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Multi-scale observation of surface temperature on Parco delle Biancane and Sasso Pisano (Italy) sites: from space to proximal measurements

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Goal of this work

During a field campaign held on June 2019, the measurement of surface temperature using three different sensor have been collected:

1) ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) satellite data .

2) HyTES airborne sensor

3) UAV thermal camera

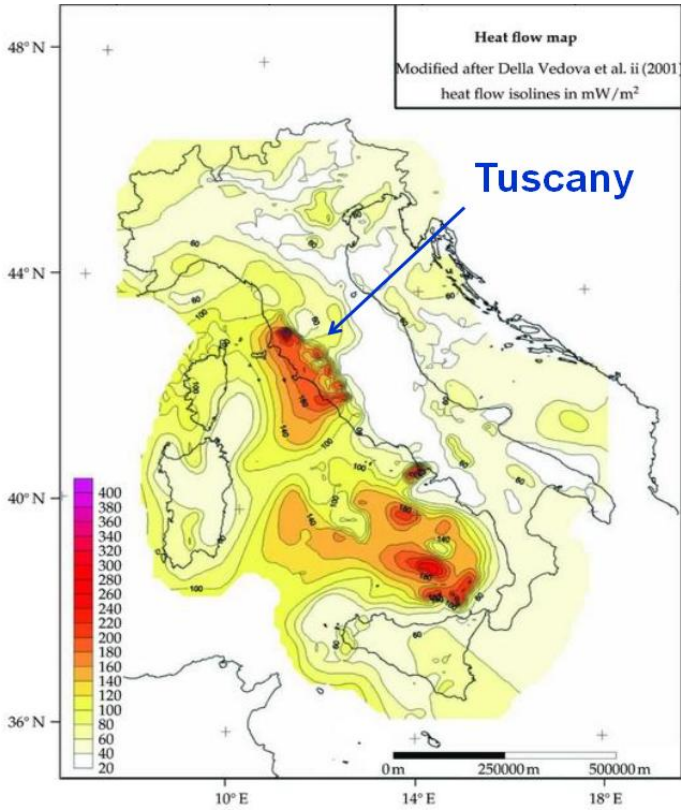
The measurements were collected simultaneously.

Our goal is to test the possibility to integrate data at different scale of observation and use the proximal measurements as an improving and validate the methodology to estimate the surface temperature using EO data.

Test site is Parco delle Biancane near Grosseto, with strong presence of thermal anomaly

Introduction and regional setting

The Italian Tyrrhenian margin is characterized by several high and medium enthalpy geothermal systems and in Tuscany several geothermal systems with a large-scale steam-dominated geothermal anomaly are presents. Surface thermal signatures may be used to define the evolution of development of shallow structures present on both volcanic districts and geothermal areas and possibly related to tectonic activity along active faults.



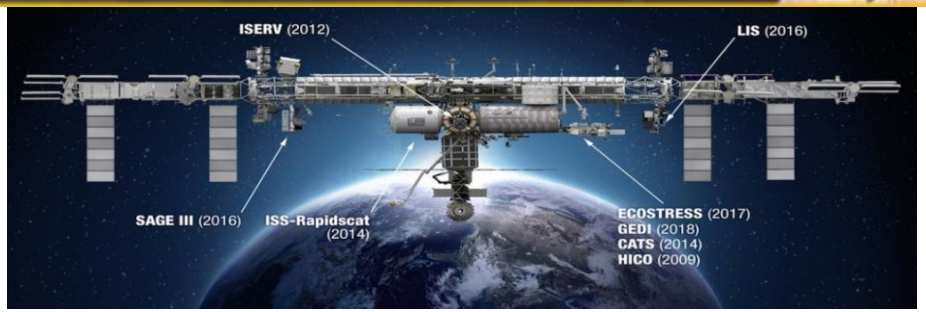
Introduction and regional setting

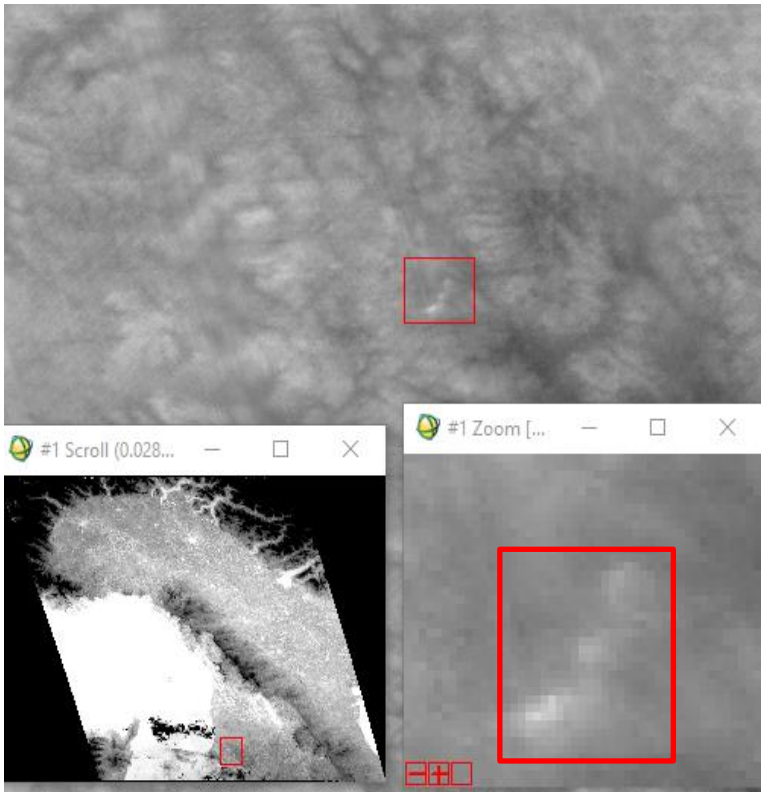
Italy has been the first country in the world to produce electricity by geothermal energy on 1904.
The Larderello area is now a centre for global geothermal energy and provides clean and sustainable energy to the entire area

Geothermal area

Test Sites

Data: ECOSTRESS





example on Parco delle Biancane

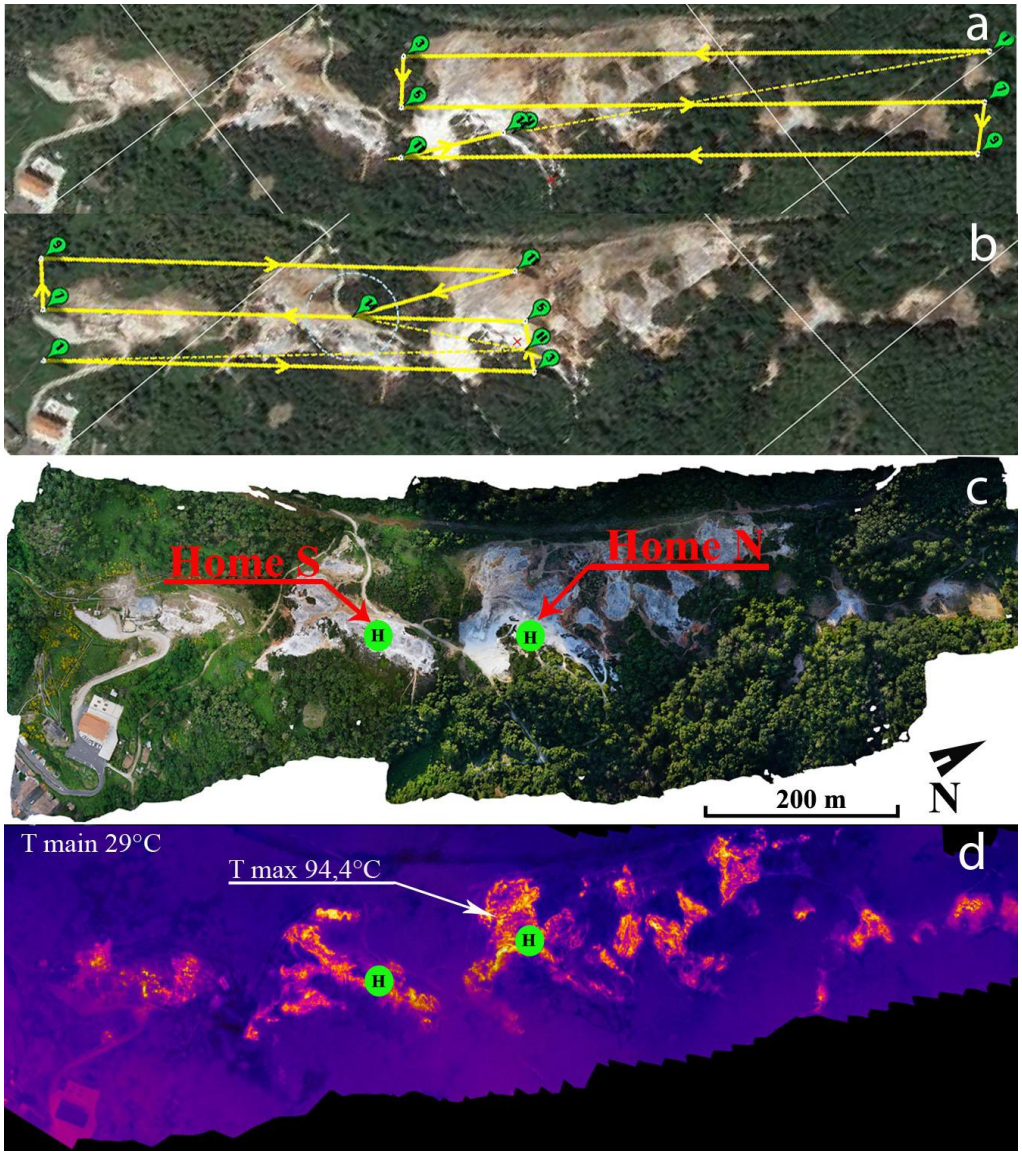
ECOSTRESS(from 2018): Five channels in the thermal infrared region with spatial resolution of about 38x68m at nadir and revisit time of 5days. From May 2019 8.29 μm and 9.20 μm are not available

Description	ECOSTRESS	Unit
Number of thermal spectral bands	5	-
Measured band centers	8.29; 8.78; 9.20; 10.49; 12.09	μm
Measured FWHM per band	0.354; 0.310; 0.396; 0.410; 0.611	μm
Pixel size at nadir	69x38	m
Swath width	384	km
Revisit time	~ 4-5	day

Data: UAV

A FlyBit octocopter has been used to carry out surveys from UAVs. It was equipped with a Sony Alpha 6000 camera (A) for photogrammetric surveys and with FLIR VUE PRO R thermal imaging camera (B) in order to gather thermal infrared measurements. For both sensors to keep constant orientation, two different specific gimbals have been developed.

Data: UAV



UAV flight of 18 June 2019 on the *Parco delle Biancane*: a) flight plan for the northern sector; b) flight plane for the southern sector c) visible mapping; d) thermal mapping. The "Home" (H) indicates the take-off point of the UAV which has a ground elevation of 621m and 610m in the northern and southern sector respectively.

Data: HyTES

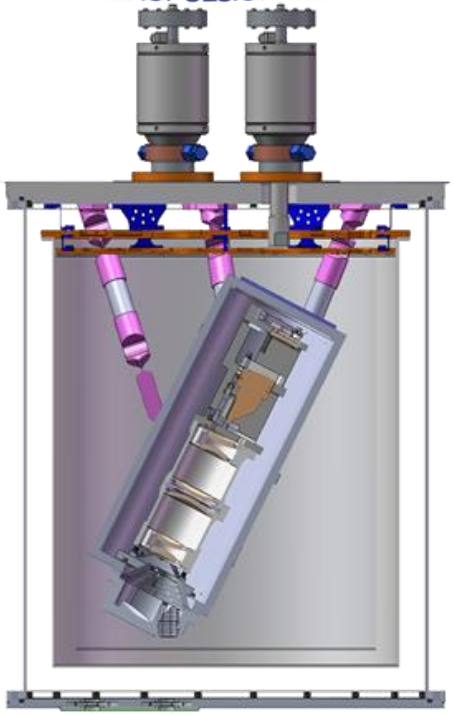
Twin Otter Airplane

HYPERSPECTRAL THERMAL EMISSION SPECTROMETER

HyTES

NASA • JET PROPULSION LABORATORY

Instrument Characteristic	HyTES
Mass (Scanhead)[1]	12kg
Power	400W
Volume	1m x 0.5m (Cylinder)
Number of pixels x track	512
Number of bands	256
Spectral Range	7.5-12 um
Detector	Multi-stack QWIP
Total Field of View	50 degrees
Calibration (preflight)	Full aperture blackbody
Swath Width	1.8 – 3.6 km
Pixel size at 2000 m flight altitude	3.64m
Pixel size at 20,000 m flight altitude	36.4m



HyTES is a compact image spectrometer acquiring data in 256 spectral bands between 7.5 and 12 micrometers.

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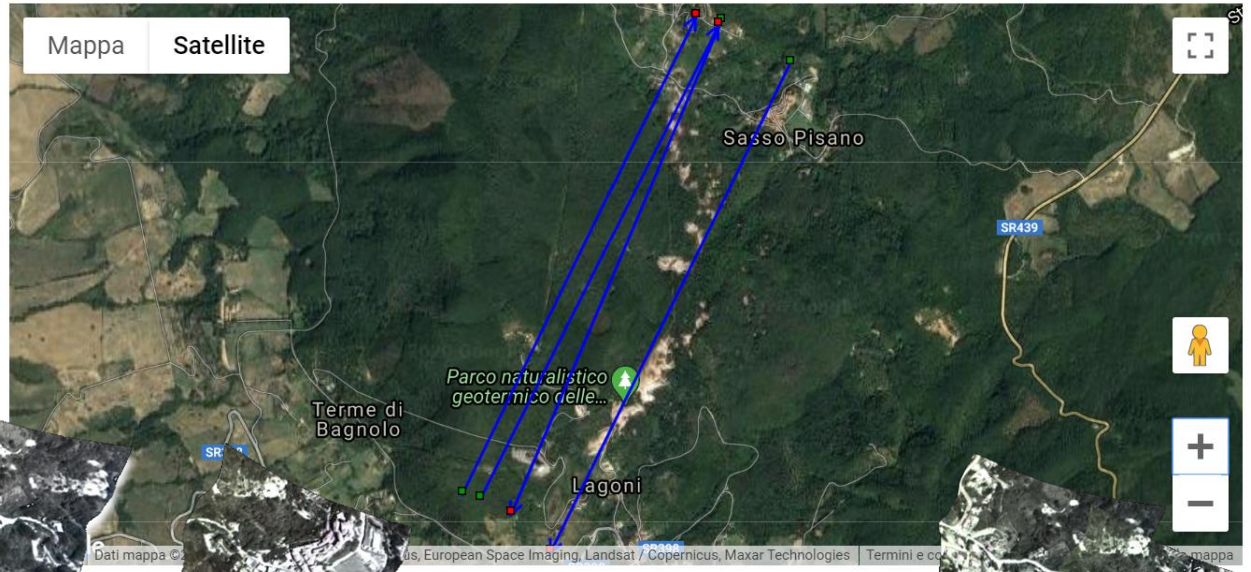
Data: HyTES

HyTES mission plan
18 June 2019



Radiances acquired with HyTES at Parco delle Biancane

After the mosaic

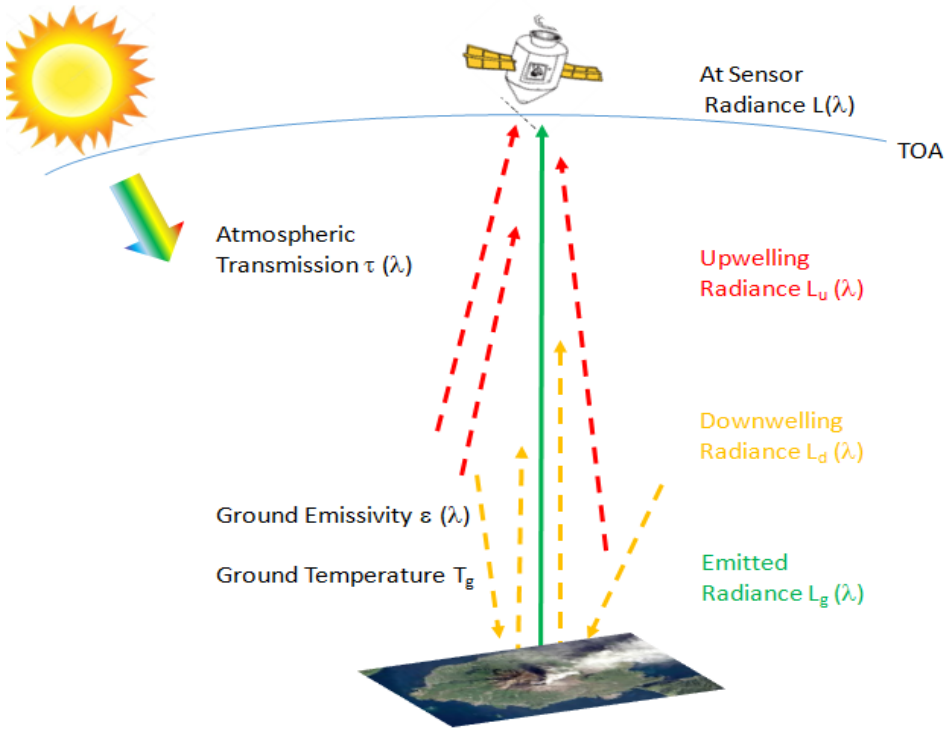
Errors during mosaic procedure

In order to remove errors, the two acquisitions have been re-georeferenced

Methodology: Satellite data

The radiance measured by sensor satellite is atmospherically corrected and used as input to TES. Information on transmittance $\tau(\lambda)$, up-welling radiance $L_u(\lambda)$ and down-welling radiance $L_d(\lambda)$ are obtained using MODTRAN

$$L(\lambda)=\varepsilon(\lambda)\tau(\lambda)B(\lambda)\ (T_g)+(1-\varepsilon(\lambda))t(\lambda)L_d(\lambda)+L_u(\lambda)$$



Temperature and Emissivity Separation (Gillespie et al., 1998)

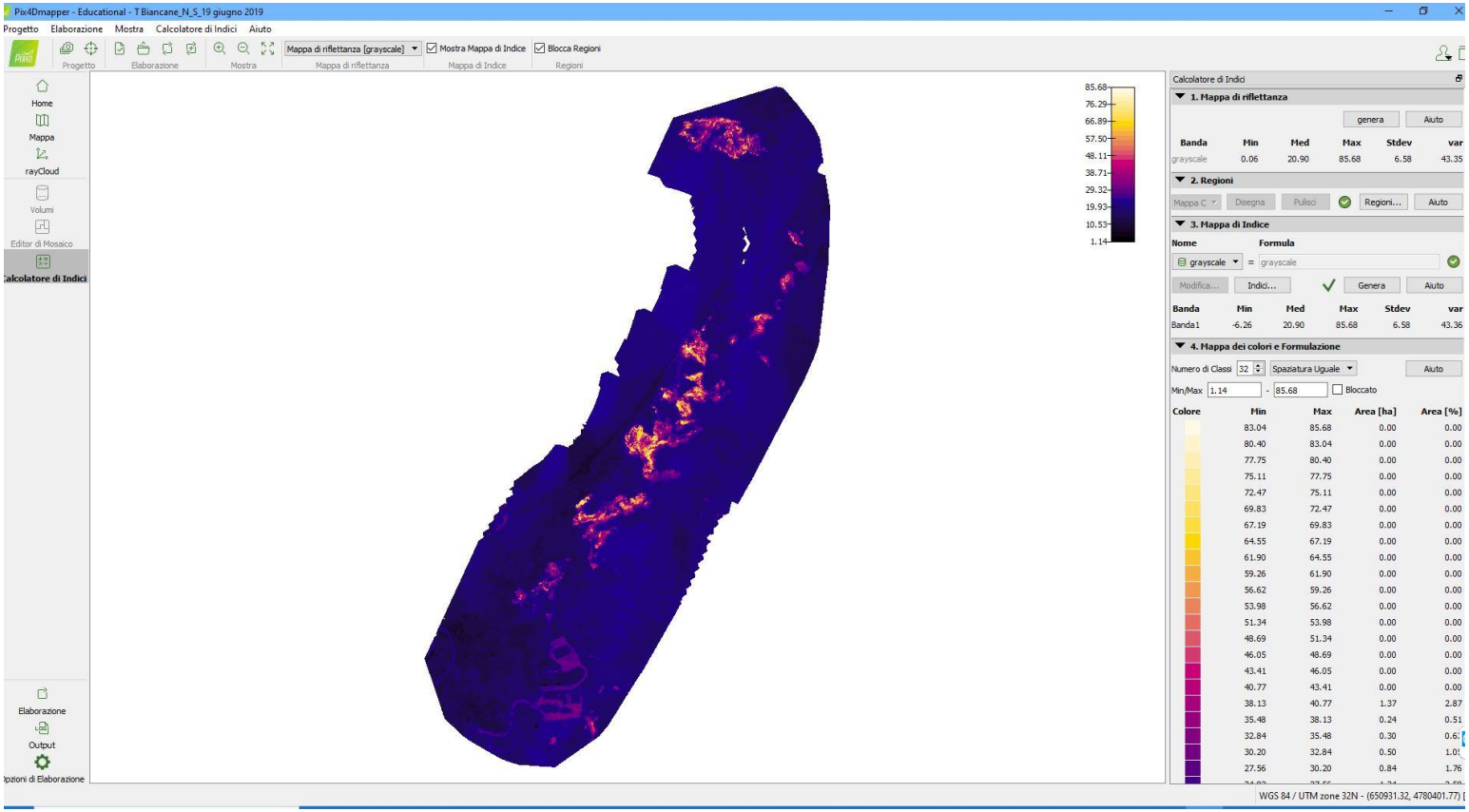
Land Surface Temperature

Methodology: Drone data

Image acquisition	
UAV	FlyBit octocopter
Image acquisition plan	2 flights, grid flight plan (overlap 80% in width and 60% in height)
Camera	FLIR VUE PRO R (thermal)
Images	
Number of images	350
Image size	640x480
Image geolocation coordinate system	WGS84

Methodology: Drone data

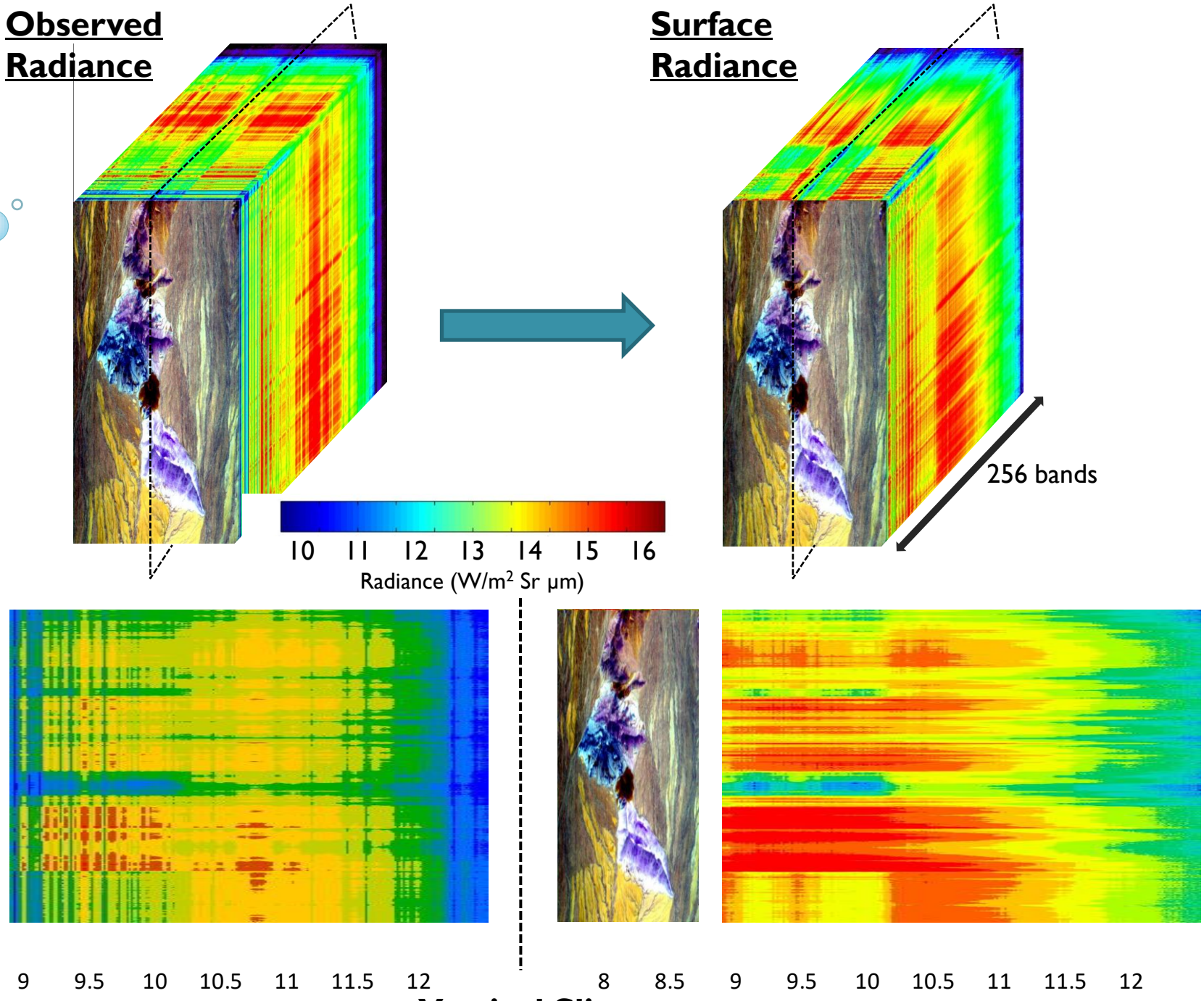
The images collected by thermal camera mounted on UAV are used as input in Pix4D Software



HyTES Atmospheric Correction

- MODTRAN 5.2
  - PROS: Fast, accurate if atmospheric profile known and data well calibrated
  - CONS: Errors from band misregistration, profile interpolation errors, calibration error
- In-Scene Atmospheric Correction (ISAC)
  - PROS: Uses spectral information from sensor
  - CONS: Slow, relies on blackbody pixels with broad temperature distribution, assumes atmosphere and elevation does not vary over scene

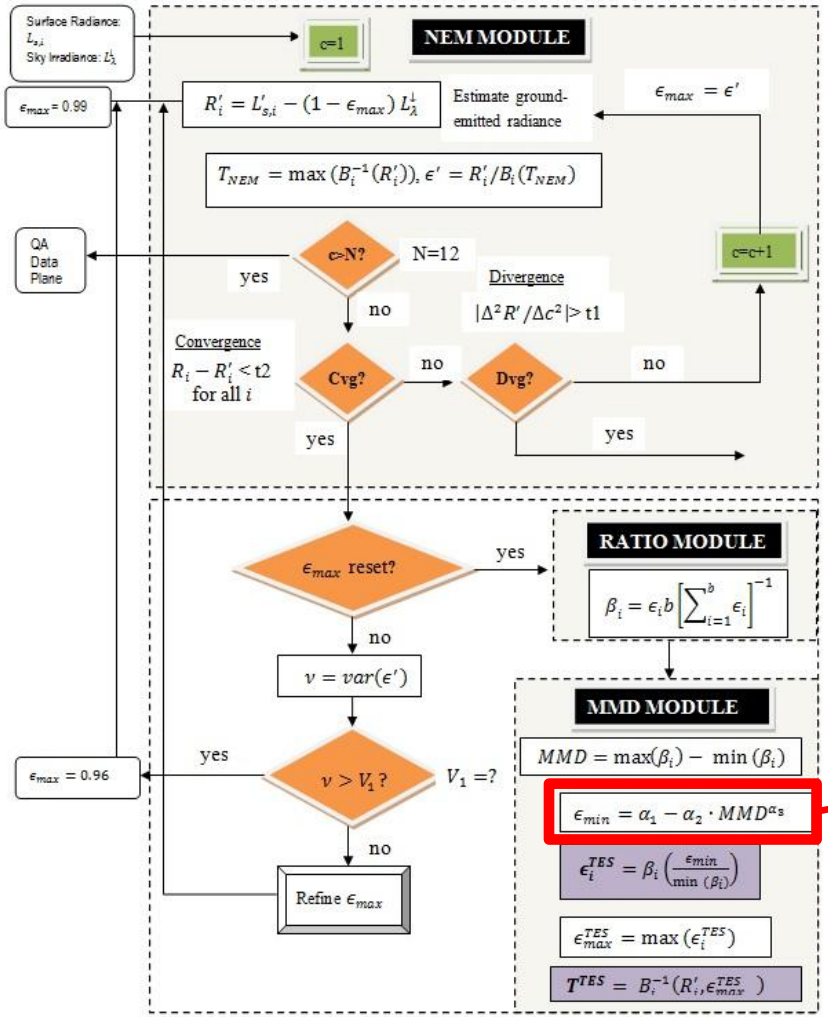
Methodology: HyTES data



Temperature/Emissivity Separation (TES)

Methodology: HyTES data

T-E separation is under-determined
If have N equations always have N+1 unknowns:
Radiance Band 1 = T + e_1
Radiance Band 2 = T + e_2
Radiance Band 3 = T + e_3

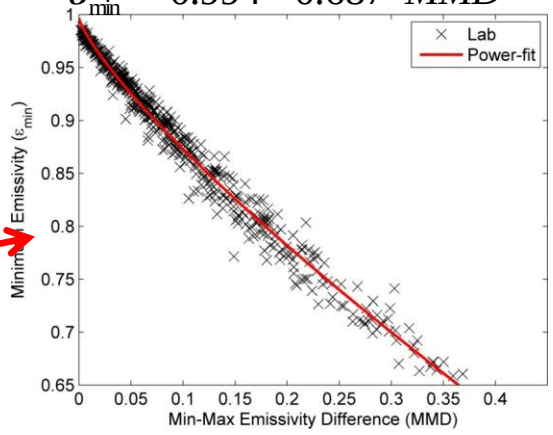


TES Algorithm
(Gillepsie et al. 1998)

TES LST&E Products:

- **ASTER**
- **MOD21 C6**
- **ASTER GED**
- **MASTER**
- **HyTES**
- **ECOSTRESS**
- **VIIRS**

$$\varepsilon_{\min} = 0.994 - 0.687 \cdot MMD^{0.737}$$



Processing data

Schematic workflow used in the ESRI ArcGIS software environment

Geo-referencing images HyTES and UAV

Considering that the two HyTES geo-referenced strips do not correspond perfectly to each other, we have considered only the HyTES strip overlapping the UAV acquisition

UAV frames are processed with a specific photogrammetric software (Pix4D) for obtaining a geo-referenced thermal orthomosaic image. Then, it is imported in environmental GIS for next processing.

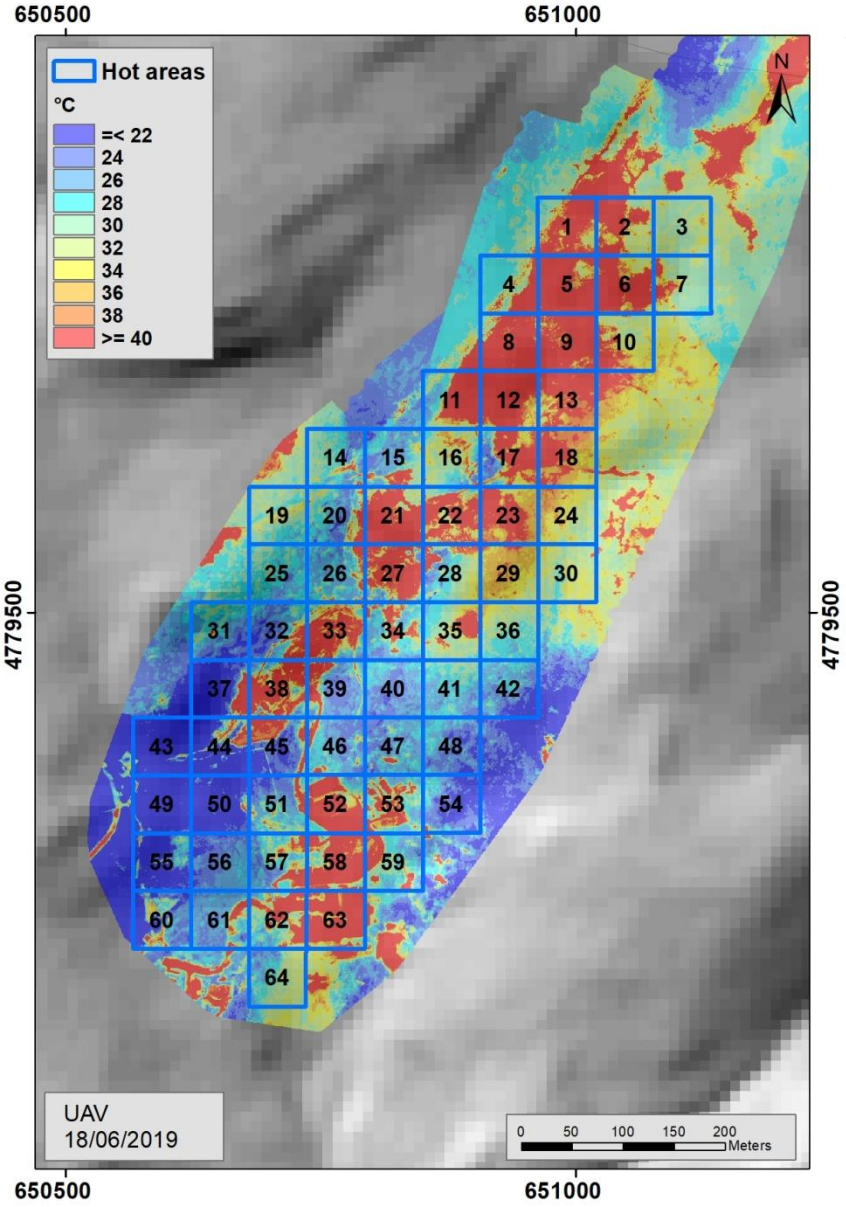
area selection for analysis

Polygons at the same pixels spatial resolution of ECOSTRESS have been selected. ECOSTRESS data has 56.7m spatial resolution and compared with HyTES (0.8 meter) and UAV (0.2 meter).

Statistic analysis on UAV, HyTES and ECOSTRESS

Statistic analysis between ECOSTRESS, HyTES and UAV temperature data inside the selected polygons was performed by computing Minimum, Maximum, Mean and Standard Deviation. In the table only Mean values are reported.

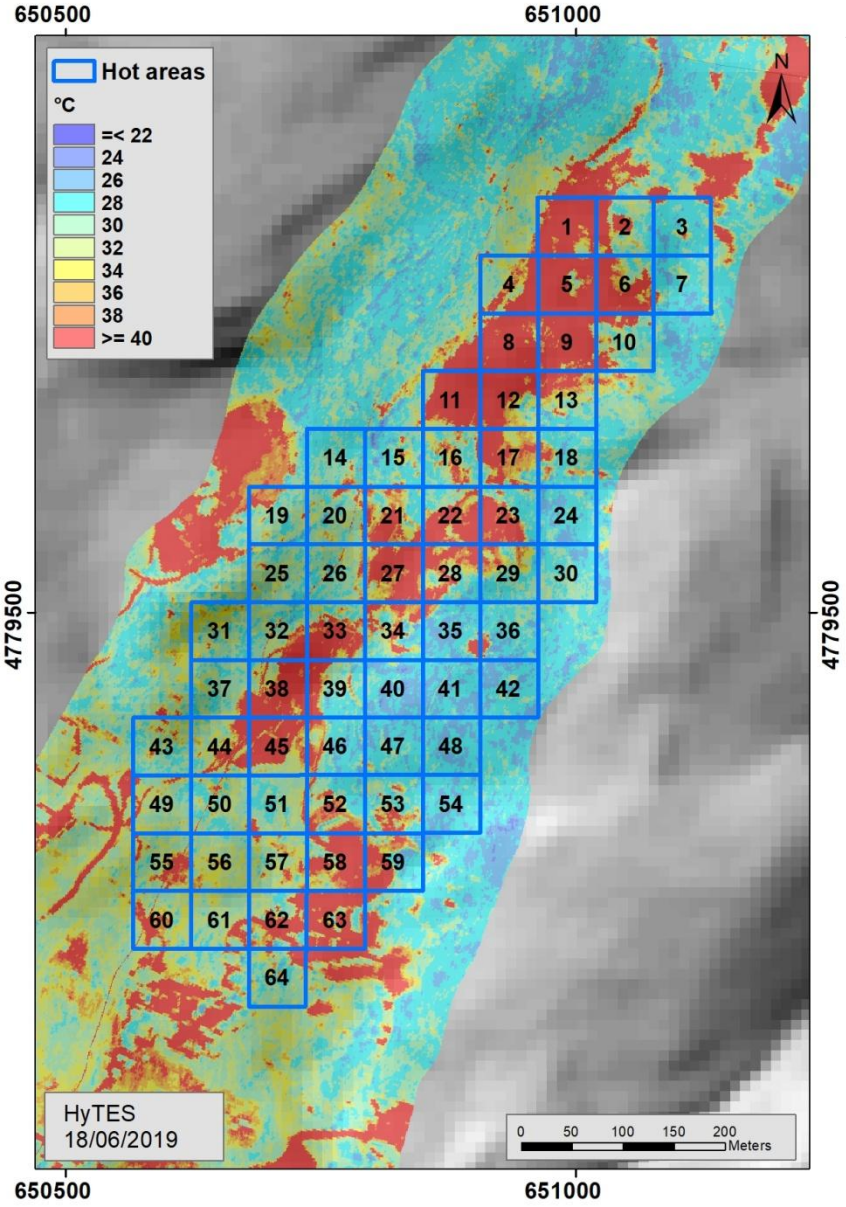
Results of comparison: UAV



Area	ECOSTRES	MEAN-HyTES	MEAN-UAV
1	29,65	47,48	42,56
2	28,93	36,17	42,96
3	28,50	28,27	30,54
4	32,55	37,53	34,49
5	32,08	48,86	51,97
6	32,28	43,37	47,99
7	28,91	27,62	31,95
8	30,93	46,13	49,49
9	32,46	48,54	49,75
10	31,49	32,97	35,41
11	31,09	47,26	42,04
12	32,77	47,04	57,07
13	32,77	33,55	40,92
14	29,70	28,49	27,78
15	30,46	28,35	28,42
16	29,66	31,21	30,77
17	32,09	38,29	36,83
18	31,83	29,10	38,66
19	29,27	30,74	29,24
20	28,58	30,27	29,10
21	28,66	36,98	48,19
22	29,63	39,70	40,85
23	31,11	36,99	40,26
24	29,45	26,73	32,84
25	28,78	29,51	26,98
26	28,95	29,74	28,24
27	28,94	42,99	40,22
28	29,16	36,20	30,79
29	29,17	30,63	34,25
30	28,04	27,83	30,96
31	28,24	30,16	25,51
32	28,18	32,36	28,25

Area	ECOSTRES	MEAN-HyTES	MEAN-UAV
33	28,84	37,21	37,31
34	28,92	32,94	30,22
35	28,76	28,22	32,87
36	28,34	27,91	29,17
37	28,07	30,47	23,38
38	28,19	41,94	38,52
39	29,03	32,99	28,92
40	28,93	26,15	24,65
41	27,87	26,29	26,43
42	28,35	26,53	24,15
43	29,21	29,92	15,40
44	28,92	34,56	22,56
45	28,93	38,73	28,28
46	28,57	30,23	26,97
47	28,56	26,90	25,37
48	27,81	26,50	24,06
49	28,88	31,21	18,15
50	28,50	29,89	20,39
51	28,55	30,07	27,24
52	28,44	32,47	39,24
53	28,82	30,71	32,97
54	27,83	26,48	23,28
55	28,90	32,90	21,68
56	27,80	30,99	23,79
57	28,55	31,60	30,90
58	30,00	39,69	43,12
59	28,29	33,93	31,46
60	28,34	33,00	24,95
61	27,75	31,39	27,04
62	28,48	36,42	35,94
63	28,84	42,50	46,78
64	28,74	31,04	28,63

Results of comparison: HyTES



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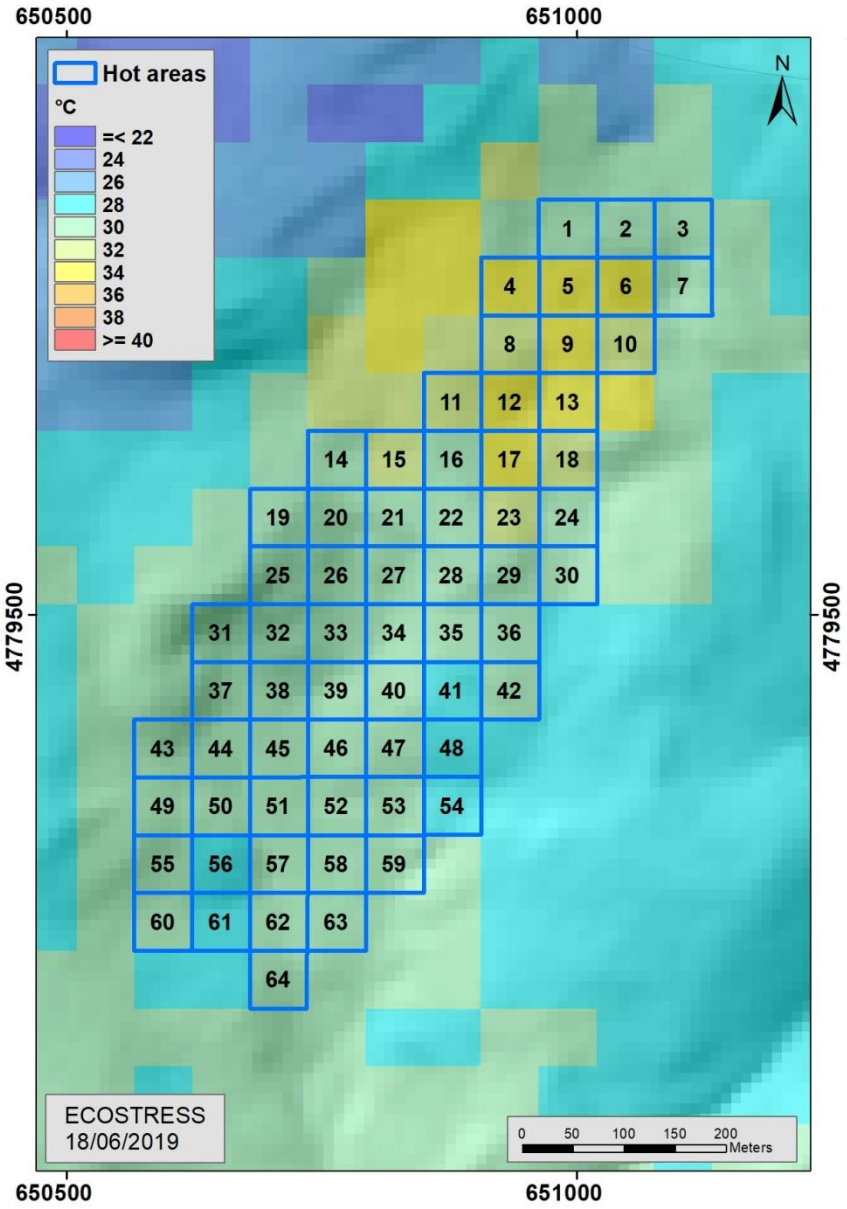
Results of comparison: ECOSTRESS



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Final Consideration

Very comparable results if we consider that satellite data has a pixel spatial resolution coarser (56.7 meter) respect to HyTES (0.8 meter) and UAV (0.2 meter)

In the cold areas there is a very good correspondence of values. Also in the mixed areas where there are hot points detected by HyTES and UAV, the means are comparable (e.g. pixels N. 16, 34, 53)

In the area where thermal anomaly fully cover the pixel area, differences between ECOSTRESS and the means of HyTES and UAV are approximately of 15-20°C (e. g. pixel N. 8)

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HyTES: Glynn Hulley or Simon Hook
(glynn.hulley@jpl.nasa.gov / simon.j.hook@jpl.nasa.gov)