EUMETSAT fellow day
Monday, 01 March 2021

Towards an automated severe weather warning tool based on MTG-LI and FCI data

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Advisor: Dieter Poelman

Funding: EUMETSAT

Introduction

(a)

(b)

From https://de.wikipedia.org/wiki/Sturzflut, accessed 14/12/2019

(c)

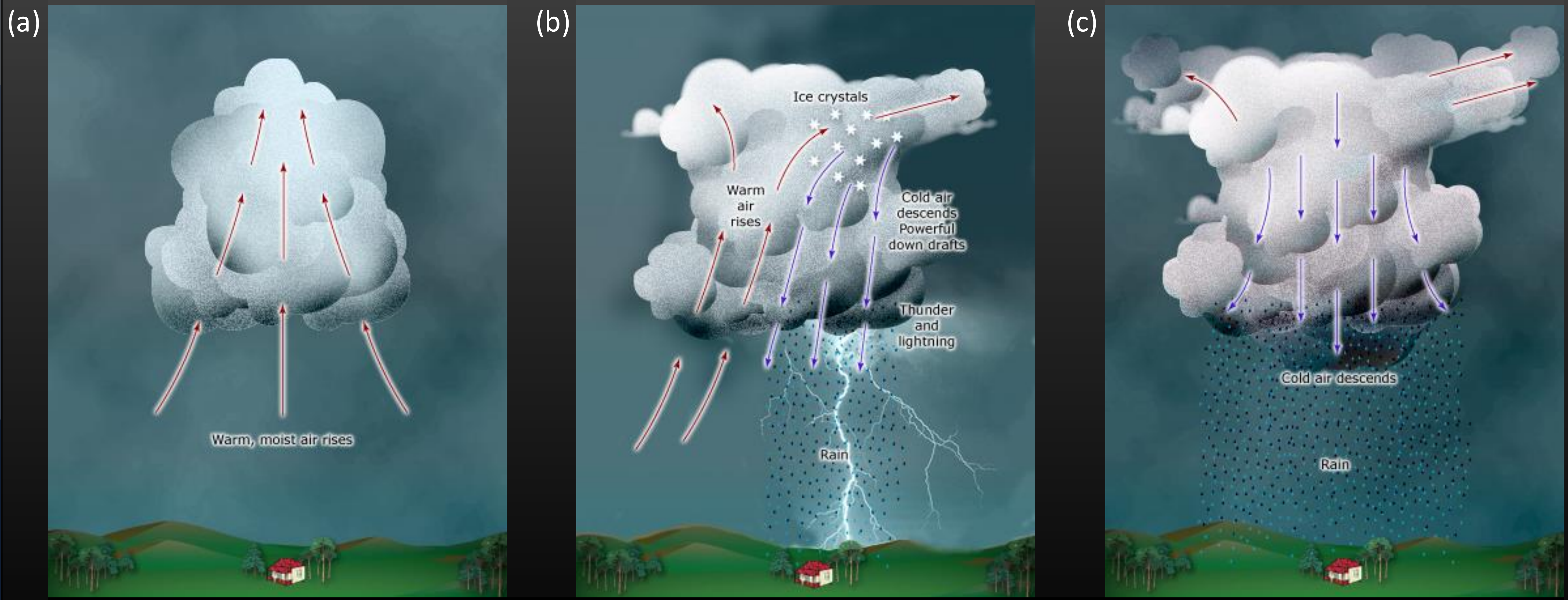
From https://www.flickr.com/photos/okweatherwatch/42186567924/in/photostream/, accessed 14/12/2019

Thunderstorms

Stage 1: Convection and Cumulus cloud formation

Stage 2: Mature phase with lightning and thunder

Stage 3: Decay and finally dissipation



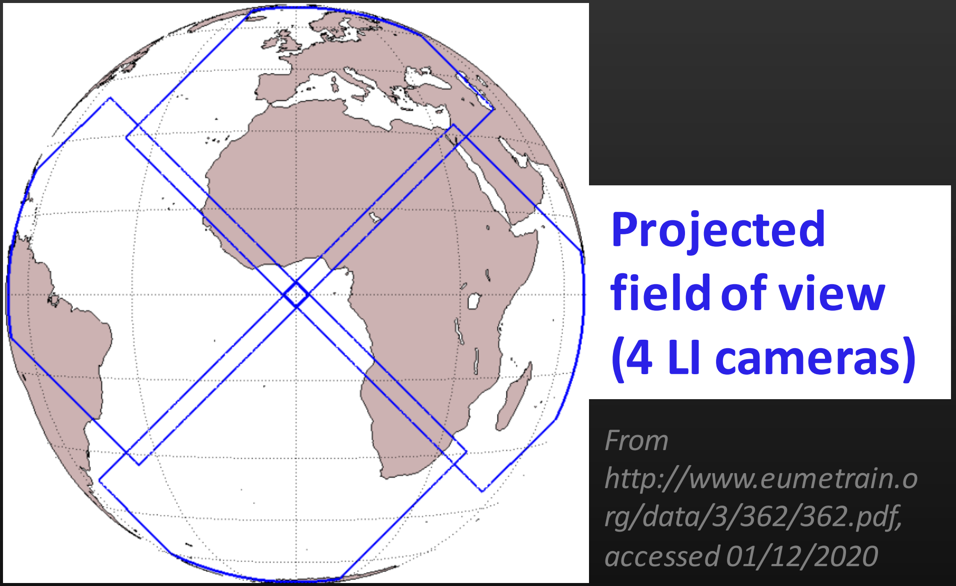
Adapted from Erick Brenstrum, 'Weather - Thunderstorms', Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/interactive/7767/how-a-thunderstorm-forms (accessed 25 November 2020)

Use of lightning observations

Spaceborne sensors on Geostationary (GEO) and low Earth orbit (LEO)

- E.g., GEO **Meteosat Third Generation (MTG) Lightning Imager (LI)** coverage

(a)



From http://www.eumetrain.org/data/3/362/362.pdf, accessed 01/12/2020

(b)

(c)

From https://directory.eoportal.org/web/eoportal/satellite-missions/iss-lis, accessed 05/04/2020

(d)

Ground-based lightning locating systems (LLSs)

Nowcasting (NWC)

- Short term (up to 2 hours) analysis and forecast of the current weather
- Satellite Application Facilities (SAF) to provide satellite based product for nowcasting
- Weather warnings

Satellite Imagery, e.g., SEVIRI, ABI → SAF NWC → Output products

Optional input:

- NWP
- Ground lightning data
- Satellite Lightning data
- Previous SAF NWC output

Output products:

- **Cloud products**, e.g., cloud type mask
- **Precipitation products**, e.g., Convective Rain Rate (CRR)
- **Convective products**, e.g., Rapid Developing Thunderstorm (RDT)
- **Satellite Humidity and Instability products**, e.g., precipitable water
- **Wind products**, e.g., Atmospheric Motion Vectors
- **Future satellite image estimation**

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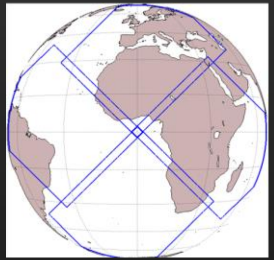
Fellowship motivation and objective

- Improve the **predictability** of deep convection (and related) events and increase of **warning lead times**

- **Automated thunderstorm warning**

- **Implementation** of lightning observations of existing lightning locating systems (**LLSs**) on Earth and in space in **NWC**



- Preparation for using the GEO **MTG-LI** [launch end of 2022] data

- **Lightning signatures** and storm structure during a thunderstorm cell life-cycle, e.g., **lightning jumps** (rapid increase in lightning activity)

Lightning initiation, types, and observation

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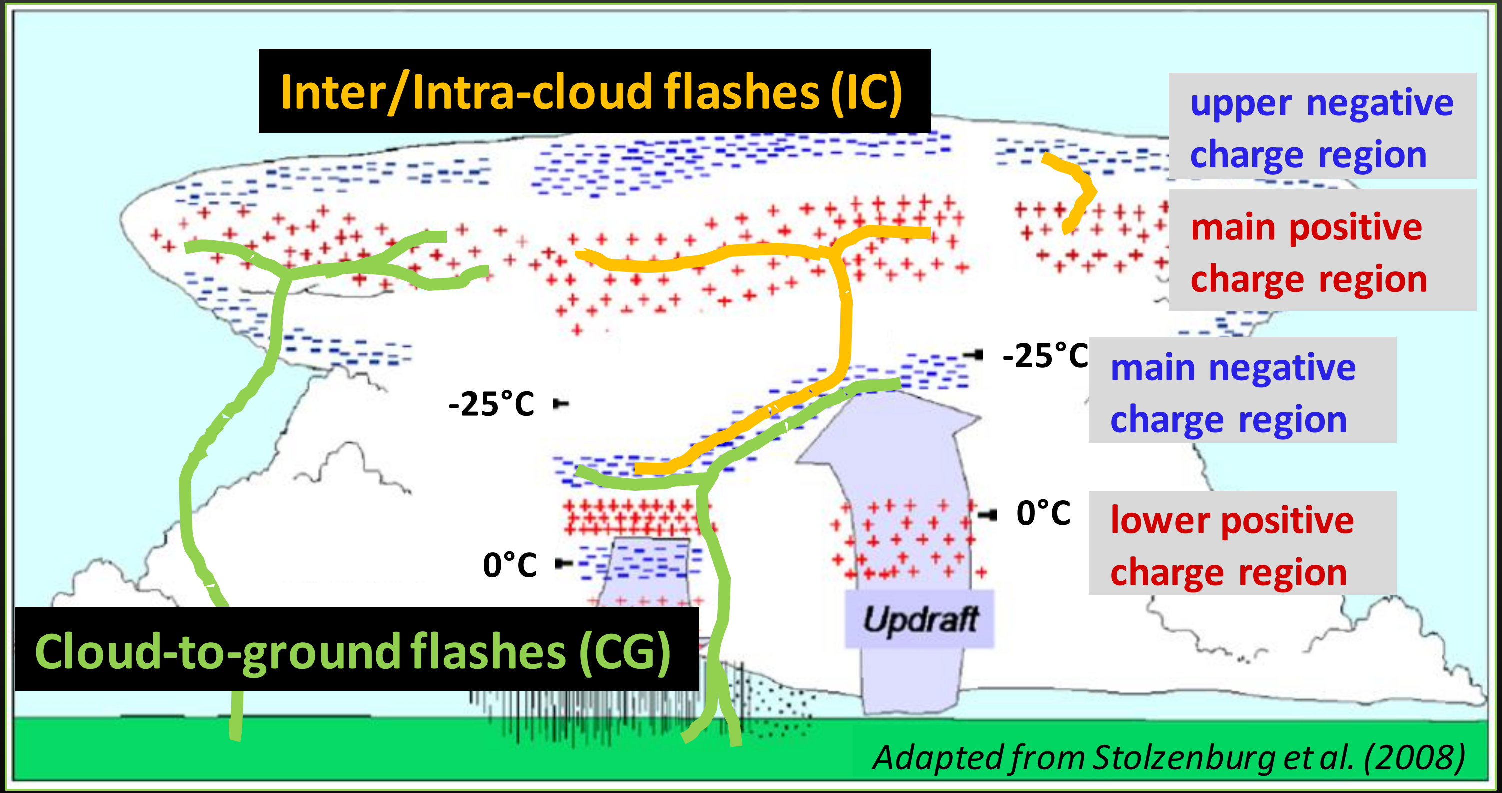
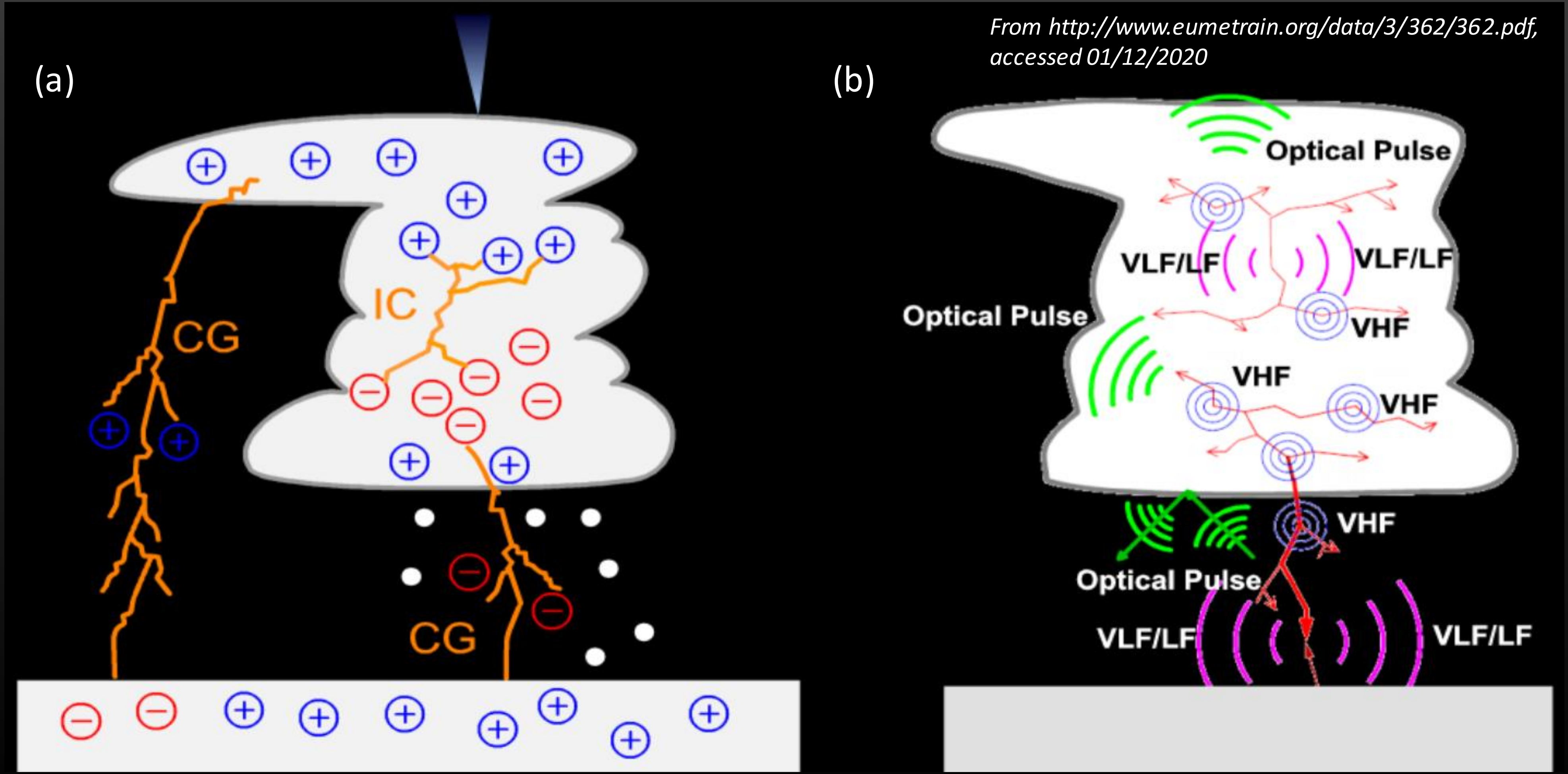
Cloud electrification

- **Flashes** as discharges between charge regions of **the cloud and the ground** and **inside one cloud or between clouds**



Lightning emissions

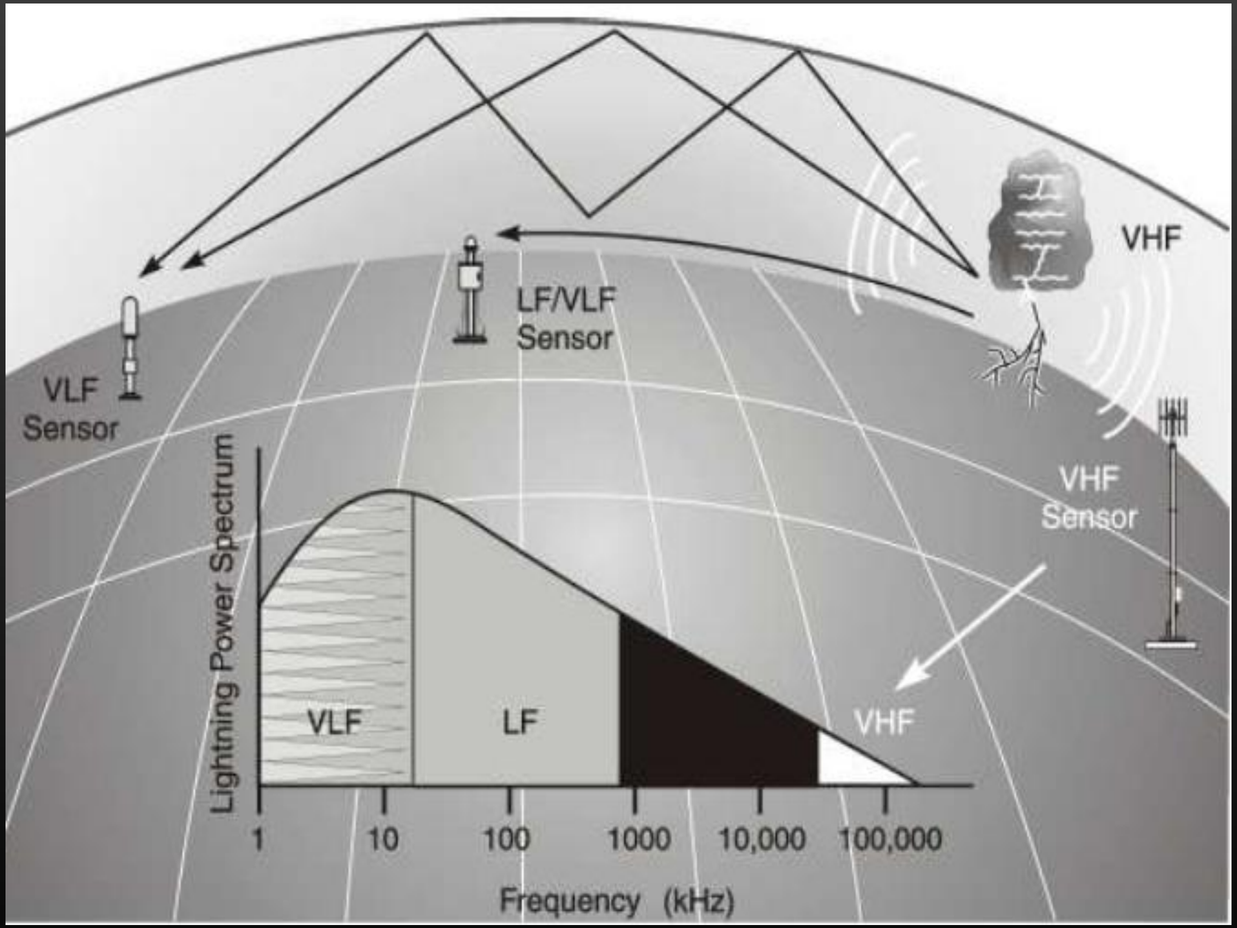
- **Radio frequency**: (Very) low frequency, **(V)LF**, and very high frequency, VHF
- **Optical** pulses



From http://www.eumetrain.org/data/3/362/362.pdf, accessed 01/12/2020

Lightning observation (1/2)

- Power spectrum of **radio frequency** range: Ground-based (V)LF and VHF networks



Adapted from Cummins et al. (2009)

	(V)LF networks
Frequency range	Few hertz to 30 kHz
Most sensitive to	**Return strokes**, fast in-cloud components
Signal propagation	Direct (line-of-sight), ground wave, ionosphere reflection
Quantities	Time, location, LF current, lightning type
Measurement	Point locations
Coverage	Global, nationwide, or regional
Example	NLDN, EUCLID, GLD360

INTRO MAIN OUTLOOK

Lightning observation (2/2)

- **Optical** imagers (**777.4 nm** or 886.3 nm) on satellites
- Storm scale spatial resolution and millisecond sampling rate
- **Total** (CG+IC) **lightning** activity
- Cloud illumination mapping as optical lightning extent

e.g., LEO: International Space Station (ISS) Lightning Imaging Sensor (LIS)

(e.g., Blakeslee and Koshak, 2016)

Adapted from Peterson et al. (2020)

e.g., GEO: Geostationary Lightning Mapper (**GLM**)

(e.g., Goodman et al., 2013)

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I.6 Tools and instruments

US GEO
- GOES Geostationary Lightning Mapper (GLM)
- Advanced Baseline Imager (ABI)

European GEO
- MTG-LI
- MTG Flexible Combined Imager (FCI), MSG SEVIRI

Ground-based network
- EUCLID, GLD360

NWP/Software
- NWC Satellite Application Facilities (SAF)
- AROME-BE

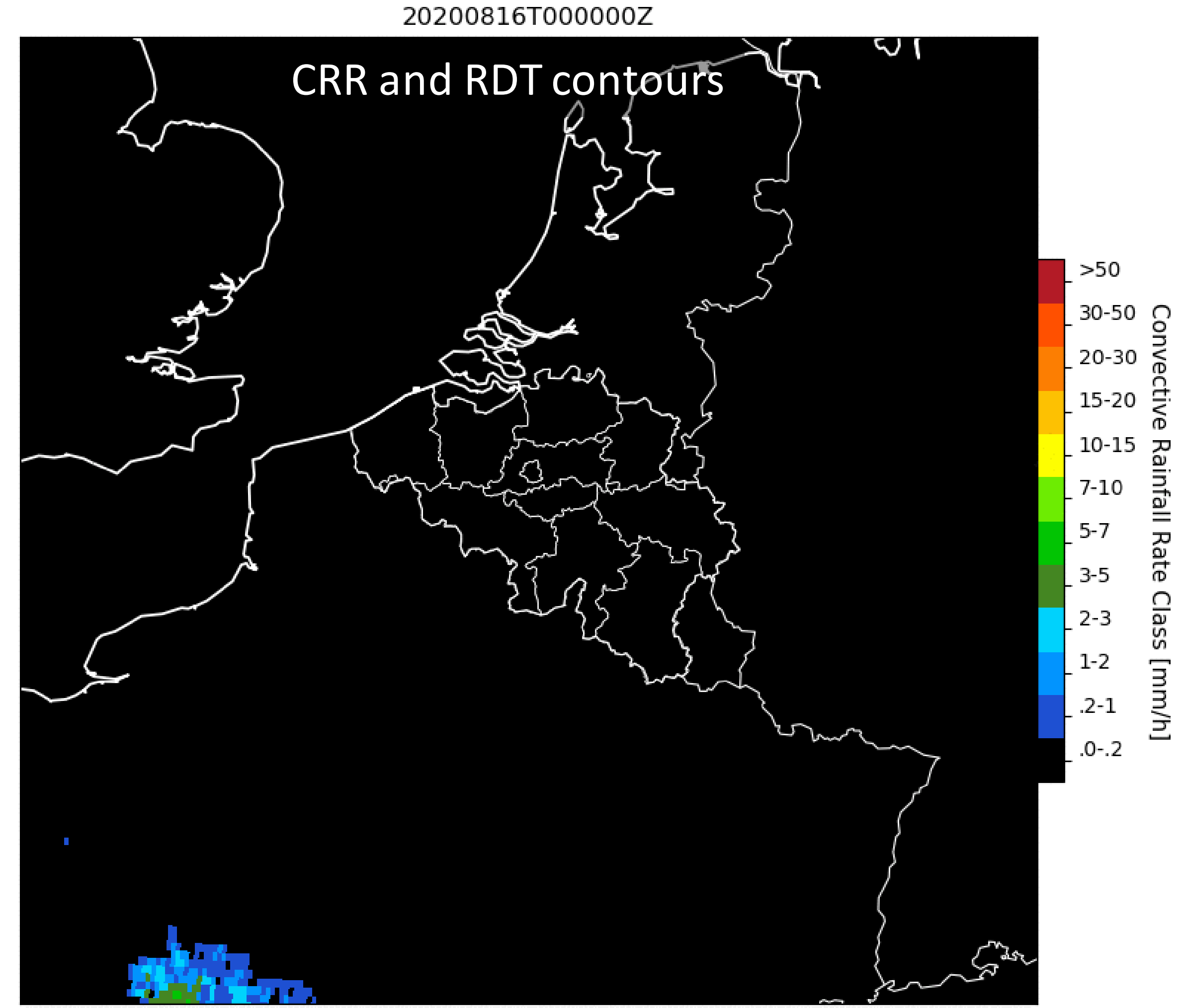
INTRO
MAIN
OUTLOOK

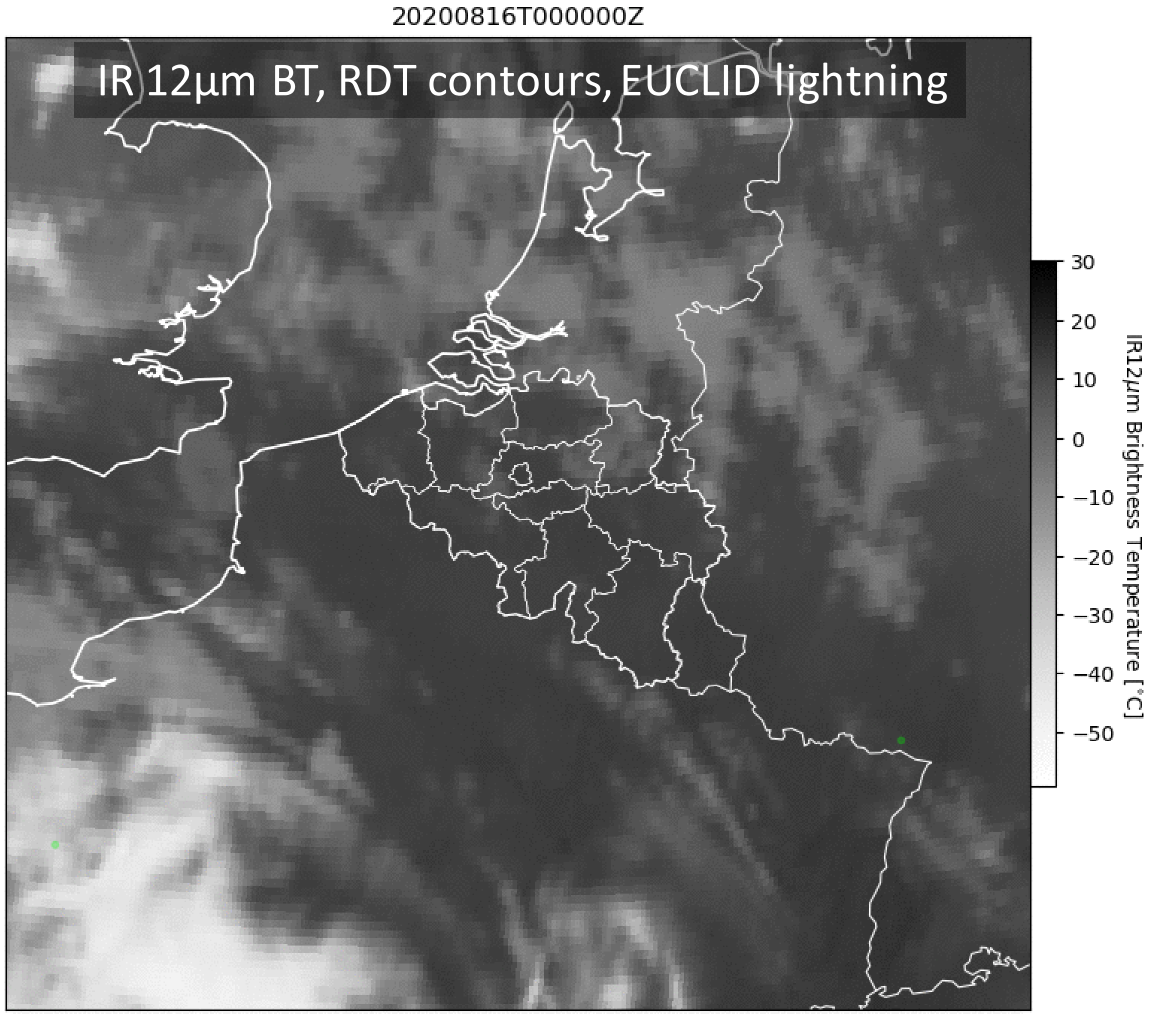
Technical details

- **SAFNWC_v2018** installed recently
- Running SAFNWC produces different output modules, such as RDT-CW, CRR, CI
- Convective Rain Rate (**CRR**) derived from MSG SEVIRI
- Rapid Developing Thunderstorm (**RDT**) package output – cell tracking – Convective Warning (**CW**)
- SAFNWC_v2018 also with lightning information and one approach to **lightning jump** identifications (RDT-LJ)
  - This 'default' LJ algorithm will be tested and adapted where needed.
- Currently **EUCLID** LF lightning data
- Perspectives:
  - **GLM data reader** and implement (next SAFNWC version)
  - MTG-LI lightning data usage

NWC: CRR + RDT Belgium

CRR and RDT loop: 16 Aug 2020 – 24 hours





Triggering | Triggering from Split | Growing | Maturity | Decaying

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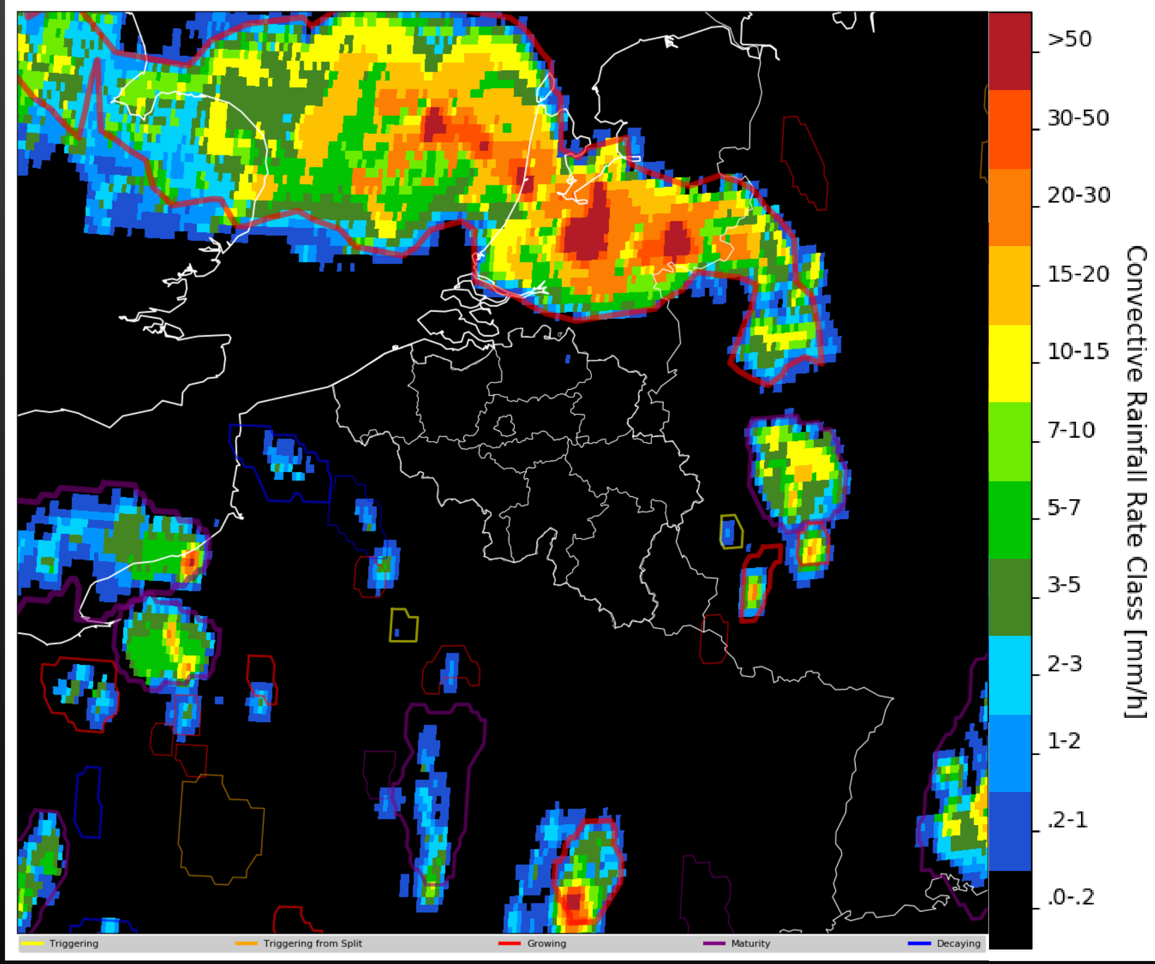
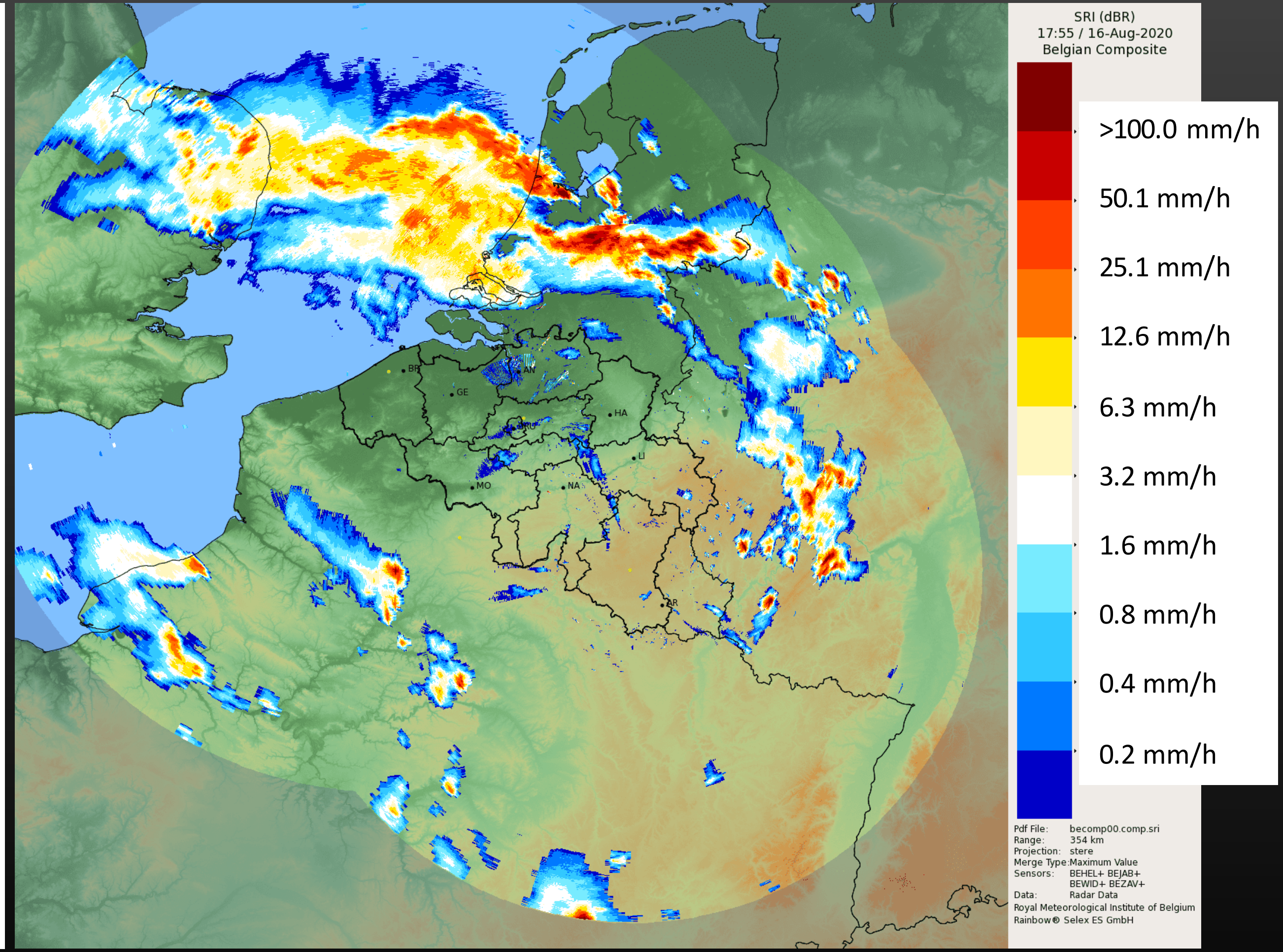
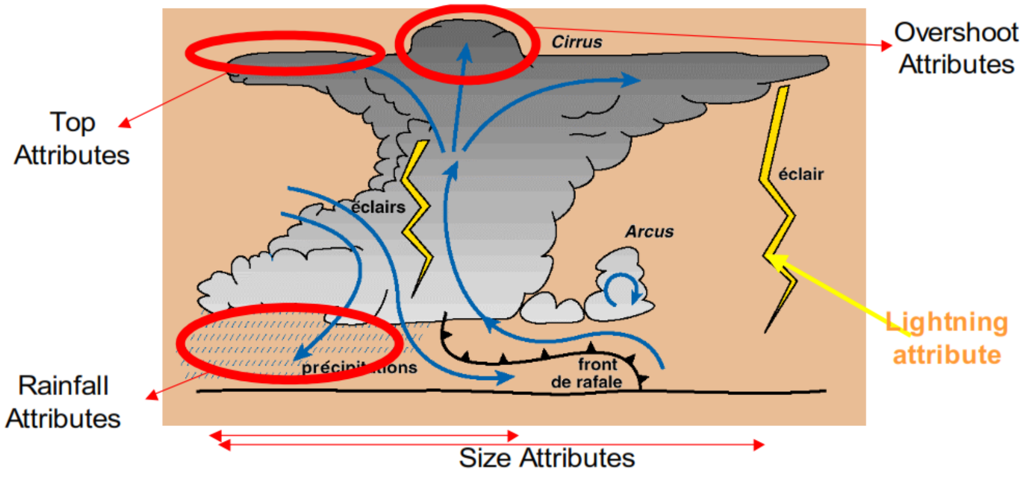
Comparison of NWC CRR and RR inferred from radar observations



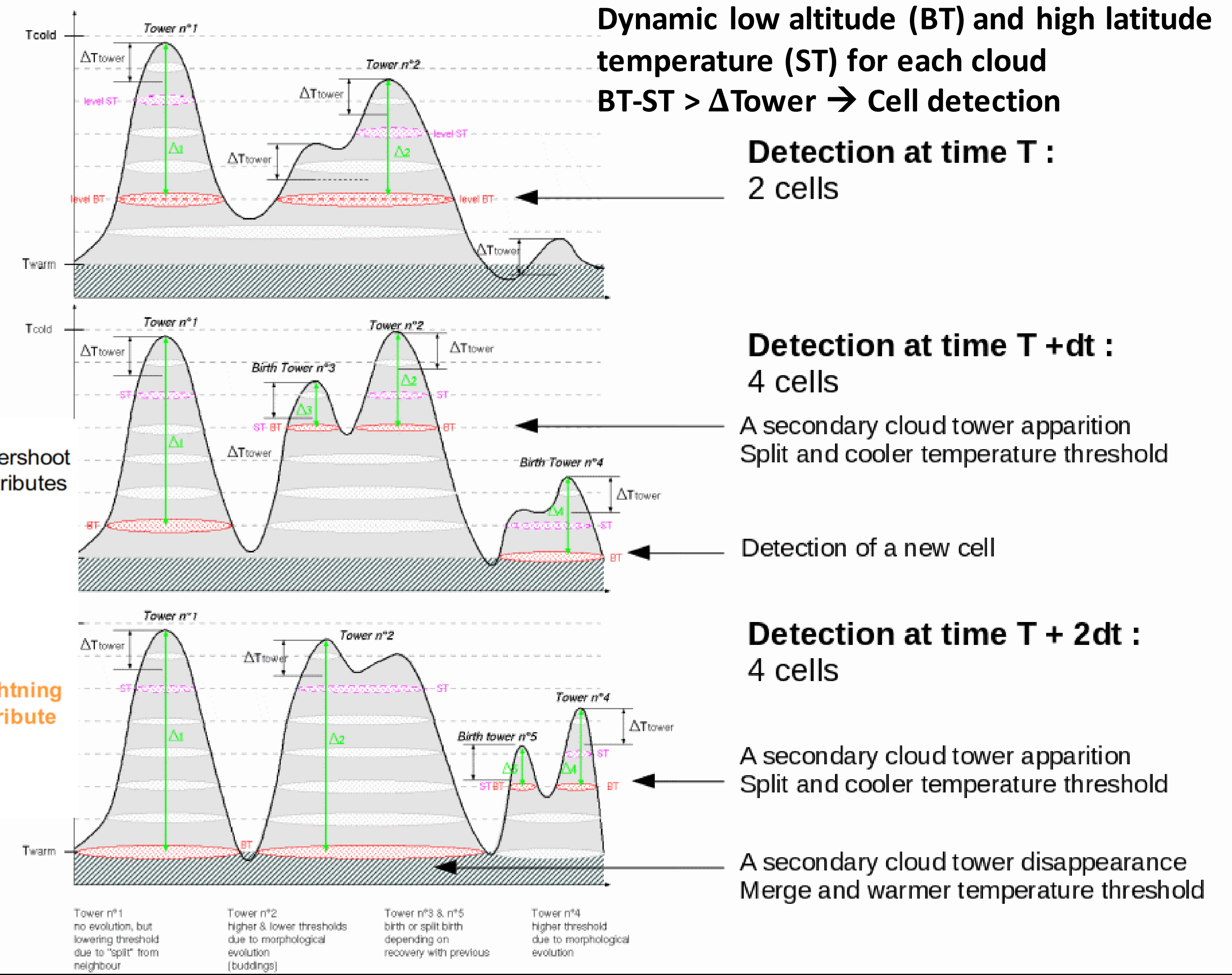


RDT cell identification and tracking – Input and Thresholds

- Detection of the cloud system
- Tracking of the cloud
- Discrimination of convection
- Convective forecast



Dynamic low altitude (BT) and high latitude temperature (ST) for each cloud
BT-ST > ΔTower → Cell detection



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Fellowship plan

Year 1

- Start in February 2021
- Familiarization with SAFNWC software and outputs
- Cell tracking
- Optical imagery lightning jumps (LJs)

Year 2

- Comparison and analysis of optical LJs
- Radar observations and storm structure
- Liquid and ice water paths, opacity
- Correlations

Year 3

- Nowcasting
- Cell development and decay
- Depending on previous results

INTRO

MAIN

OUTLOOK

Summary

- Test runs and first outputs with the new **SAFNWC_v2018.1**
- EUCLID lightning impact on SAFNWC output

- Collaboration with Météo-France – exchange of results
- Preparation for the use of GLM data in SAFNWC (**SAFNWC_v2018.2**)
- First result:
  - Stroke-type data input leads to high numbers of lightning jumps (LJs)

  → use **flash data** (e.g., Schultz et al. 2009)

Thank you for the attention!

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Backup slides

INTRO
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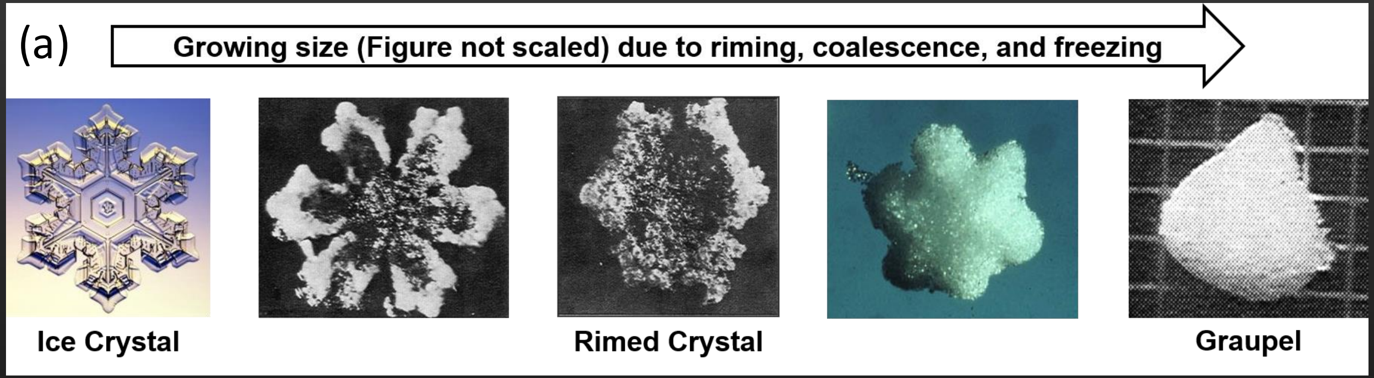
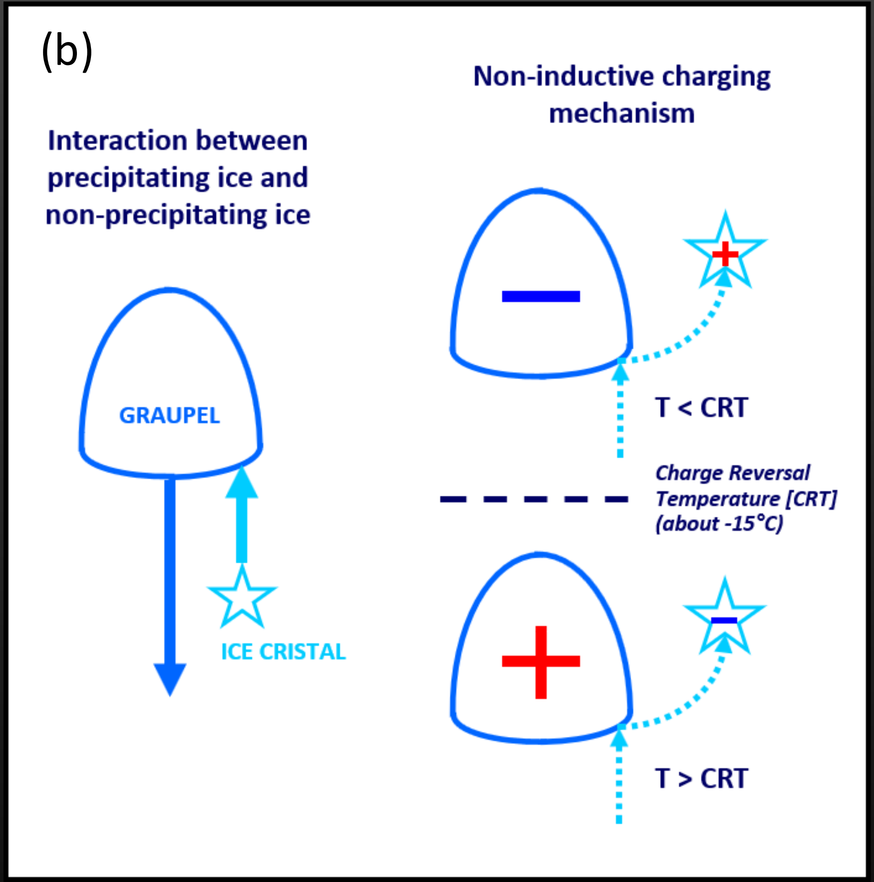
OUTLOOK

Cloud electrification (1/4)

- Need of **electric field** sufficient to cause a **breakdown**
- **Non-inductive** graupel ice charging



From personal communication, S. Coquillat (2019)

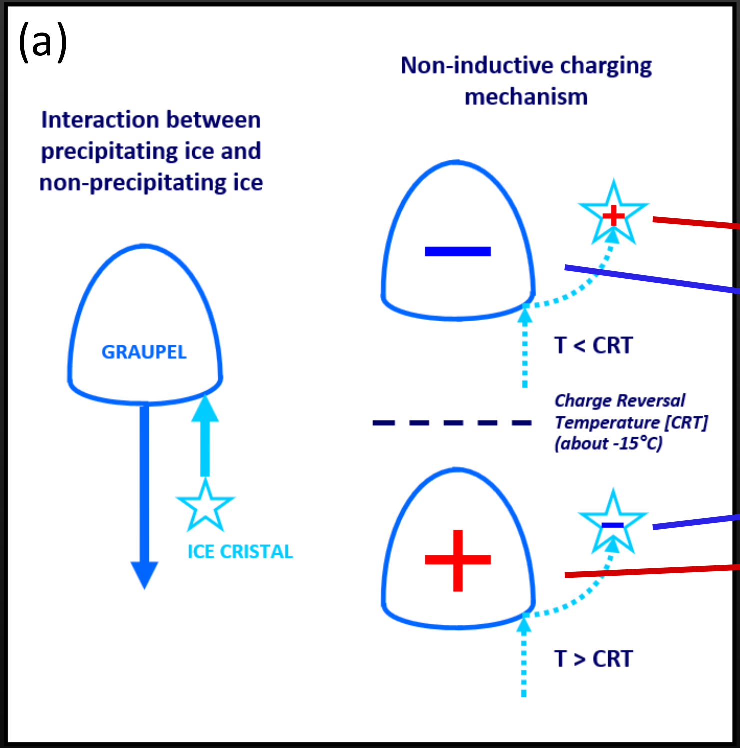


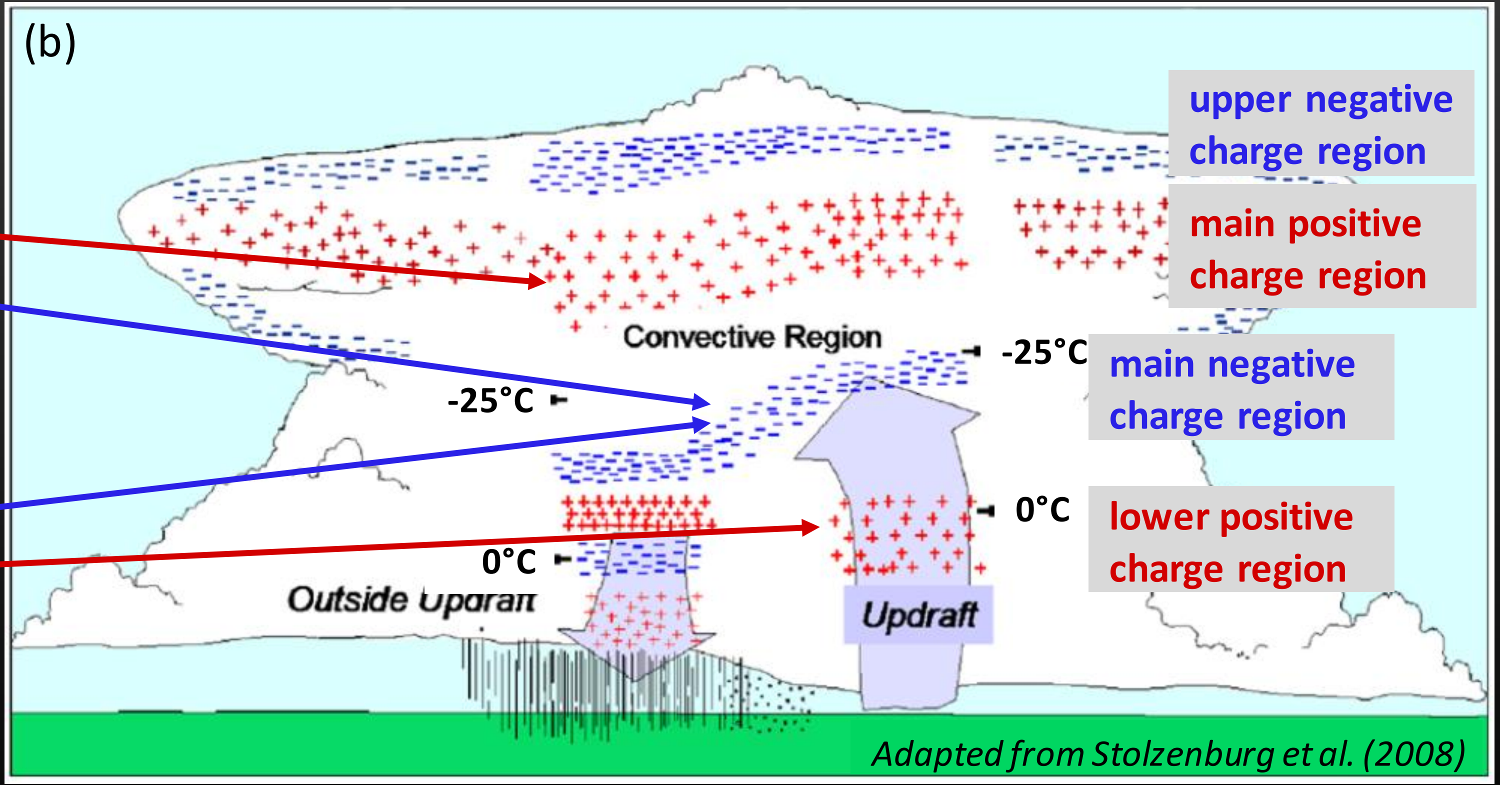
- **Other hypothesis**:
  - Inductive charging: particle-particle and ion capture
  - Convective charging: importance of the screening layer and corona discharges

INTRO MAIN OUTLOOK

Cloud electrification (2/4)

- **Transport** of charged particles → **Charge structure** within thunderclouds (normal polarity storm)





GLM and NLDN data - GEO lightning pseudo-observation generator (2/4)

Ground-based LF stroke-type data

Training Input

- 6 NLDN **features** per flash:
  - Extent,
  - Stroke+pulse number,
  - Duration,
  - Mean absolute current,
  - Maximum current,
  - CG ratio
- 3 observed GLM **targets** per flash:
  - Extent,
  - Event number,
  - Duration

1. Pseudo-GEO target generator

- LF observation flash features
- Machine learning based target generator
- Simulated pseudo-GEO targets

2. Simulation of pseudo-GEO events

- Use simulated pseudo-GEO targets
- Pseudo-GEO events on regular lat-lon grid

Test

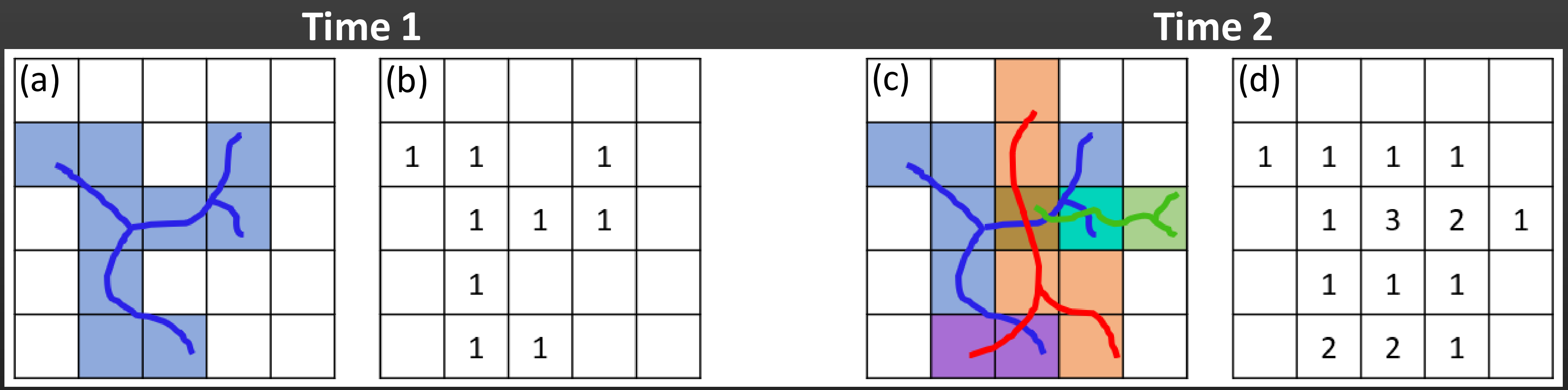
- Statistics of distributions of observed and pseudo-GLM flash characteristics
- Comparison of observed GLM FED and simulated FED

GEO Flash Extent Density (FED)

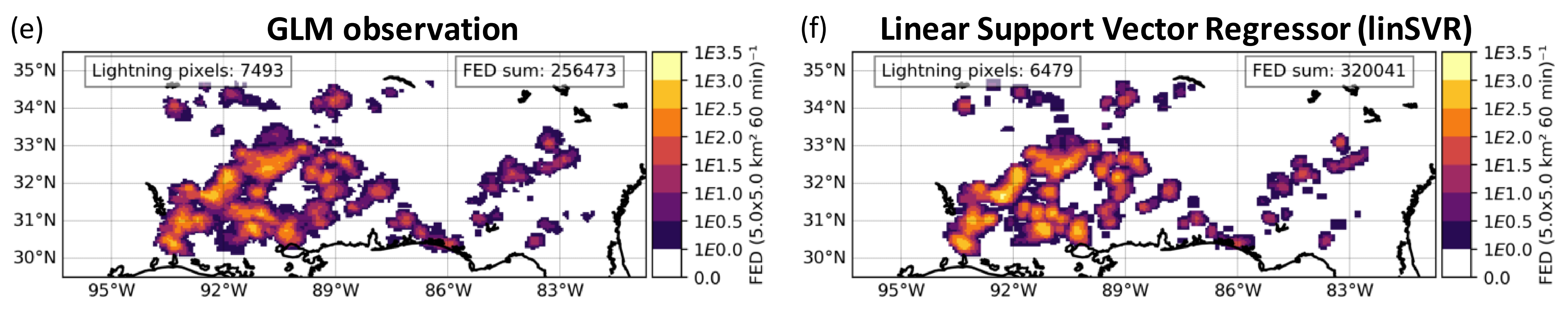
- Submitted paper to JTECH: **Erdmann et al.** [Erdmann, F., Caumont, O., and Defer, E.: A geostationary lightning pseudo-observation generator utilizing low frequency ground-based lightning observations, submitted to the Journal of Atmospheric and Oceanic Technology in October 2020]

GLM and NLDN data - GEO lightning pseudo-observation generator (3/4)

- **Flash extent density (FED)** on regular grid and within a given time period

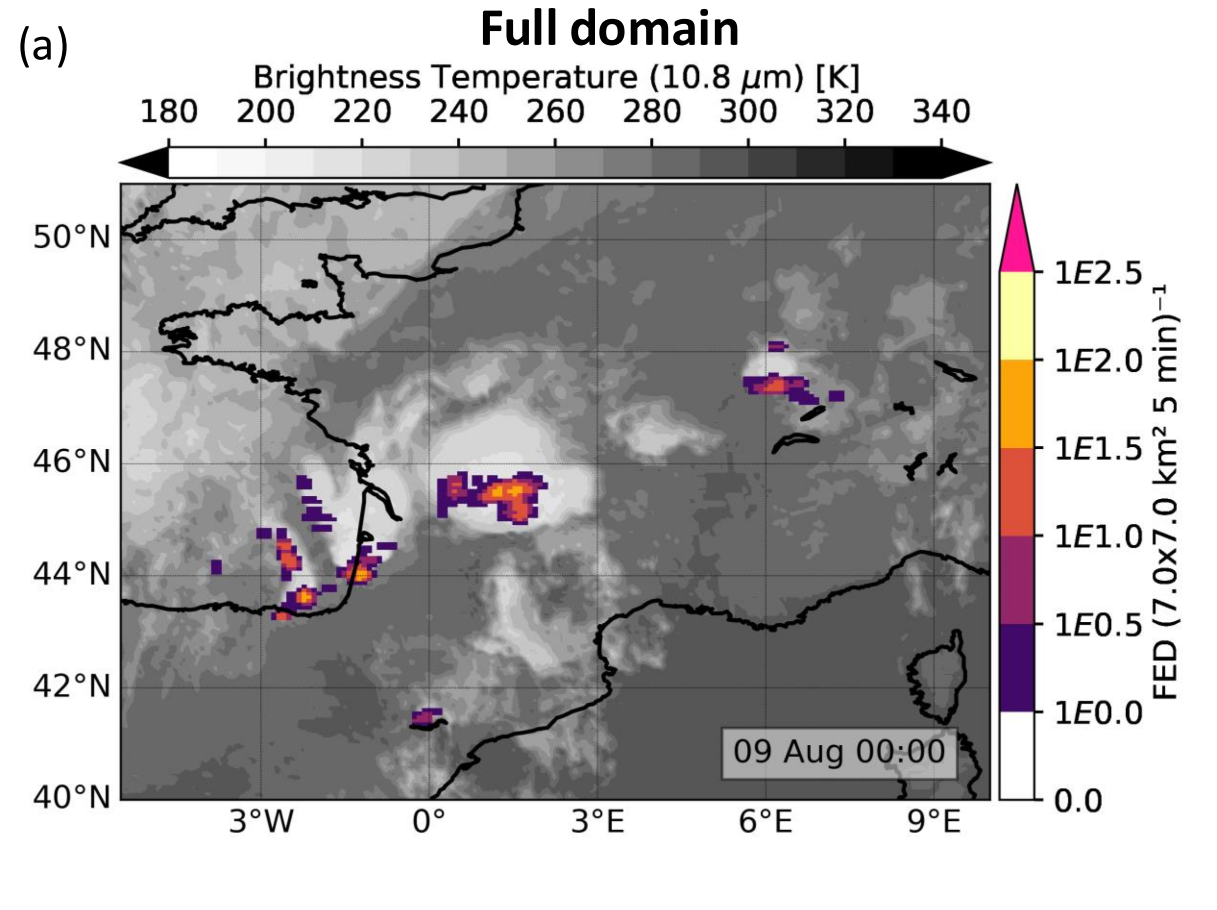


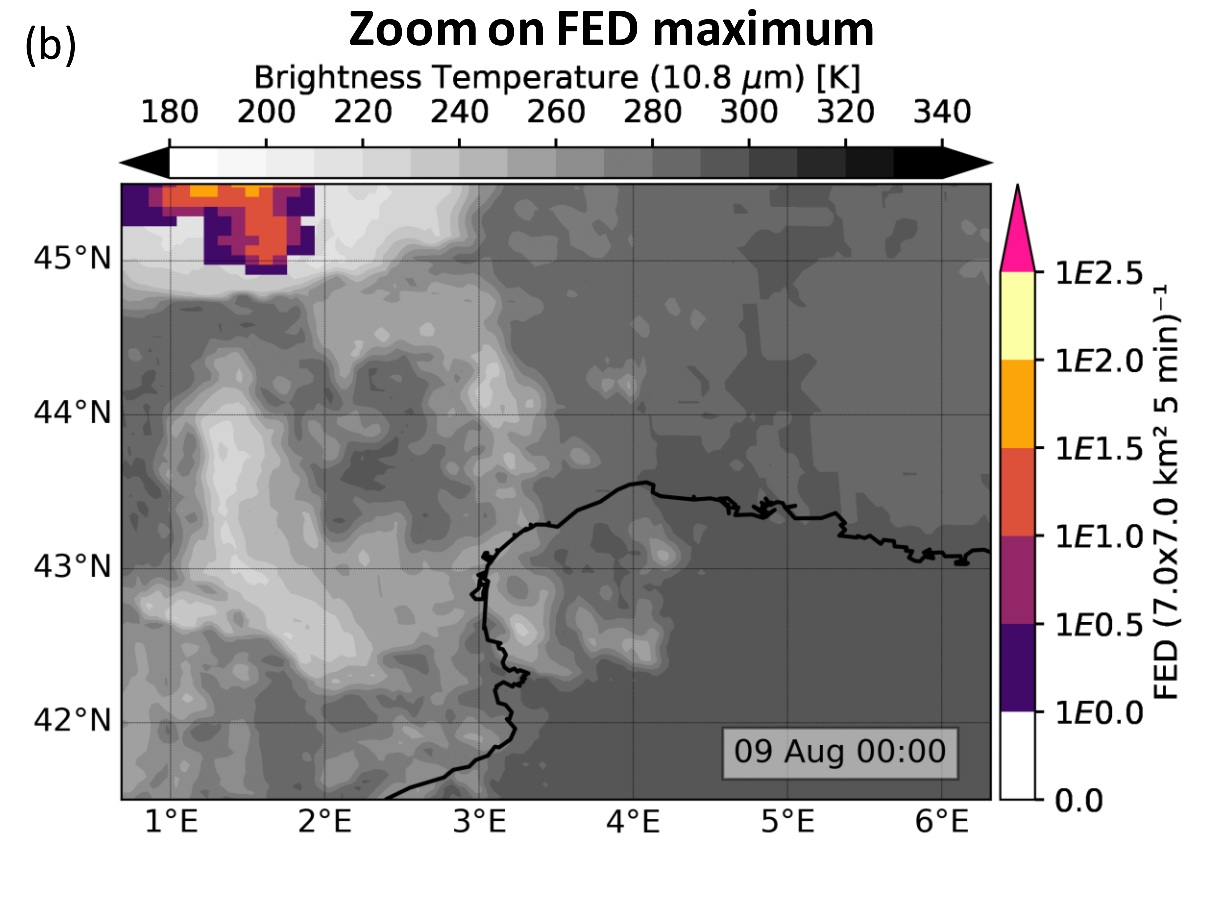
- Example 26 May 2018, 20:00-21:00 UTC, FED on 5km x 5km pixels within 60 min



IV.1 Lightning data – MTG-LI flash extent density (FED)

- GEO lightning pseudo-observation generator for **MTG-LI spatial** and **temporal resolution**
- Ex.: Pseudo **MTG-LI FED** based on Meteorage records + IR 10.8 µm MSG – SEVIRI images

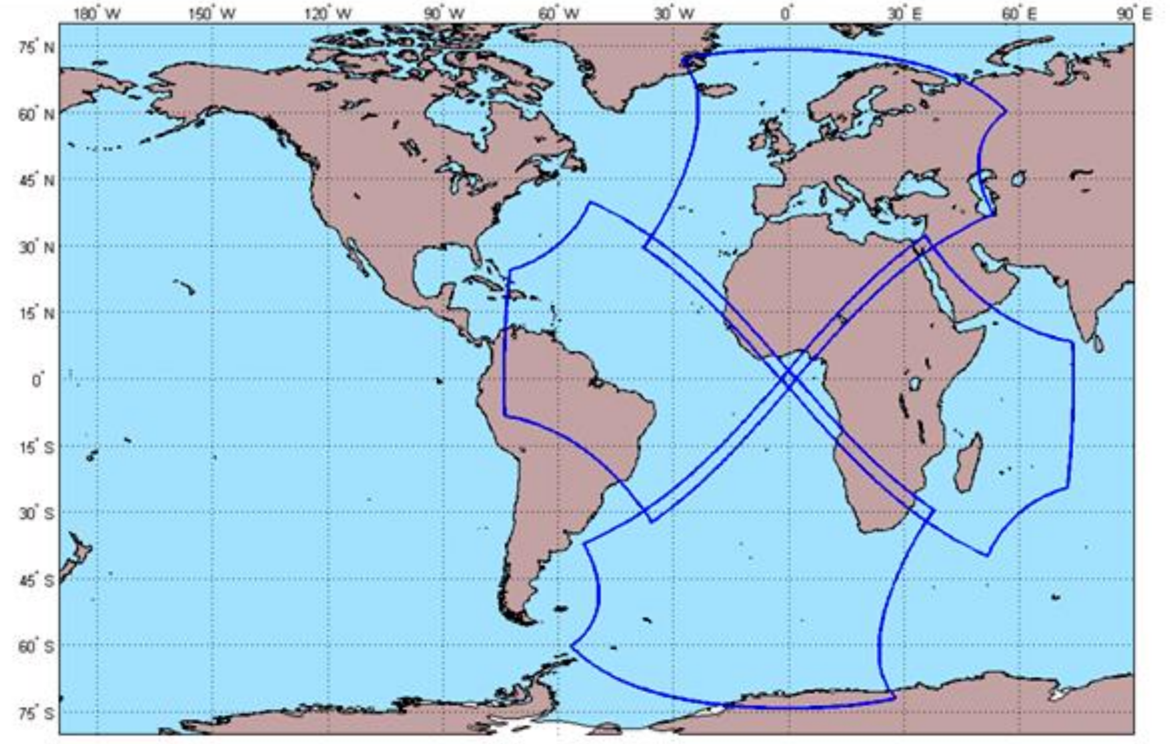




MTG-LI

- 777.4 nm oxygen band optical sensor
- 1 ms temporal resolution
- Spatial resolution of 4km nadir and about 7 km over France

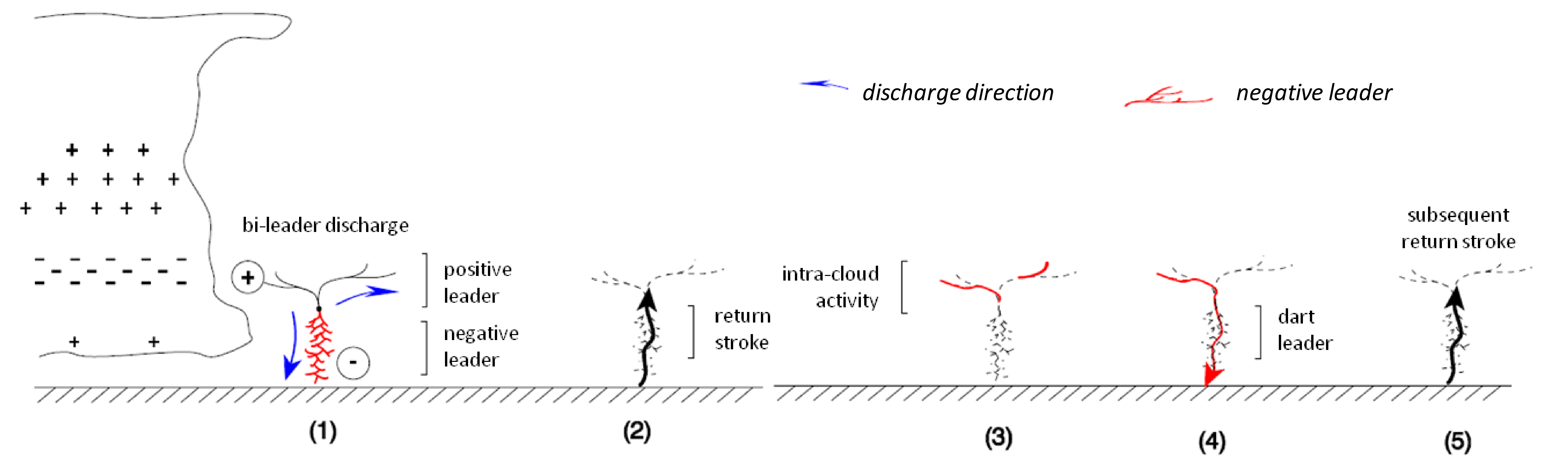
MTG-LI coverage (source: eumetrain)



Lightning flashes (1/2)

Negative CG flash

- Most common CG flash type – negative charge from the cloud to the ground



Adapted from personal communication, E. Defer (2020)

- Flash process lasts usually a few hundred milliseconds

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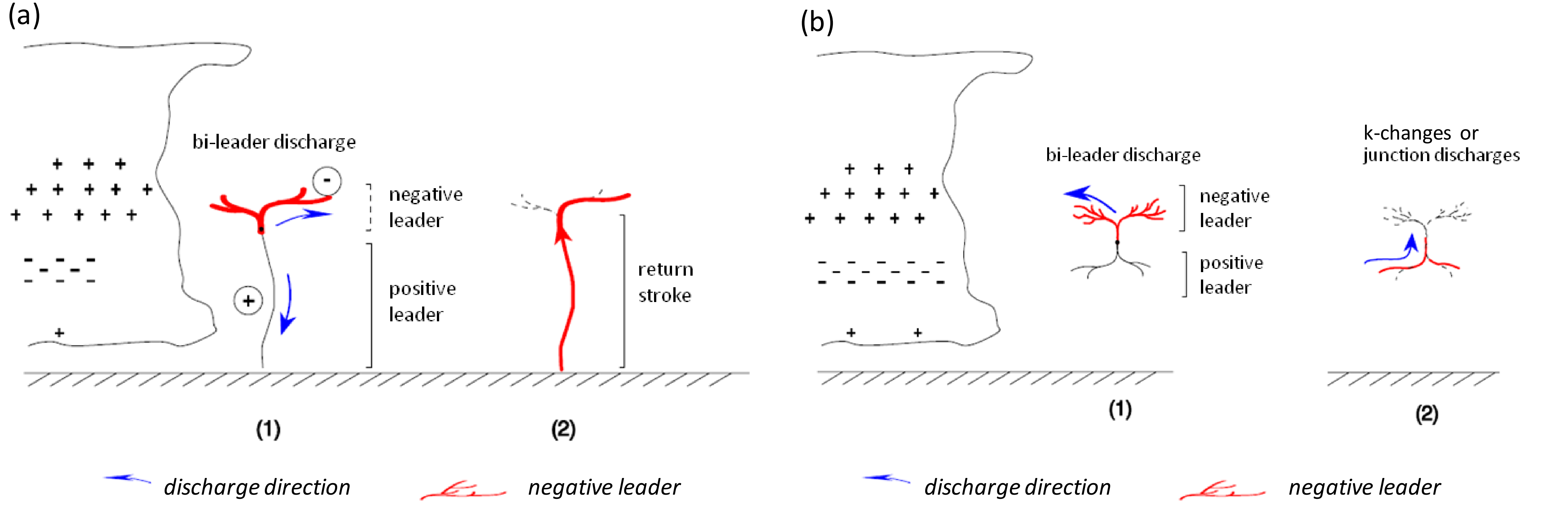
Lightning flashes (2/2)

Positive CG flash

IC flash

- At least 2/3 of all flashes are IC type



Adapted from personal communication, E. Defer (2020)

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Objectives

- Lightning time series for individual storm cells
- Identification of **(optical) lightning jumps (LJs)**
  - Dependency on RDT parameters and thresholds
- **Lightning data in SAFNWC_v2018**
  - Impact of current EUCLID input possibility
  - GLM data input
  - Research on input of MTG-LI (proxy) data
- Understanding and **characterization of optical LJs**
  - E.g, radar observations, weather reports
- **Automated severe weather warning** based on optical LJs