Meteosat Third Generation Lightning Imager Mission (LI)

Part 1: Instrument overview data acquisition principle and data filtering (L0 and L1b)

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Remote Sensing and Products (RSP) Division, EUMETSAT

Basic information on lightning and lightning 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)

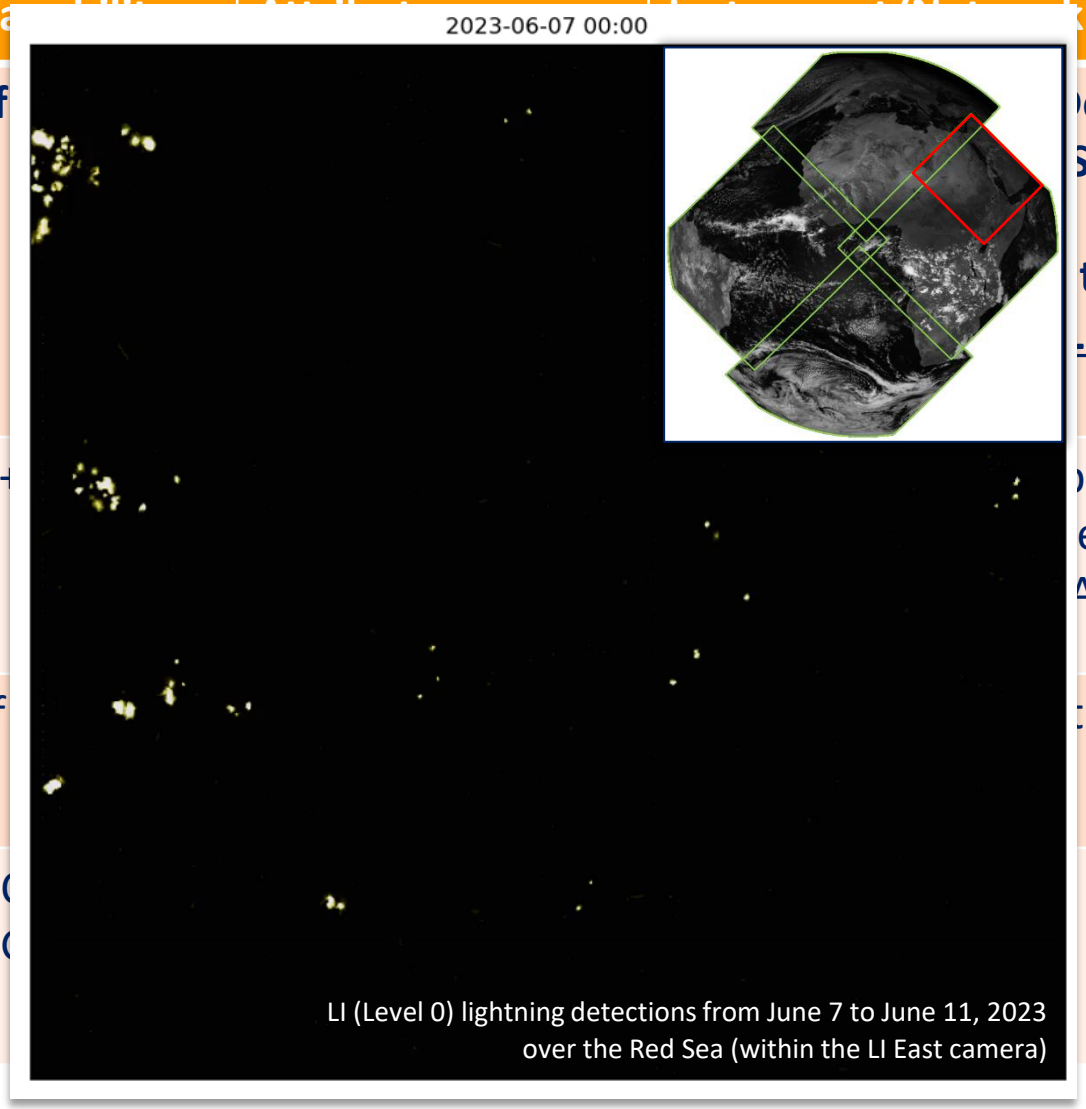
The radiation produced by an electric discharge within or below a cloud reaches the cloud top after multiple scattering through the cloud and is detected by lightning imagers in space

Basic information on lightning and lightning detection

Signal	Baseline	Detection capability	Attributes	Instrument/Network
VIS	**Space borne**	**80%-90% of CG+CC+IC**	**2D mapping and radiance GEO/LEO FOV**	• **Optical Transient Detector (OTD, 1995)** • **Lightning Imaging Sensor** • **(LIS, 1997)** • **Geostationary Lightning Mapper (GLM, 2016)** • **Lightning Imager (LI, end of 2022)**
VHF	10-20 km	100% of CG+CC+IC	Very localized 3D mapping	• Ebro Lightning Mapping Array (ELMA) • Suivi de l'Activité Electrique Tridimensionnelle Totale de l'Atmosphère (SAETTA)
LF	50-300 km	50%-90% of IC+CC >95% CG	Europe coverage	• European Cooperation for Lightning Detection (EUCLID)
VLF	>1000 km	10%–30% CC+IC 70%–80% CG	Global coverage	• Vaisala GLD360 • Met Office Leela

Basic information on lightning and lightning detection

Signal	Baseline	Detection ca		
VIS	**Space borne**	**80%-90% of**		**etector (OTD, 1995)** **Sensor** **tning Mapper (GLM, 2016)** **I, end of 2022)**
VHF	10-20 km	100% of CG-		pping Array (ELMA) ectrique Tridimensionnelle Totale AETTA)
LF	50-300 km	50%-90% of >95% CG		tion for Lightning Detection
VLF	>1000 km	10%–30% C 70%–80% C		

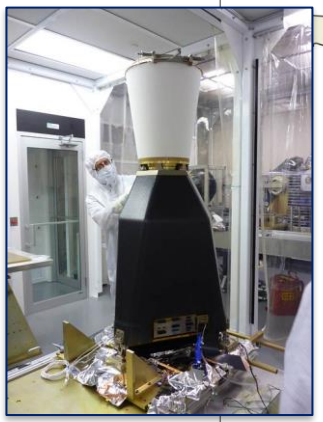


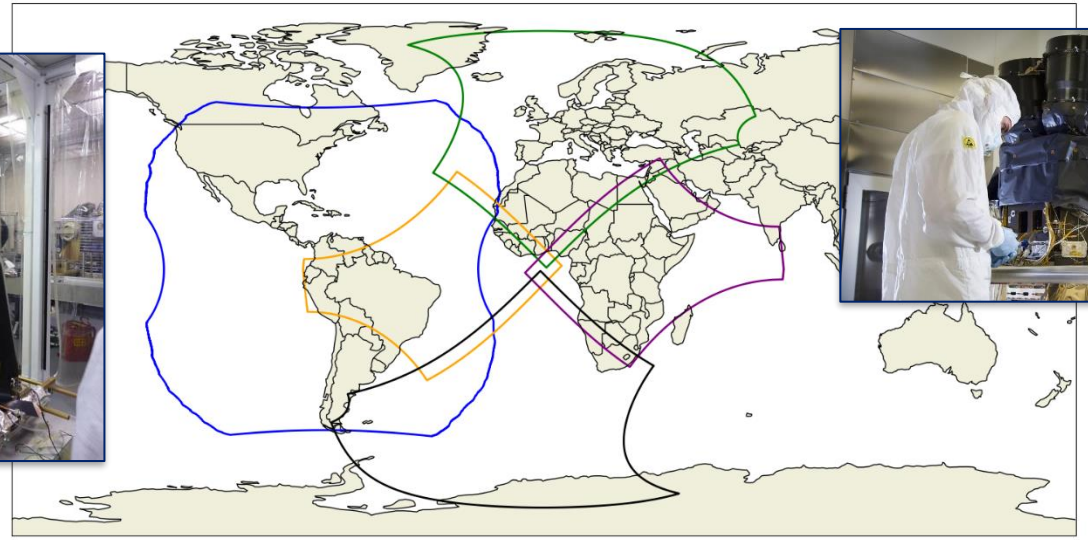
LI (Level 0) lightning detections from June 7 to June 11, 2023 over the Red Sea (within the LI East camera)

LI instrument

Key design feature	LI*	GLM
Detector	1000x1170 (x4) pixels CMOS	1372x1300 pixels CCD
Spatial resolution	4.5 km at Nadir (variable within the FOV; about 8 km over Europe)	8 km (nearly constant; 14 km at FOV edge)
Coverage	Up to 80 degrees North	Up to 52 degrees North
Spectral band	777.4 nm with 1.9 nm bandwidth	777.4 nm with 1 nm bandwidth
Integration time (frame rate)	1 ms	2 ms
On-board processing	Lightning detection and data filtering	Lightning detection
Bandwidth	30 Mbps (3x3 pixel window for each detection)	7.7 Mbps
Latency (timeliness)	1 min	20 sec
Detection efficiency	70-90% flash detection efficiency (expected)	70-90% flash detection efficiency

*LI is manufactured by Leonardo (Italy) under the industrial prime contractor Thales Alenia Space (France) as part of the ESA lead MTG space segment development





FOV of GLM on GOES-16 (blue) and FOV of the four cameras of LI (west in yellow, north in green, east in purple, and south in brown, respectively)

LI system

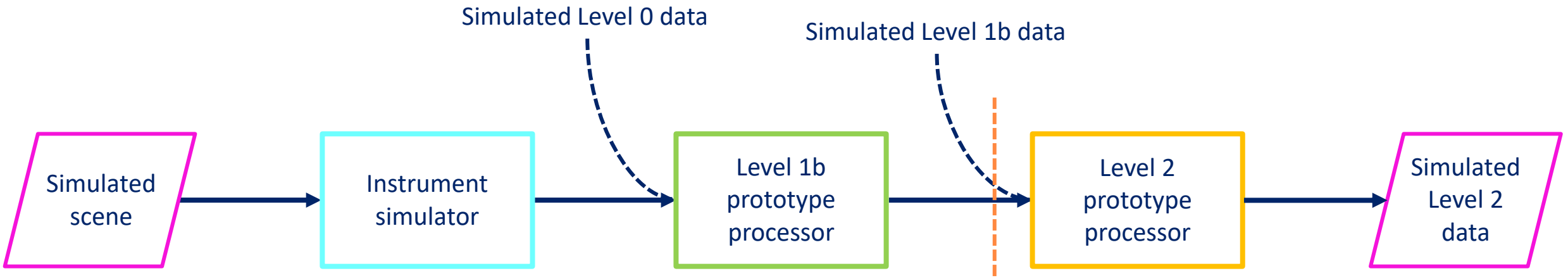
ESA and LDO

- Design: ESA, EUM, and LDO
- Operational implementation: TAS and EUM

- Design: EUM
- Operational implementation: Thales and EUM

- EUM: EUMETSAT
- ESA: European Space Agency
- LDO: Leonardo (Italy)
- TAS: Thales Alenia Space (France)

LI end-to-end Reference Processor (RP)



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

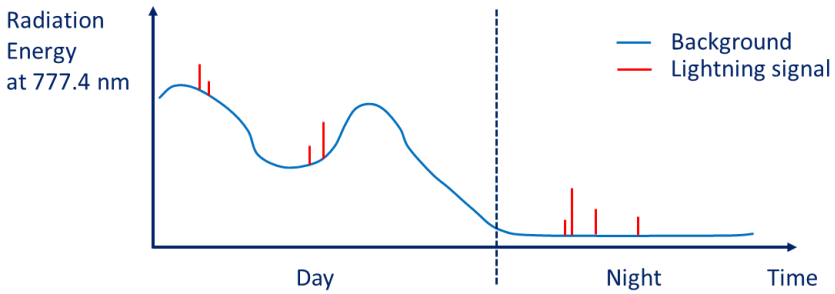
- Observation geometry
- Micro-Vibration
- Radiometric detection including noise
- Real Time Pixel Processor (RTPP) detection
- Single detection filter (SDT)
- Micro-Vibration filter (MVF)

- 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

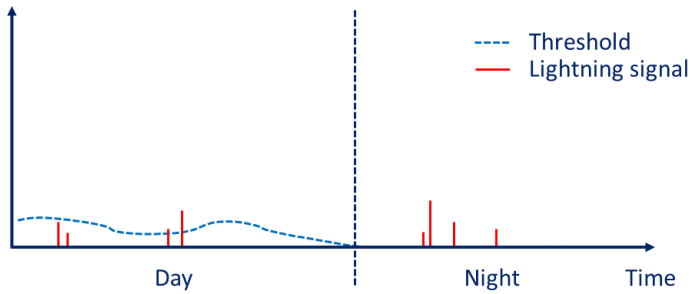
- DT acceptance for Level2 processing
- Group computation
- Group filtering
- Flash computation
- Flash filtering
- Definition of the Level 2 products

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

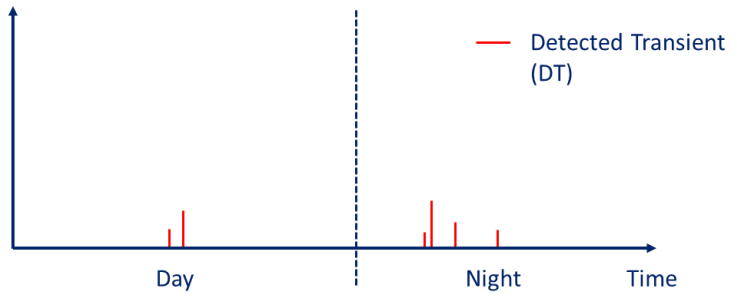
LI detection principle (Real Time Pixel Processor)



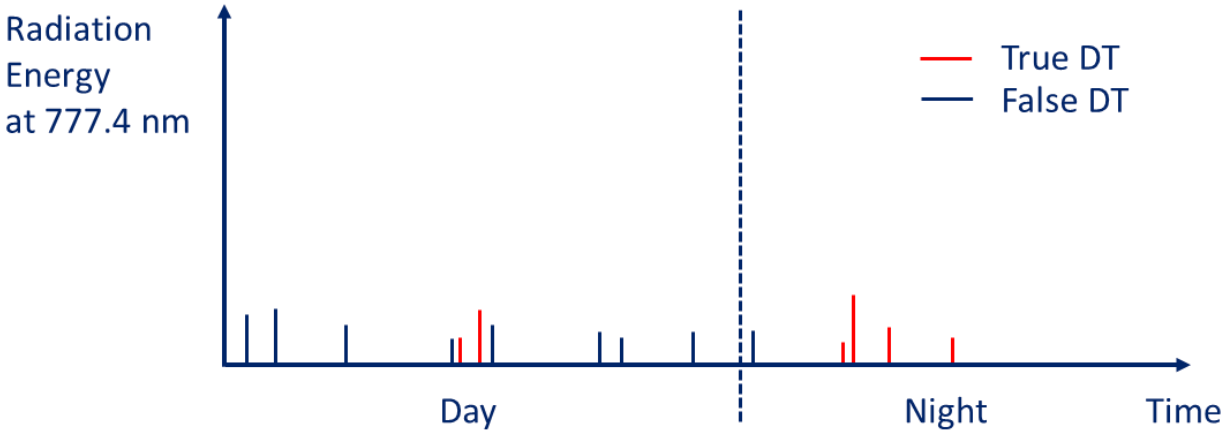
Typical pixel signal



Background removal and
detection threshold computation



Detection (ideal case)

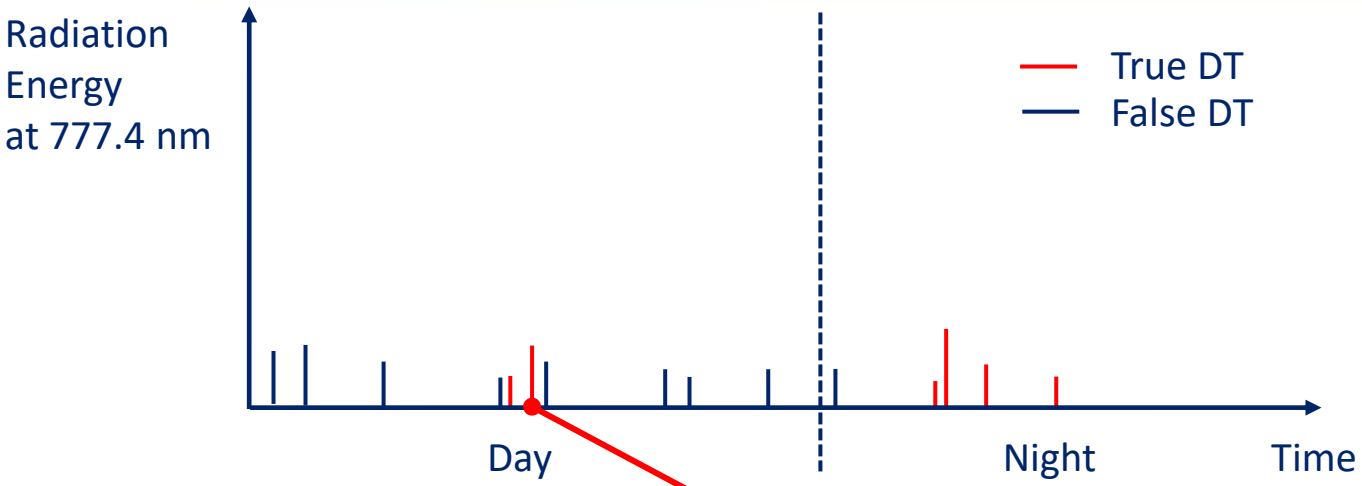


Detection (real case)

Sources of false transients:

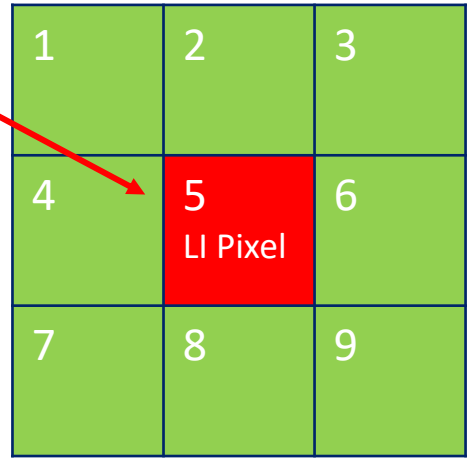
- radiometric noise;
- micro–vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …

LI data content



Sources of false transients:

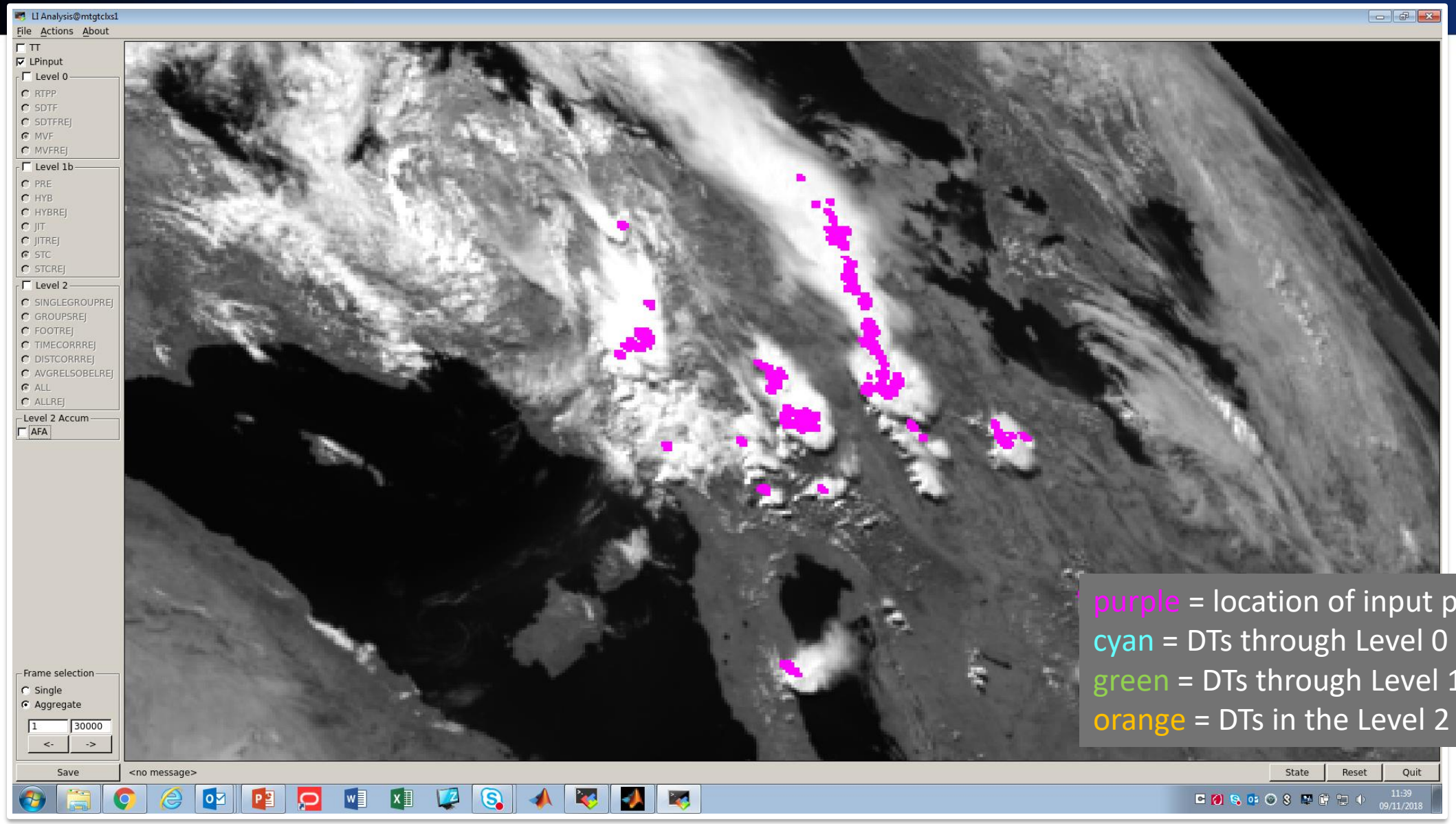
- local fluctuations of the radiometric noise;
- micro-vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …



For each DT the following info is available:

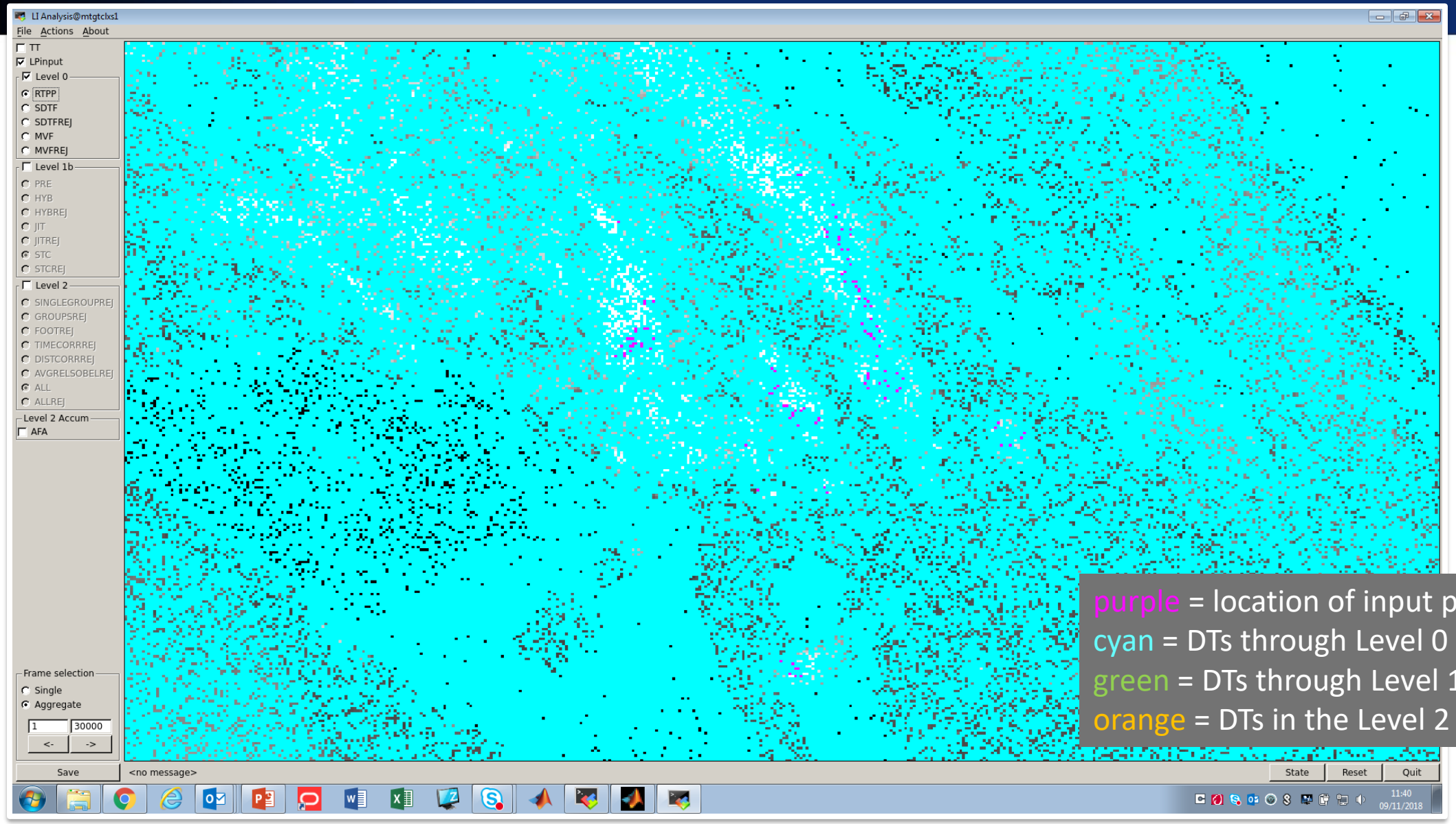
1. 3x3 window with measurement
2. 3x3 window with the estimated background measurement
3. location in space (lat/lon) and time

Simulation input



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 RTPP



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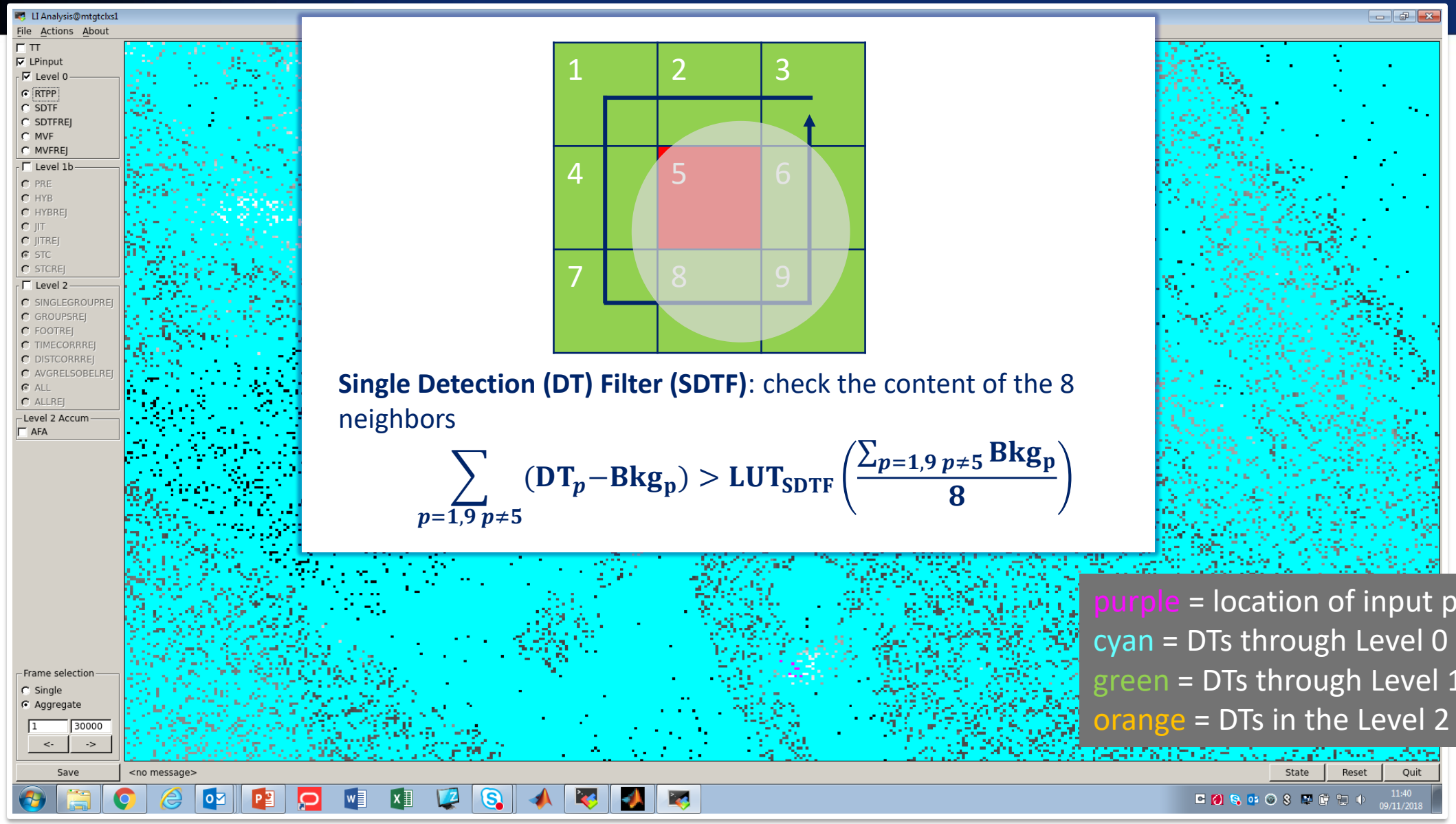
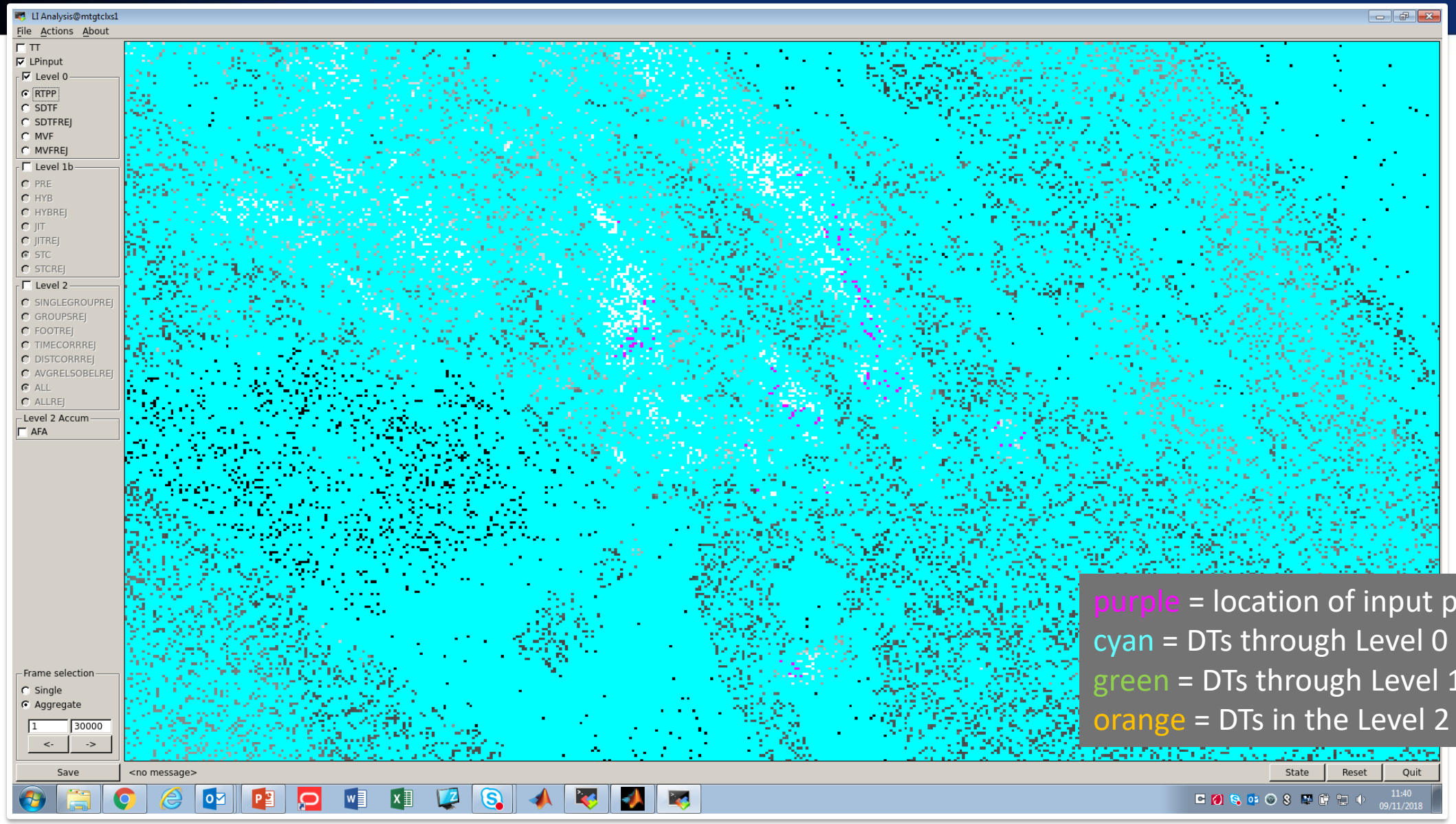
DTs at Level 0 RTPP



DTs at Level 0 RTPP



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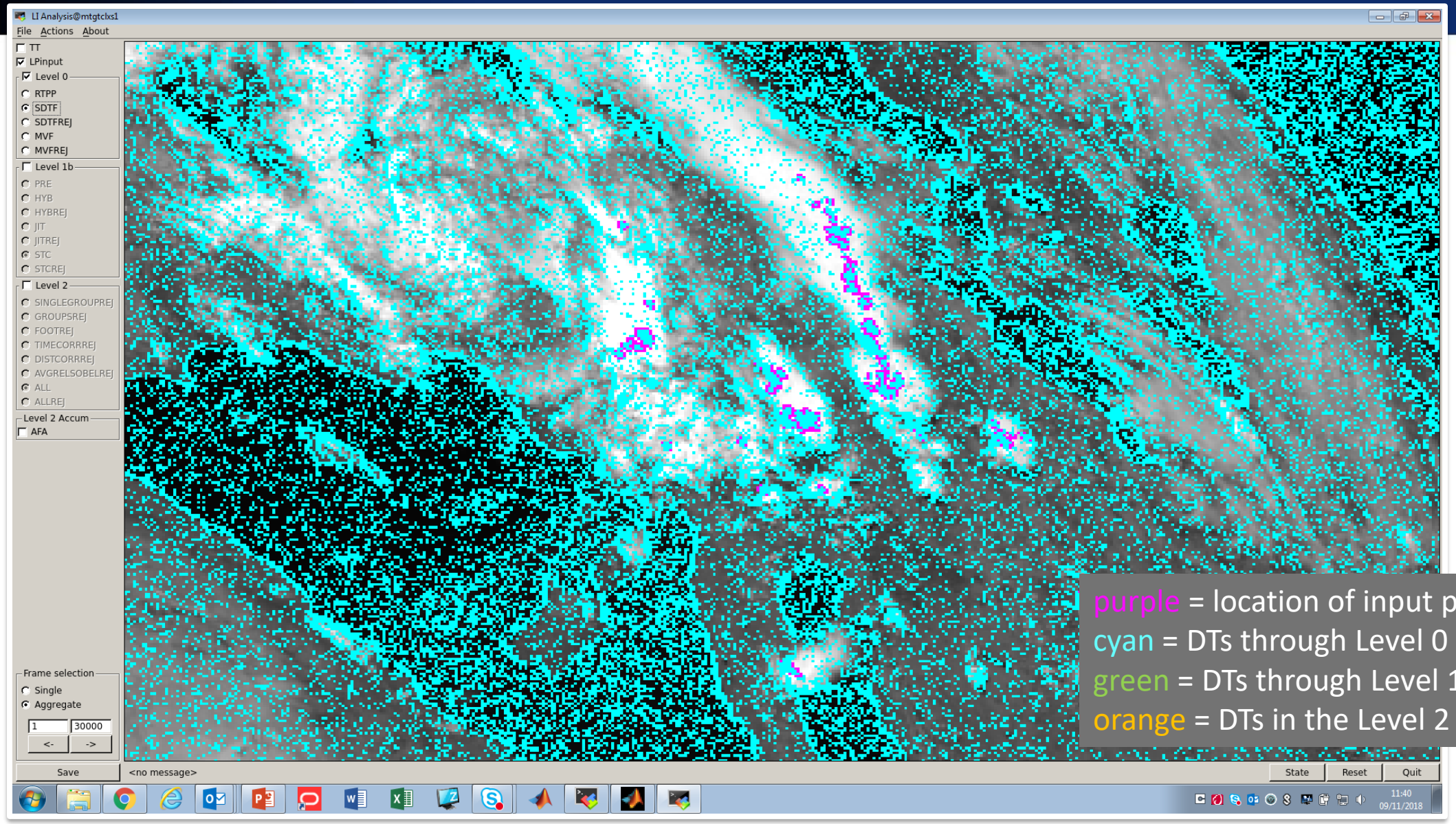
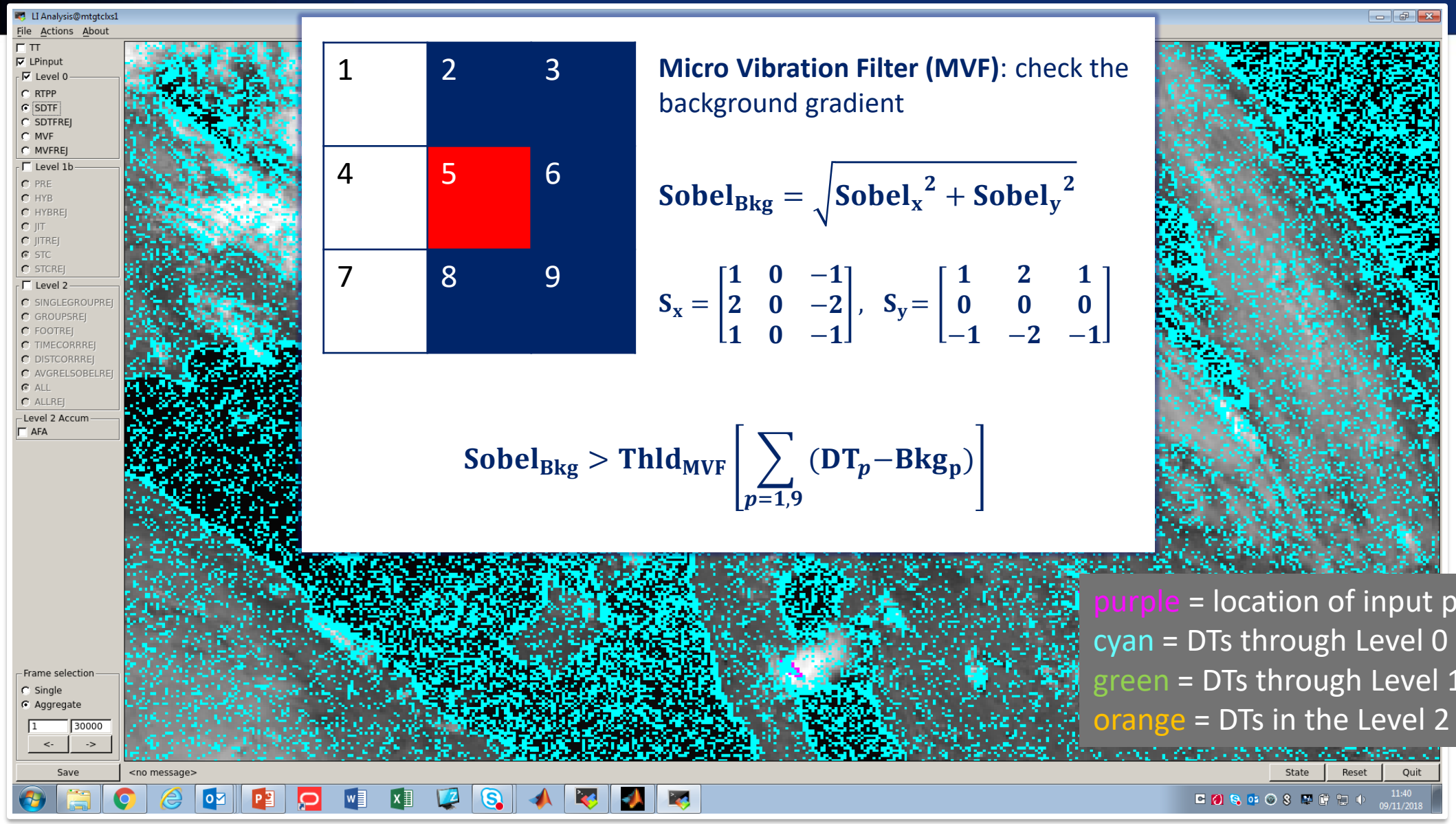
DTs at Level 0 SDTF



DTs at Level 0 SDTF



1	2	3
4	5	6
7	8	9

Micro Vibration Filter (MVF): check the background gradient

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

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

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

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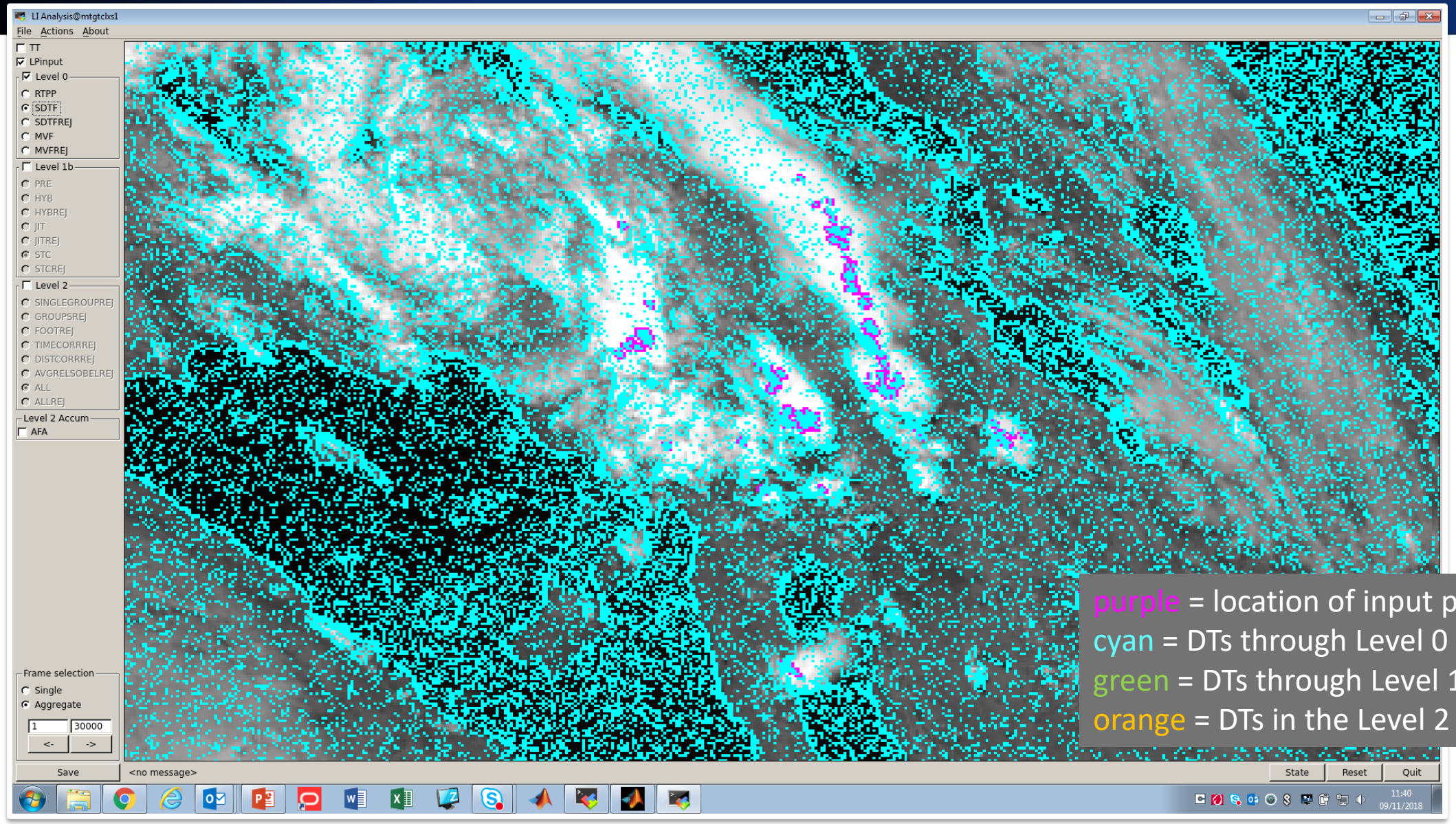
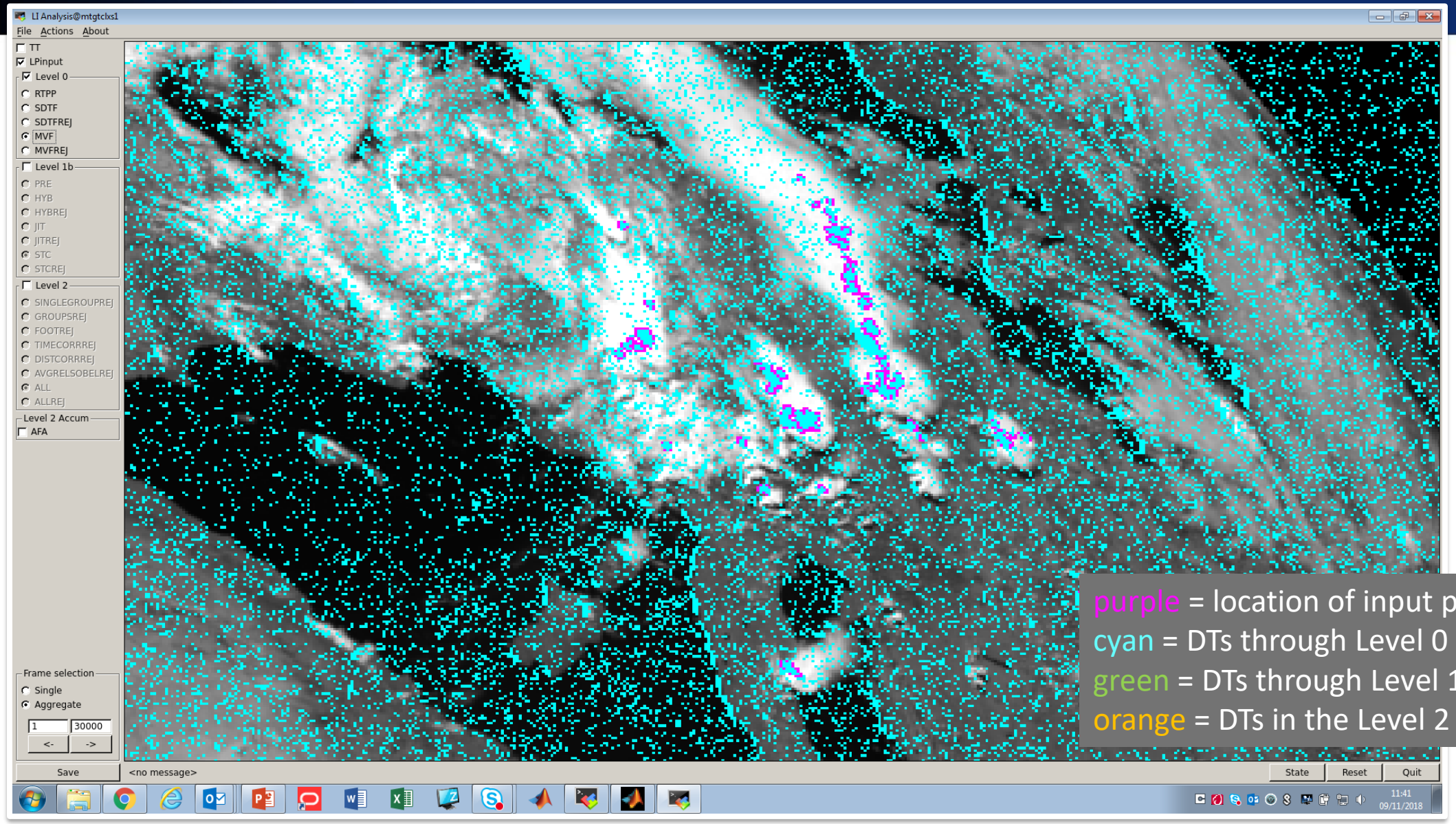
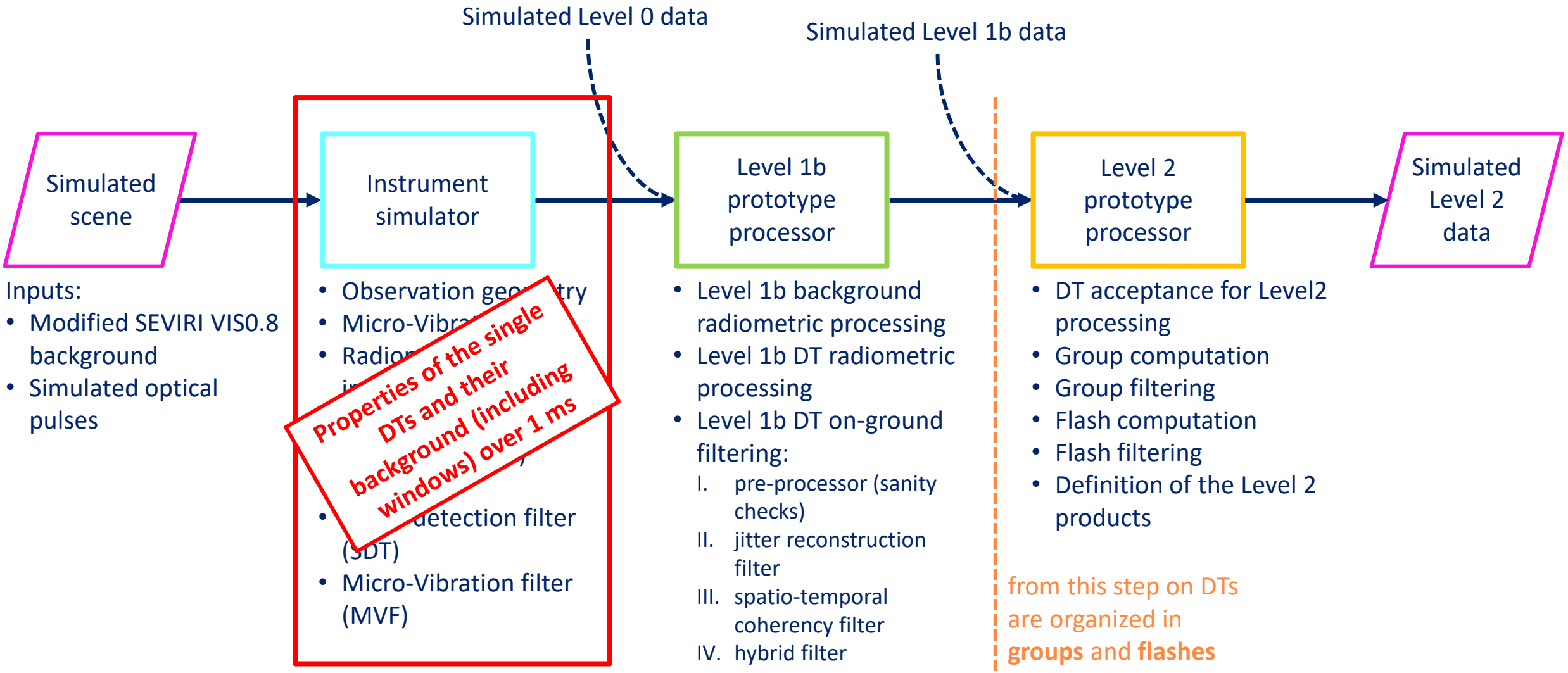
DTs at Level 0 SDTF



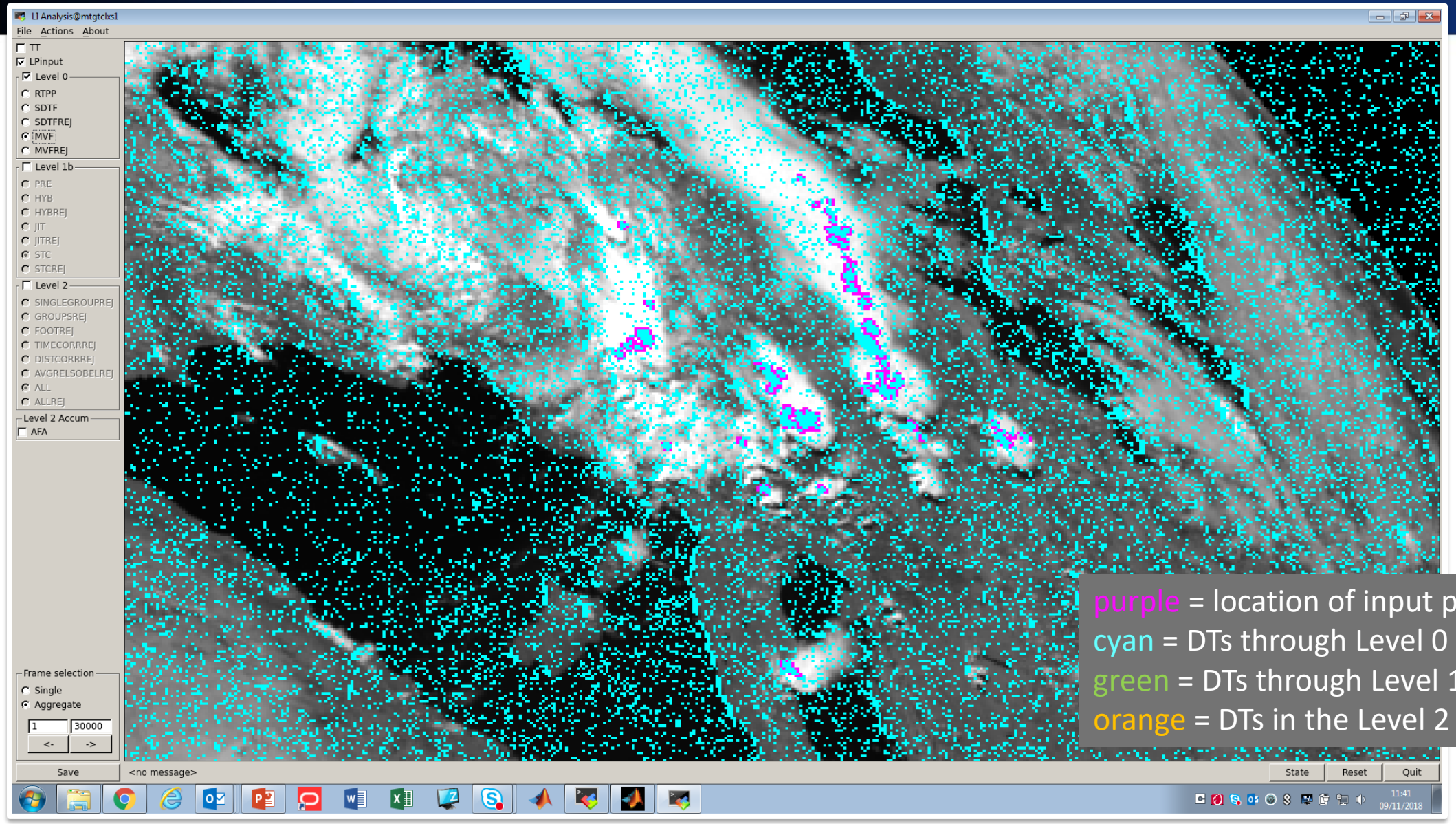
DTs at Level 0 MVF



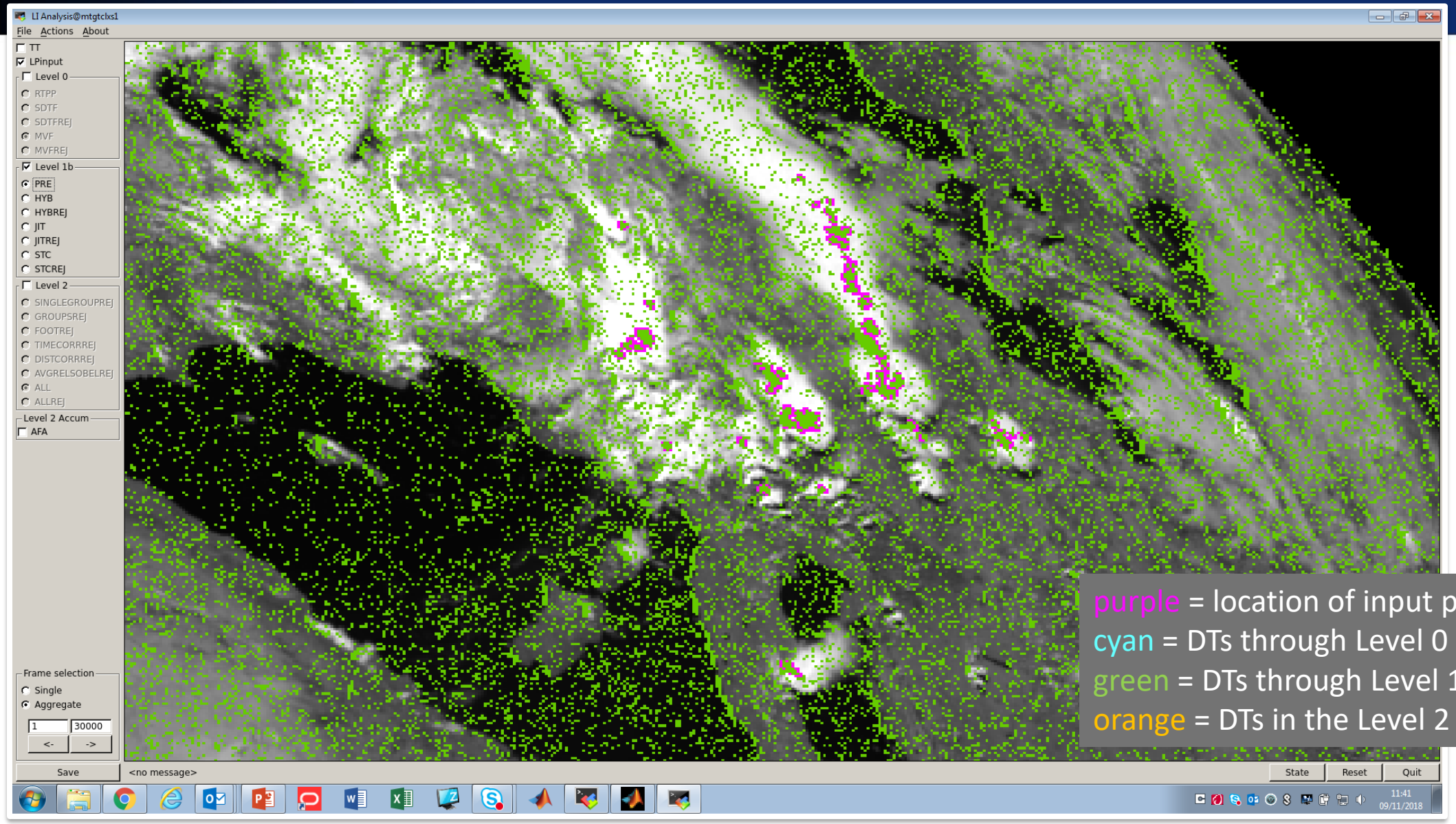
LI data processing in the end-to-end Reference Processor (RP)



DTs to be processed on-ground (Level 0 data)



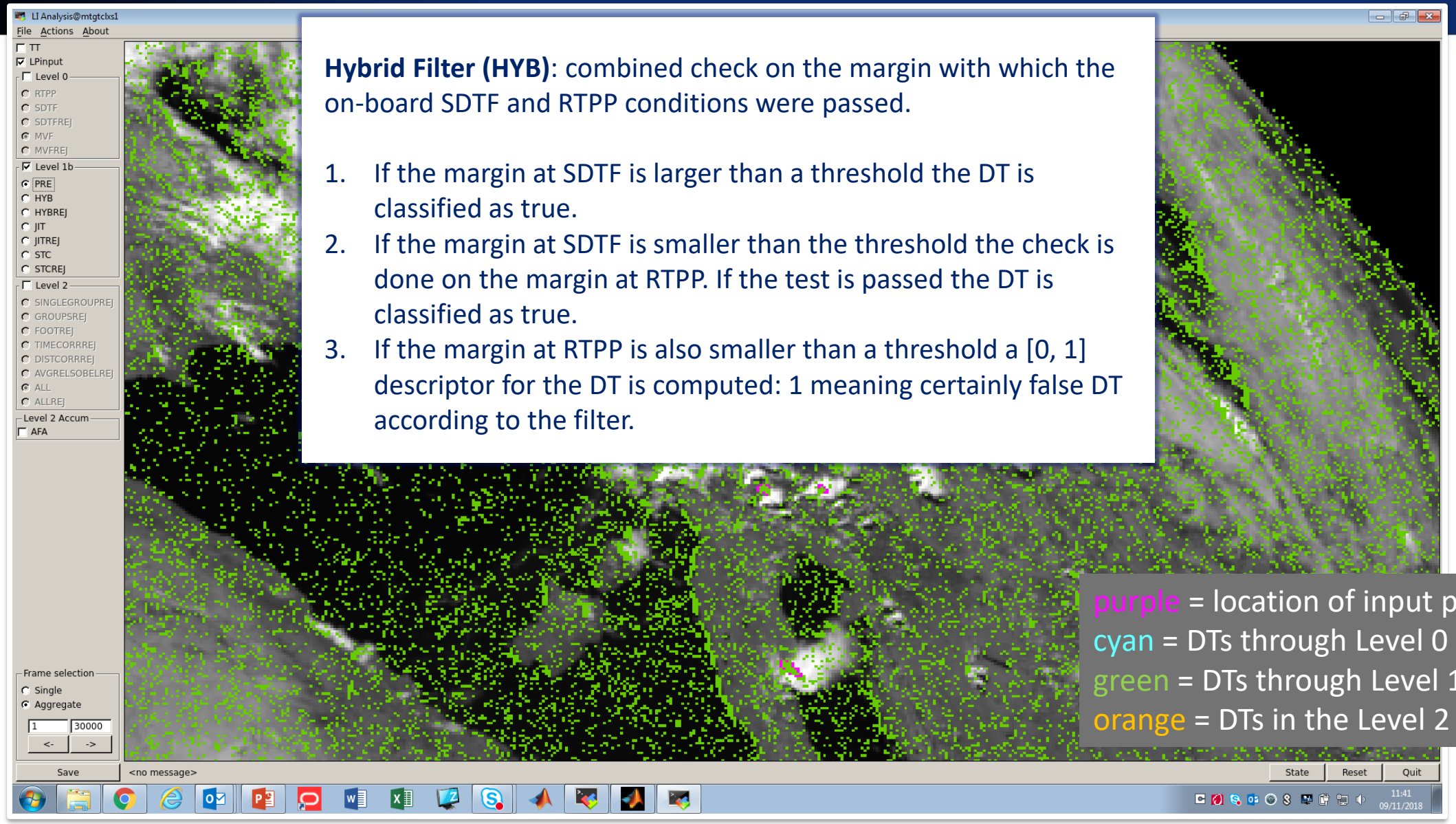
DTs at Level 1b pre-processing



DTs at Level 1b pre-processing

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.



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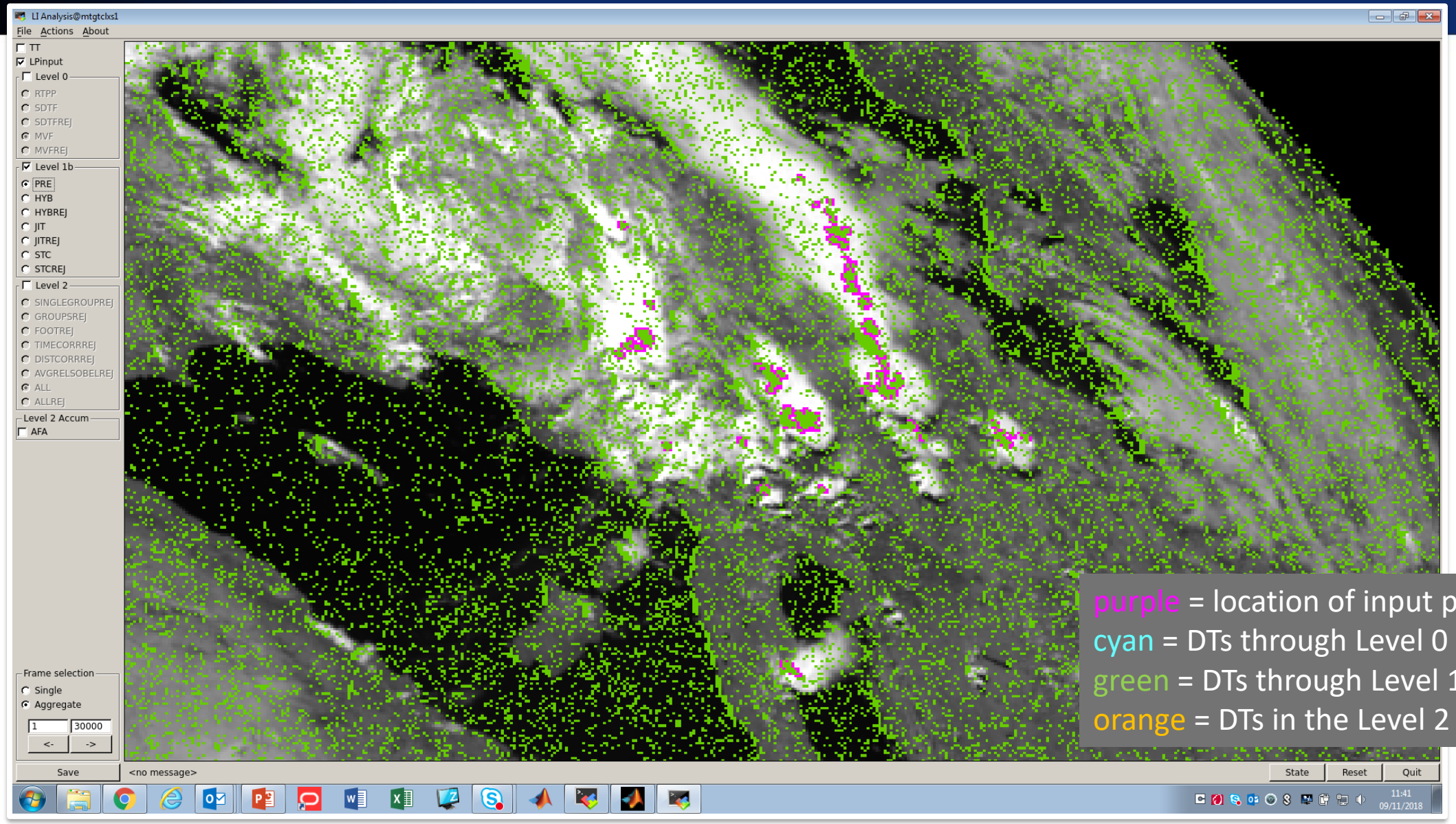
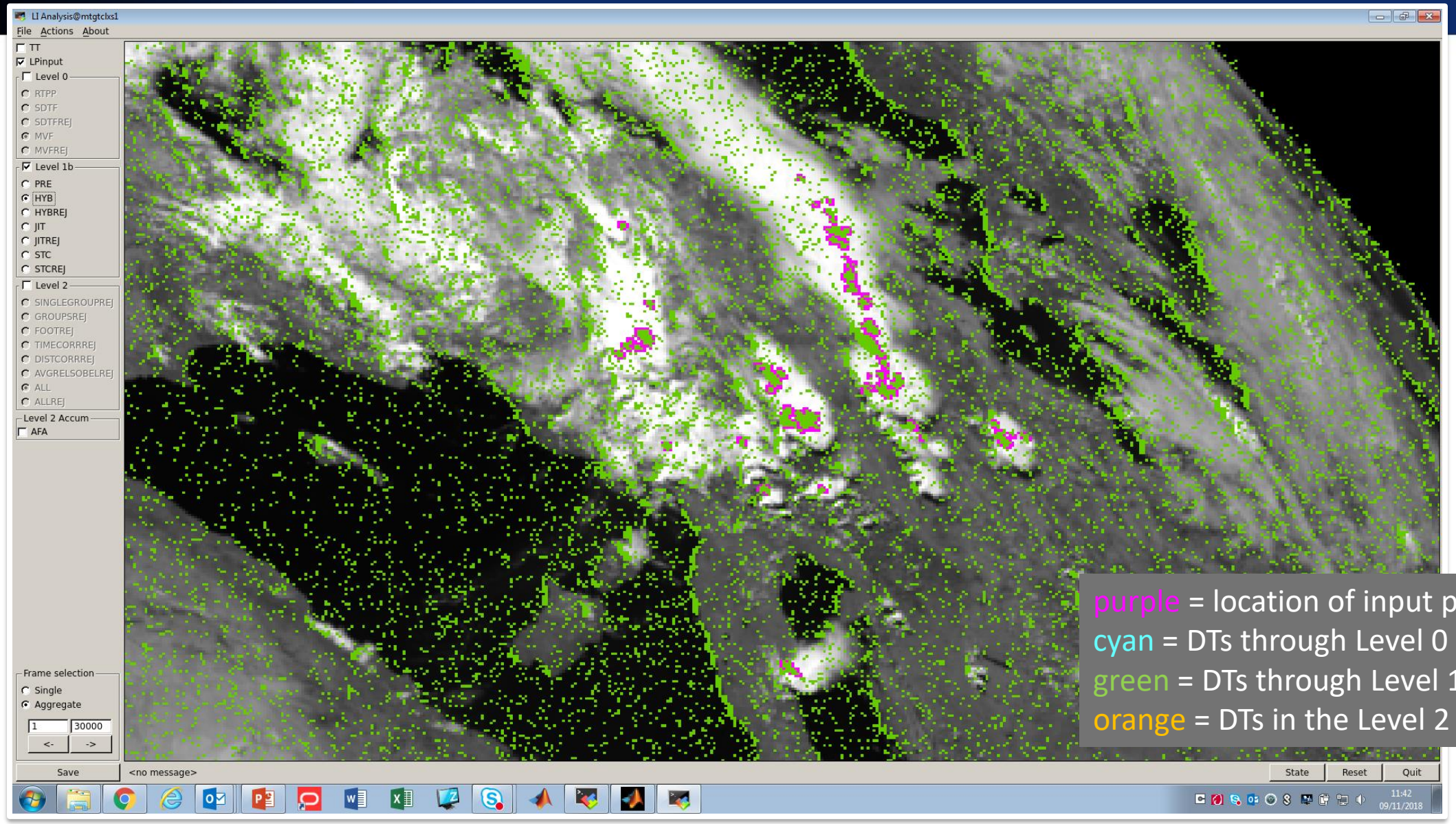
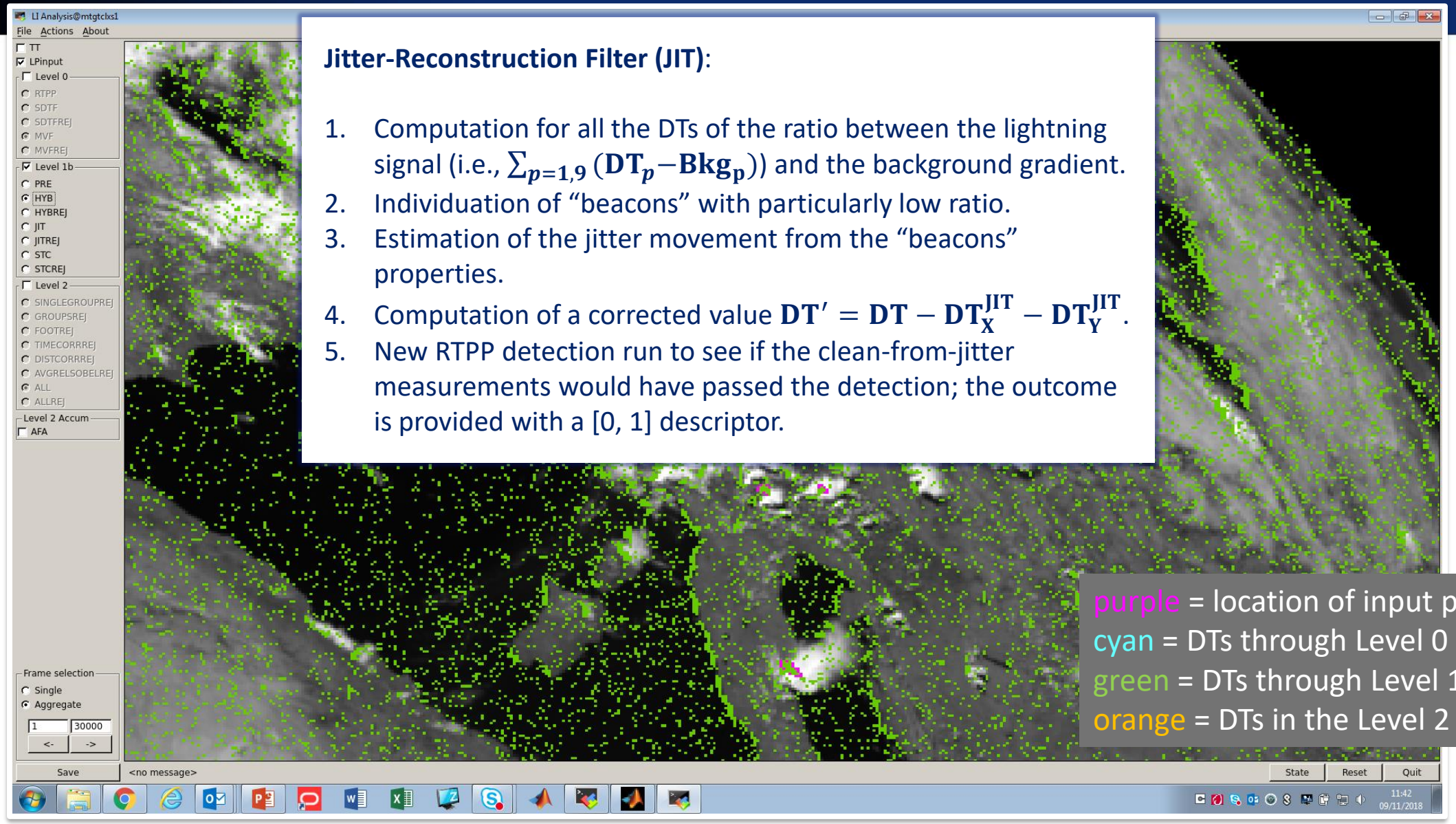
DTs at Level 1b pre-processing



DTs at Level 1b HYB



DTs at Level 1b HYB



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.

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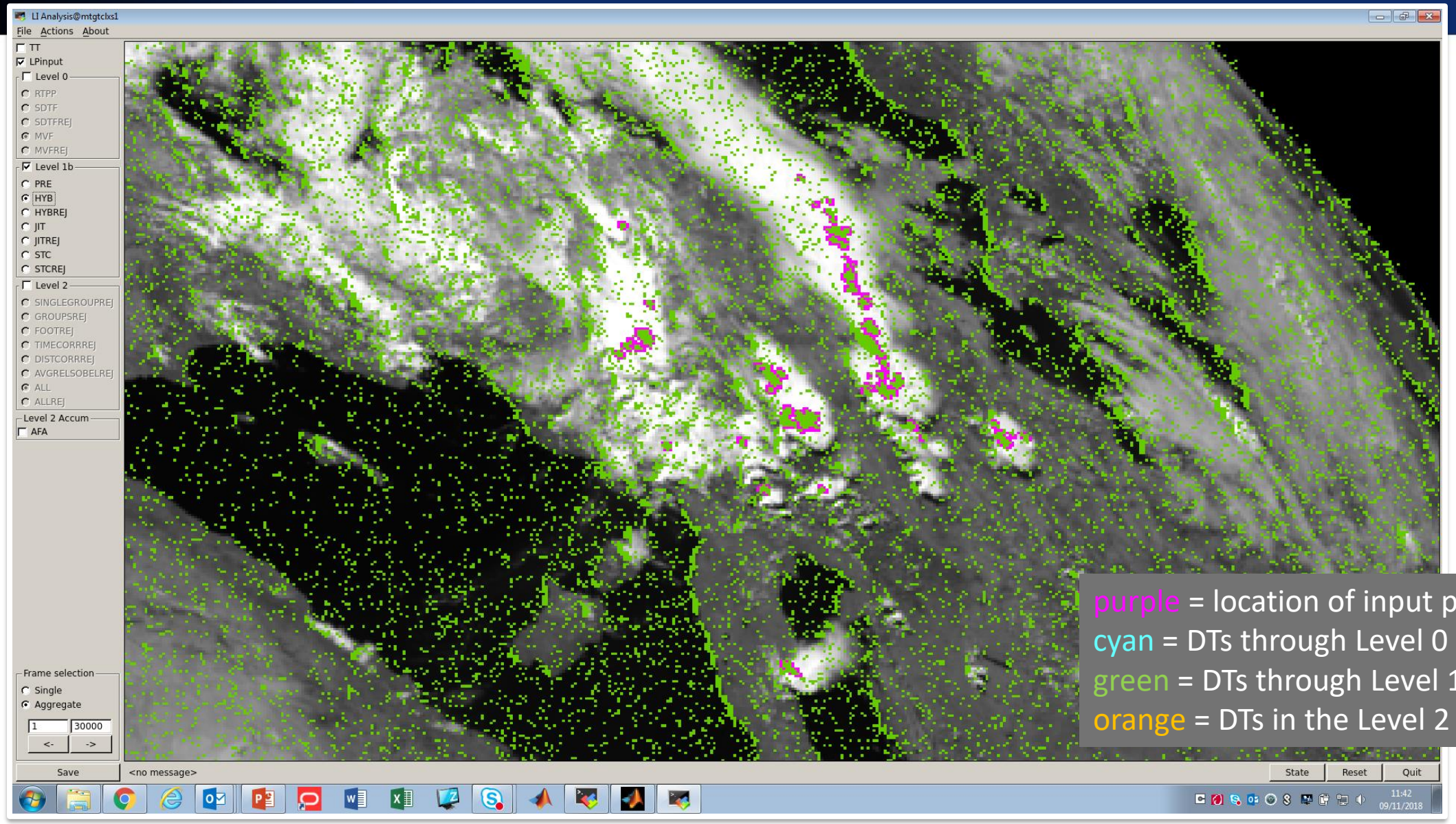
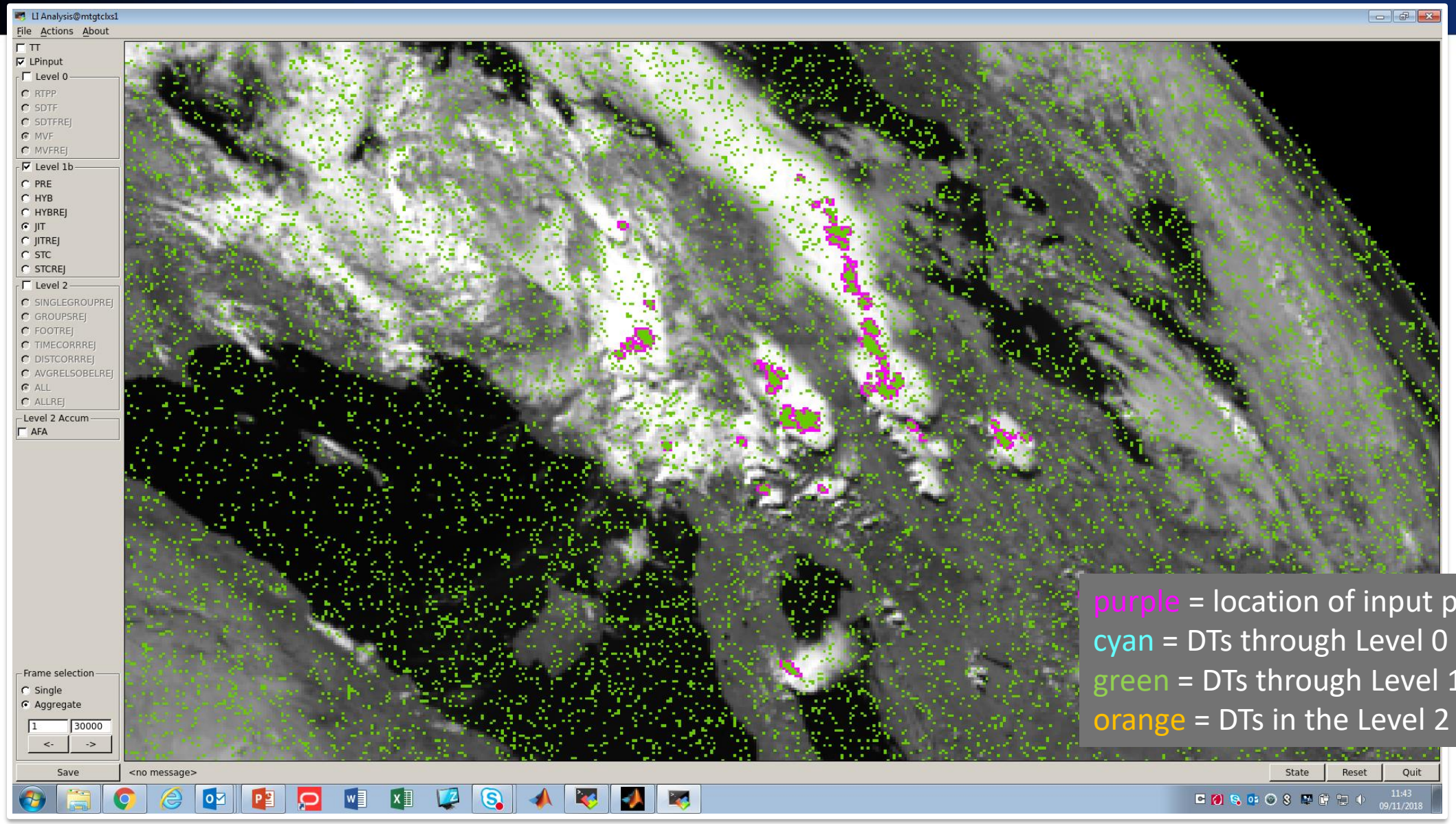
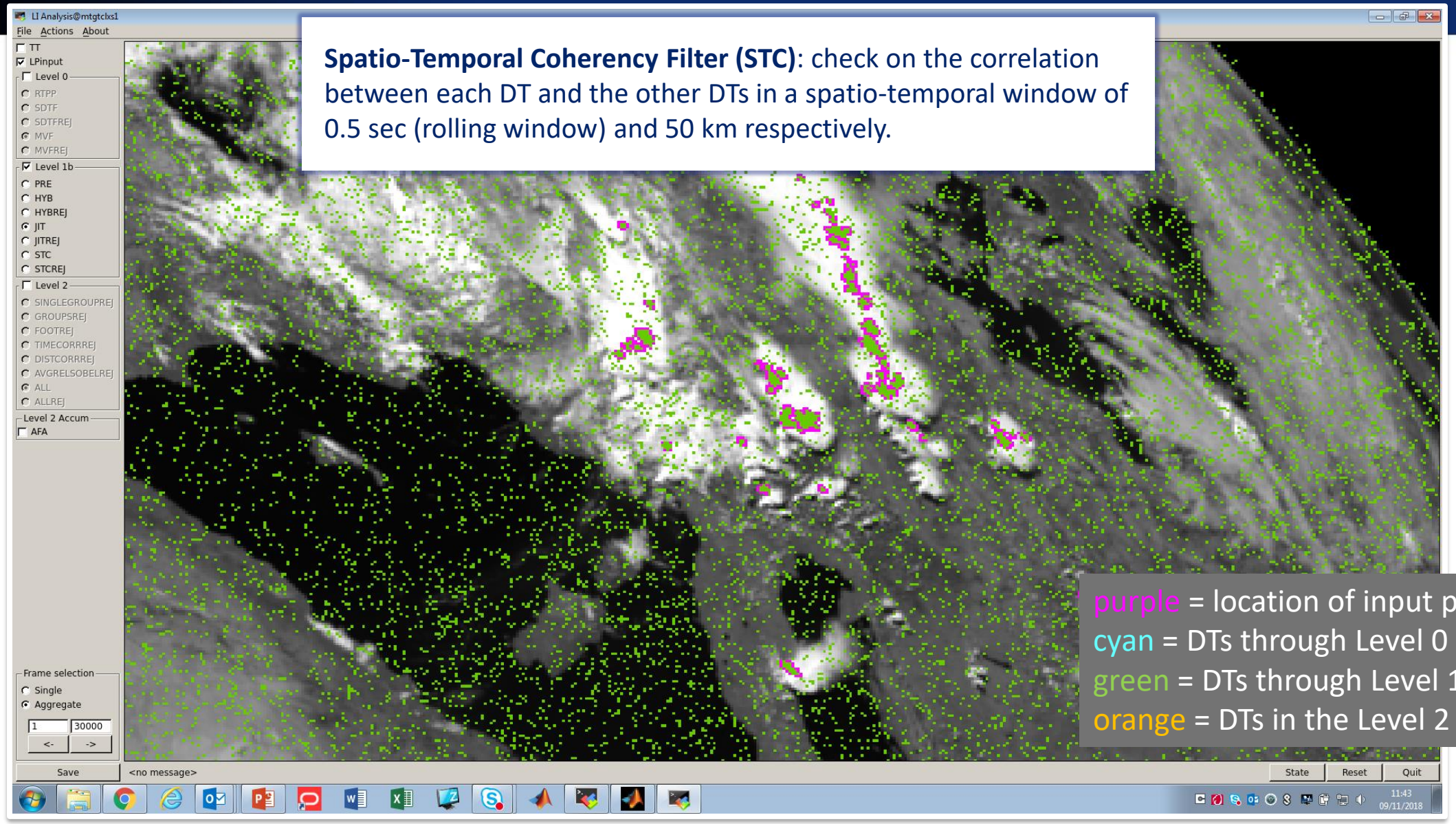
DTs at Level 1b HYB



DTs at Level 1b JIT



DTs at Level 1b JIT



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.

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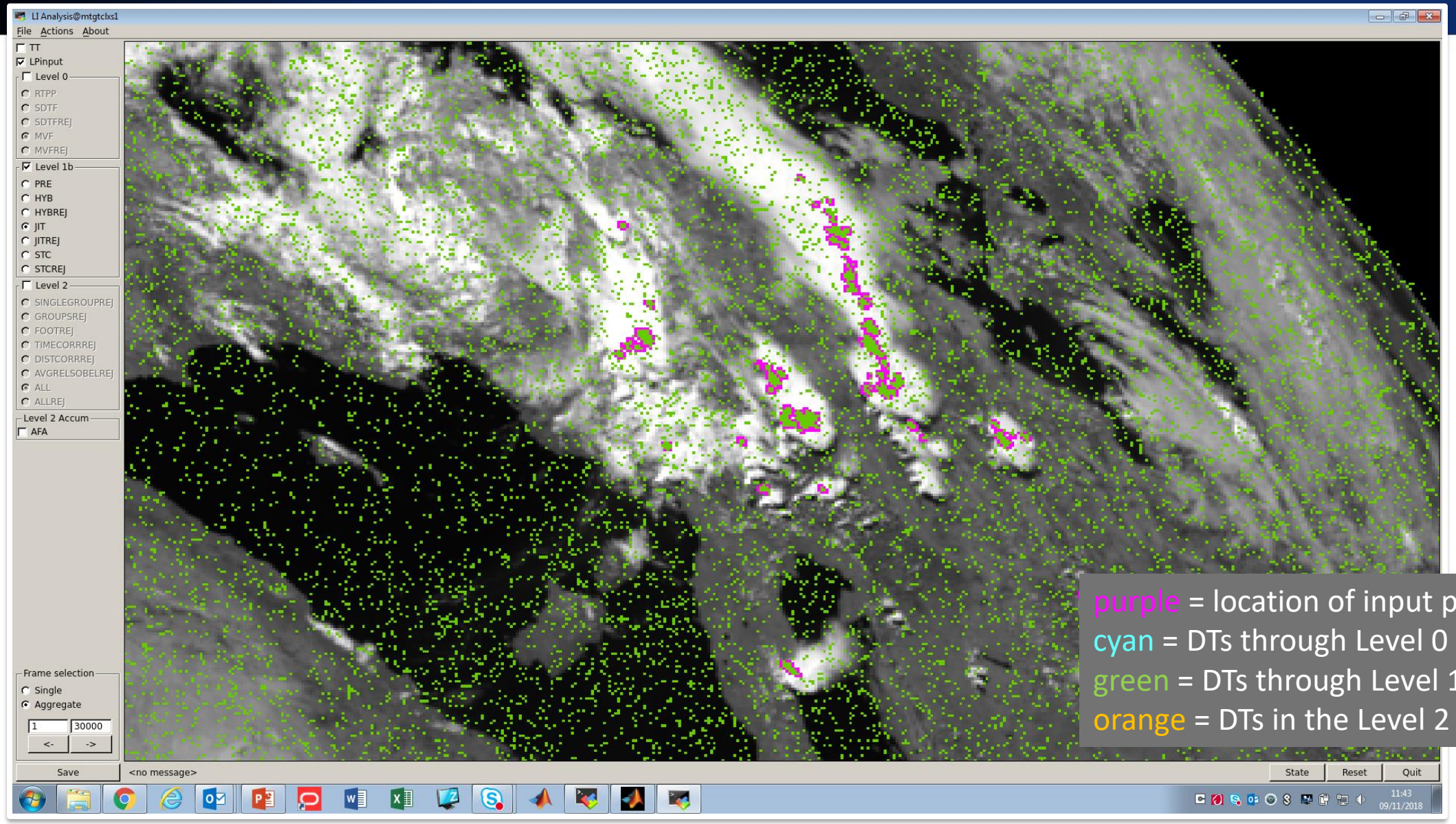
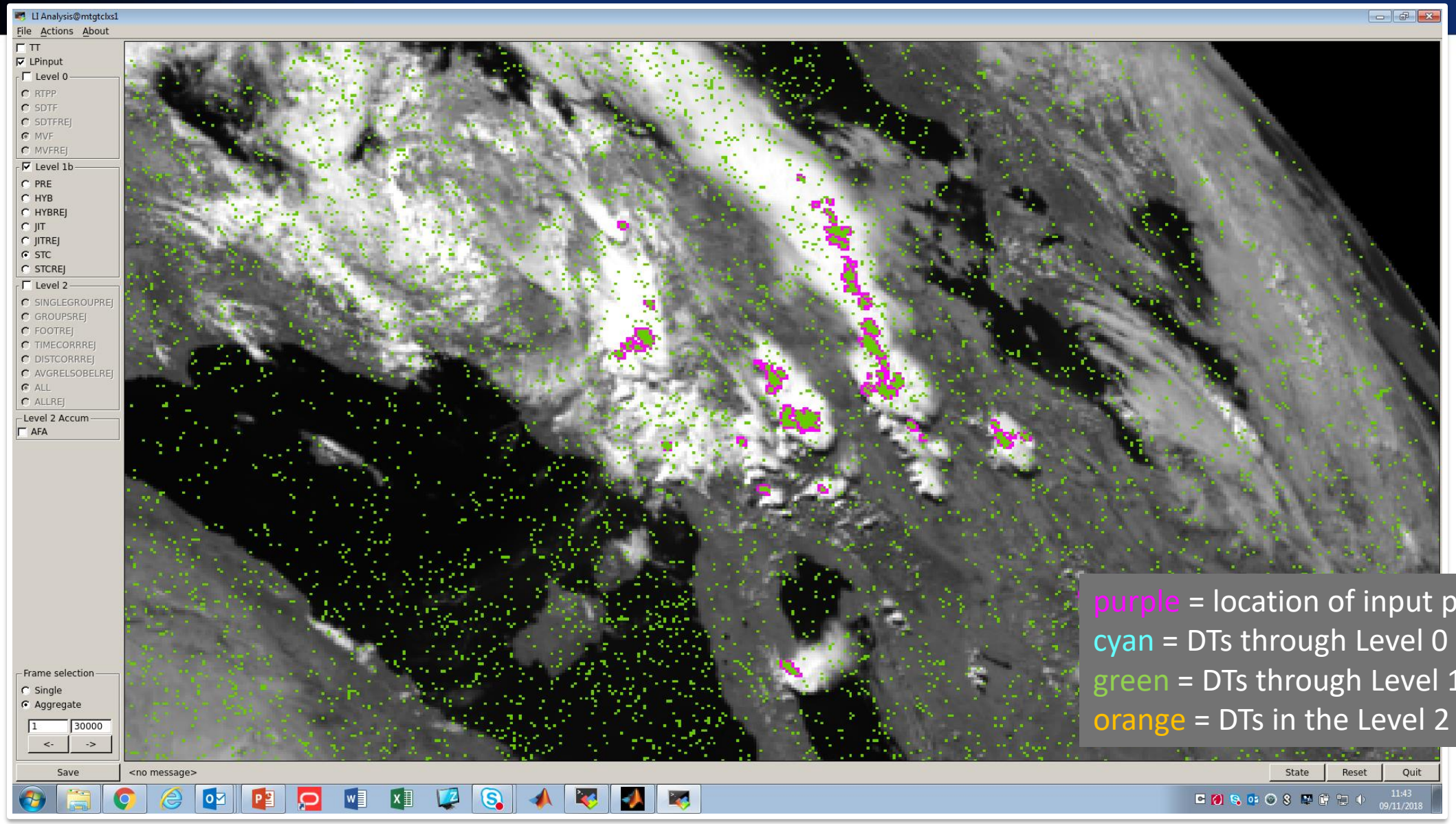
DTs at Level 1b JIT



DTs at Level 1b STC



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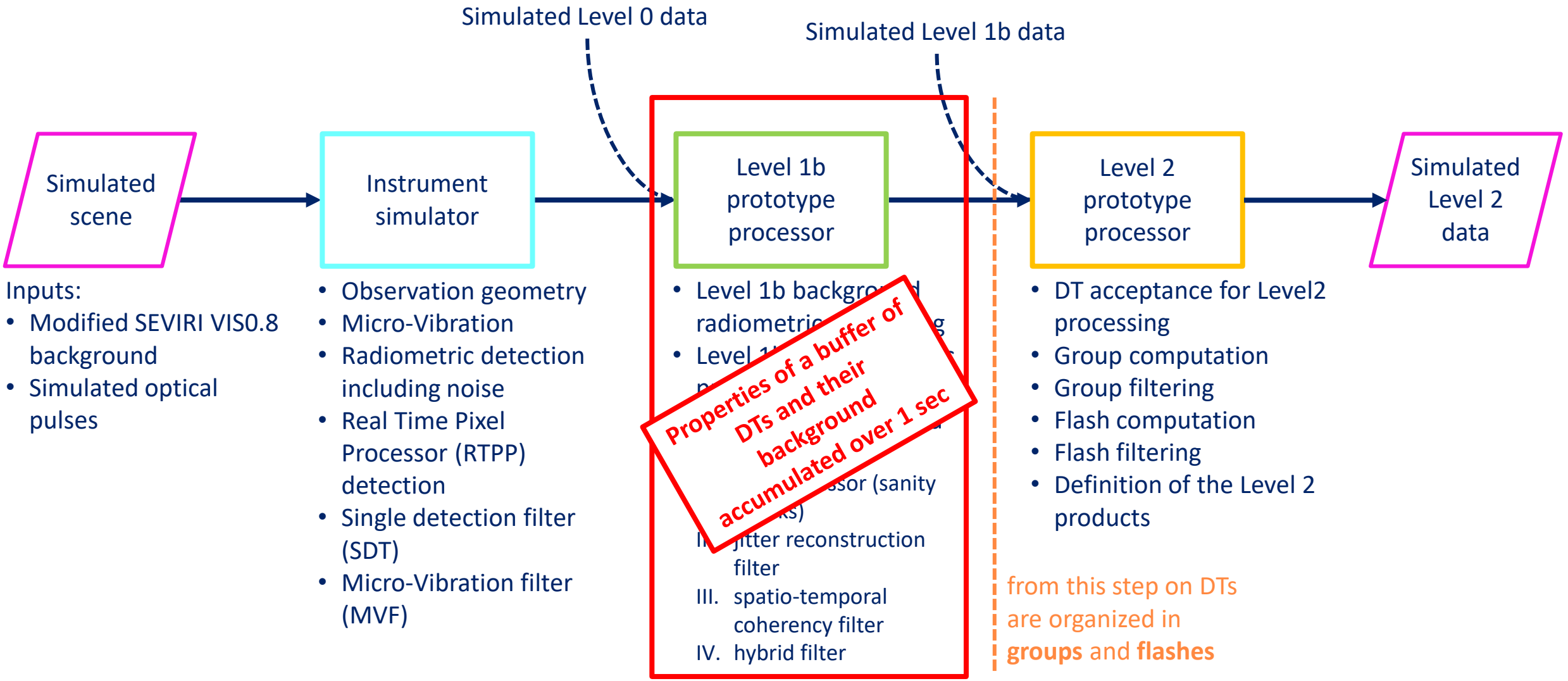
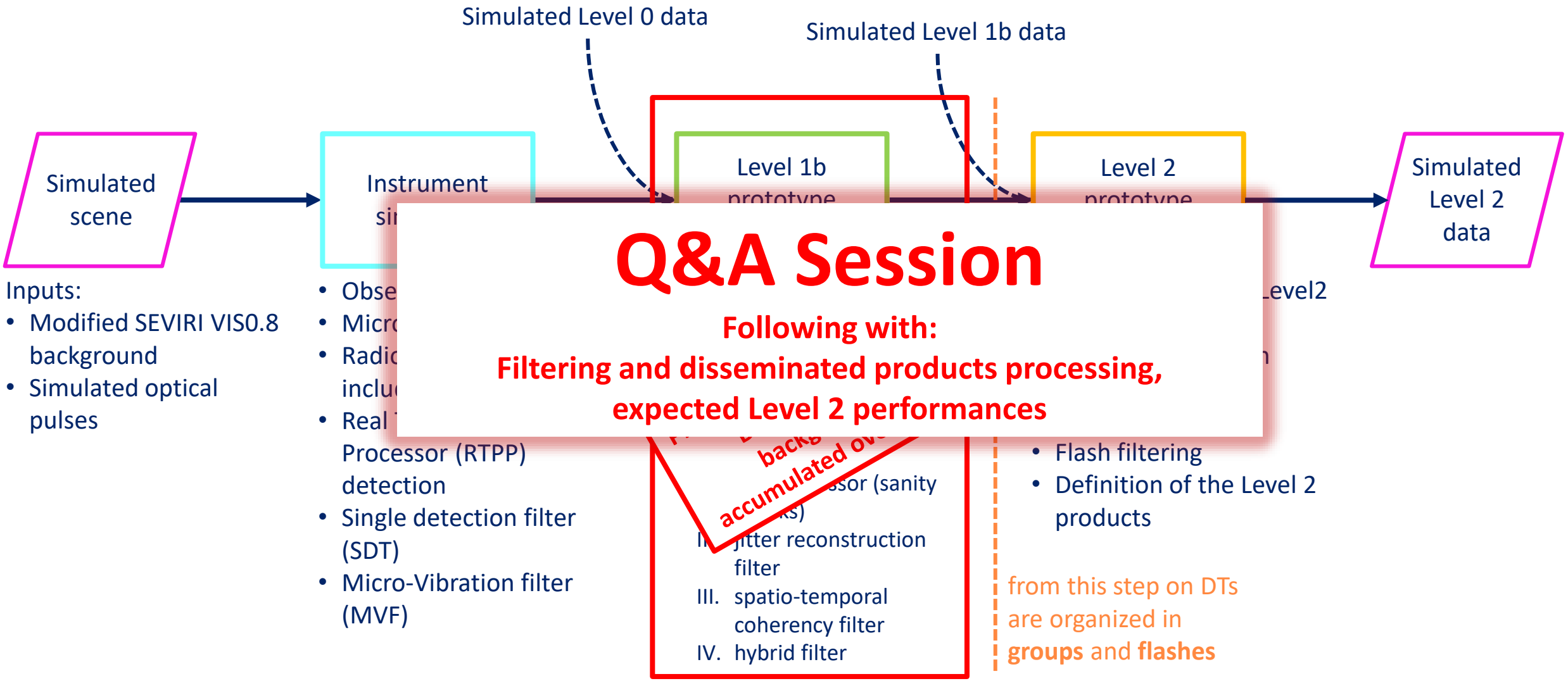
LI data processing in the end-to-end Reference Processor (RP)



LI data processing in the end-to-end Reference Processor (RP)



Q&A Session

Following with:
Filtering and disseminated products processing, expected Level 2 performances

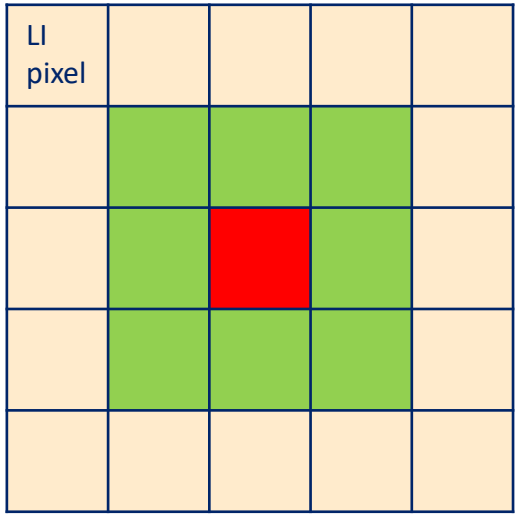
Meteosat Third Generation Lightning Imager Mission (LI)

Part 2: L2 filtering and disseminated products

Bartolomeo Viticchiè & Sven-Erik Enno – LI Science Team

Remote Sensing and Products (RSP) Division, EUMETSAT

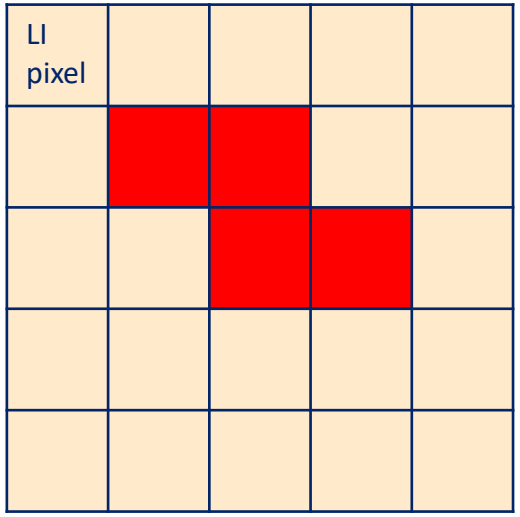
LI data content



LI Event (or Detected Transient) with 3x3 window

Pixel-sized energy measurement above the detection threshold (at RTPP)

This is the basic component of the optical pulse detection of LI and is the basic component of the data processing from Level 0 to Level 2

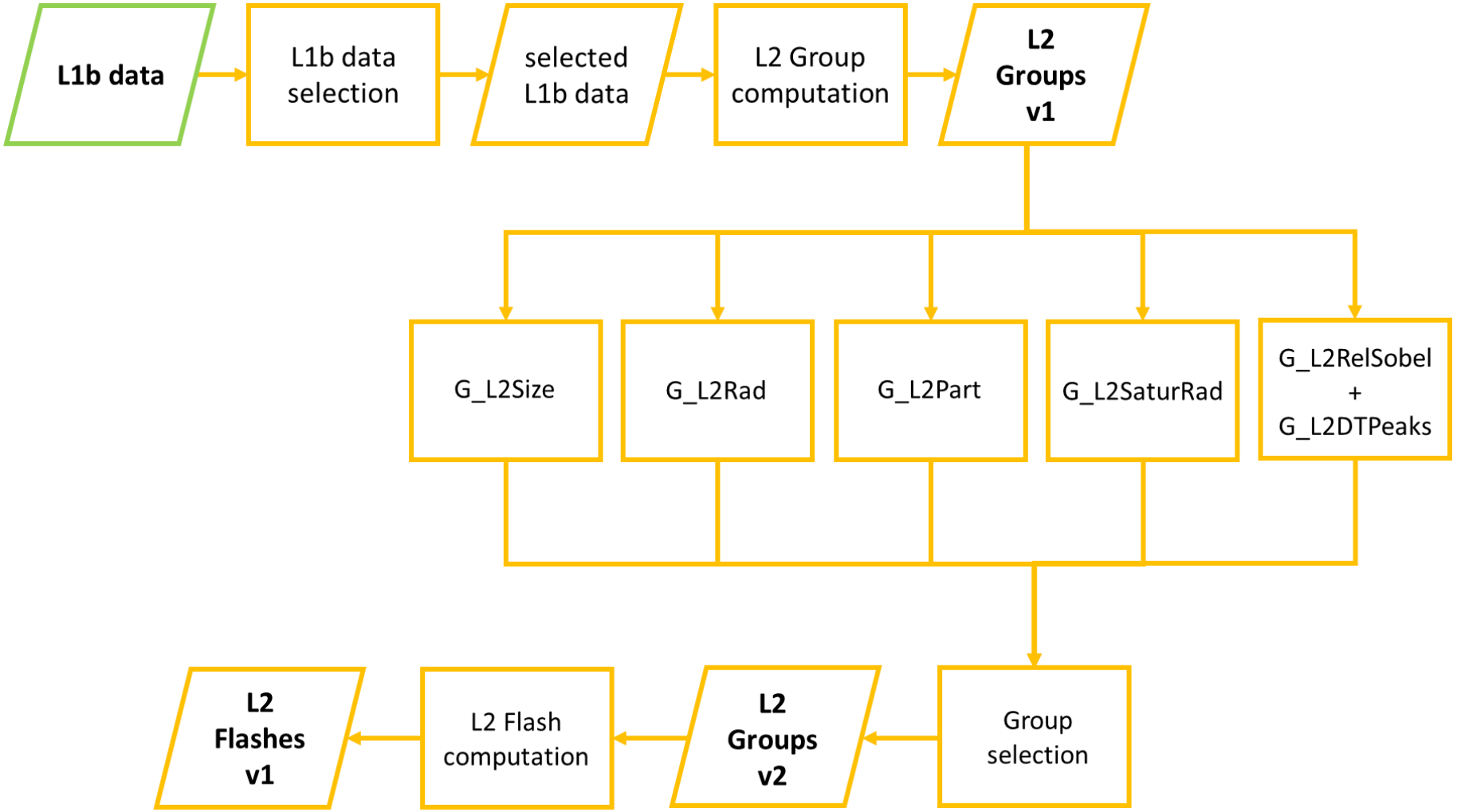


LI Group

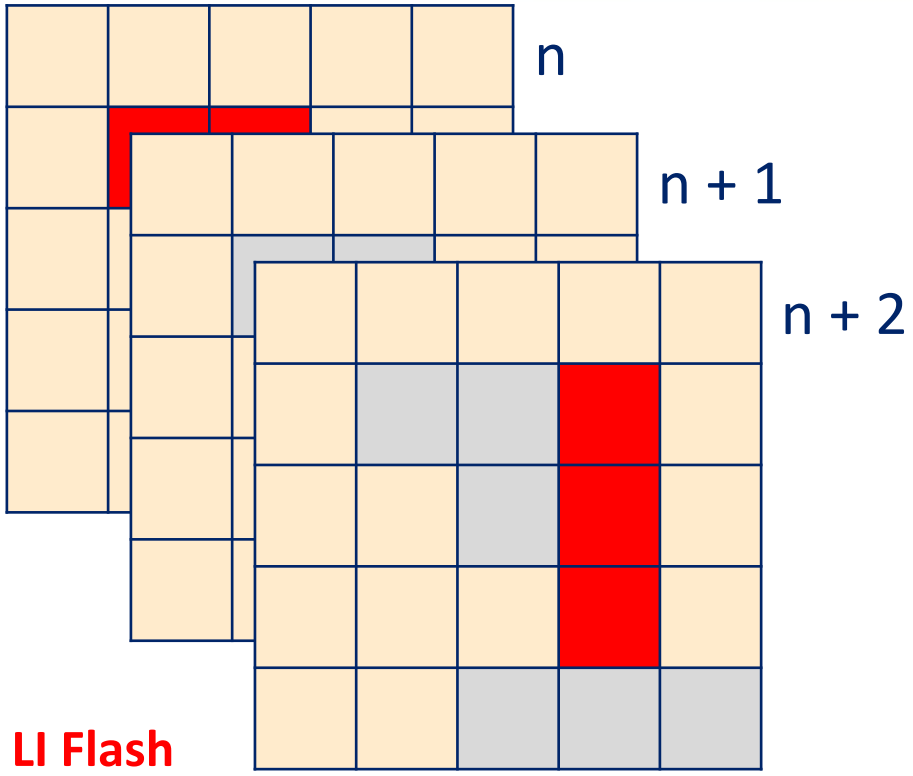
Collection of connected DTs on a single acquisition frame

This is an optical pulse detected by LI in one frame. Groups are defined and analyzed at Level 2

LI Level 2 processing (1 of 2)



LI data content

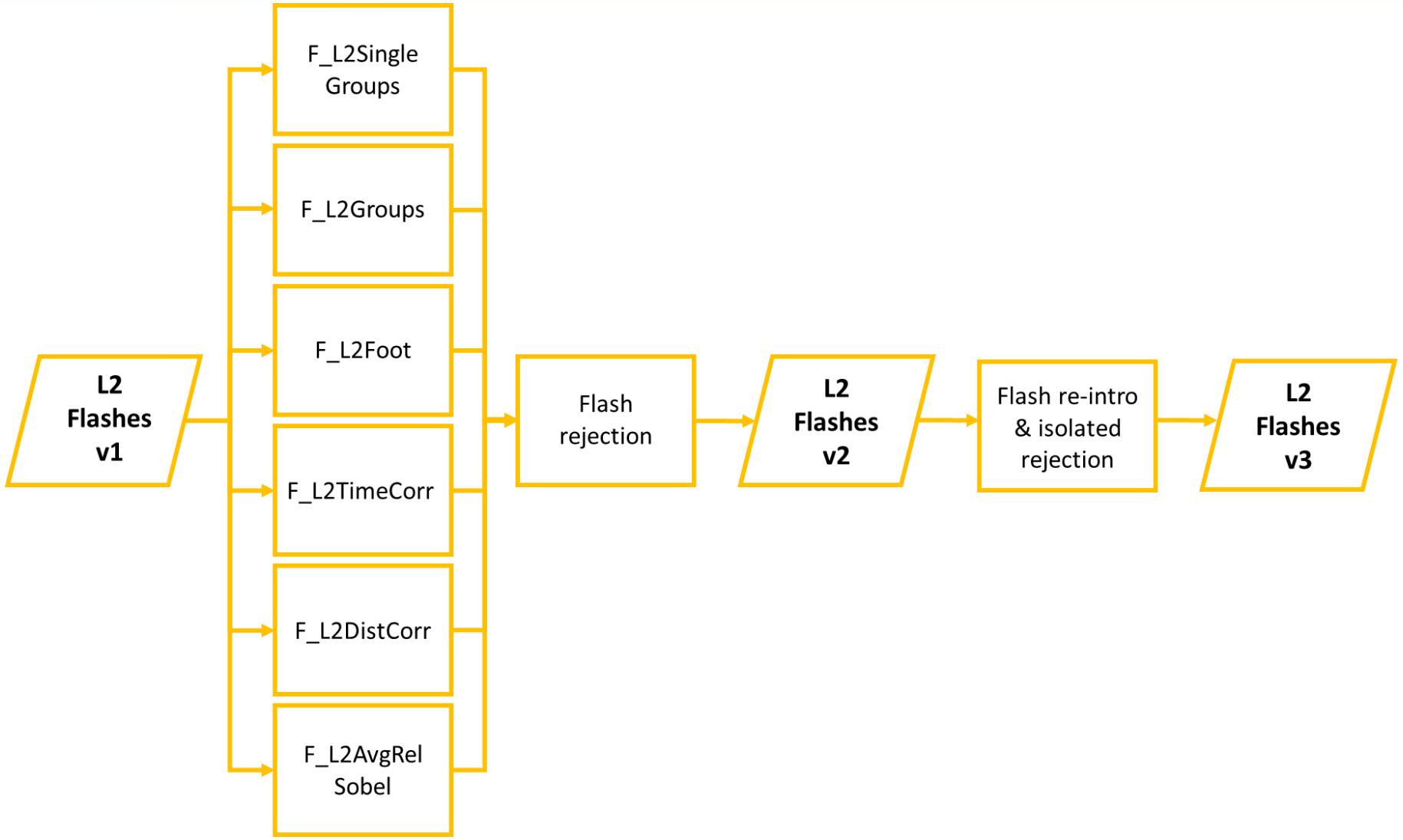


An example of lightning flash observed by ISS-LIS https://ghrc.nsstc.nasa.gov

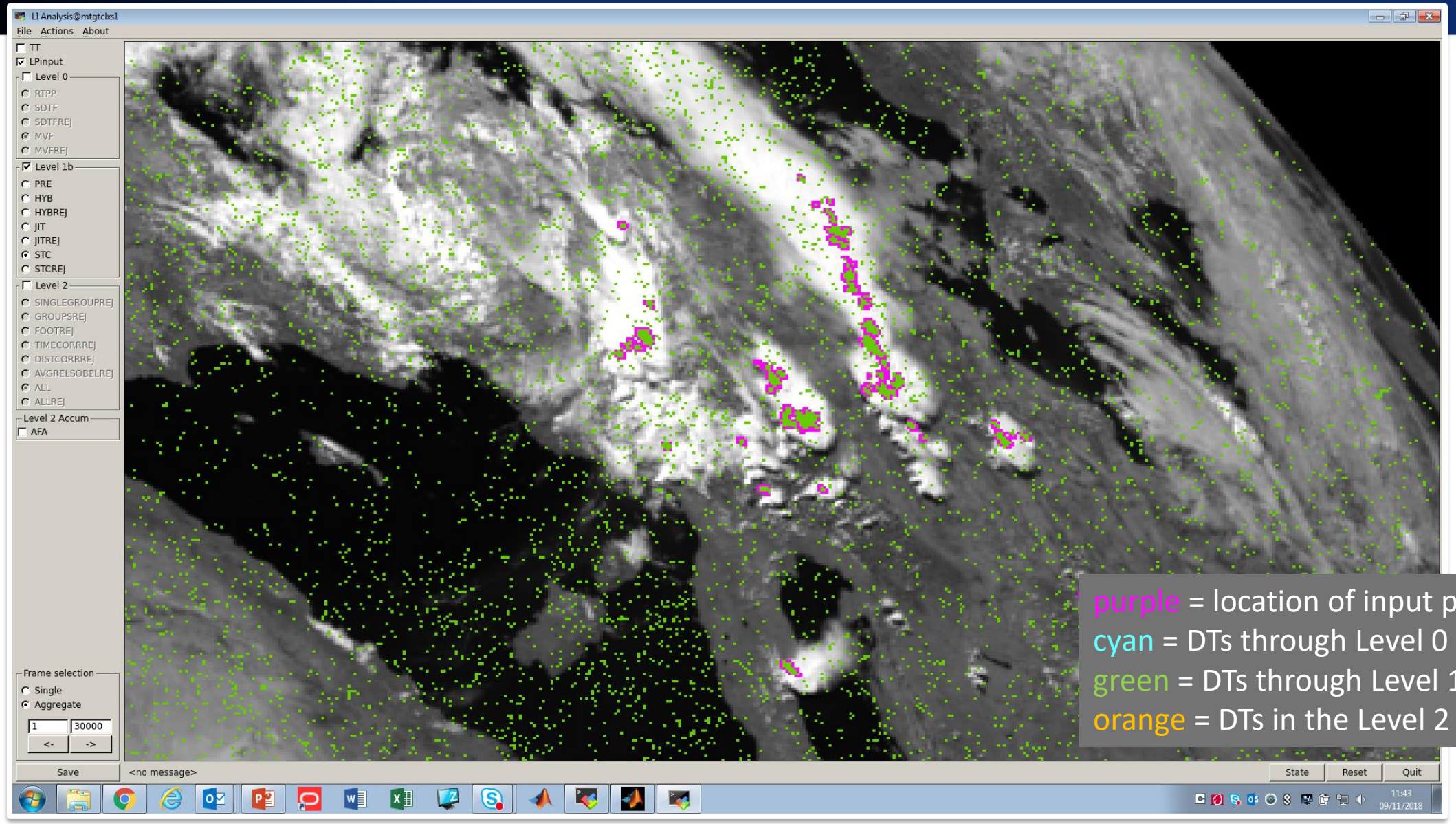
Collection of groups that are correlated in space and time

This is a collection of optical pulses (detected as groups) correlated in space and time. Flashes are defined and analyzed at Level 2

LI Level 2 processing (2 of 2)



DTs at Level 1b STC



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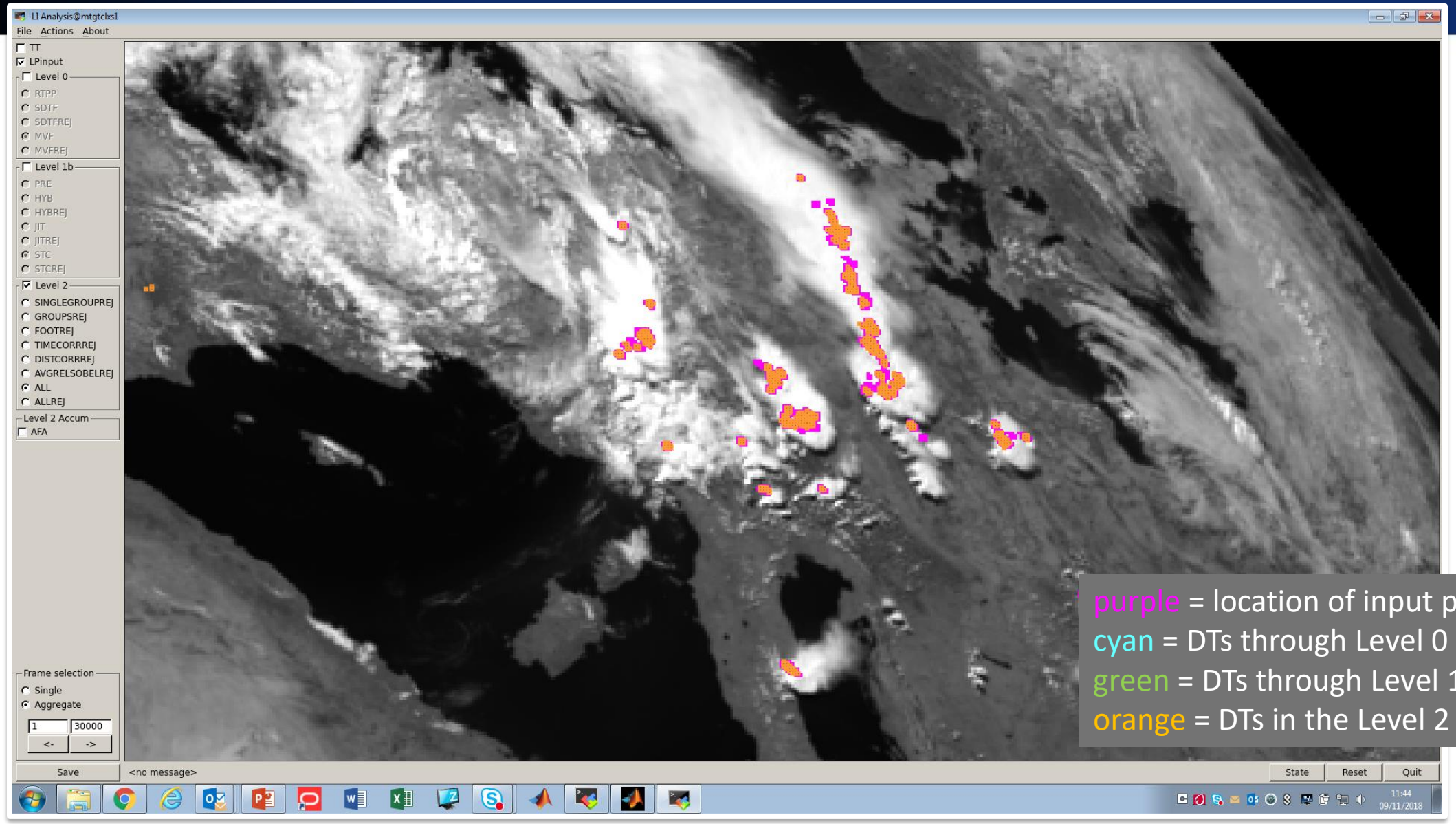
DTs at Level 2



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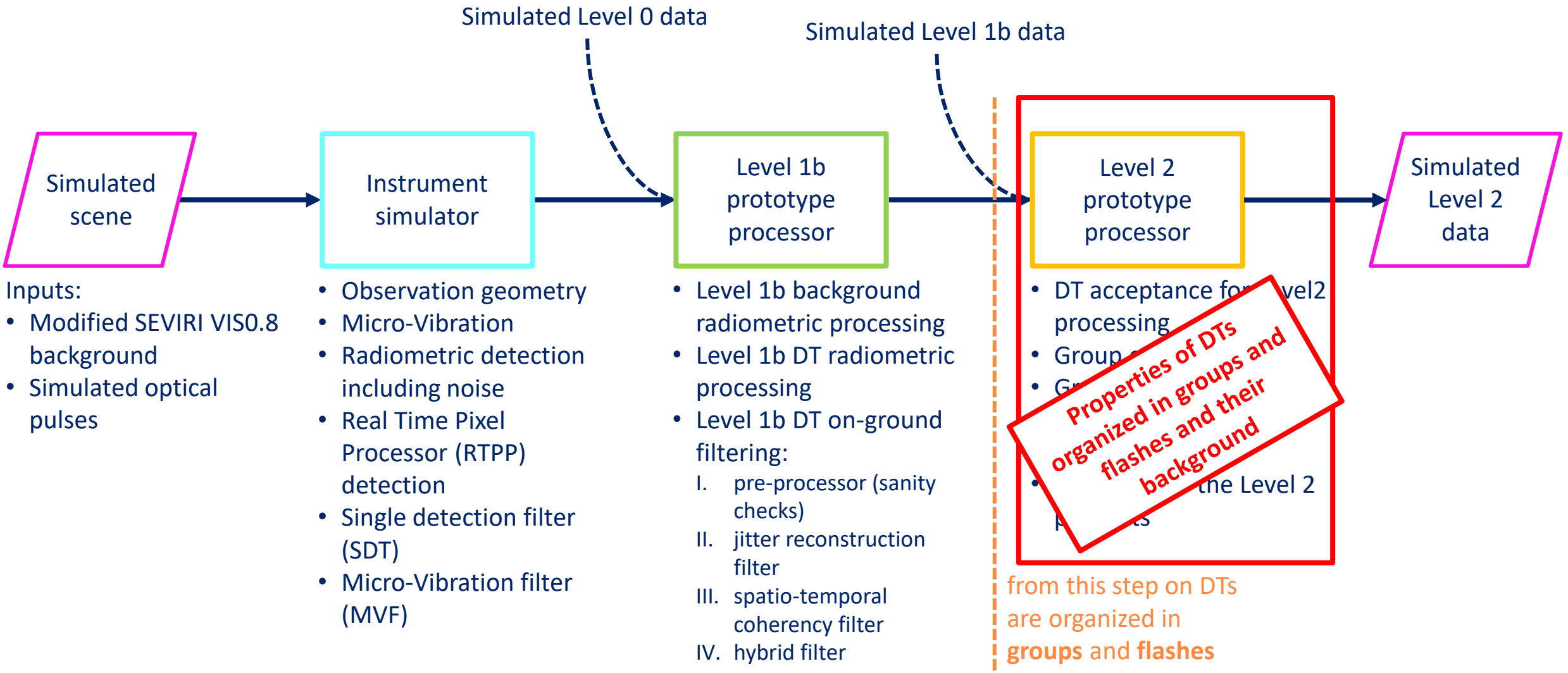
orange = DTs in the Level 2 product

LI data processing in the end-to-end Reference Processor (RP)



Level 2 disseminated products – LI-2-LGR AKA Group product

Product	Key Variables
LI-L2-LGR-BODY	• group_time (frame) • latitude (weighted average) • longitude (weighted avearge) • radiance (total) • group_id (relates Level 2 DTs to the group) • flash_id (relates groups to flashes) • group_filter_qa (outcome of the group analysis at Level 2) • number_of_events

1. Despite LI imaging and detection capabilities, LI-L2-LGR-BODY provides groups as points. This is due to the limits imposed by the dissemination bandwidth
2. From 1. stems that LI groups should be considered as the counterpart of the ground-detected strokes with radiance as physical property
3. The LI-L2-LGR-BODY are produced every 10 sec and are provided in NetCDF format

Level 2 disseminated products – LI-2-LFL AKA Flash product

Product	Key Variables
LI-L2-LFL-BODY	• flash_time (frame of the first group) • flash_duration (frame difference) • latitude (weighted average) • longitude (weighted avearge) • radiance (total) • flash_id (relates groups to flashes) • number_of_events • number_of_groups • flash_footprint (in pixels) • flash_filter_confidence (outcome of the flash analysis at Level 2)

1. LI-L2-LFL-BODY provides flashes as points
2. From 1. stems that LI flashes should be considered as the counterpart of the ground-detected flashes
3. The LI-L2-LFL-BODY are produced every 10 sec and are provided in NetCDF fomat

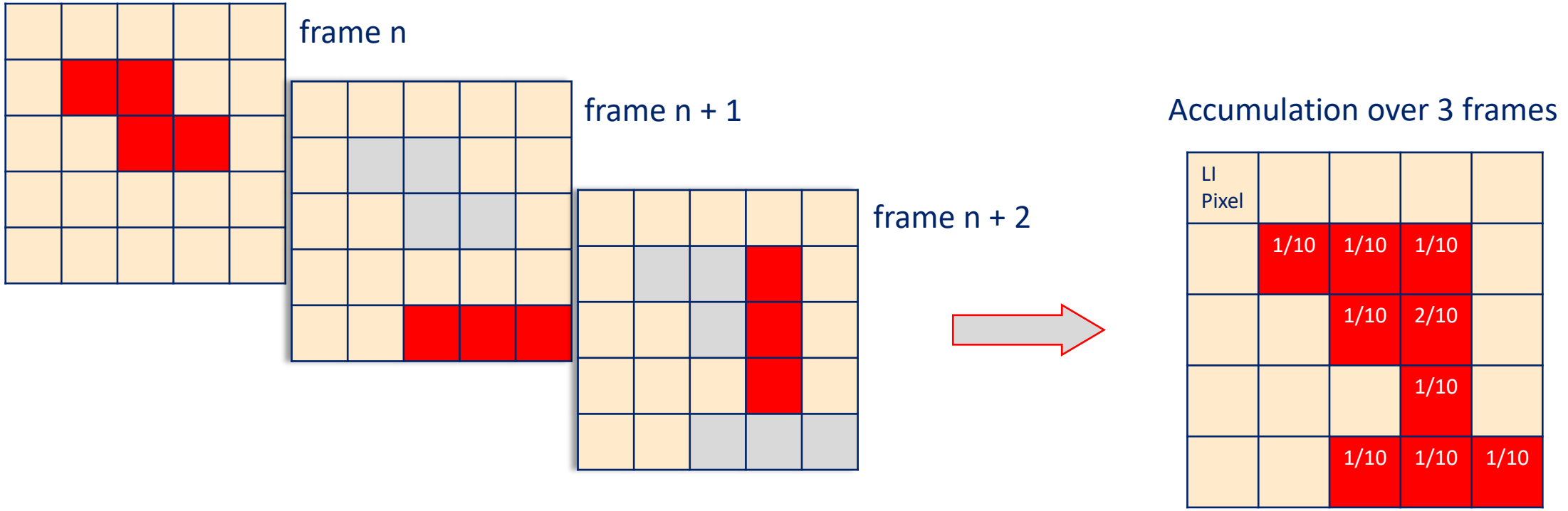
Level 2 disseminated products – accumulated products

Product	Key Variables
LI-L2-AF-BODY	• x (x in the FCI IR 2 km grid) • y (y in the FCI IR 2 km grid) • **flash_accumulation** • average_flash_qa (average flash_filter_confidence) from LI-L2-LFL
LI-L2-AFA-BODY	• x • y • **accumulated_flash_area** • average_flash_qa
LI-L2-AFR-BODY	• x • y • **flash_radiance** • average_flash_qa

Level 2 disseminated products – LI-L2-AF AKA Accumulated Flash

LI Level 2 Accumulated Flash (AF)

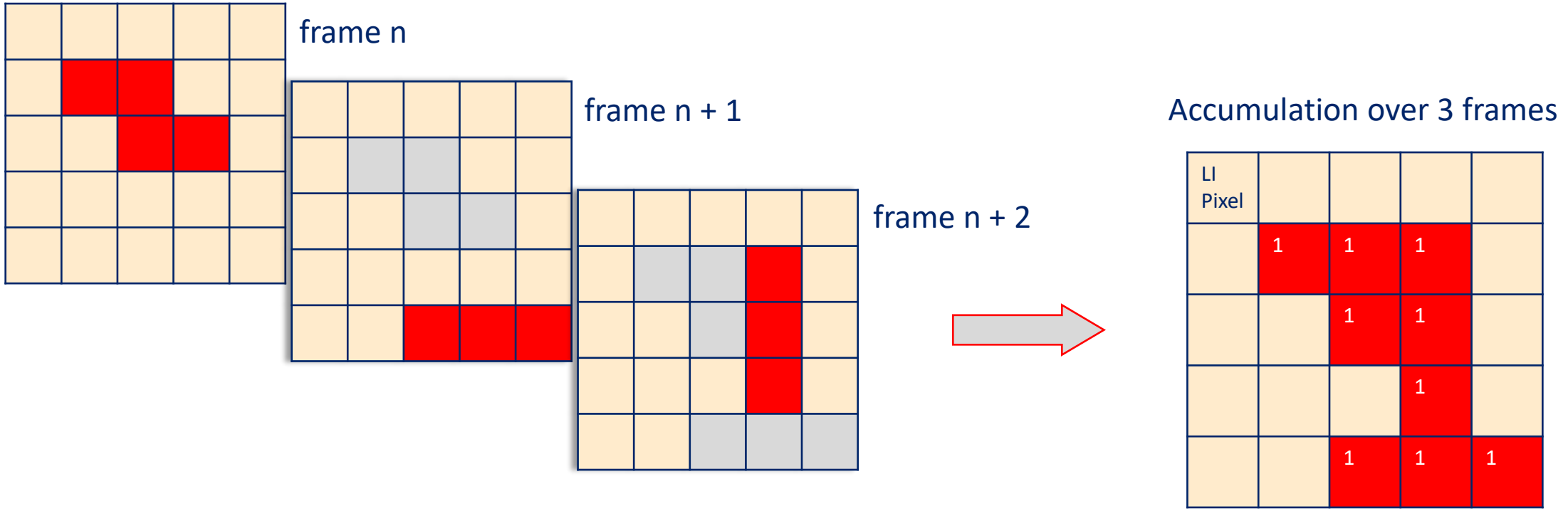
Allows one to keep track of the density of events within the flash and within sequences of accumulated flashes



Level 2 disseminated products – LI-L2-AFA AKA Acc. Flash Area

LI Level 2 Accumulated Flash Area (AFA)

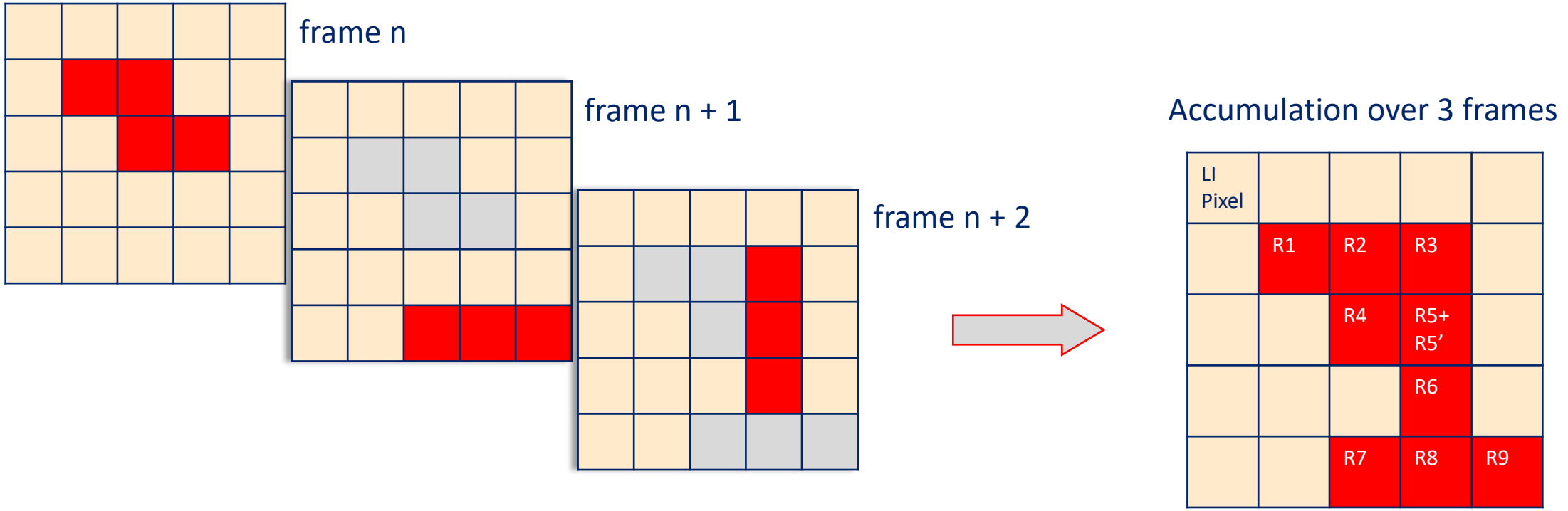
Allows one to keep track of the areas touched by multiple flashes (does not provide the event density)



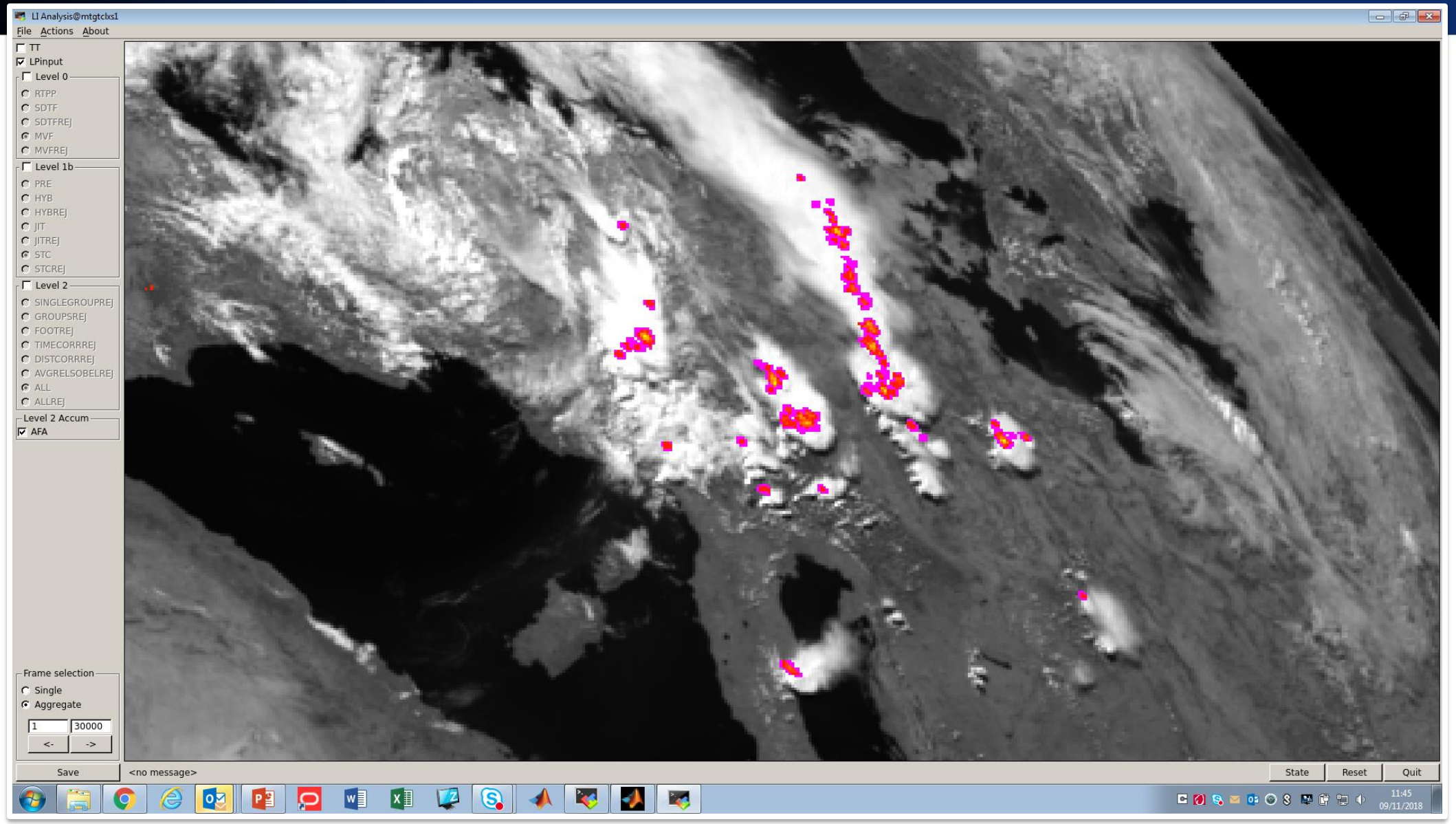
Level 2 disseminated products – LI-L2-AFA AKA Acc. Flash Radiance

LI Level 2 Accumulated Flash Radiance (AFR)

Allows one to represent the total radiance within a certain pixel from multiple flashes



Level 2 Accumulated Product



Level 2 Accumulated Product (ZOOM IN)