Ground strike point properties derived from observations of the European Lightning Location System EUCLID

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13/06/2023

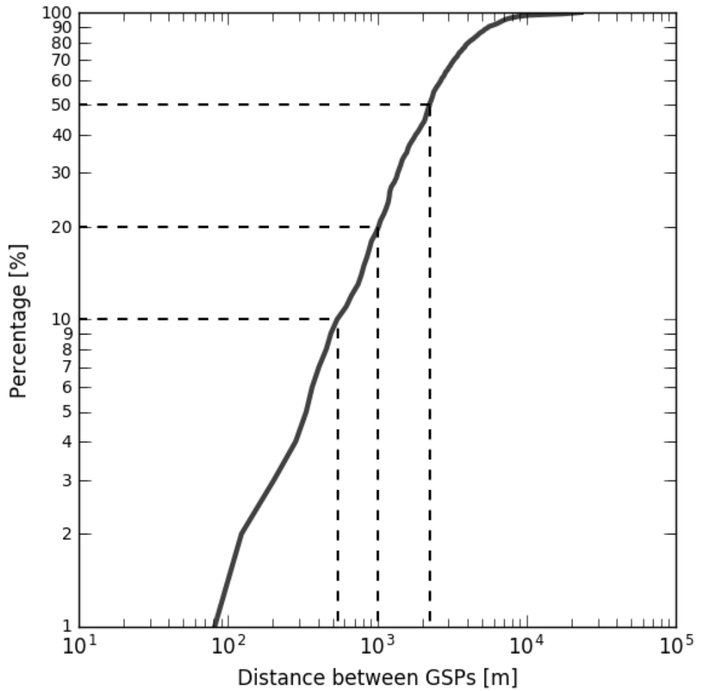
Introduction

- In order to evaluate the lightning risk to a particular structure, it is common practice to use the guidelines set out in IEC 62305-2.
- A key parameter that has a big impact on the outcome of the lightning risk calculation is the flash density N_g.
- A flash has, per definition, only 1 ground termination point. However, high-speed camera observations have proven that flashes have on average more than 1 ground termination point.
- In this presentation:
    1. We investigate whether existing ground strike point (GSP) algorithms estimate correctly the actual observed number of GSPs per flash based on observations made by high-speed cameras.
    2. We apply a GSP algorithm to data observed by the European Cooperation for Lightning Detection (EUCLID) network to retrieve spatial and temporal behavior of GSPs in Europe.

Ground-truth data

- High-speed video recordings are gathered from Austria (2012, 2015, 2017, 2018), France (2013-2016) & Spain (2017-2018).
  - frame rates >= 200 fps
- Only flashes where a clear channel to ground is observed for all associated strokes are included.
- Each stroke is classified as creating a new ground strike point (GSP) or as following a pre-existing channel (PEC).
- Location and peak current estimation is retrieved by linking the ground-truth data to the observations made by a local LLS, i.e., ALDIS (Austria), Météorage (France, Spain).

Parameter	Location ground-truth observations		
	AT	ES	FR
N(flashes)	474	76	354
N(strokes)	1373	183	894
N(GSP)	808	121	585
Average N(GSP/flash)	1.7	1.6	1.65



- References:

  - Poelman, D. R., Schulz, W., Pedeboy, S., Hill, D., Saba, M., Hunt, H., Schwalt, L., Vergeiner, C., Mata, C., Schumann, C., and Warner, T.: Global ground strike point characteristics in negative downward lightning flashes – part 1: Observations, Nat. Hazards Earth Syst. Sci., 21, 1909-1919, 2021
  - Poelman, D. R., Schulz, W., Pedeboy, S., Campos, L. Z. S., Matsui, M., Hill, D., Saba, M., Hunt, H.: Global ground strike point characteristics in negative downward lightning flashes – part 2: Algorithm validation, Nat. Hazards Earth Syst. Sci., 21, 1921-1933, 2021

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- Loop through strokes in flash
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- Subsequent strokes assigned to GSP if distance < threshold
- If not, stroke creates new GSP
- After last stroke in flash, the position of each GSP is updated based on the average of the positions of the assigned strokes, inversely weighted by their respective SMA.
- A new iteration starts (to assign single stroke GSPs to existing multiple stroke GSPs) until the GSP positions do not vary anymore
- The algorithm takes care of the SMA and the peak current amplitude in order to prevent the possible creation of a fake GSP in case of a poor location accuracy for a stroke, i.e., if |Ip| < 6kA and/or SMA > 2 km then stroke automatically assigned to previous GSP.

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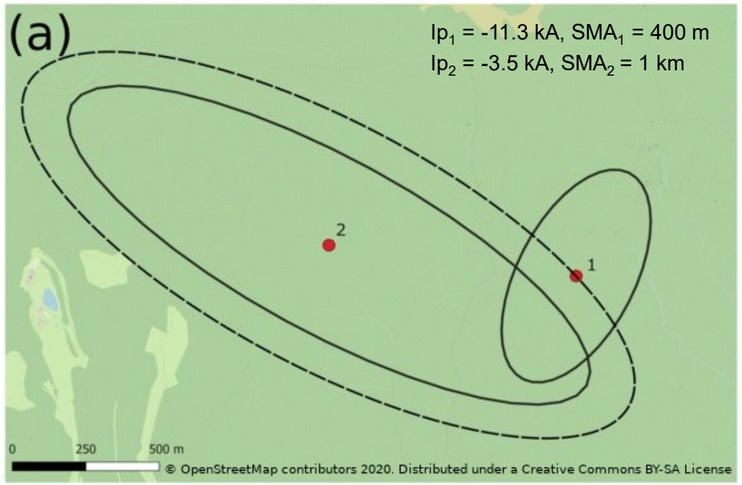

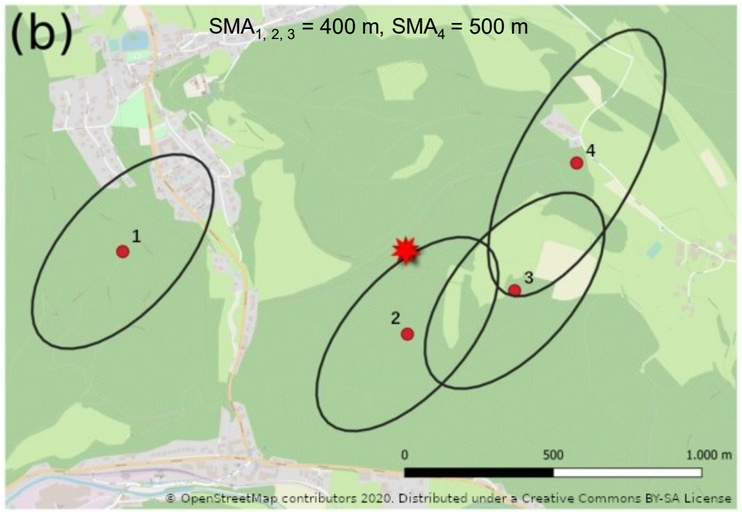

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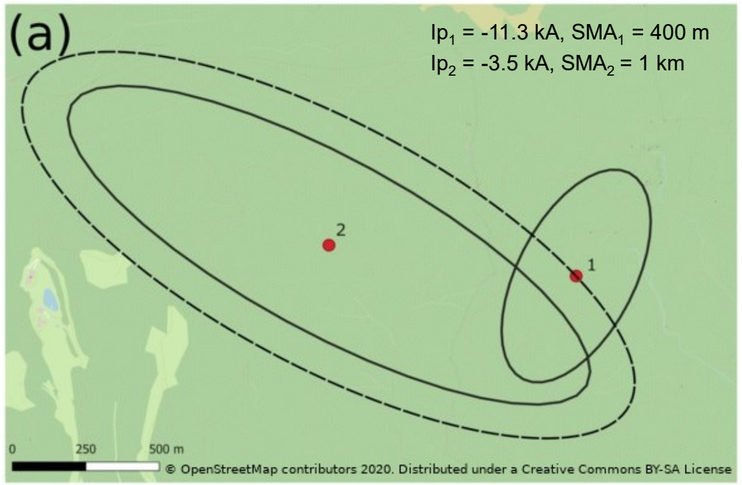

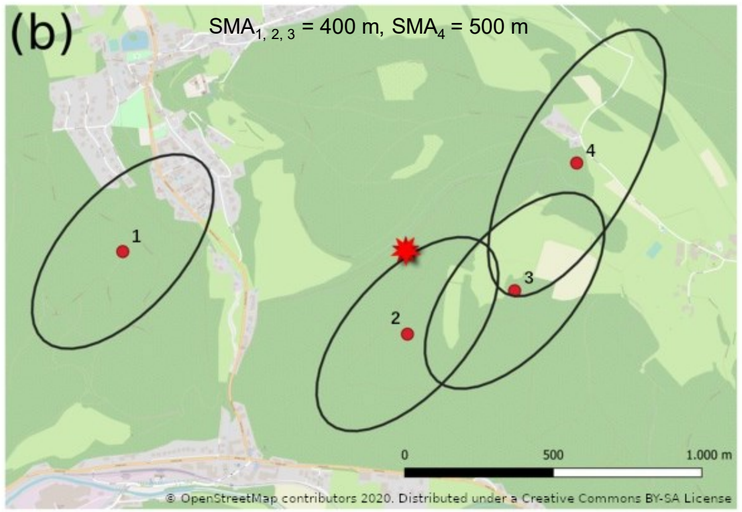

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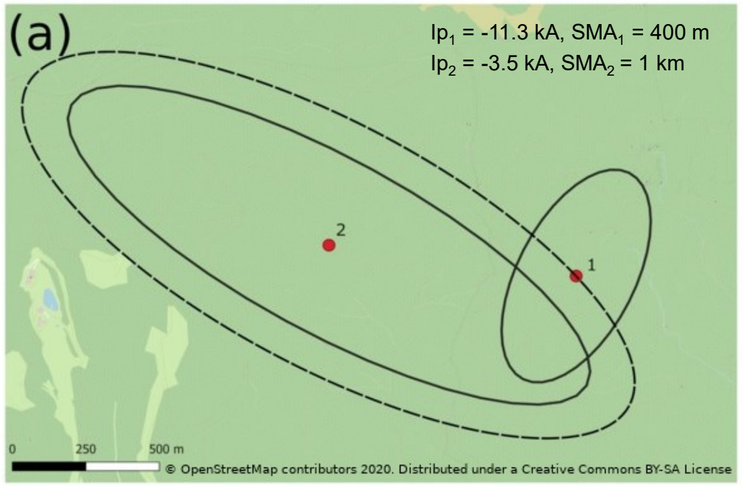

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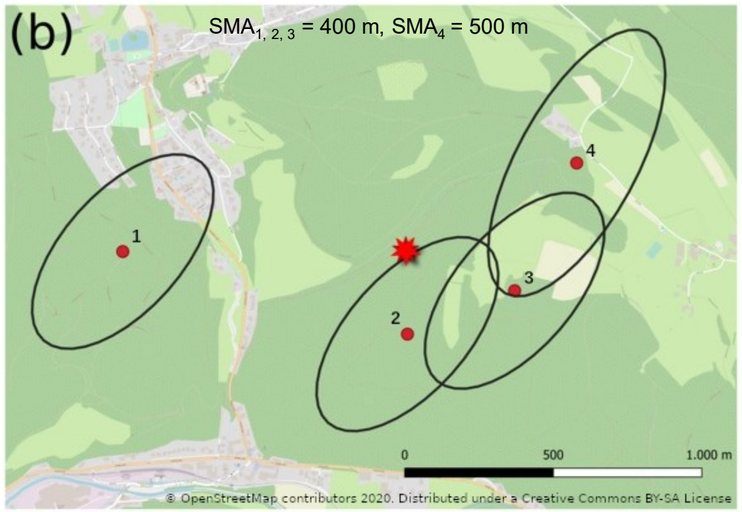
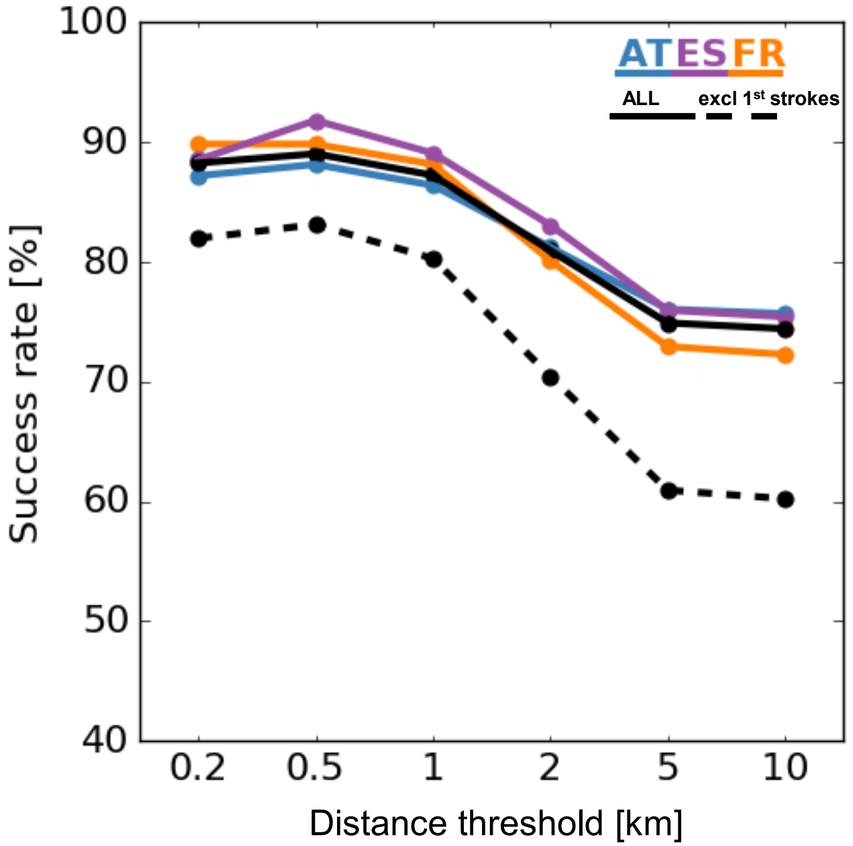


- If threshold_distance = 200 m, A1 will create 4 GSPs.
- If threshold_distance = 1 km, A1 will create 1 GSP.

GSP algorithms: results



- Success rates of up to 90% to retrieve the correct type of the stroke in the flash, i.e., new ground contact (NGC) or pre-existing channel (PEC).
- Success rate drops by ~5-10% when 1st strokes are excluded from the dataset

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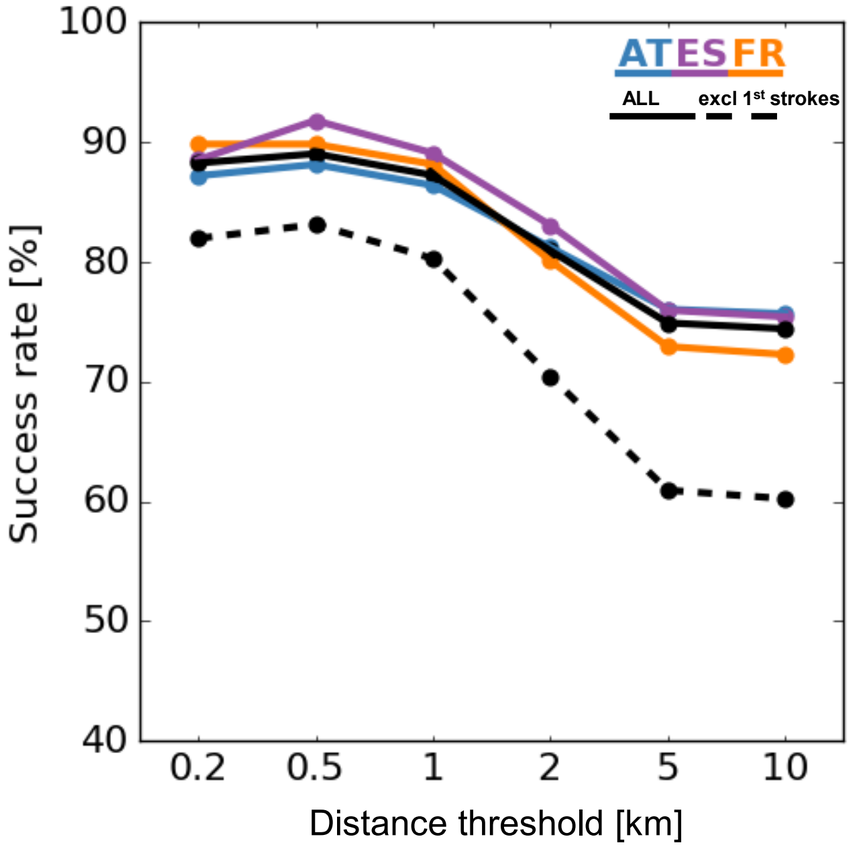

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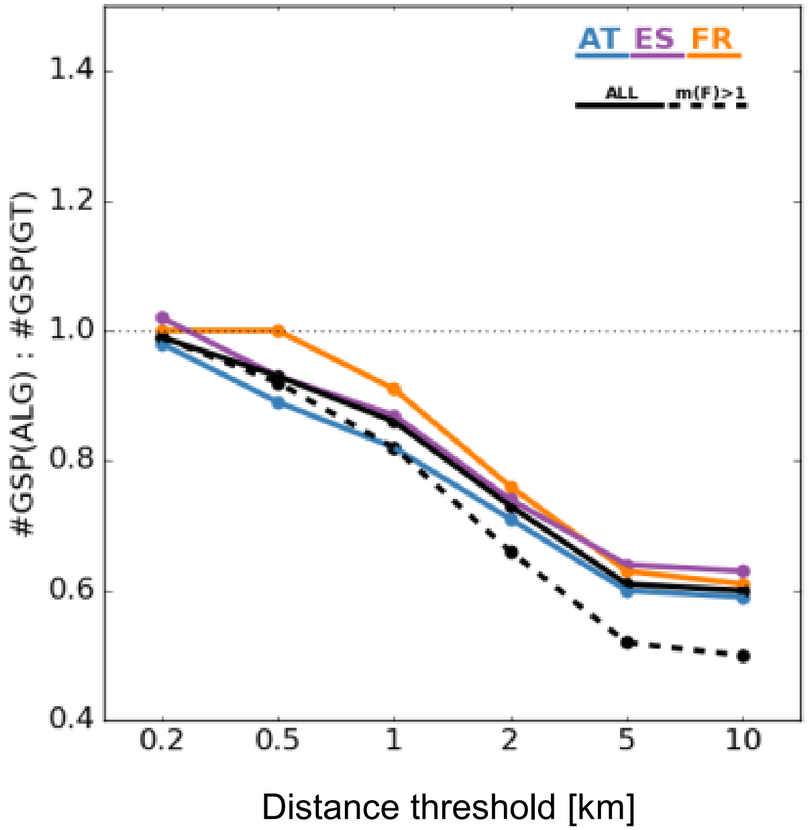
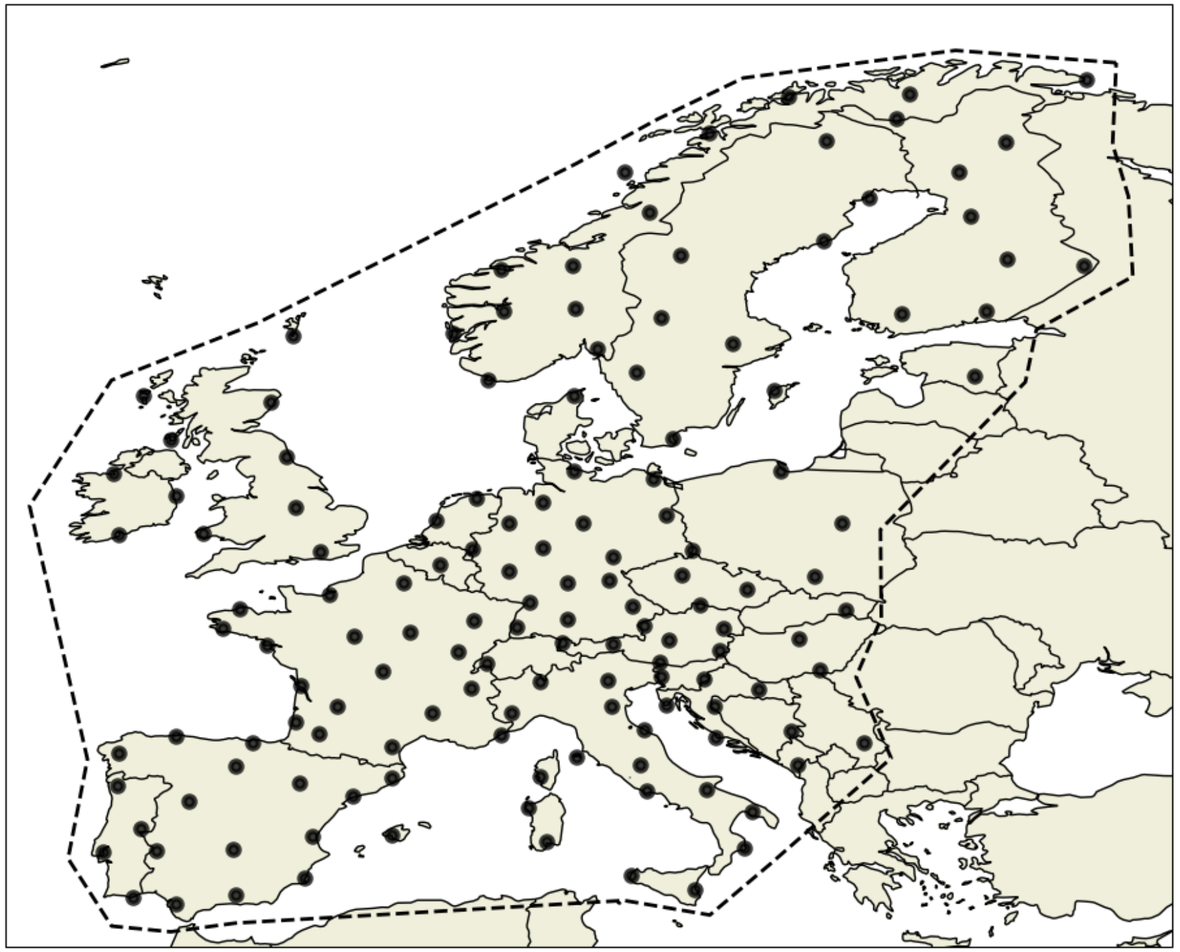


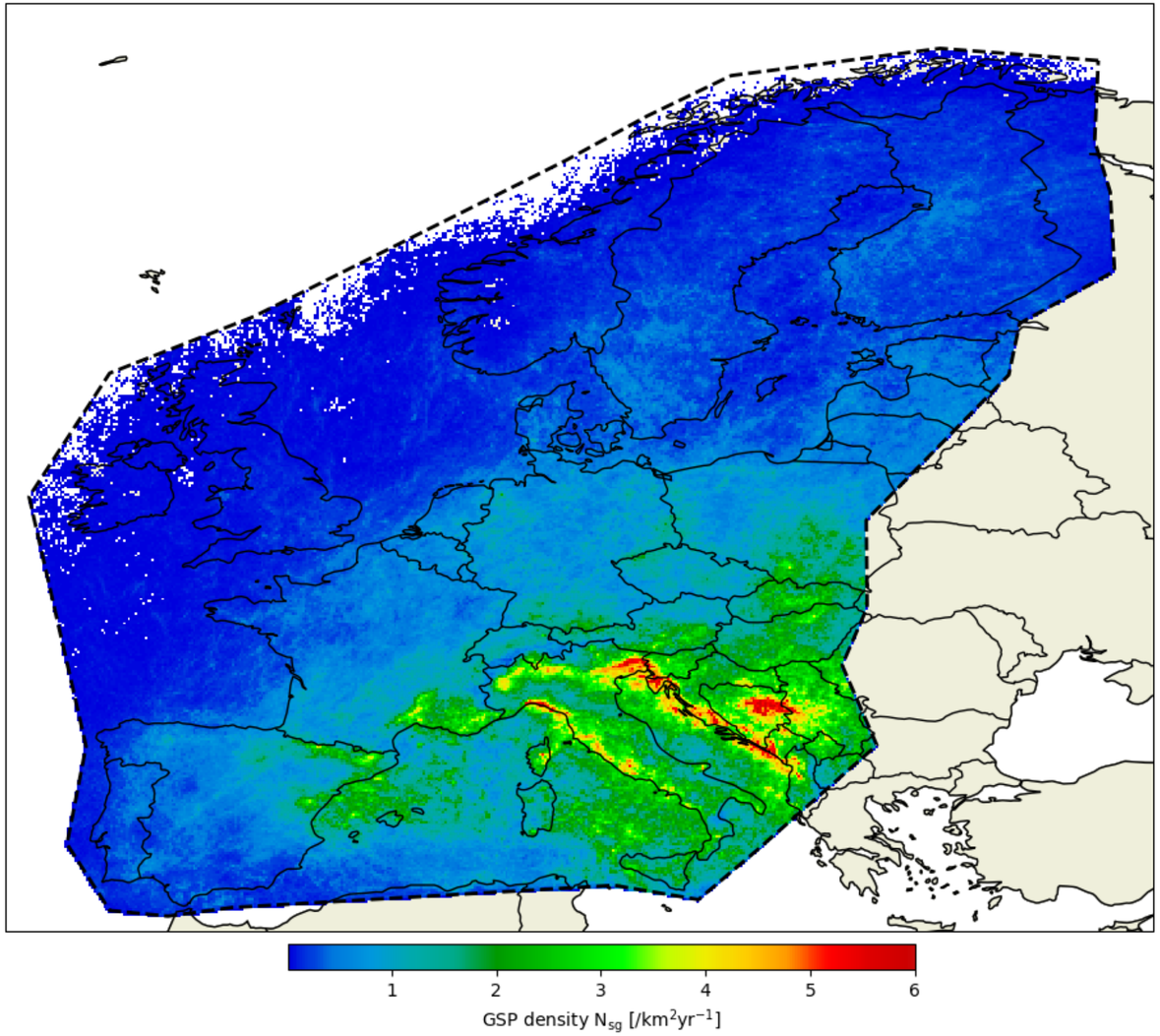
- A ratio greater/smaller than 1 indicates an over/underestimation of the number of GSPs by the GSP algorithm
- Applying a distance threshold of 500m, the GSP algorithm underestimates the number of GSP by ~5% for the 3 data sets combined.

LLS observations: EUCLID



- European Cooperation for Lightning Detection.
- Location of sensors indicated as black dots.
- Dashed polygon highlights the area within which EUCLID performs at its best.
- Flash DE > 95%.
- Stroke DE ~ 85%.
- Median LA ~ 150m.
- In this study data from 2013-2022 are used

LLS observations: N_{sg}



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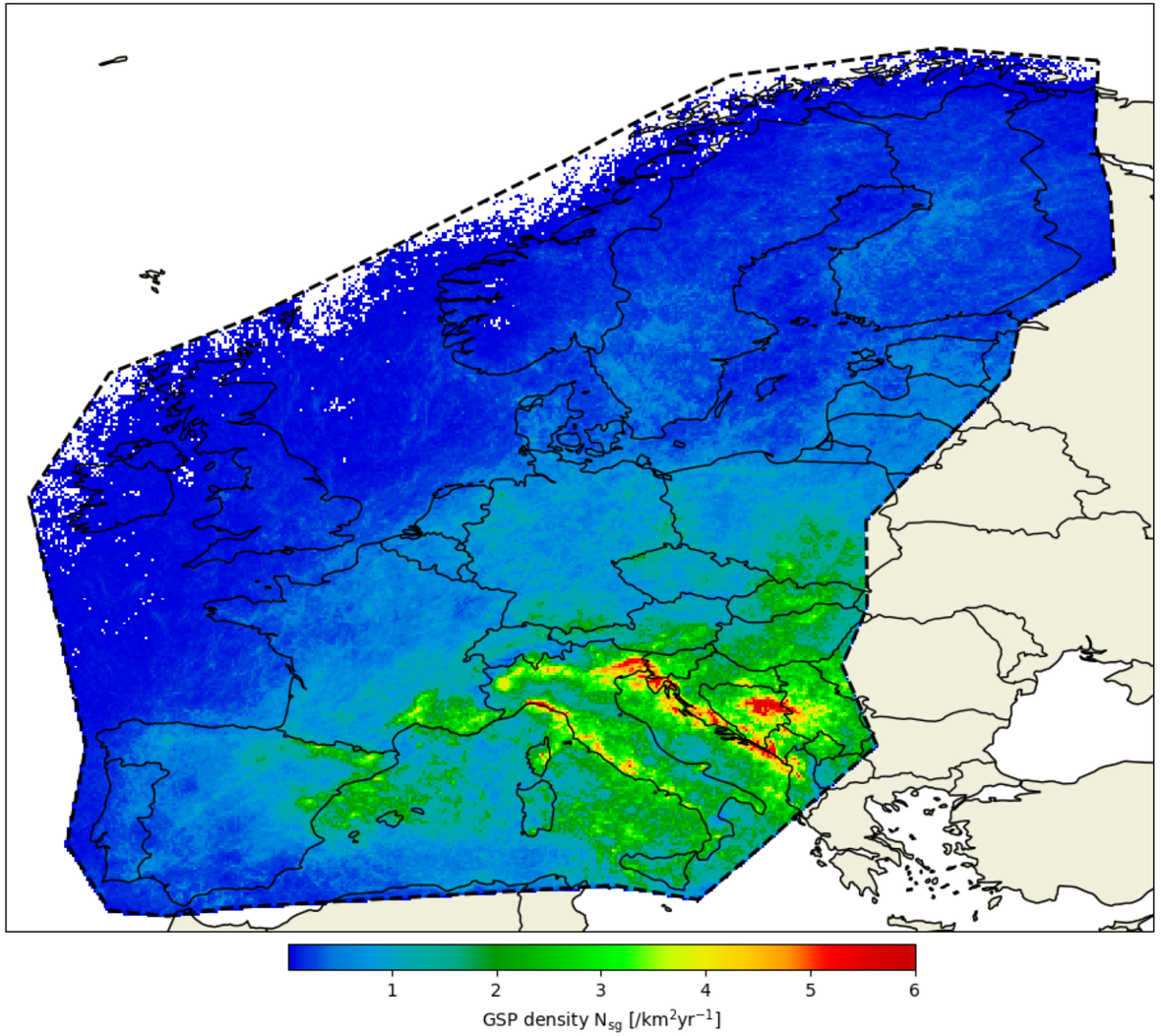
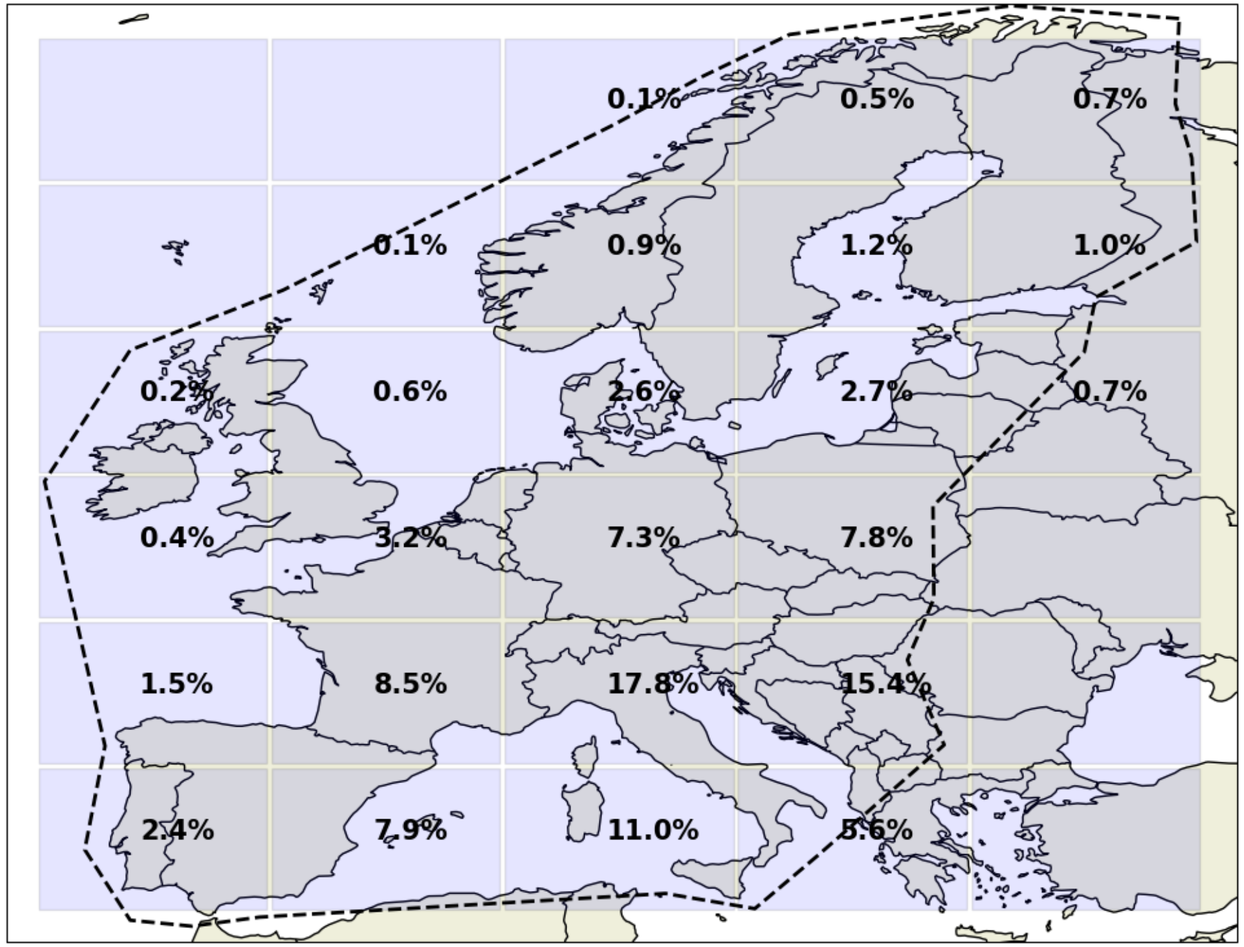
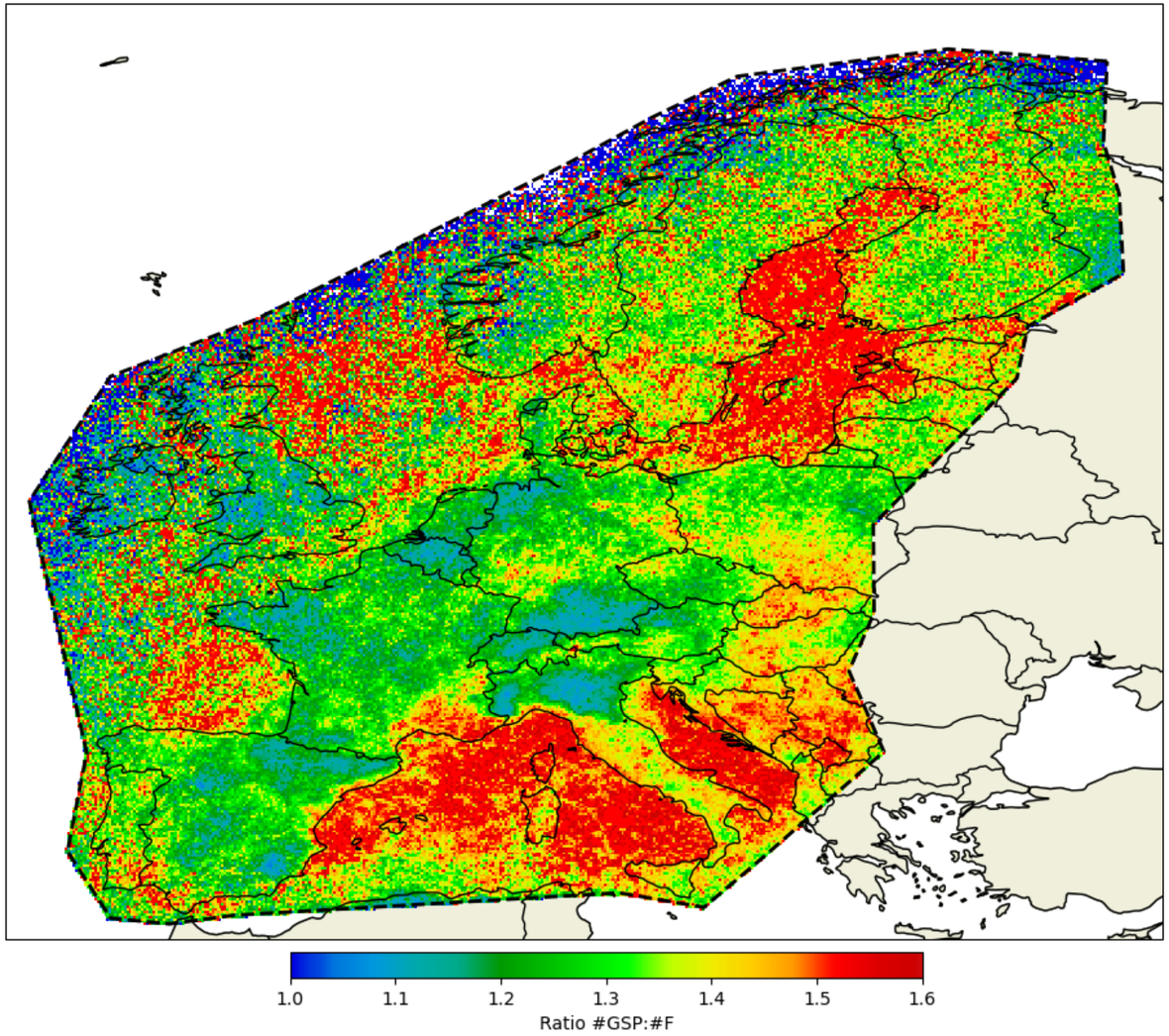




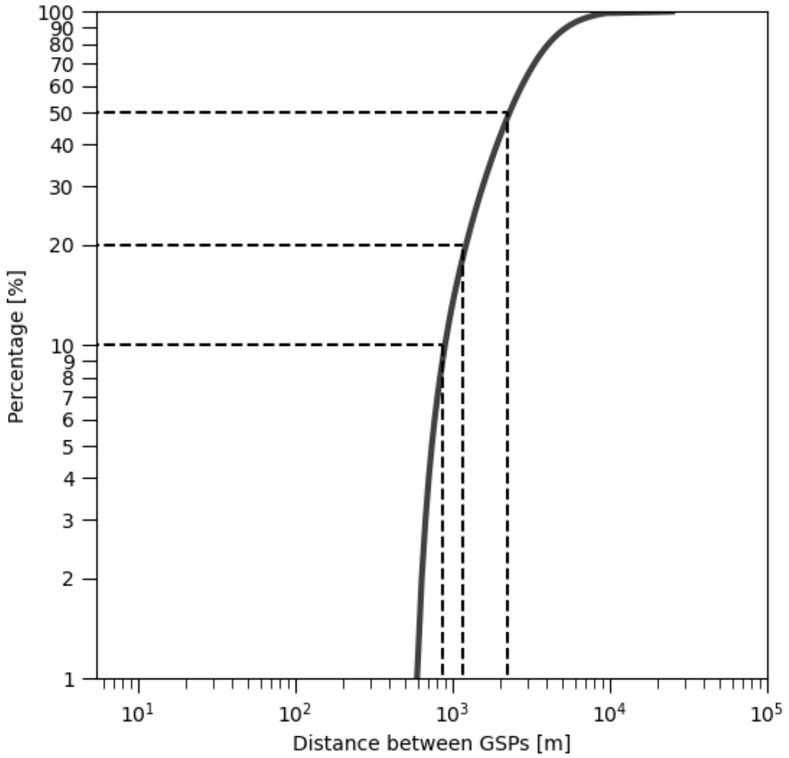
Proportion GSPs

LLS observations: #GSP / #F



- Median = 1.35
- Median land = 1.32
- Median sea = 1.42

LLS observations: separation distance GSPs



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- 20% < 1.2 km
- 50% < 2.2 km
- 95% < 6.7 km

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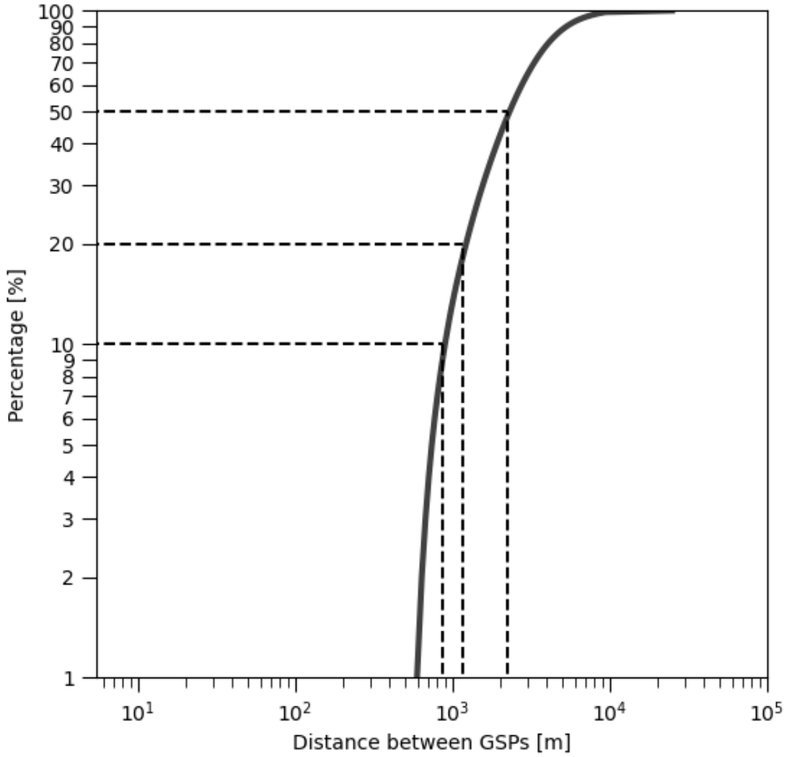

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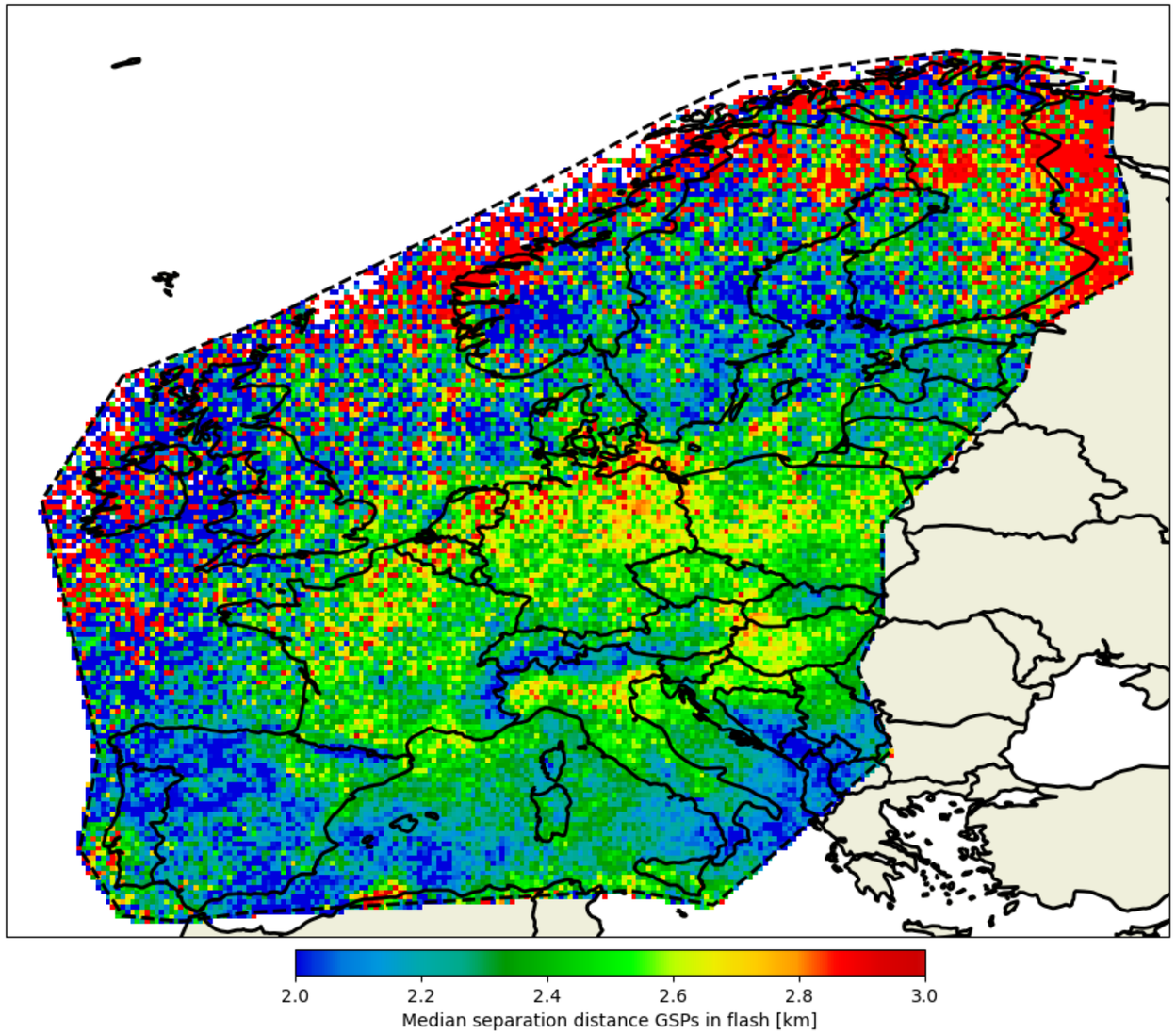

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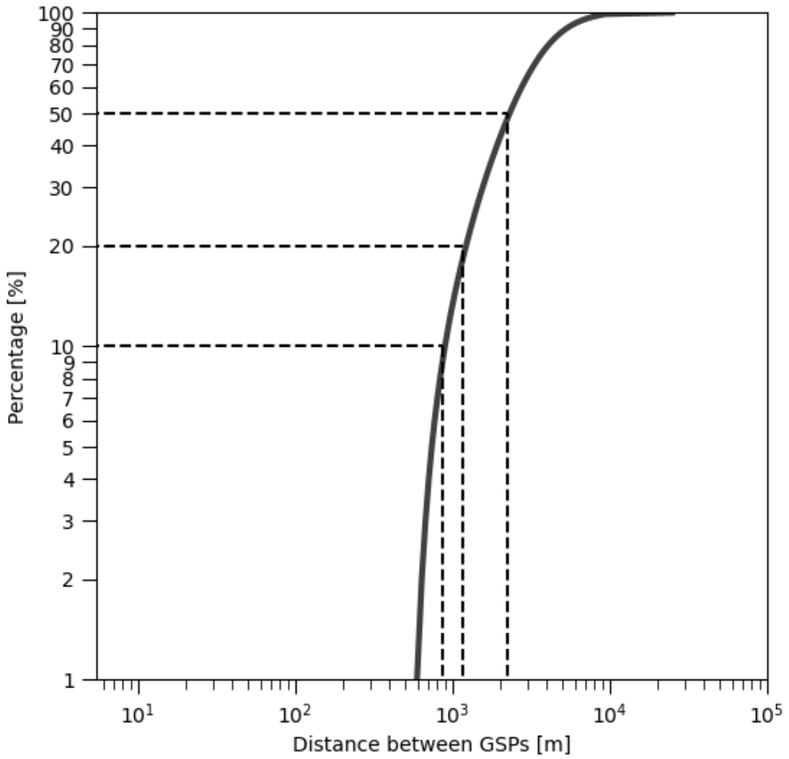

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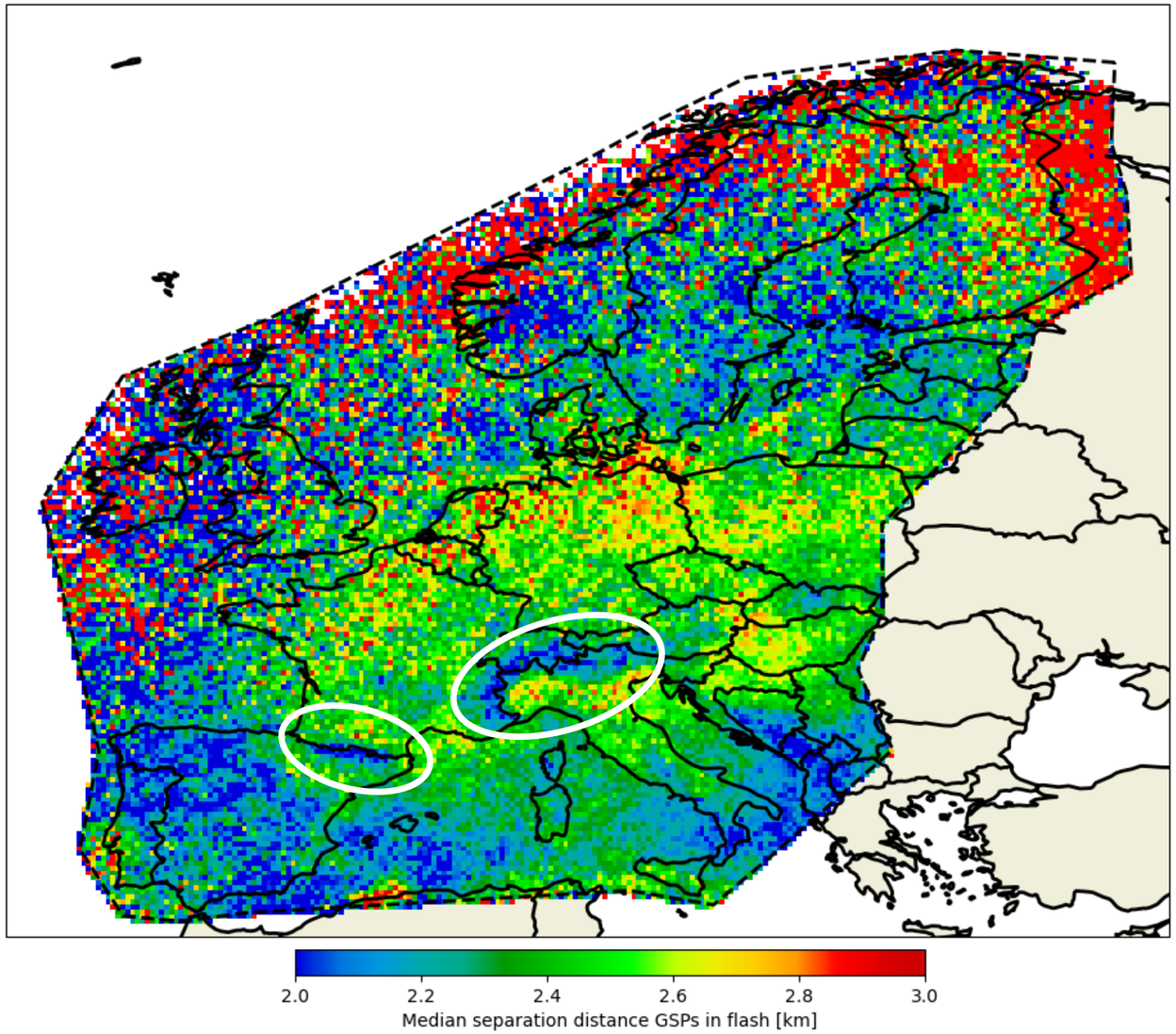
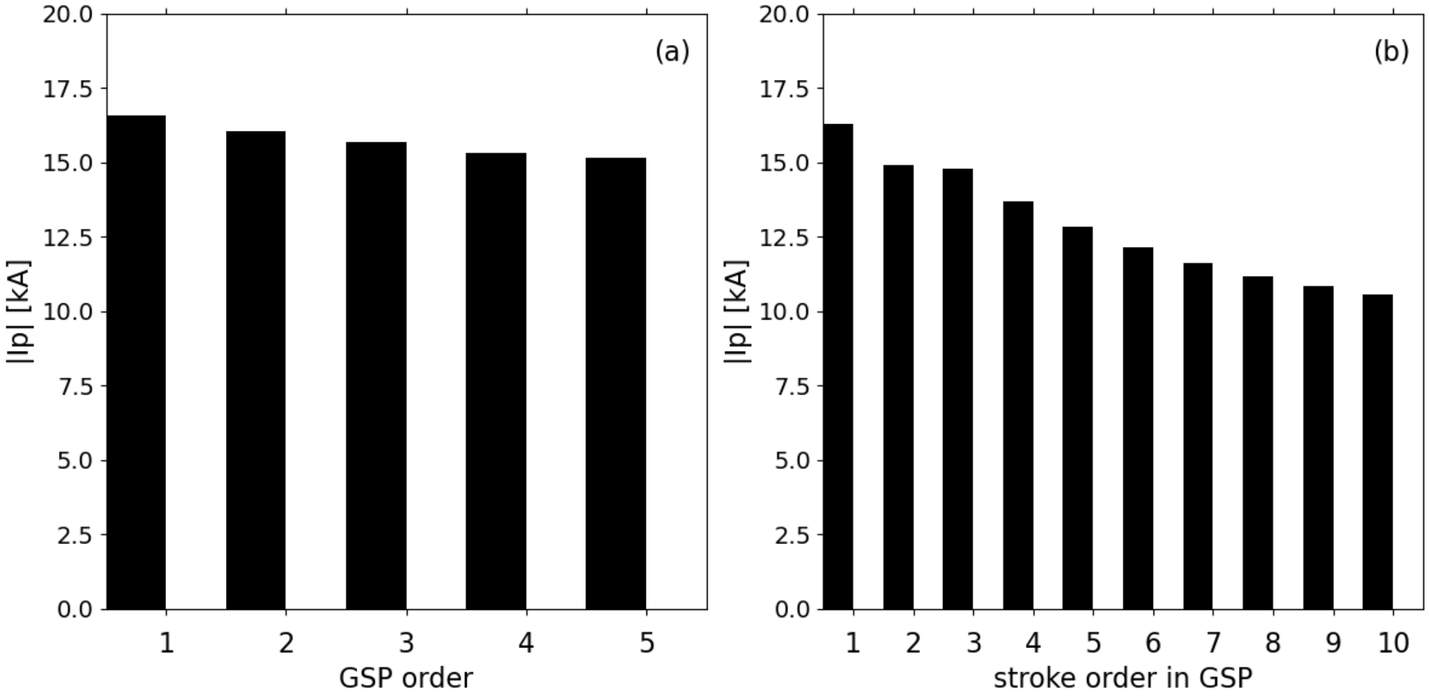


LLS observations: peak current GSPs



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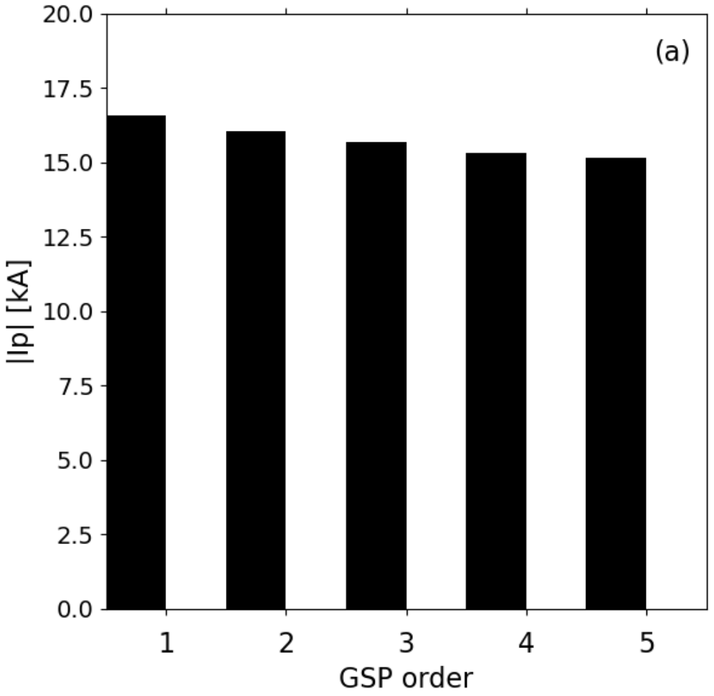

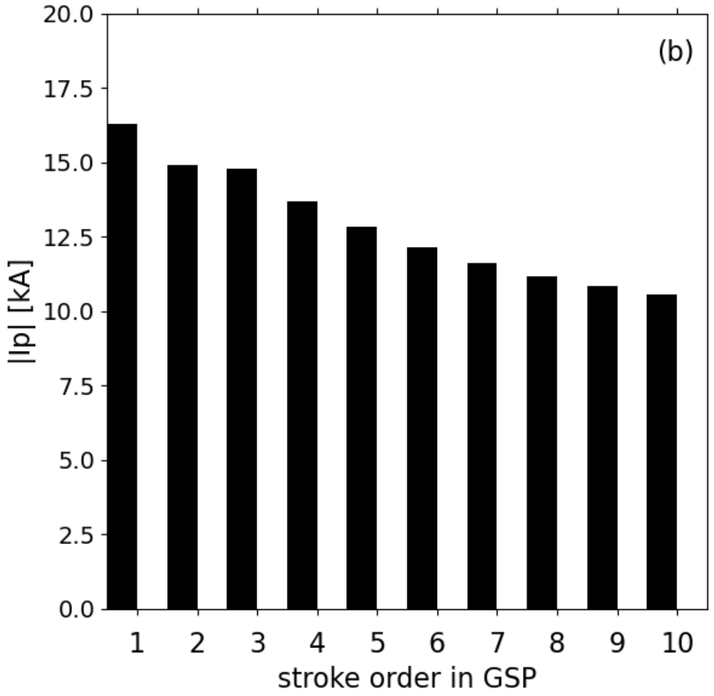

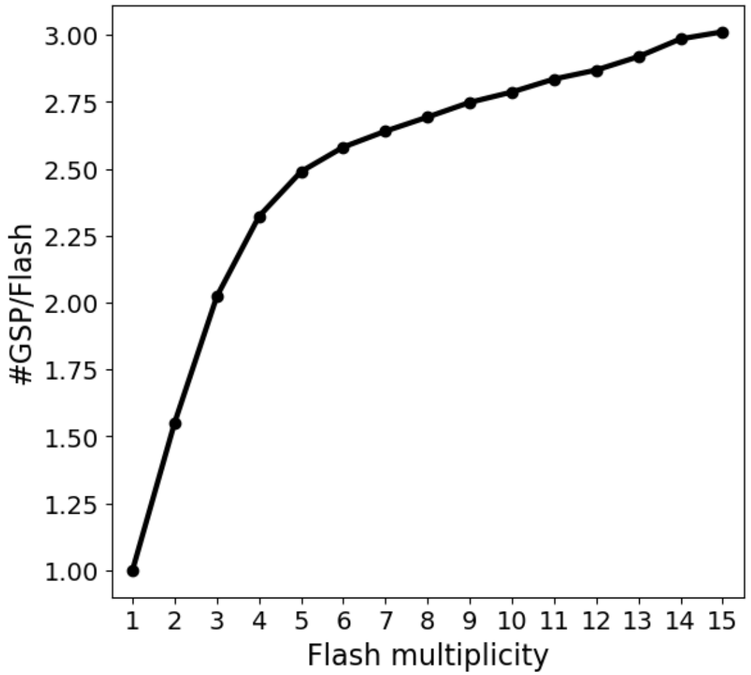

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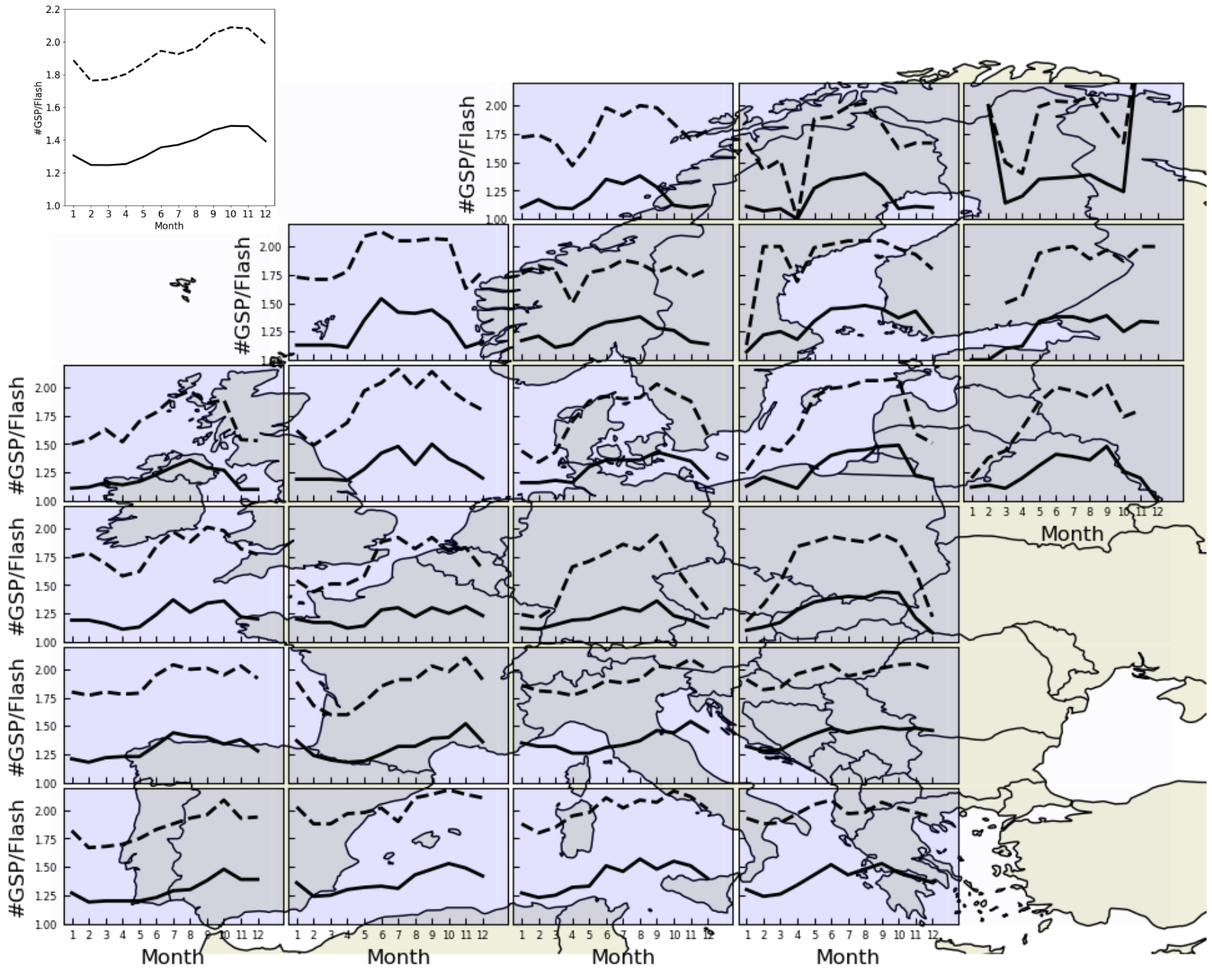
- #GSP/flash proportional with flash multiplicity

LLS observations: monthly distribution



Excluding single stroke flashes

All flashes

- #GSPs per flash in general highest in Oct-Dec
- Similar trend over land & sea

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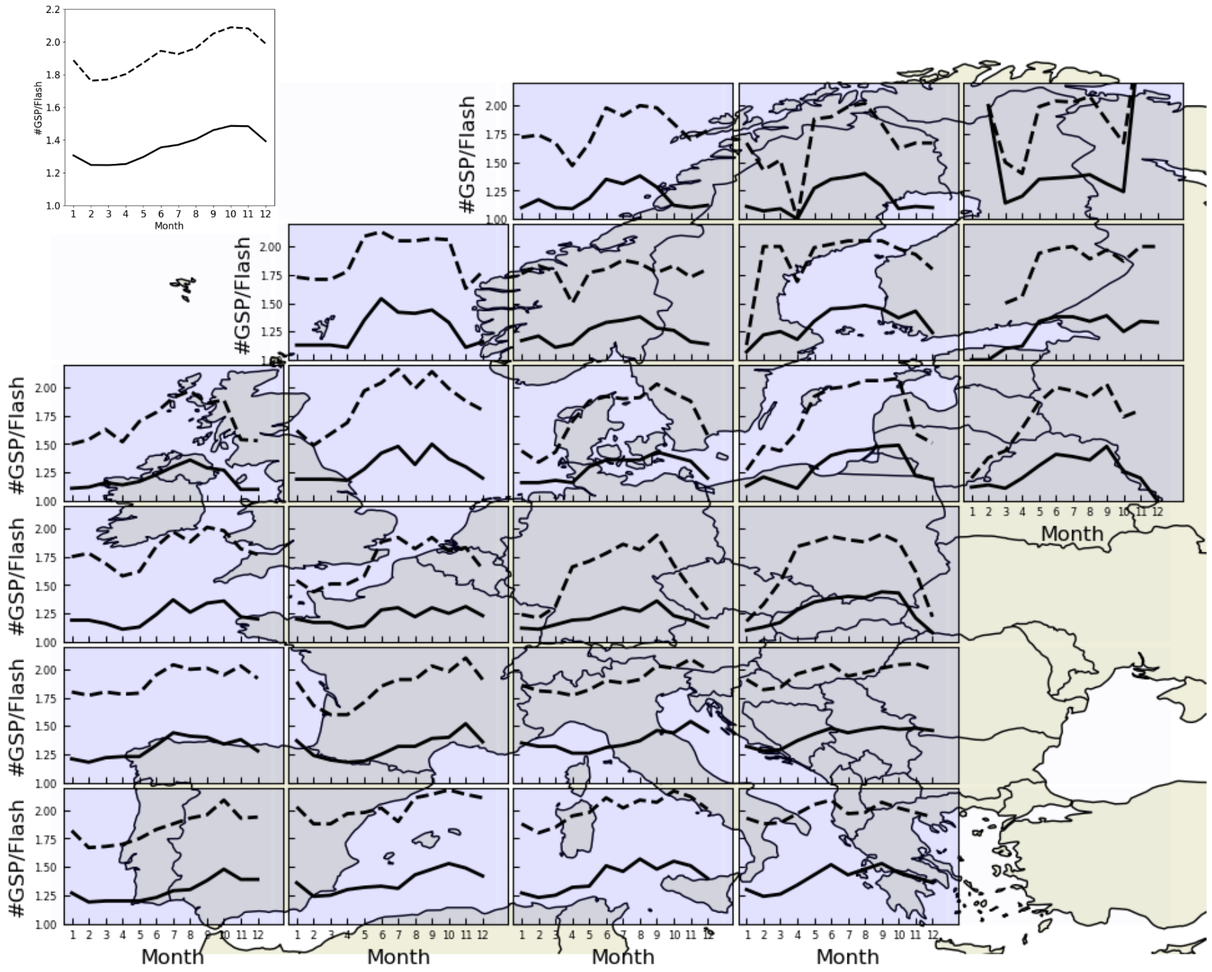

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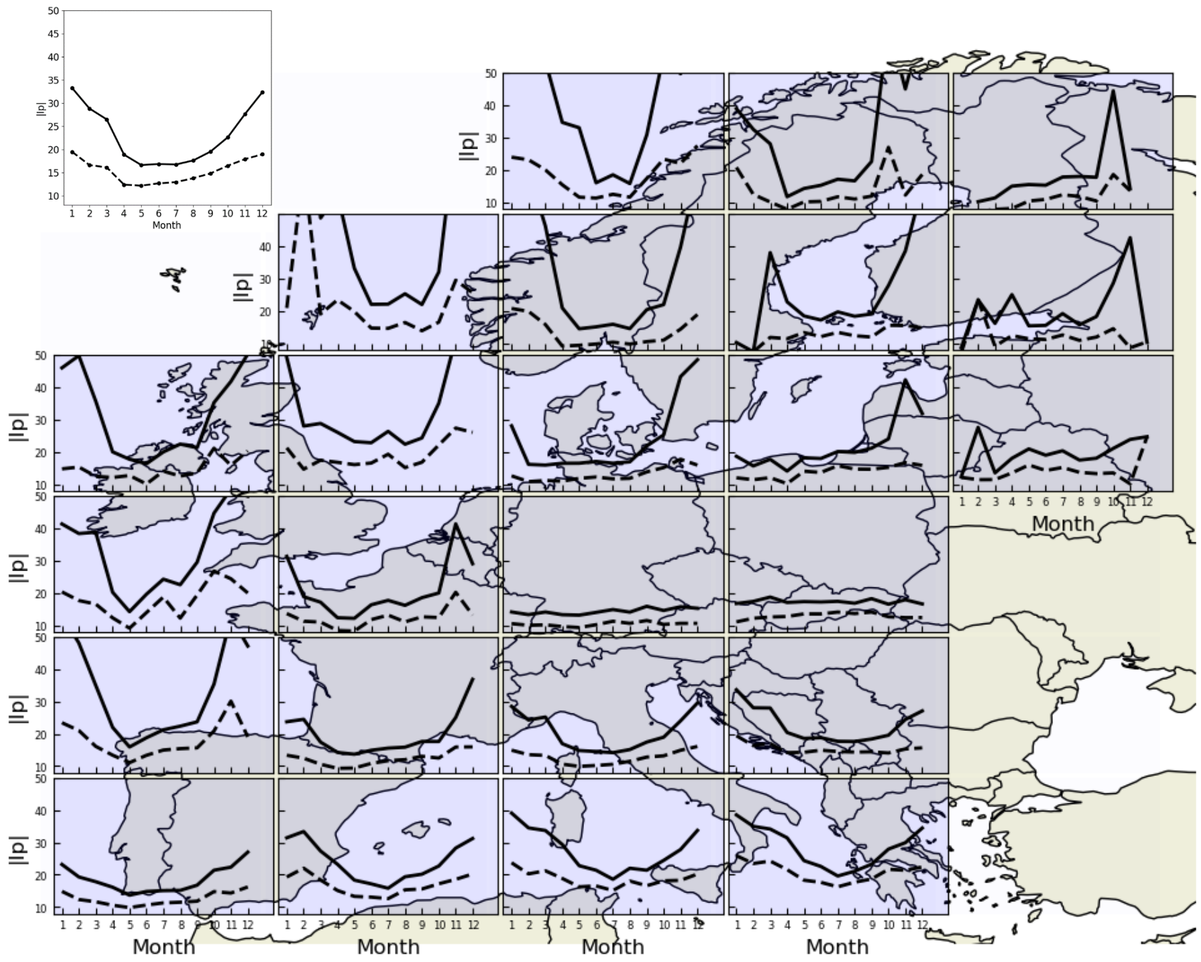
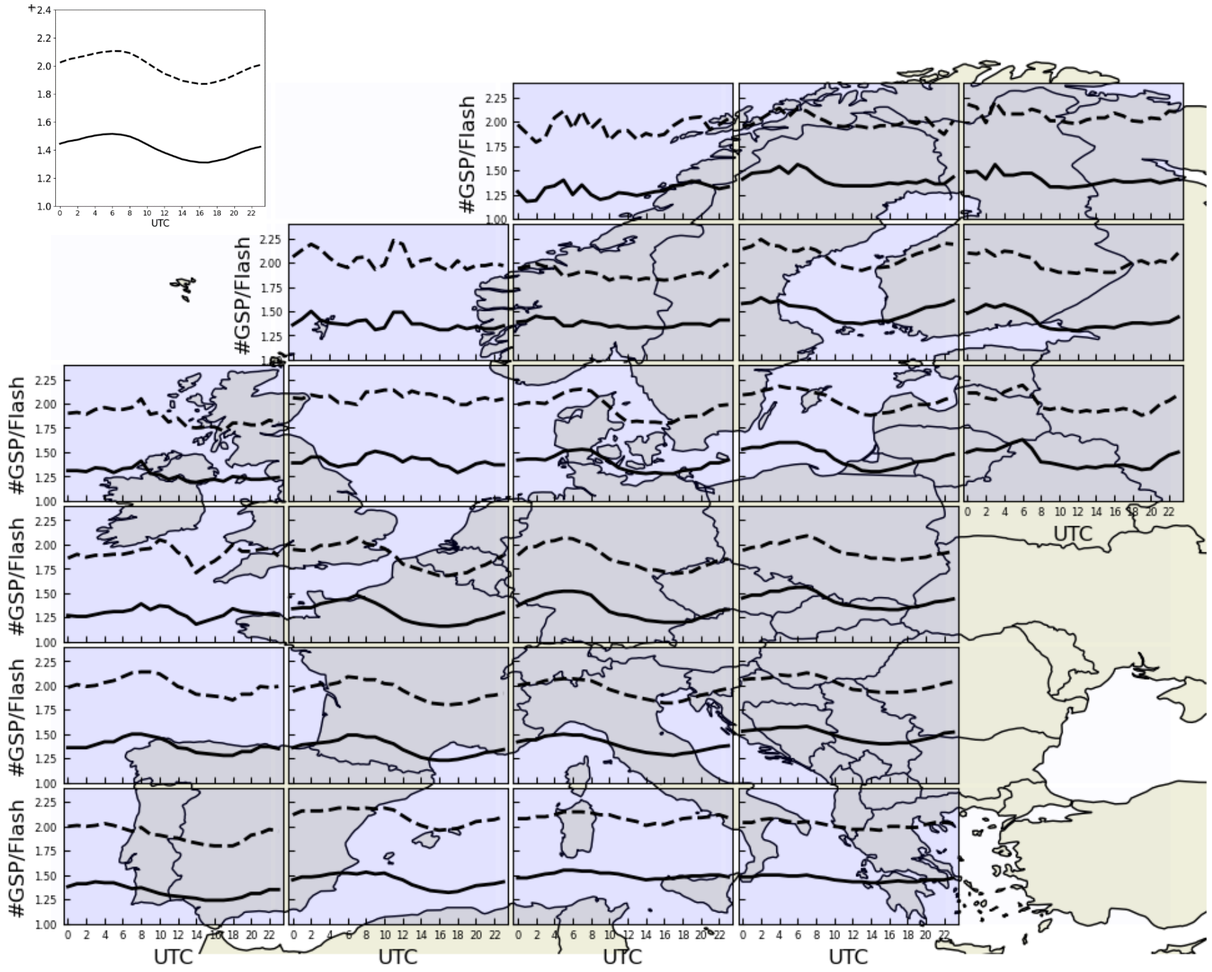


- |I|p| higher in cold season
- Similar trend over land & sea
- Can this explain the monthly distribution in #GSPs per flash?

LLS observations: hourly distribution



Excluding single stroke flashes

All flashes

- #GSPs per flash in general lowest between 12-18UTC
- Similar trend over land & sea

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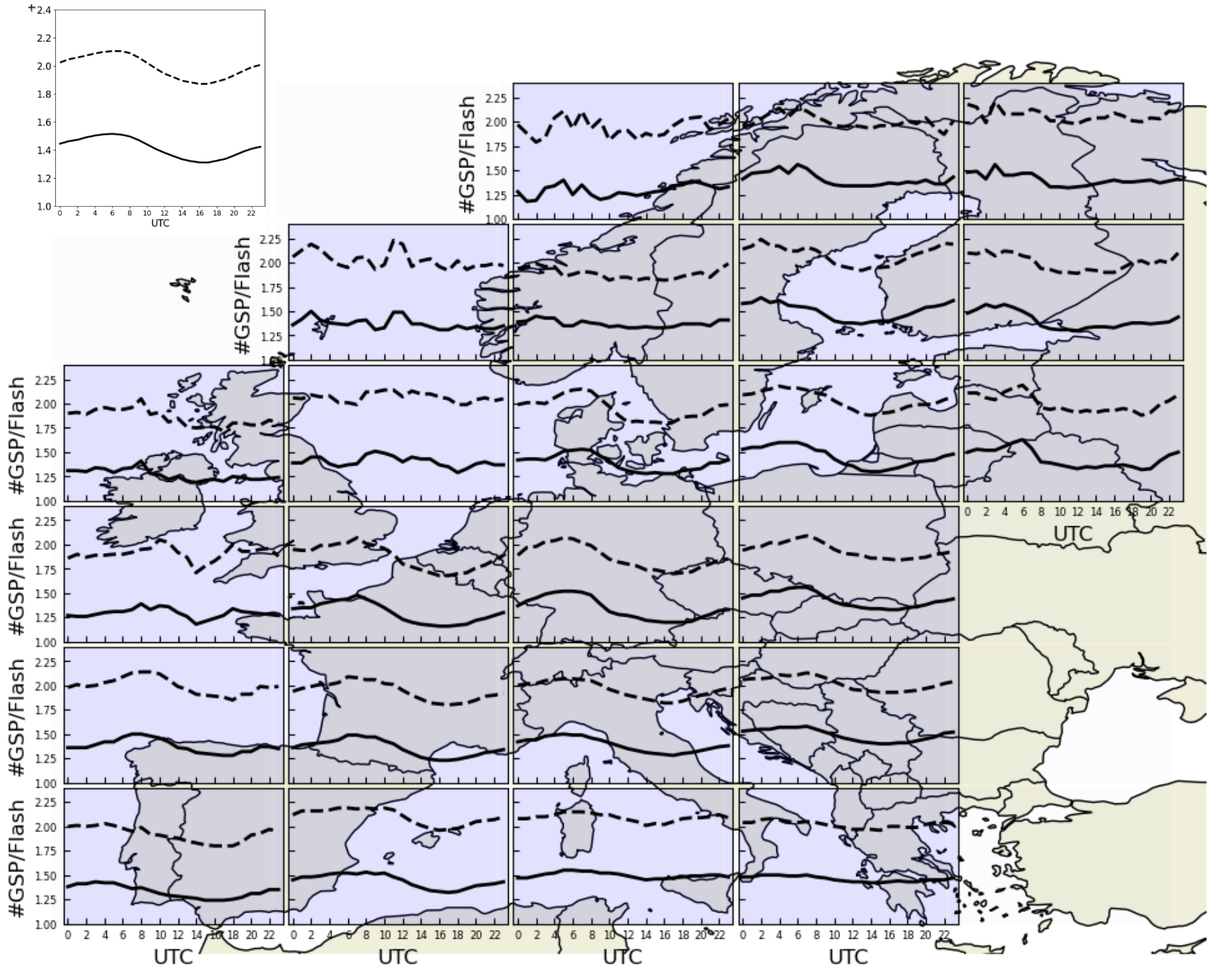

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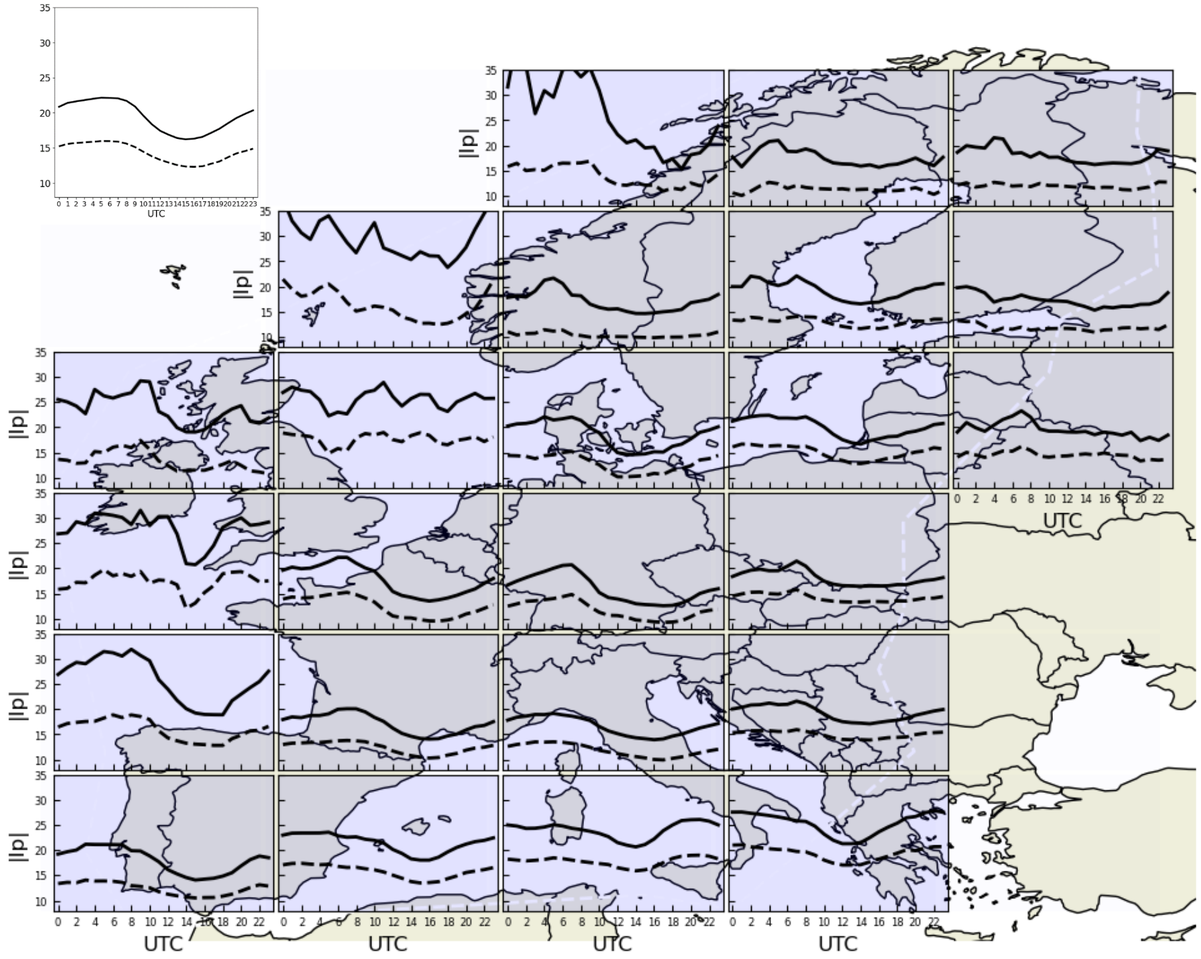

Mean

Median

- |I| lowest between 12-18UTC
- Similar trend over land & sea
- Can this explain the hourly distribution in #GSPs per flash?

Conclusions

- On average more than 1 GSP is observed per flash, hence the use of N_G in risk calculation of lightning protection leads to an underestimation of the hazard.

- Ground strike point algorithms exist grouping individual strokes into ground strike points. GSP algorithms accurately estimate the number of GSPs compared to ground truth data.

- Ingesting LLS observations in GSP algorithms provide a means to study GSP characteristics on a larger temporal and spatial scale.

APL 2023

12TH ASIA-PACIFIC INTERNATIONAL CONFERENCE ON LIGHTNING (APL 2023)

Thank You