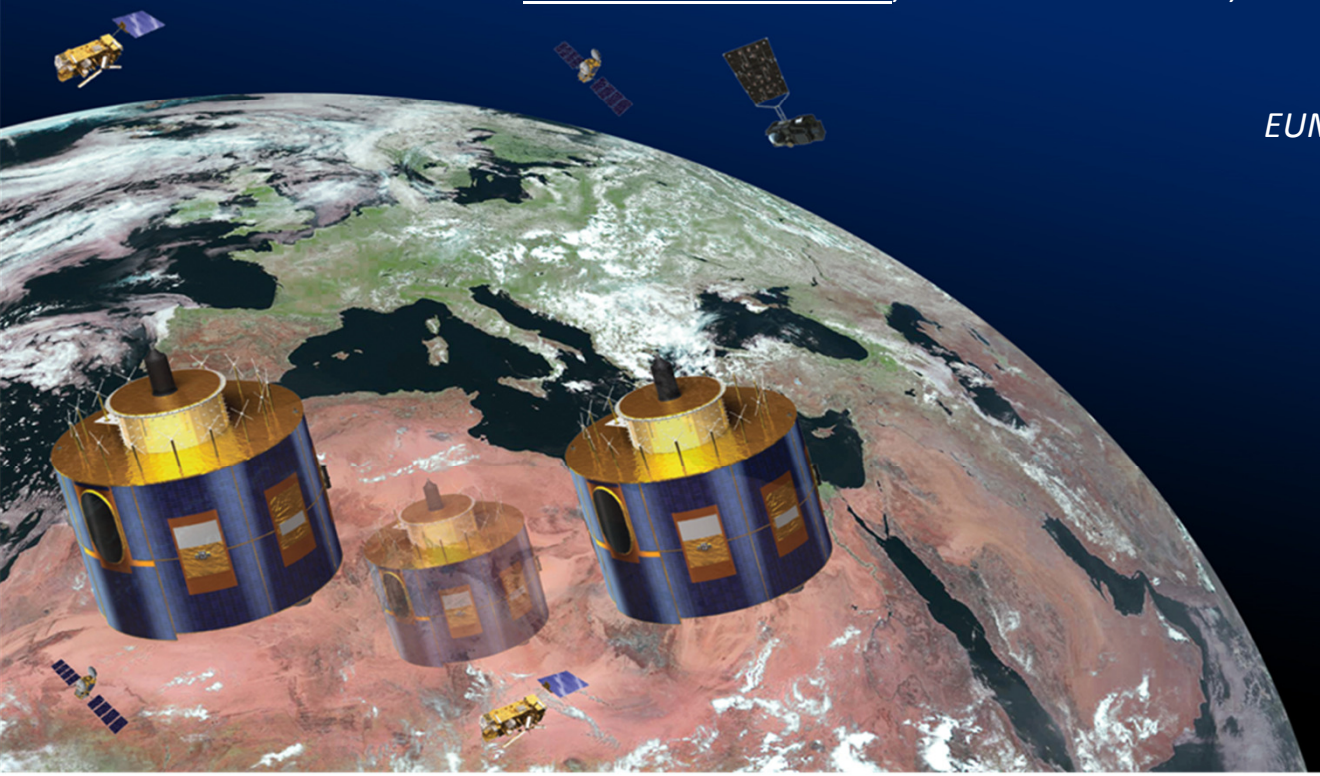
# Lightning Imager (LI) end-to-end prototype processor

[1]Bartolomeo Viticchié, [1]Mounir Lekouara, [1]Jochen Grandell, [1]Heikki Pohjola, [1]Sauli Joro, [2]Marcel Dobber & [2]Gary Fowler

*EUMETSAT Allee 1, 64295, Darmstadt Deutschland*

bartolomeo.viticchie(at)eumetsat.int

[1]EUMETSAT/RSP, [2]EUMETSAT/GEO



# Outline of the talk

- Basic information on lightning and lighting detection
- LI instrument and detection principle
- LI ground processing concept and end-to-end processor
- Examples

# Basic information on lightning and lighting detection

Lightning is a sudden electrostatic discharge between electrically charged regions:

- of a cloud (intra – cloud lightning or IC);
- of two clouds (cloud – to – cloud lightning or CC);
- of a cloud and the ground (cloud – to – ground lightning or CG).

# Basic information on lightning and lighting detection

Lightning is a source of:

- Very High Frequency signals (VHF);
- Very Low Frequency signals (VLF);
- Low Frequency  signals (LF);
- optical pulses.

Such signals allow one to detect lightning and to characterize them.

# Basic information on lightning and lighting detection

Lightning is a source of:

- Very Hig
- Very Lo
- Low Fre
- optical

Such signals allow one to detect lightning and to characterize them

- Lightning is a precursor of severe weather with a lead time of tens of minutes
- The key observable to detect “weather intensification” is the total lightning rate variation (CG + IC + CC)

# Basic information on lightning and lighting detection

| Signal | Baseline | Detection capability | Attributes | Instrument/Network |
|---|---|---|---|---|
| Optical | Space borne | 80% – 90% of CG + CC +IC | 2D mapping and radiance<br>GEO/LEO FOV | • Optical Transient Detector (OTD, 1995)<br>• Lightning Imaging Sensor<br>• (LIS, 1997)<br>• Geostationary Lightning Mapper (GLM, 2016)<br>• Lightning Imager (LI, 2021) |
| VHF | 10 – 20 km | 100% of CG + CC +IC | 3D mapping | e.g., Ebro Lightning Mapping Array (ELMA), and Suivi de l'Activité Electrique Tridimensionnelle Totale de l'Atmosphère (SAETTA) |
| LF | 50 – 300 km | 50% – 90% of IC + CC<br>> 95% CG | Waveform analysis | • European Cooperation for Lightning Detection (EUCLID)<br>• North American Lightning Detection Network (NLDN)<br>• LINET |
| VLF | > 1000 km | 10% – 30% CC + IC<br>70% – 80% CG | Global coverage | • Vaisala GLD360<br>• Met Office ATDnet<br>• Earth Networks ENTLN |

# Basic information on lightning and lighting detection

| Signal | Baseline | Detection capability | Attributes | Instrument/Network |
|---|---|---|---|---|
| **Optical** | **Space borne** | **80% – 90% of CG + CC +IC** | **2D mapping and radiance GEO/LEO FOV** | • **Optical Transient Detector (OTD, 1995)**<br>• **Lightning Imaging Sensor**<br>• **(LIS, 1997)**<br>• **Geostationary Lightning Mapper (GLM, 2016)**<br>• **Lightning Imager (LI, 2021)** |
| VHF | 10 – 20 km | 100% of CG + CC +IC | 3D mapping | e.g., Ebro Lightning Mapping Array (ELMA), and Suivi de l'Activité Electrique Tridimensionnelle Totale de l'Atmosphère (SAETTA) |
| LF | 50 – 300 km | 50% – 90% of IC + CC<br>> 95% CG | Waveform analysis | • European Cooperation for Lightning Detection (EUCLID)<br>• North American Lightning Detection Network (NLDN)<br>• LINET |
| VLF | > 1000 km | 10% – 30% CC + IC<br>70% – 80% CG | Global coverage | • Vaisala GLD360<br>• Met Office ATDnet<br>• Earth Networks ENTLN |

# LI instrument and detection principle

| LI main characteristics |
| --- |
| **Measurements in a 1.9 nm narrow band around 777.4 nm**<br>designed to detect the emission of a triplet of lines from the neutral oxygen triggered by the lightning |
| |
| |
| |
| |
| |
| |

# LI instrument and detection principle

| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| **4.5 km pixel size at Sub-Satellite-Point**<br>designed to sample a “typical lightning” with size of the order of 100 $km^2$ (i.e., 10 km radius) |
| |
| |
| |
| |
| |

# LI instrument and detection principle

| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| 4.5 km pixel size at Sub-Satellite-Point |
| **1000 Hz acquisition frequency (1 ms integration time)**<br>designed to detect the “typical lightning” with 0.6 ms duration |
| |
| |
| |
| |

# LI instrument and detection principle

| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| 4.5 km pixel size at Sub-Satellite-Point |
| 1000 Hz acquisition frequency (1 ms integration time) |
| **Four optical heads capable of capturing almost the whole Earth disk visible from GEO position** |
| |
| |
| |

# LI instrument and detection principle

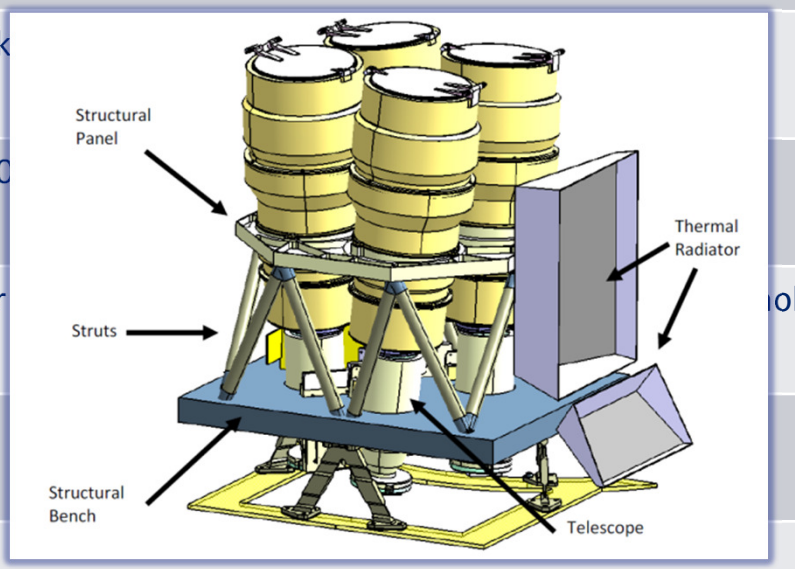
## LI main characteristics

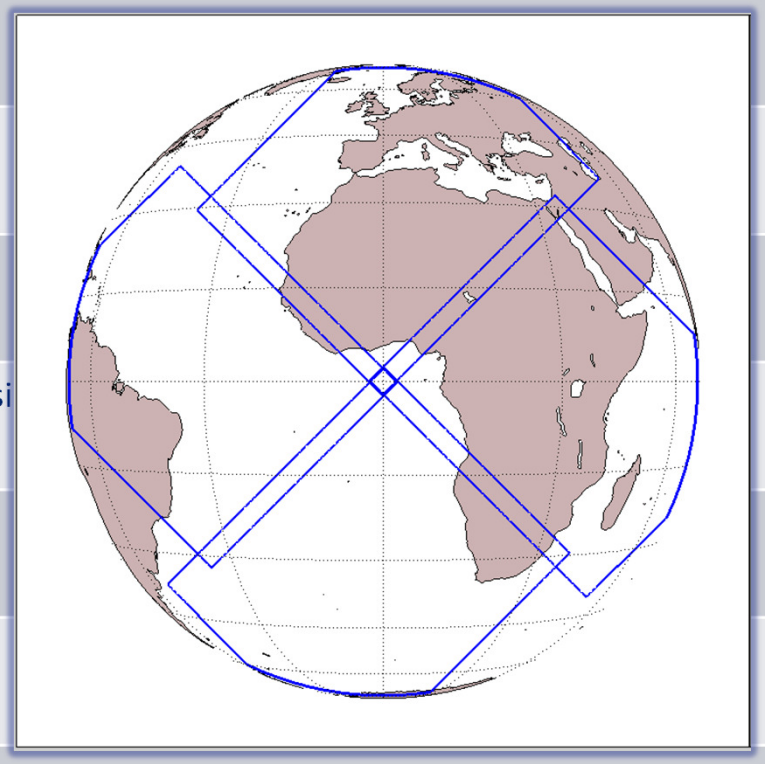
Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 k

1000

Four ole Earth disk visi



# LI instrument and detection principle

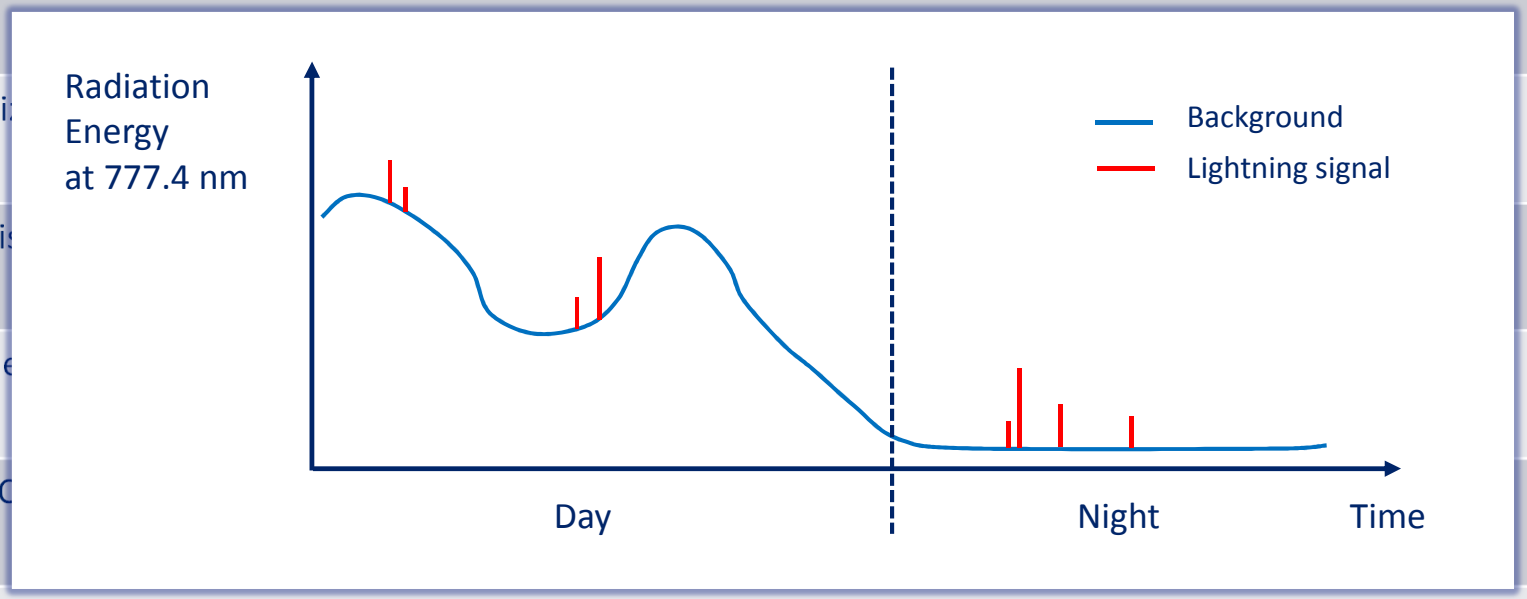
| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| 4.5 km pixel size at Sub-Satellite-Point |
| 1000 Hz acquisition frequency (1 ms integration time) |
| Four optical heads capable of capturing almost the whole Earth disk visible from GEO position |
| **Detects CG + CC + IC** |
| |
| |

# LI instrument and detection principle

| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| 4.5 km pixel size at Sub-Satellite-Point |
| 1000 Hz acquisition frequency (1 ms integration time) |
| Four optical heads capable of capturing almost the whole Earth disk visible from GEO position |
| Detects CG + CC + IC |
| **Continuous measurements of (lightning) triggered events** |
| **Background subtraction, event detection and event processing performed by on-board electronics** |

# LI instrument and detection principle

| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| 4.5 km pixel si |
| 1000 Hz acqui |
| Four optical h |
| Detects CG + C |
| Continuous measurements of (lightning) triggered events |
| Background subtraction, event detection and event processing performed by on-board electronics |



# LI instrument and detection principle

## LI main characteristics

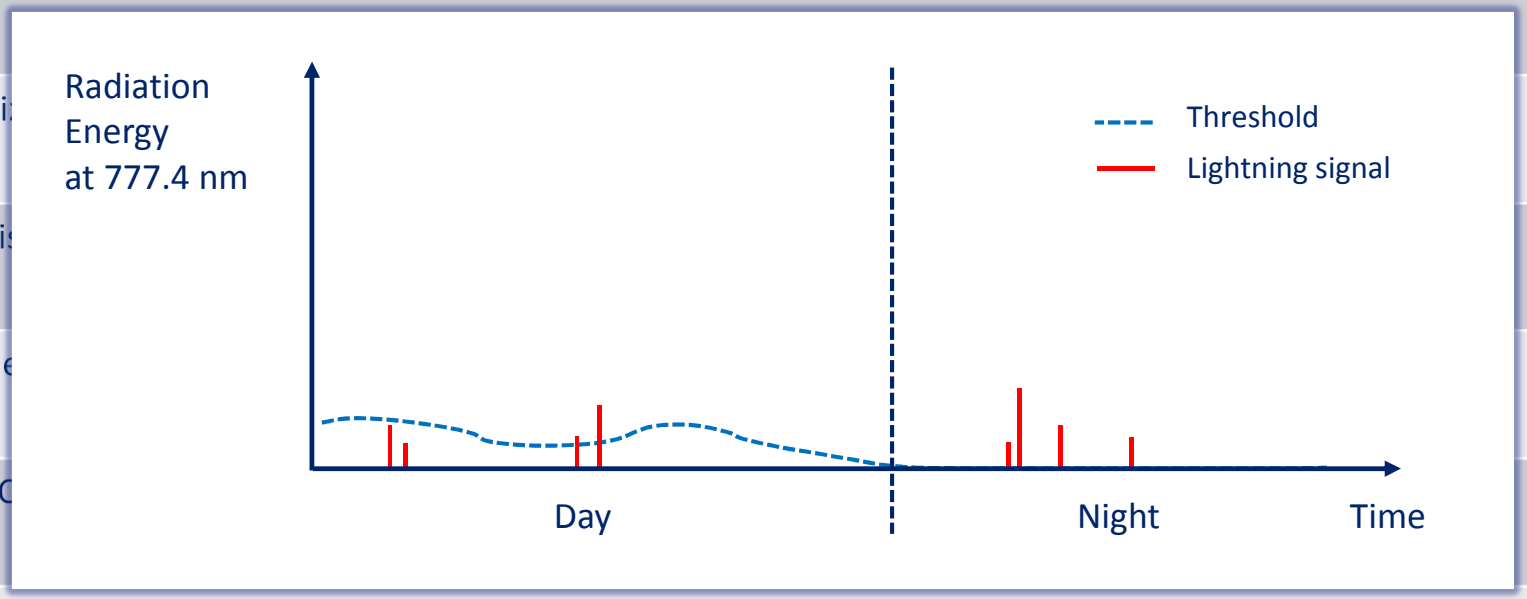
Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 km pixel si

1000 Hz acqui

Four optical he

Detects CG + C

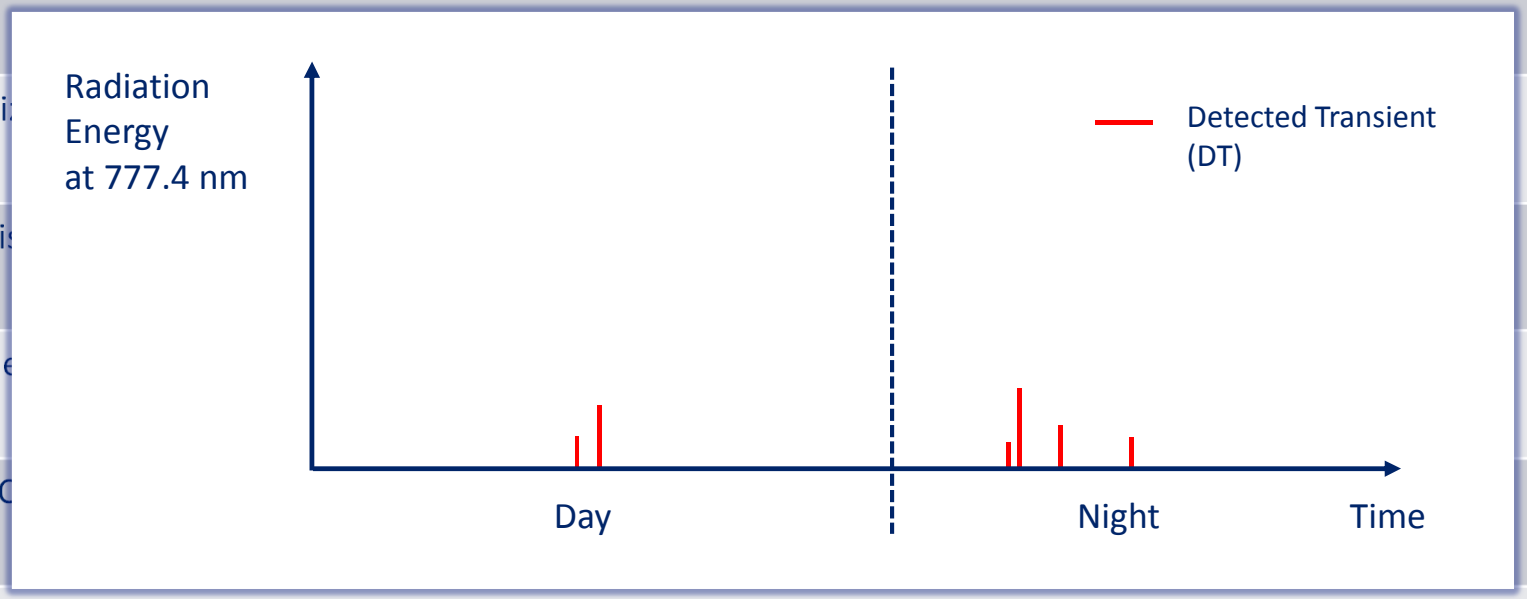



Continuous measurements of (lightning) triggered events

Background subtraction, event detection and event processing performed by on-board electronics

# LI instrument and detection principle

| LI main characteristics |
| --- |
| Measurements in a 1.9 nm narrow band around 777.4 nm |
| 4.5 km pixel si |
| 1000 Hz acqui |
| Four optical h |
| Detects CG + C |
| Continuous measurements of (lightning) triggered events |
| Background subtraction, event detection and event processing performed by on-board electronics |



# LI instrument and detection principle

## LI main characteristics

Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 km pixel si

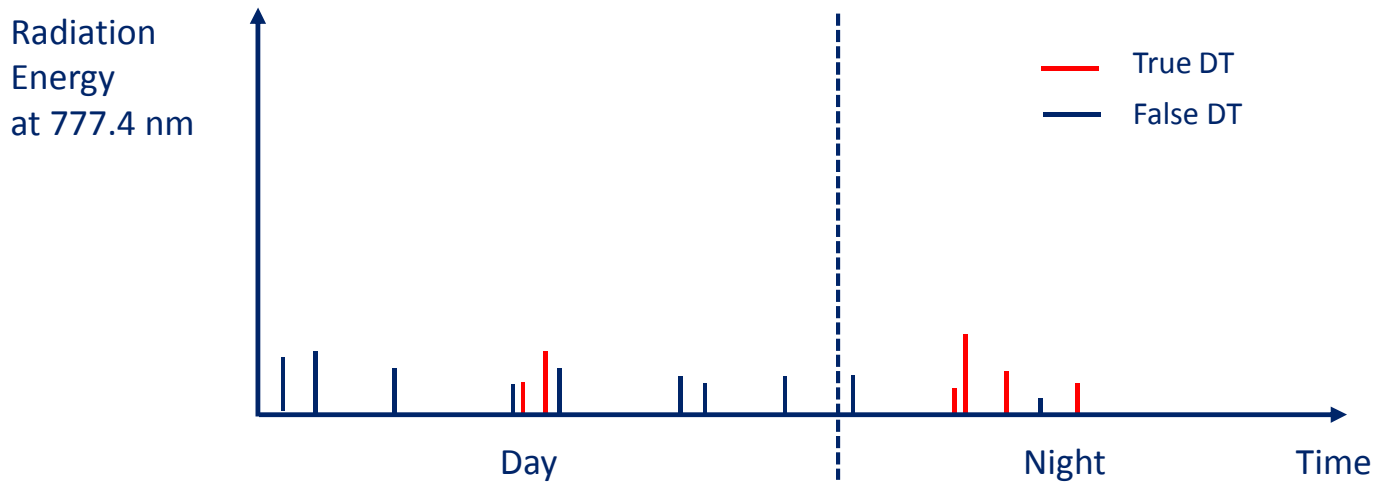
1000 Hz acqui

Four optical he

Detects CG + C

Continuous m

Background su




Sources of false transients:

- local fluctuations of the radiometric noise;

# LI instrument and detection principle

## LI main characteristics

Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 km pixel si

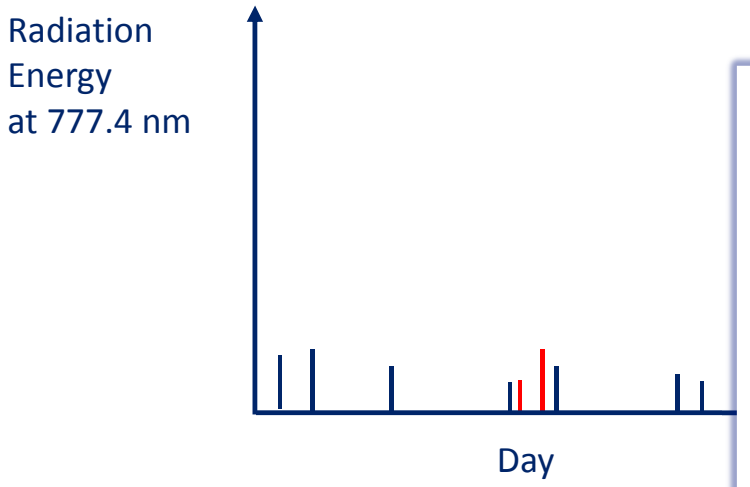
1000 Hz acqui

Four optical he

Detects CG + C

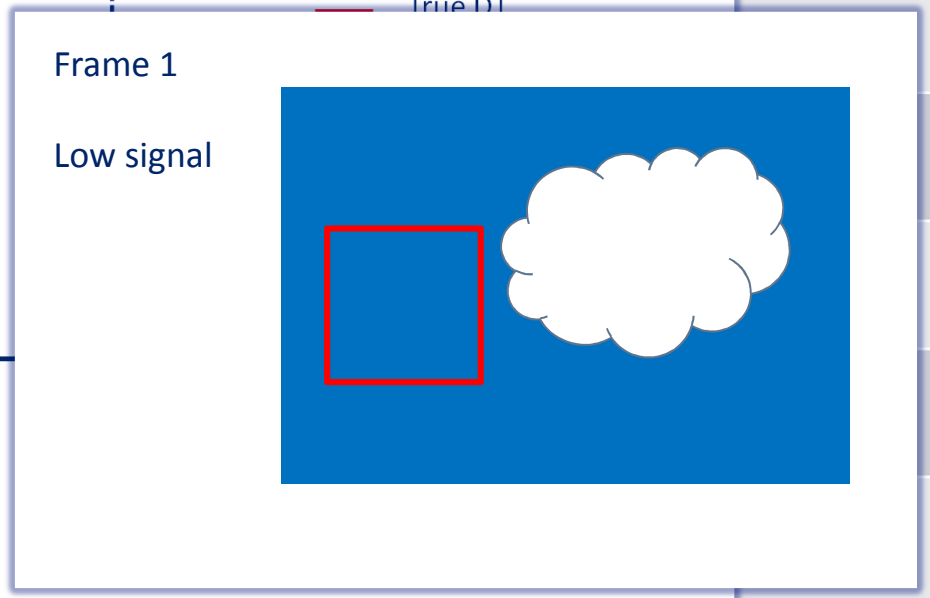
Continuous m

Background su




Sources of false transients:

- local fluctuations of the radiometric noise;
- micro – vibration of the platform;



# LI instrument and detection principle

## LI main characteristics

Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 km pixel si

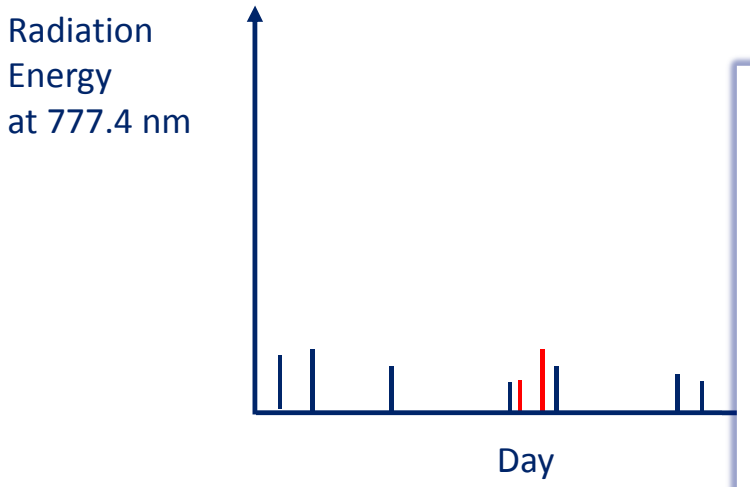
1000 Hz acqui

Four optical he

Detects CG + C

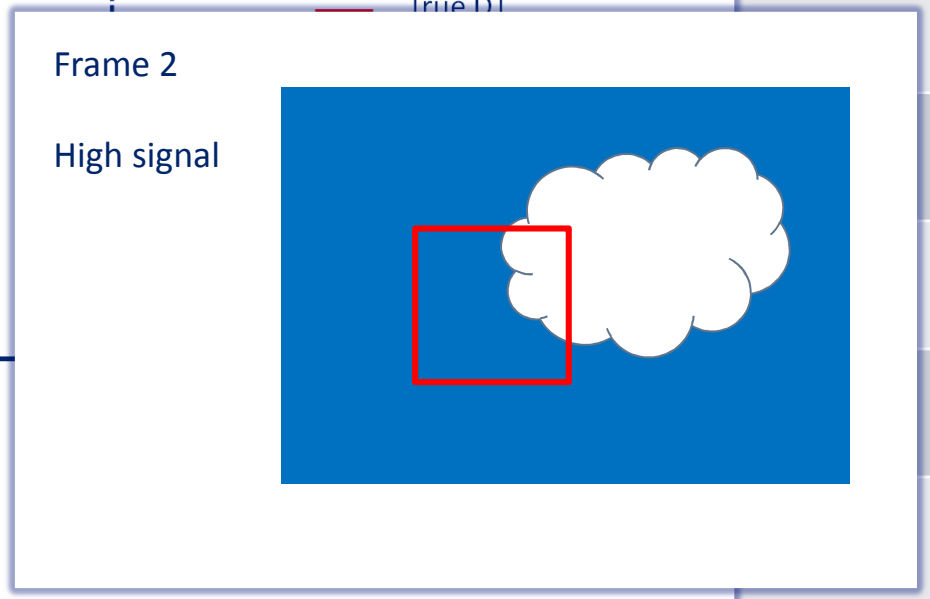
Continuous m

Background su




Sources of false transients:

- local fluctuations of the radiometric noise;
- micro – vibration of the platform;



# LI instrument and detection principle

## LI main characteristics

Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 km pixel si

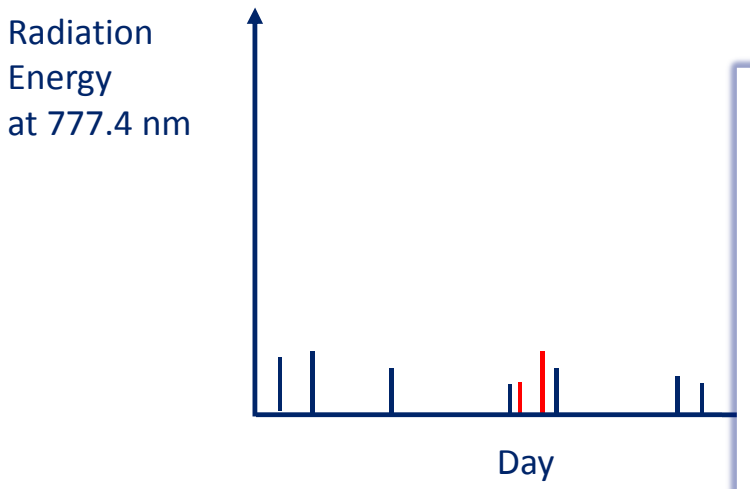
1000 Hz acqui

Four optical he

Detects CG + C

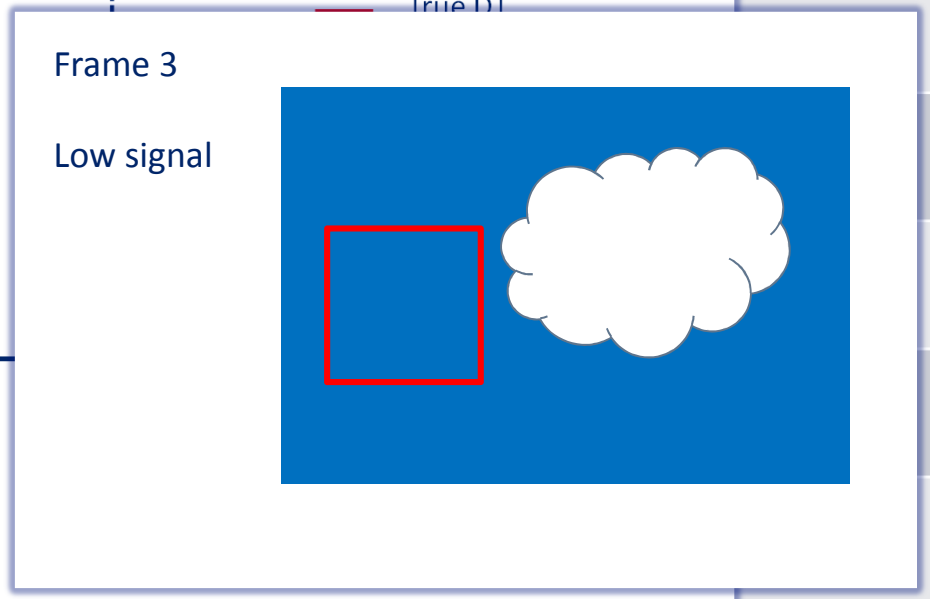
Continuous m

Background su




Sources of false transients:

- local fluctuations of the radiometric noise;
- micro – vibration of the platform;



# LI instrument and detection principle

## LI main characteristics

Measurements in a 1.9 nm narrow band around 777.4 nm

4.5 km pixel si

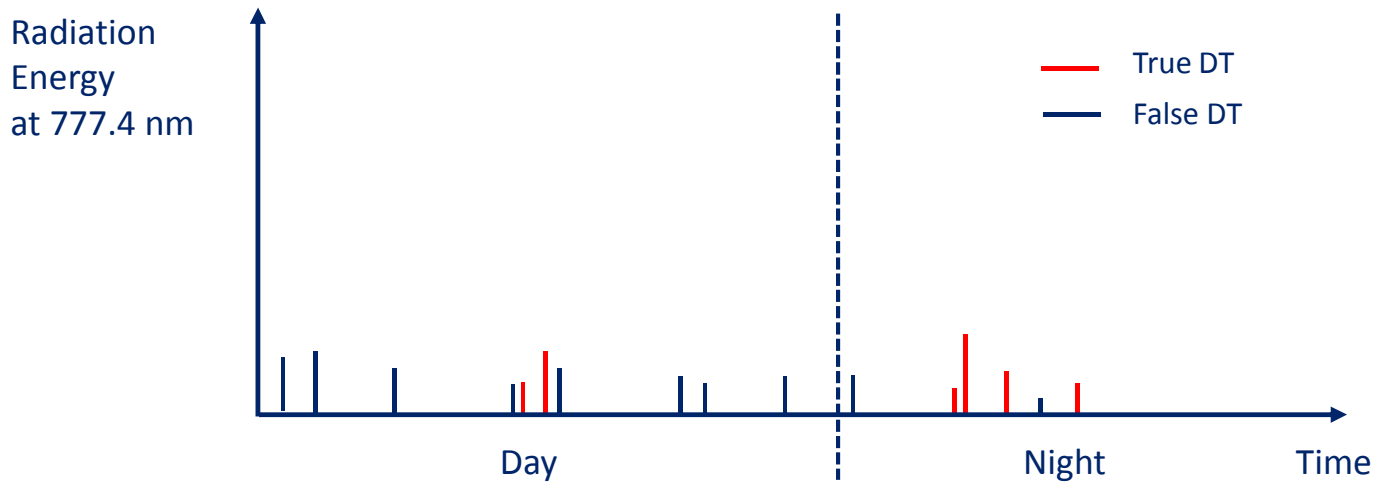
1000 Hz acqui

Four optical he

Detects CG + C

Continuous m

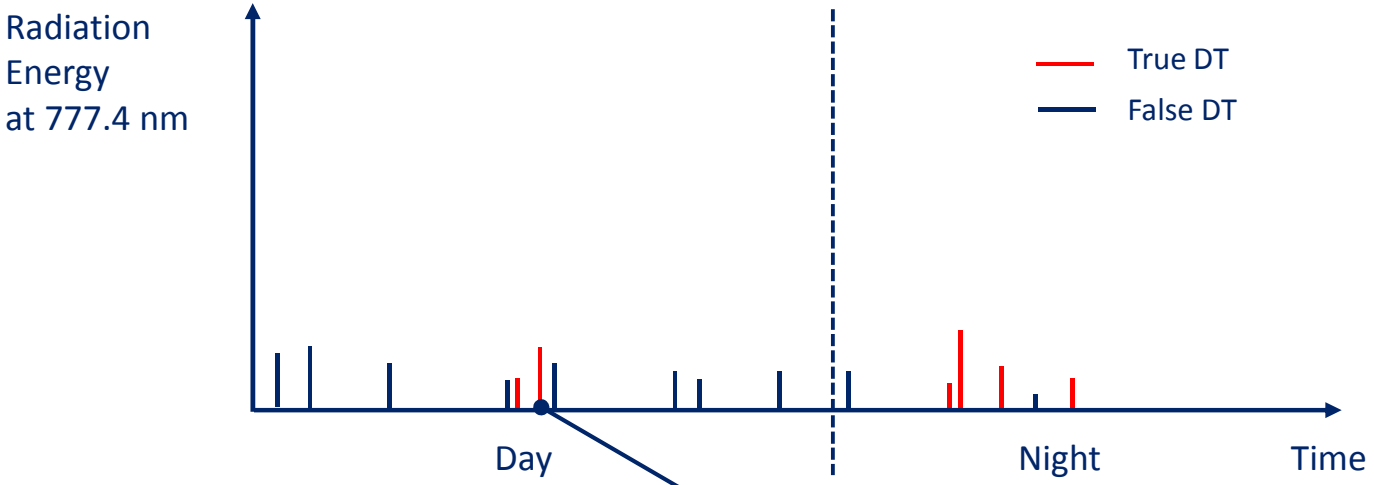
Background su




Sources of false transients:

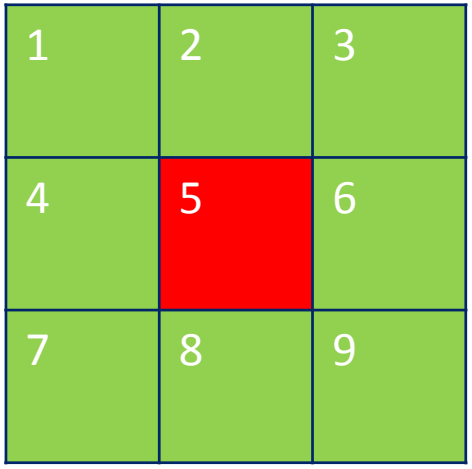
- local fluctuations of the radiometric noise;
- micro – vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …

# LI processing concept and end – to – end processor




Sources of false transients:

- local fluctuations of the radiometric noise;
- micro – vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …

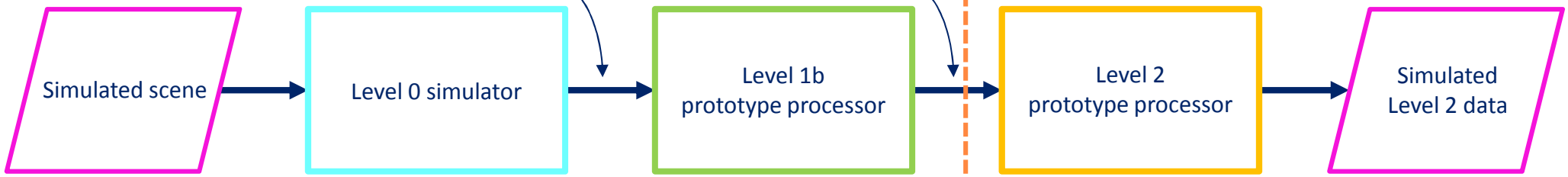



For each DT:

1. 3 x 3 window with the pulse measurement;
2. 3 x 3 window with the background measurement;
3. location in space and time.

This is all it is processed at L0, L1, and L2

# LI processing concept and end – to – end processor



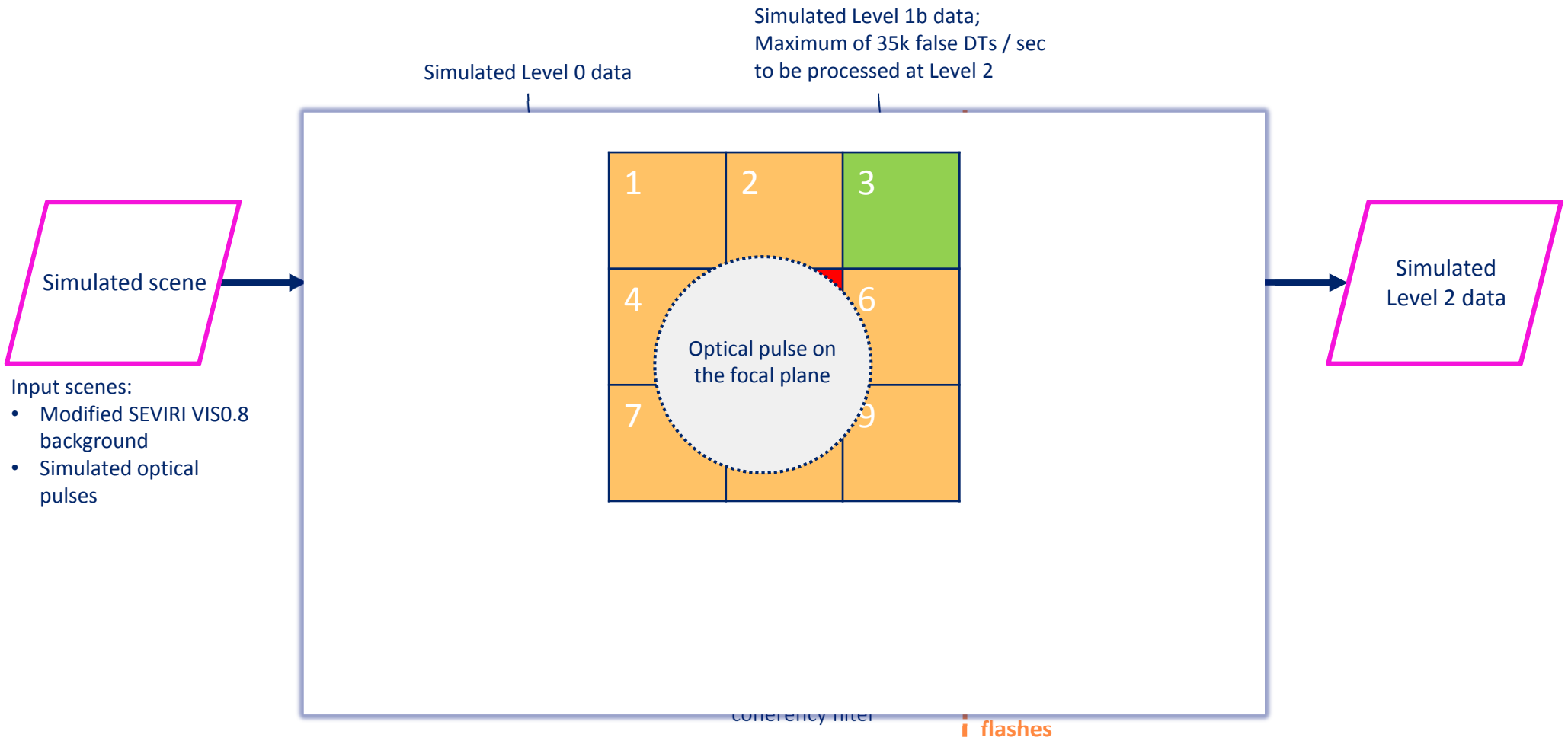

Input scenes:
- Modified SEVIRI VIS0.8 background
- Simulated optical pulses

- Observation geometry
- Micro-Vibration
- Radiometric detection including noise
- Real Time Pixel Processor (RTPP) detection
- Single detection filter (SDT)
- Micro-Vibration filter (MVF)

- Level 1b background radiometric processing
- Level 1b DT radiometric processing
- Level 1b DT on-ground filtering:
  I. pre-processor (sanity checks)
  II. jitter reconstruction filter
  III. spatio-temporal coherency filter

from this step on DTs are organized in **groups** and **flashes**

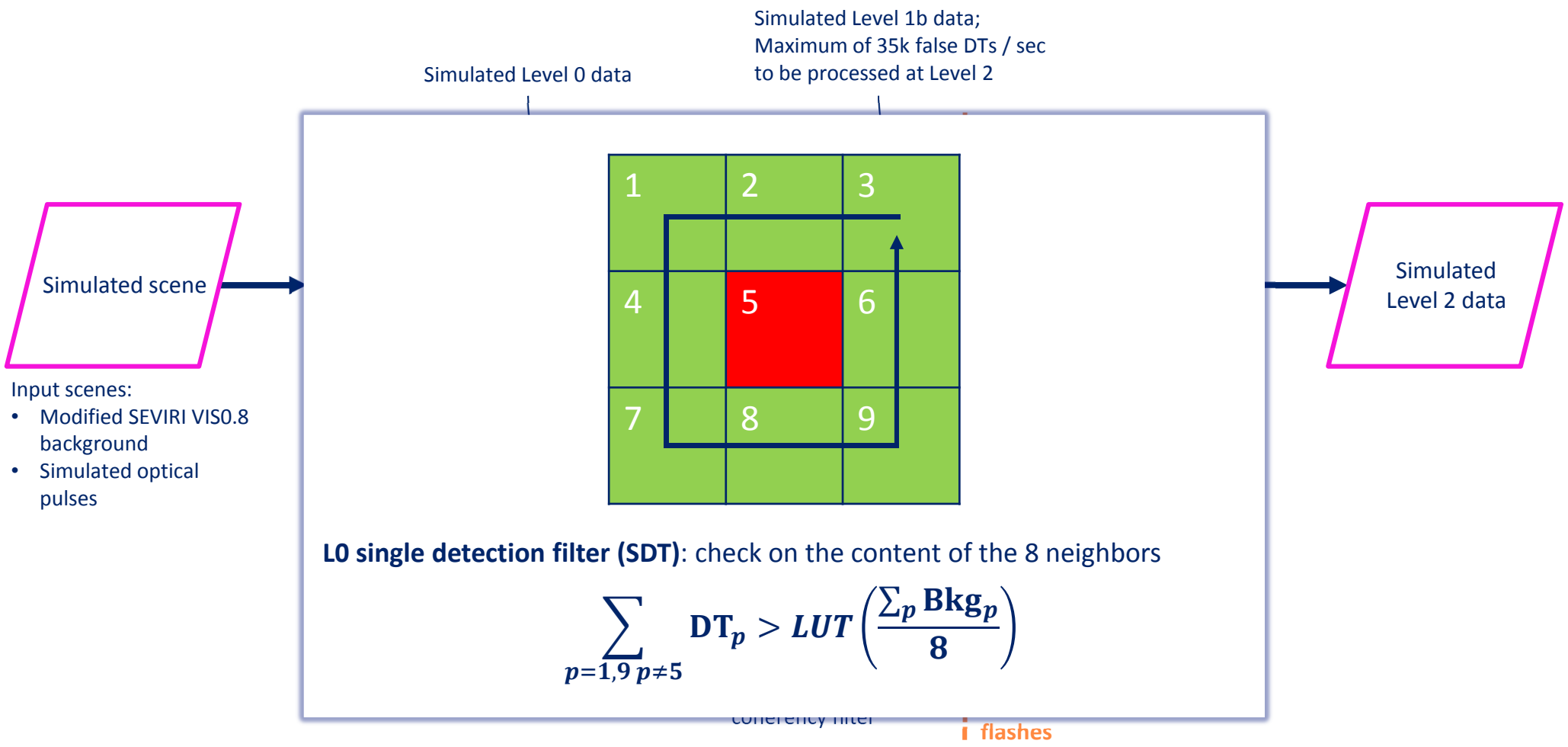
# LI processing concept and end – to – end processor



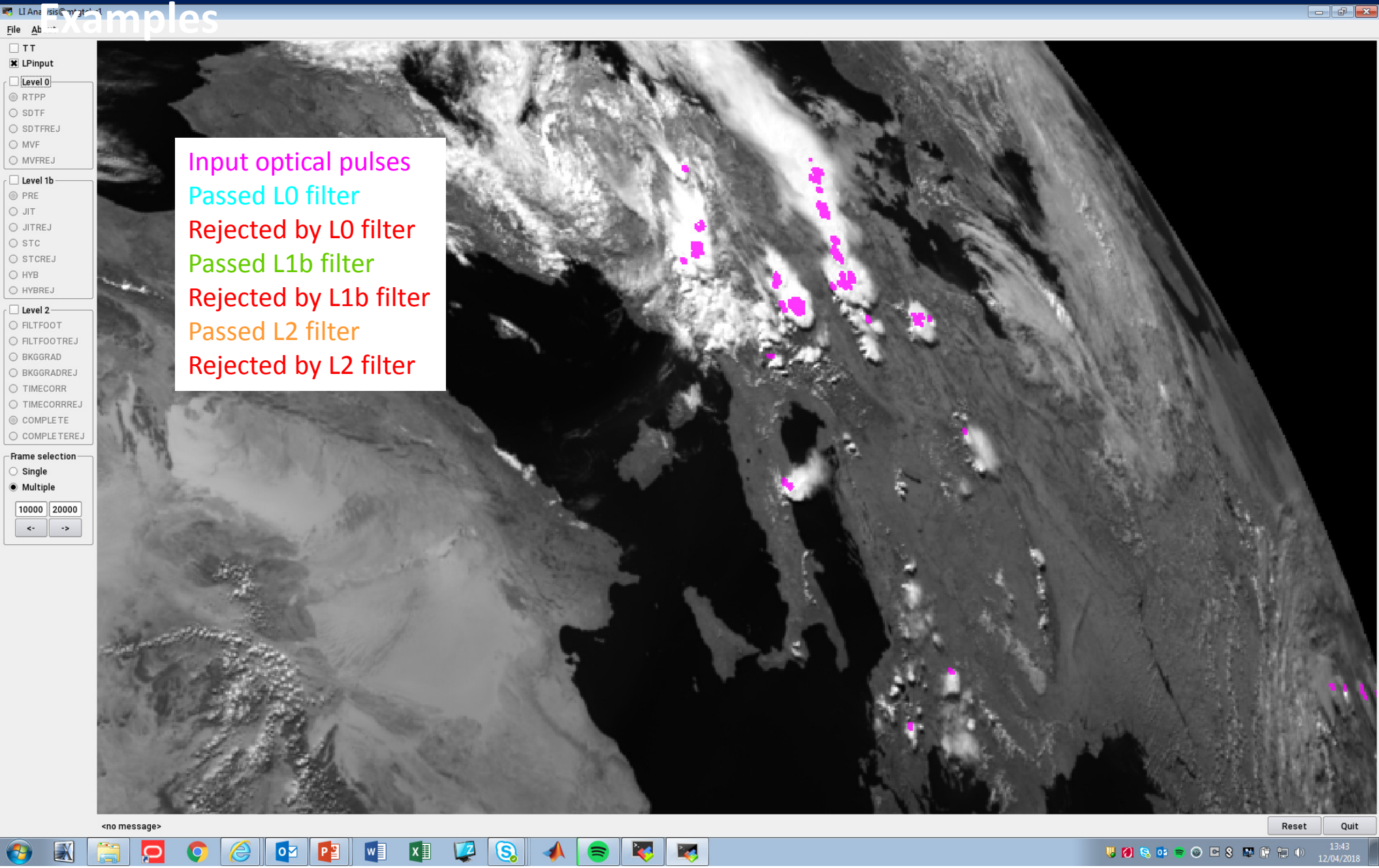

Input scenes:

- Modified SEVIRI VIS0.8 background
- Simulated optical pulses

# LI processing concept and end – to – end processor



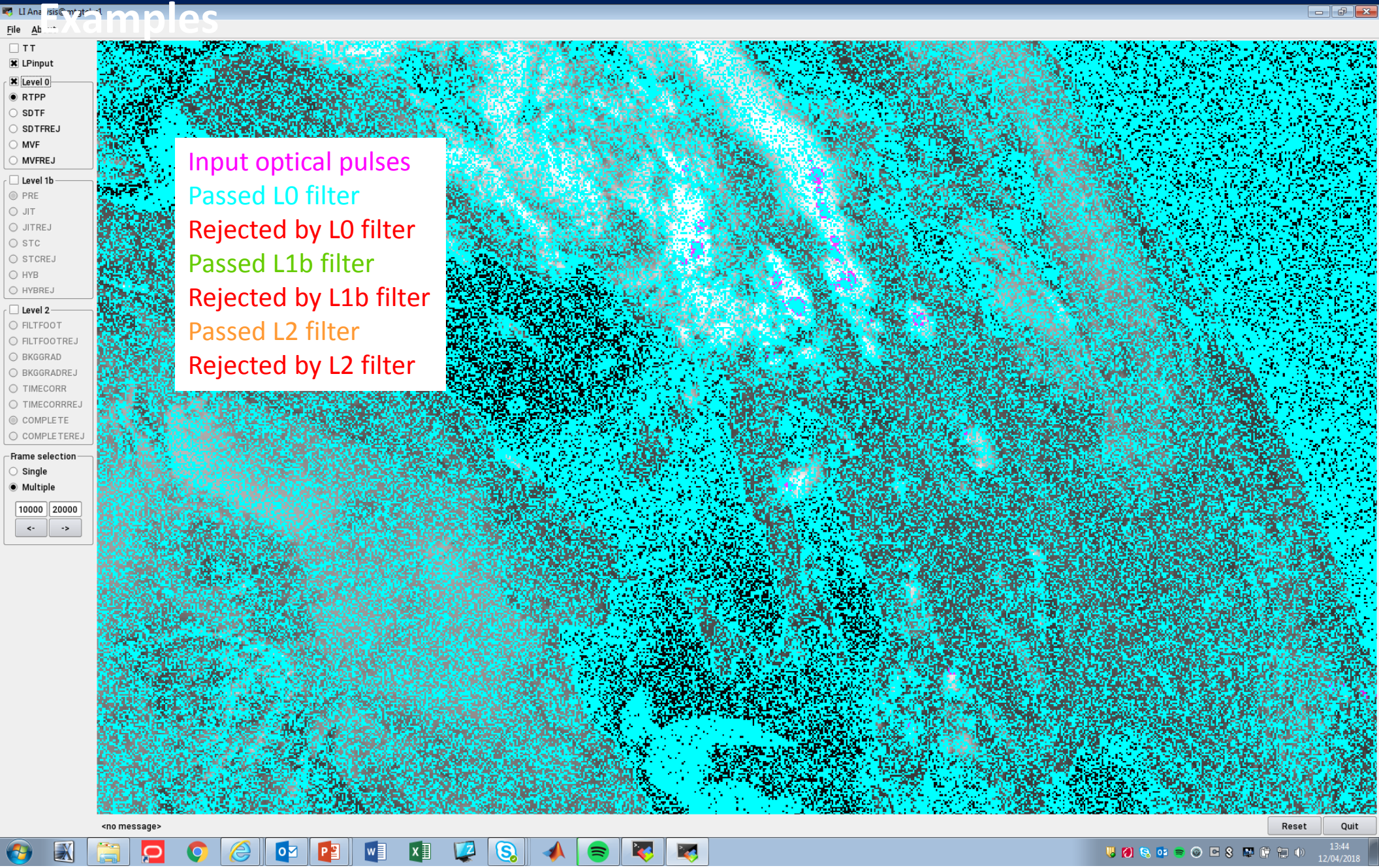
# Examples



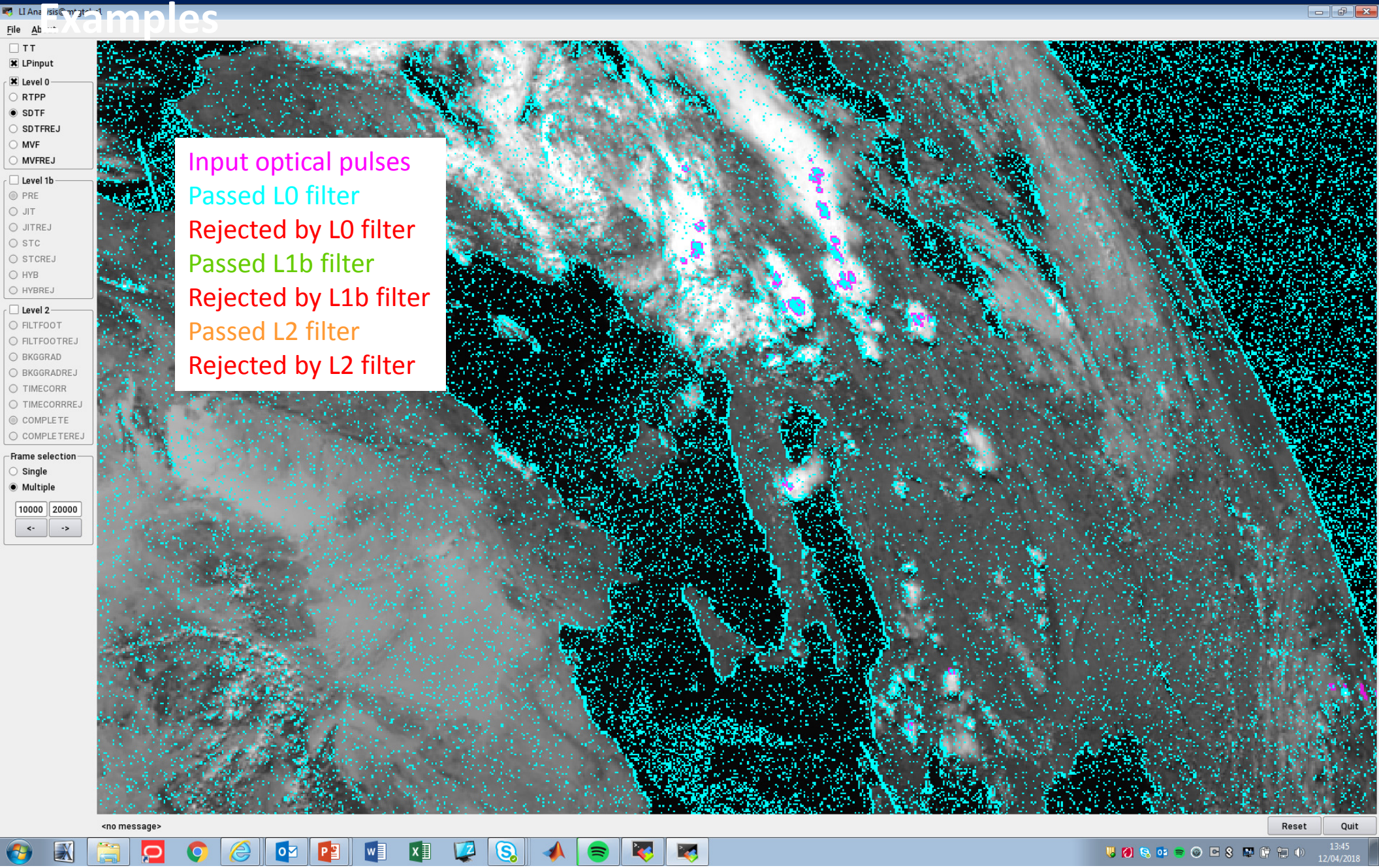



EUMETSAT

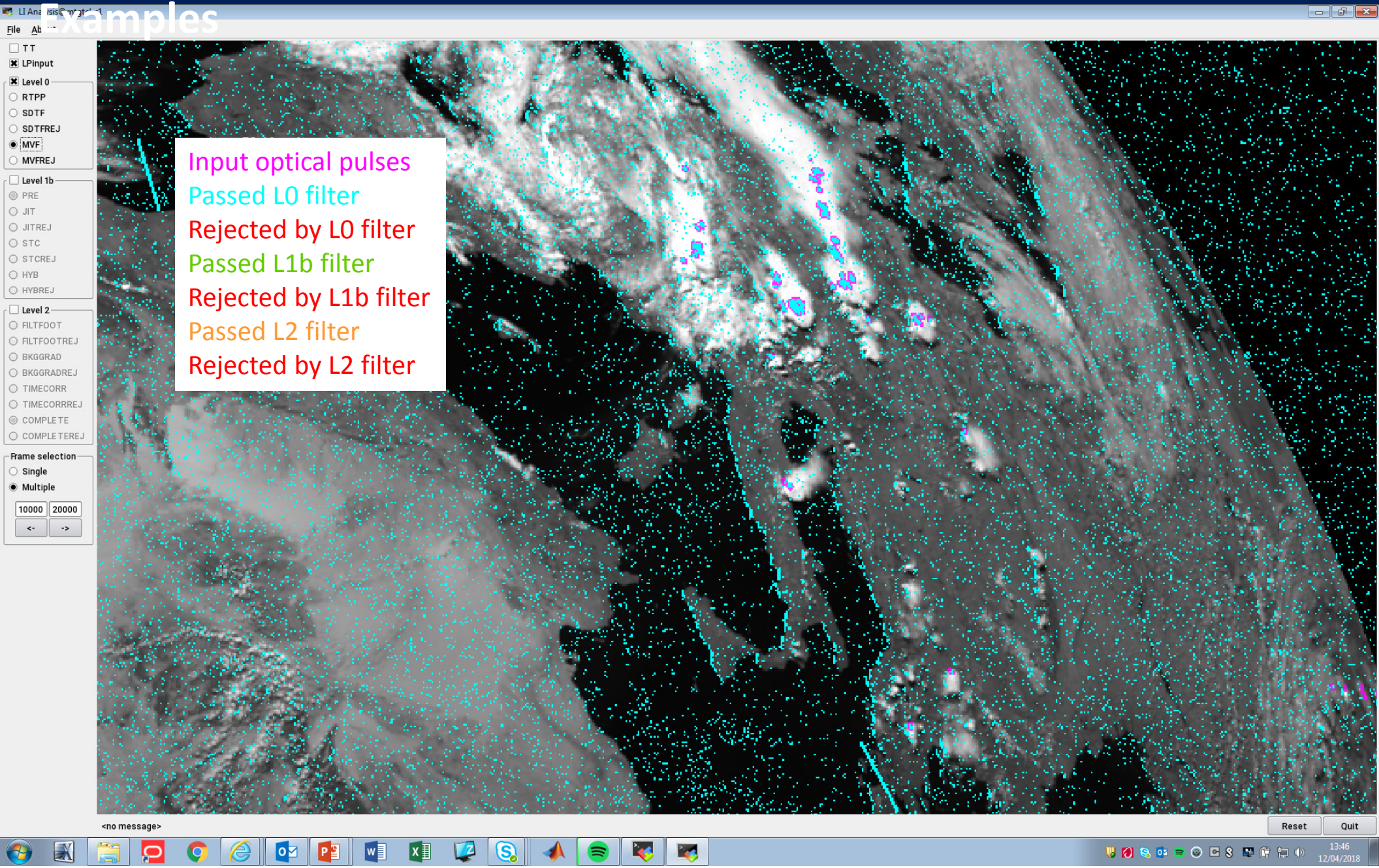
# Examples

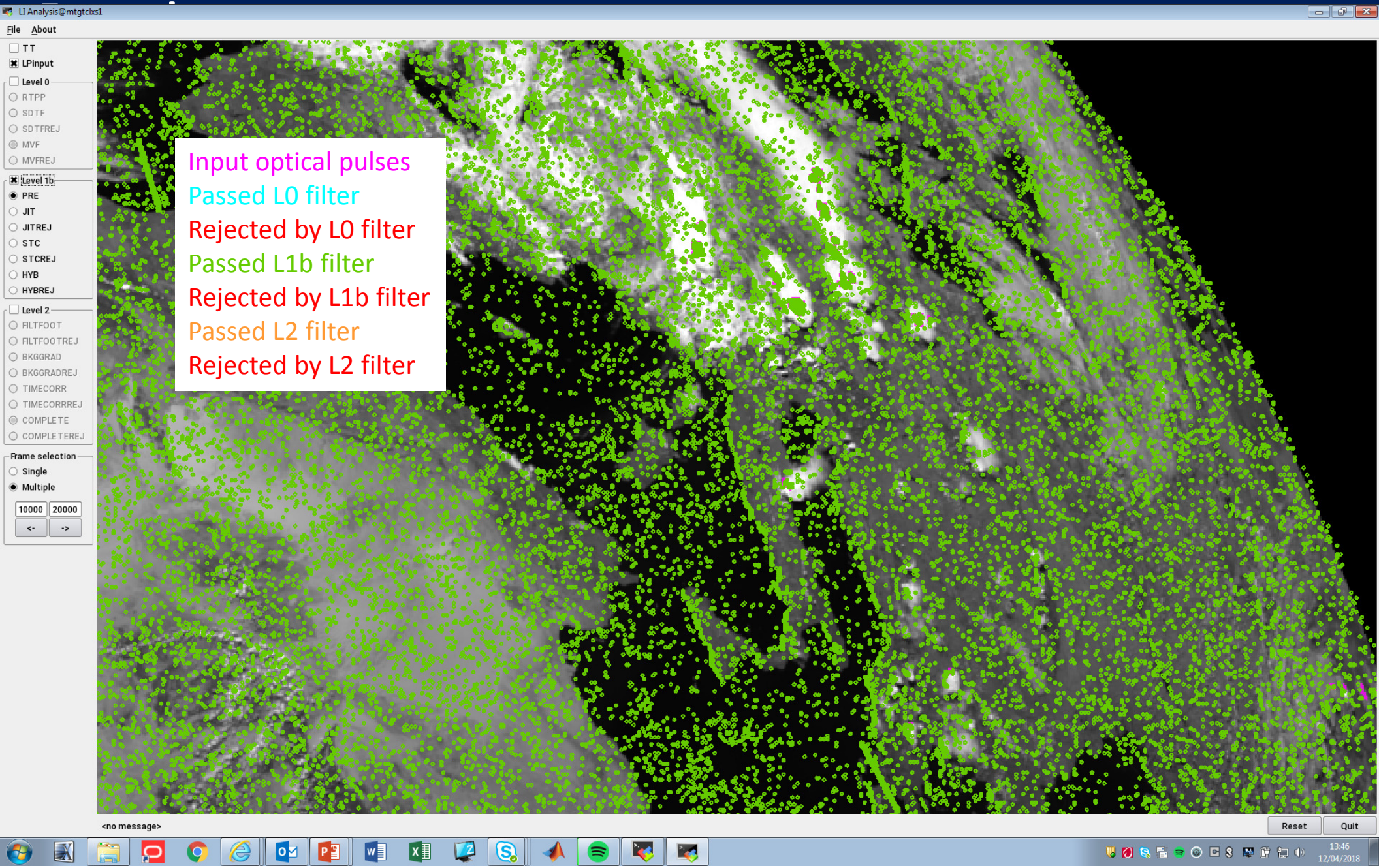

File
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:44
12/04/2018

# Examples


File
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:45
12/04/2018

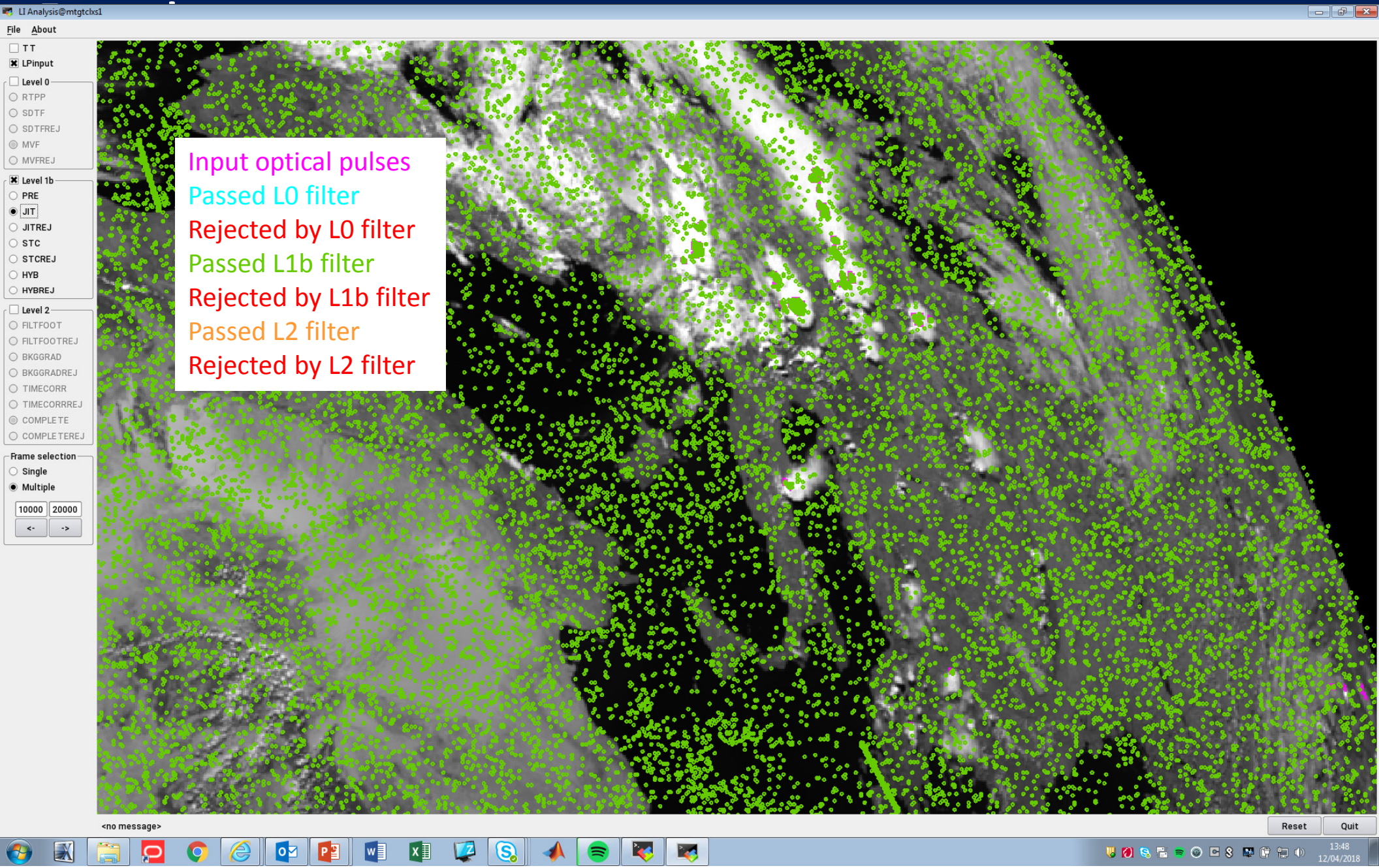
# Examples


File
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:46
12/04/2018

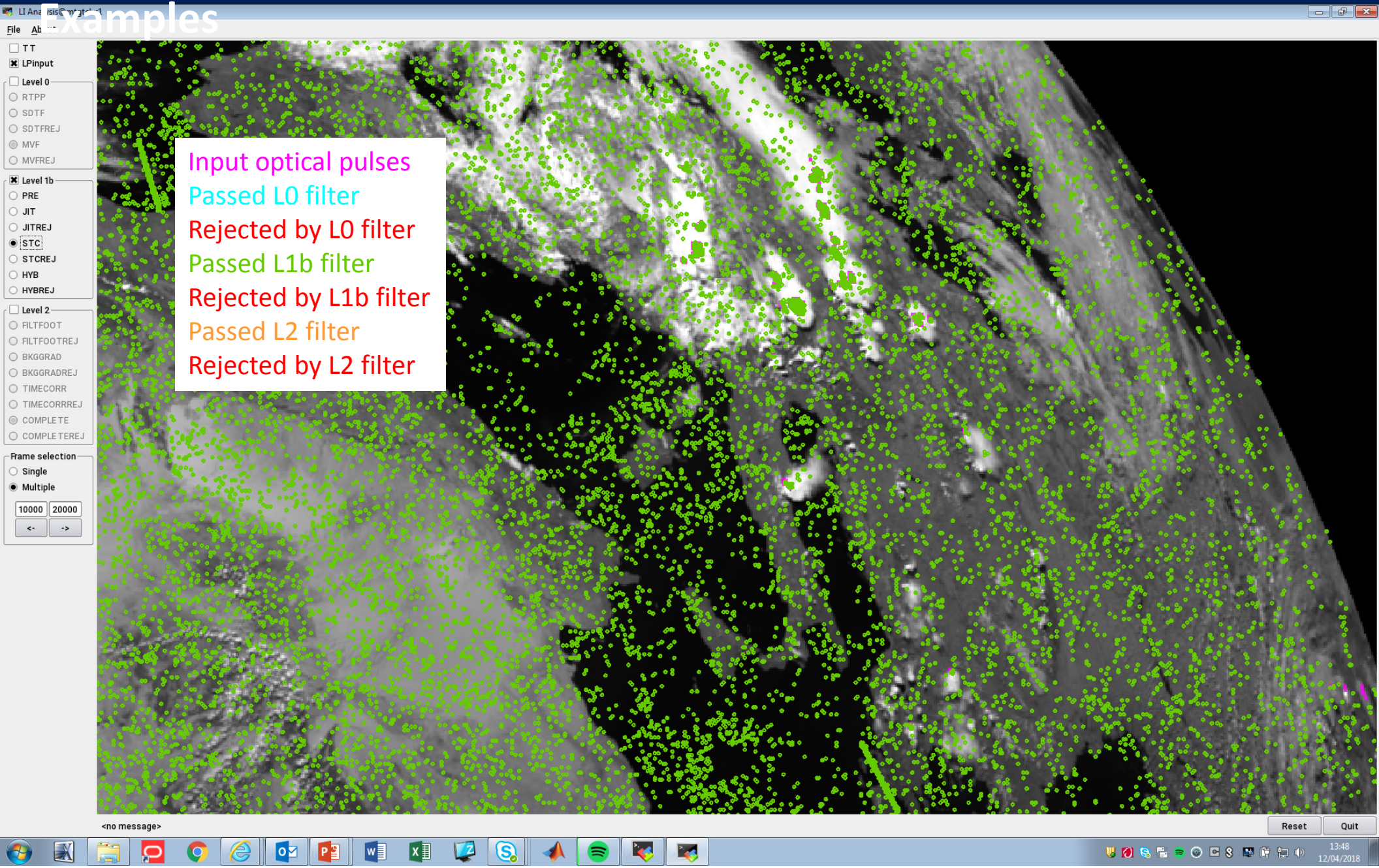

LI Analysis@mtgtclxs1
File
About
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:46
12/04/2018

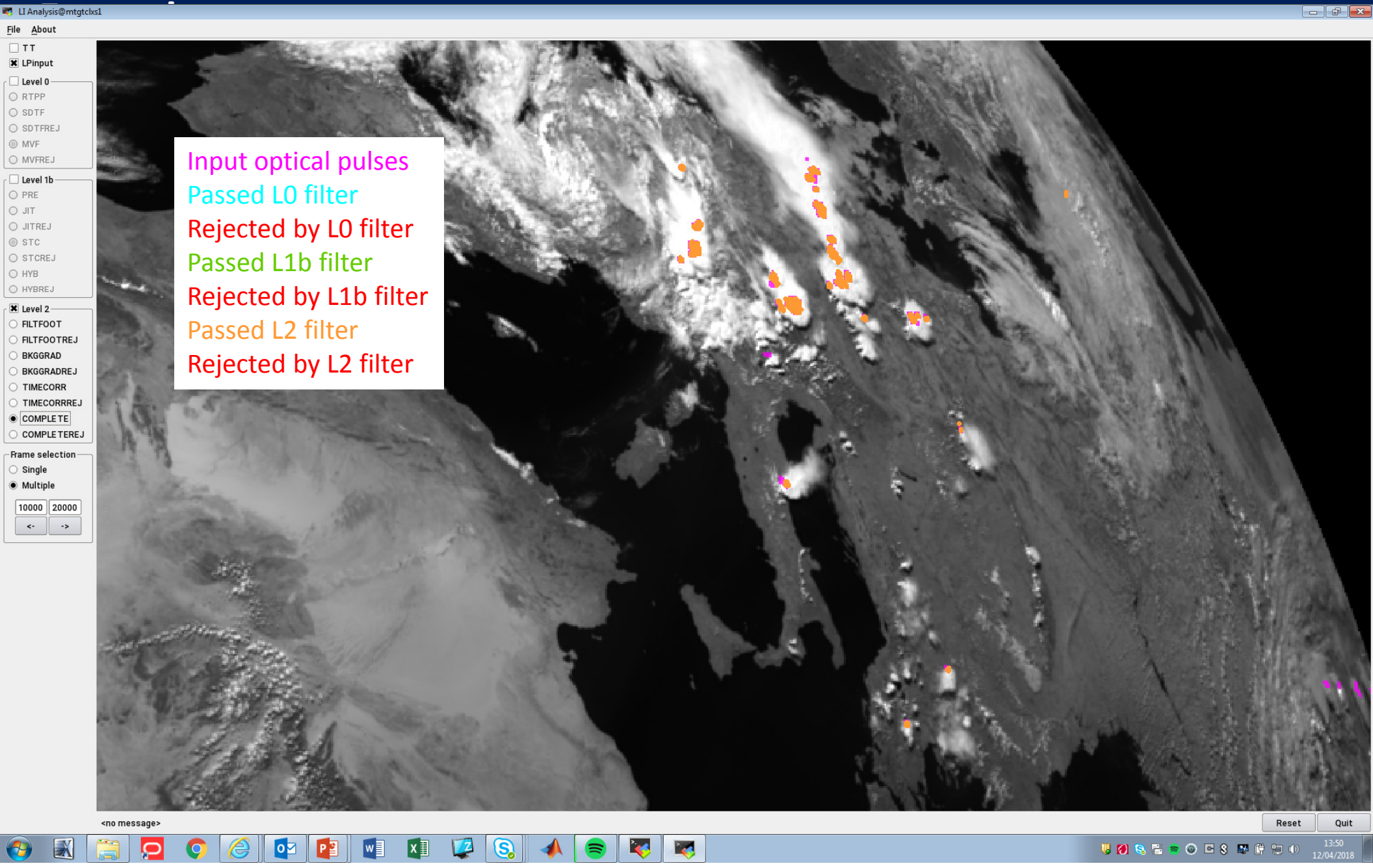


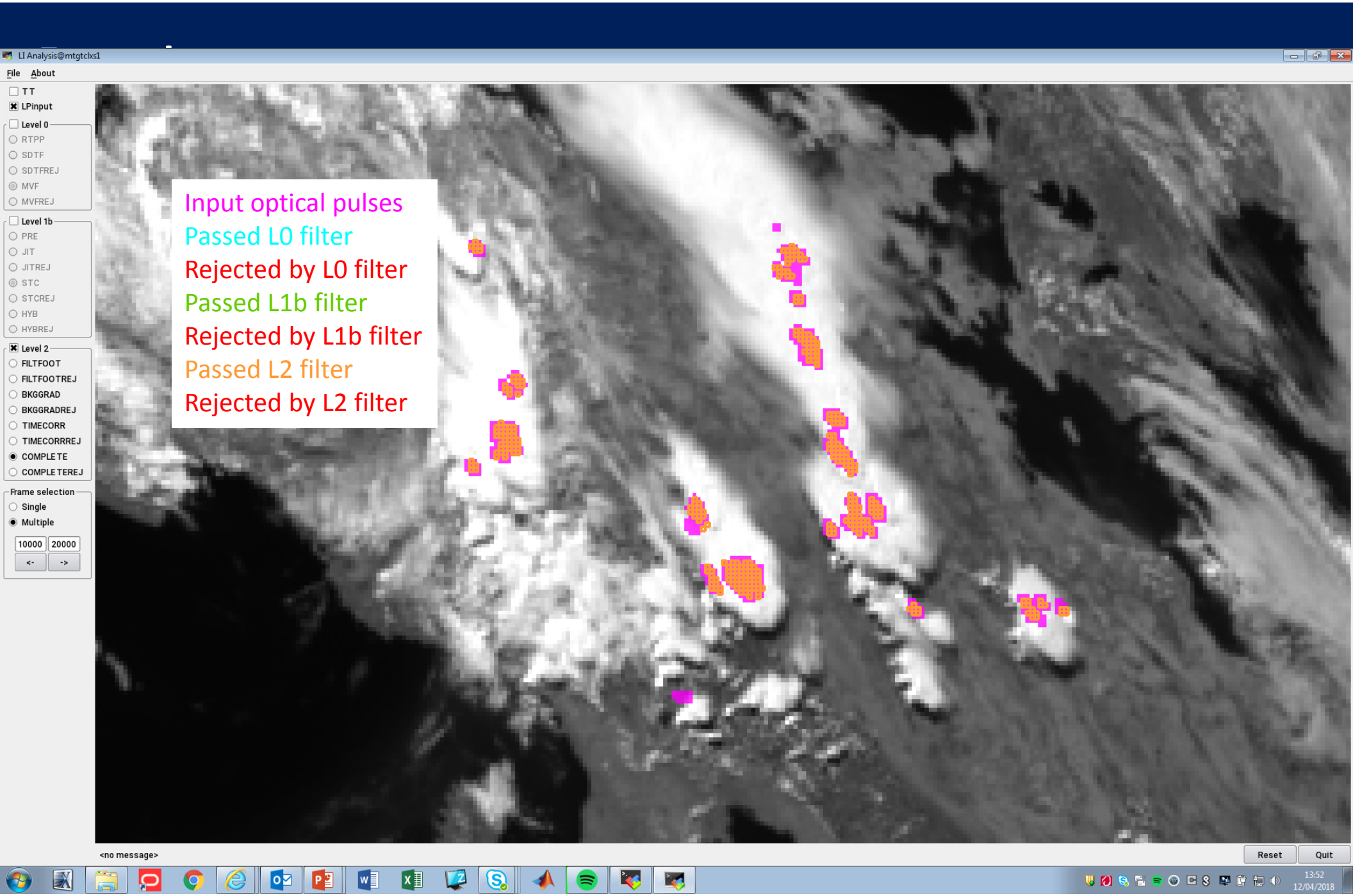
EUMETSAT


LI Analysis@mtgtclxs1
File
About
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:48
12/04/2018

# Examples


File
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:48
12/04/2018

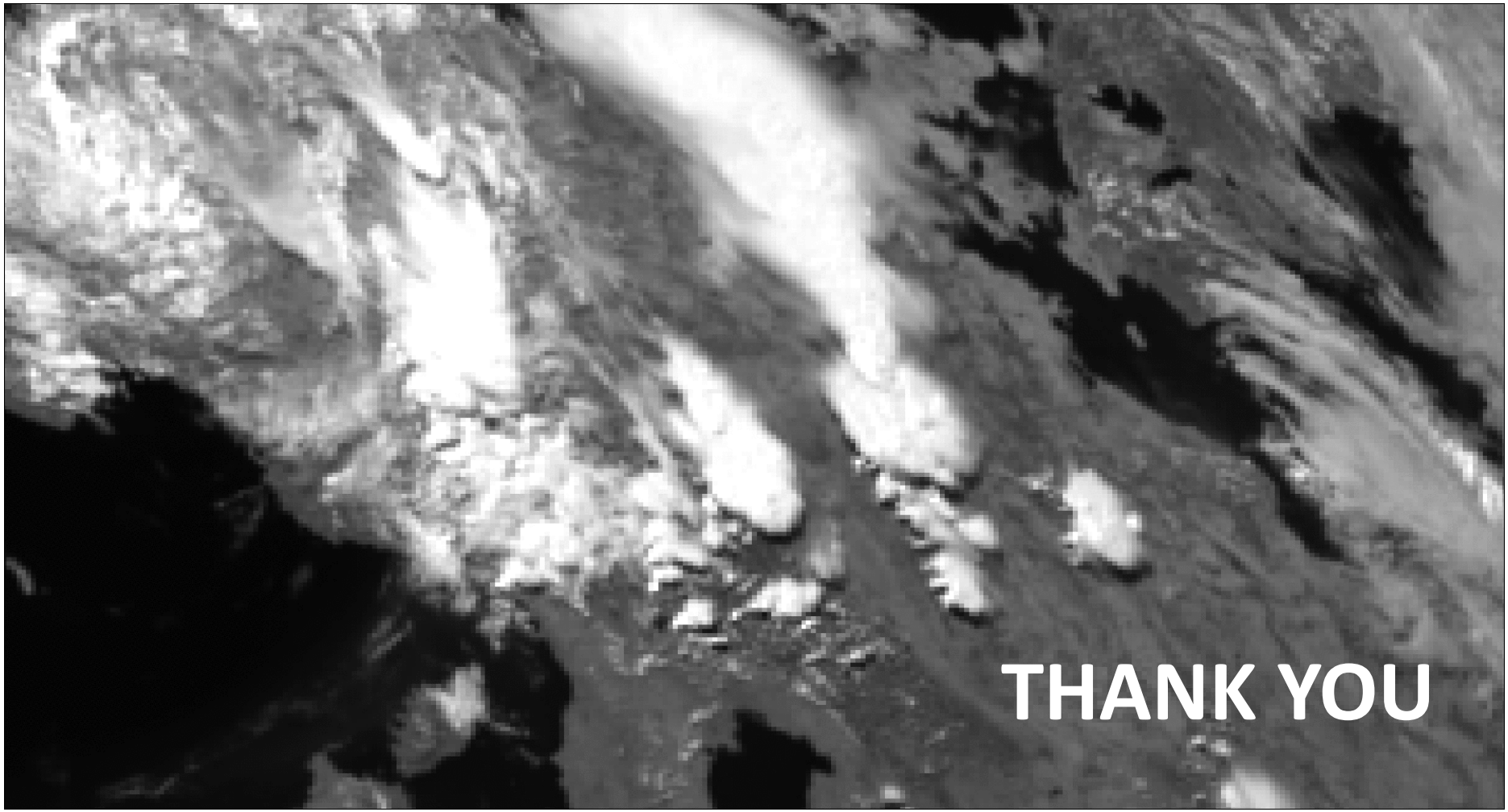

LI Analysis@mtgtclxs1
File
About
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:50
12/04/2018


LI Analysis@mtgtclxs1
File
About
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:52
12/04/2018

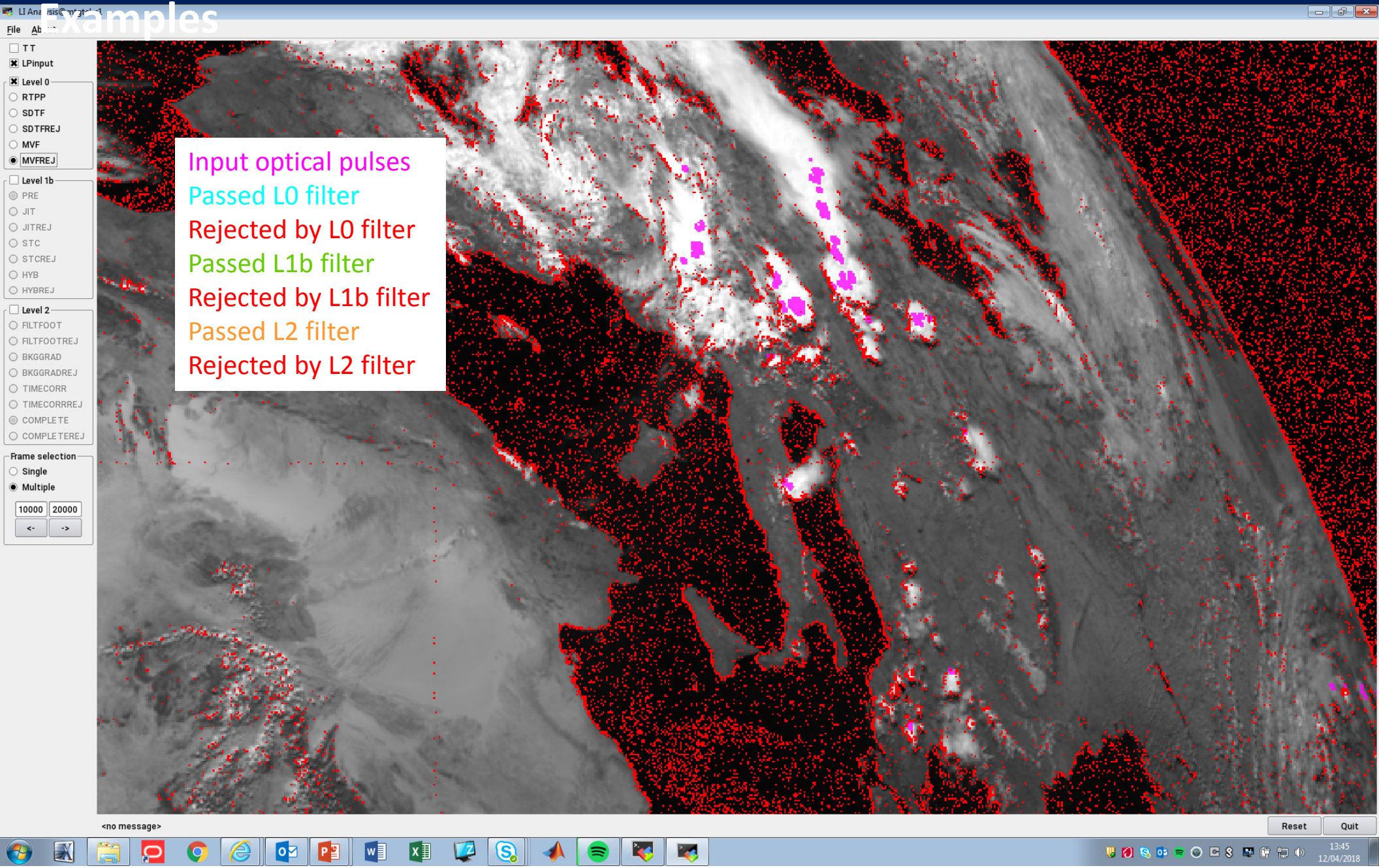
# Summary

- The monitoring of the total lightning activity is important to trace weather intensification and atmospheric convection.
- The LI instrument detects lightning (CC + CG + IC) in the 777.4 nm band with 4.5 km resolution at SSP and 1 ms acquisition time over about 80% of the Earth-disk observable from GEO location at 0 deg longitude.
- The LI L0, L1, and L2 processing and filtering is aimed at retaining as many true detected transients (DTs) as possible whilst rejecting the false DTs. The whole LI on – board and on – ground processing chain is a collaborative effort of EUMETSAT, ESA, Leonardo, Thales.
- In order to test and develop each filtering step and evaluate the detection performances of the LI an end – to – end prototype processor has been put in place by EUMETSAT; this allows one to evaluate end – to – end performances quickly in case of instrument and/or parameter changes.
- EUMETSAT is completing the definition of the LI L2 processing baseline that will define the LI L2 product content.

## 4 sec simulated L2 detection (orange open squares) of optical pulses (purple pixels)



# Examples


File
TT
LPinput
Level 0
RTPP
SDTF
SDTFREJ
MVF
MVFREJ
Level 1b
PRE
JIT
JITREJ
STC
STCREJ
HYB
HYBREJ
Level 2
FILTFOOT
FILTFOOTREJ
BKGGRAD
BKGGRADREJ
TIMECORR
TIMECORRREJ
COMPLETE
COMPLETEREJ
Frame selection
Single
Multiple
10000
20000
<-
->
Input optical pulses
Passed L0 filter
Rejected by L0 filter
Passed L1b filter
Rejected by L1b filter
Passed L2 filter
Rejected by L2 filter
<no message>
Reset
Quit
13:45
12/04/2018