HALESIS ou l'étude de phénomènes lumineux transitoires par imagerie hyperspectrale embarquée sous ballon

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FEASIBILITY OF HIGH ALTITUDES LUMINOUS EVENTS STUDY BY INFRARED SPECTRO-IMAGERY EMBEDDED IN A STRATOSPHERIC BALLOON.

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Abstract

HALESIS (High Altitude Luminous Events Studied by Infrared Spectro-imagery) is an innovative project based on hyperspectral imagery. The purpose of this experience is to measure the atmospheric perturbation in the minutes following the occurrence of Transient Luminous Events (TLEs) from a stratospheric balloon in the altitude range of 20 to 40 km. We present the preliminary study that has established the feasibility of the project.

I – Motivation and scientific context

- 1989: 1st record of transient luminous events (TLEs) in the high atmosphere. => Demonstration of the existence of another interaction processes between the different atmospheric layers (troposphere, stratosphere, mesosphere and ionosphere).

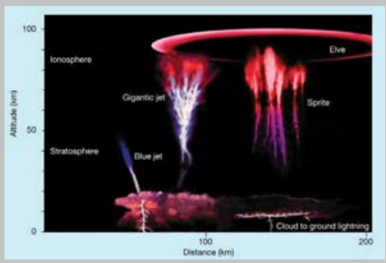


Figure 1: Lightning related TLEs (Pasko V P 2003 Electric jetsNature423927–9)

Name	Altitude	Duration
Blue Jets	10-40 km	A few 100 ms
Gigantic Jets	10-90 km	A few 100 ms
Sprites	50-90 km	10 ms
Elves or Halos	70-90 km	1 ms

Tableau 1: Altitude and duration of TLEs (Pasko V P 2010 JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, A00E35)

Consequences :

- interaction processes between the different atmospheric layers, which was not considered before
- impact not yet quantified
- chemical processes involved having potential broader consequences

II – HALESIS PURPOSE

- The presence of oxygen atoms in electronic excited states has an impact on ozone chemistry.
- Atomic or molecular species excited in electronic or vibrational states can induce various chains of chemical reactions and local enhancements of the concentrations of O_3, NO_x ($NO+NO_2$), NO^+, OH,

Figure 2: HALESIS experiment timeline.

HALESIS PURPOSE:
What's happened in the minutes following the events;.
To **measure the effect of these events on stratospheric chemistry** by retrieving the concentration of species potentially produced or perturbed (NO_x, O_3, OH, ...)
To monitor the **vibrationally excited chemical reactions** associated with TLEs.

III. Physical Processes at the origin of TLE

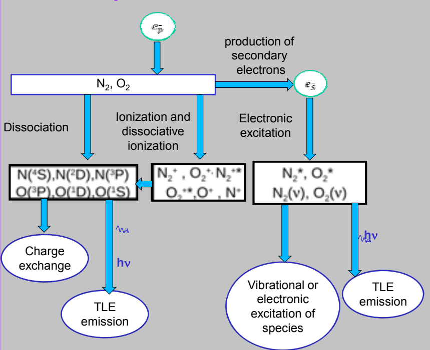
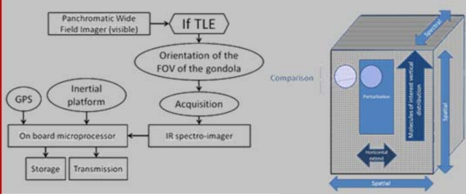


Figure 3: Physical processes at the origin of TLE.

- An electrical perturbation caused by a thunderstorm can trigger a discharge above the clouds in the upper layers of the atmosphere.
- The associated energized electrons excite, ionize or dissociate the major constituents N_2 and O_2 of the atmosphere leading to atomic, molecular, or ionic species.
- When relaxing to lower energy states, visible photons are emitted.

IV – Instrumental setup

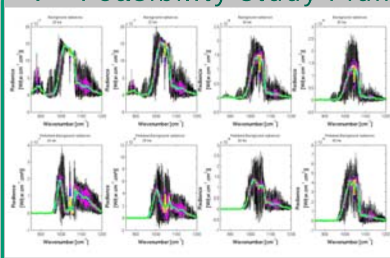


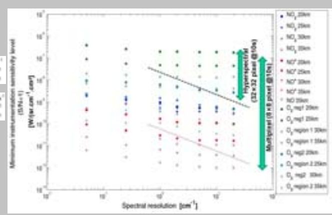
Spectro-imagery is a combination of imaging and spectroscopy. It allows for acquiring images that are spectrally resolved.

Figure 4: HALESIS instrumentation principle and interest of the use of an hyperspectral imager.

- Horizontal spatial dimension: comparison between central and edge pixels.
- Vertical spatial dimension: vertical distribution of species.
- Spectral dimension: depends on the target species produced or perturbed (NO, O_3, NO_2, NO^+)

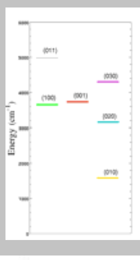
V – Feasibility study : fundamental bands

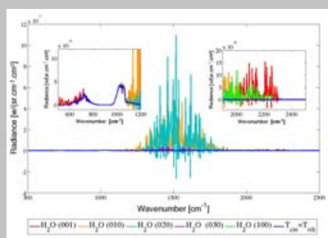




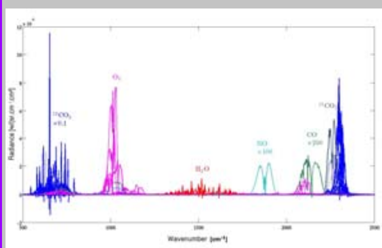
- Signature of the O_3 effect on "easily" detectable in the TIR
- NO_2 and O_3 effect signatures requires multipixel medium resolution concept

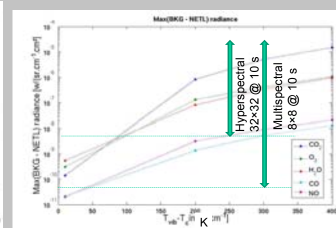
VI – Feasibility study : hot bands





The simulations were performed considering the internal energy levels of molecules were **populated** according to a **Maxwell-Boltzmann** statistic
(LTE = Local Thermodynamic Equilibrium)
But if the molecules are vibrationally excited, it is necessary to consider individually **the population of each energy level**
(NLTE = Non Local Thermodynamic Equilibrium)
=> spectral signatures in the hot vibrational band possibly with a larger amplitude than for the cold ones.





- O_3, H_2O, CO_2 signatures « easily » detectable in the MIR;
- NO and CO signature detectable with a multipixel concept.

VII – Conclusion and Outlook

- Very poor information on the impact of TLEs on the chemical composition of the stratosphere;
- We are currently establishing the feasibility of an **innovative project** to measure **the impact of TLEs on atmospheric compositions**.
- Need to simultaneously acquire spectral measurements in disturbed and undisturbed atmosphere, at different time, and at different altitudes → **hyperspectral imaging** !
- **Preliminary simulations** showed that the order of magnitude expected to detect a disturbance are consistent with detection limits of
  - A commercial spectro-imager to (950-1075 cm-1) for O_3
  - A multipixel spectrometer (1675-1750 cm^{-1}) for NO
- Need to **explore the hot bands** to probe more species and more information;
- Need to **explore innovative FTS instrument concepts** for an acquisition frequency and sufficient sensitivity (GLORIA/IMK, SIELETERS/ONERA, ...)

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