Thermal domain directional effects in flying missions: Landsat-8 and Master

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2023.05.12, Thermal EO Workshop, ESA, Italy

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Introduction

Open questions for Trishna

- What is the error budget of directional effects ?
- Do we have to correct for directional effects outside of the hotspot ?
- What is the width of the hotspot ?

How to adress them

- Simulation (DART, scope ...)
- Field campaign and instrumentation

This study tries an orthogonal path

- Look for directional effects in existing data:
  - 2 satellite TIR observations at the same time
  - In the same wavelengths
  - With different viewing angles
- Today talk: MASTER vs. Landsat-8

Master (`https://masterprojects.jpl.nasa.gov/`)

- Airborne TIR sensor from NASA
- FOV $\pm$ 45°, Spatial resolution 15m-30m
- 658 flights between 1998 and 2022

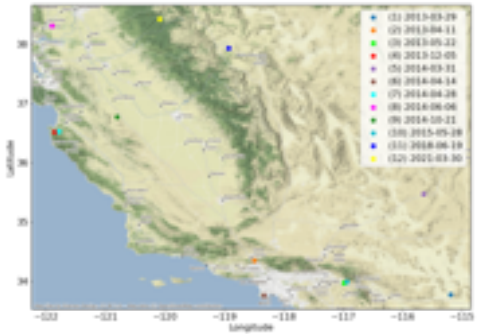
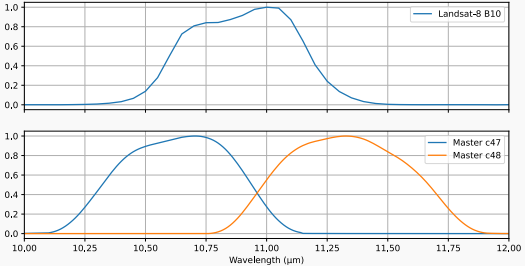


Figure 1: Location of Landsat-8 and MASTER simultaneous acquisitions

Processing and parametric directional models

Main Processing steps

- Reproject on common 100m grid
- Interpolate MASTER emissivity from c47 and c48
- Compute Surface Brightness Temperature (SBT) using B10 for Landsat-8 and interpolated emissivity for MASTER: SBT $= B_\lambda^{-1}(emis * B_\lambda(LST))$
- Remove bias per track based on Nadir (<7°) pixels
- Dataset available on Zenodo



Parametric directional models

Model	Isotropic	Volumetric	Geometric / Hotpsot
Ross-Li	k_0	$+ k_1 K_{RossThick}(\theta_v, \theta_s, \Delta_{phi})$	$+k_2 K_{LiSparseR}(\theta_v, \theta_s, \Delta_{phi})$
LSF-Li	k_0	$+ k_1 K_{lsf}(\theta_v, \theta_s, \Delta_{phi})$	$+k_2 K_{LiDenseR}(\theta_v, \theta_s, \Delta_{phi})$
Vinnikov	k_0	$+ k_1 K_{emis}(\theta_v, \theta_s, \Delta_{phi})$	$+k_2 K_{solar}(\theta_v, \theta_s, \Delta_{phi})$
RL	k_0		$+ k_2 K_{RL}(\theta_v, \theta_s, \Delta_{phi}, k_{hs})$

Surface Brightness Temperature differences (Landsat-8 - Master)

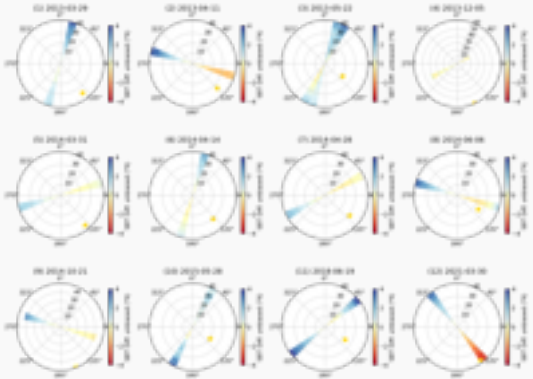


Figure 2: Surface Brightness Temperature Difference in polar coordinates representing Master viewing angle. Mean solar position is marked by yellow star.

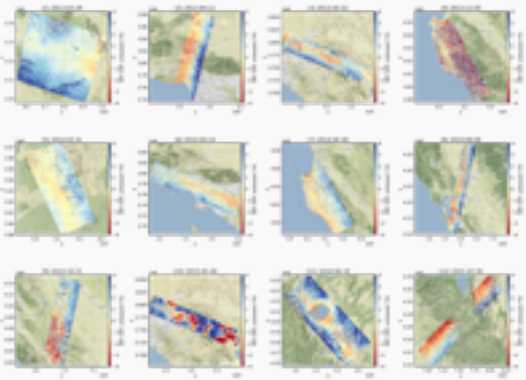


Figure 3: Surface Brightness Temperature Difference maps

Amplitude of directional effects

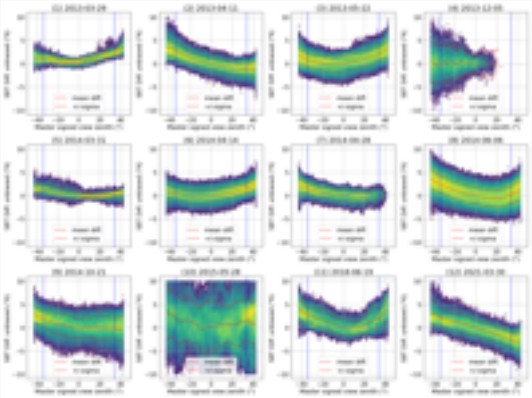


Figure 4: Surface Brightness Temperature Difference wrt. Master signed view zenith angle

	Trishna			
id	Min.	-34°	34°	amp.
(1)	0.25	1.12	2.49	2.26
(2)	-1.24	2.62	-1.19	3.85
(3)	-0.29	0.64	2.03	2.32
(4)	-0.40	-0.18	1.18	1.57
(5)	-0.12	1.38	0.19	1.50
(6)	-0.27	0.40	1.49	1.75
(7)	-0.51	1.46	-0.04	1.98
(8)	-0.65	2.43	0.13	3.08
(9)	-0.12	1.82	-0.04	1.95
(10)	-0.32	1.82	1.52	2.13
(11)	-0.20	2.64	2.03	2.85
(12)	-2.35	2.17	-2.54	4.71

Table 1: Amplitude of directional effects within Trishna FOV for each track

Model fitting, separately on each track

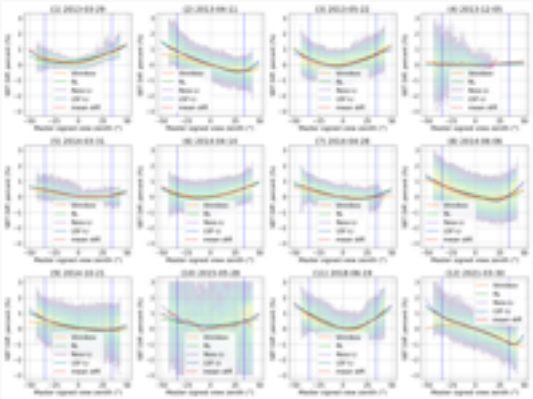


Figure 5: Surface Brightness Temperature variation in %, with the 4 fitted models

id	Amp				
	Raw	Vin.	RL	Ross	LSF
(1)	3.41	0.63	1.05	1.03	0.79
(2)	4.88	0.27	0.54	1.09	1.10
(3)	3.55	0.46	0.98	1.09	1.26
(4)	1.57	1.45	1.57	1.54	1.50
(5)	1.86	0.37	0.44	0.30	0.21
(6)	2.67	0.26	0.37	0.60	0.45
(7)	2.51	0.37	0.92	0.87	0.78
(8)	4.09	0.79	1.25	0.72	0.42
(9)	3.06	0.53	0.89	1.05	0.79
(10)	3.85	2.63	2.83	1.55	2.61
(11)	4.23	1.13	1.40	0.91	1.05
(12)	6.25	0.68	0.45	0.65	0.50

Table 2: Performances of each of the 4 fitted models on each track

Model fitting, on all tracks except for (4) and (10)

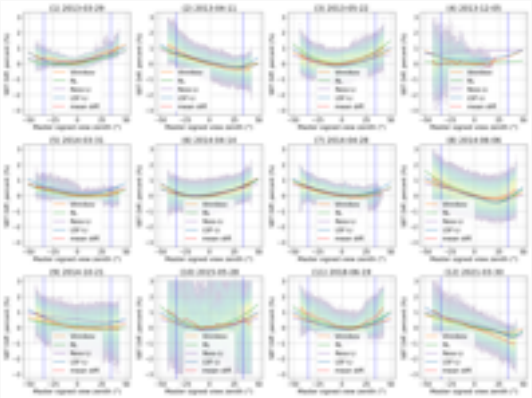


Figure 6: Surface Brightness Temperature variation in %, with the 4 fitted models

id	Amp				
	Raw	Vin.	RL	Ross	LSF
(1)	3.41	1.15	1.42	1.89	0.99
(2)	4.88	1.02	1.77	2.07	2.21
(3)	3.55	1.45	1.09	1.80	1.38
(4)	1.57	1.97	1.52	1.52	1.73
(5)	1.86	0.96	0.54	0.63	1.12
(6)	2.67	0.62	0.37	0.94	0.70
(7)	2.51	0.81	0.84	1.07	1.47
(8)	4.09	1.41	1.52	1.72	0.95
(9)	3.06	0.90	1.83	1.92	1.59
(10)	3.85	3.09	3.22	2.97	2.84
(11)	4.23	2.85	2.12	2.98	1.94
(12)	6.25	2.51	2.89	2.13	1.57

Table 3: Performances of each of the 4 fitted models on each track

Examples of Master SBT correction with estimated models

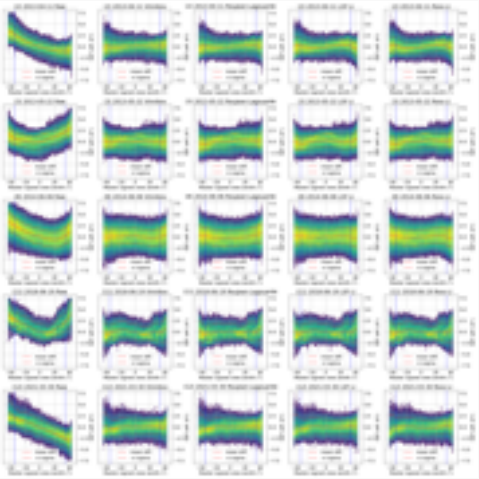


Figure 7: Corrected SBT differences with model fitted on each track separately

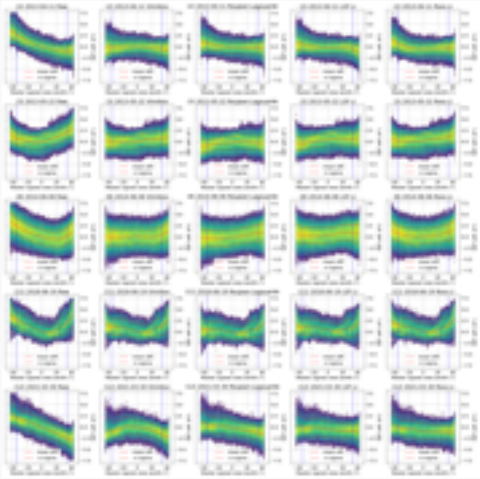


Figure 8: Corrected SBT differences with model fitted on all tracks at once, except for (4) and (10)

Conclusions

What is the error budget of directional effects ?

- Up to 4.7K in Trishna FOV
- For California landscape, at 10:30 AM, within LS8 B10 wavelengths

Do we have to correct for directional effects outside of the hotspot ?

- There are effects even far from hospot conditions
- Local models reduce error below 1K, global models below 2K

What is the width of the hotspot ?

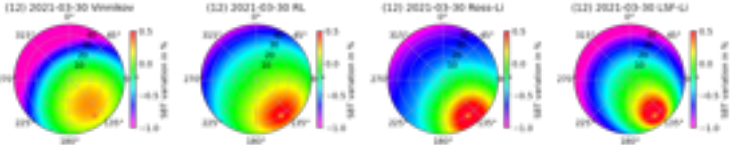


Figure 9: Global directional models in solar and viewing conditions of track (12)

Julien Michel, Olivier Hagolle, Simon J Hook, Jean-Louis Roujean, Philippe Gamet. Quantifying Thermal Infra-Red directional anisotropy using Master and Landsat-8 simultaneous acquisitions. Submitted to Remote Sensing of Environment, April 2023.