in-flight vicarious calibration of airborne and space borne thermal infrared instruments

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retour sur innovation

Context

- Goals : In-flight calibration assessment in the IR domain
  - Spectral domain : [3 – 12µm]
  - Broadband / multispectral / hyperspectral instruments
  - Airborne / spaceborne instruments
  - Multi-temporal / cross calibration / absolute calibration

- Background
  - Satellite cross calibration using MODIS L1B / SST products as a reference
  - moon's infrared characterization review
  - natural/artificial ground targets and instrumentation for in-flight calibration review

⇨ Vicarious calibration of a broadband LWIR airborne camera

Outline

- Experimental set-up
- Laboratory Instrument calibration
- In-flight calibration methodology
- Data processing
- Conclusion

Experiment description

FLIR A325 SC (LWIR)

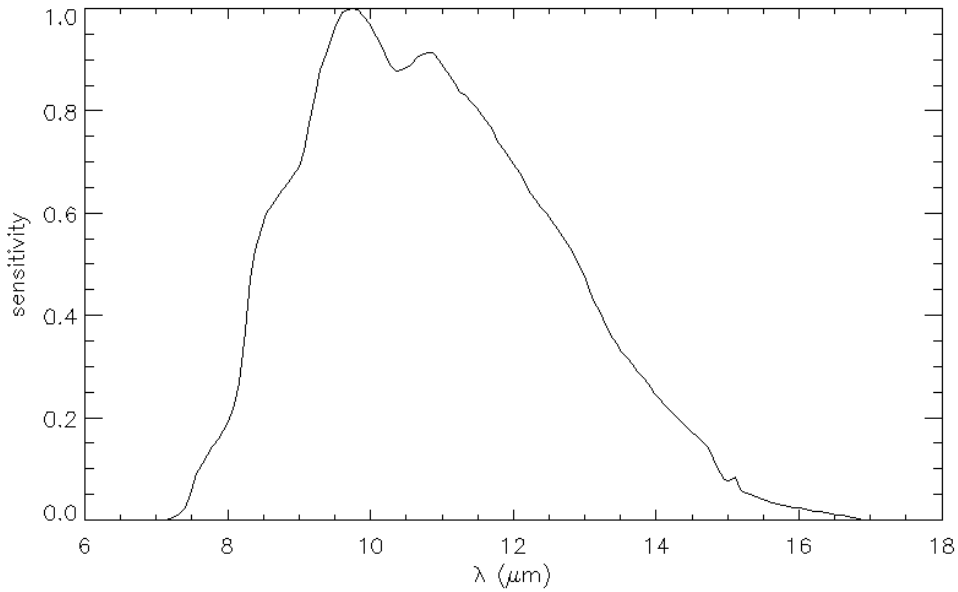
ONERA Busard motoglider


BA701 FTM target

- 7 altitudes between 1000 and 4000m
- Daytime & clearsky conditions

Laboratory spectroradiometric characterization

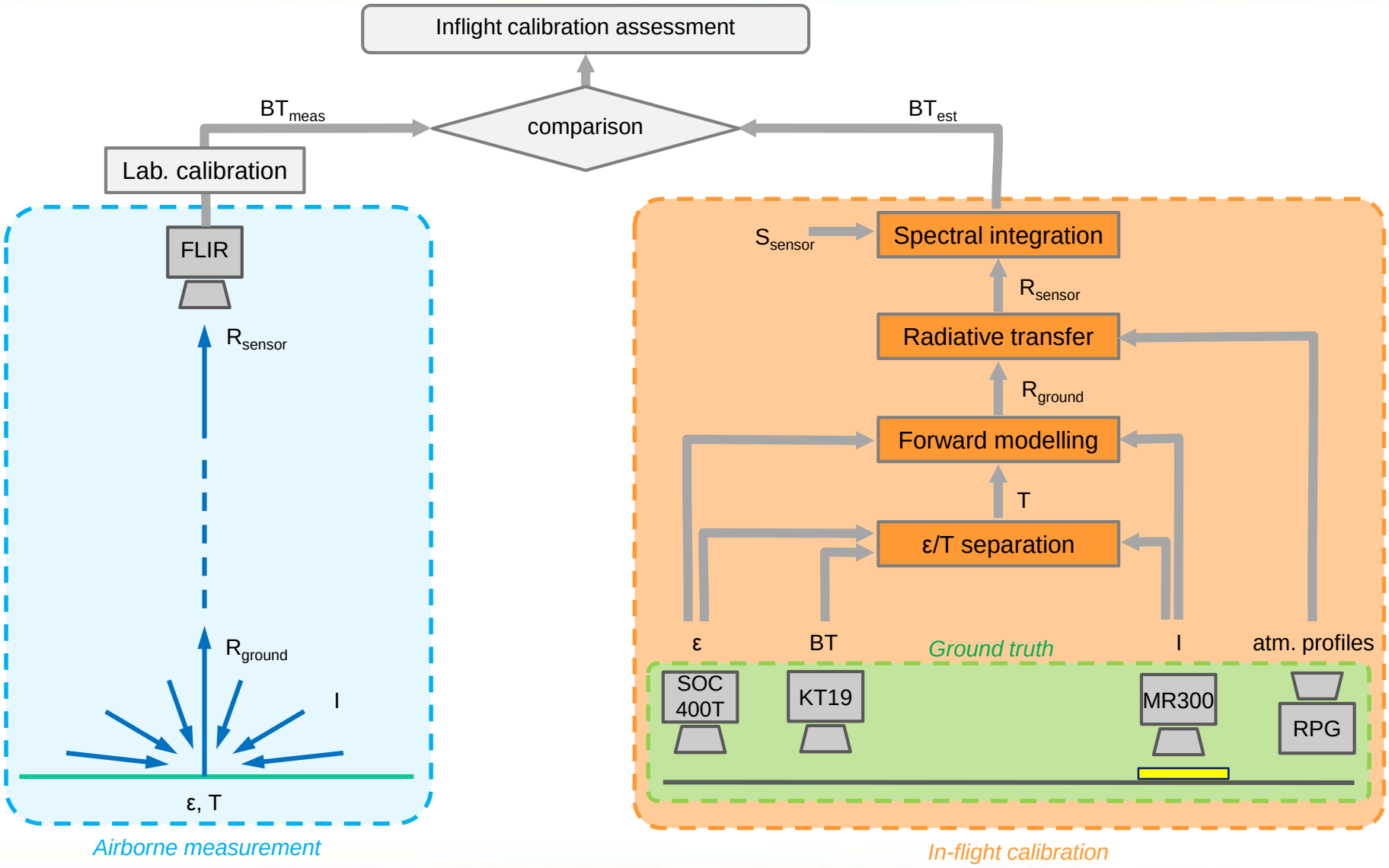
- Spectral characterization



- Linearity
- Spatial/temporal noise measurement
- Dependency upon ambient temperature (in the range [0 - 30°C])

  ⇨ noise < ±0,1K
  ⇨ accuracy < ±0,5K

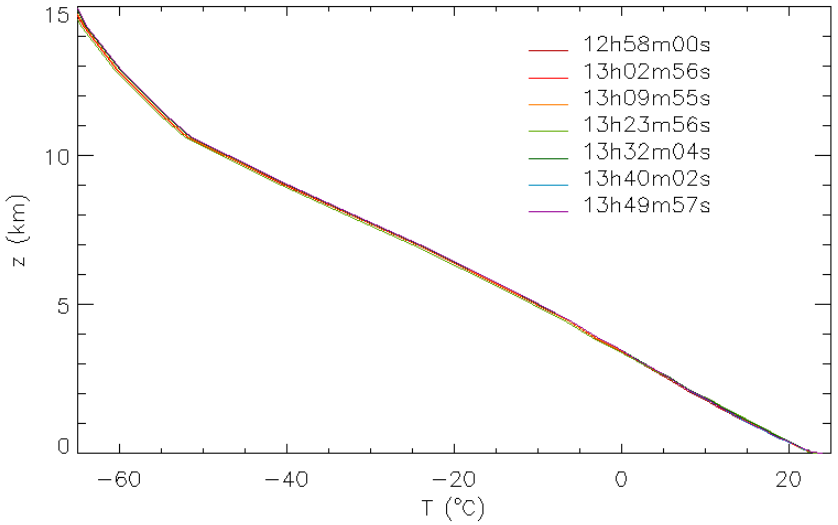
In-flight calibration methodology

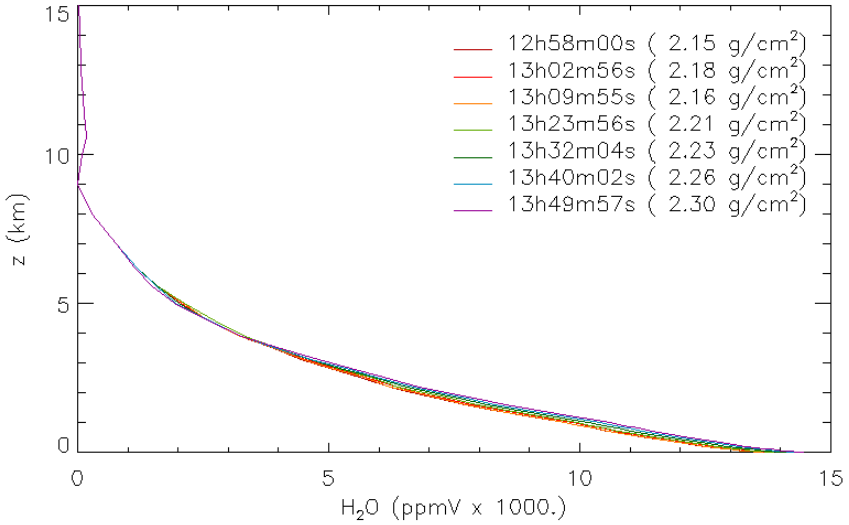


Atmospheric profile retrieval

RPG Hatpro radiometer

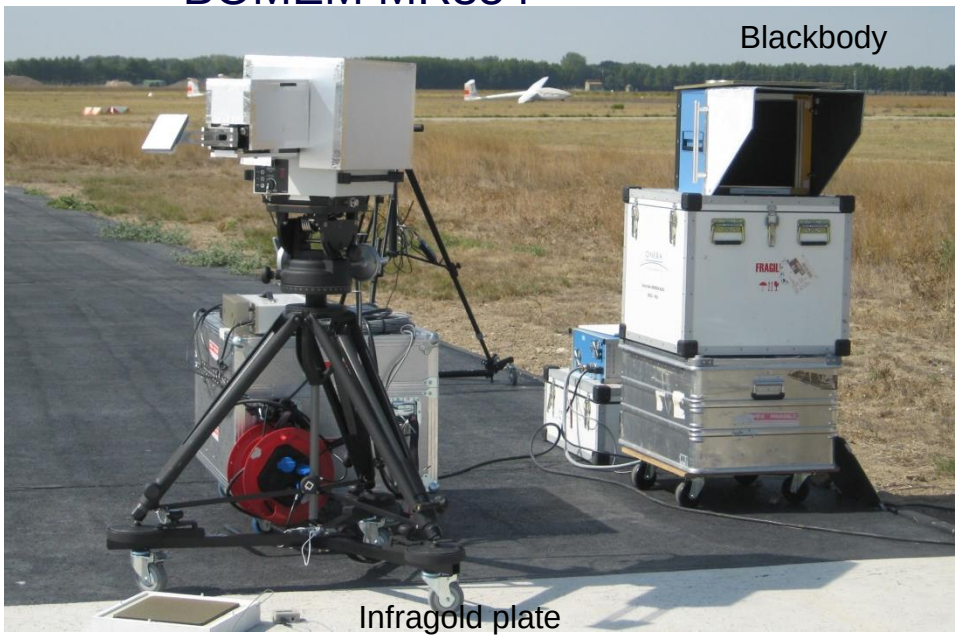
Alt (m)	δT rms (K)	δH rms (%)
10000		
	1	
4000		
	0,75	
1200		5
	0,5	
500		
	0,25	
0		





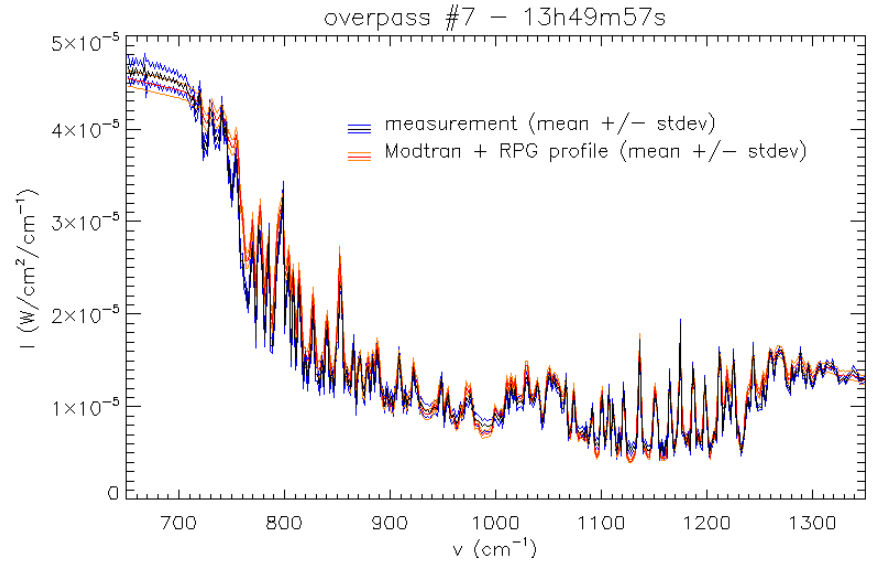
Downwelling irradiance

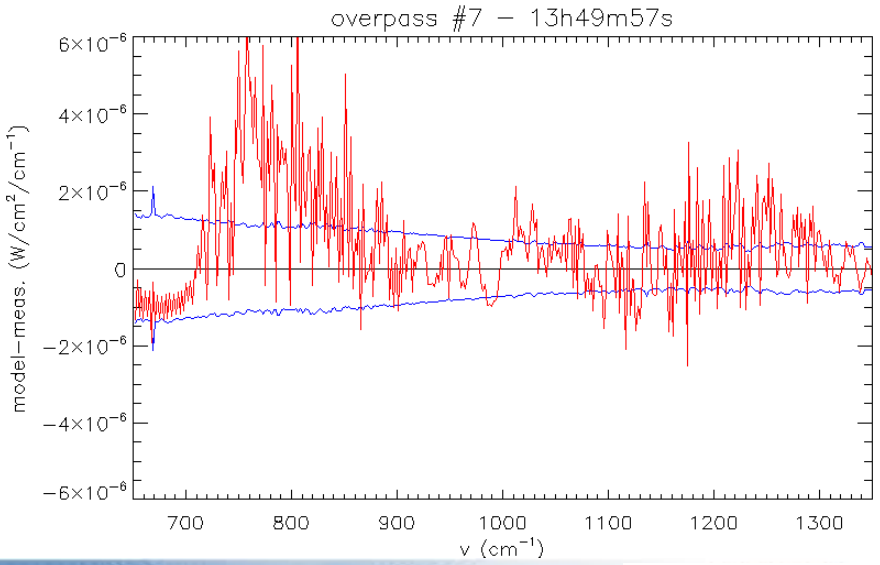
BOMEM MR354



Irradiance estimation :

$$I = \frac{\pi}{\rho_{ref}}\left[R_{ref} - \left(1-\rho_{ref}\right).B\left(T_{ref}\right)\right]$$

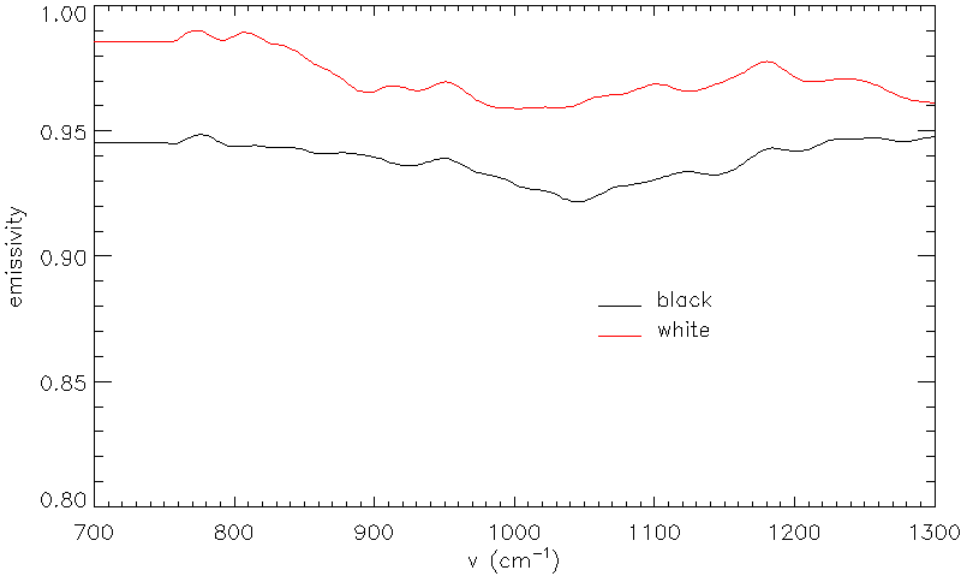




Surface emissivity

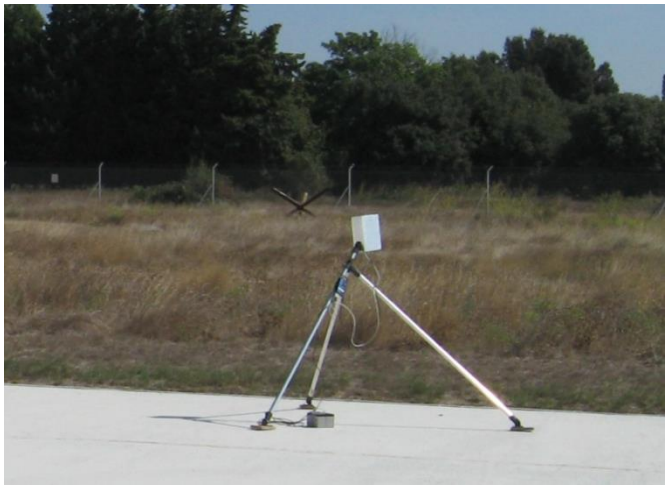
SOC-400T
spectroreflectancemeter

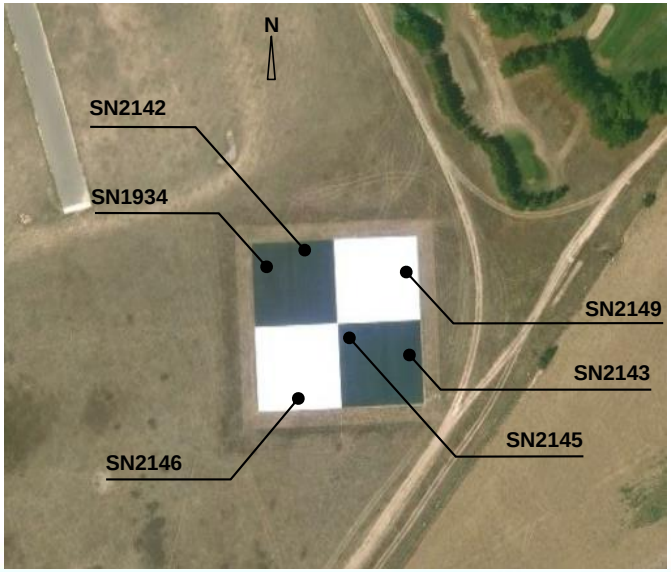
- 5 measurements for each quadrant
- Spectral resolution : 4cm^{-1}
- Consistant with 2011 SOC + Bomem measurements
- Accuracy : 0,02 rms



Surface temperature

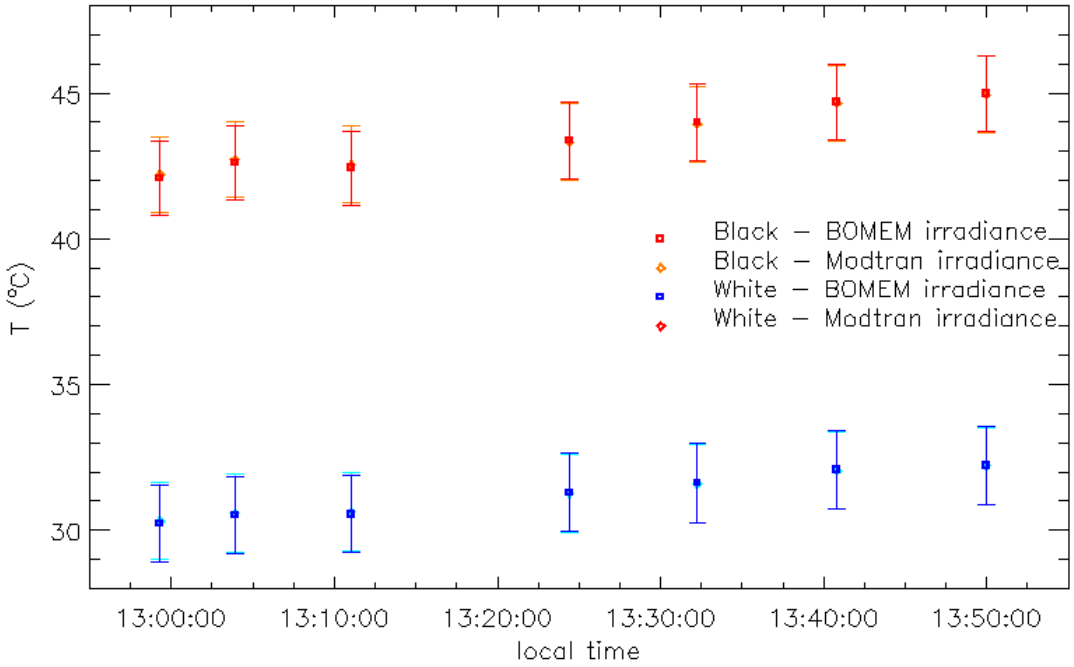
Estimated with 6 KT19 radiometers





T is solution of :

$$\int \varepsilon_\nu B_\nu(T) S_\nu^{KT} d\nu + \frac{1}{\pi}\int [1-\varepsilon_\nu] I_\nu S_\nu^{KT} d\nu = \int B_\nu(TB_{KT}) S_\nu^{KT} d\nu$$



Absolute calibration : 0,6 K rms

Temporal uncertainty : 0,2 K rms

Spatial variability : 0,7 K rms

At-sensor brightness temperature

simulation

measurement

Ground upwelling spectral radiance

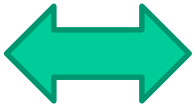
$$R_\nu^{ground} = \varepsilon_\nu B_\nu(T) + \frac{1}{\pi}[1-\varepsilon_\nu]I_\nu$$

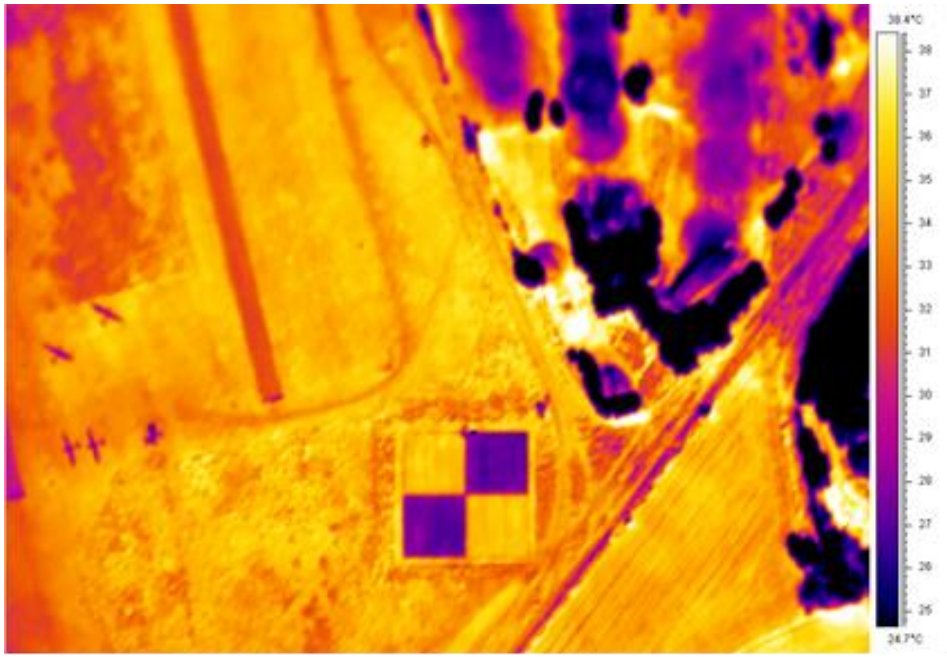
At-sensor spectral radiance

$$R_\nu^{sensor} = R_\nu^{ground}.t_\nu^{atm} + R_\nu^{atm}$$

Brightness temperature

$$TB_{est} = B^{-1}\left(\int R_\nu^{sensor}.S_\nu^{sensor} d\nu\right)$$

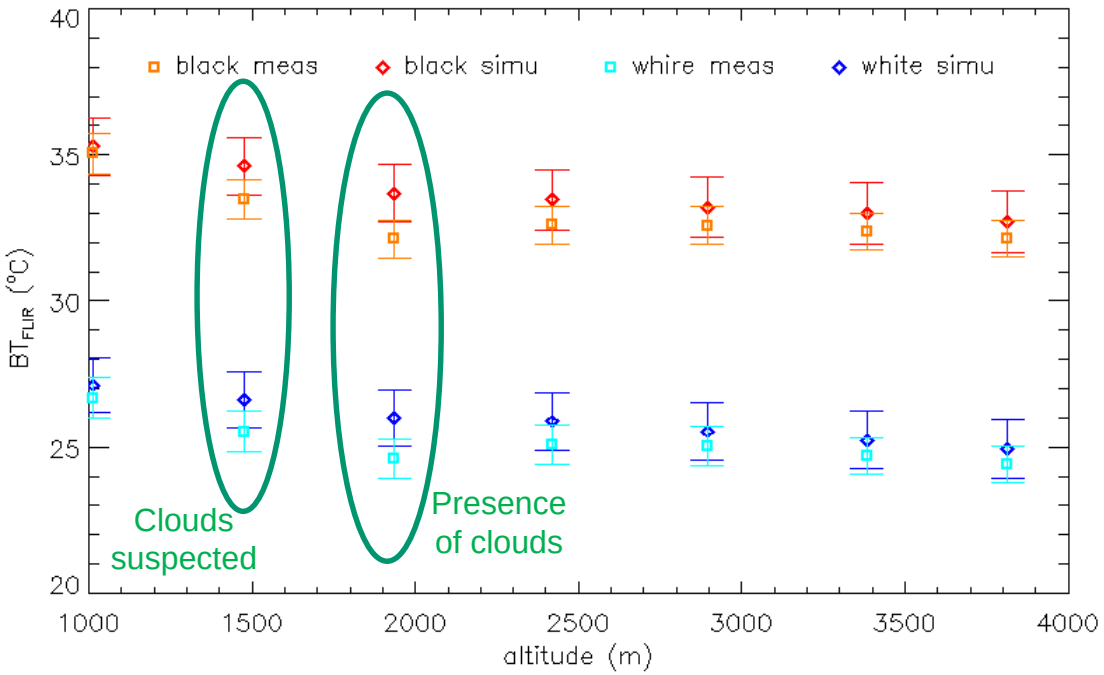




Absolute calibration

$$TB_{meas}$$

Results



Target	Simu. uncertainty rms	Meas. uncertainty rms	Inflight calibration bias	Inflight calib. Error rms
Black	1,03	0,65	0,58	0,62
White	0,99	0,66	0,56	0,58
average	1,01	0,65	0,57	0,60

Conclusions

- Inflight calibration methodology validated in the LWIR domain
- Bias attributed mainly to uncertainty on spectral sensitivity (the impact should be lower with selective filters)
- Uncertainty of the method : < 1K rms

- Methodology applied in other conditions :
  - Satellite instrument nighttime
  - MWIR hyperspectral instrument in daytime
  - Sysiphe MWIR/LWIR hyperspectral airborne system with a « portable » 4.5 x 9m black and white target, daytime/nightime and a network of 9 KT19 radiometers

- Perspectives
  - Sysiphe spectral emissivity + surface temperature product validation
  - Calibration of the Trishna Franco-Indian mission
  - Calibration of Terriscope airborne instruments
  - Atmospheric profile assessment using the spectroradiometer