MTG LI simulated performances: update and future plans

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EUMETSAT LI IFCT

LI performance metric

Quantifying the performances of LI: it's a matter of balance

- Level 1b
  1. **Average Detection Probability (ADP): percentage of small pulses that that passes the Level 0 + Level 1b filtering (ESA presentation)**
  2. False Alarm Rate (FAR): number of false detections at Level 1b (expressed as a rate)
  3. Pulse Detection Efficiency (DE): percentage pulses that passes the Level 0 + Level 1b filtering

- Level 2
  1. Flash False Alarm Rate (FFAR): number of false flashes at Level 2 (expressed as a rate)
  2. Flash Detection Efficiency (FDE): percentage of real flashes that passes the Level 0 + Level 1b + Level 2 filtering
     (IMPORTANT! A lightning flash is detected if at least one of its pulses reaches Level 2)

Key information from ESA on LI performances

LI Level 1b expected performances

Presented the variation of the ADP with time during the day. ADP below 70% between 9h and 15h (roughly)

Sun near the FOV

1. Impact on the ADP (decrease) and FAR (increase)
2. Impact on the radiometric performances
3. Introduced a restriction zone of 16 deg around the center of each OC
4. Example of stray light pattern
    - The Sun directly in the FOV will not cause any leakage! The impact is localized

Key information from ESA on LI performances

LI Level 1b expected performances

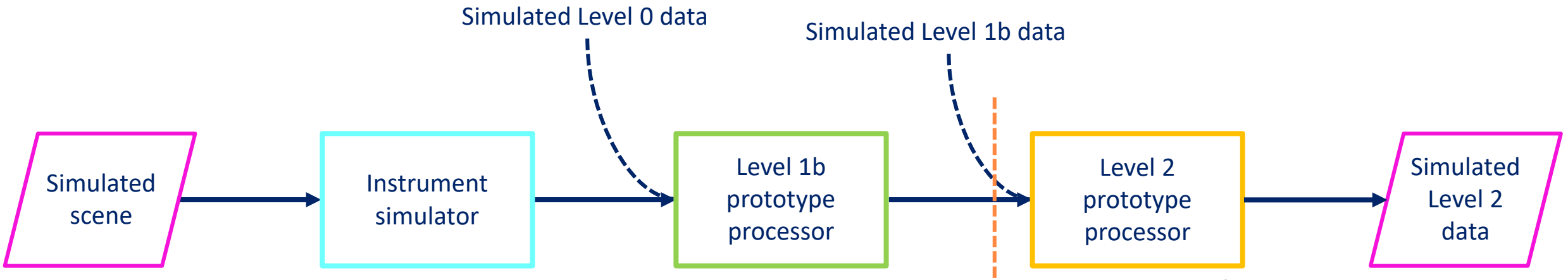
Presented the variation of the ADP with time during the day. ADP below 70% between 9h and 15h (roughly)

In the context of the LI MAG

Su

1. **Assessment of the impact of the ADP variation in space and time on the Level 2**
2. **performances and on the use of the Level 2 products:**
3. **I. as a function of time as average in the FOV**
4. **II. as a function of time and geolocation as DE/sensitivity maps (already discussed in the LI MAG forum)**

End-to-end Reference Processor



Inputs:
- Modified SEVIRI VIS0.8 background
- Simulated optical pulses

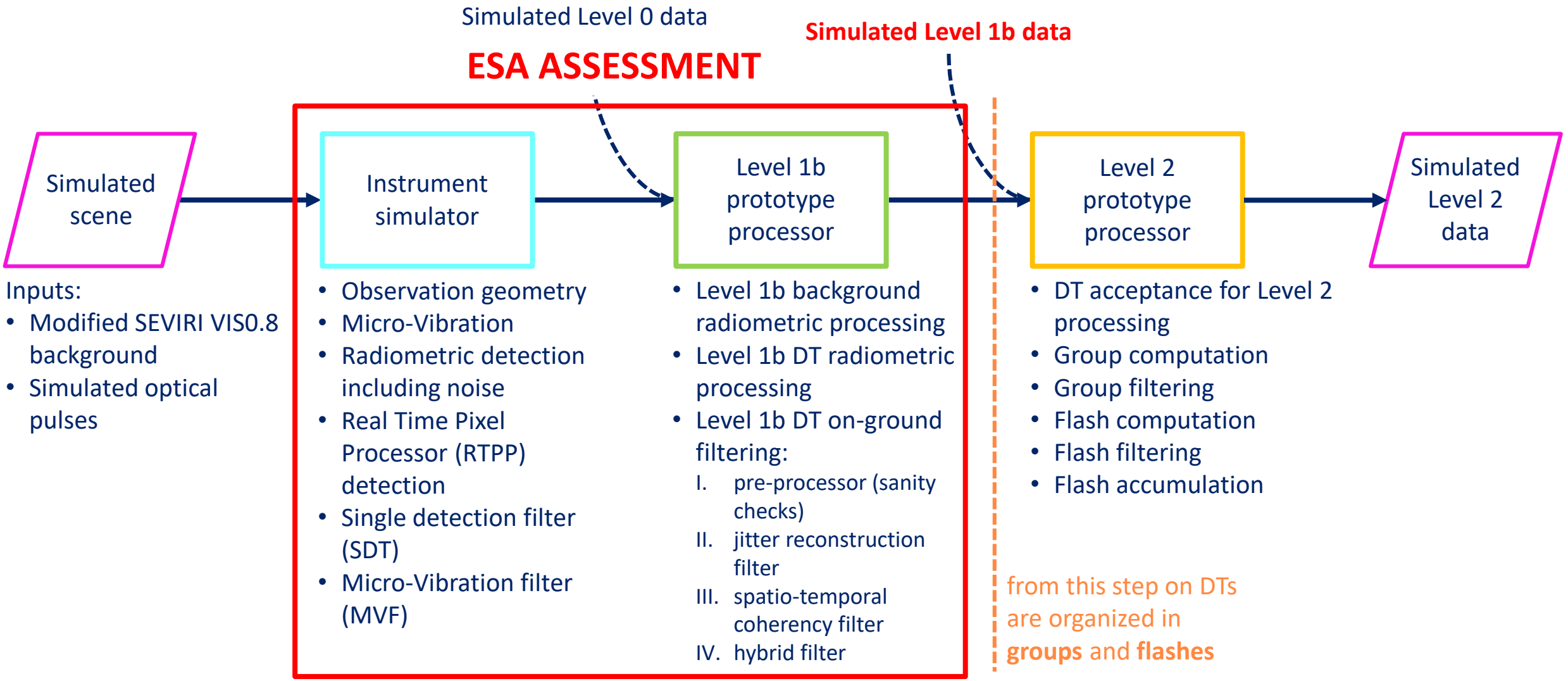
- Observation geometry
- Micro-Vibration
- Radiometric detection including noise
- Real Time Pixel Processor (RTPP) detection
- Single detection filter (SDT)
- Micro-Vibration filter (MVF)

- 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
  IV. hybrid filter

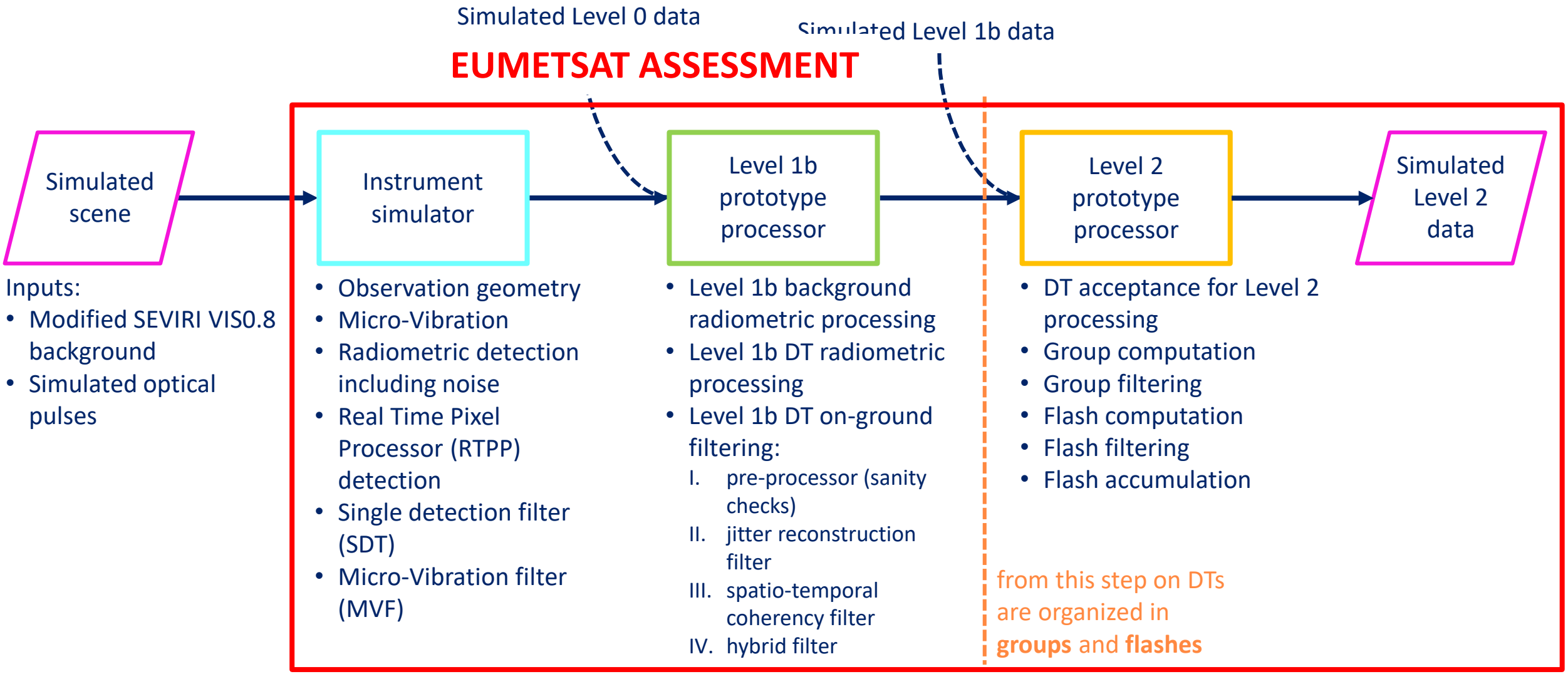
- DT acceptance for Level 2 processing
- Group computation
- Group filtering
- Flash computation
- Flash filtering
- Flash accumulation

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

End-to-end Reference Processor



End-to-end Reference Processor



LI performance assessment – pre-launch at Level 1b

Input settings			Performance Impact
Background scenarios	• Full illumination • Night • Day-night terminator		• The higher the illumination the higher the shot noise • The stronger the image contrast the larger the micro-vibration false events
Parameters		**Value**	
Pulse properties	1. Size 2. Energy 3. Duration 4. Location 5. Start time	1. 5 km rad. 2. Min 3. 0.6 msec 4. Random 5. Random	1. Worst case 2. Worst case 3. Worst case 4. The closer to nadir and/or pixel centre the higher the DE 5. The closer to the frame centre the higher the DE

Leonardo and ESA focus on the assessment of worst case scenario performances → ADP

LI performance assessment – pre-launch at Level 1b and Level 2

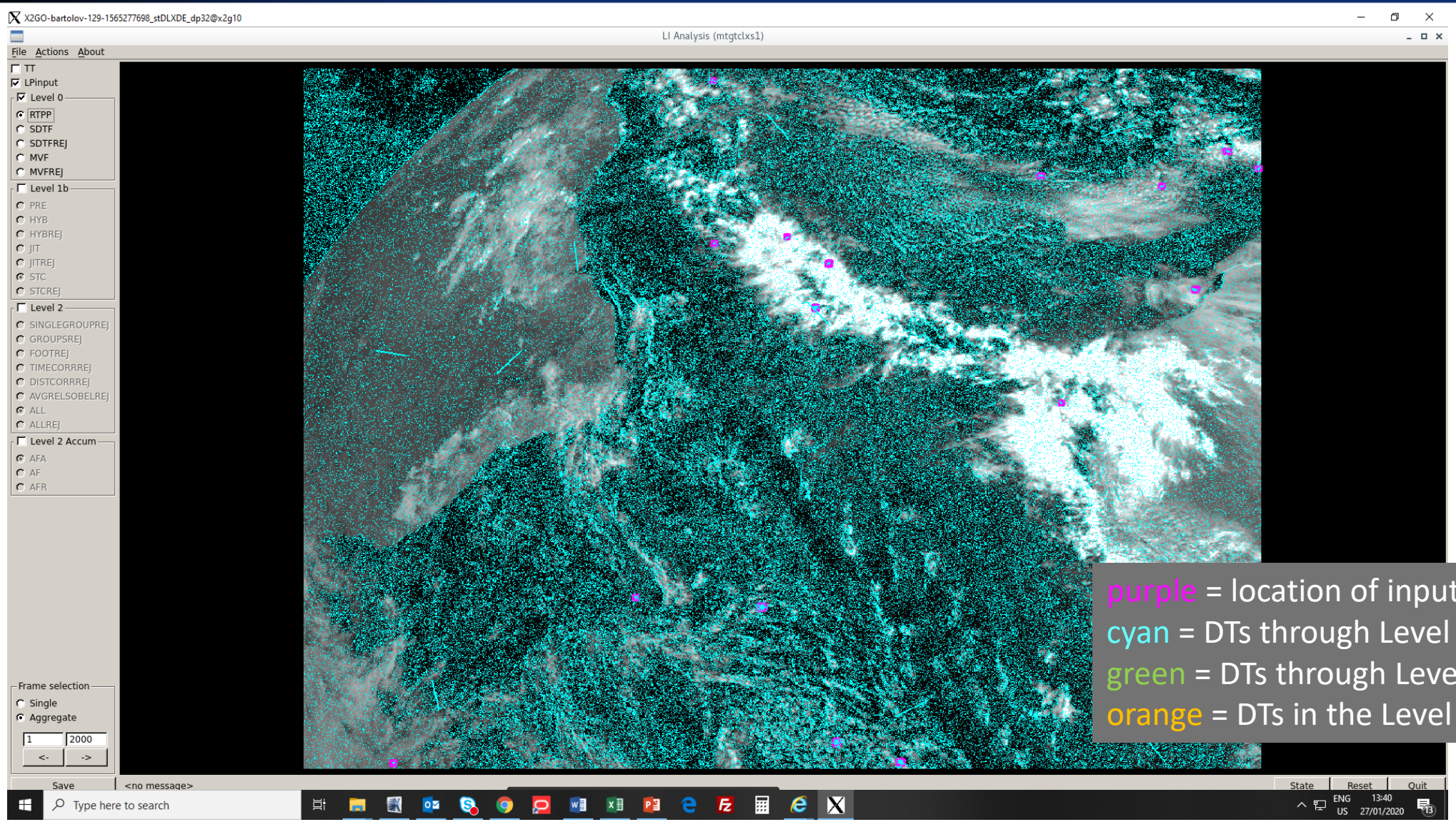
Input settings			Performance Impact
Background scenarios	• Full illumination • Night • Day-night terminator		• The higher the illumination the higher the short noise • The stronger the image contrast the larger the micro-vibration false events
Parameters		**Value**	
Pulse properties	1. Size 2. Energy 3. Duration 4. Location 5. Start time	1. Realistic 2. Realistic 3. Realistic 4. Random 5. Random	1. The larger the pulse the higher the DE 2. The “stronger” the pulse the higher the DE 3. The longer the pulse the higher the DE 4. The closer to nadir and/or pixel centre the higher the DE 5. The closer to the frame centre the higher the DE
Flash properties	6. Flash time 7. Number of pulses 8. Time difference between pulses 9. Distance between pulses	6. Realistic 7. Realistic 8. Realistic 9. Random	7. The richer in number of pulses the higher the FDE

LI performance assessment – pre-launch at Level 1b and Level 2

Input settings			Data source / choice
Background scenarios	• Full illumination • Night • Day-night terminator		**SEVIRI 0.8 micron images**
Parameters		**Value**	
Pulse properties	1. Size 2. Energy 3. Duration 4. Location 5. Start time	1. Realistic 2. Realistic 3. Realistic 4. Random 5. Random	**1. LIS distribution of group sizes** **2. LIS distribution of event energies** **3. Uniformly distributed in [0.6, 2] msec** **4. Random in the FOV (on background cloud mask)** **5. Random**
Flash properties	6. Flash time 7. Number of pulses 8. Time difference between pulses 9. Distance between pulses	6. na 7. Realistic 8. Realistic 9. Random	**6. Stems from other properties** **7. LIS distribution of number of groups in flashes** **8. LIS distribution of time difference between groups** **9. Uniformly distributed in [0, 10] km wrt the flash barycentre**

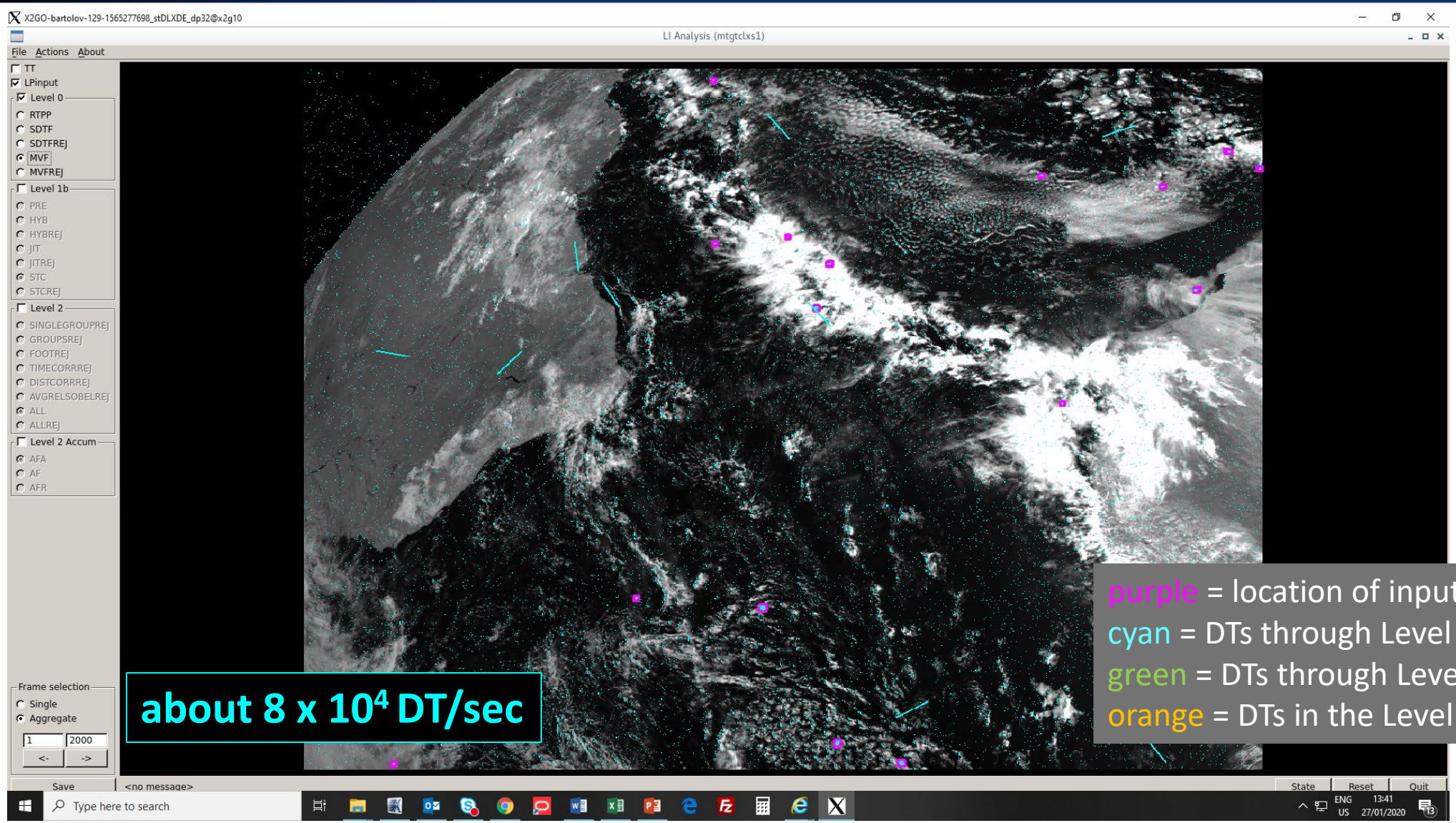
EUMETSAT will run an ensemble of simulations with different combinations of input parameters to assess realistic and exhaustive Level 1b and Level 2 performances (and dependencies)

Detected DTs

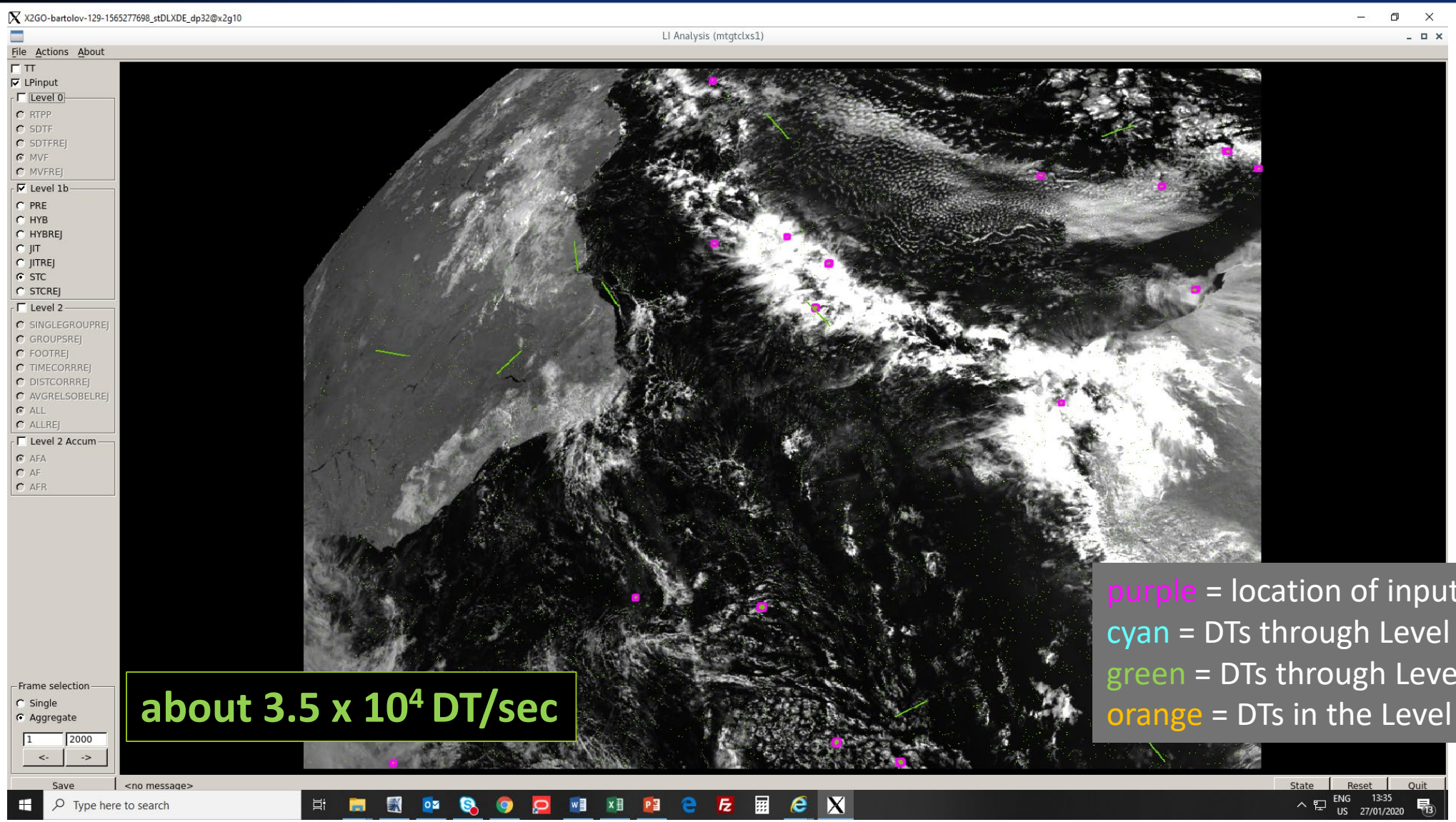


purple = location of input pulses
cyan = DTs through Level 0 proc.
green = DTs through Level 1b proc.
orange = DTs in the Level 2 product

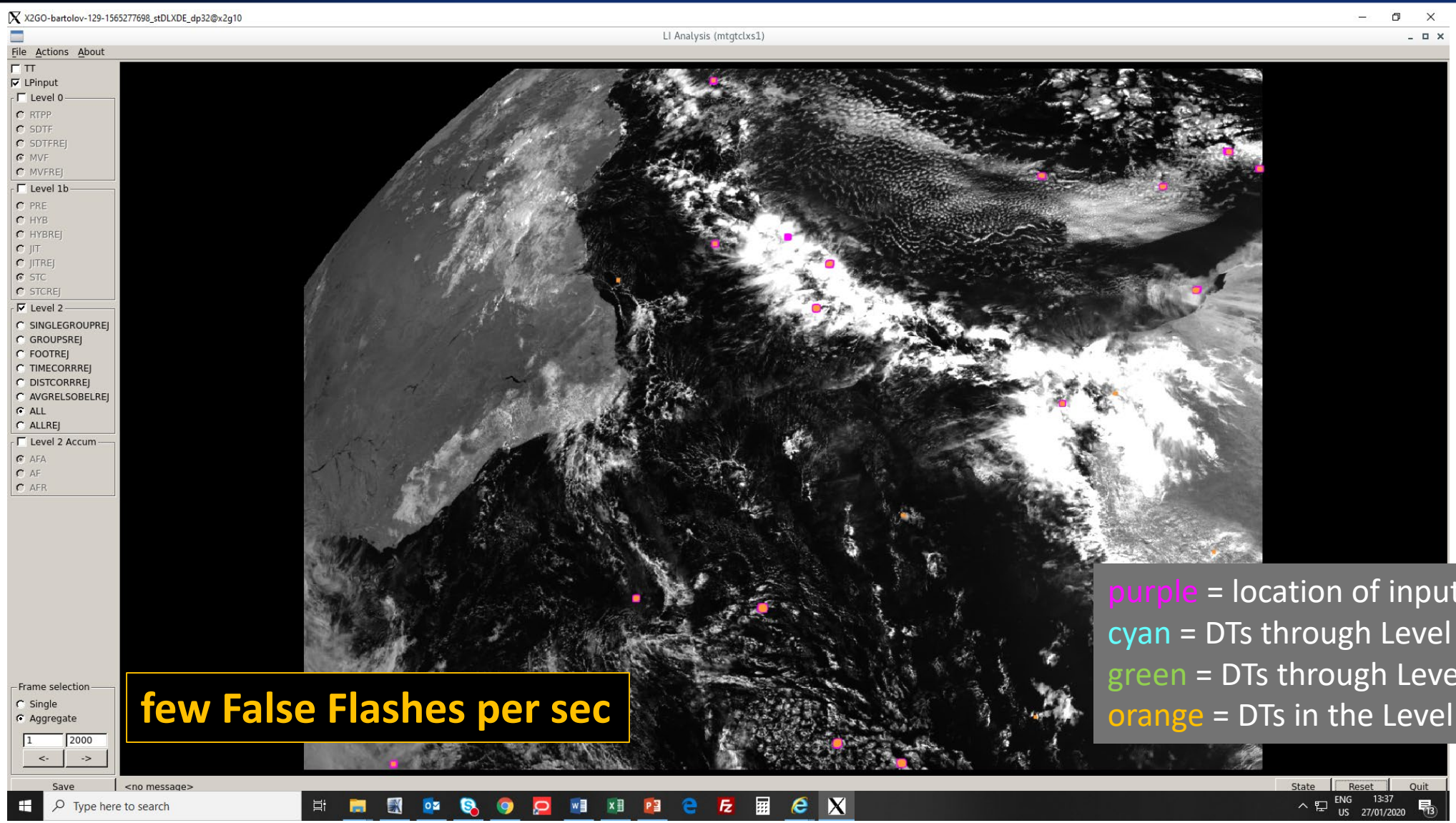
DTs at Level 0 (after on-board filtering)



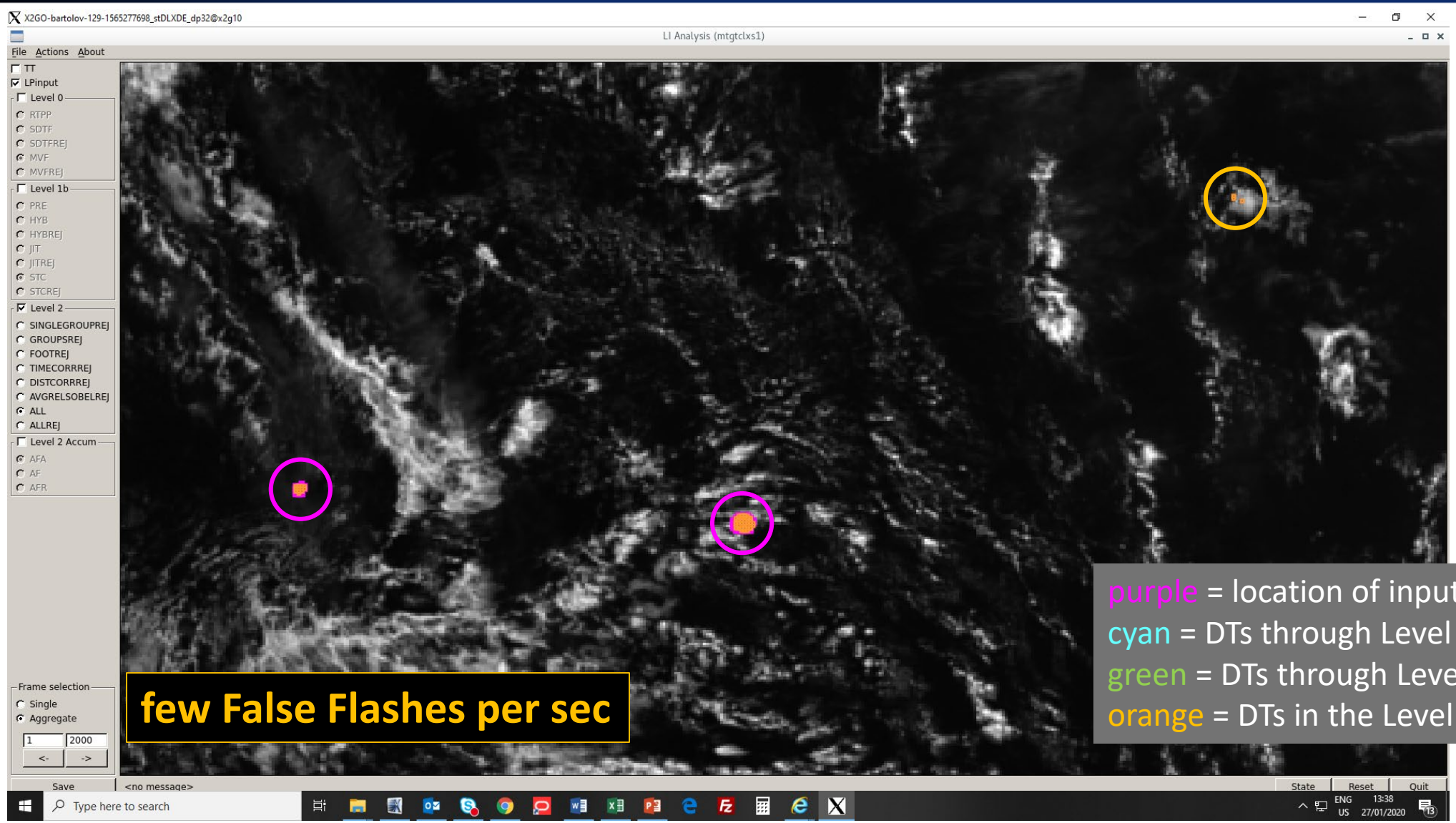
DTs at Level 1b (on-ground processing)



DTs at Level 2 (on-ground processing)



DTs at Level 2 (on-ground processing)



Pulse DE and Flash DE

201110291212	Level 0	Level 1b	Level 2 Pulse	Level 2 Flash
OC1	0.59	0.50	0.46	0.89
OC2	0.47	0.45	0.41	0.75
OC3	0.43	0.43	0.43	1.00
OC4	0.45	0.44	0.39	0.79
FOV average	**0.49**	**0.46**	**0.42**	**0.86**

Energy of pulses from **event** energy statistics of LIS

Pulse DE and Flash DE

201110291212	Level 0	Level 1b	Level 2 Pulse	Level 2 Flash
OC1	0.81	0.80	0.77	0.94
OC2	0.60	0.60	0.60	1.00
OC3	0.77	0.77	0.74	1.00
OC4	0.80	0.80	0.74	0.89
FOV average	**0.75**	**0.74**	**0.71**	**0.96**

Energy of pulses from **group** energy statistics of LIS

Simulation inputs

Pulse Size expressed as a radius

- Derived from the LIS distribution of number of events per group → total group area → $r = \sqrt{\frac{A}{\pi}}$
- LIS PROS:
  I. Pixel size comparable to LI size
  II. Always detects pulses at nadir → no impact of projection

Simulation inputs

Pulse energy

- Possibility of using LIS distribution of group energies
- Possibility of using LIS distribution of event energies (lower than group energies)
- Not correlated to the background level (ESA/industry settings)
- LIS CONS:
  I. Limited by LIS detection performances
  II. Good assessment for daylight conditions since faint optical pulses detected by LIS at night are most likely fainter that the faintest pulse LI will be able to detect during the day

Simulation inputs

Pulse duration

- Uniform random distribution between two values; in the example between [0.6, 2] msec
- Possibility of using FEGS data

Simulation inputs

Pulse location

- Random distribution in the FOV
  I. Uniform distribution wrt the viewing angle
  II. Cloud mask
  III. Possibility of using a reflectance threshold
  IV. Possibility of employing cloud properties (also at night)

Simulation inputs

Number of pulses/groups in a flash

- Assumption pulses = groups
- Derived form the LIS distribution of number of groups in flashes

Simulation inputs

Flash duration and/or time difference between groups in flashes

- The time difference between groups in flashes has been employed
- Flash duration stems from the number of pulses and their relative time difference

Simulation inputs

Distance of pulses from the flash barycentre

- Uniform random distribution between two values; in the example between [0, 10] km
- Refine with LIS statistics

DE/sensitivity efficiency map for users

Qualitative information to support the use of the Level 2 data

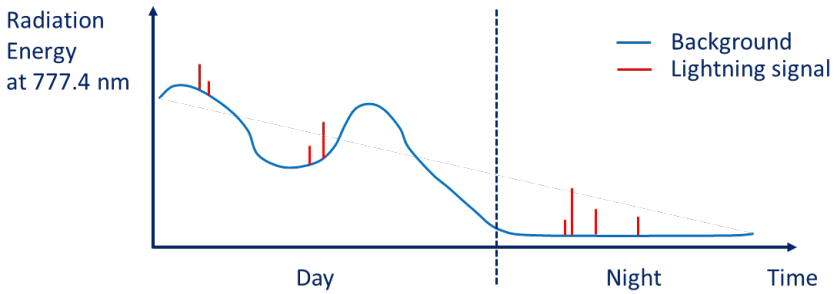
1. Pre-flight stray light patterns (ESA contribution)
2. Properties of the LI Level 1b background images
3. Complemented by the computation of the DE and FDE against ground networks

The information will be provided offline (mechanism to be defined); in the future EUMETSAT may decide to have this computation integrated in the ground segment

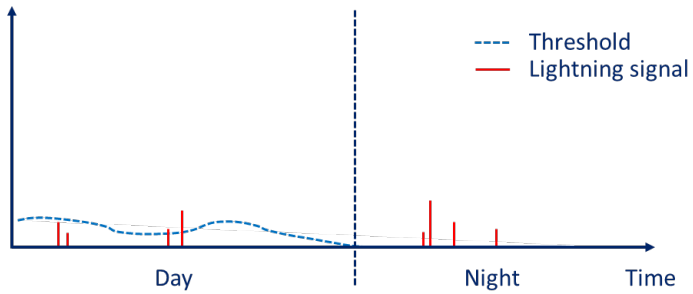
An example of use:
Sun in the LI FOV → portions of the OC will saturate preventing the lightning detection in part of the LI FOV
In this case, no lightning measured DOES NOT INDICATE THE ABSEBCE OF STORMS!

Backup slides

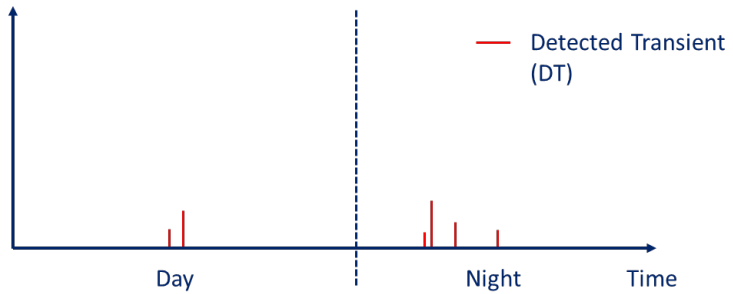
RTPP – LI detection principle



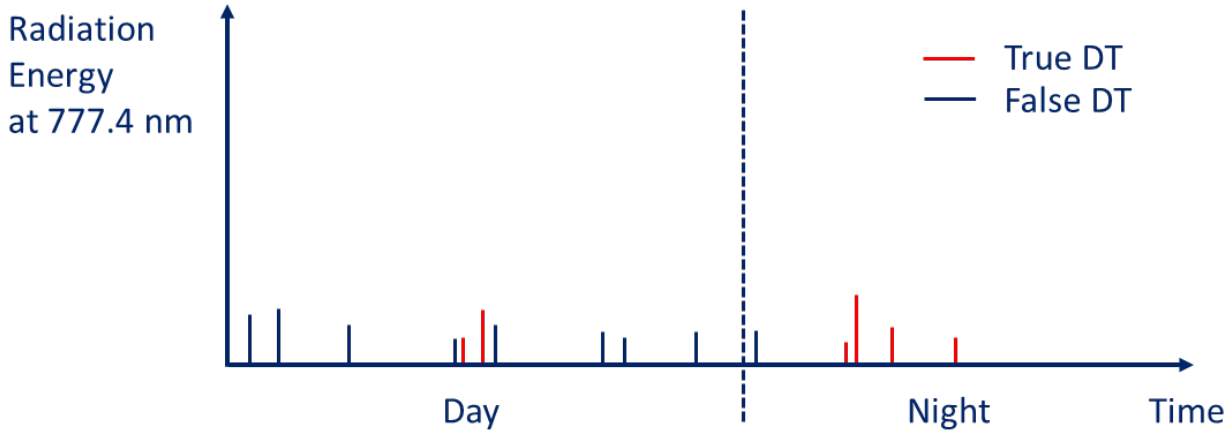
Typical pixel signal



Background removal and
detection threshold computation



Detection (ideal case)



Detection (real case)

Sources of false transients:

- Radiometric noise;
- Micro–vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …

SDTF – LI on-board filtering

Simulated Level 0 data

Simulated Level 1b data

Simulated scene

Simulated Level 2 data

Inputs:
- Modified SEVIRI VIS0.8 background
- Simulated optical pulses

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- Micro-Vibration filter (MVF)

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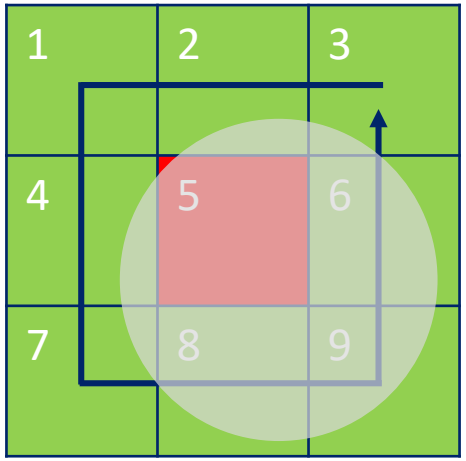

Single Detection (DT) Filter (SDTF): check the content of the 8 neighbors

$$\sum_{p=1,9\ p\neq 5} (\mathbf{DT}_p - \mathbf{Bkg_p}) > \mathbf{LUT_{SDTF}} \left(\frac{\sum_{p=1,9\ p\neq 5} \mathbf{Bkg_p}}{\mathbf{8}} \right)$$

II. jitter reconstruction filter
III. spatio-temporal coherency filter
IV. hybrid filter

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

MVF – LI on-board filtering

Simulated Level 0 data

Simulated Level 1b data

Simulated scene

Inputs:
- Modified SEVIRI VIS0.8 background
- Simulated optical pulses

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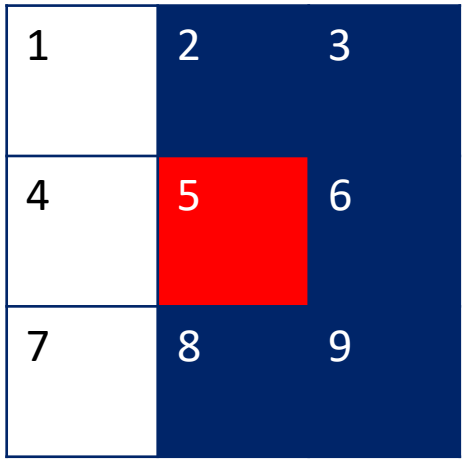
- Sing
  (SDT)
- Micro-Vibration filter (MVF)



Micro Vibration Filter (MVF): check the background gradient

$$\mathbf{Sobel_{Bkg}} = \sqrt{\mathbf{Sobel_x}^2 + \mathbf{Sobel_y}^2}$$

$$\mathbf{S_x} = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}, \quad \mathbf{S_y} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

$$\mathbf{Sobel_{Bkg}} > \mathbf{Thld_{MVF}} \left[\sum_{p=1,9} (\mathbf{DT}_p - \mathbf{Bkg_p}) \right]$$

II. jitter reconstruction filter
III. spatio-temporal coherency filter
IV. hybrid filter

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

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Simulated Level 2 data

Level 1b filtering – key filtering steps

Jitter-Reconstruction Filter (JIT):

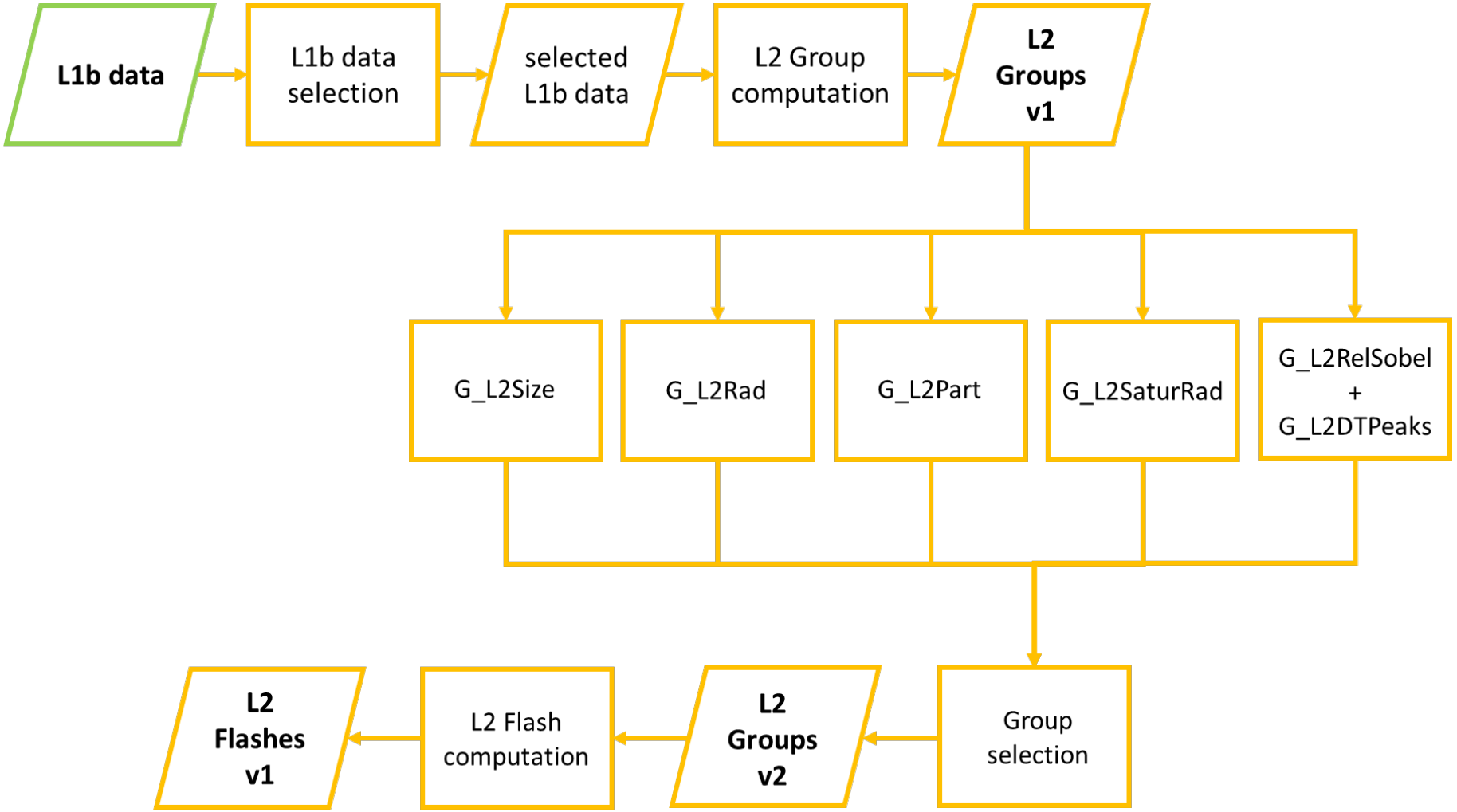
1. Computation for all the DTs of the ratio between the lightning signal (i.e., $\sum_{p=1,9}(\mathbf{DT}_p - \mathbf{Bkg_p})$) and the background gradient.
2. Individuation of "beacons" with particularly low ratio.
3. Estimation of the jitter movement from the "beacons" properties.
4. Computation of a corrected value $\mathbf{DT}' = \mathbf{DT} - \mathbf{DT_X^{JIT}} - \mathbf{DT_Y^{JIT}}$.
5. New RTPP detection run to see if the clean-from-jitter measurements would have passed the detection; the outcome is provided with a [0, 1] descriptor.

Hybrid Filter (HYB): combined check on the margin with which the on-board SDTF and RTPP conditions were passed.

1. If the margin at SDTF is larger than a threshold the DT is classified as true.
2. If the margin at SDTF is smaller than the threshold the check is done on the margin at RTPP. If the test is passed the DT is classified as true.
3. If the margin at RTPP is also smaller than a threshold a [0, 1] descriptor for the DT is computed: 1 meaning certainly false DT according to the filter.

Spatio-Temporal Coherency Filter (STC): check on the correlation between each DT and the other DTs in a spatio-temporal window of 0.5 sec (rolling window) and 50 km respectively.

Level 2 filtering



Level 2 filtering