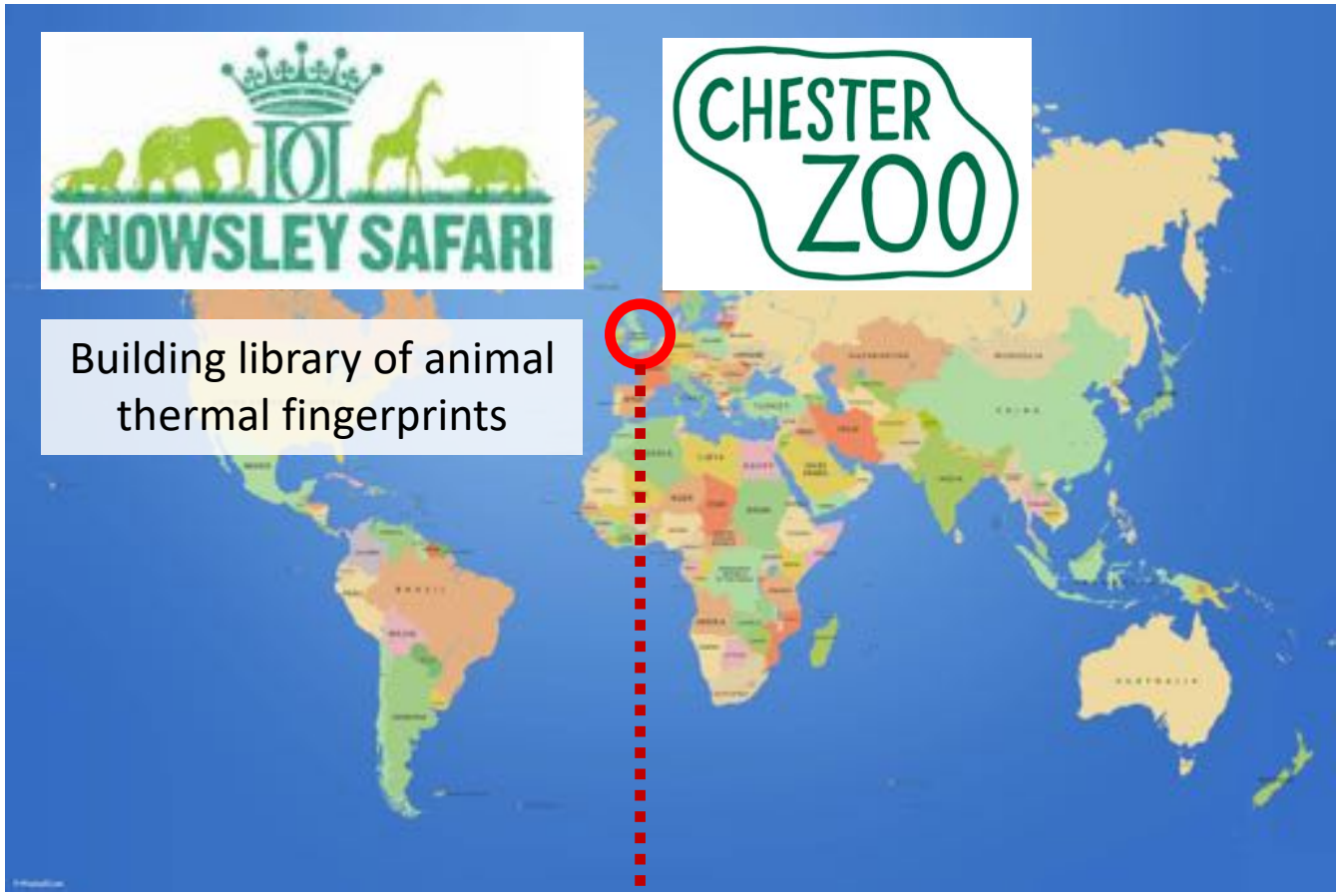
Does this work on endangered animals?



Does this work on endangered animals?

Yes! Well, at least in captivity… what about in the wild?



Steve Longmore

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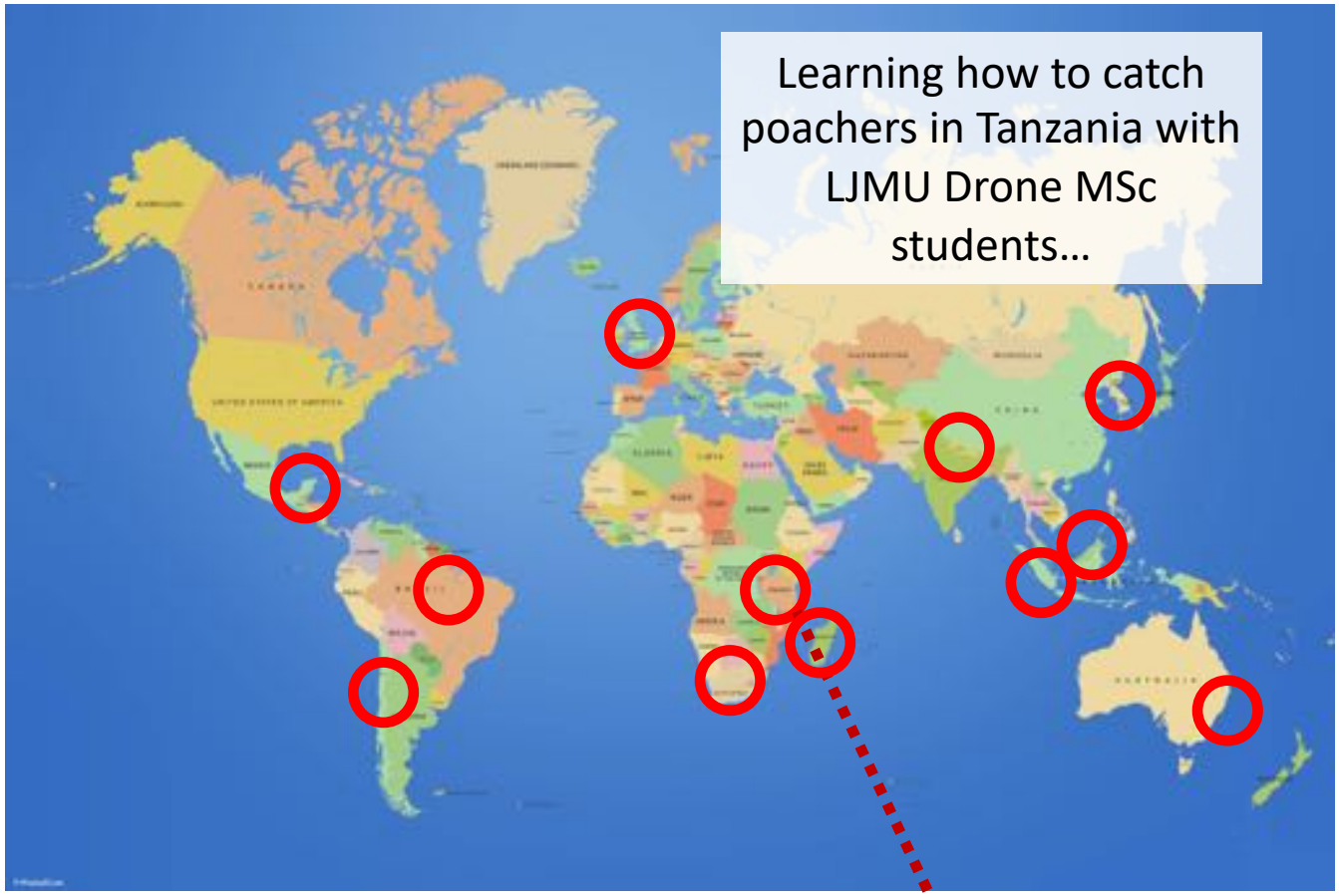
How to use this to try and help conservation efforts?

Contacted by conservation agencies around the world

2014 2015 2016 2017 2018 2019

First steps: hunting the hunters



2014 2015 2016 2017 2018 2019

First steps: hunting the hunters

Steve Longmore

Video credit: Lenny Hambrect

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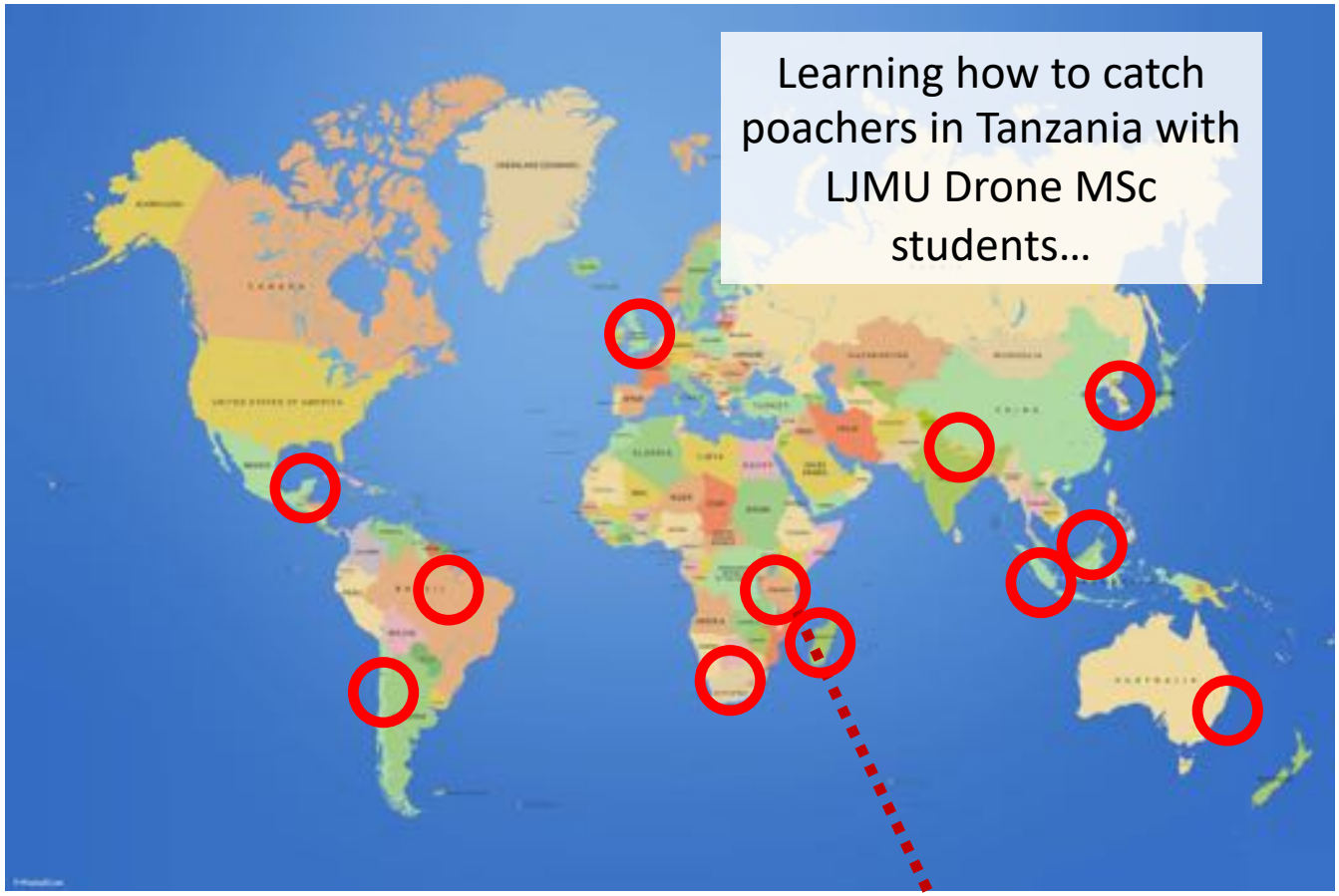

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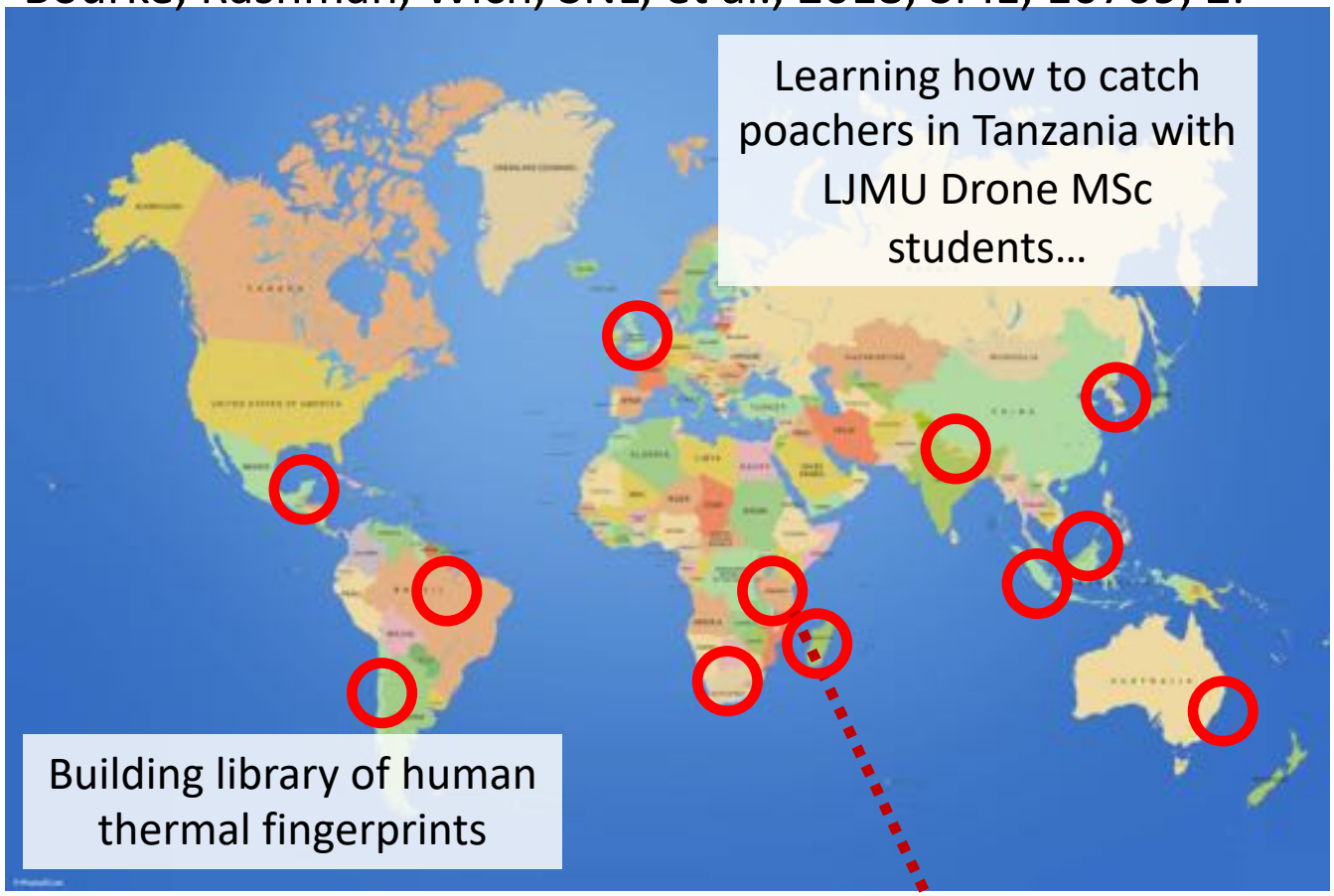
First steps: hunting the hunters

Bourke, Rashman, Wich, SNL, et al., 2018, SPIE, 10709, 2.



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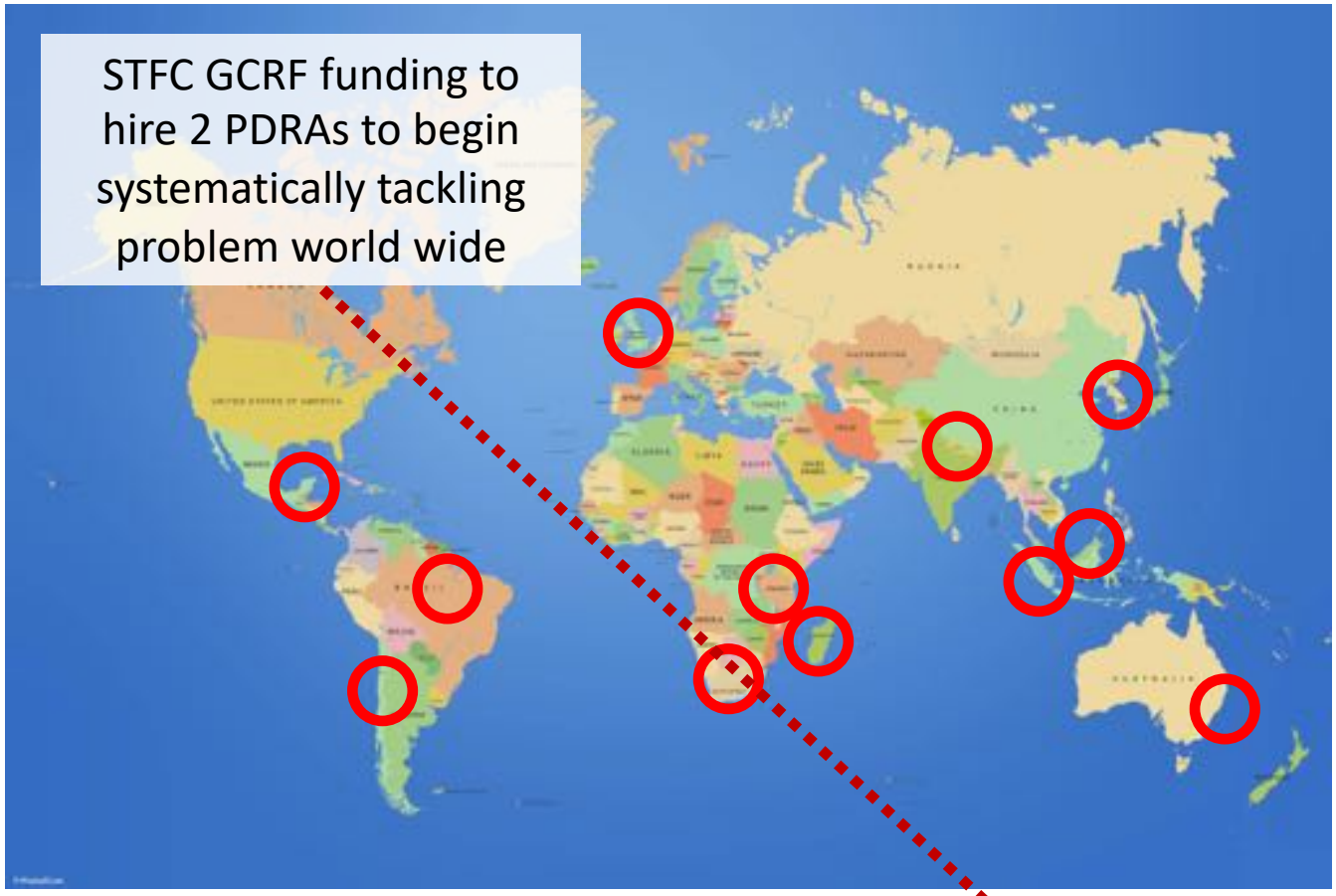
Next steps: helping conservation efforts

Ross McWhirter

Josh Veitch-Michaelis



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Next steps: helping conservation efforts

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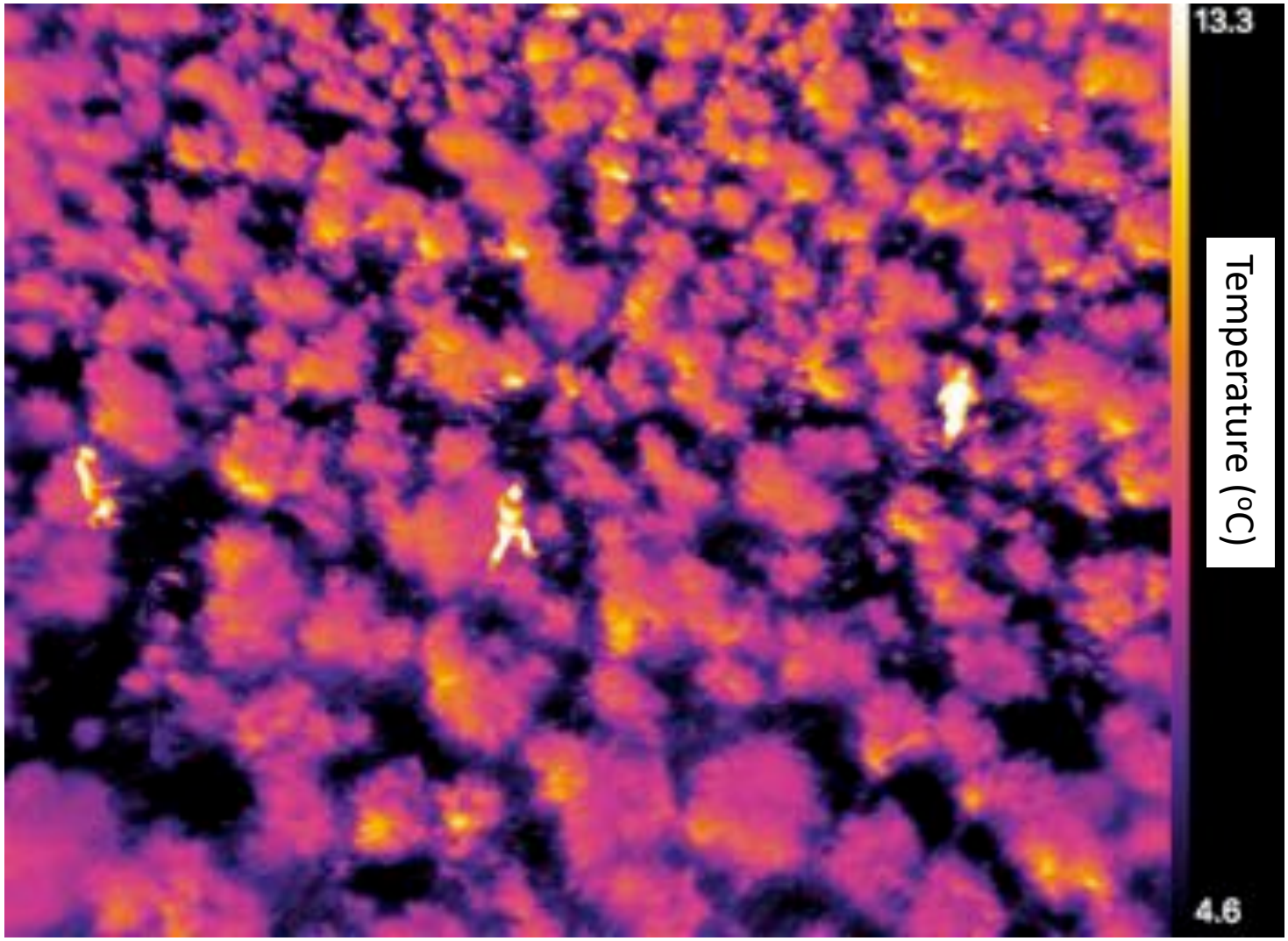
We're hunting rabbits…



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Next steps: helping conservation efforts

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Next steps: helping conservation efforts

The New York Times

BBC

theguardian

Discovery CHANNEL

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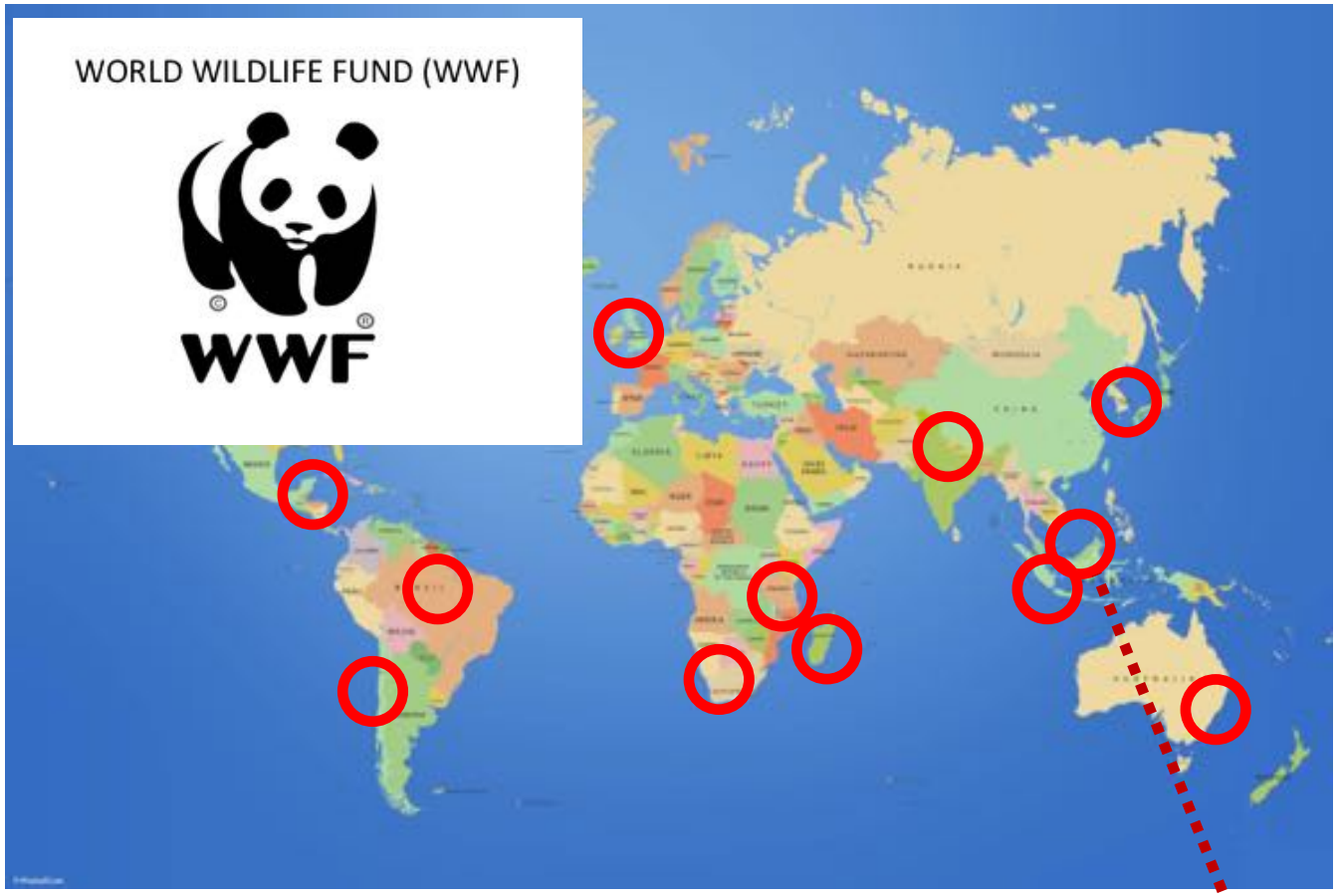

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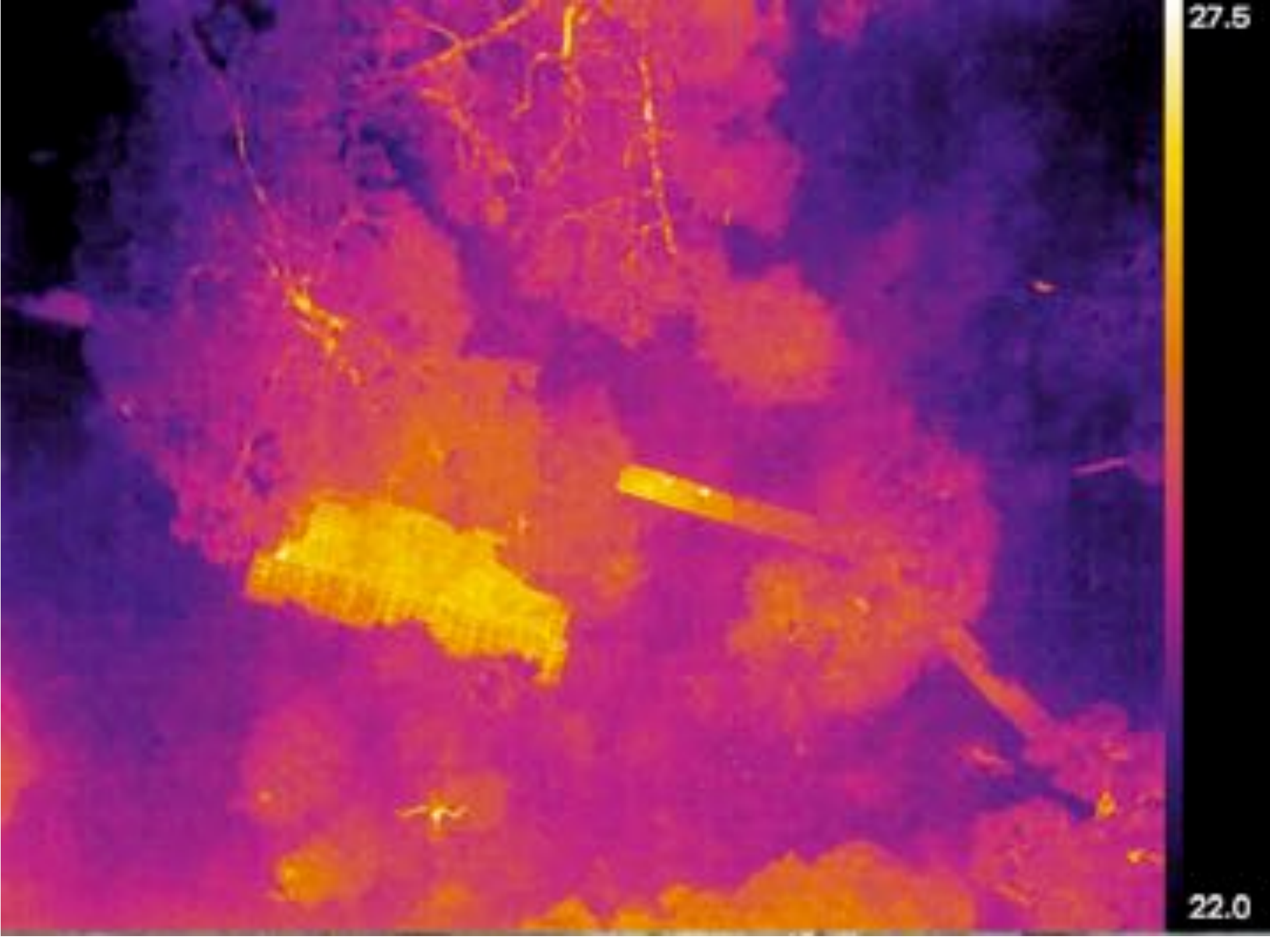
Next steps: helping conservation efforts

WORLD WILDLIFE FUND (WWF)

WWF

2014 2015 2016 2017 2018 2019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Next steps: helping conservation efforts

WORLD WILDLIFE FUND (WWF)

WWF

2014 2015 2016 2017 2018 2019

Next steps: helping conservation efforts

WORLD WILDLIFE FUND (WWF)

WWF

BBC

BBC 2 nature program in spring 2019

2014 2015 2016 2017 2018 2019

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WORLD WILDLIFE FUND (WWF)

WWF

BBC

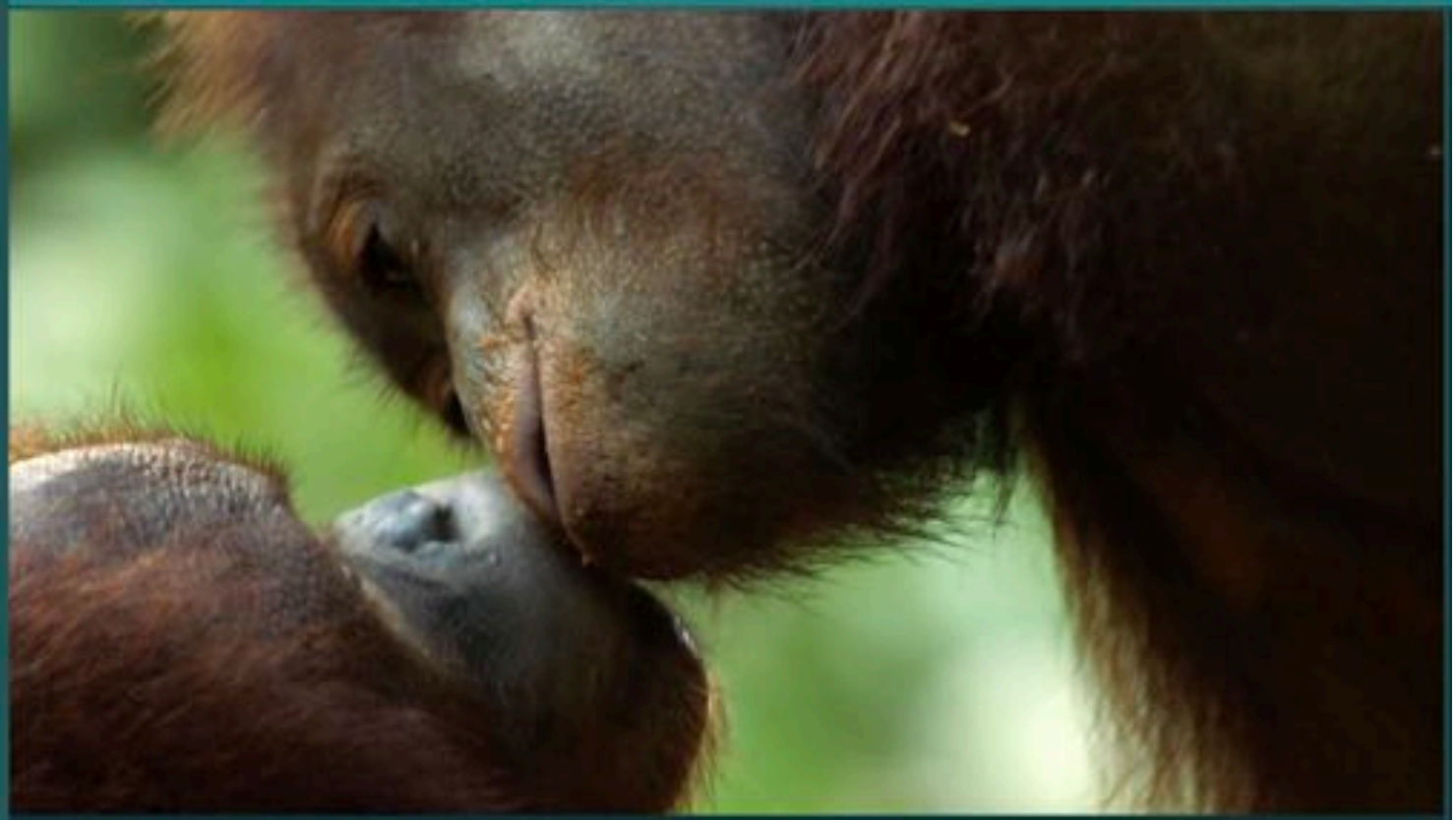
BBC 2 nature program in spring 2019

2014

BBC | Your account | Home | News | Sport | Reel | Work

TWO Equator from the Air

Home Episodes Clips



In a defining moment for the natural world, Gordon Buchanan makes an epic journey round the equator - taking to the skies with experts racing to protect both wildlife and people.

Steve

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Next steps: helping conservation efforts

2014 2015 2016 2017 2018 2019

Next steps: helping conservation efforts

Temitope Sam-Odusina

2014 2015 2016 2017 2018 2019

Steve Longmore

LIVERPOOL JOHN MOORES UNIVERSITY

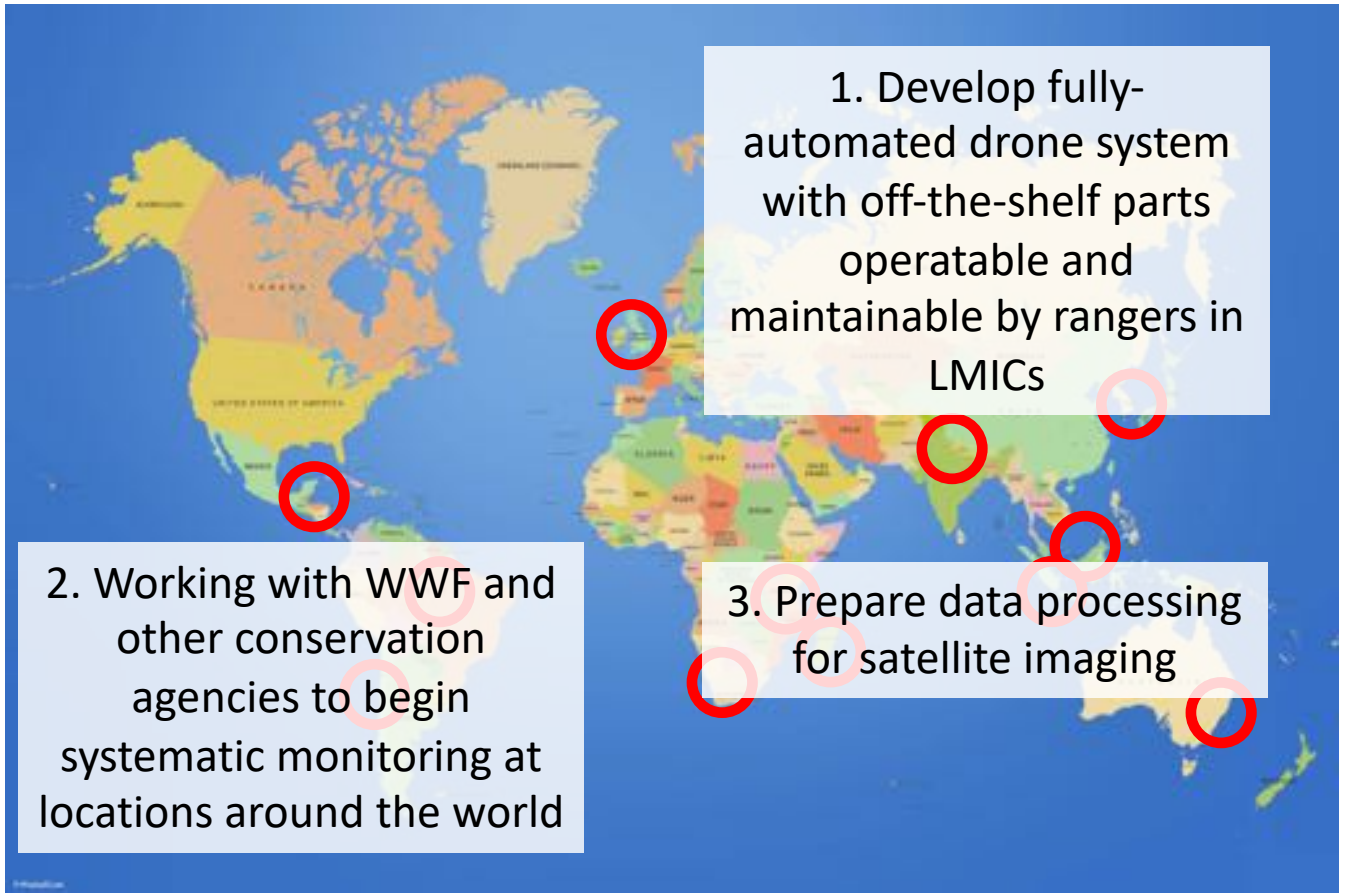
Next steps: helping conservation efforts

2014 2015 2016 2017 2018 2019


Surya


YAMAHA

Next steps: helping conservation efforts



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Long-term goals

1. Fully-automated thermal drone system that can automatically detect and identify animals/fires, geotag their location and send cutout images back the ground.

2. Web-based system to which users can upload data, that will process the data and automatically identify different animal species or fires in the data, and send the results back to the user

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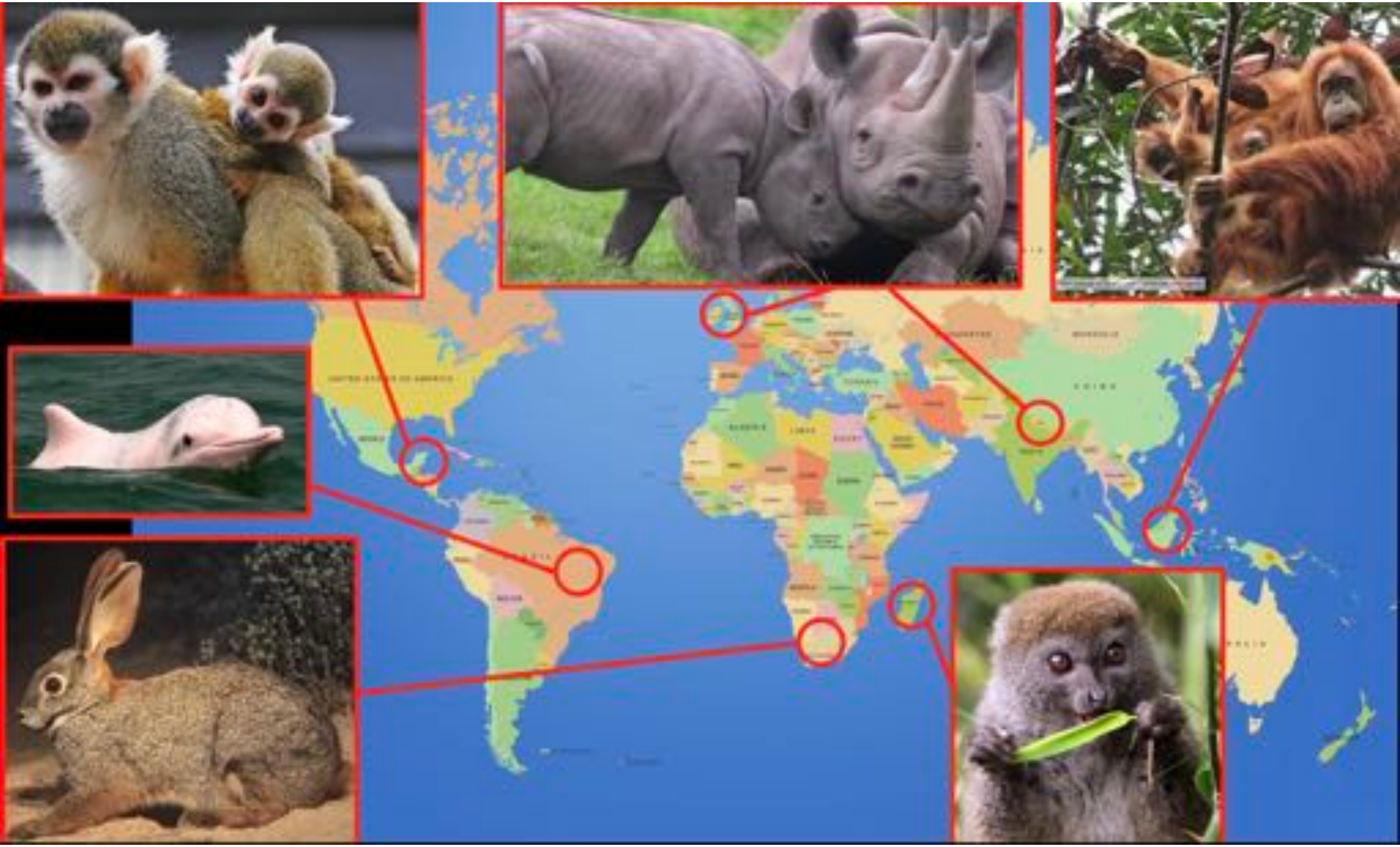
Intermediate outcomes



Intermediate outcomes

1. Longmore+17 → initial demonstration of astro + machine learning animal/human thermal detection

2. Burke+18,19 → using (astro)physics to optimize thermal drone observations for animal surveys

3. Rashman+18 → adapting thermal tech and astro techniques for astro-ecology

4. Burke+19 → pilot study quantifying detection completeness for peat fires in Indonesia

5. Burke+19 → Field demonstration of astro-ecology techniques to detect Orangutans in Borneo

6. Spaan+19 → Field demonstration in Mexico quantifying improvement thermal drones offer for spider monkey surveys

Intermediate outcomes

Collaboration with WWF in Borneo – improved efficiency for orangutan detection.

Intermediate outcomes

Many collaborators using online system

Goal = quantify increased efficiency in determining animal number densities

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Intermediate outcomes

Working with search and rescue organisations in the UK to try and use system to save lives

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Intermediate outcomes

Working with conservation agencies for automatic poacher detection

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System development

1. **Thermal camera development** *(Maisie Rashman, Iain Steele)*
   - Stability, improved noise characteristics, Absolute temperature calibration
2. **Observing guide** *(Claire Burke, Andy Symons)*
3. **Environment effects** *(Claire Burke)*
   - Climate → ground temperature
   - Obscuration by vegetation
   - Radiative transfer modelling through atmosphere
4. **Tracking objects in footage** *(Yifan Zhou, Simon Maskell)*
5. **Training CNNs** *(Ross McWhirter, Paul Fergus, Carl Chalmers, Josh Veitch-Michaelis)*
   - Transfer learning
   - Citizen science → "Galaxy Zoo" project
   - Multi-wavelength → use thermal to automate labelling
6. **Adding "Astrophysics" knowledge**
   - Geometry → size of animals to constrain
   - Background subtraction
7. **Automated drone system** *(Josh Veitch-Michaelis, Owen McAree)*
   - Data flow: camera → on-board detection/identification → send cutout to ground
   - Smart flights
8. **Web-based service** *(Carl Chalmers, Paul Fergus, Marco Lam)*
   - Database, metadata, security
9. **Other use cases** (e.g. Search and Rescue, agriculture)

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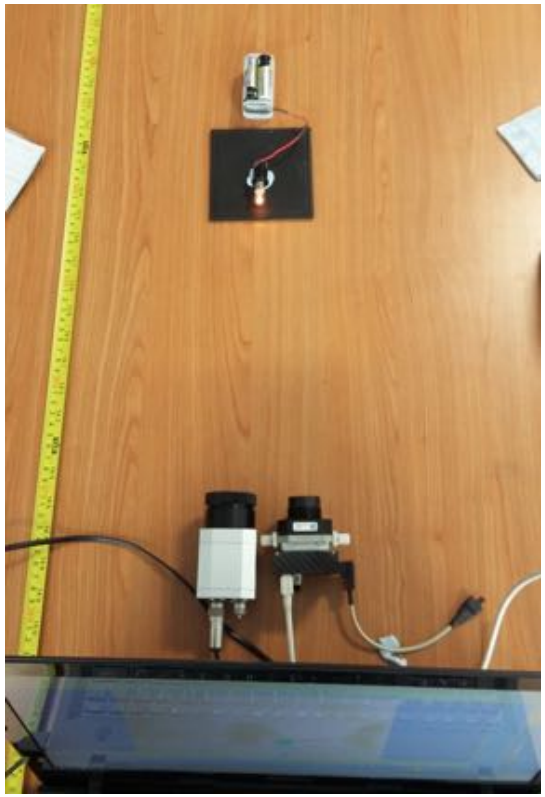
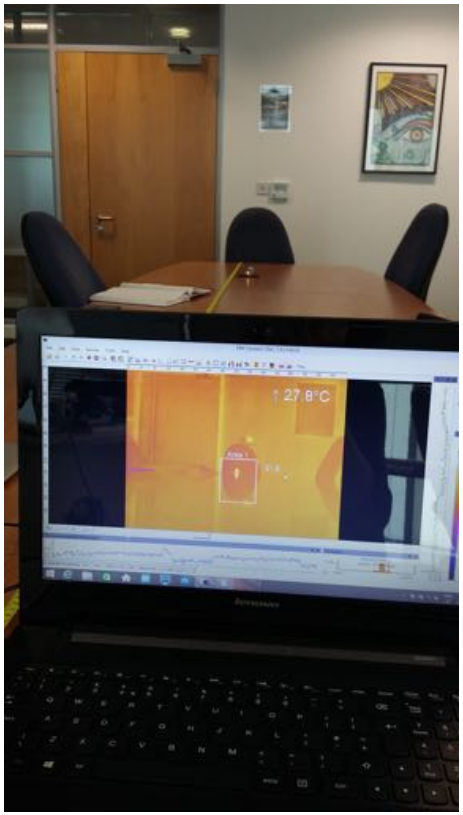
Instrumentation

- Thermal infrared: 8-14 micron
- Flir Tau2 640
  - 640 x 512 pixels :
    - 45 x 37 degrees - 13 mm lens
    - 32 x 26 degrees - 19 mm lens
- Accuracy: +/- 5%
- Micro bolometers different to CCDs
- More affordable for our system

Testing

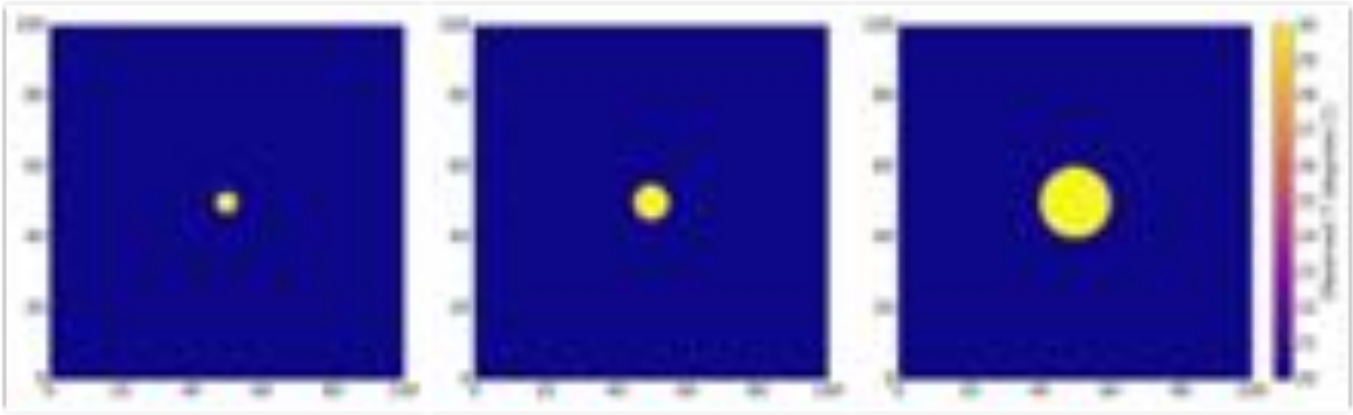
How accurately can we measure absolute temperature?

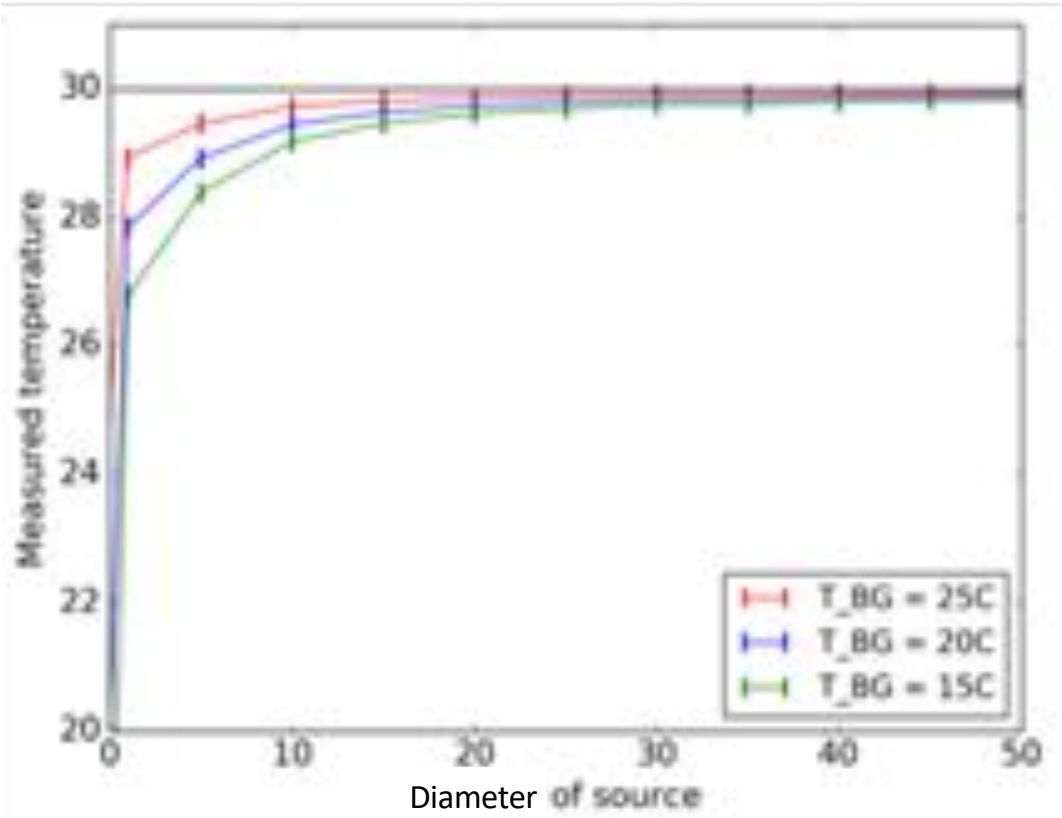


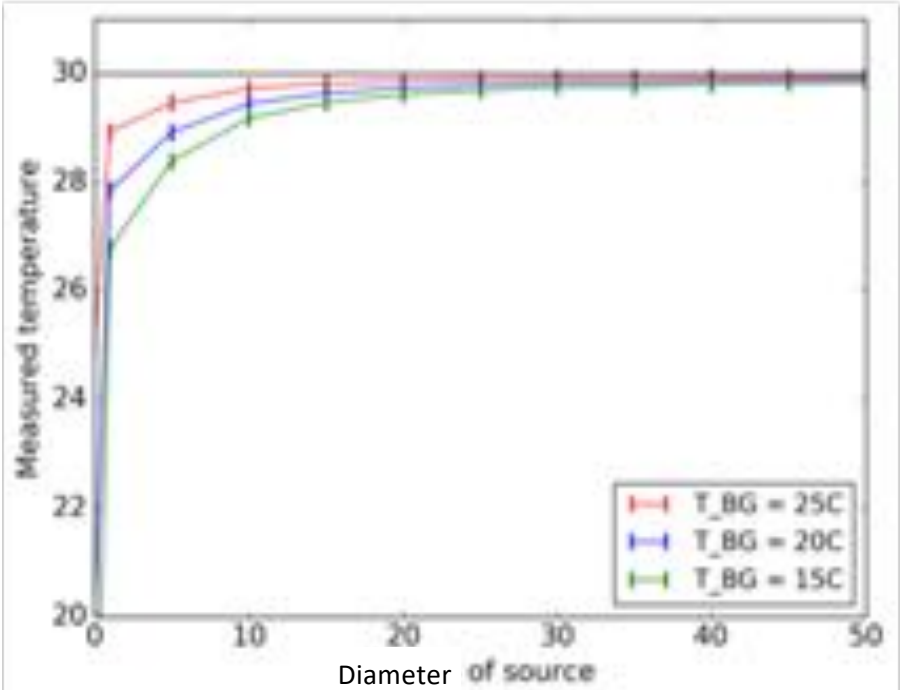


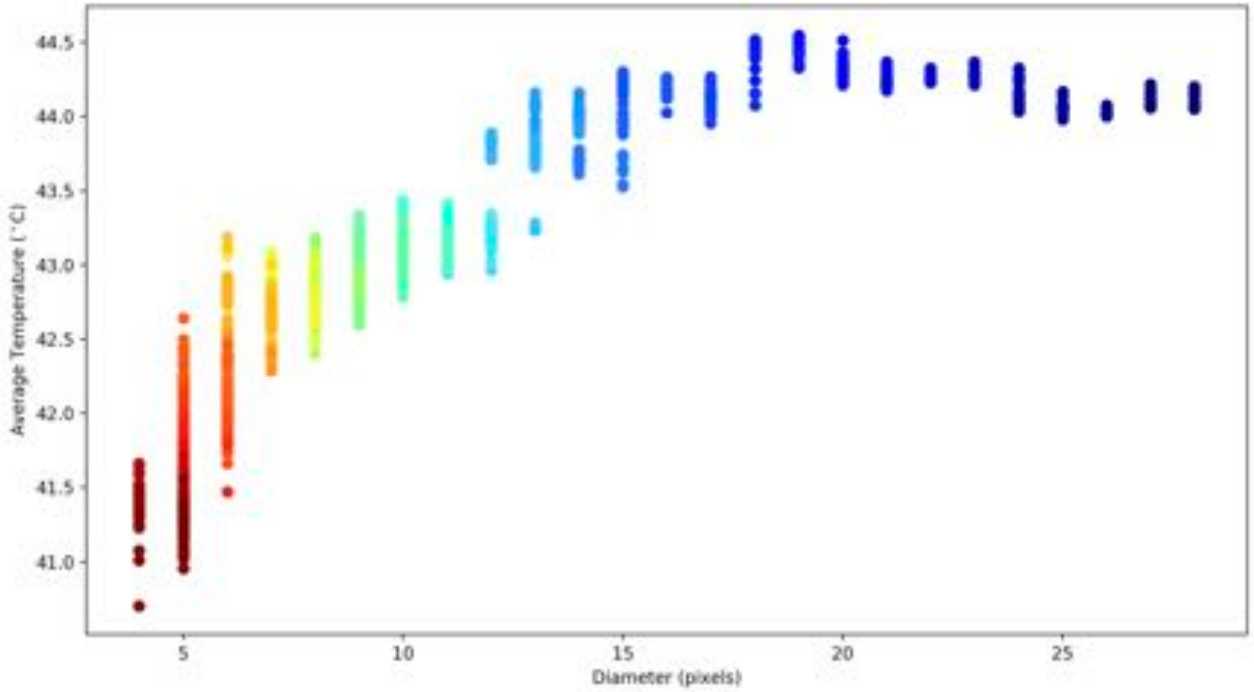
Burke et al 2018b

$$T_{obs} = \frac{T_A A_A + T_B A_B + T_C A_C + ...}{A_{total}}$$

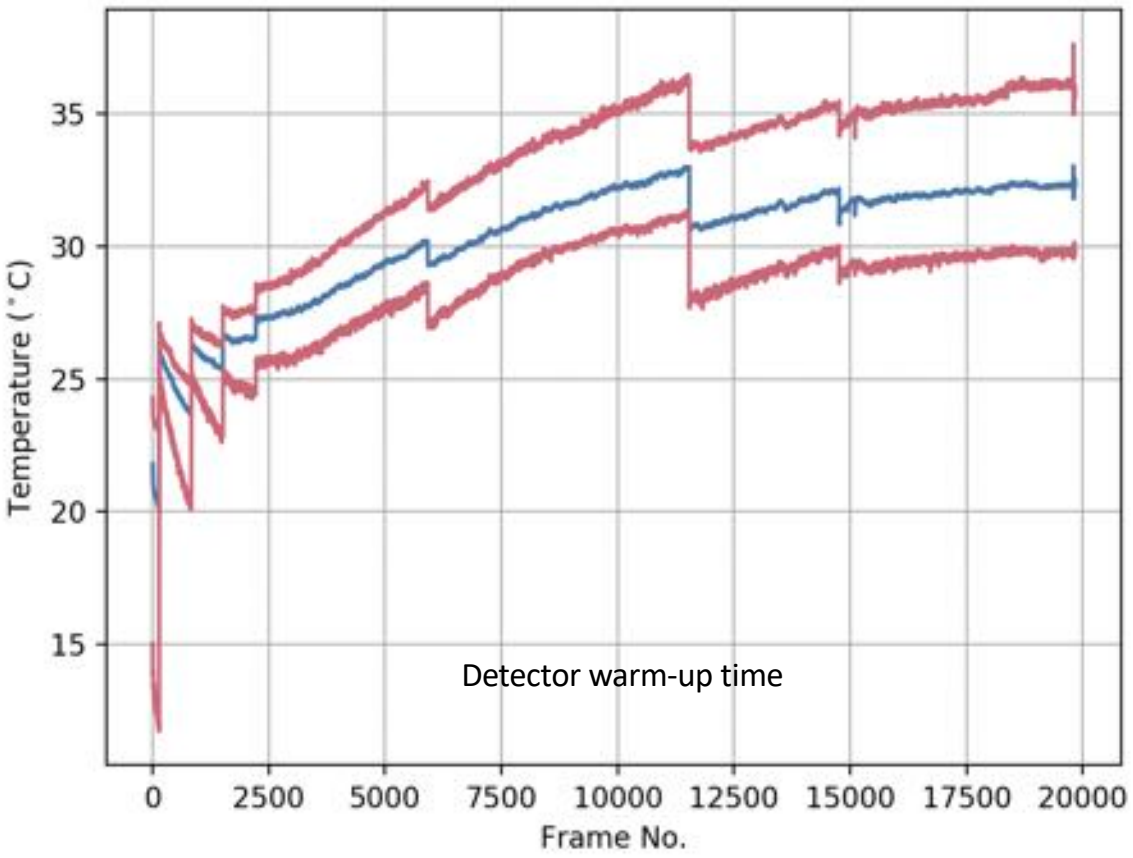





Measured temperature
30
28
26
24
22
20
0
10
20
30
40
50
T_BG = 25C
T_BG = 20C
T_BG = 15C
Diameter of source


Average Temperature (°C)
44.5
44.0
43.5
43.0
42.5
42.0
41.5
41.0
5
10
15
20
25
Diameter (pixels)

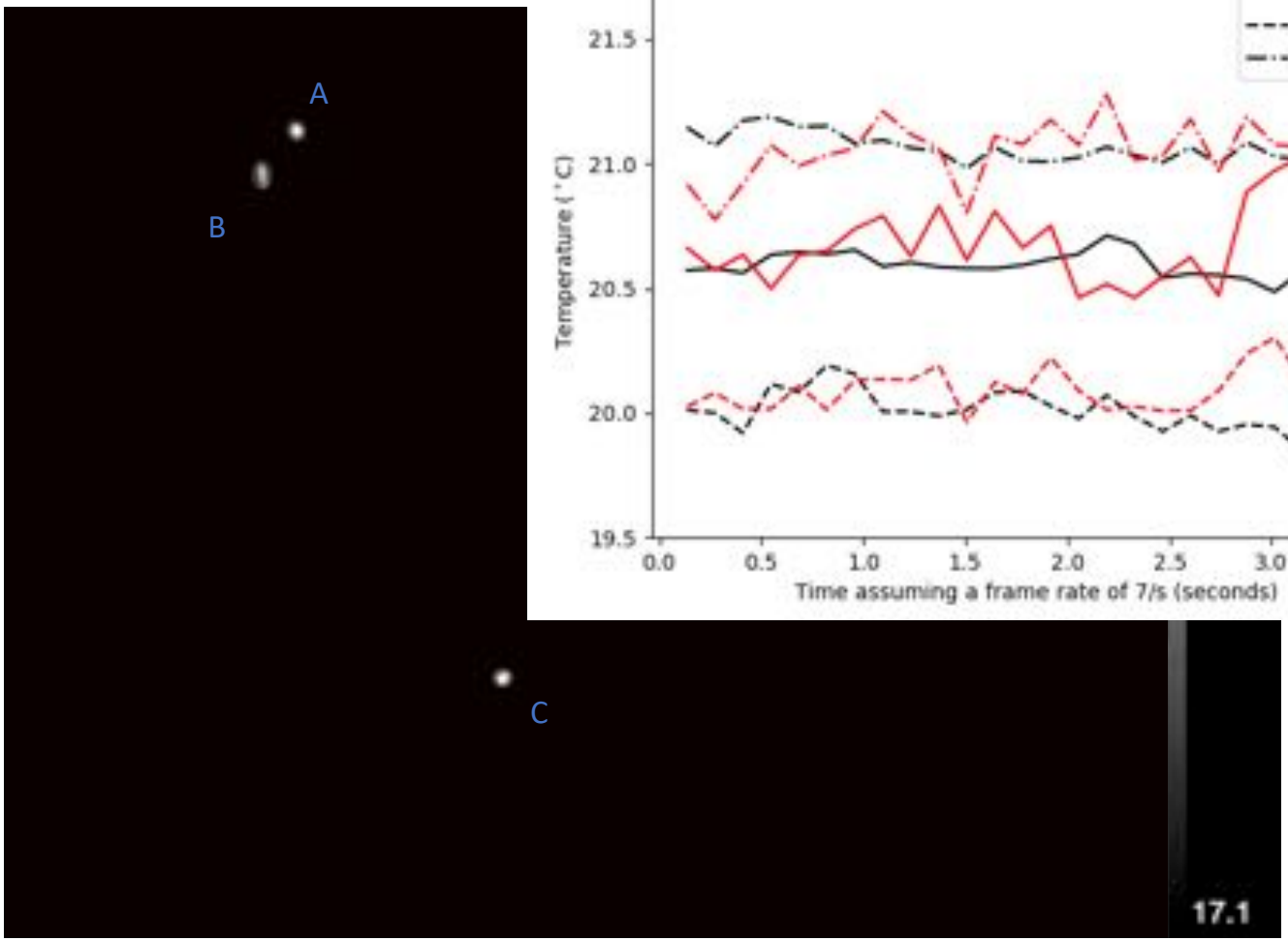
How stable is measured temperature?



Rashman et al 2019 in prep

Also, other sources of systematic error;
Flat fielding
Lens ‘roll off’
Heating of camera housing
Internal noise
…

Proof of concept – poachers



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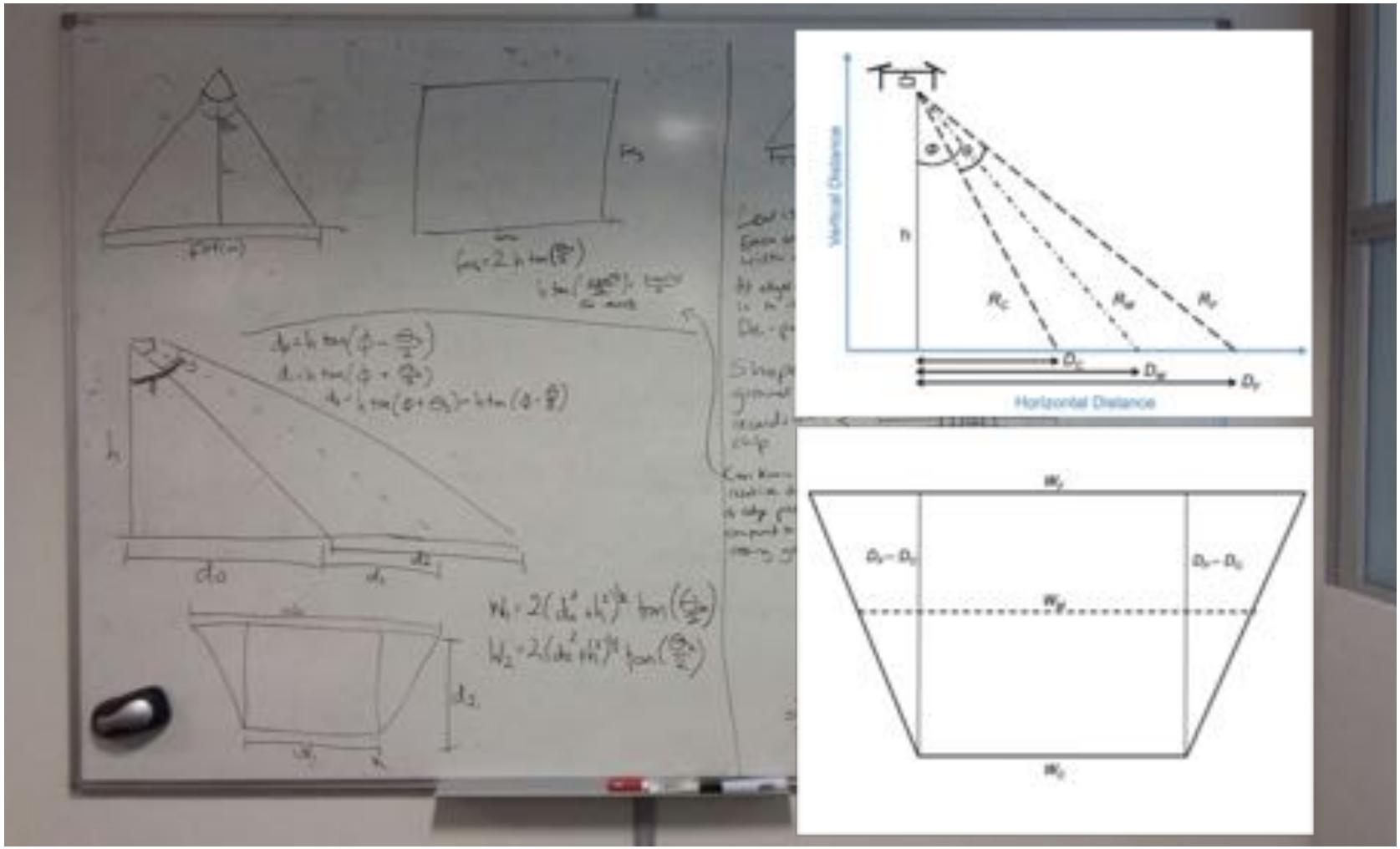
Longmore et al. 2017, Burke et al 2018b

How best to observe?



Burke et al 2018b

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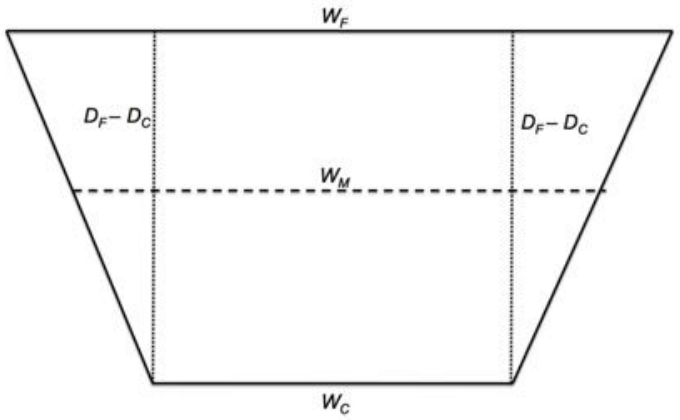

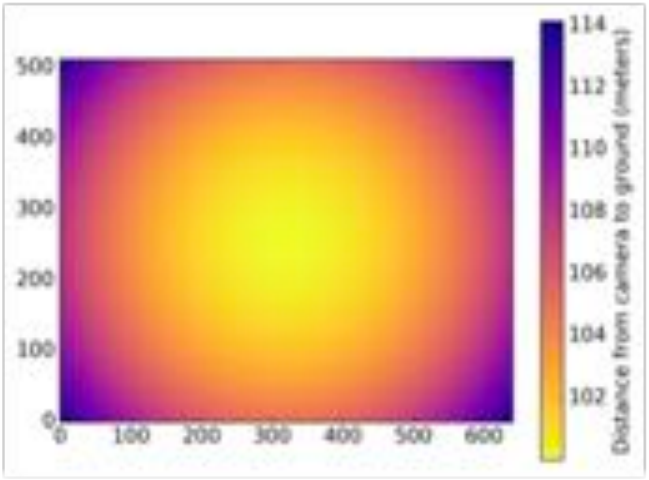

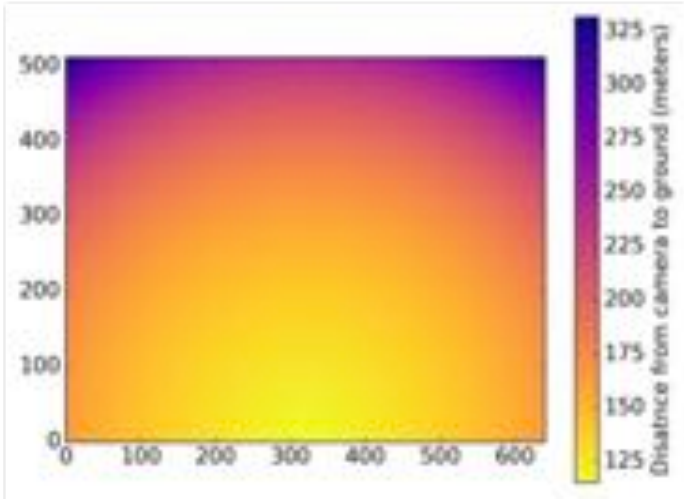

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If you use our calculator to help you publish something, **please cite us.**

Details of how this site works can also be found in this paper:
Burke et al., 2018, International Journal of Remote Sensing (currently in review)

Environmental conditions at your location

LATITUDE, LONGITUDE:

5.853431, 117.957794

INITIATE

Flight setup

Camera detials:

Camera resolution (Pixels)

640 x 512

Angular field of view (Degrees)

45 x 37

Animal or object details:

Animal length - aerial perspective (Metres)

1

Required animal size in data (Pixels)

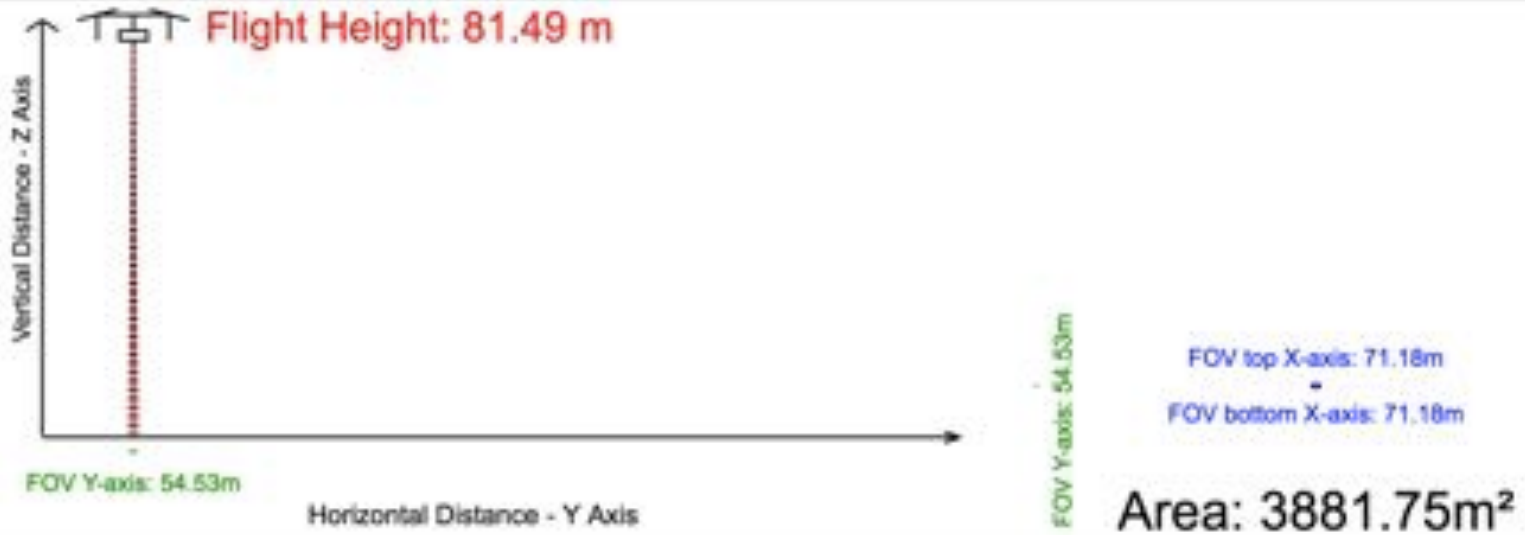
10

INITIATE

Camera Angle

0

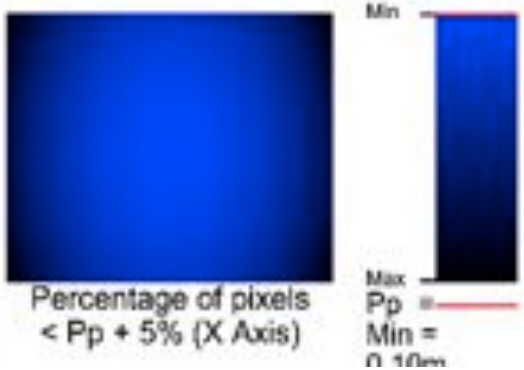
UAV Flight Height and Field of View (FOV) on Ground



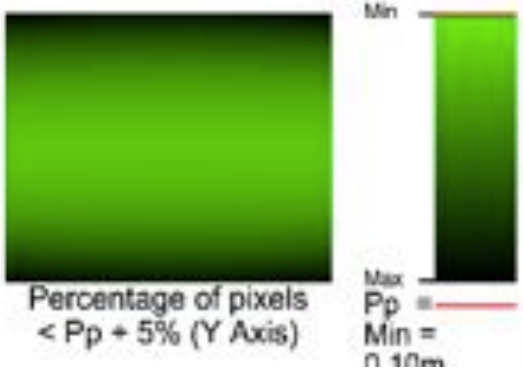
Area in data where pixel scale (Pp = 0.1 meters per pixel) is within 5% of specified value.

Useful if planning orthomosaics.

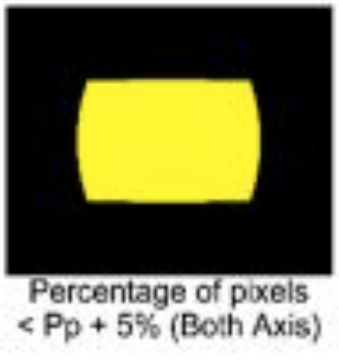
Pixels within 5% of Pp on X Axis



Pixels within 5% of Pp on Y Axis



Pixels within 5% of Pp on Both Axis



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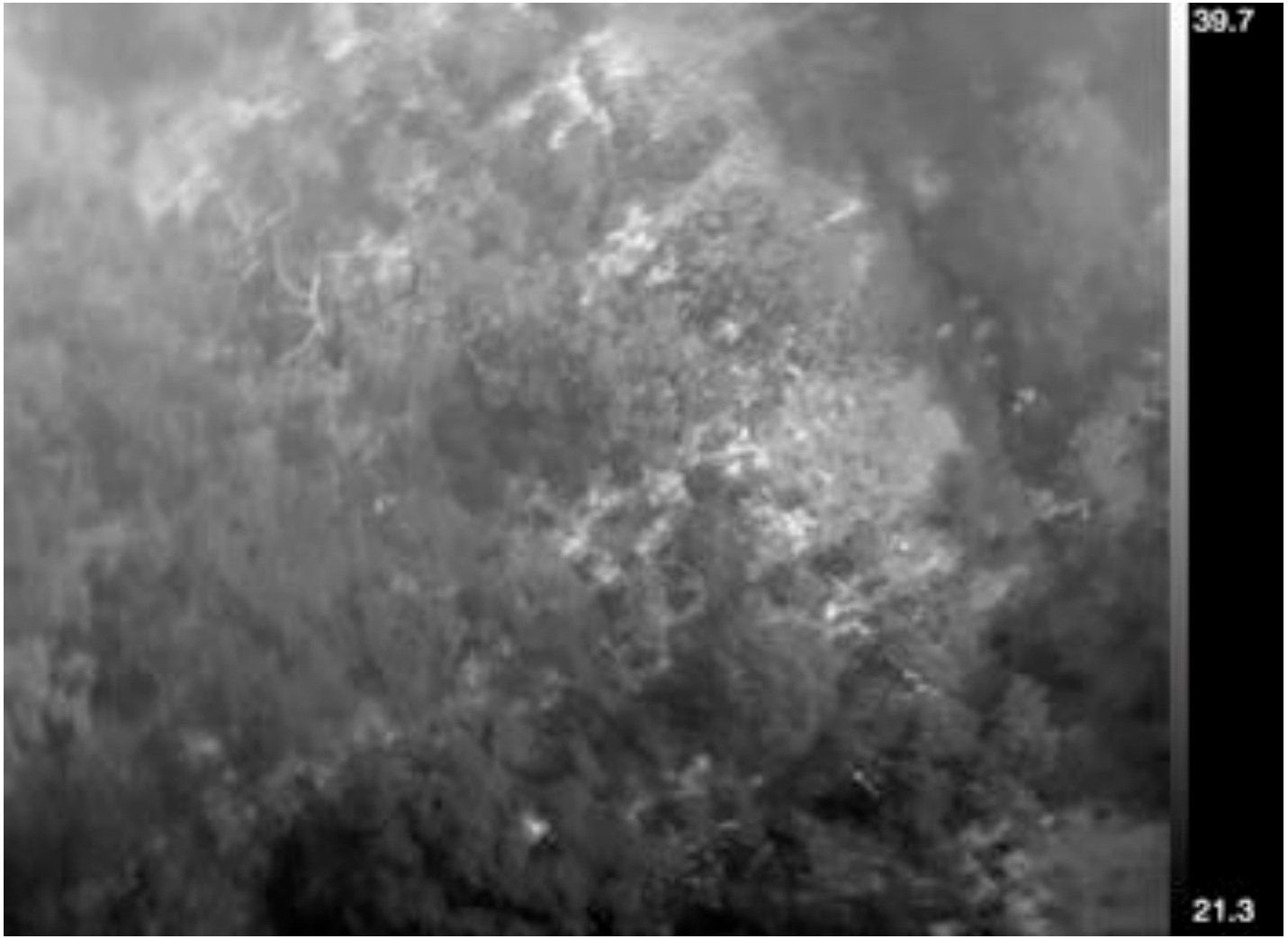
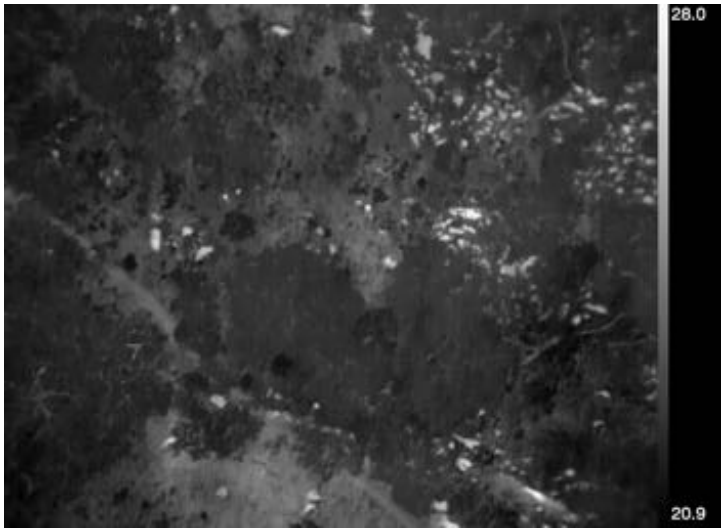
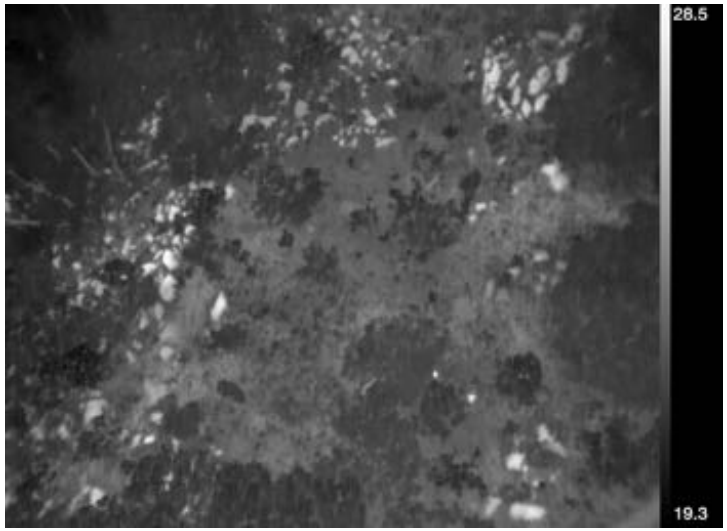
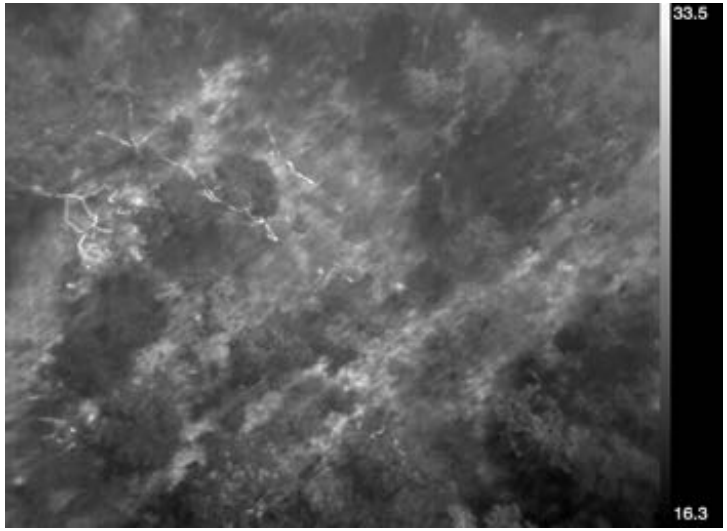
Environmental “issues”



Spot the poachers







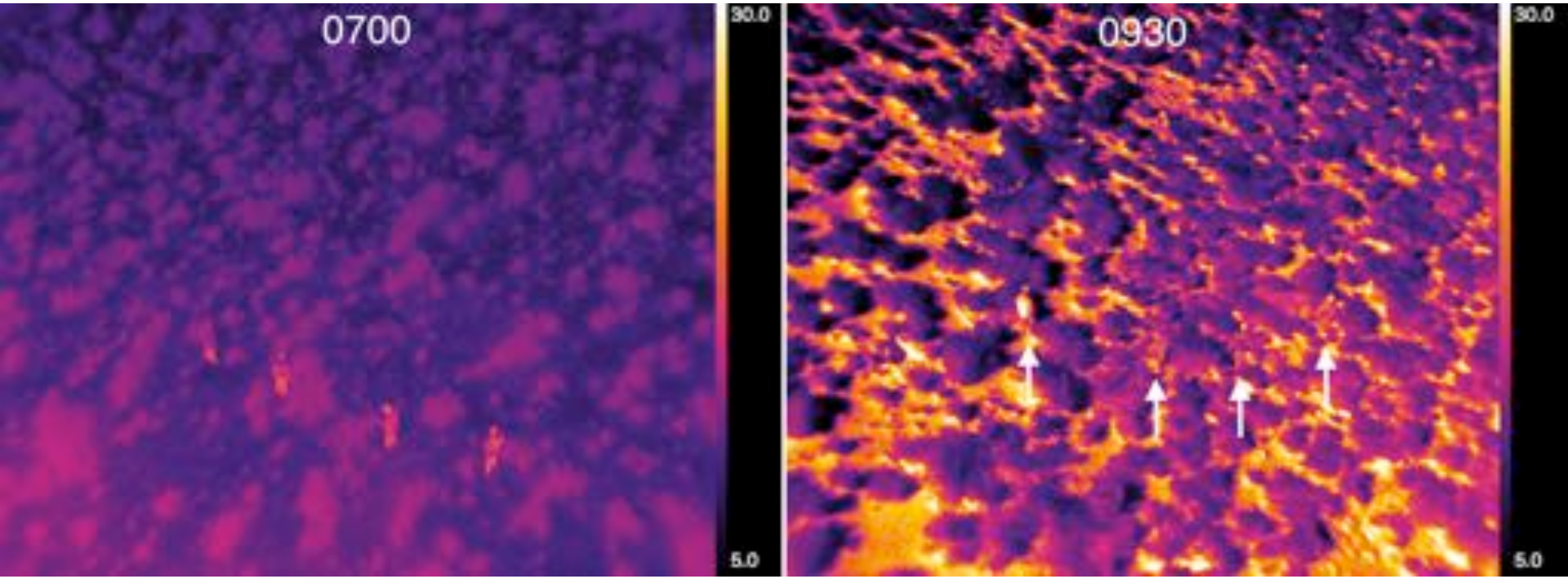
False detections
‘Bright compact objects’
Rocks
Tree branches
Bodies of water

Sources of thermal radiation

Other ‘false detections’

Spot the poachers II

"Issues" with the ground



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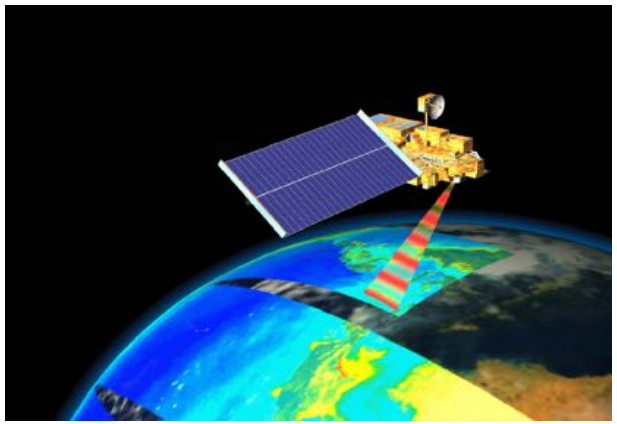
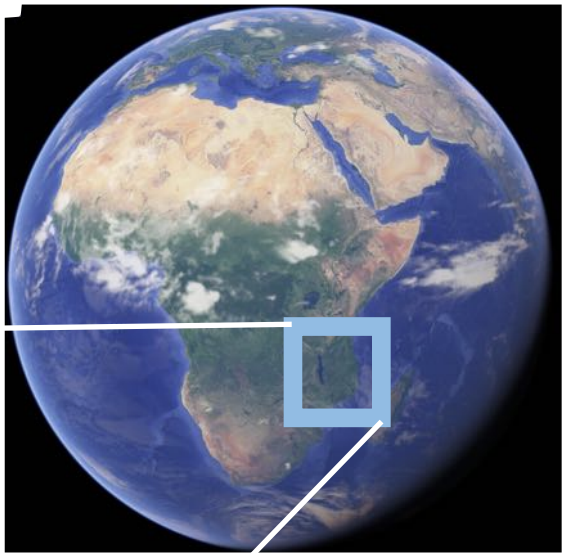
Understanding the background



Climate monitoring satellites

MODIS

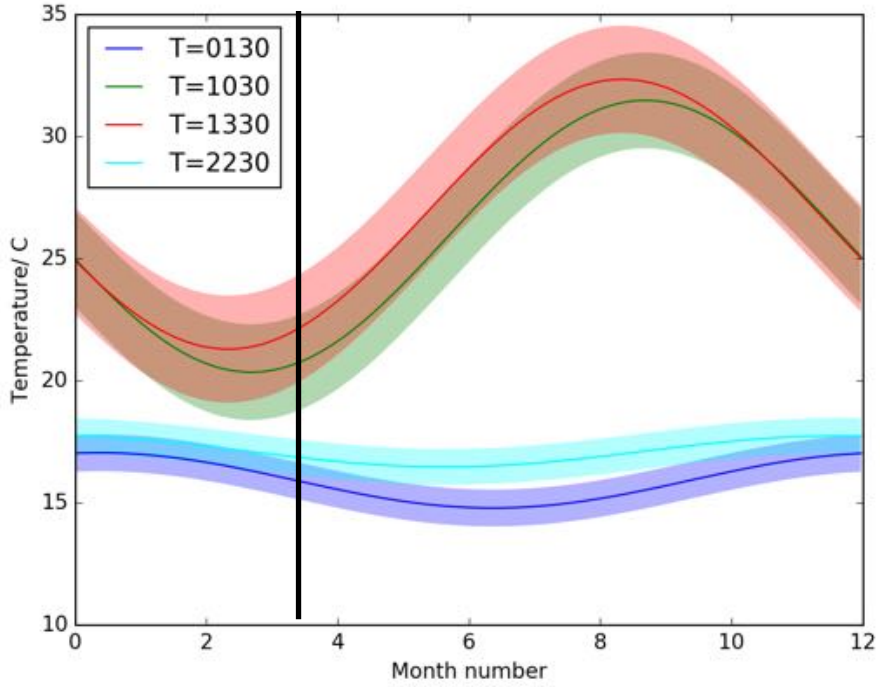


Ugalla Park, Tanzania

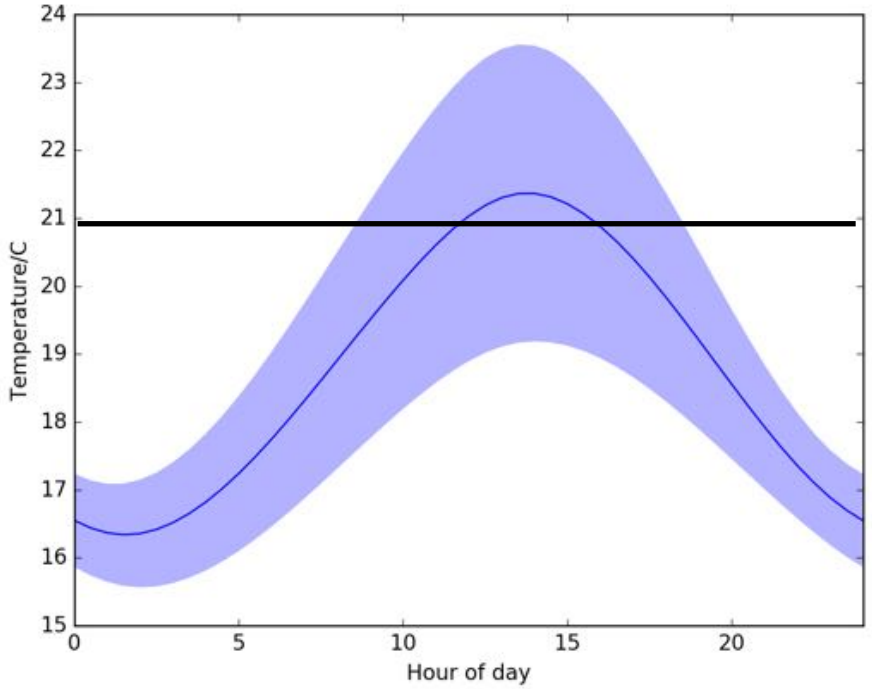
1km scale

Predicting the ground temperature

Annual land surface temperature climatology

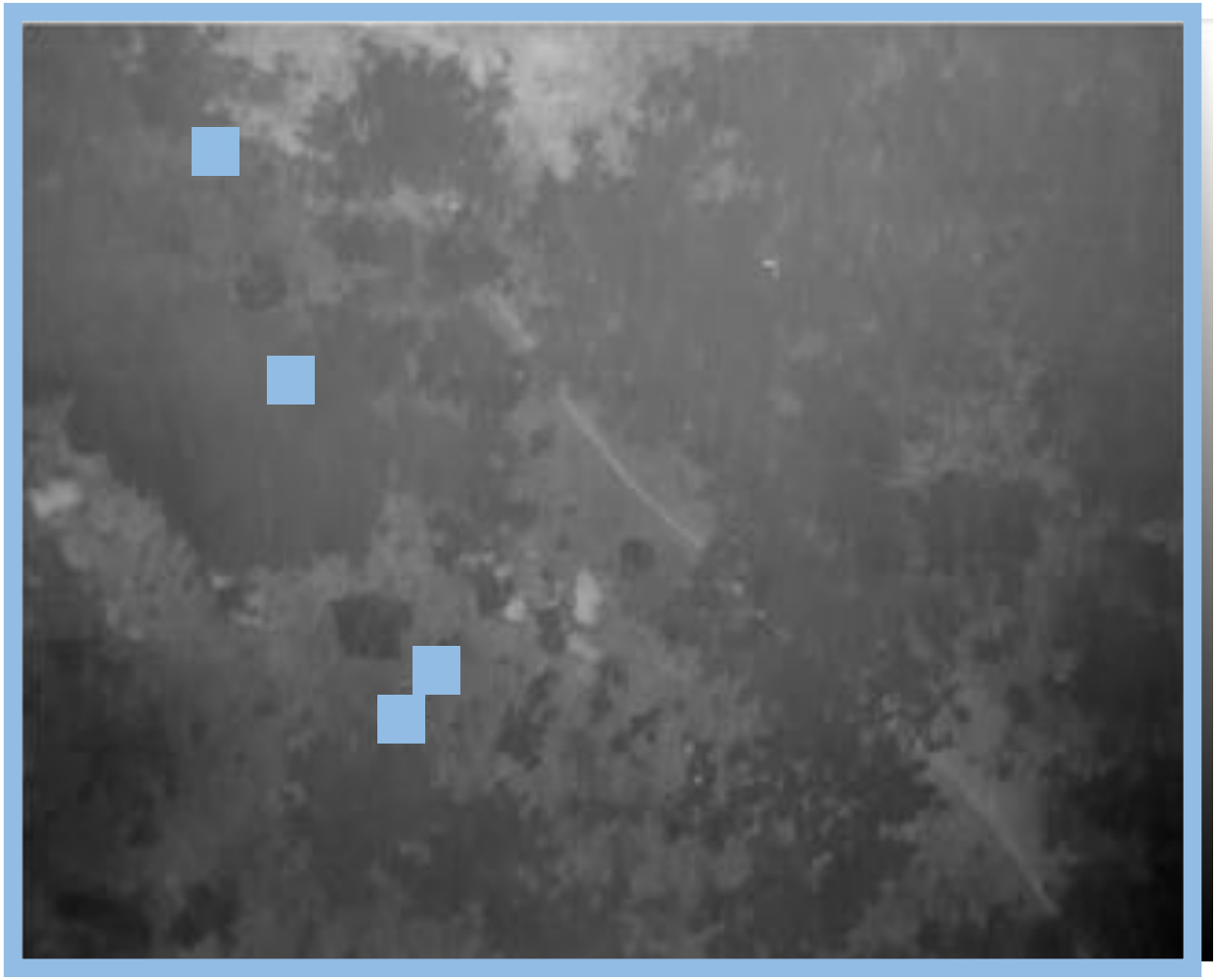


Daily temperature range for mid-March



Burke et al 2018b

Testing our climatology



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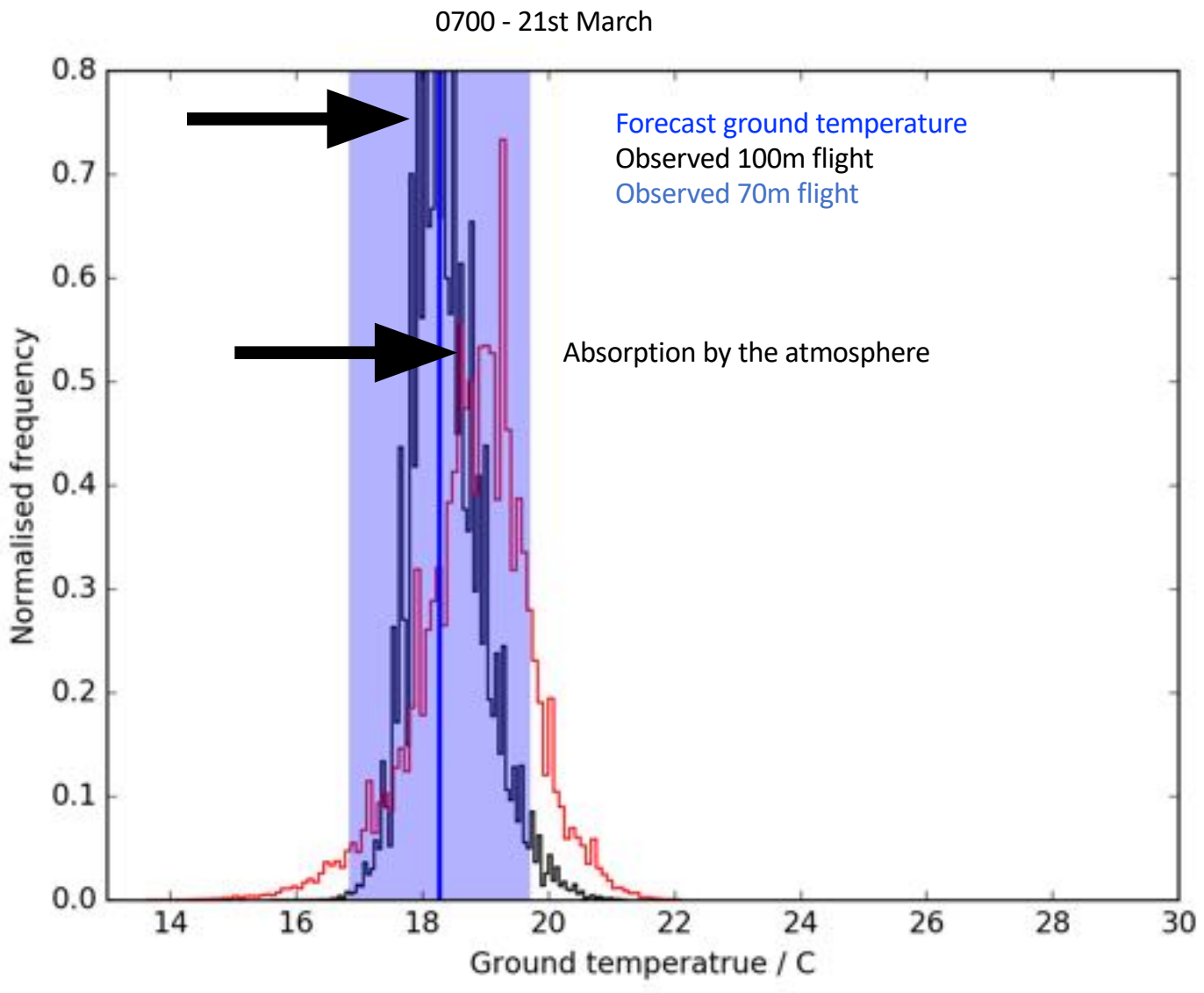
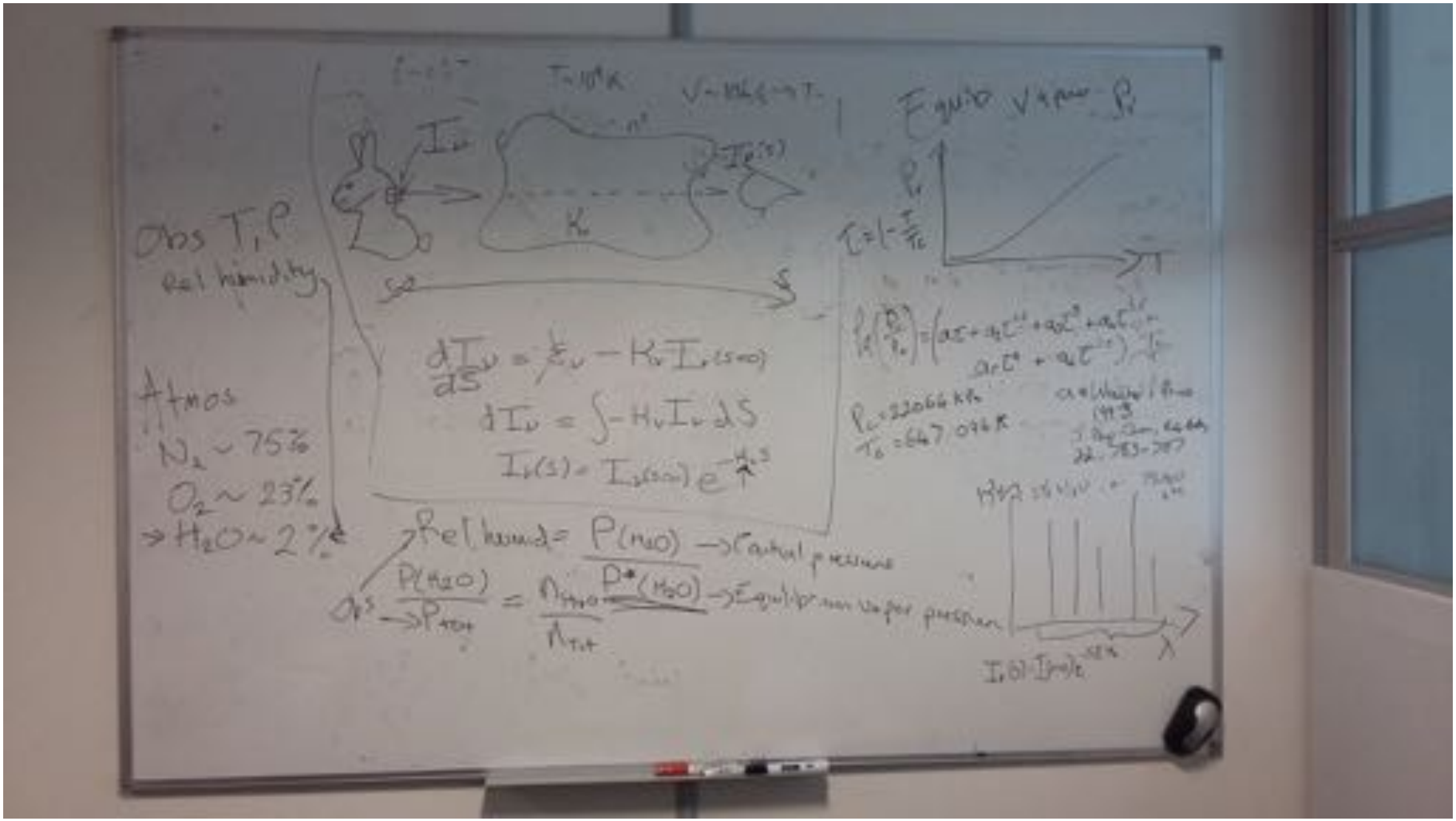


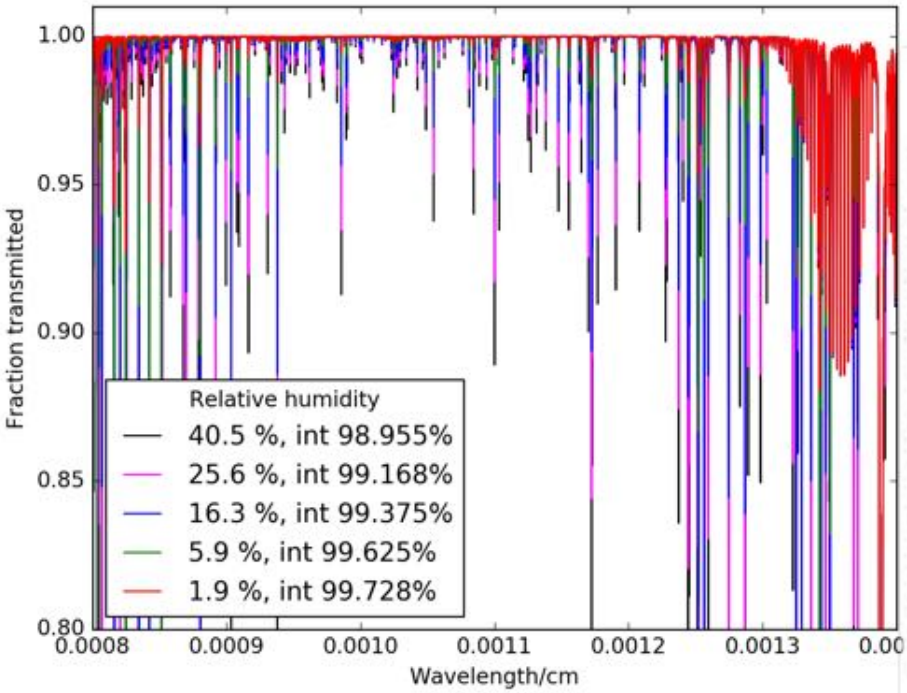
Radiative transfer



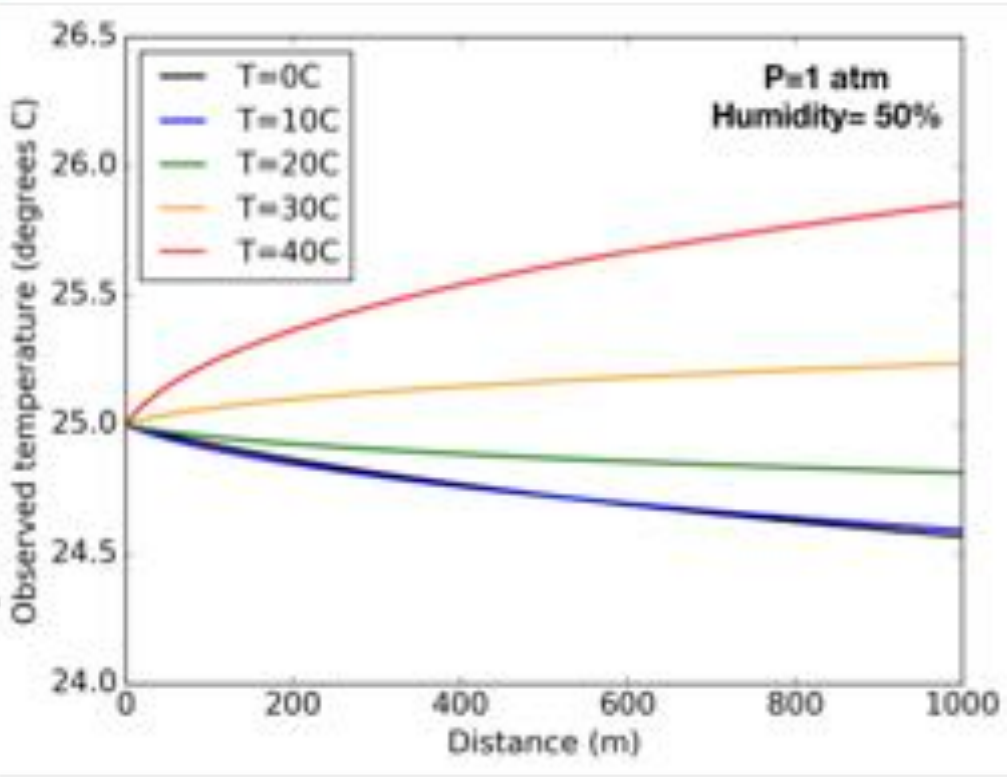
Burke et al 2018b

Radiative transfer

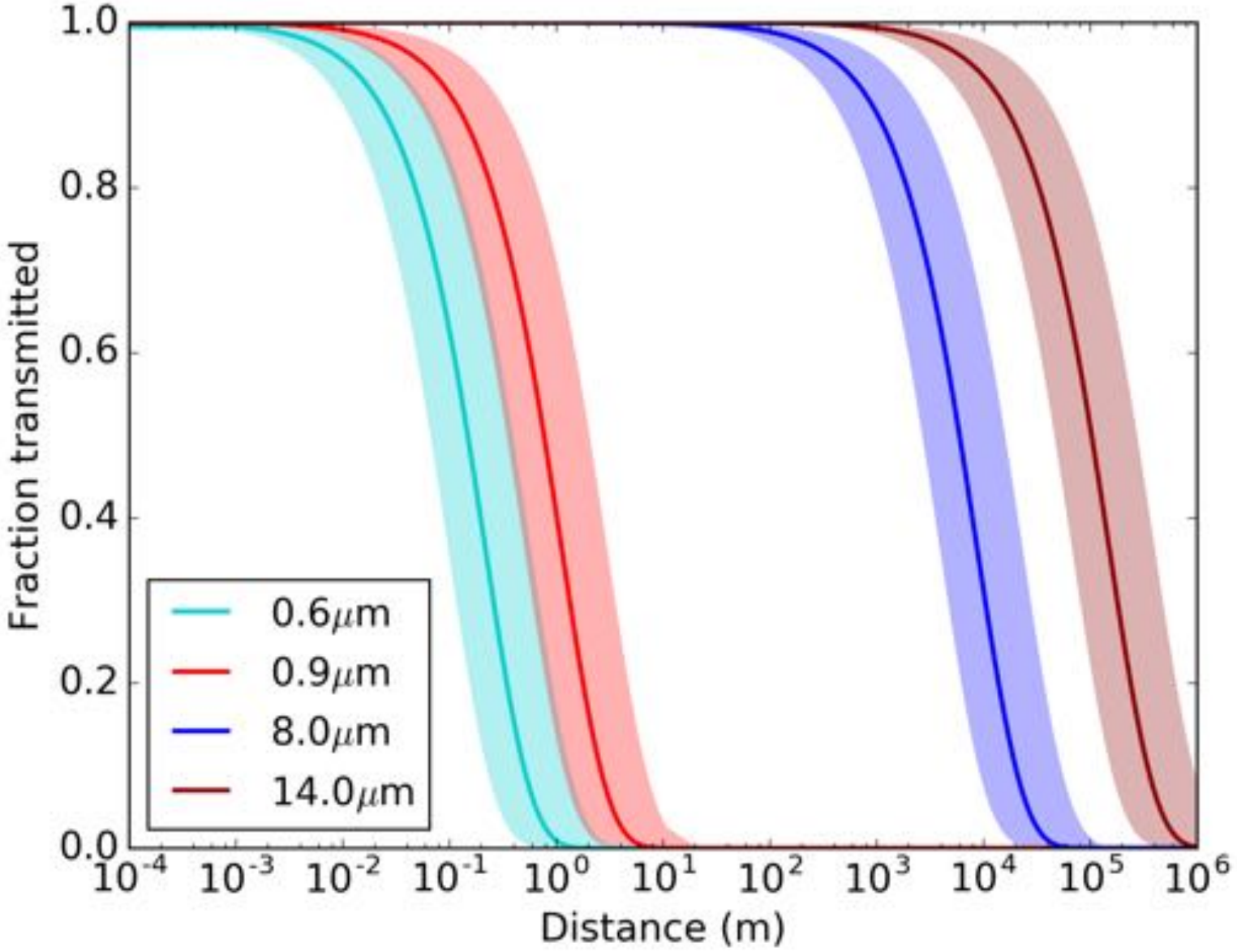
Absorption spectra
8-14 micron
100 meters from source



Absorption is function of;
Distance
Pressure
Temperature
Humidity (composition)

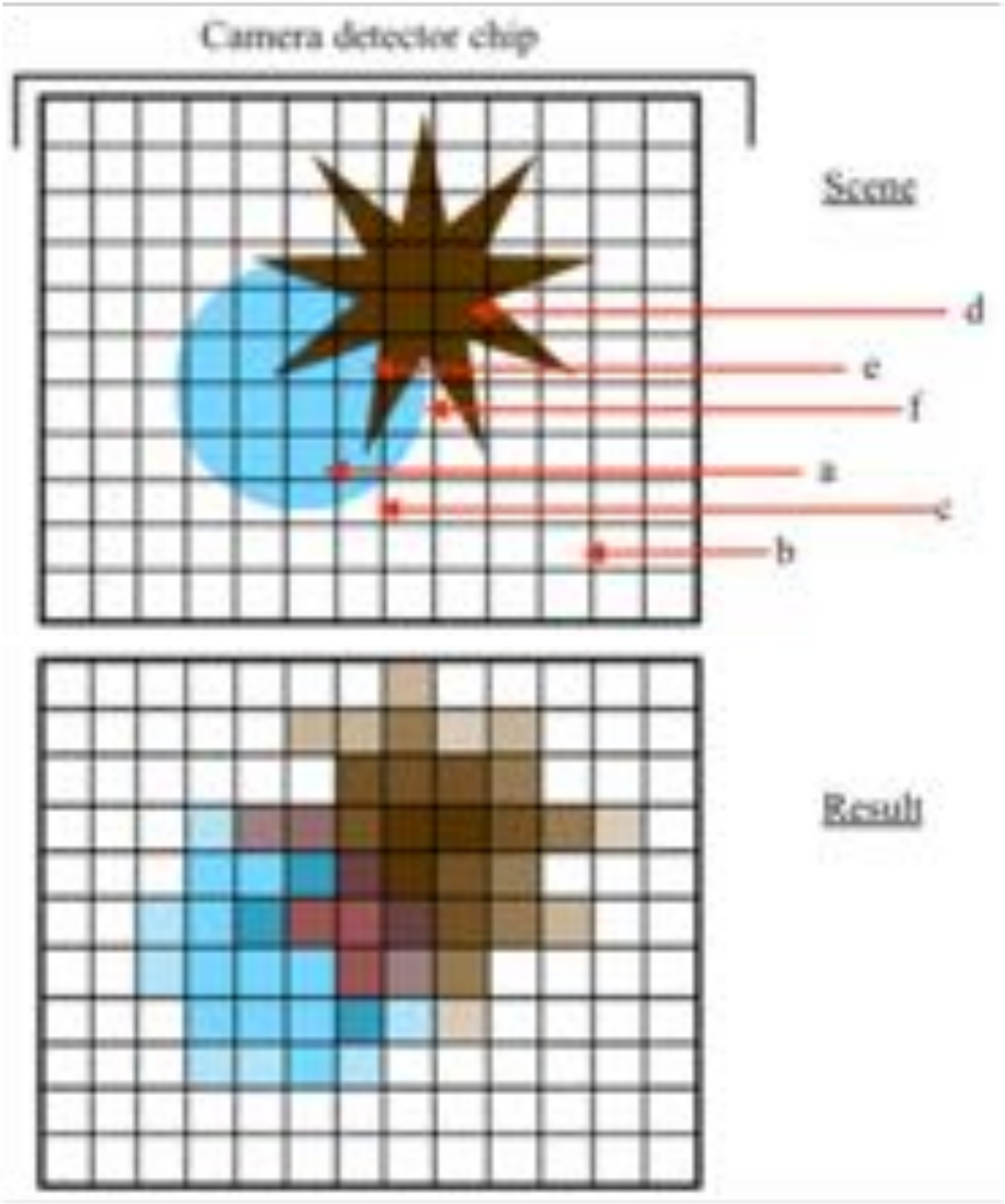


Scattering of photons by water vapour (fog)



Things in the way

Burke et al 2018b



So eventually…

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Automatic poacher detection/identification

Mosaic image and detections --- Red: History detections, Cyan: Current View.

Input Image --- Green: Current Detections (Bright Area)

Yifan Zhou, Simon Maskell (University of Liverpool)

Steve Longmore

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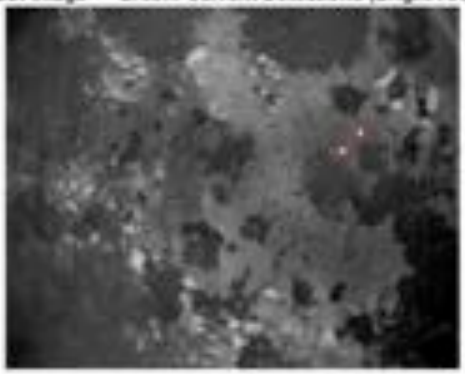

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Credit: Ross McWhirter

Chimp enclosure at Chester Zoo

Object detection and classification in thermal infrared camera data using YOLOv3

Astro-Ecology group

Astrophysics Research Institute

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Rhino paddock at Knowsley Safari

Credit: Josh Veitch-Michaelis

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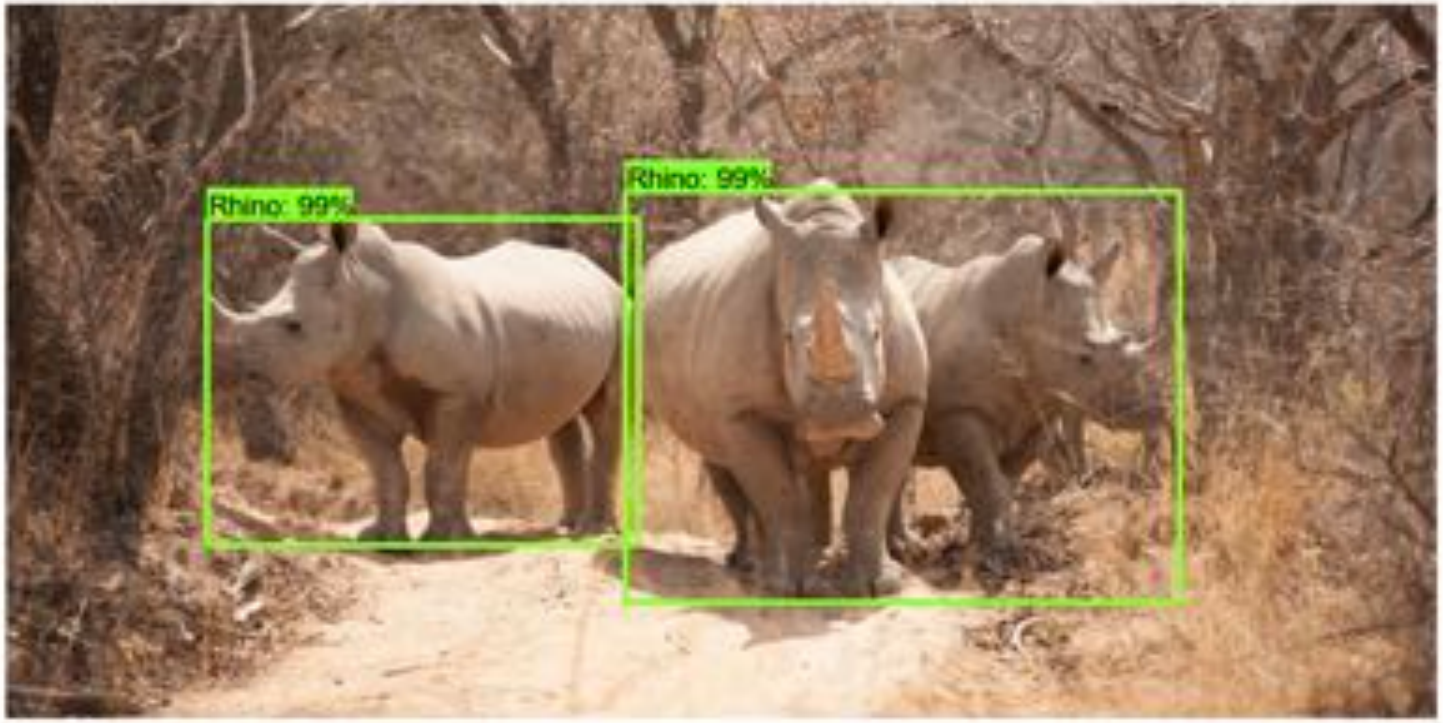
Complete

Result:



File name: rhino.jpg

Grade:[{'id': 1, 'name': 'Rhino'}, {'id': 1, 'name': 'Rhino'}]

Description: No information available for this classification

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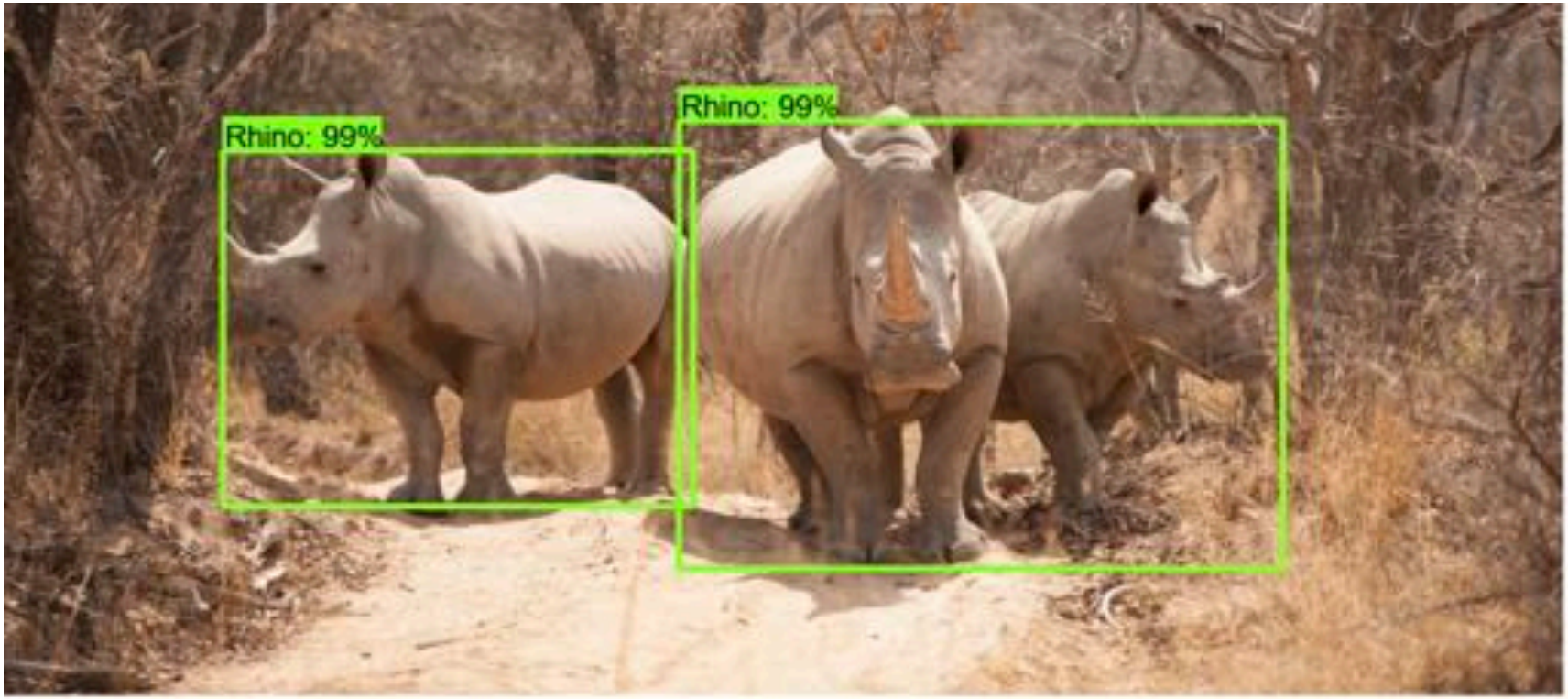

File name: rhino.jpg

Grade:[{'id': 1, 'name': 'Rhino'}, {'id': 1, 'name': 'Rhino'}]

Description: No information available for this classification

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If this result is incorrect, please report it below:

What was wrong? 1 two rhino on the right a

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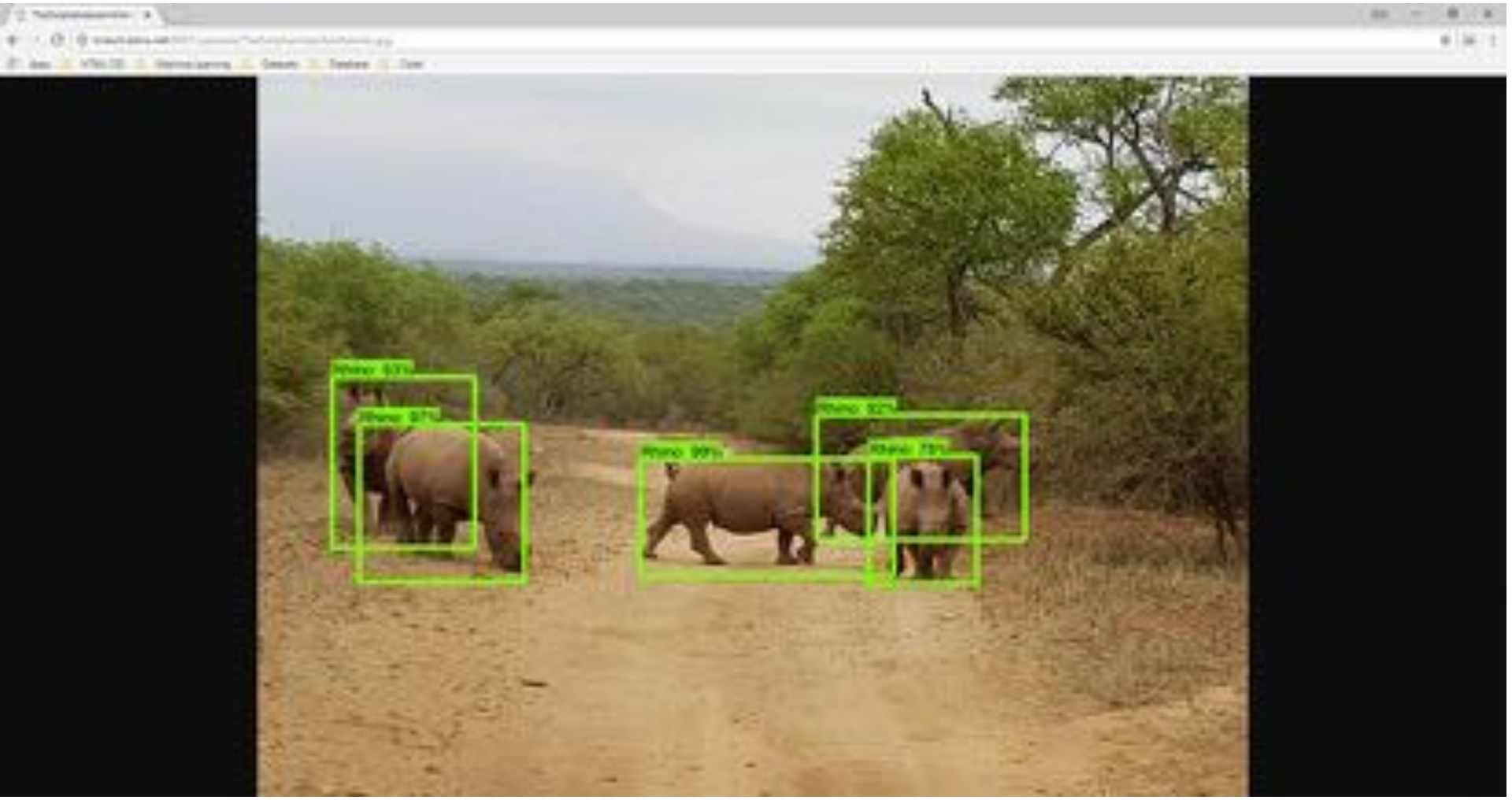
Rhino Object Detection

Model Version: 1 Date:22/06/2018 Epoch:9622


Rhino 97%
Rhino 99%
Rhino 72%

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2. Background/timeline of the project
3. Long-term goals
4. Progress towards long-term goals
5. Questions

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