EVALUATING SURCES OF UNCERTAINTY AND VARIABILITY IN ROCK GLACIER INVENTORIES

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Chambery, 20.03.2019

GENERAL OBJECTIVE

Quantify **uncertainty** and **variability** in rock glacier inventories compiled by **different operators** from RS imagery → **provide range of variability**

THREE MAPPING EXERCISES

1) We asked **6 operators** to map and assess the degree of activity of **all rock glaciers** they could **identify**: first, on **Google Earth** (GE) imagery, and then on **higher resolution** orthophotos and LiDAR-derived images (LO)

→ The effect of operator's **mapping style** and **imagery resolution** on:
   (i) **Number** of rock glaciers identified
   (ii) **Total** rock glacier **area**
   (iii) **Size** of single rock glaciers
   (iii) **Minimum** and **maximum** rock glacier **elevation** for relict and intact at the basin scale

OPERATORS: Guillermo Felipe Azócar Sandoval, Renato Roberto Colucci, Daniel Falaschi, Andreas Kellerer-Pirklbauer, Robert Kenner, Kathrin Lang, Karianne Staalesen Lilleøren, Marco Marcer, Constance I. Millar, Umberto Morra di Cella, Alexandru Onaca, Lorenzo Rieg, Roberto Seppi, and David Tonidandel + paper co-authors.

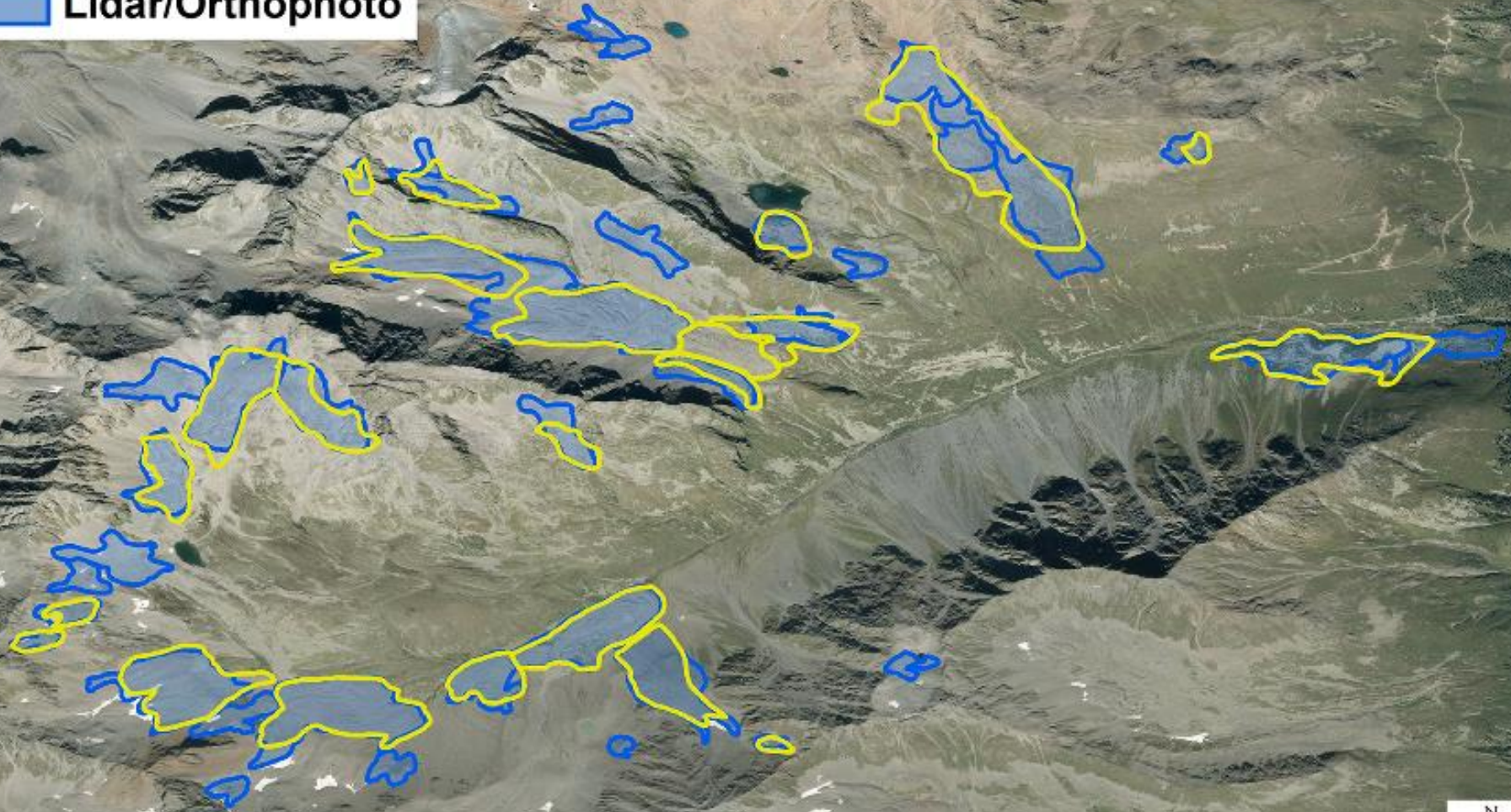# STUDY AREA: Kaiserbergtal (14 km^2) – western Ötztal Alps, Austria
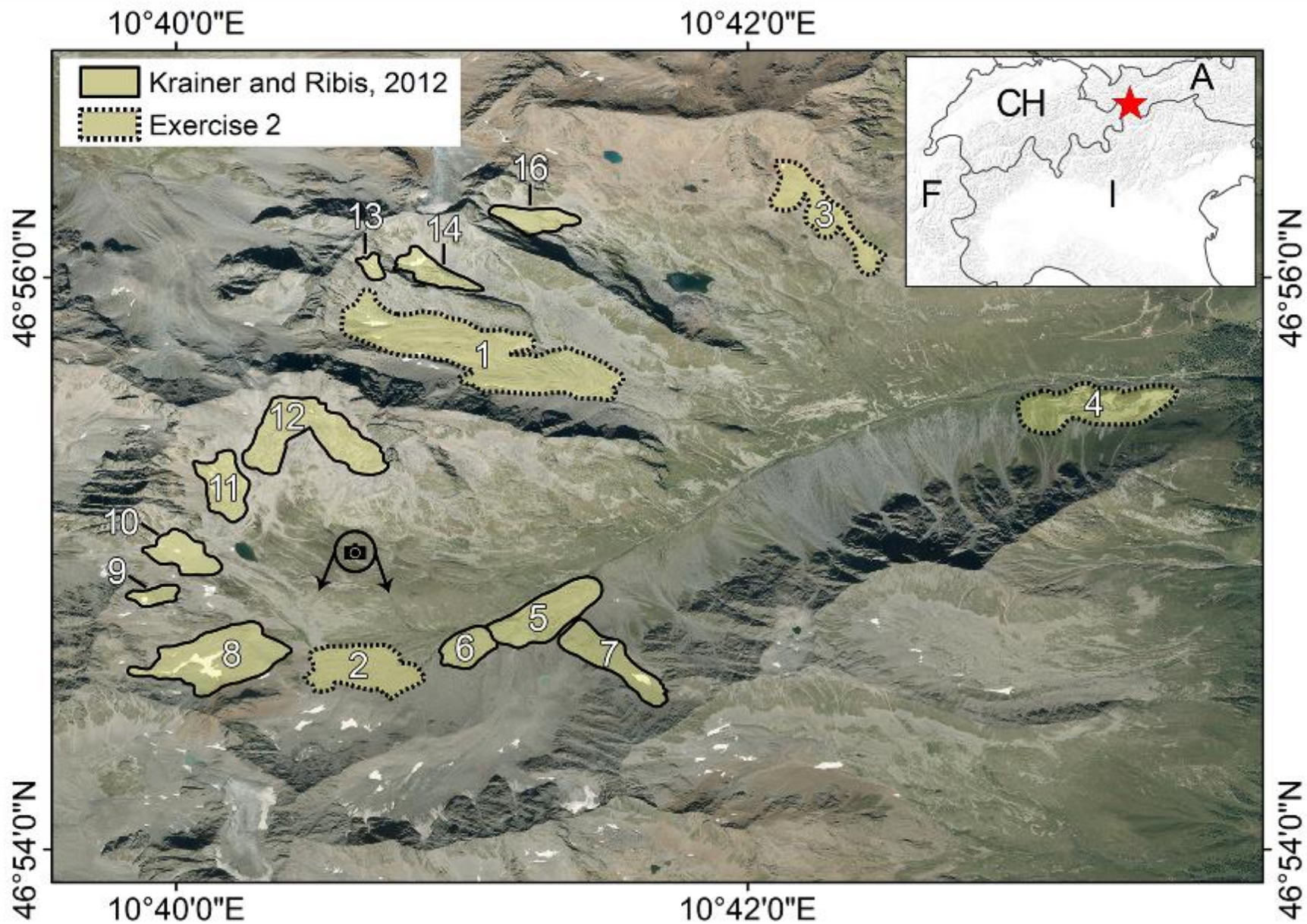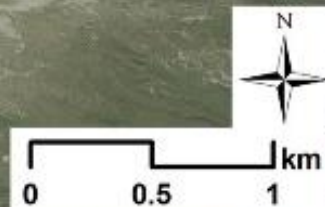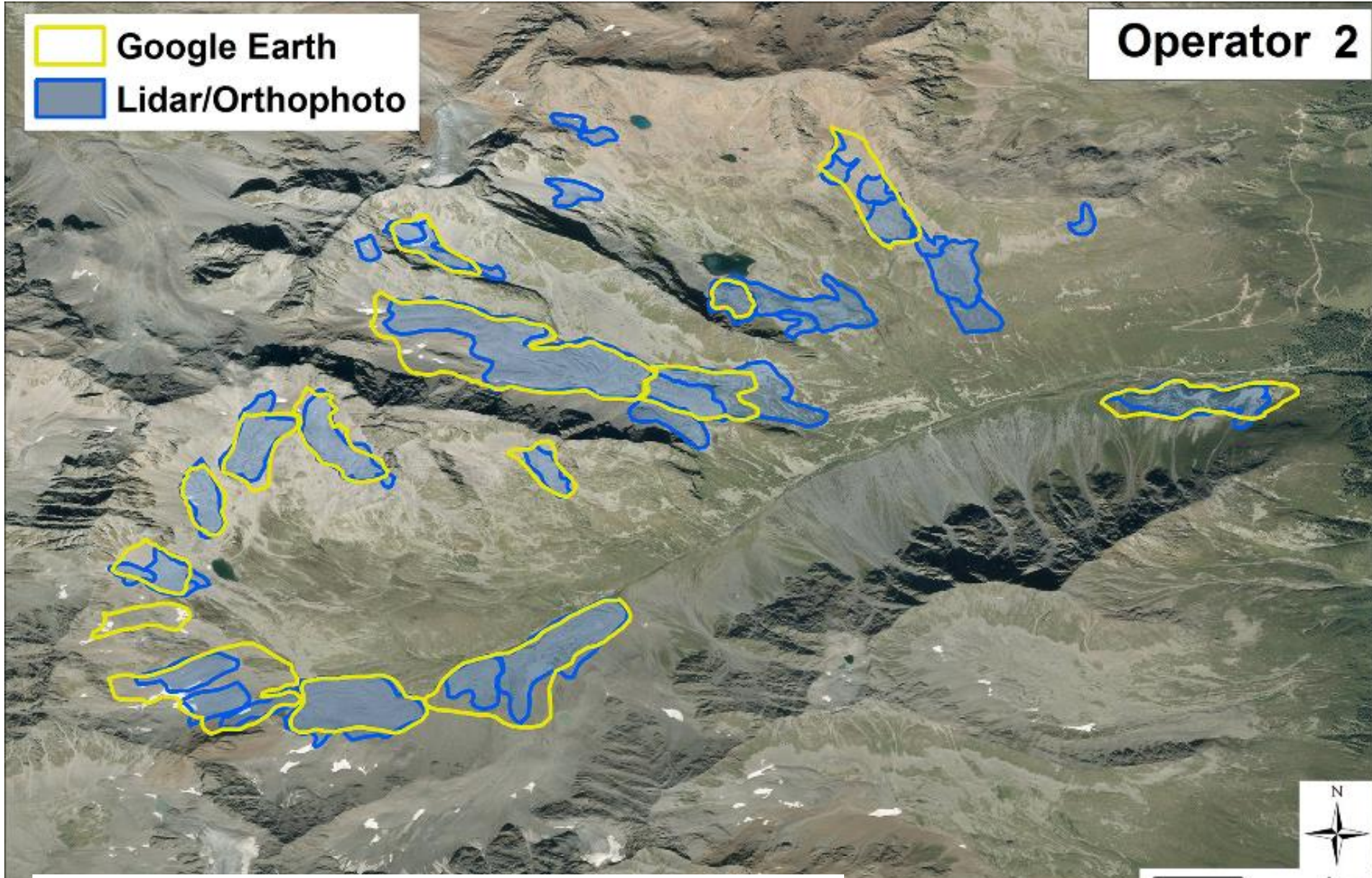

Modified from Brardinoni et al., in press in ESPL

EXERCISE 1: VALLEY-WIDE MAPPING TEST (6 operators)

Legend:
- Google Earth
- Lidar/Orthophoto

Operator 1

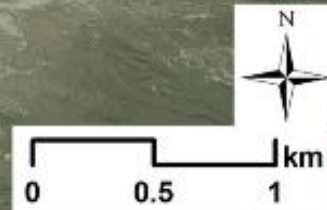*Modified from Brardinoni et al., in press in ESPL*

EXERCISE 1: VALLEY-WIDE MAPPING TEST (6 operators)

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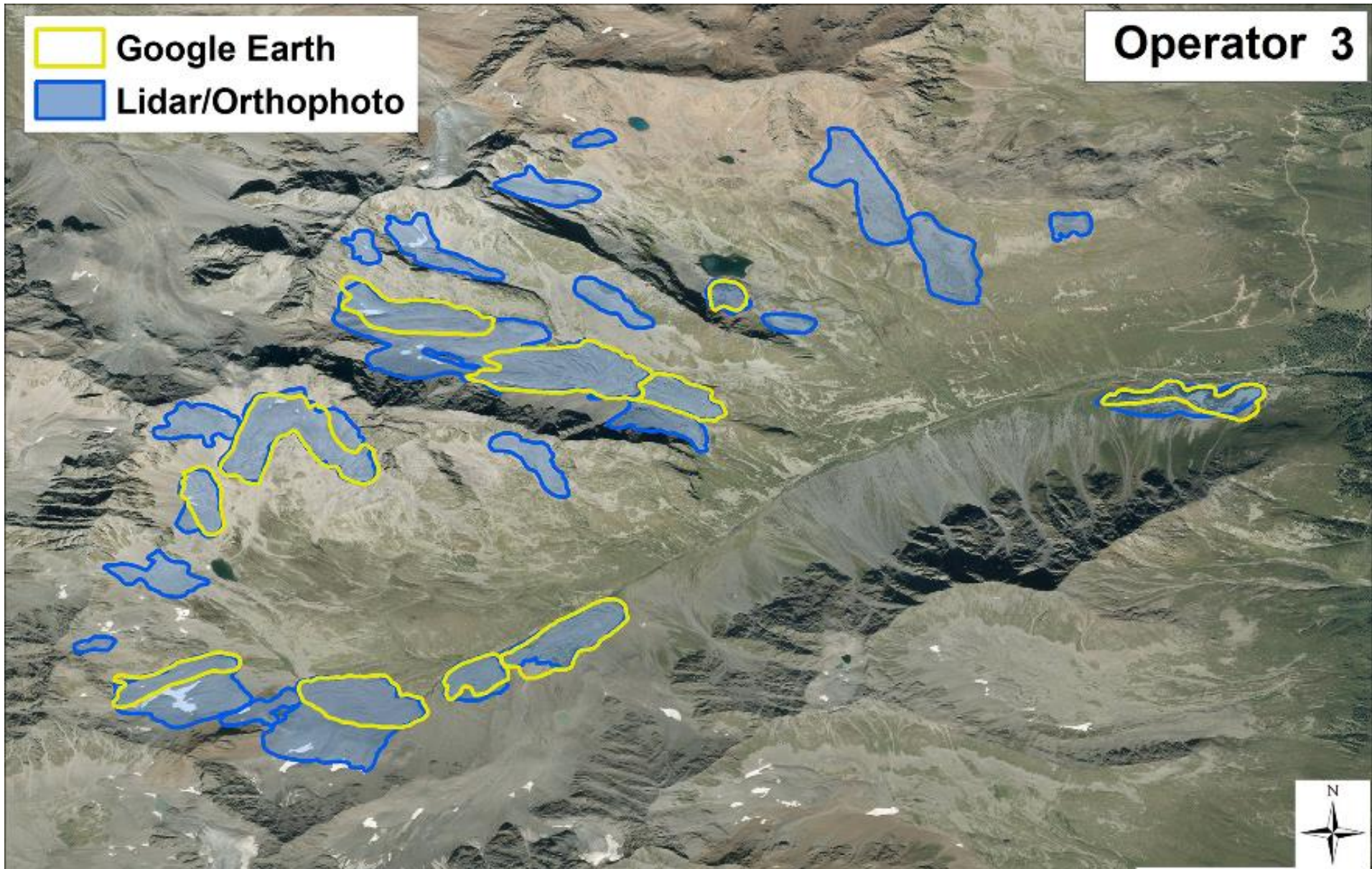- Google Earth
- Lidar/Orthophoto

Operator 2

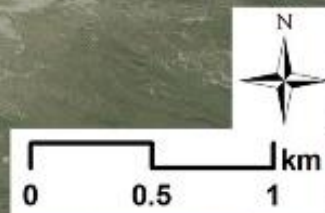*Modified from Brardinoni et al., in press in ESPL*

EXERCISE 1: VALLEY-WIDE MAPPING TEST (6 operators)

Google Earth
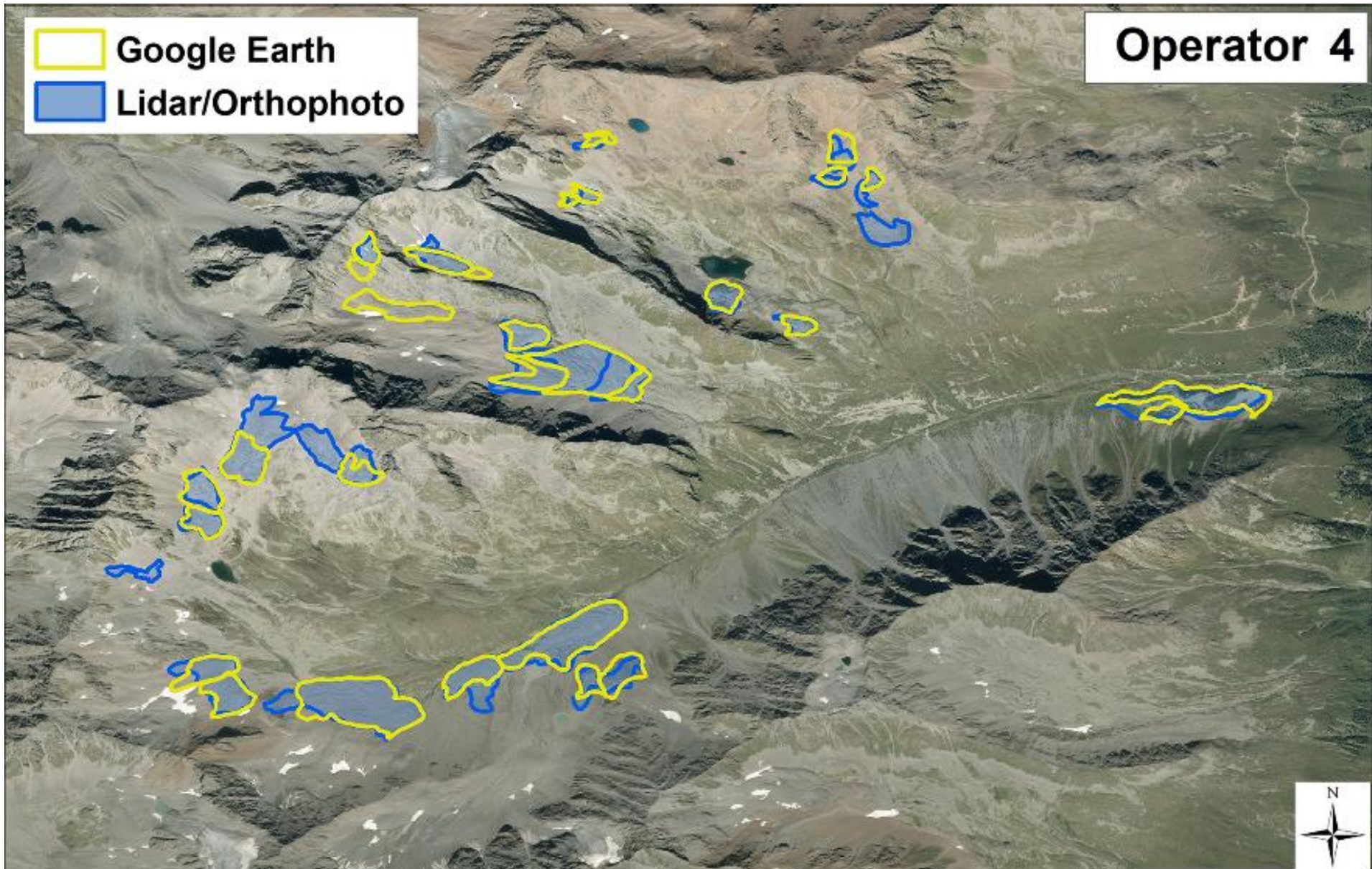Lidar/Orthophoto

Operator 3

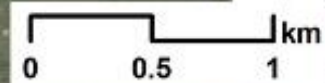*Modified from Brardinoni et al., in press in ESPL*

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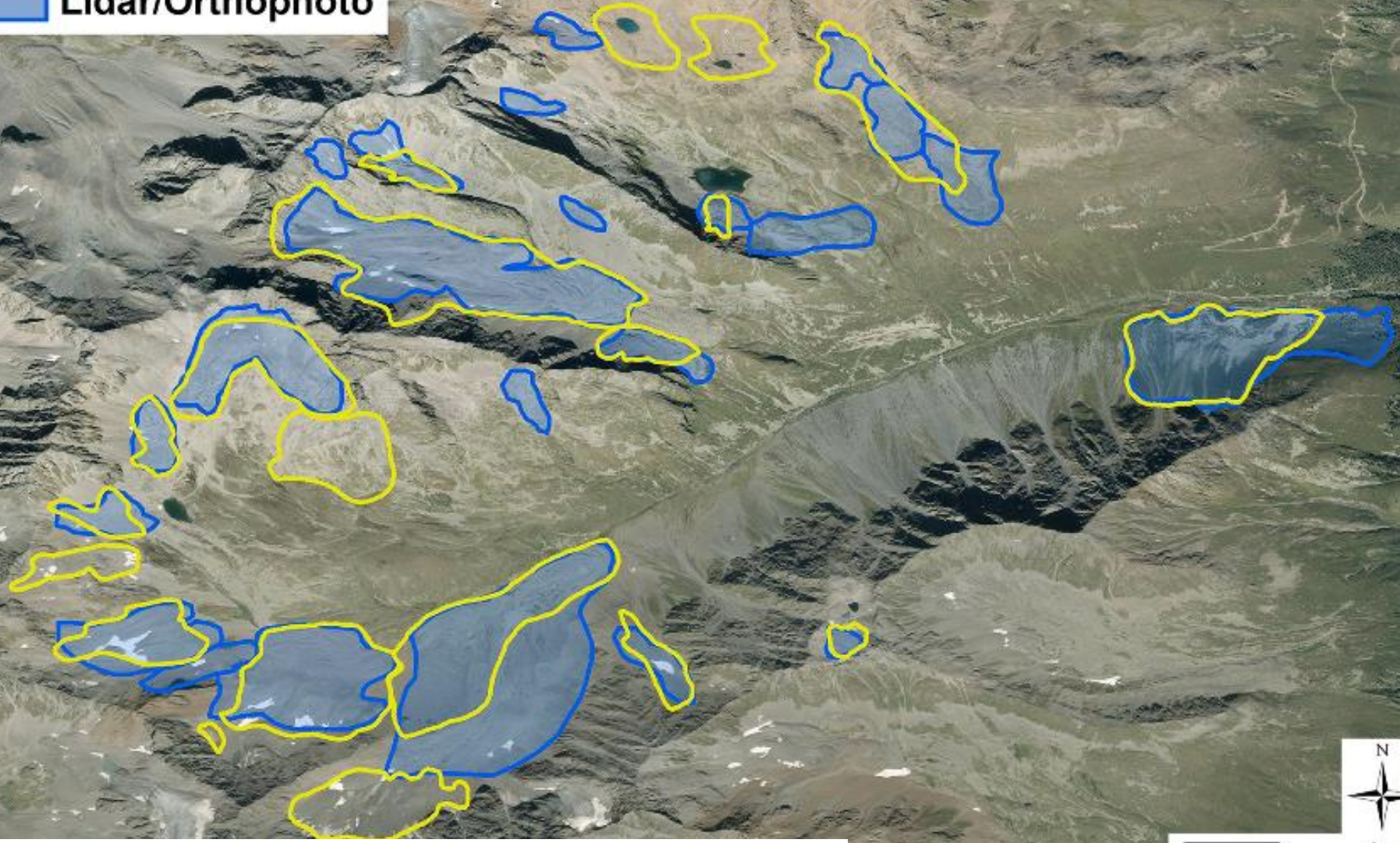

Google Earth
Lidar/Orthophoto

Operator 4

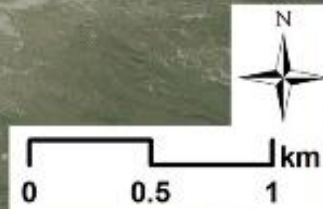*Modified from Brardinoni et al., in press in ESPL*

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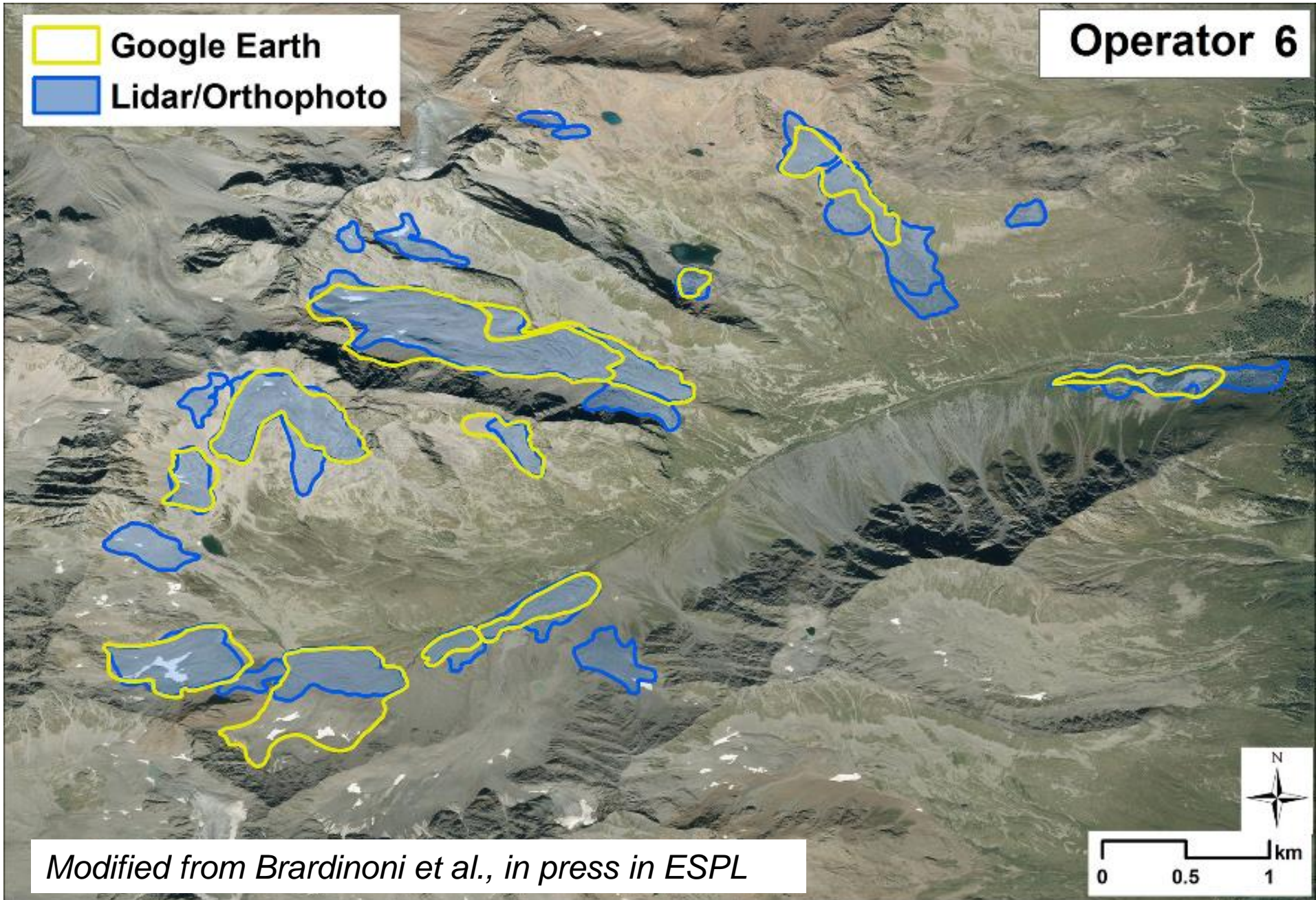

Google Earth
Lidar/Orthophoto

Operator 5

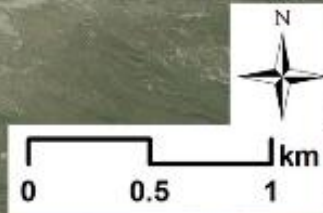*Modified from Brardinoni et al., in press in ESPL*

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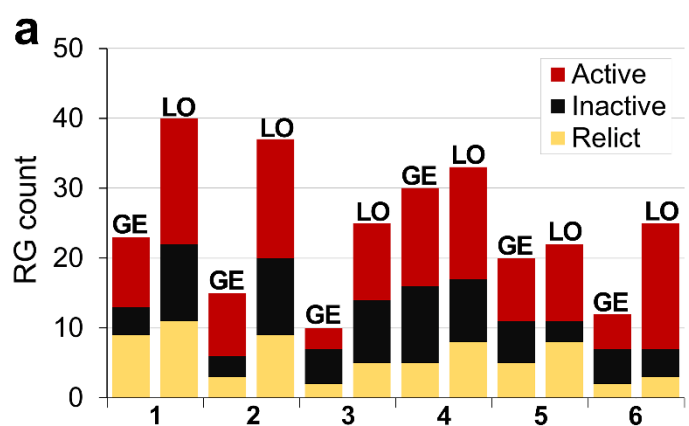

Google Earth
Lidar/Orthophoto

Operator 6

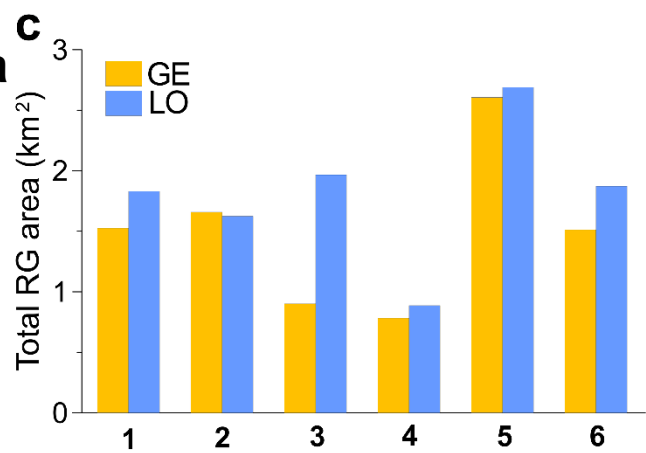*Modified from Brardinoni et al., in press in ESPL*

Higher image resolution yields:

1. Large increase in **number of detected RG**

2. Small increase in mapped **Total RG Area**

3. Single RGs become generally smaller

4. Reclassification: mostly A → I & I → A

High variability in **minimum RG elevation**

Modified from Brardinoni et al., in press in ESPL
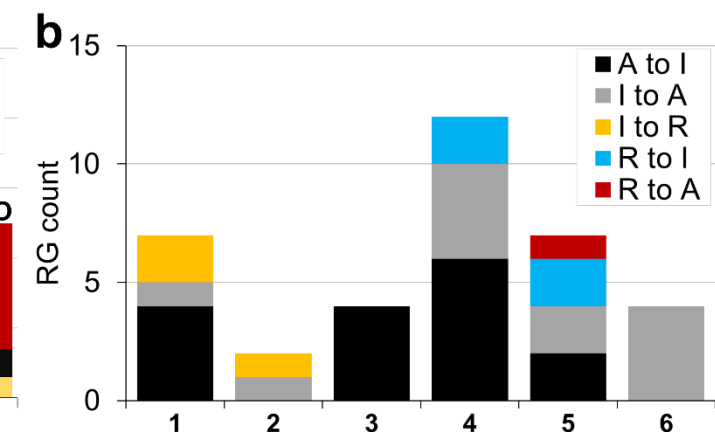
Higher image resolution yields:

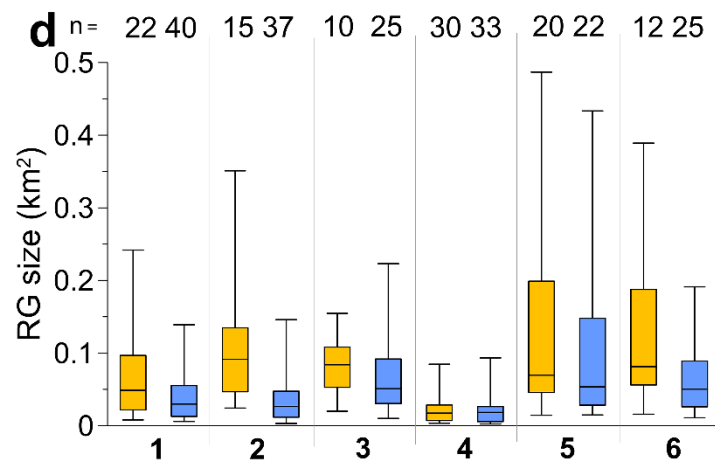1. Large increase in **number of detected RG**
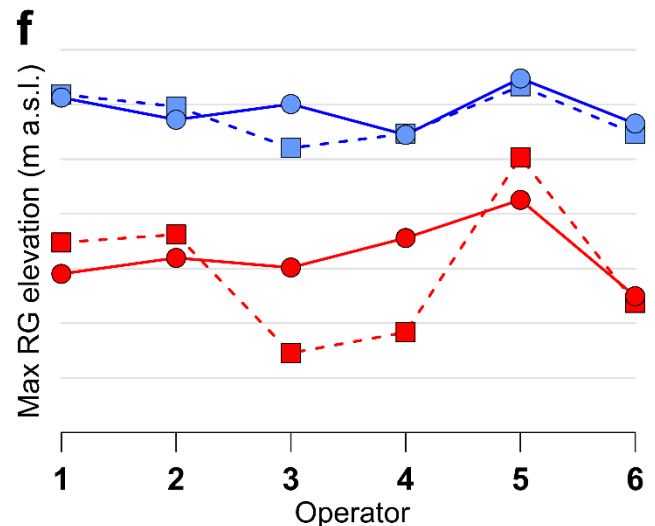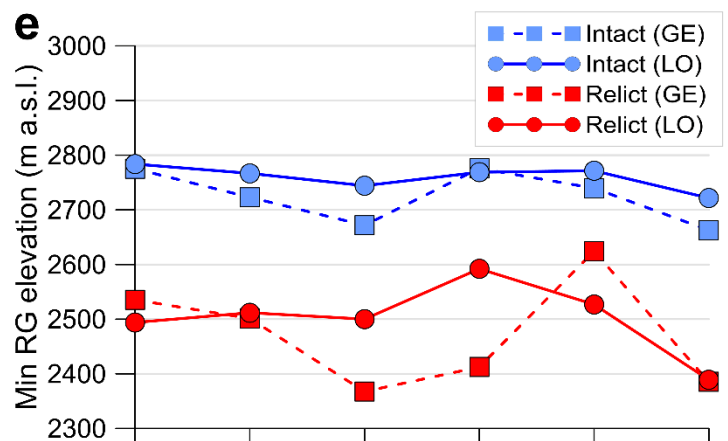
2. Small increase in mapped **Total RG Area**

3. Single RGs become generally smaller
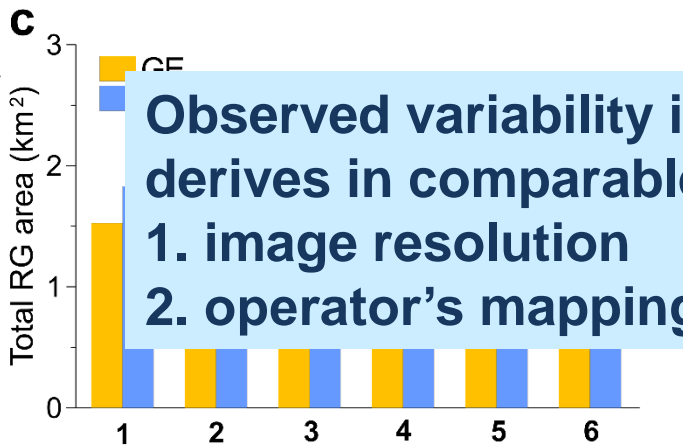
4. Reclassification: mostly A → I & I → A
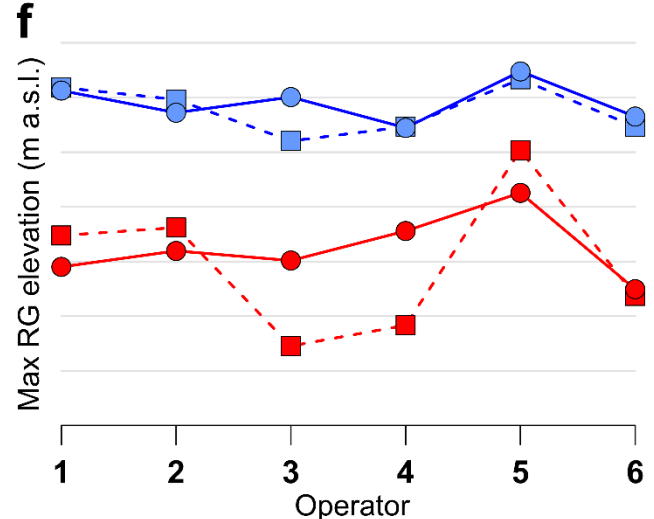
High variability in **minimum RG elevation**

Modified from Brardinoni et al., in press in ESPL
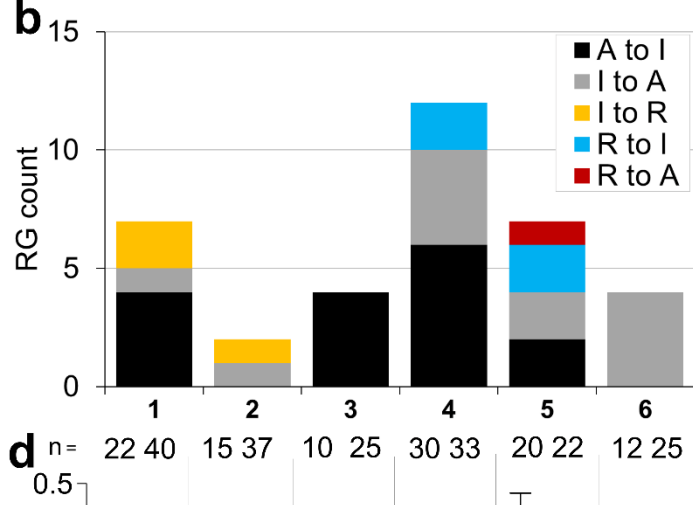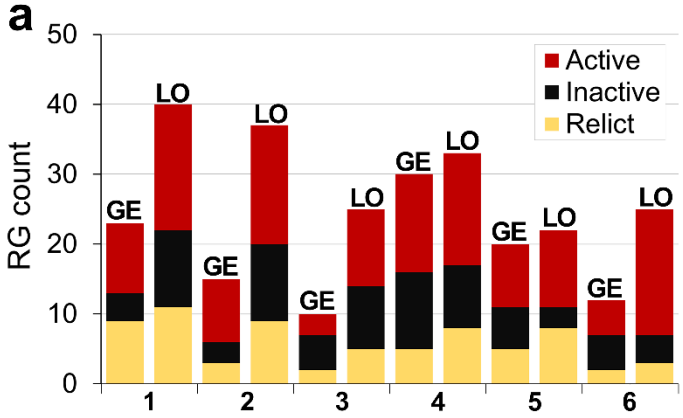
Observed variability in RG inventories derives in comparable proportions from:
1. image resolution
2. operator's mapping style

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→ The effect of operator's **mapping style** and **imagery resolution** on:
  (i) number of rock glaciers identified
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2) We asked **14 operators** to delineate the outline of **4 designated rock glaciers**

→ Comparison of mapping styles on a **common set of rock glaciers**

EXERCISE 2: 14 operators mapping 4 designated rock glaciers
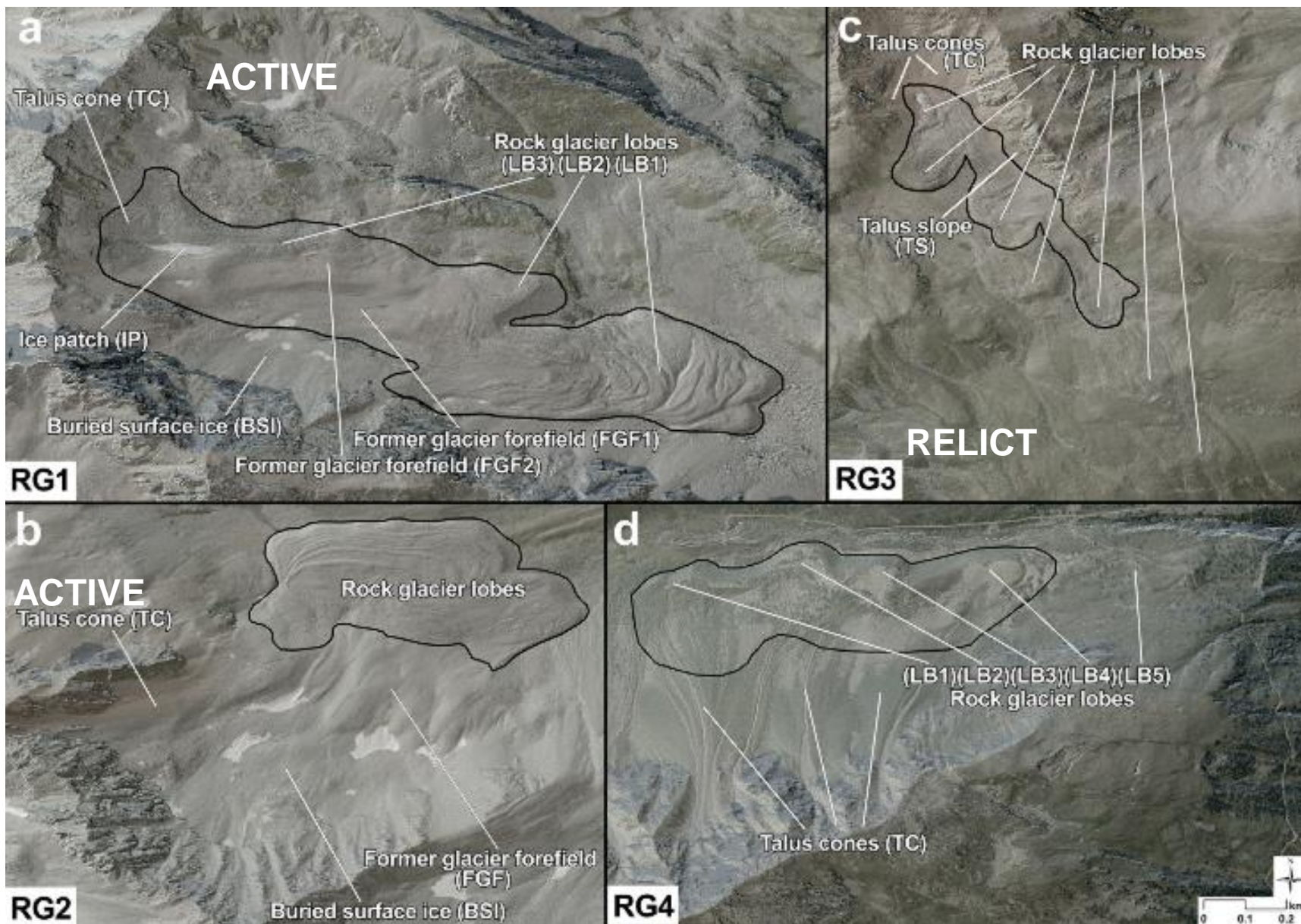
Modified from Brardinoni et al., in press in ESPL

Four rock glaciers were selected also by looking at RGI (Bollmann et al., 2015)

Modified from Brardinoni et al., in press in ESPL

a

RG1

Operators
- 1
- 2
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14

LiDAR DSM hillshade
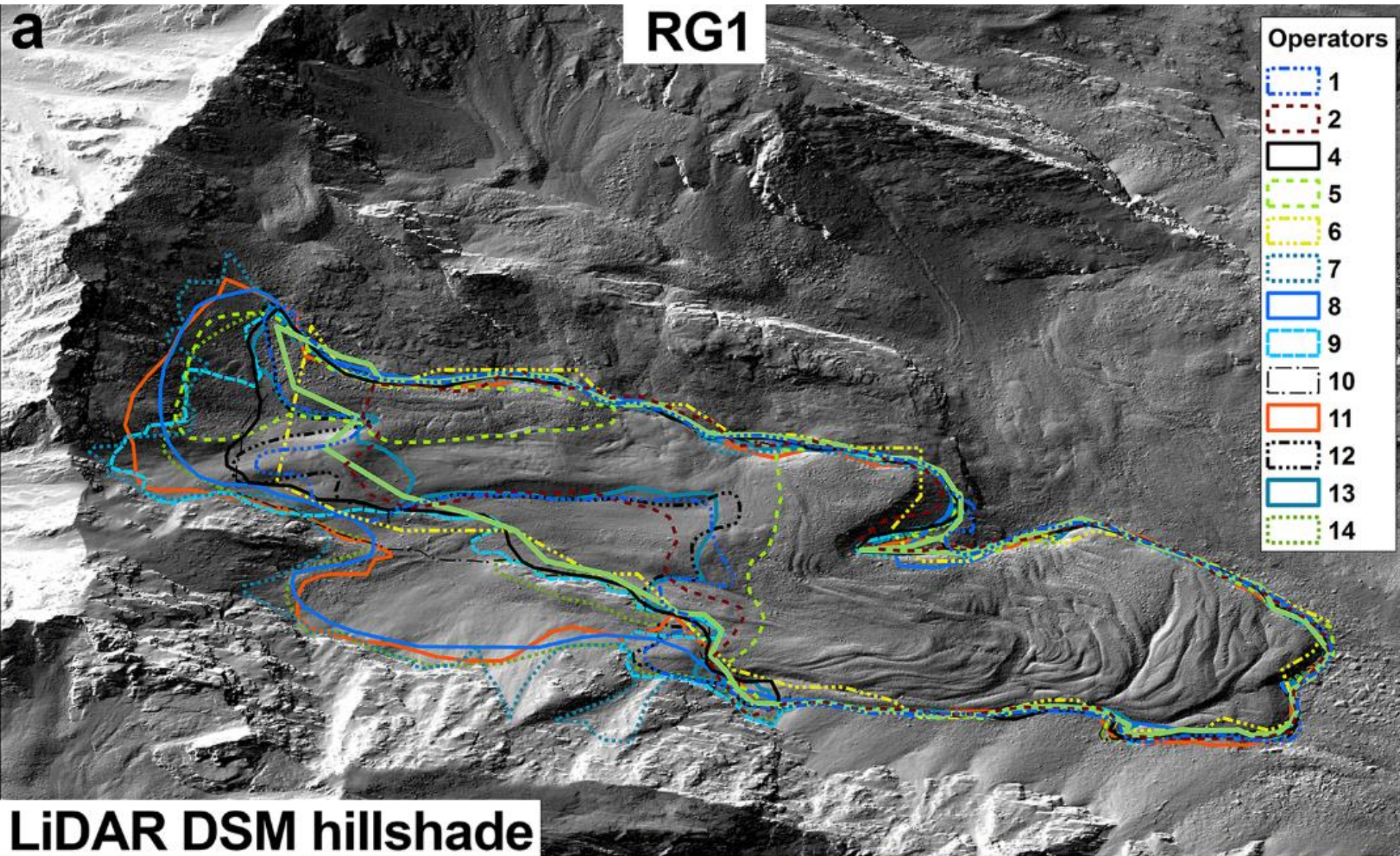
Modified from Brardinoni et al., in press in ESPL

b

Orthophoto 2015

Modified from Brardinoni et al., in press in ESPL

C

IP

TC

LB3

LB2

FGF2

FGF1

BSI

LB1

Orthophoto 1974

N

km
0   0.1   0.2
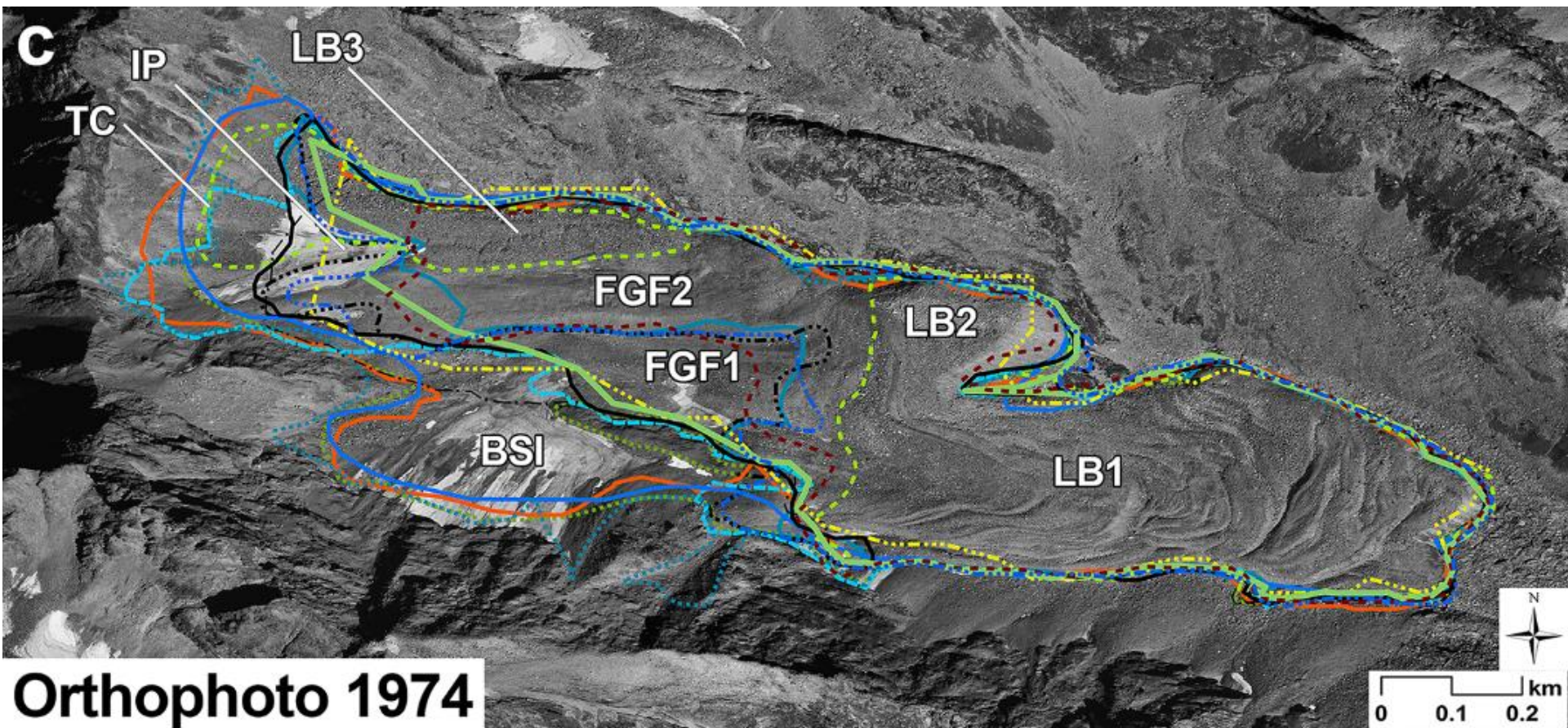
Modified from Brardinoni et al., in press in ESPL

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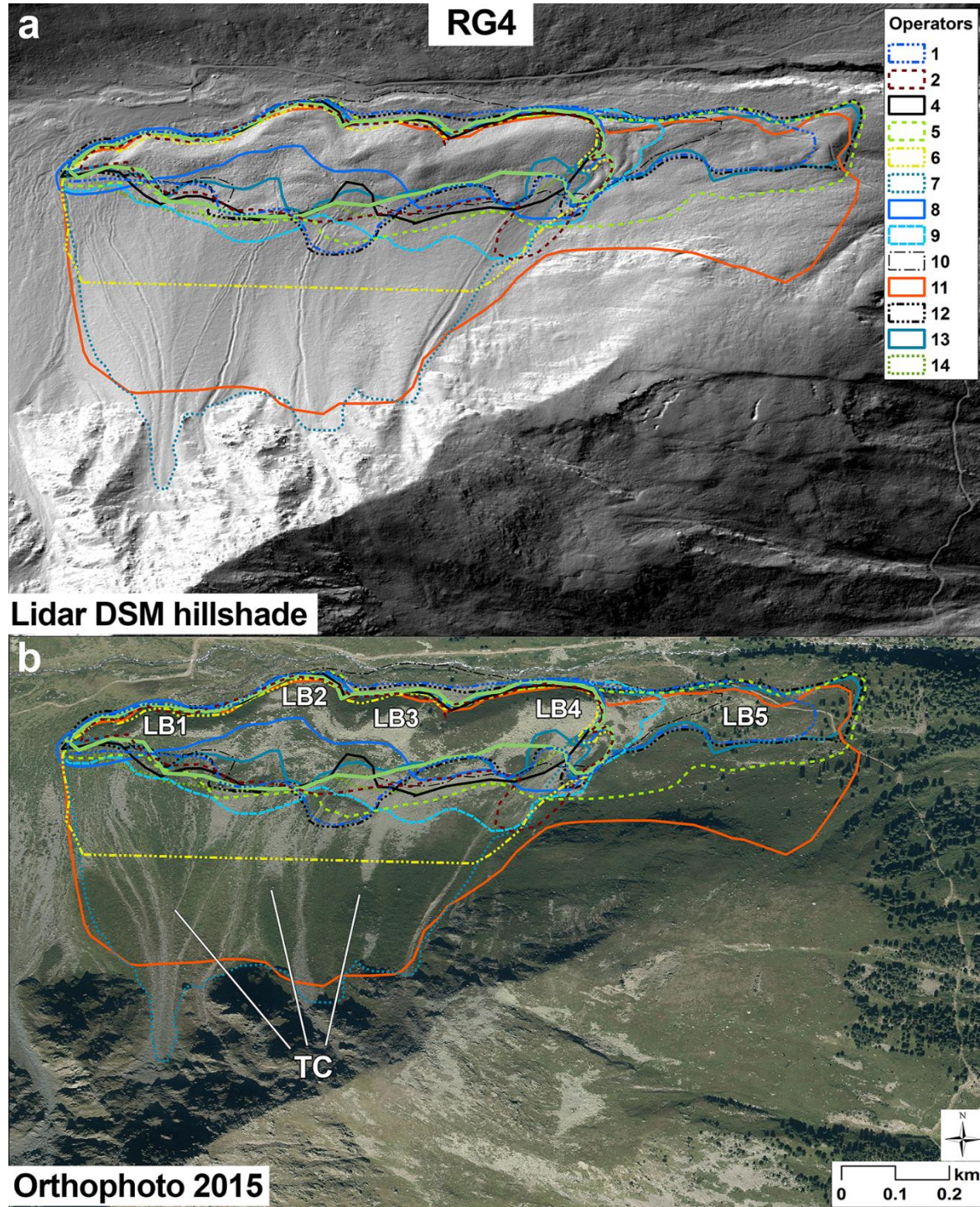
a RG4

Operators
- 1
- 2
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14

Lidar DSM hillshade

b

LB1 LB2 LB3 LB4 LB5

TC

Orthophoto 2015

km
0   0.1   0.2

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→ Comparison of mapping styles on a **common set of rock glaciers**

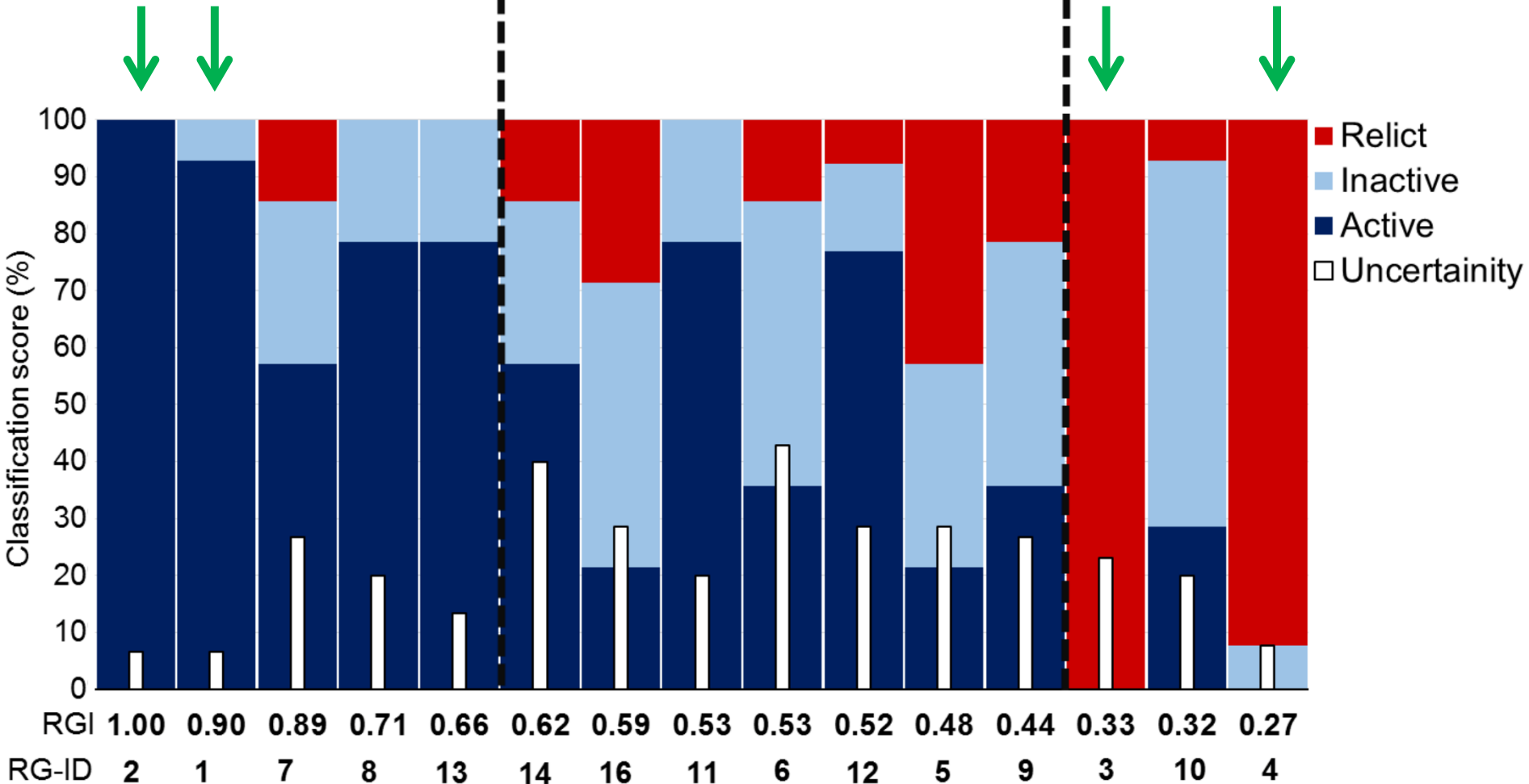3) We asked 14 operators to classify the **activity** of **15 designated rock glaciers** on high resolution (LO) imagery

→ Comparison of the **qualitative dynamic classification** against an **independent** and **quantitative activity index** (Bollmann et al., 2015)

EXERCISE 3: 14 operators classifying 15 designated rock glaciers)

> 0.65 Very likely to be active ⬅

Transition zone

➡ < 0.4 Majority of relict RG

Classification score (%)

Legend:
- **Relict** (red)
- **Inactive** (light blue)
- **Active** (dark blue)
- **Uncertainty** (white)

RGI	1.00	0.90	0.89	0.71	0.66	0.62	0.59	0.53	0.53	0.52	0.48	0.44	0.33	0.32	0.27
RG-ID	2	1	7	8	13	14	16	11	6	12	5	9	3	10	4

**HOW DO WE DEAL WITH THE TRANSITION ZONE?**
HOW DO WE DEAL WITH INACTIVE ROCK GLACIERS?

Modified from Brardinoni et al., in press in ESPL
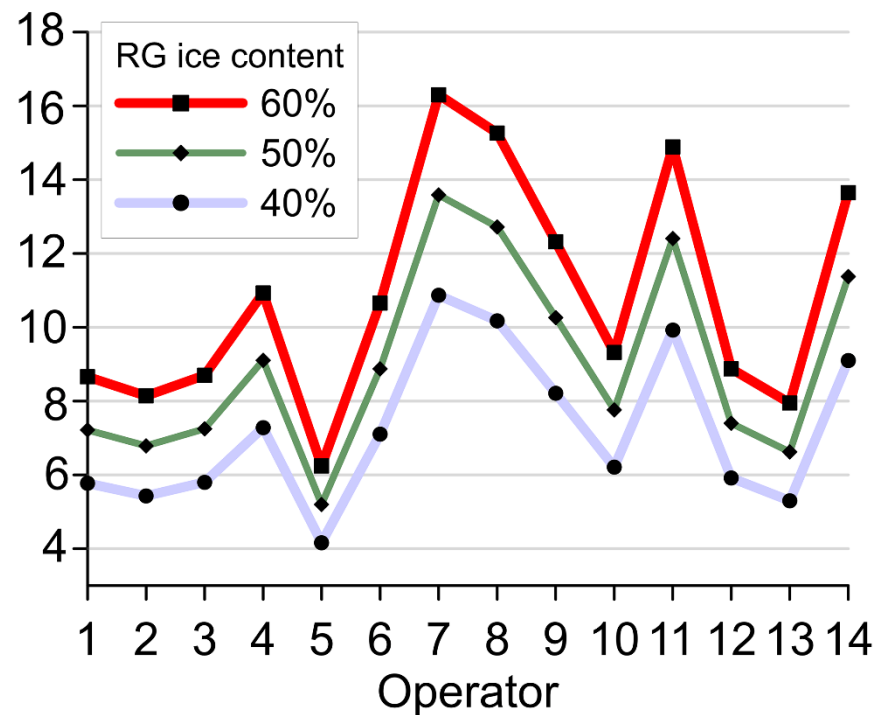
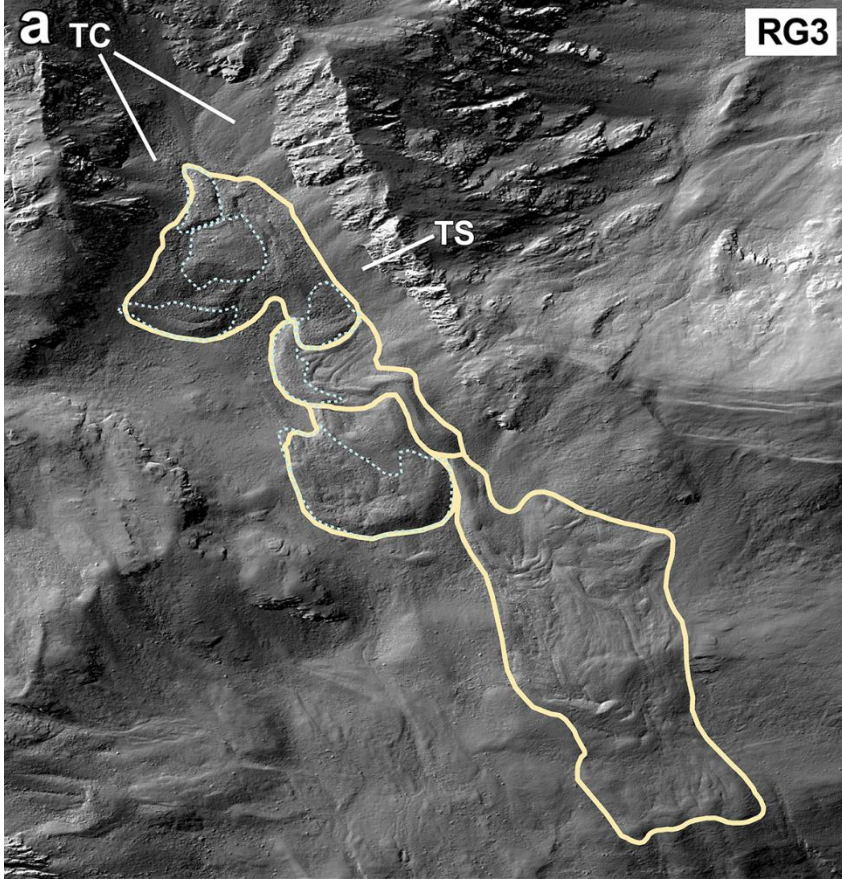# IMPACT on Rock Glacier WATER STORAGE POTENTIAL (*Jones et al 2018*)

Volume inter-operator variability → up to a factor of 3
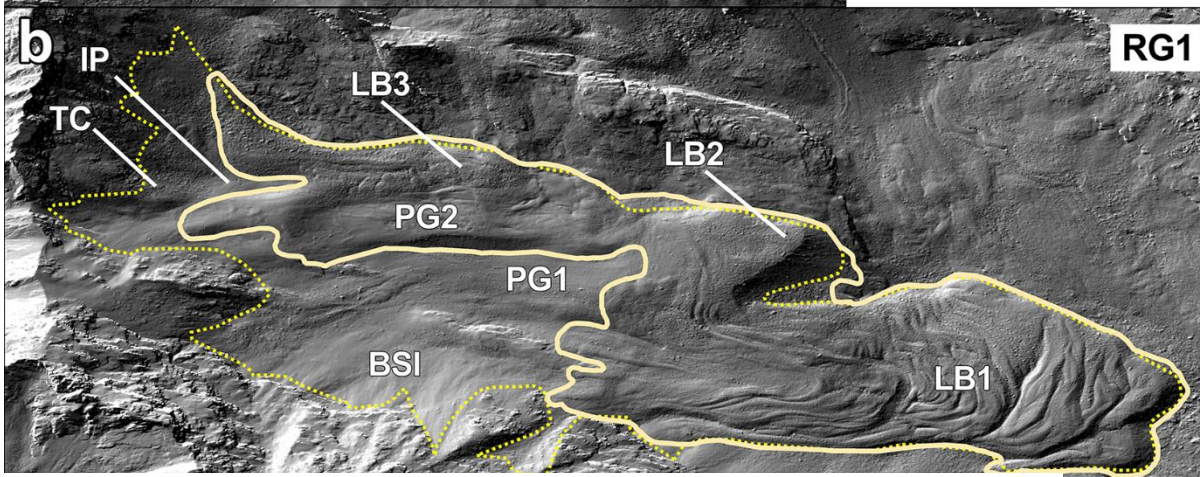

a Exercise 1 (LO mapping Valley wide)

b Exercise 2 (RG1+RG2)

RG ice content
- 60%
- 50%
- 40%

Modified from Brardinoni et al., in press in ESPL
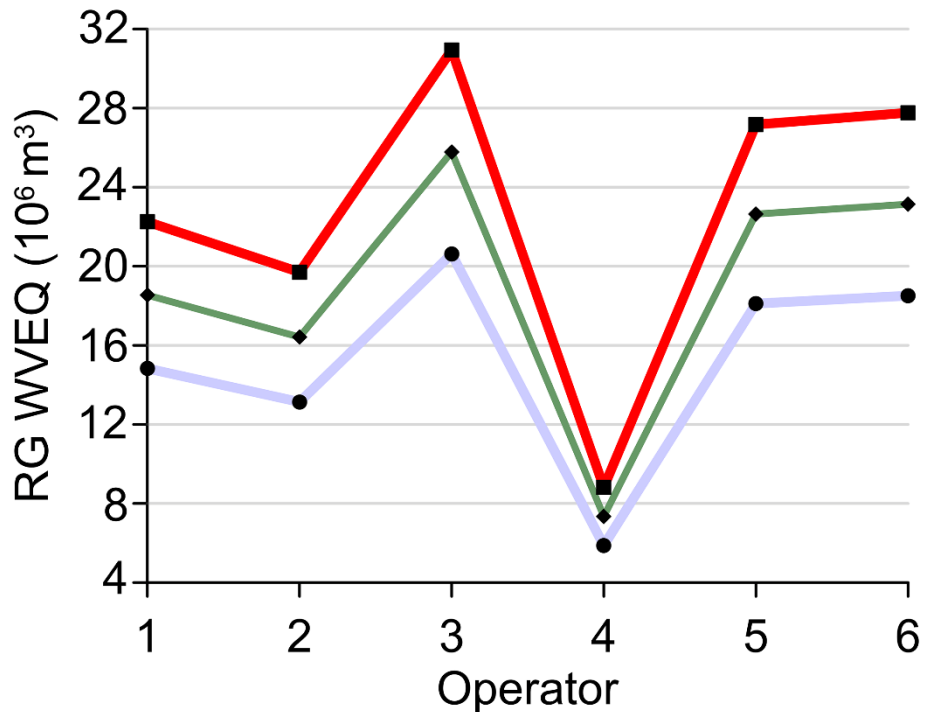
Need for shared, international guidelines to map rock glaciers

Modified from Brardinoni et al., in press in ESPL