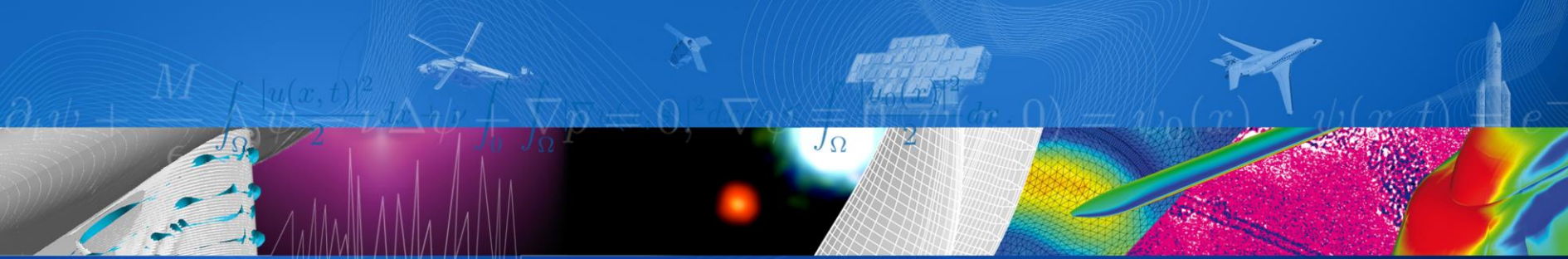

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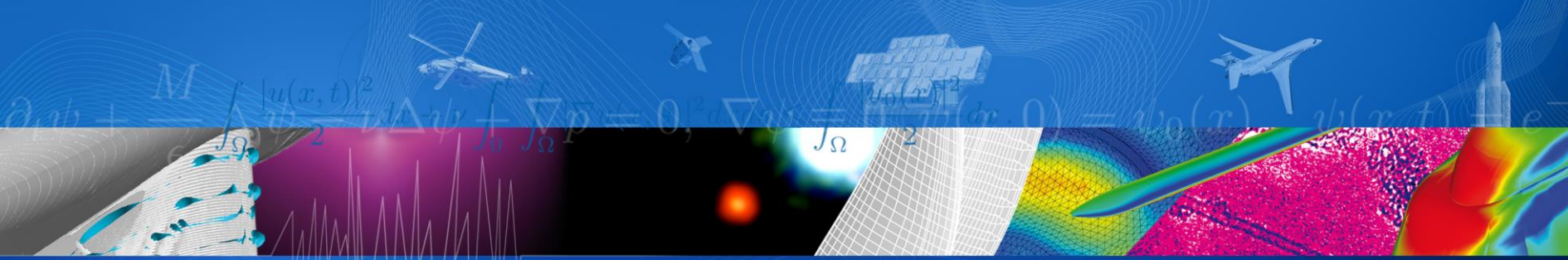

Real Time Gas Quantification Using Thermal Hyperspectral Imaging: Ground and Airborne Applications

Pierre-Yves Foucher, Stéphanie Doz

15 october 2019

SET-277 Workshop on Phenomenology and Exploitation of Hyperspectral Sensing within NATO

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Gas detection by remote sensing

environmental, safety and health issues

↳ in case of accidental gas leakage,

↳ rapid flow estimation is necessary

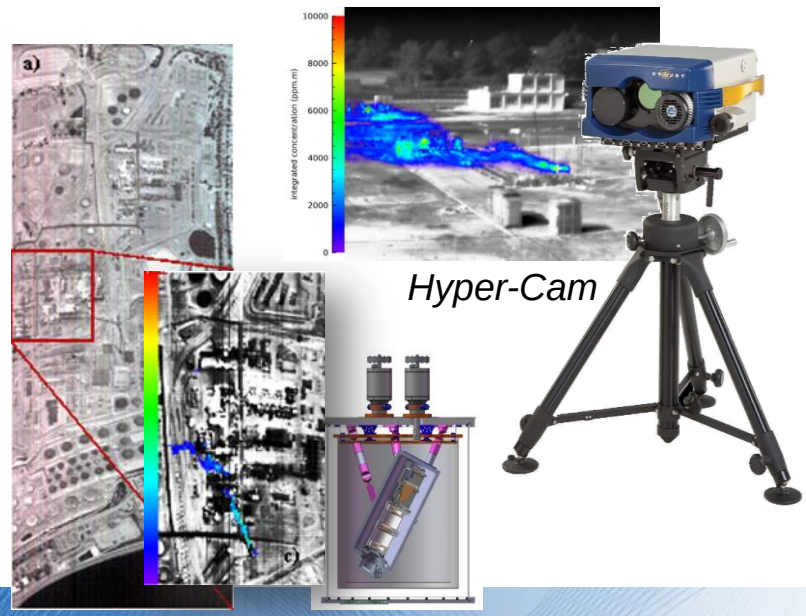
Real time methodology

Quantification requires separation of ground and gas properties.

Classic optimisation algorithms are time consuming

IMGSPEC provides real time quantitative map

High spatial resolution
(ex : HyTES, Hyper-Cam,..)



Hyper-Cam

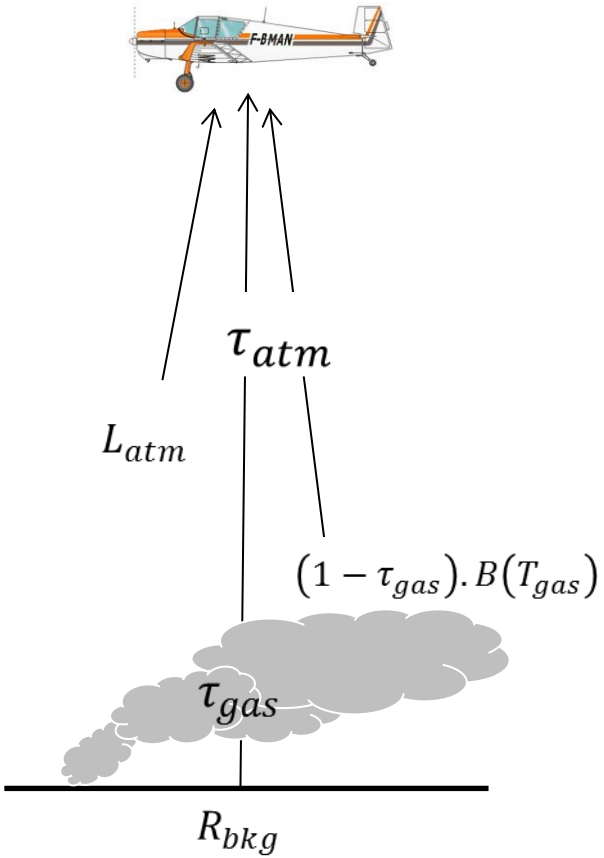
HyTES

Multi-gas tool
hyperspectral

SF6
Acétone
Ethylene
Methane
…

1. Real time methodology : principle

Quantification principle lies on transmission computation.
Concentration (ppm.m) is deducted from transmission



- Rgas : *Input radiance with gas*

$$R_{gas} = \tau_{gas}.\tau_{atm}.R_{bkg} + \tau_{atm}.(1-\tau_{gas}).B(T_{gas}) + L_{atm}$$

- Rref : *reference radiance without gas*

$$R_{ref} = \tau_{atm}.R_{bkg} + R_{atm}$$

- Transmission

$$\tau_{gas} = 1 + \frac{R_{gas} - R_{ref}}{(R_{ref} - R_{atm} - \tau_{atm}.B(T_{gas}))}$$

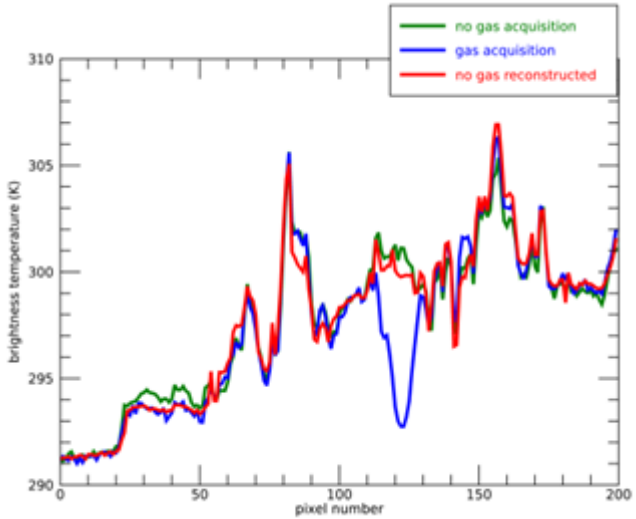
1. Real time methodology : reference reconstruction

- $T_{gas} = T_{atm}$

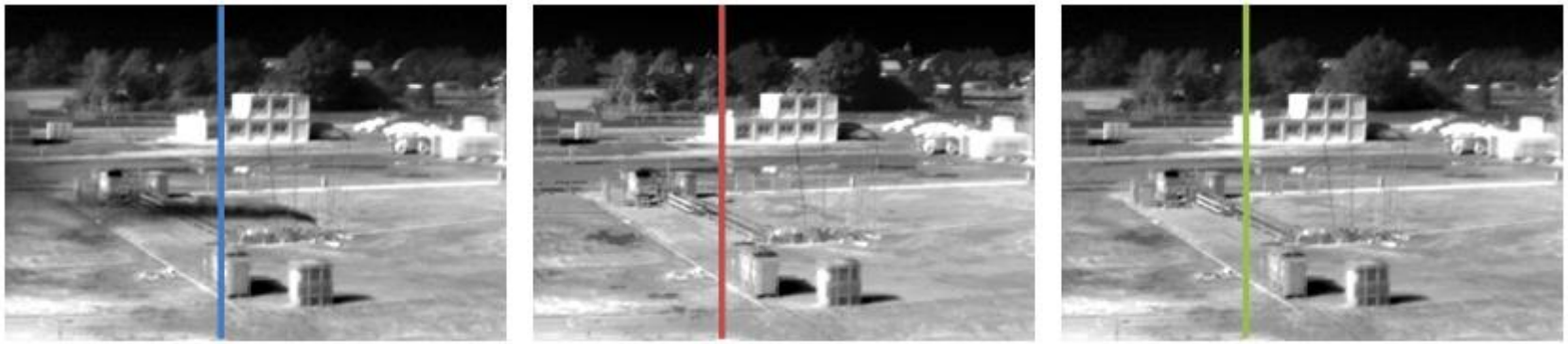
- R_{atm} and T_{atm}

are computed from water vapor content at ground level

are deducted from ISAC(*) correction for airborne case



•R_{ref} *Reference is reconstructed thanks to CSB method (*)*



(*) References are included in the proceeding

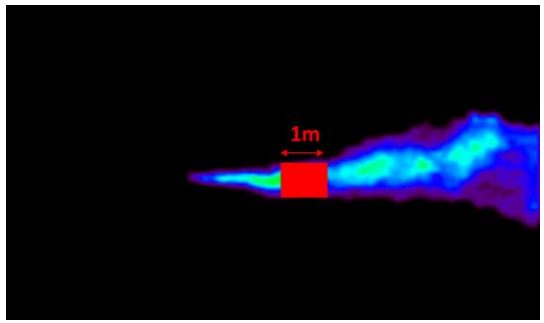
1. Real time methodology : flow rate estimation

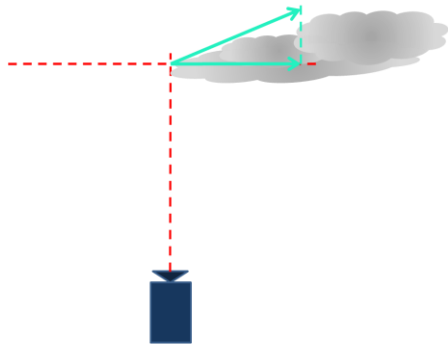
Flow rate of the gas plume is computed by estimating the mass of the gas transported by the wind in one second

$$f = m_{gas\_1m} \times s_{wind}$$

g/s g/m m/s

- Mass (for a 1m « slice ») is deducted from concentration map and massive density of gas
- Wind speed is measured with a meteorological station (or directly from images if frame rate is <= 1Hz)

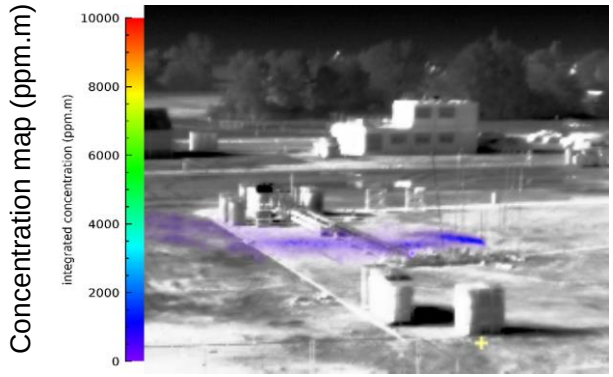


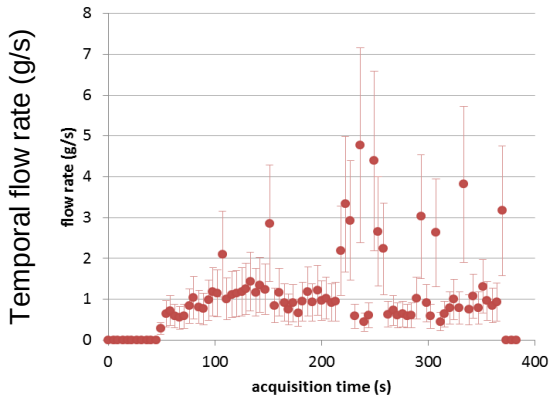


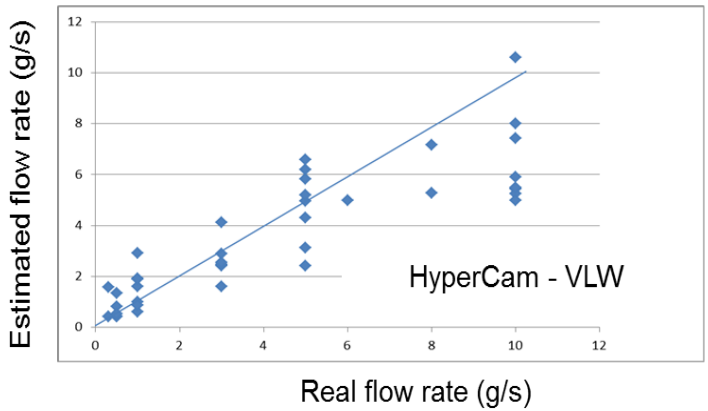
This method is valid only is the wind direction is orthogonal to viewing direction

2. Ground results: validation in case of methane

Test campaigns with controlled flow rate on Lacq Platform (Fr) from 2015 to 2018.
Collaboration with TOTAL company





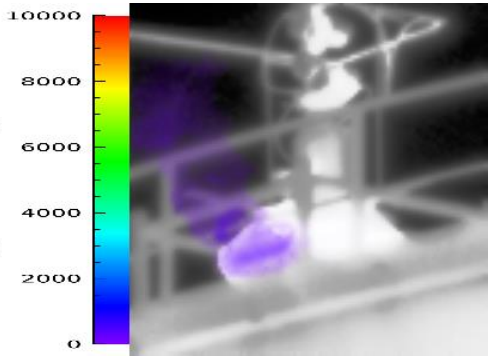


Incertitude is mainly due to wind measurement unaccuracy

2. Ground results : Case of other gases

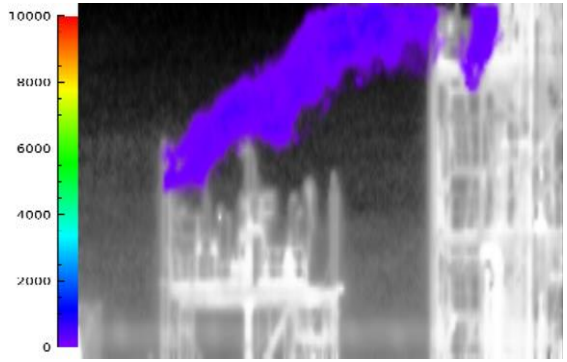
With the courtesy of J.P Gagnon from Telops

MTBE

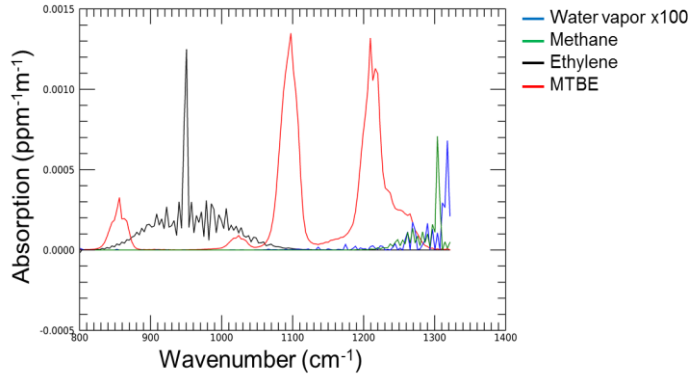


Integrated concentration (ppm.m)

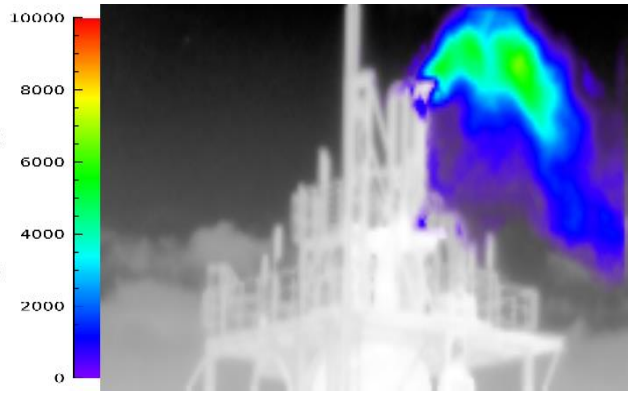
chlorodifluoromethane (F22)



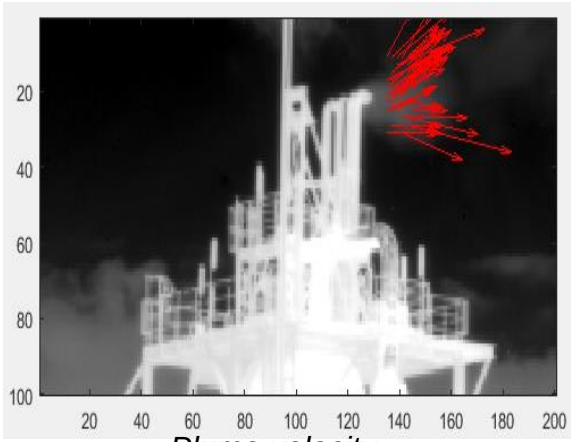
Integrated concentration (ppm.m)



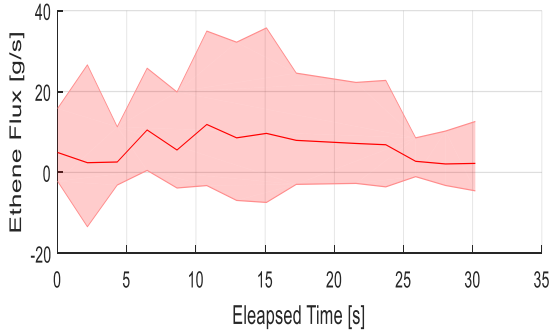
Ethylene



Integrated concentration (ppm.m)



Plume velocity



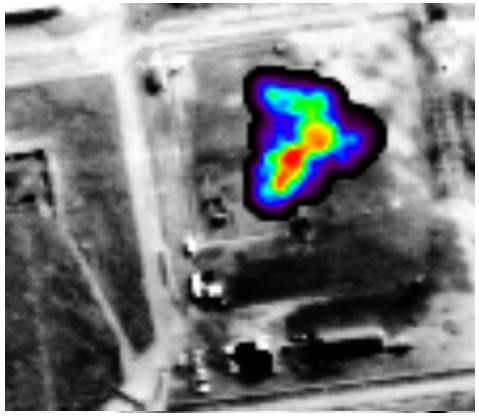
Flow rate

3. Airborne results : Validation in the case of methane

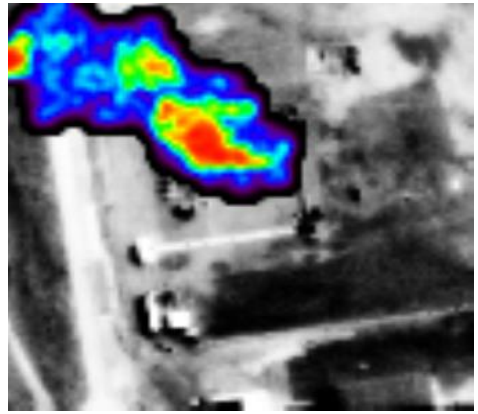
Test campaigns with controlled flow rate on Lacq Platform (Fr) in 2018.
Collaboration with TOTAL company

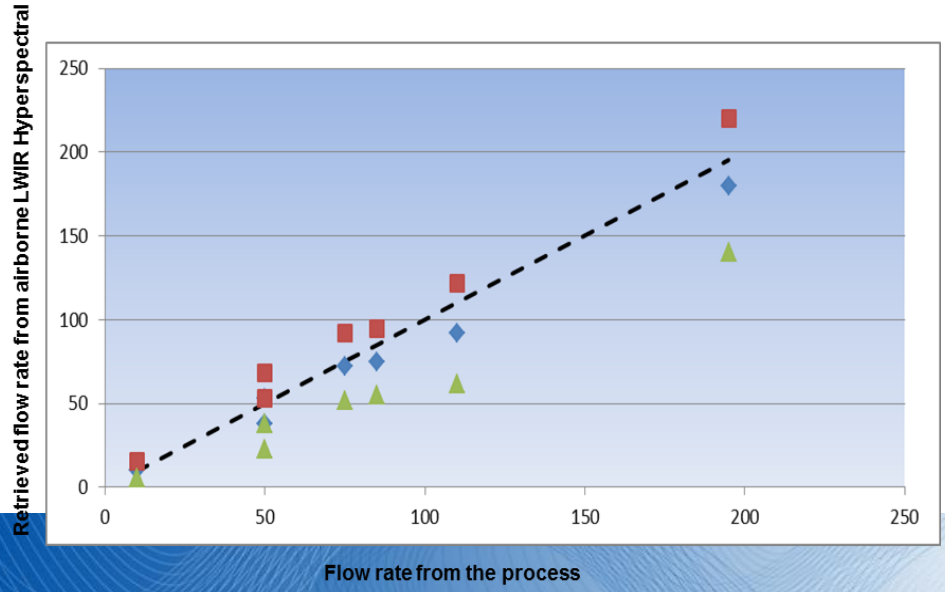
1g/s @ 600m

80g/s @ 1250m

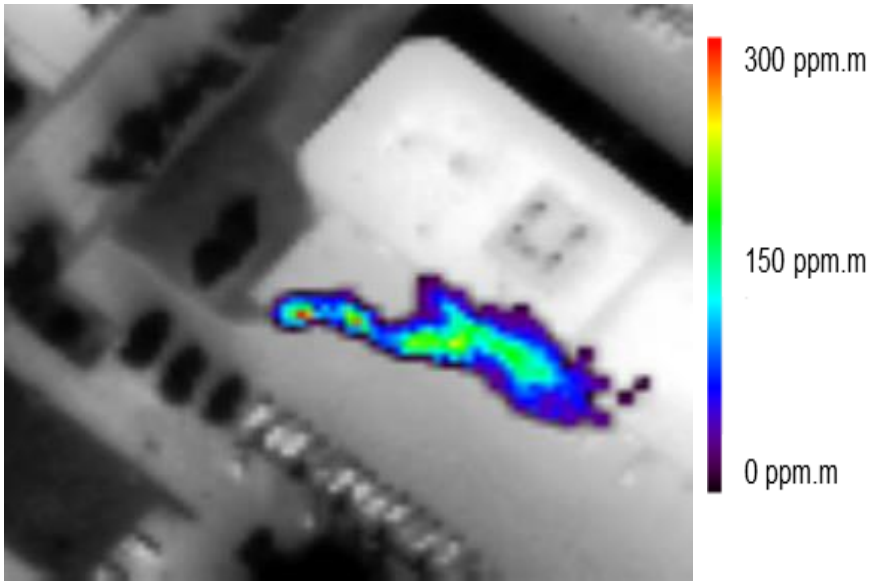


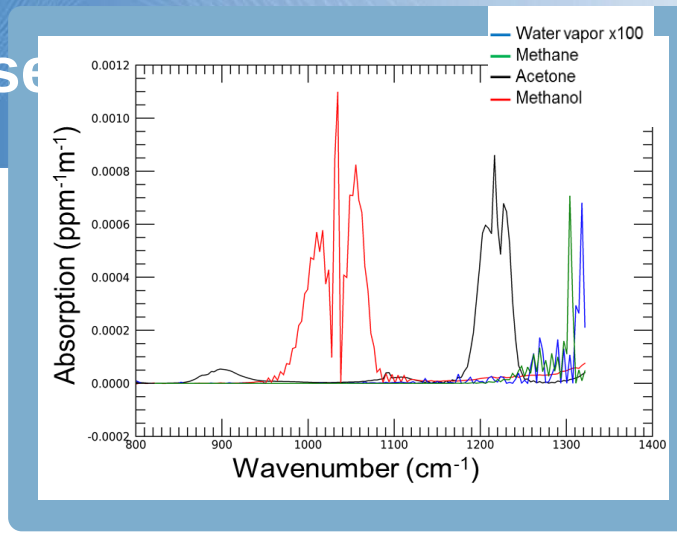
200 g/s @ 900m





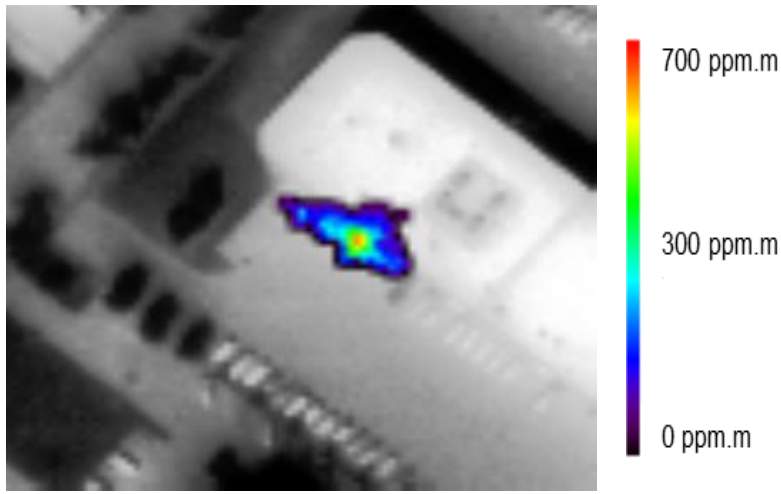
3. Airborne results : case of other gase





Evaporating Methanol flow rate estimation:

- Cross wind linear mass : 1.2 g/m
- Plume velocity : 1.5 m/s
- Flow rate : 1.8g/s
- Total mass : 18g
- Local concentration (centre of the plume) : 25 pmm



Evaporating Acetone flow rate estimation:

- Flow rate : 3.1g/s
- Total mass : 11g
- Local concentration (centre of the plume) : 65 pmm

Conclusion

- IMGSPEC is a fast quantitative algorithm estimating column path concentration from ground or airborne LWIR thermal hyperspectral data.

- This algorithm also provide plume propagation direction, linear mass in the cross wind direction (flow rate if wind is known), total mass and an estimation of the local concentration under Gaussian distribution hypothesis.

- An exhaustive validation in the case of methane corresponding to many experiments : hundreds test over three different campaigns (mean error around 50%).

- coupling IMGSPEC with instrument which can provide directly plume velocity (using a frame rate at least of 1hz) is a great advantage.

THANK YOU