Meteosat Third Generation Lightning Imager

instrument, data processing and products

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EUMETSAT

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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)

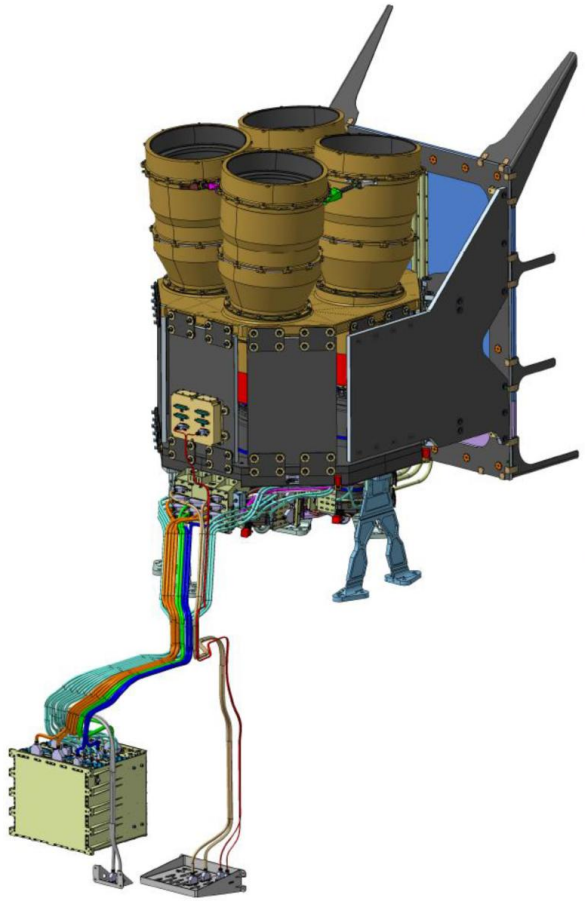
The radiation produced by an electric discharge within or below a cloud reaches the cloud top after multiple scattering through the cloud and is detected by lightning imagers in space

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, 2021)**
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 ATDnet (soon to be Leela)

LI instrument

In a nutshell	
Spatial Resolution at Nadir	4.5 km (variable throughout the Filed of View, FOV)
Spectral band	777.4 nm and 1.9 nm narrow band
Detector(s)	1000 x 1170 pixel (x 4) CMOS
Frame rate	1 ms (1 kHz acquisition frequency)
On-board processing	• Background evaluation and subtraction • Lightning detection • On-board filtering
Bandwidth	30 Mbps
Manufacturer	*Leonardo* (Italy) under the industrial prime contractor *Thales Alenia Space* (France) as part of the ESA lead MTG space segment development



LI instrument

In a nutshell

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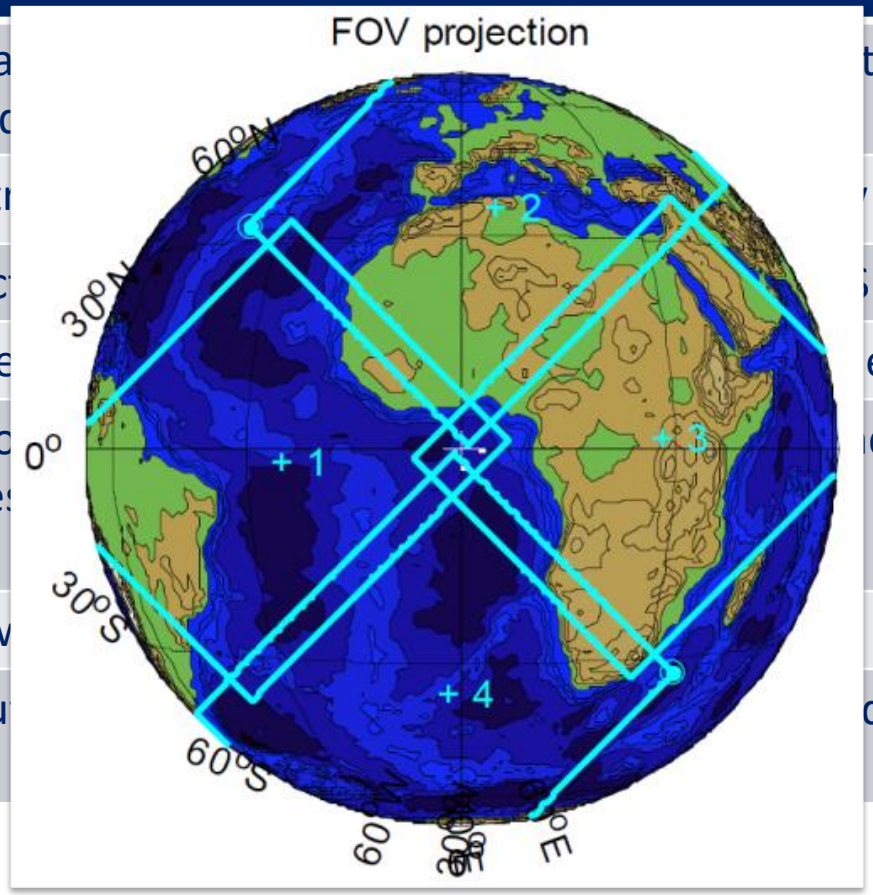
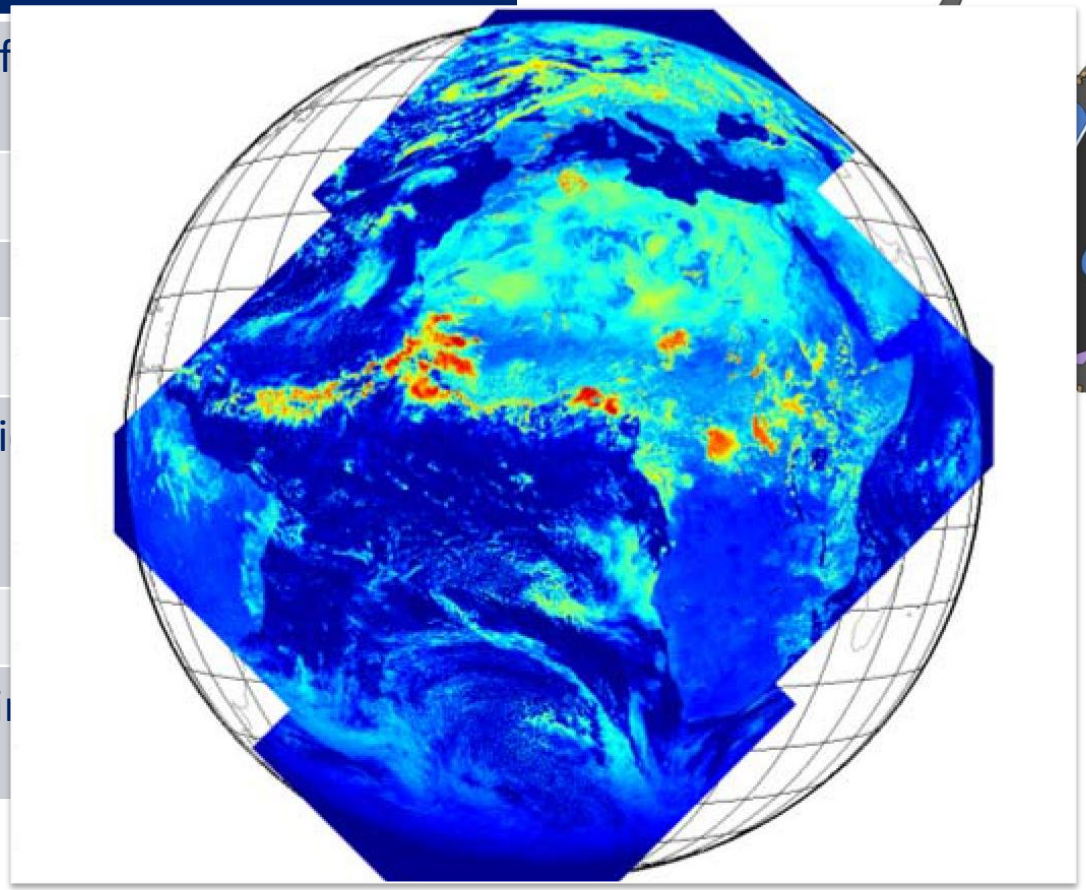




LI system

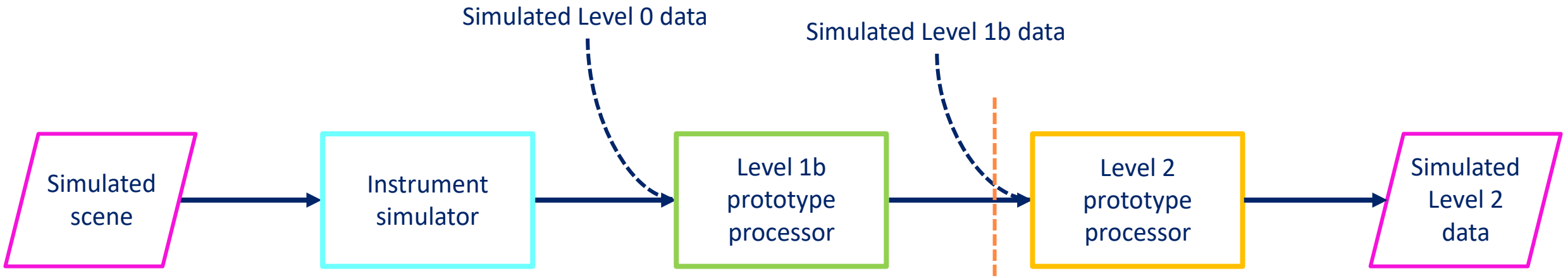
ESA and LDO

- 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

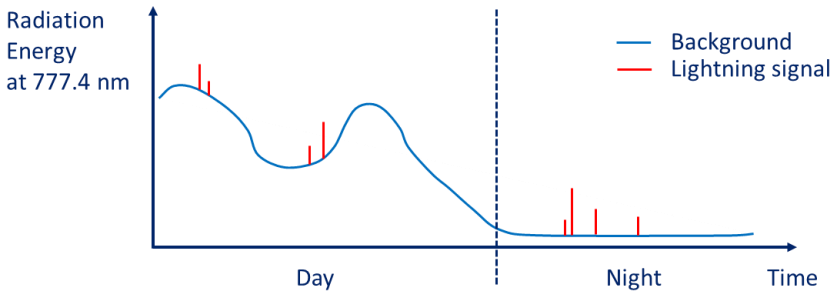
- Observation geometry
- Micro-Vibration
- Radiometric detection including noise
- **Real Time Pixel Processor (RTPP) detection**
- Single detection filter (SDT)
- Micro-Vibration filter (MVF)

- 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

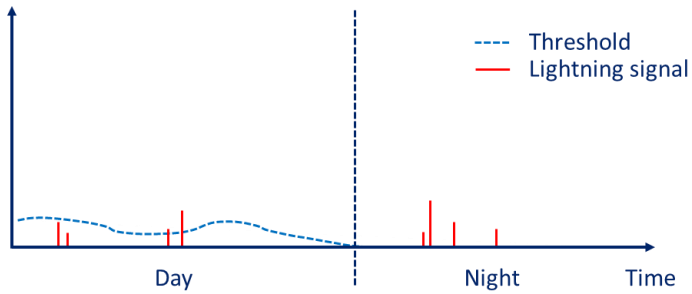
- DT acceptance for Level2 processing
- Group computation
- Group filtering
- Flash computation
- Flash filtering
- Definition of the Level 2 products

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

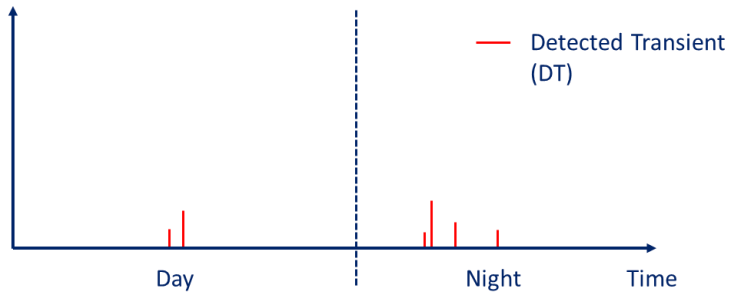
LI detection principle (Real Time Pixel Processor)



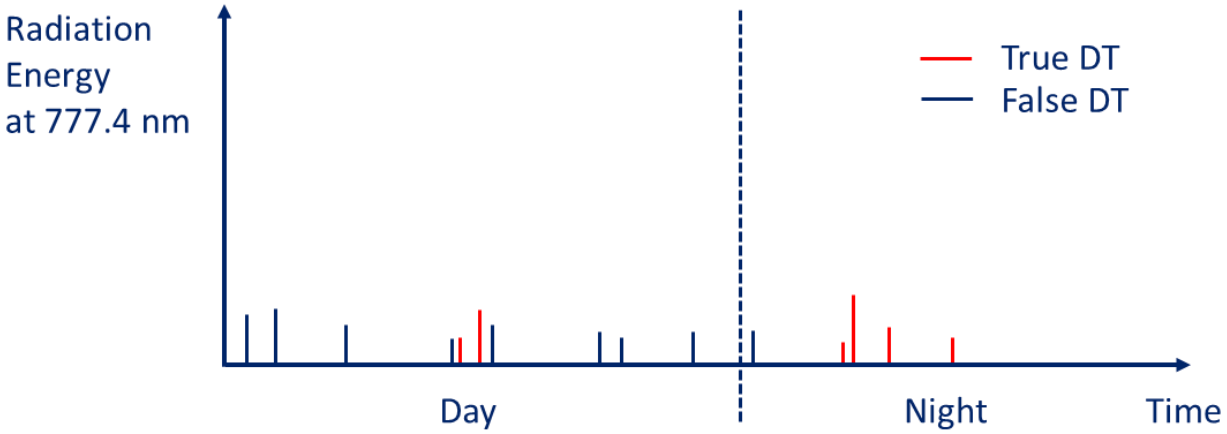
Typical pixel signal



Background removal and
detection threshold computation



Detection (ideal case)

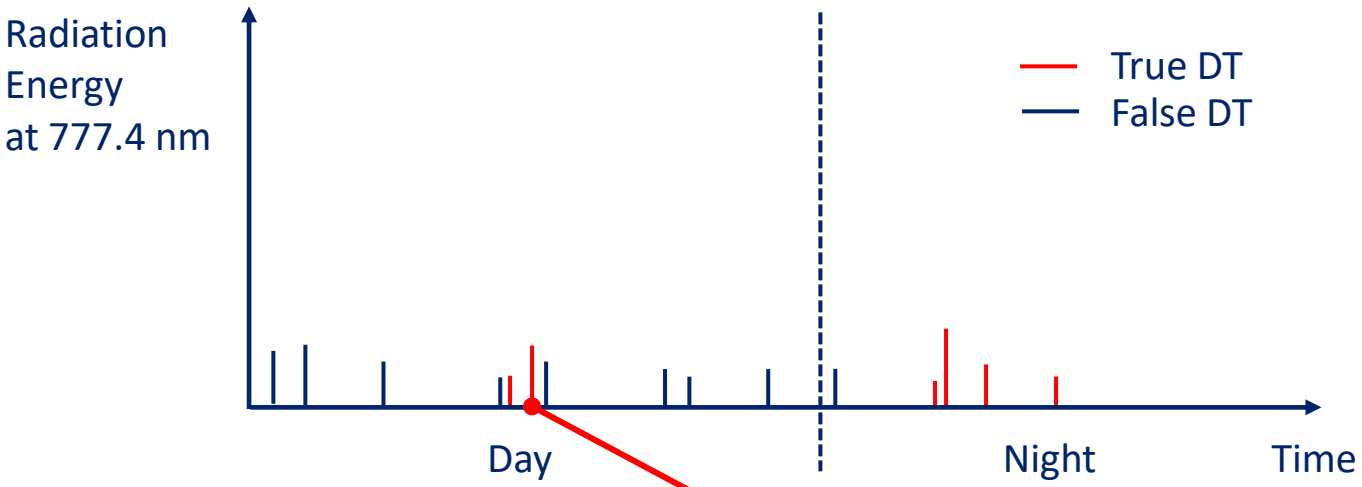


Detection (real case)

Sources of false transients:

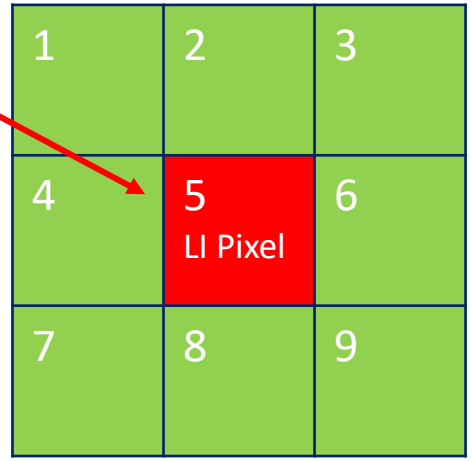
- radiometric noise;
- micro–vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …

LI data content



Sources of false transients:

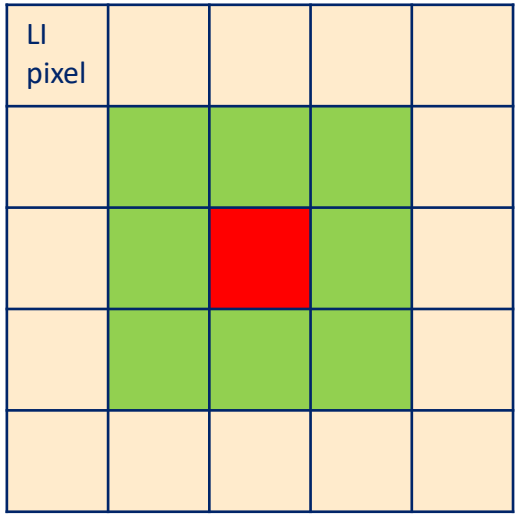
- local fluctuations of the radiometric noise;
- micro-vibration of the platform;
- particle impacts on the focal plane;
- Sun glint;
- …



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

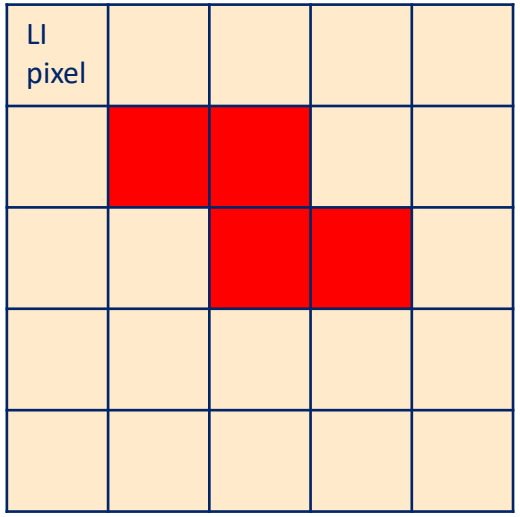
LI data content



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

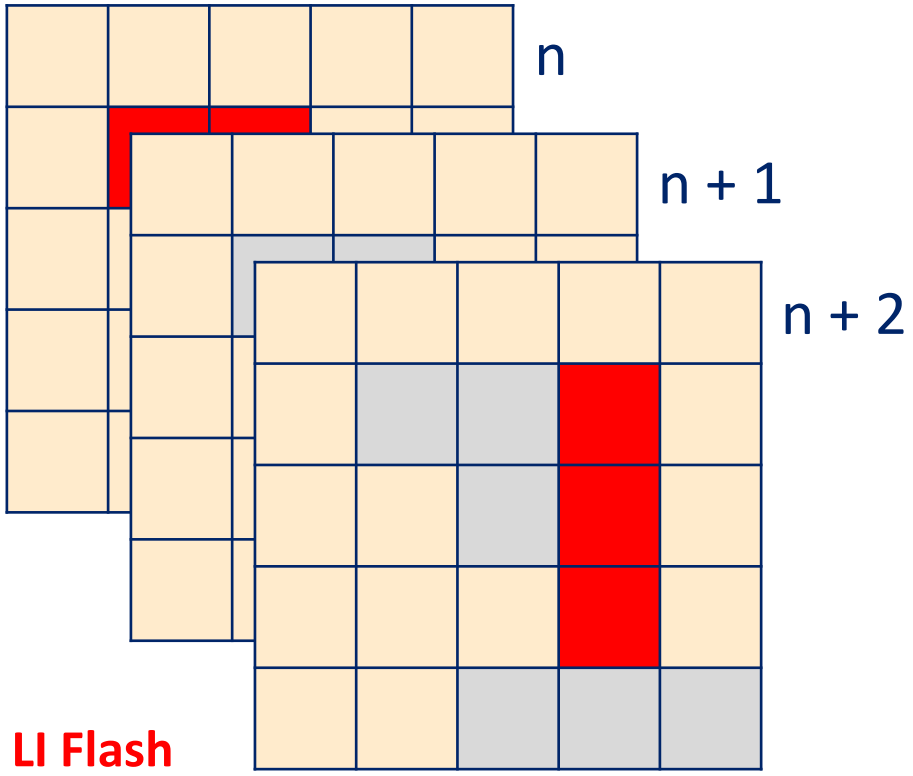


LI Group

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 data content

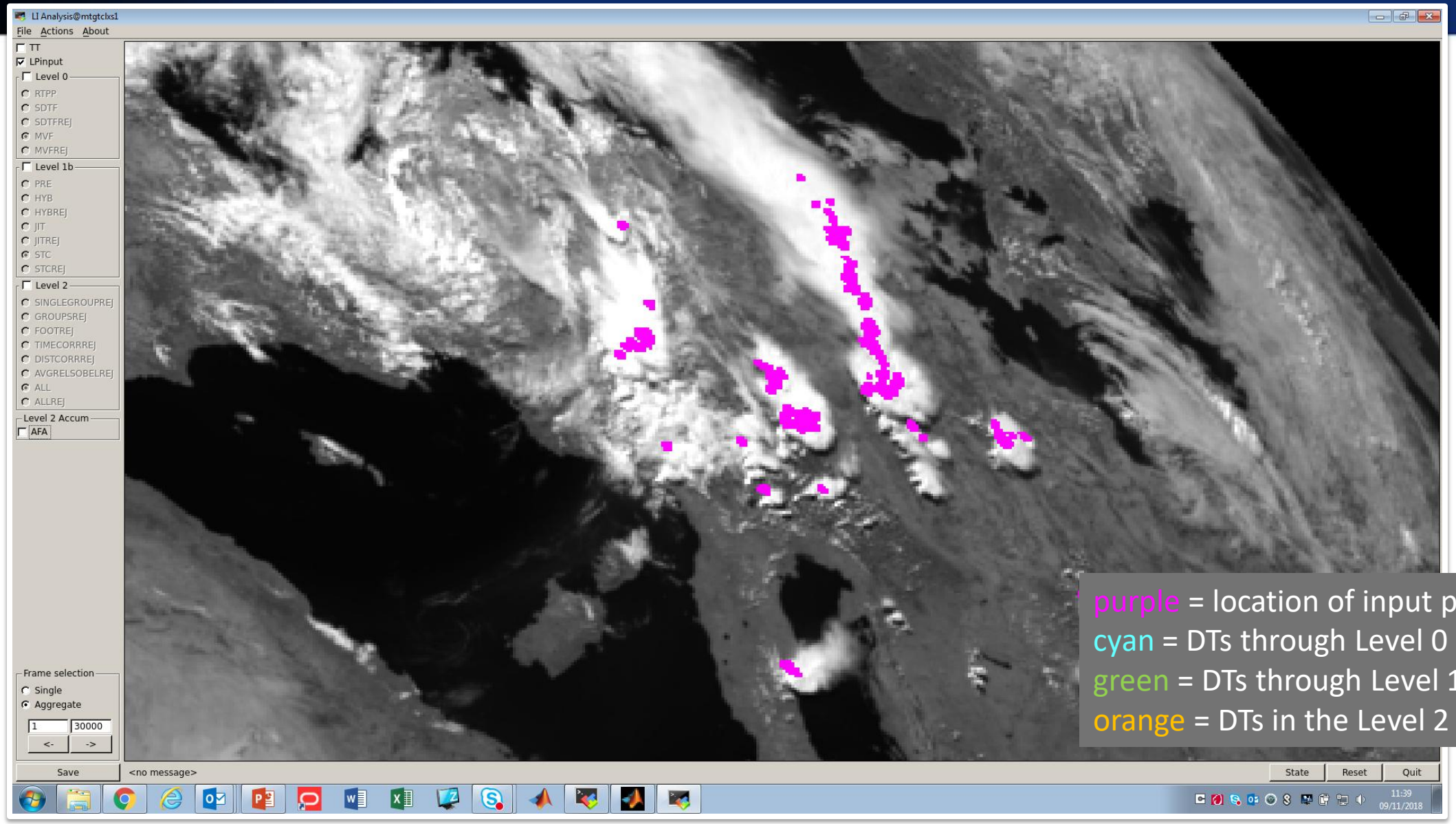


An example of lightning flash observed by ISS-LIS https://ghrc.nsstc.nasa.gov

Collection of groups that are correlated in space and time

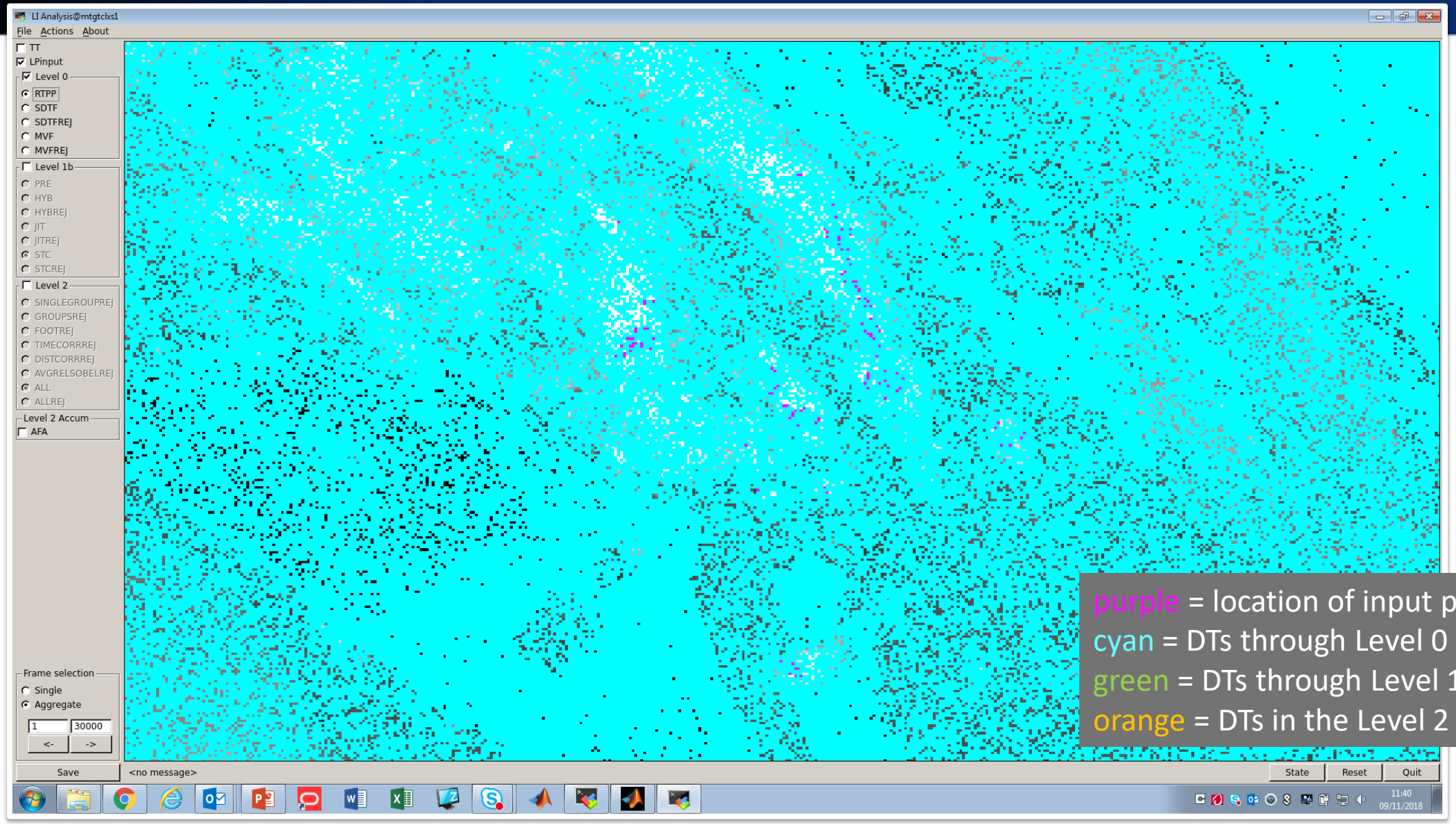
This is a collection of optical pulses (detected as groups) correlated in space and time. Flashes are defined and analyzed at Level 2

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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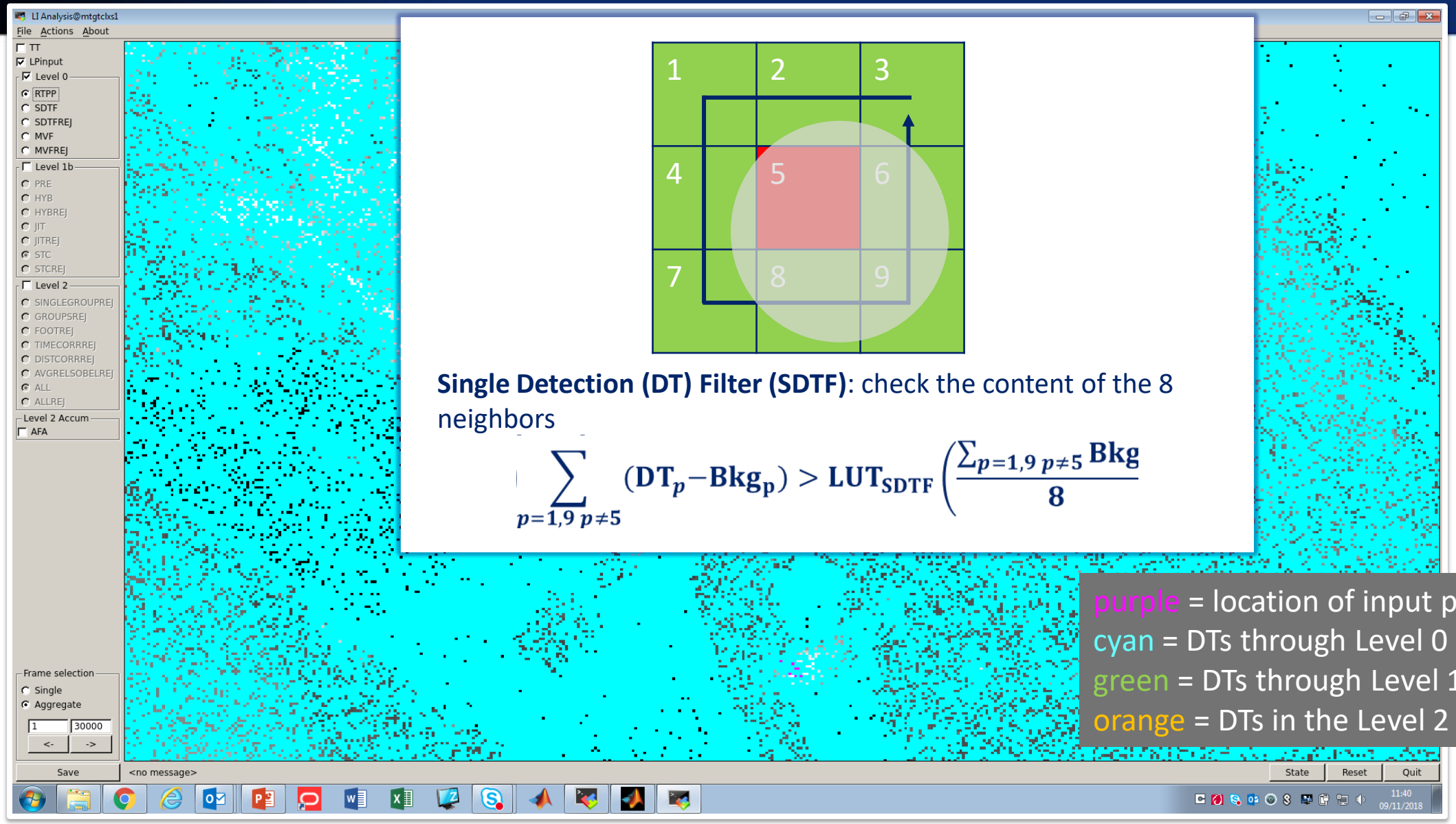
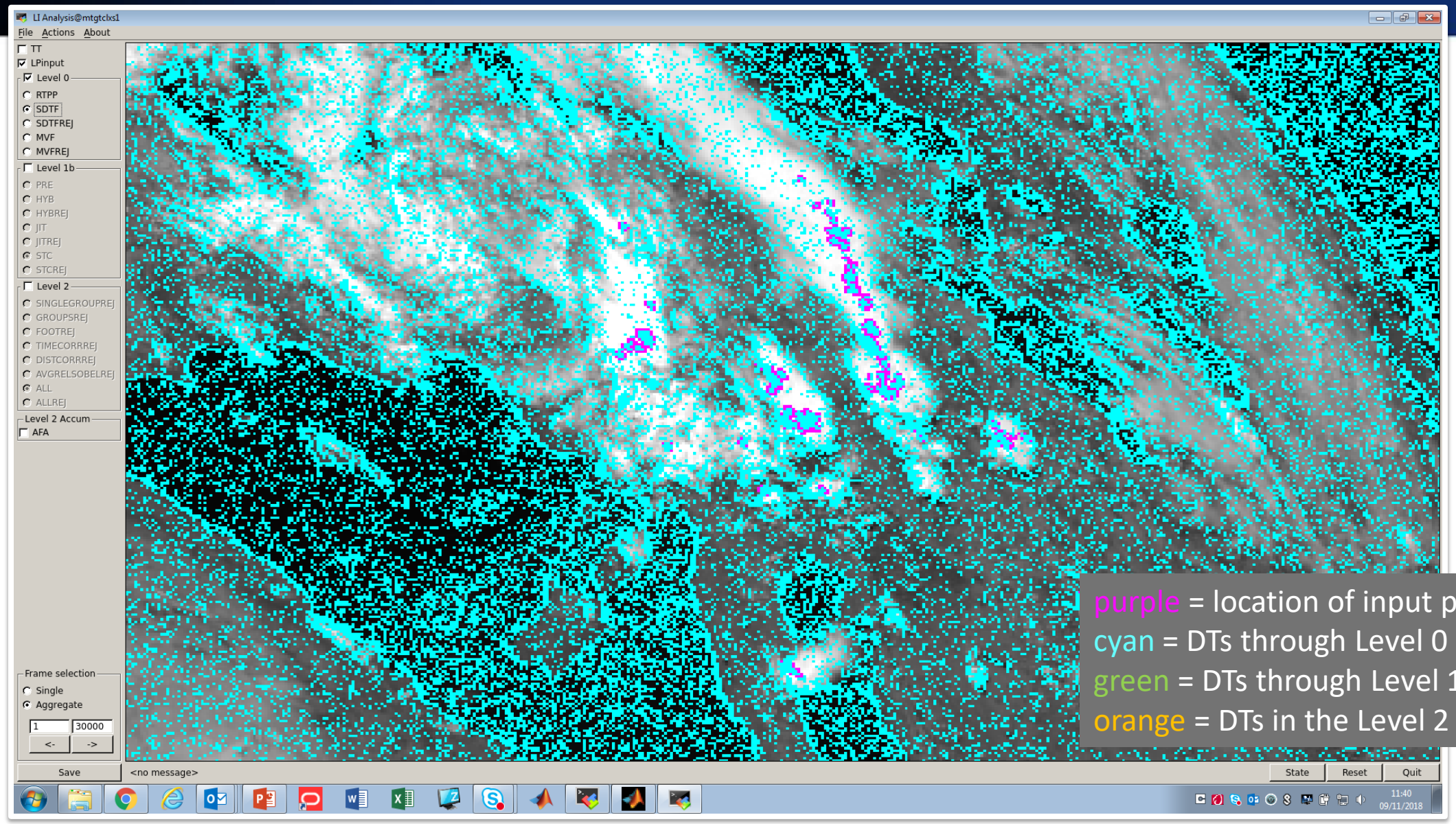
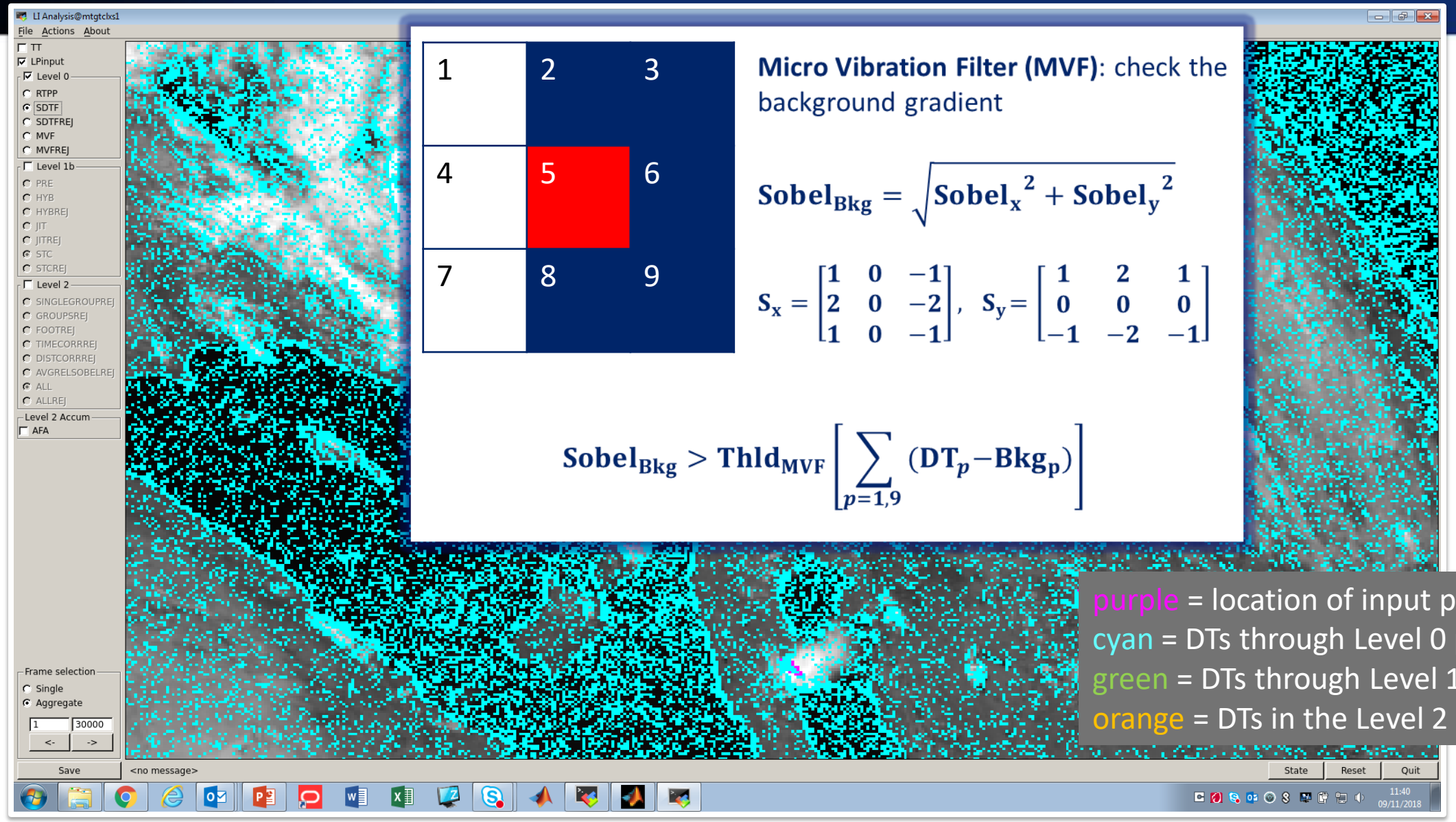
DTs at Level 0 RTPP



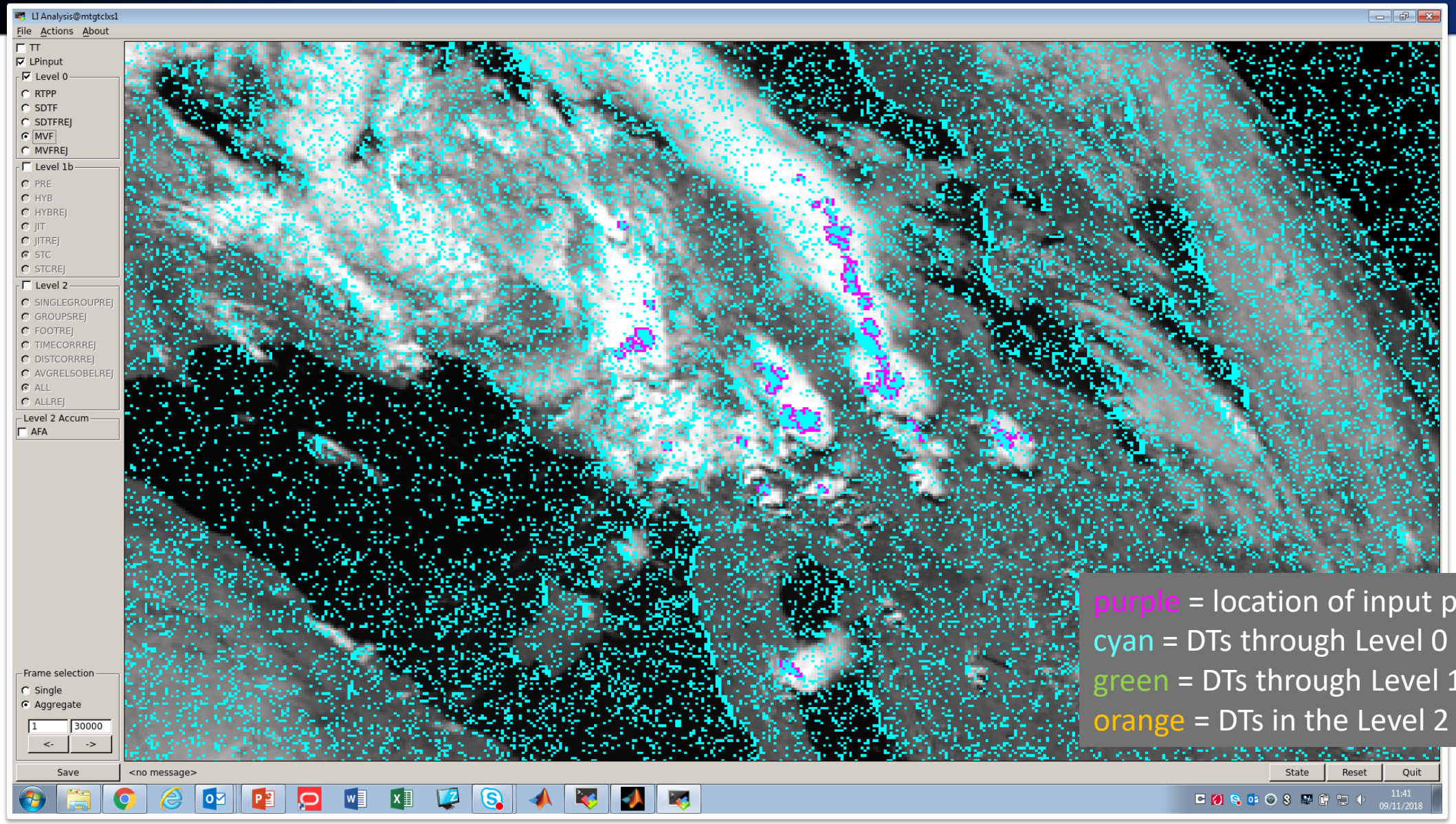
DTs at Level 0 SDTF



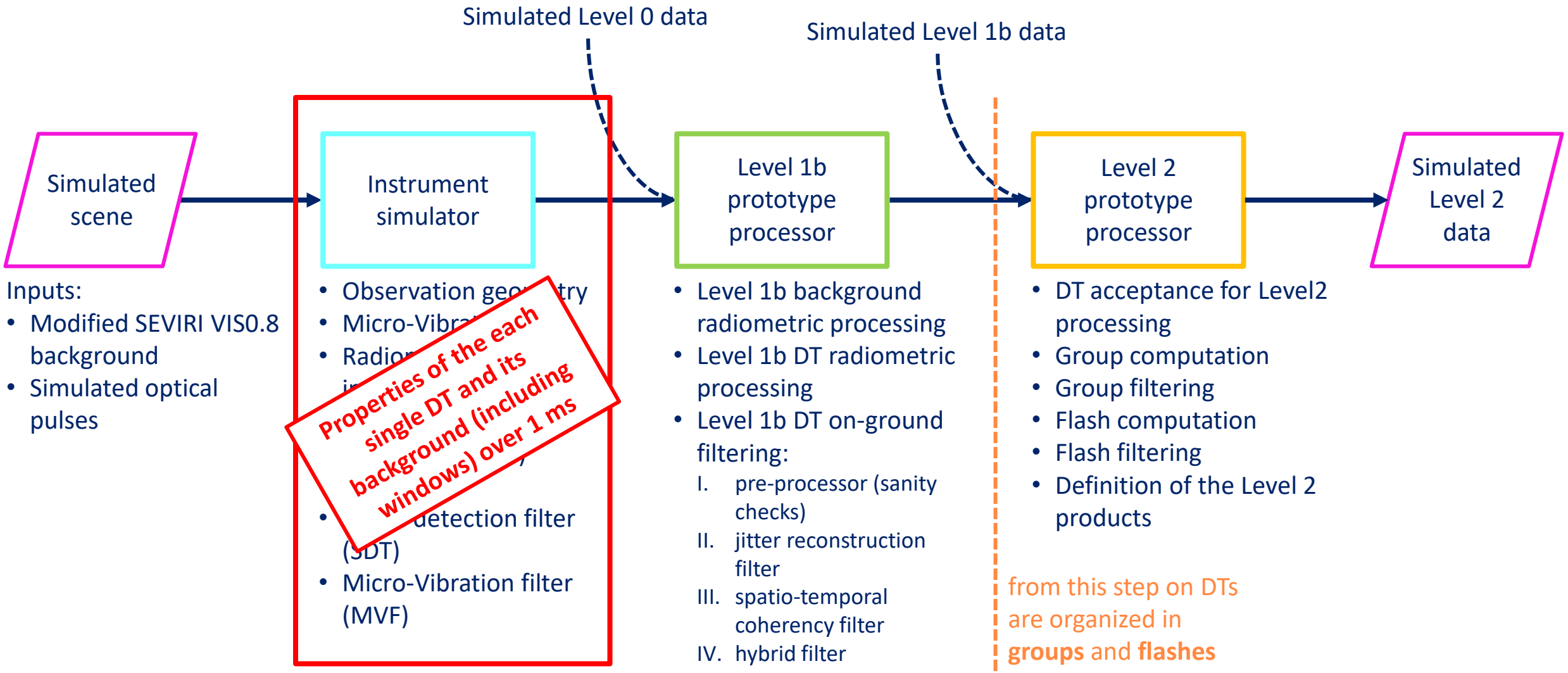
DTs at Level 0 SDTF



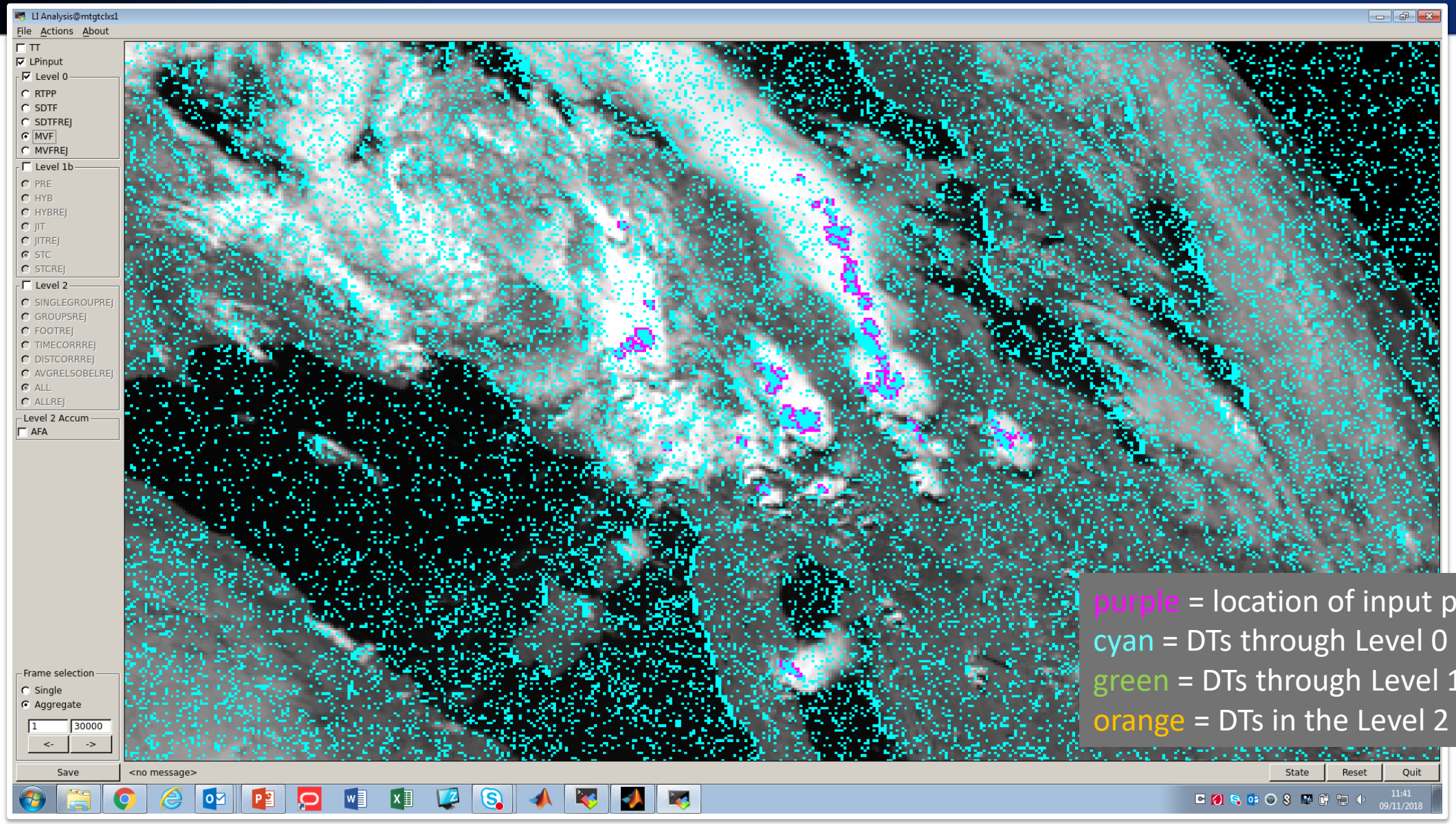
DTs at Level 0 MVF



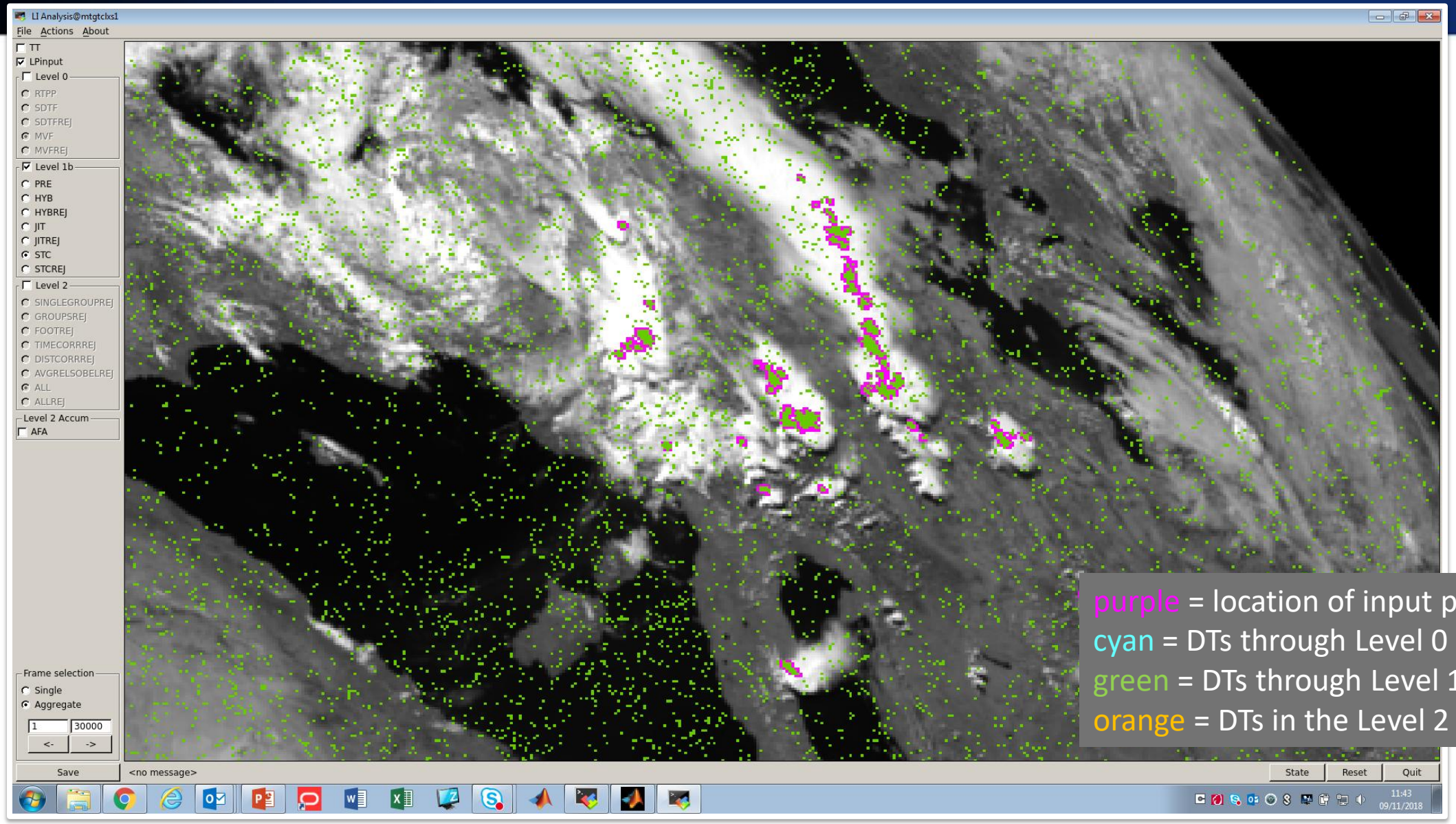
LI end-to-end Reference Processor (RP)



DTs at Level 0 (analyzed at Level 1b)

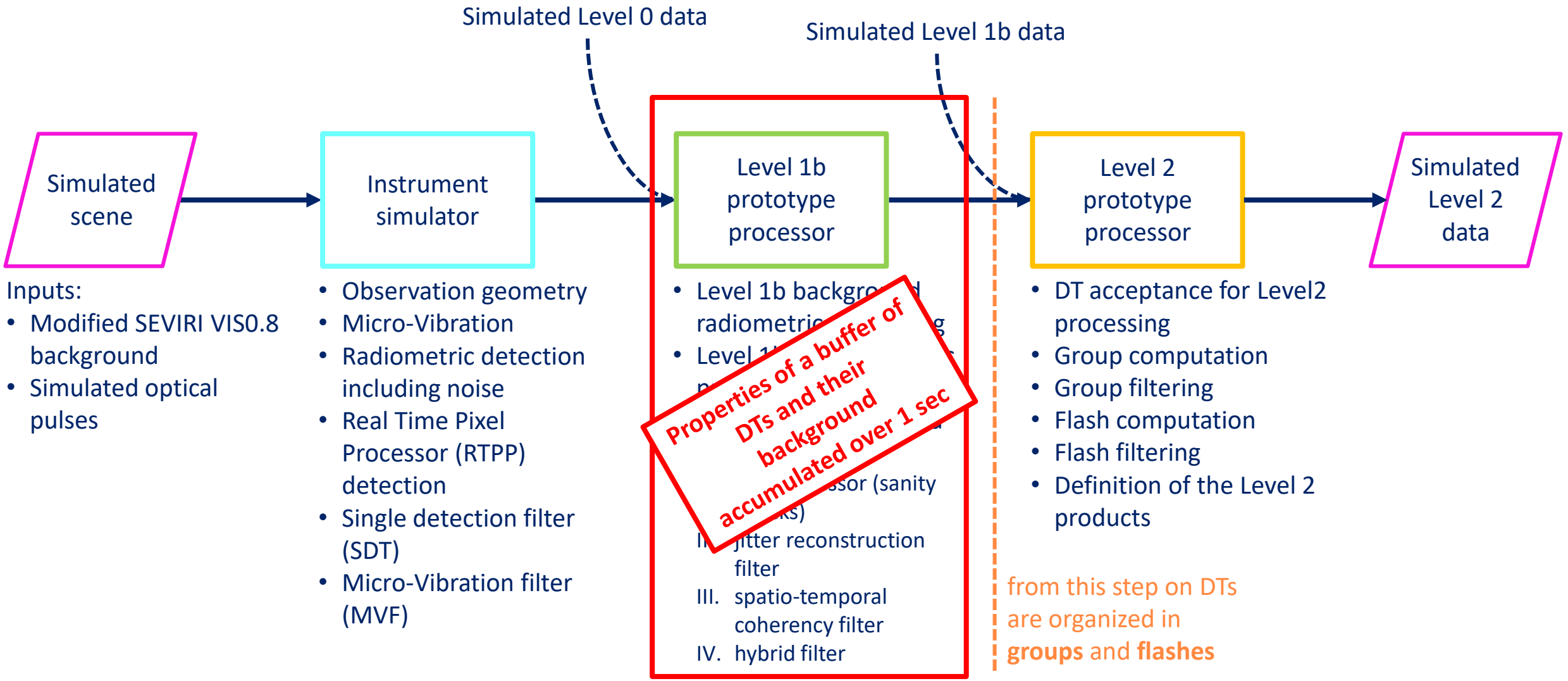


DTs at Level 1b (on-ground processing)

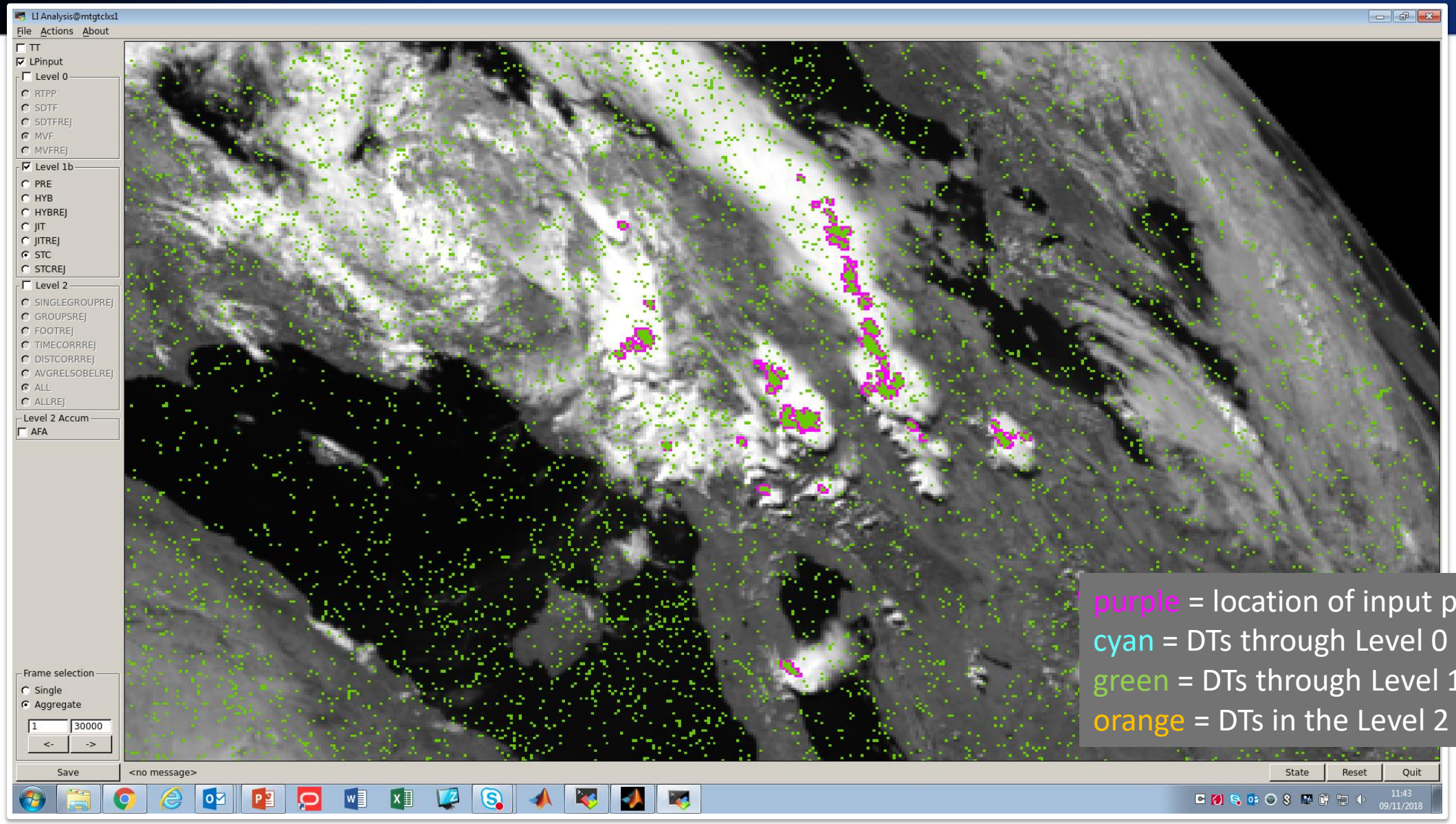


purple = location of input pulses
cyan = DTs through Level 0 proc.
green = DTs through Level 1b proc.
orange = DTs in the Level 2 product

LI end-to-end Reference Processor (RP)



DTs at Level 1b (analysed at Level 2)



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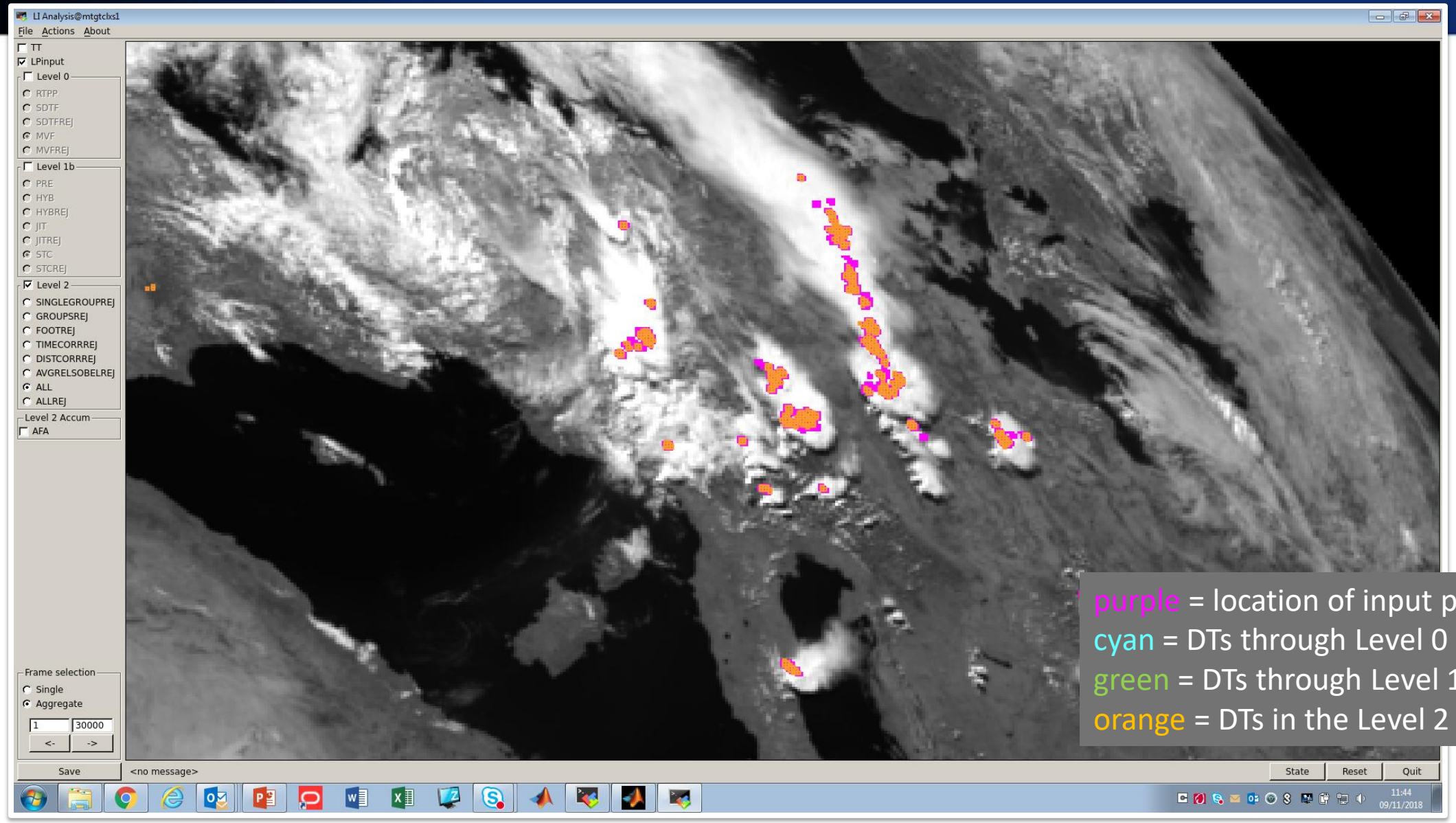
DTs at Level 2



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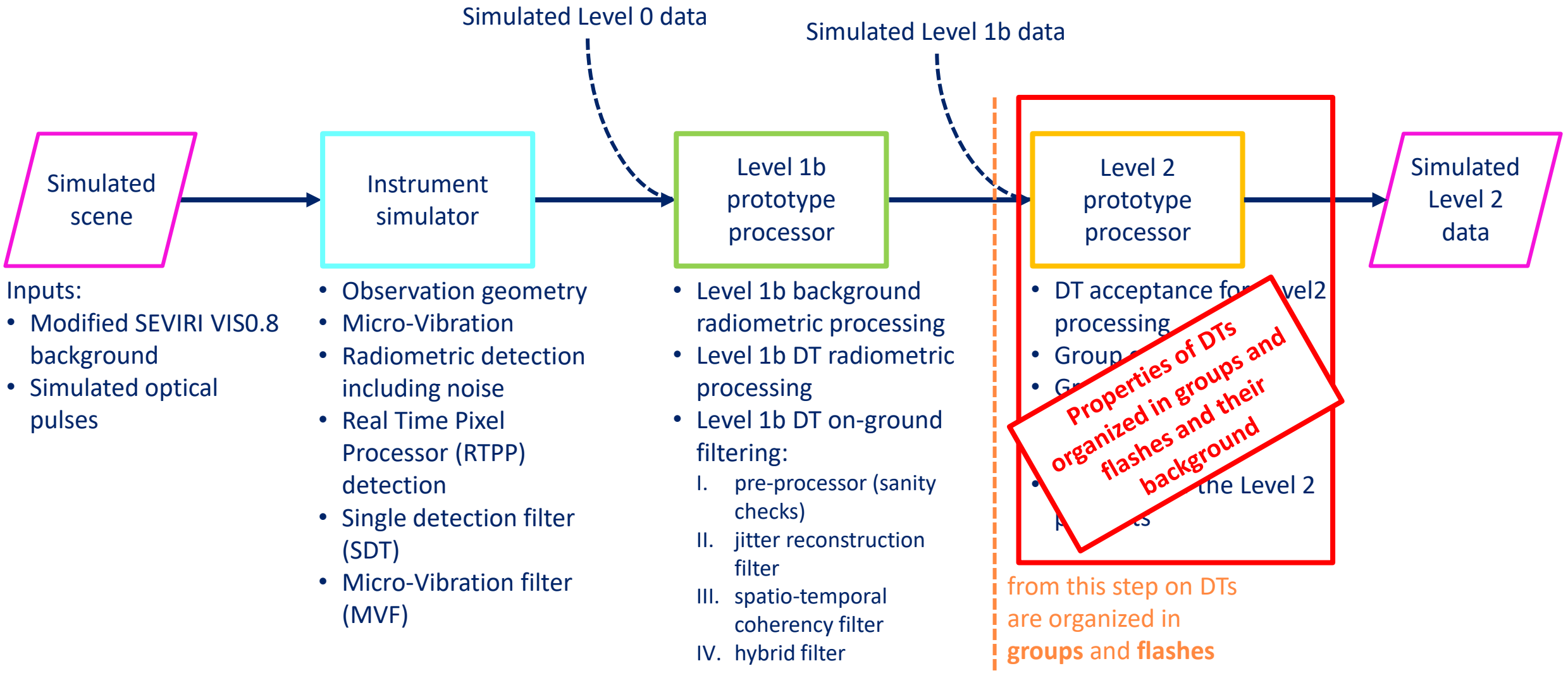
LI end-to-end Reference Processor (RP)



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

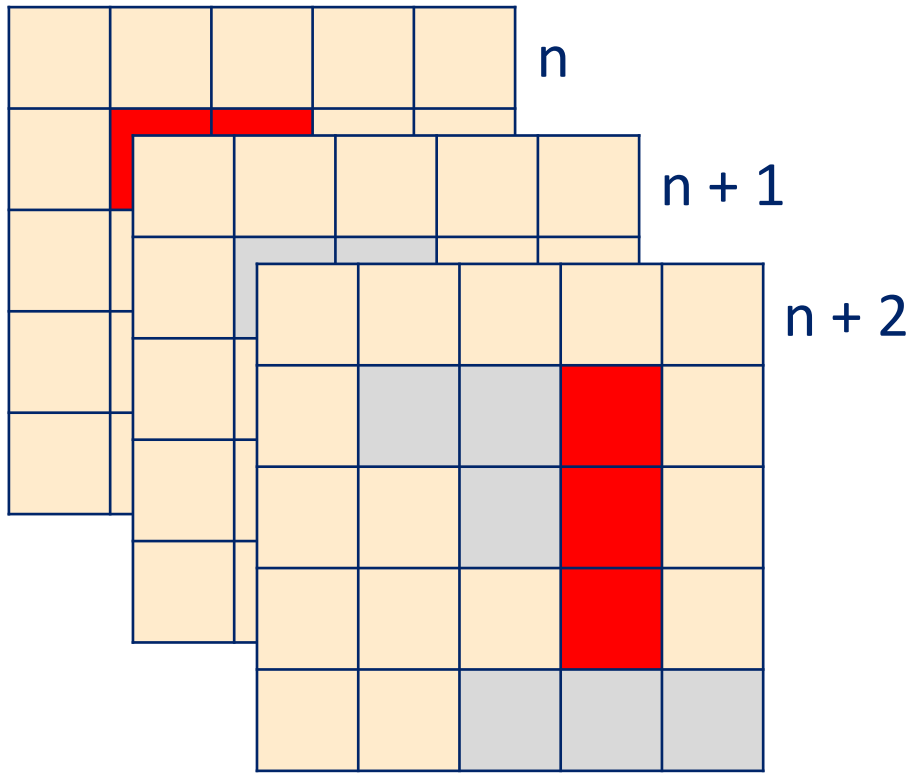
Level 2 disseminated products – accumulated products

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

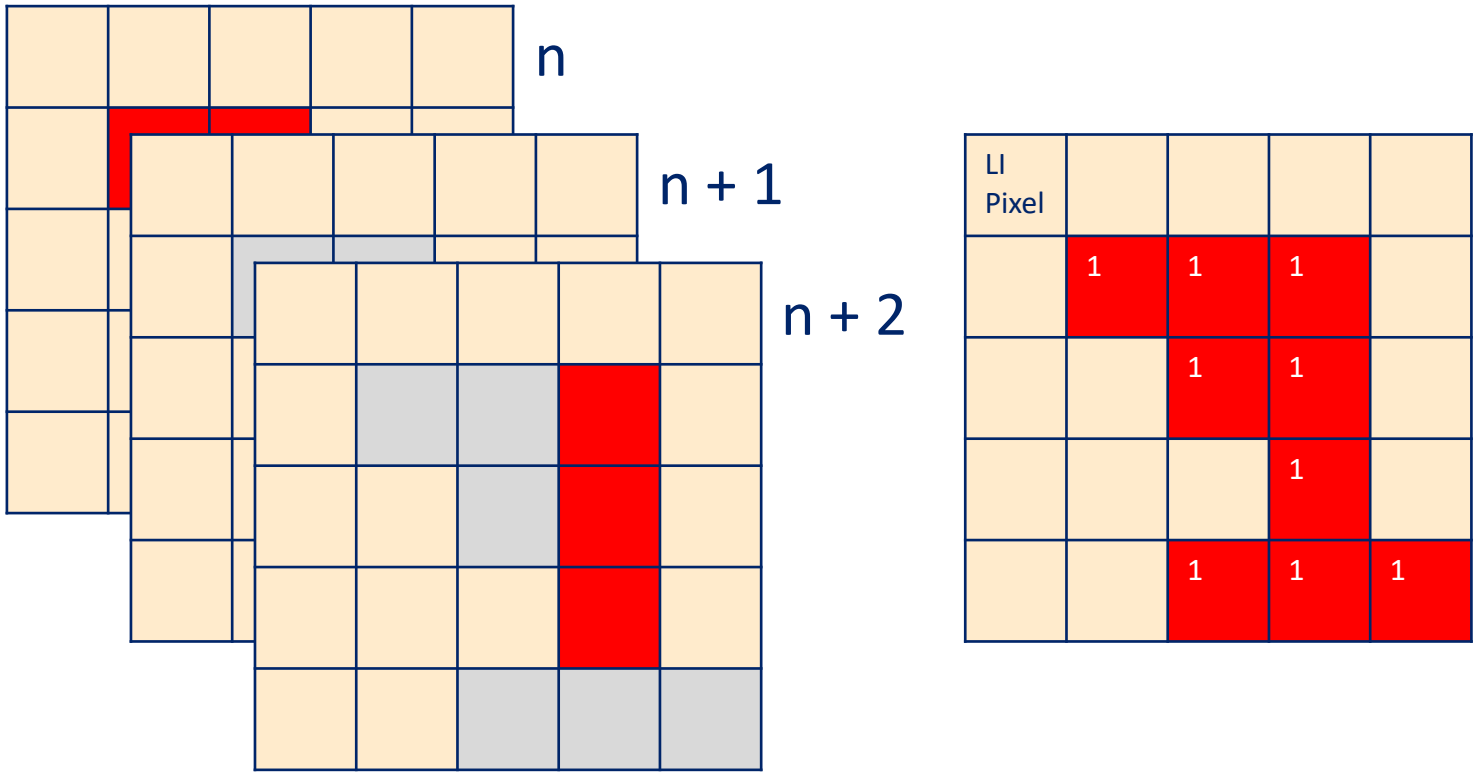


LI Pixel				
	1/10	1/10	1/10	
		1/10	2/10	
			1/10	
		1/10	1/10	1/10

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

LI Level 2 Accumulated Flash Area (AFA)

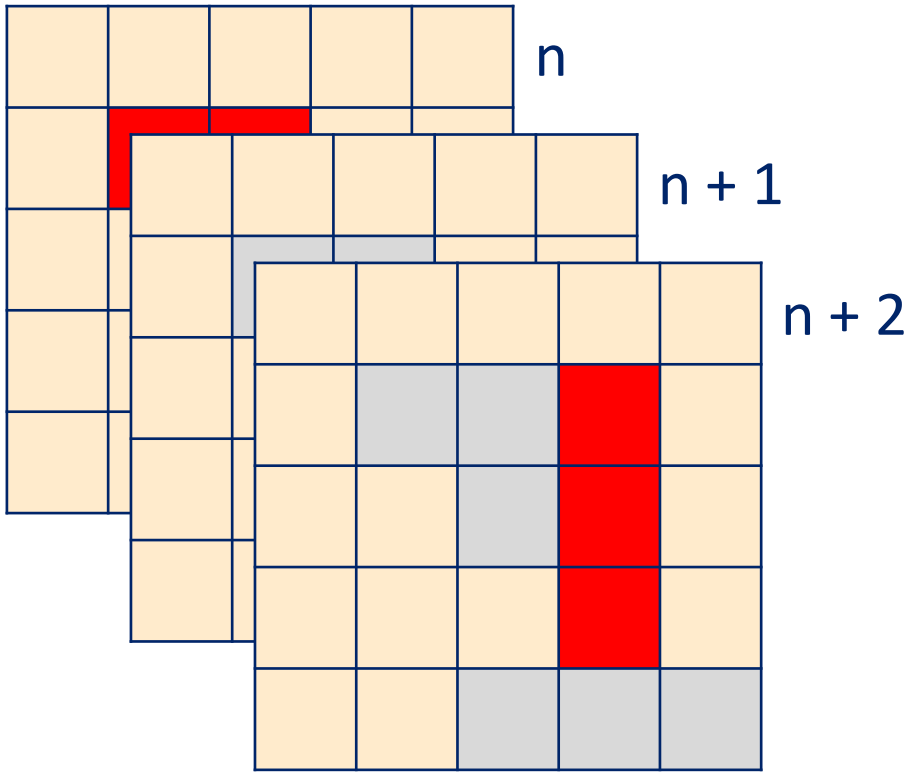
Allows one to keep track of the areas touched by multiple flashes (does not provide the event density)



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

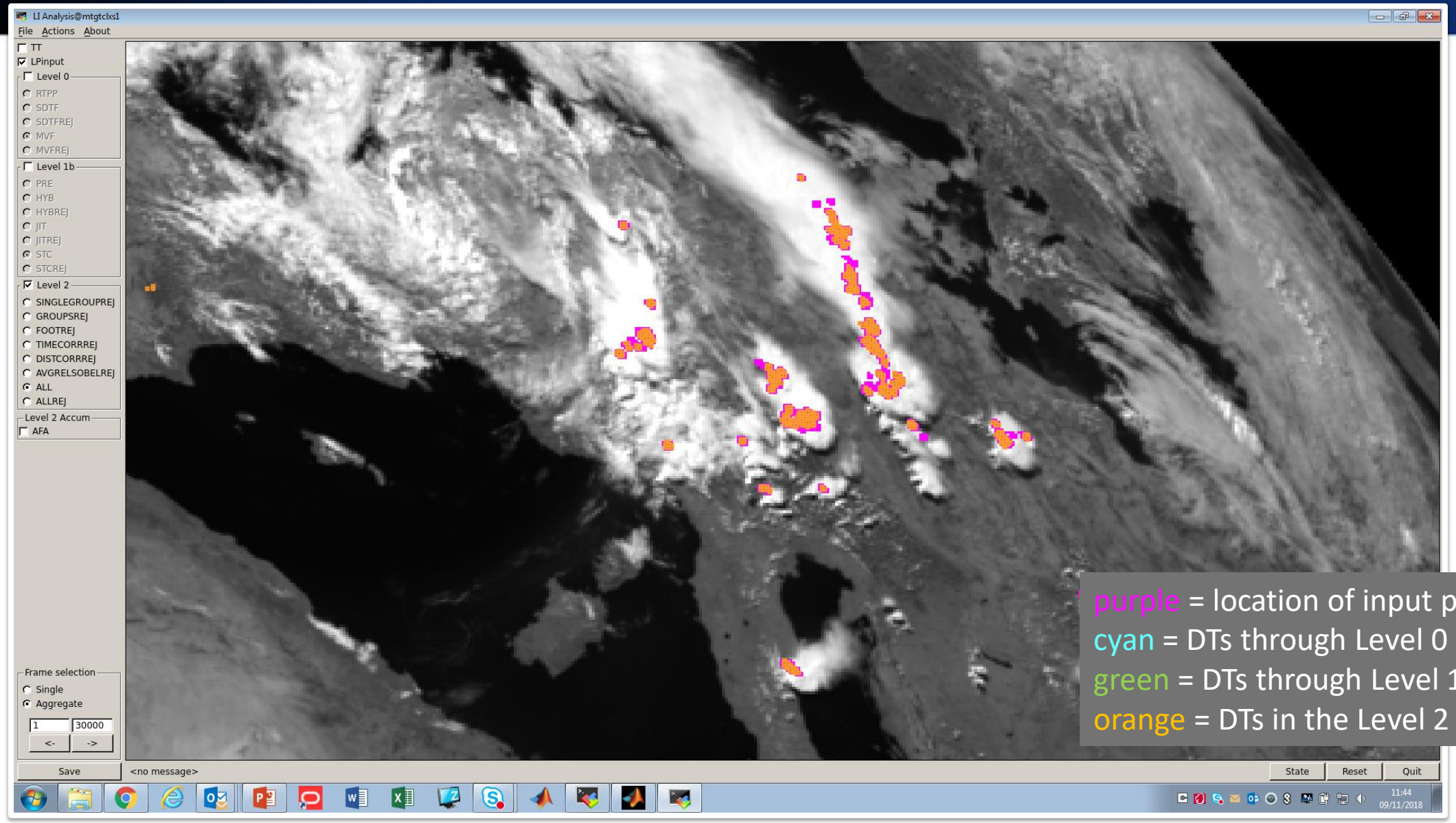


LI Pixel				
	R1	R2	R3	
		R4	R5+ R5’	
			R6	
		R7	R8	R9

Level 2 disseminated products – accumulated products

- The LI accumulated products are providing imaging information. In fact, such products contain spatially extended features
- Such features represent one of the most important added values of the LI mission
- GLM has now “gridded products” (originally not in the product baseline). These are possibly the most used products from GLM (currently). GLM accumulated products are computed over 5-10 min with a refreshing rate of about 1 min
- LI accumulated products will be provided every 30 sec. These can be easily combined (accumulated) over a generic time, e.g., typical FCI repeat cycle of the order of 10 min

DTs at Level 2



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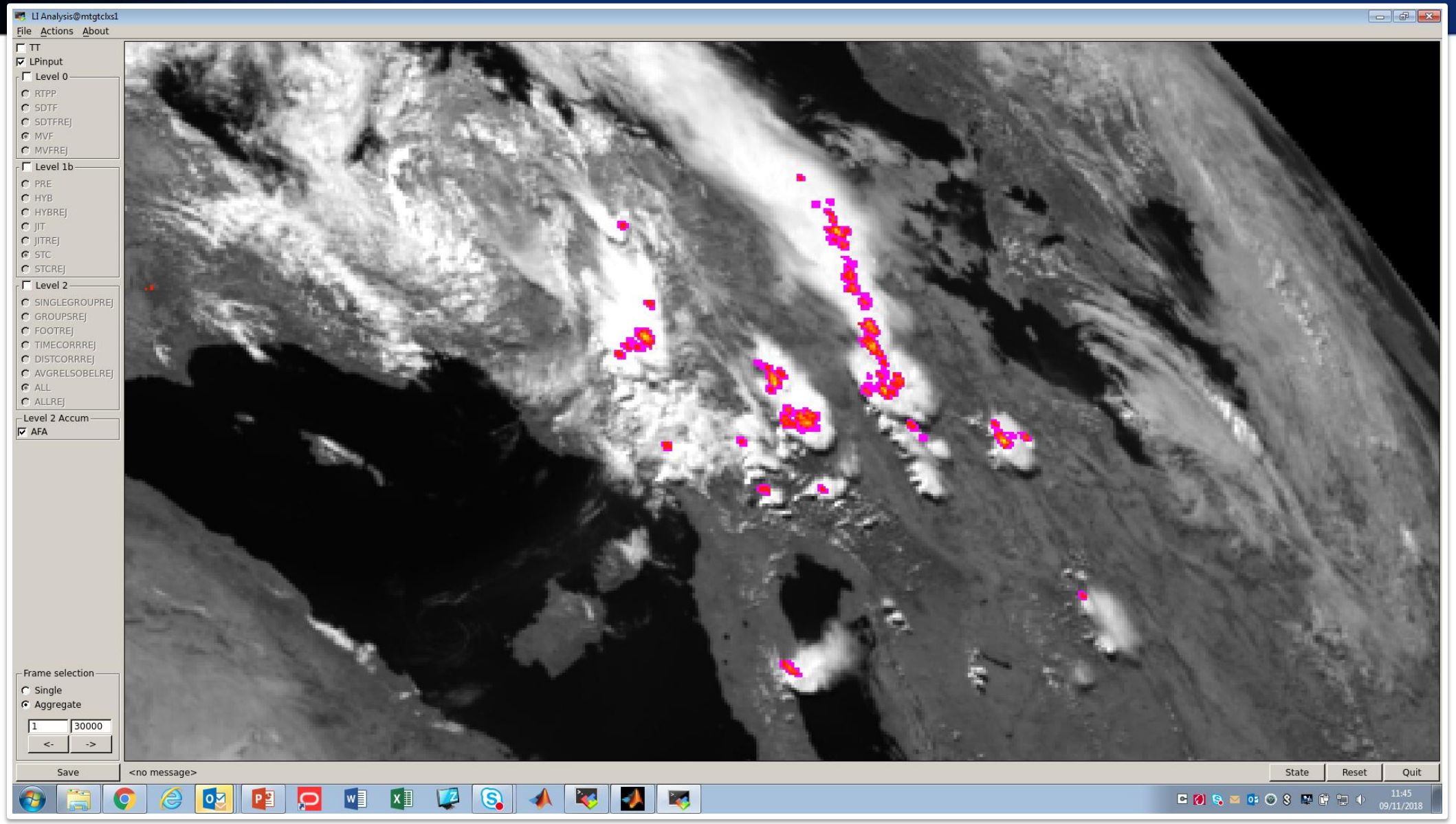
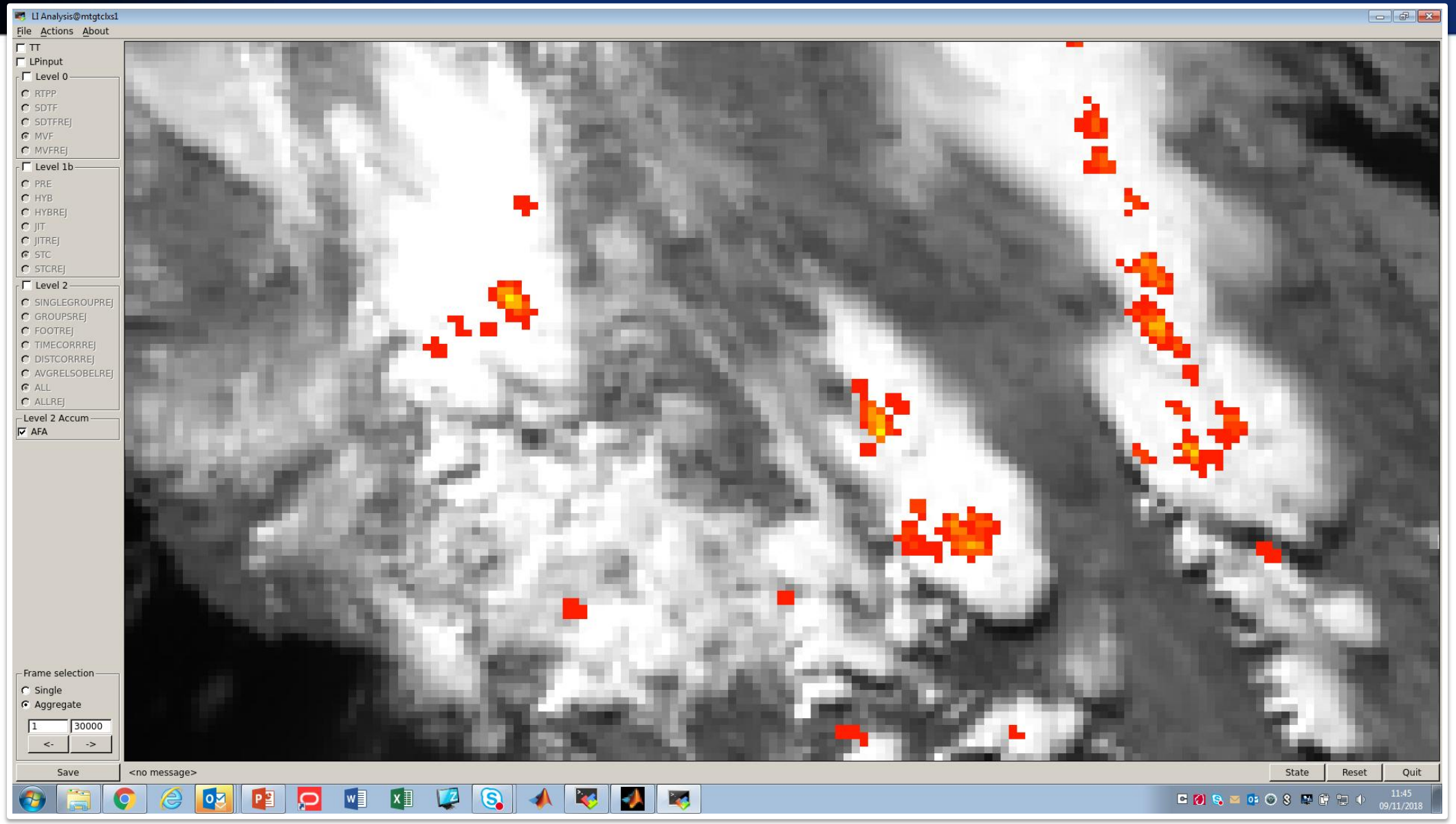
Level 2 Accumulated Product



Level 2 Accumulated Product (ZOOM IN)



EUMETSAT

Conclusions

- The Meteosat Third Generation Lightning Imager (MTG LI) will perform the geostationary detection of lightning optical cloud top emissions from space. The LI senses such emission within a 1.9 nm wide band centred on 777 nm, with a 4.5 km resolution at sub-satellite point, and 1 kHz acquisition frequency

- The detection and filtering logic: send to the ground as many DTs as we can fit in the Level 0 downlink bandwidth and "clean" the data through a sequence of processing steps on ground:
  I. Level 0 filtering: single-DT analysis every millisecond
  II. Level 1b filtering: analysis over a buffer of DTs
  III. Level 2 filtering: computation and analysis of groups and flashes

- EUMETSAT has the capabilities of performing realistic simulations of the LI detection and filtering through the LI Reference Processor. This is used for:
  I. Test data (products) simulations
  II. Pre-flight performance assessment (did not touch this topic today)

- LI Level 2 disseminated products: `LI-L2-LGR`, `LI-L2-LFL`, `LI-L2-AF`, `LI-L2-AFA`, `LI-L2-AFR`. Such products are complementary to the ones produced by ground networks. The accumulated products are expected to represent the added value of the LI mission.