ONERA — THE FRENCH AEROSPACE LAB — retour sur innovation

Coupling Hyperspectral imaging and Lidar measurements to estimate gas and aerosols emissions from industrial and anthropogenic sources

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Goal

Current developments in Hyperspectral imaging and Lidar technologies provide new opportunities, for high spatial resolution monitoring of emission factors for anthropogenic sources and biomass fires. We aim to develop a method to improve the **3D characterization and quantification of anthropogenic emissions at high spatial resolution for gas species (CO_2, CH_4, SO_2, NH_3, VOC, ...) and aerosols (BC, organic, sulfate, mineral...).**

Technical means

Airborne Hyperspectral imaging

- **Aerosol + Gas 2D retrieval**
- **High spatial resolution : 1m**
- **Wide spectral range : 0.4-12.5µm**
- **Spectral resolution : 3nm (0.4-2.5µm), 10cm^{-1}(3-5µm), 5cm^{-1} (8-12µm)**

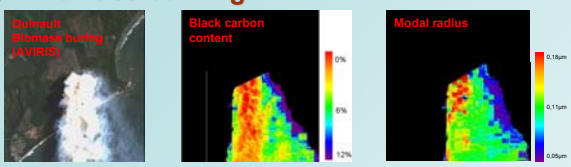
On ground Lidar

- **Aerosol + Gas retrieval**
- **Vertical profile**
- **Multi-wavelength**

Aerosols retrieval

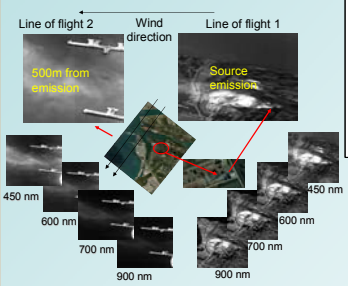
Hyperspectral imaging

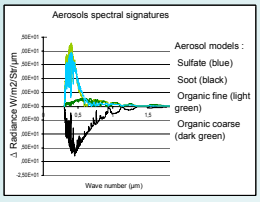
Biomass burning



BC estimation from AVIRIS Hyperspectral data [A. Alakian et al., 2009]

Industrial sources





First quantitative result of analysis coming soon…

(Deschamps et al. In prep.)

- **Optical properties quantification (extinction coefficient, albedo, optical depth)**
- **2D estimation of aerosols type and abundance**

✓ Meteorological data (wind direction, temperature/pression profile, humidity,…)

✓ Aerosol model

Data fusion

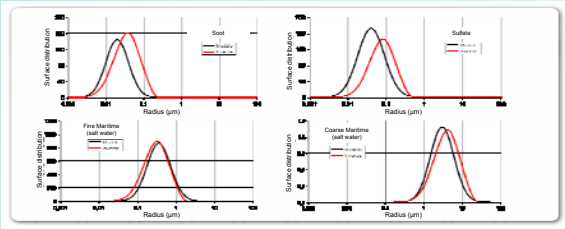
- Improvement of optical properties retrieval
- **3D mapping of aerosol plume, with high spatial resolution**

VIS-NIR Lidar multi-λ

Lidar CALI : Lidar multi-wavelength to a 3D scan of atmospheric aerosols

Simultaneous pulse of :
1 stable wavelength : 532 nm
3 tunable wavelength : UV-VIS (355-532nm)/ NIR (680-900nm) / SWIR (1.2-2µm)

Nominal concept (summer 2013) :
- *Detection of 4 granulometry modes from (50nm to 2µm)* ***using 8 wavelength***
- 3D scan (30min need) : Angular sampling : 5° / Vertical sampling : 10m / Range : 2km



Simulation : Retrieved Granulometry for 4 differents modes in the case of a mix of soot – sulfate and salt water: case of polluted maritime aerosols

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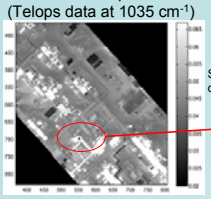
Gas retrieval

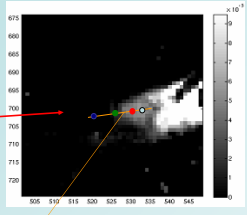
Hyperspectral imaging

Industrial plant (Telops data at 1035 cm^{-1})

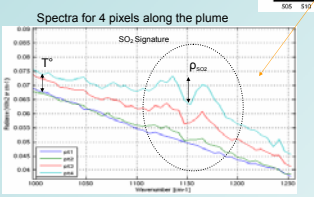


SO_2 plume detection

SO2 retrieved emission map



Spectra for 4 pixels along the plume



spatial characterization of concentration and temperature along the plume

- **2D mapping of gas (CO_2, SO_2, CH_4, NH_3, NOx, COV,…) plume, with high spatial resolution**
- **Multi-gas detection (unmixing)**
- **Temperature and concentration retrieval**

✓ Meteorological data (wind direction, temperature/pression profile, humidity,…)

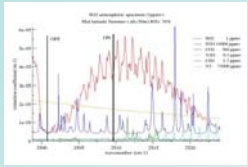
✓ Gas dispersion model

Data fusion

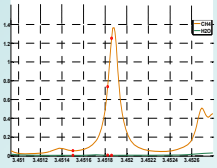
- **3D mapping of gas plume, with high spatial resolution**
- Improvement of the temperature and concentration retrieval

IR Lidar multi-λ

New Lidar Concept to explore 3.3 µm spectral area

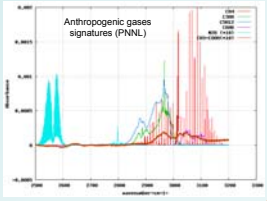


SO_2 Dial IR selection at 2540 cm^{-1}



CH_4 multi wavelength selection at 2897 cm^{-1}

- Development (2013) of a new Tunable MWIR OPO Lidar multi wavelength : Multi-gas retrievals
- Gas : SO_2, CH_4, COV
- **Vertical** resolution : 10m
- Spectral range : 2500-3200 cm^{-1}
- Distance range : 2km



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Validation : simulation Tools

- **Ground :** ONERA Database (emissivity for different materials with high resolution)
- **Gas :** PNNL / GEISA / HITRAN
- **Aerosols properties :** Industrial plume specific properties (Flamant et al., ESCOMPTE data) / OPAC database / Laser measurements (specific refractive index estimation)
- **Radiative transfer model :** MATISSE (ONERA) / 4A / MODTRAN

3D polluted scene simulation (gas + aerosols) for the spectral range [0.4-12µm]

Validation Campaign

- **Validation on airborne hyperspectral images**
  - Coming **measurement campaign** : ONERA (Lidar + hyperspectral) + in-situ measurements (Ground truth)
  - Existing images : (Telops, SPIM,…)

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