# GEOPROCESSING OF HISTORICAL AERIAL IMAGES


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with contributions of
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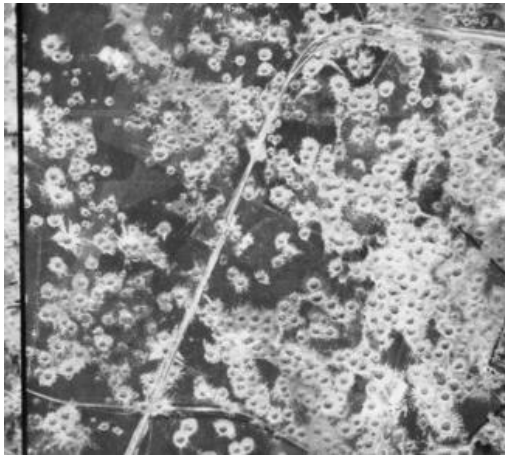
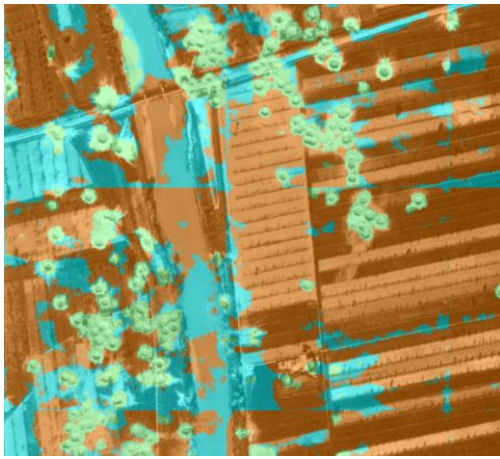
and various NMCAs in Europe

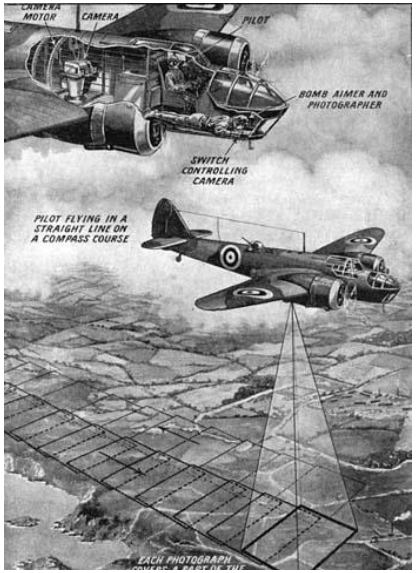




# HISTORICAL IMAGES

- Historical: from the origin of photography to the beginning of the digital era (ca 2005)
- Aerial vs terrestrial
- Nadir vs oblique
- Many collections around the world, under digitization
- Invaluable value for multiple purposes
- Challenging input for standard photogrammetry
- A good test for modern Machine/Deep learning methods

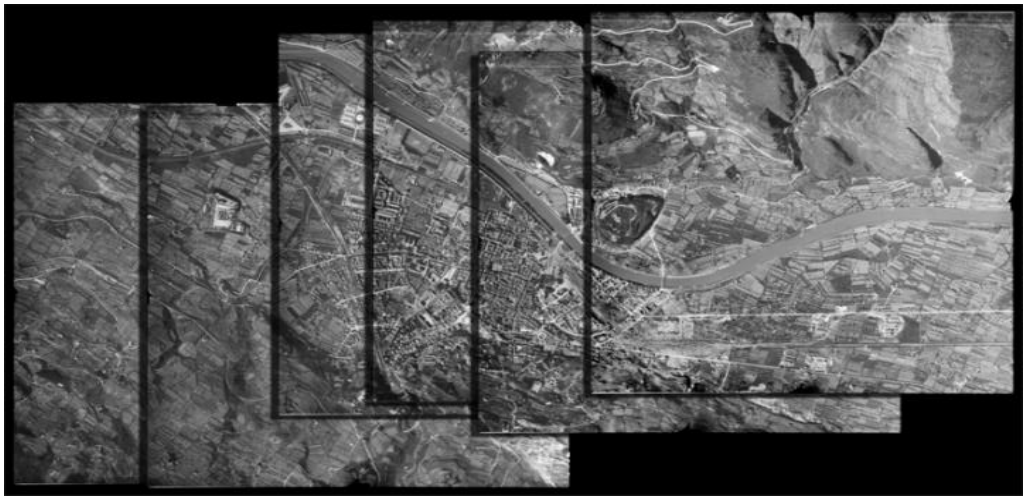
*Source: NCAP, UK*




# MAIN CHARACTERISTICS

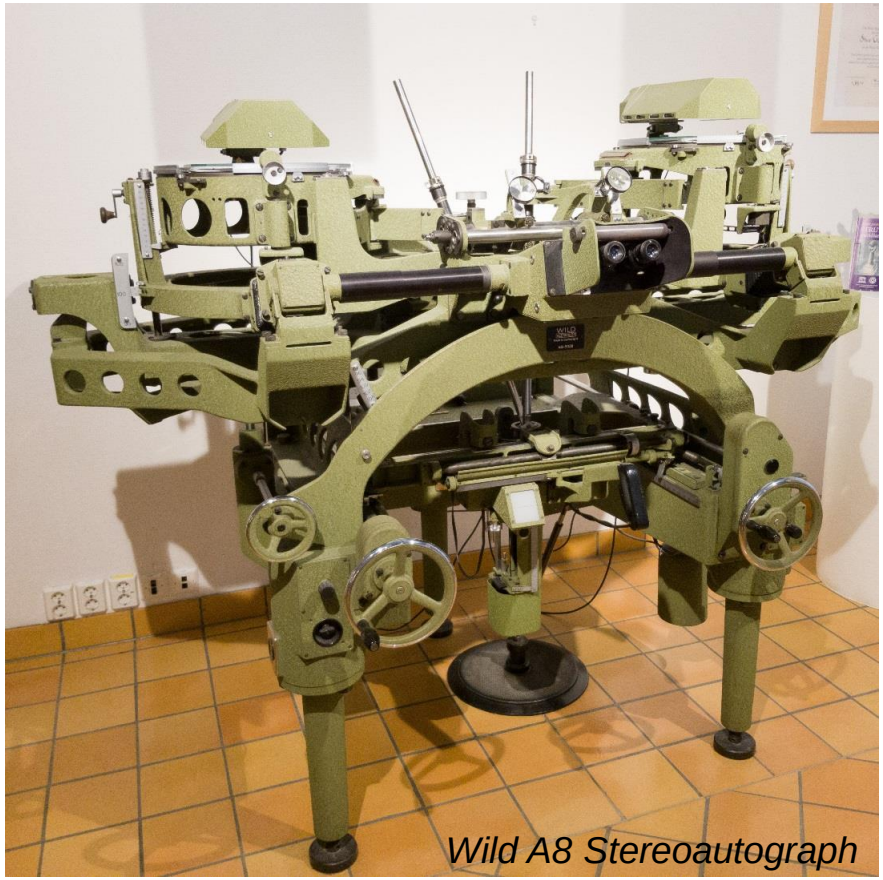
- Long-term time series (after 1920)
- Relatively dense temporal resolution (2-5 years)
- Quite high geometric resolution (20-100 cm)
- Very often stereo coverage
- Panchromatic channel
- Different formats: 23x23 cm, 30x30 cm, microfilm, etc.
- Coarse/Absent camera (int/ext) parameters
- Long strips along valleys, communication paths, etc.

*Source: Medmenham Association*

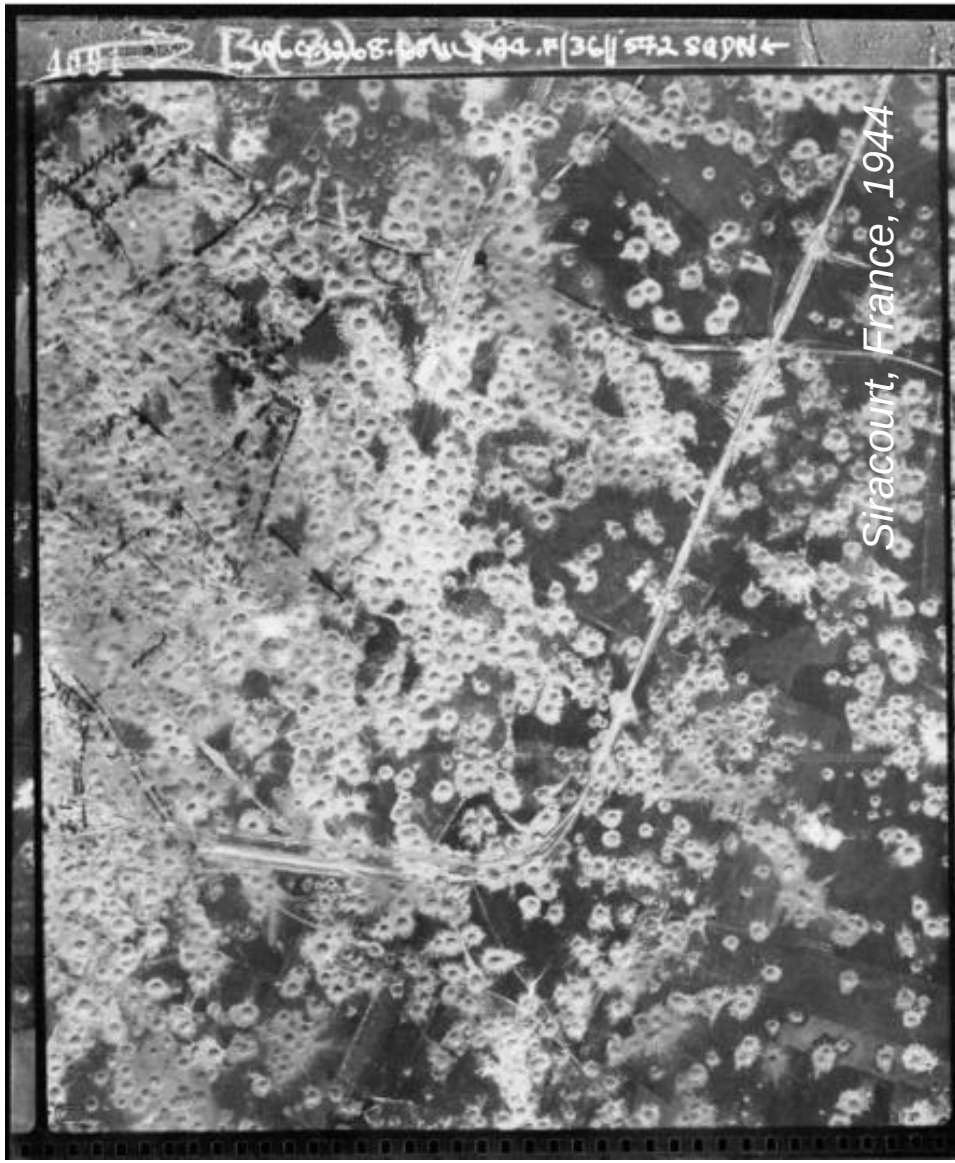


# PURPOSES of ACQUISITIONS

- Topographic map generation and updating
- Visual interpretation
- Reconnaissance (e.g. before/after bombing)



*Wild A8 Stereoautograph*




*Source: NCAP, UK*

# PURPOSES of ACQUISITIONS

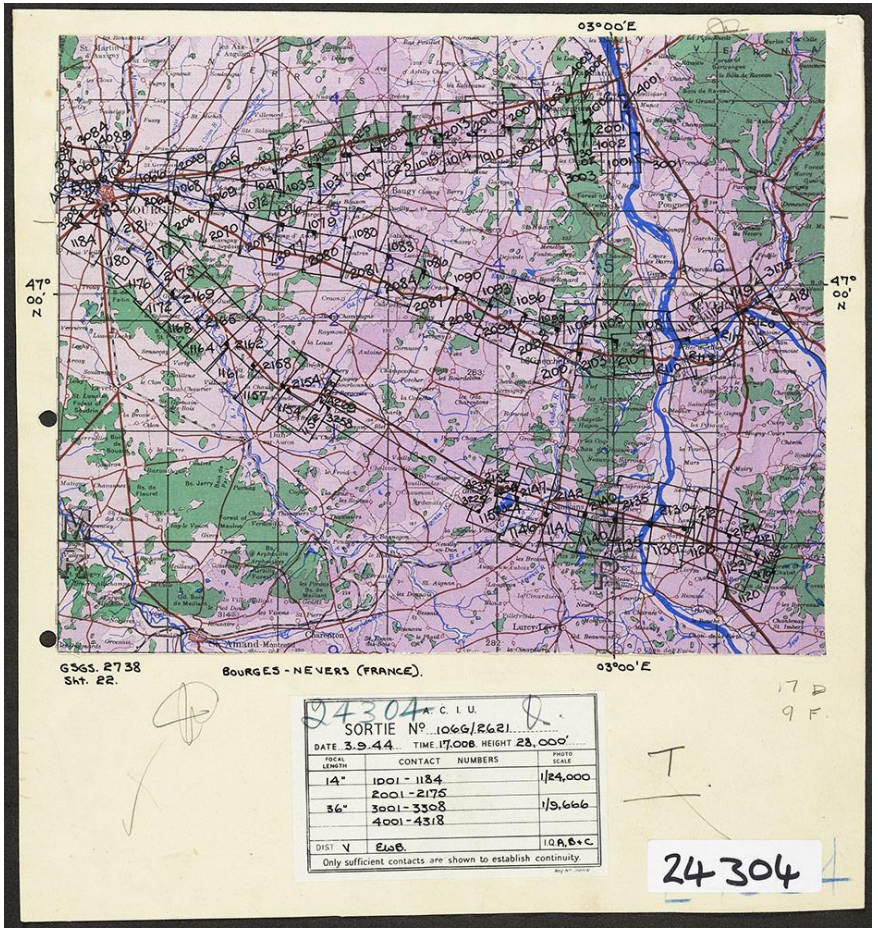


*Source: NCAP, UK*

# CHALLENGES with HISTORICAL IMAGES

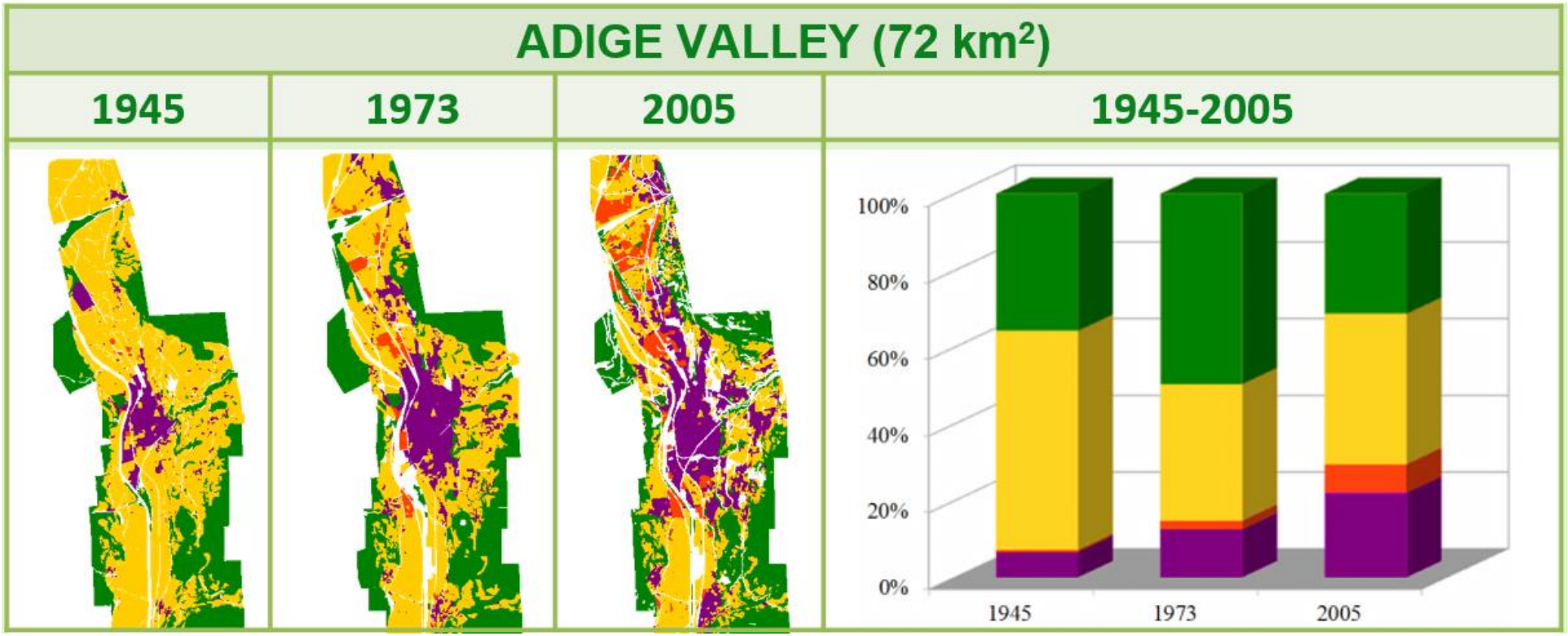
- Conservation
- Digitization
- Storage
- Sharing / Accessing

- Radiometric resolution
- Cataloguing and interpretation of plots
- Geo-localization
- Feature extraction
- Lack of metadata (interior param., etc.)
- Need of 4D GCPs




# ACTUAL USAGE of HISTORICAL IMAGES

- Multi-temporal analyses / LULC changes from orthos




rural area and urban green

grass and wooded areas or wild lands

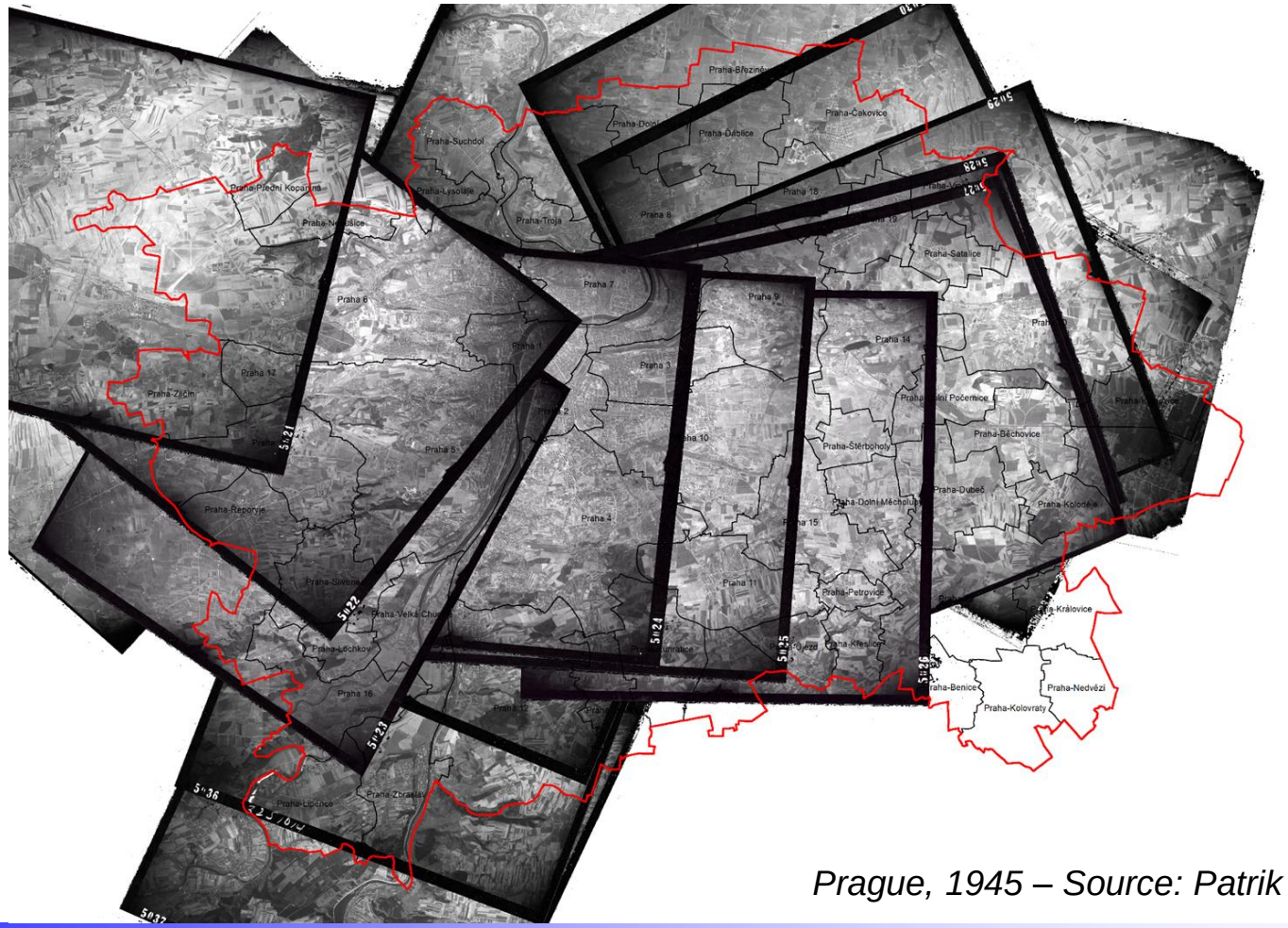
manufacturing and commercial areas

built-up or urban areas

*[Nocerino, E., Menna, F., Remondino, F., 2012: **Multi-temporal analysis of landscapes and urban areas**. Int. Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 39(4), pp. 85-90]*

# ACTUAL USAGE of HISTORICAL IMAGES

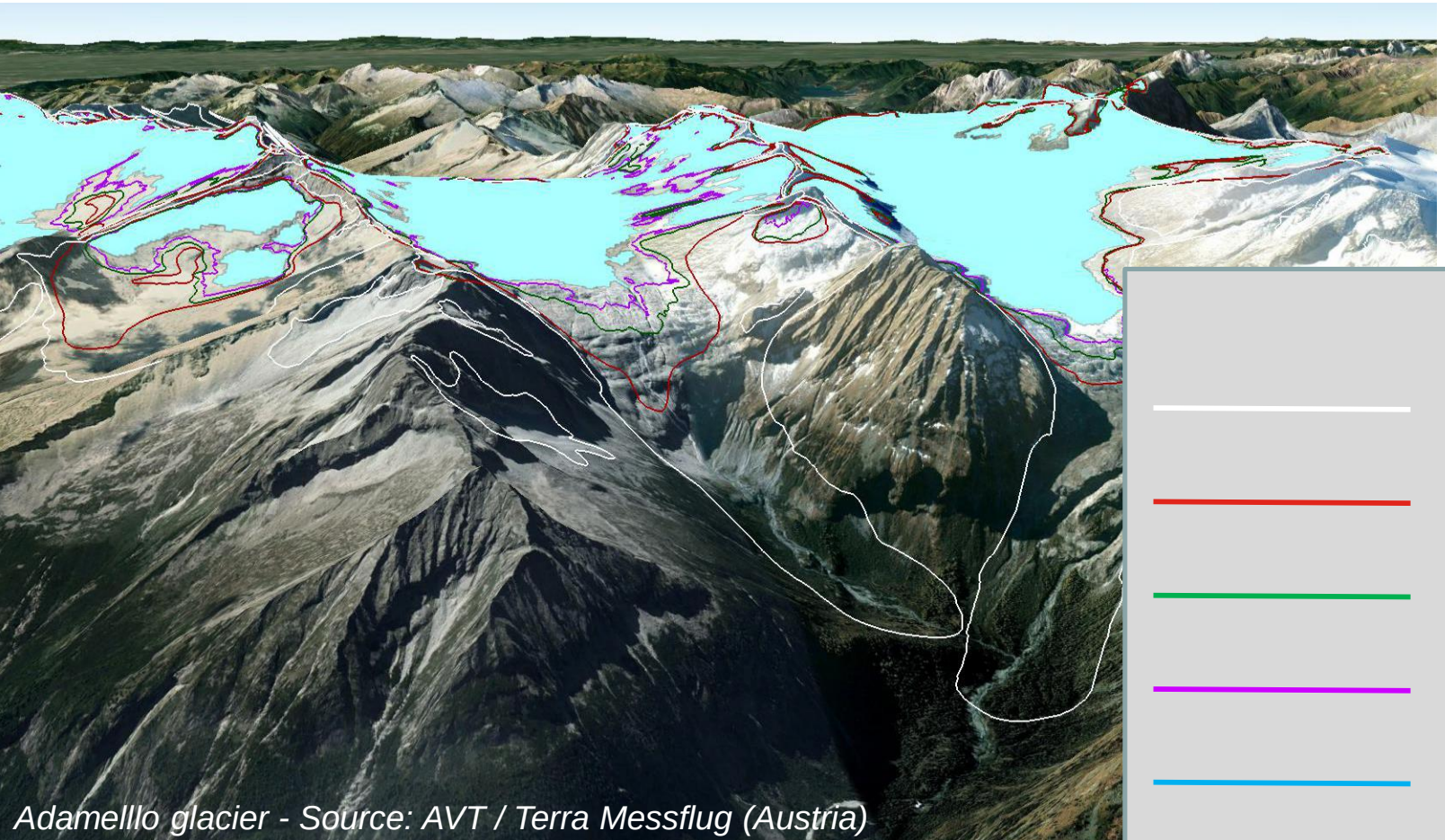
- Multi-temporal analyses / LULC changes
- Localization of past buildings / Legal affairs in real estate
- Historical orthoimage production (visualization, studies, memory, etc.)




*Prague, 1945 – Source: Patrik Meixner, PRIMIS (CZ)*

# ACTUAL USAGE of HISTORICAL IMAGES

- ❑ Multi-temporal analyses / LULC changes
- ❑ Localization of past buildings / Legal affairs in real estate
- ❑ Historical orthoimage production
- ❑ Glaciology analyses




*Adamelllo glacier - Source: AVT / Terra Messflug (Austria)*

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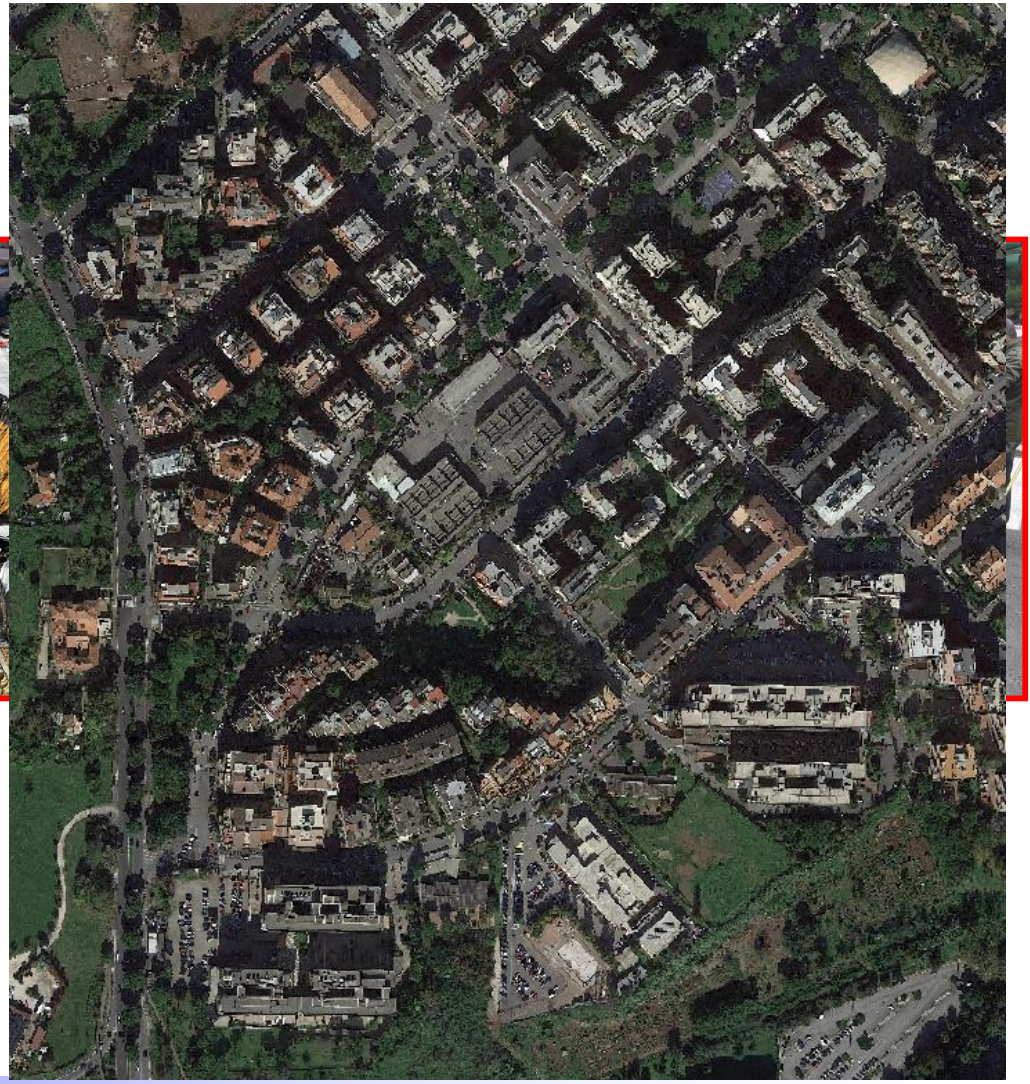
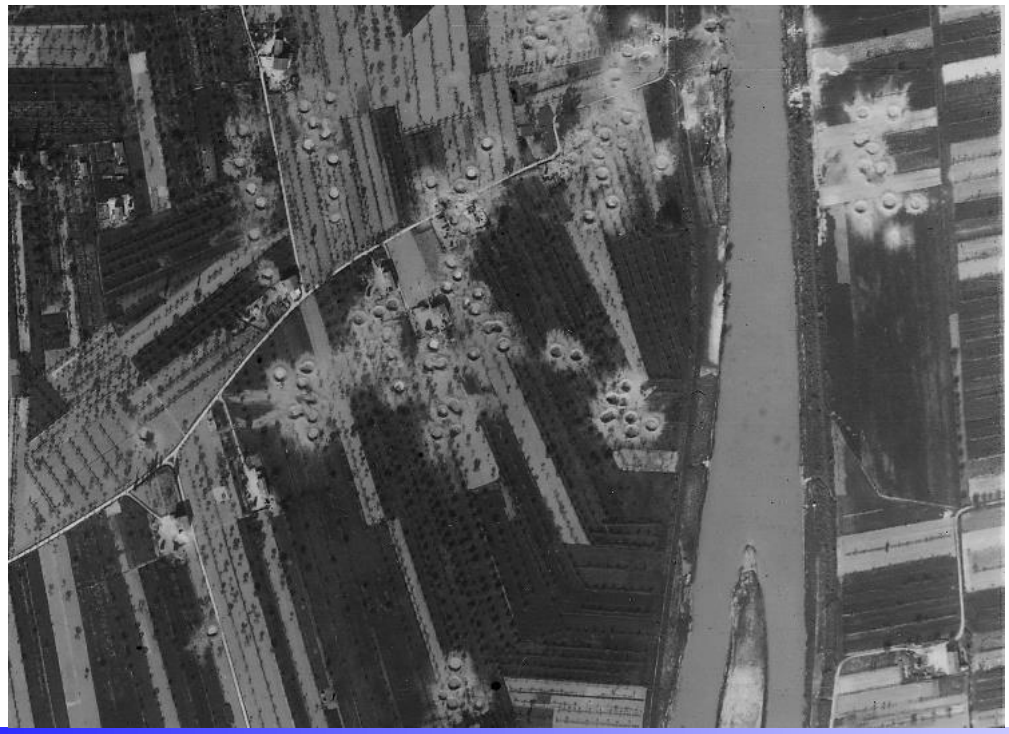


# ACTUAL USAGE of HISTORICAL IMAGES

- Multi-temporal analyses / LULC changes
- Localization of past buildings / Legal affairs in real estate
- Historical orthoimage production
- Glaciology analyses
- Geological analyses
- Explosive Ordnance Disposal (EOD) / UneXploded Ordnance (UXO) disposal



# ACTUAL USAGE of HISTORICAL IMAGES

- Multi-temporal analyses / LULC changes
- Localization of past buildings / Legal affairs in real estate
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- Geological analyses
- Explosive Ordnance Disposal (EOD) / UneXploded Ordnance (UXO) disposal
- Etc.

Most of these applications / usages of aerial historical image require geo-processing (i.e. photogrammetric methods) in order to extract info of interest

*Source: Medmenham Association*

# EuroSDR workshop and publication

http://www.eurosdr.net/workshops/geoprocessing-and-archiving-historical-aerial-images


EuroSDR

European Spatial Data Research

February 2019

http://www.eurosdr.net/publications

Archiving and geoprocessing of historical aerial images: current status in Europe

Sébastien Giordano, Clément Mallet

# GEO-PROCESSING

- Scanning
- Geo-referencing
  - Interior orientation
  - Exterior orientation
- Generation of geo-products
  - DTM / DSM extraction
  - 3D building modeling
  - Orthoimage production
  - Crater detection (UXO)
- Data visualization

- **Why there is a hype in geo-processing?**
  - Availability of digital images
  - Increase power of computer
  - New processing methods
    - ✓ *Machine/deep learning*

# GEO-PROCESSING

**SCANNING / DIGITIZATION**

**GEO-REFERENCING**

**GEO-PRODUCTS**

**VISUALIZATION**

# SCANNING

## Methods / Instruments

- ❑ Flatbed scanning
- ❑ DSLR camera
- ❑ Photogrammetric scanning (e.g. Geosystem/Wehrli Delta, Leica DSW 700, Vexcel UltraScan 5000, etc.)

## Digitize what?

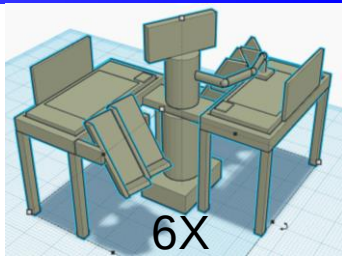
- ❑ Analogue photographs (films or plates)
- ❑ Flight plans
- ❑ Camera calibration certificates
- ❑ Image orientation parameters

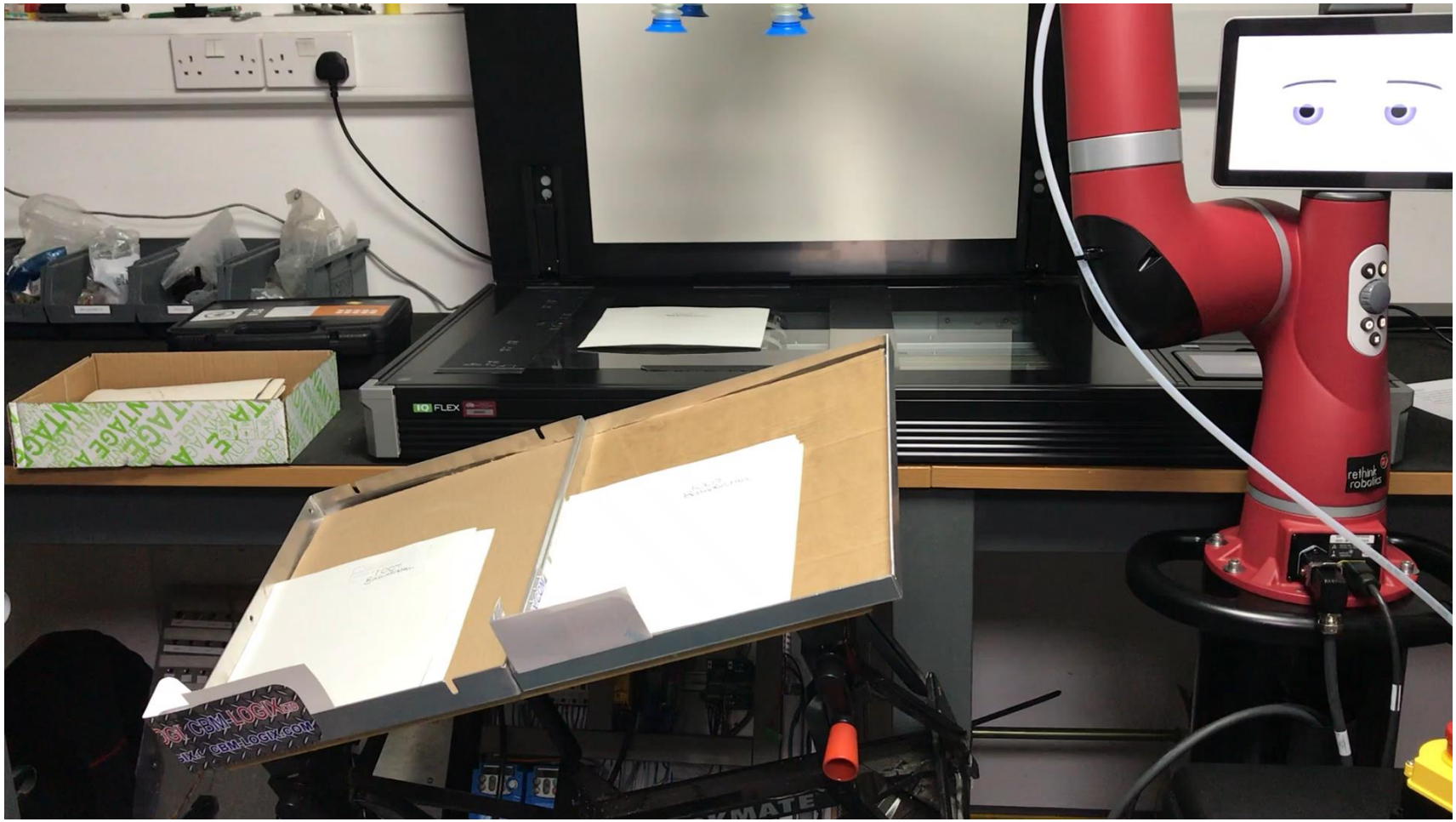
# SCANNING around EUROPE

- Archives around the world have millions of historical photographs (negatives, contact copies, rolls, cuts, etc.), so **scanning is the most laborious phase**
  - Sweden (Lantmäteriet): 4 photogrammetric scanners for ca 1 mil photos (ca 50% digitized)
  - Norway (Kartverket): 3 photogrammetric scanners for ca 1.3 mil photos (ca 30% digitized)
  - UK (NCAP): 6 photogrammetric scanners for 30 mil photos (ca 1.5% digitized)
  - Switzerland (Swisstopo): 2 photogrammetric scanners for ca 400K photos (all digitized)
  - CZ (COSMC): 5 photogrammetric scanner for ca 700K photos (ca 20% digitized)
  - Italy (AFN): 1 photographic scanner for ca 6 mil photos (10% digitized)
- Typical scanning resolution: **15 μm** (23x23 cm @ 4600m, f=15cm => ca 0.5 m GSD)
- **12 bit/channel** (stored in 8 bit after some radiometric adjustment)
- Ca **100 negatives/day** for an expert operator
- Scanning time: ca **1 min b/w**, 2 min color

# AUTOMATING SCANNING PROCEDURES

- NCAP (UK - https://ncap.org.uk/) is launching the digitization of its archives using 6 Sawyer cobots prototypes developed by Hahn Robotics




*Source: Prototype of NCAP cobotics scanning - Sawyer Cobot by Hahn Robotics*

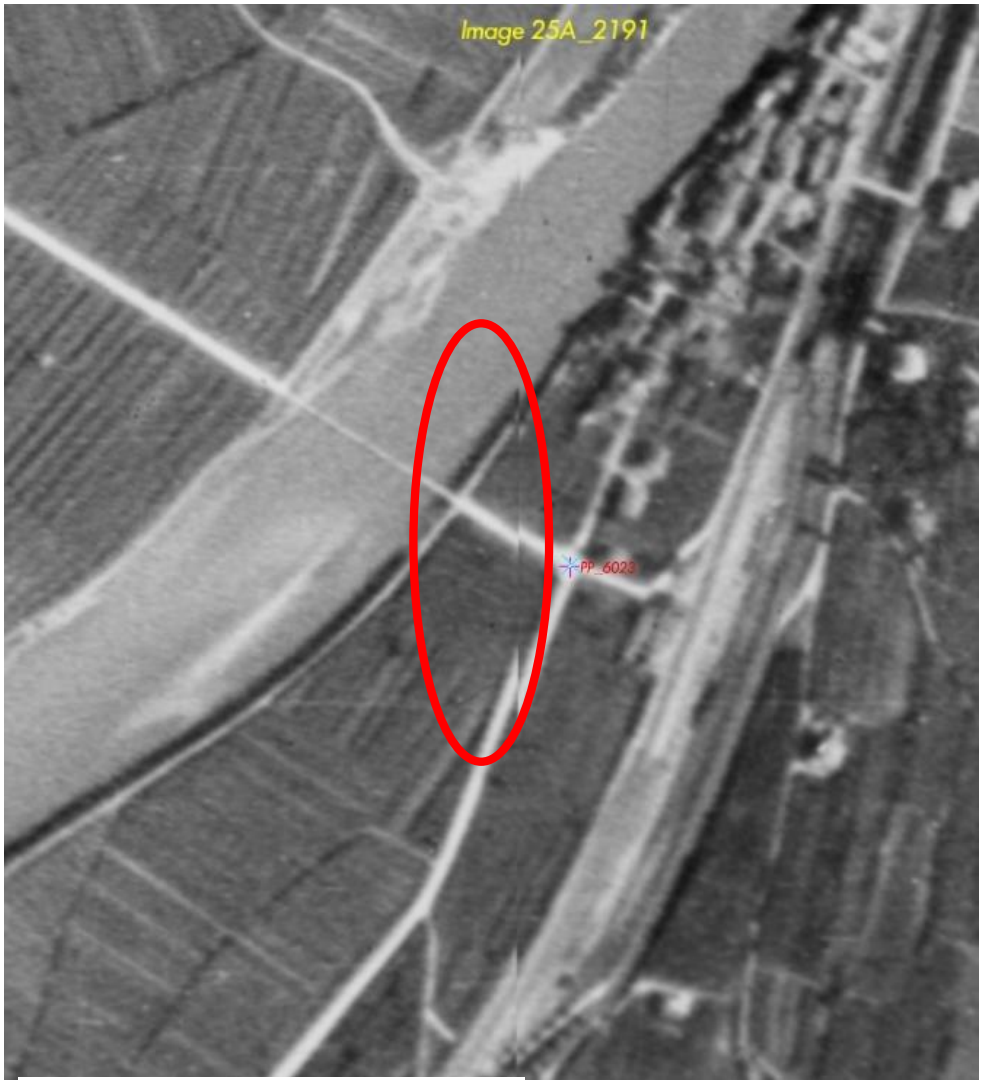
# SCANNING ISSUES

Before digitisation - to ensure no physical damage is caused to the photographic emulsion or paper base - all contact prints are humidified (using procedures developed with a photographic conservator) and flattened using a nipping press.


*Source: NCAP*

In order to remove dust and dirt - which can scratch aerial film during the digitisation process - electrostatic film cleaners are used.

# SCANNING ISSUES

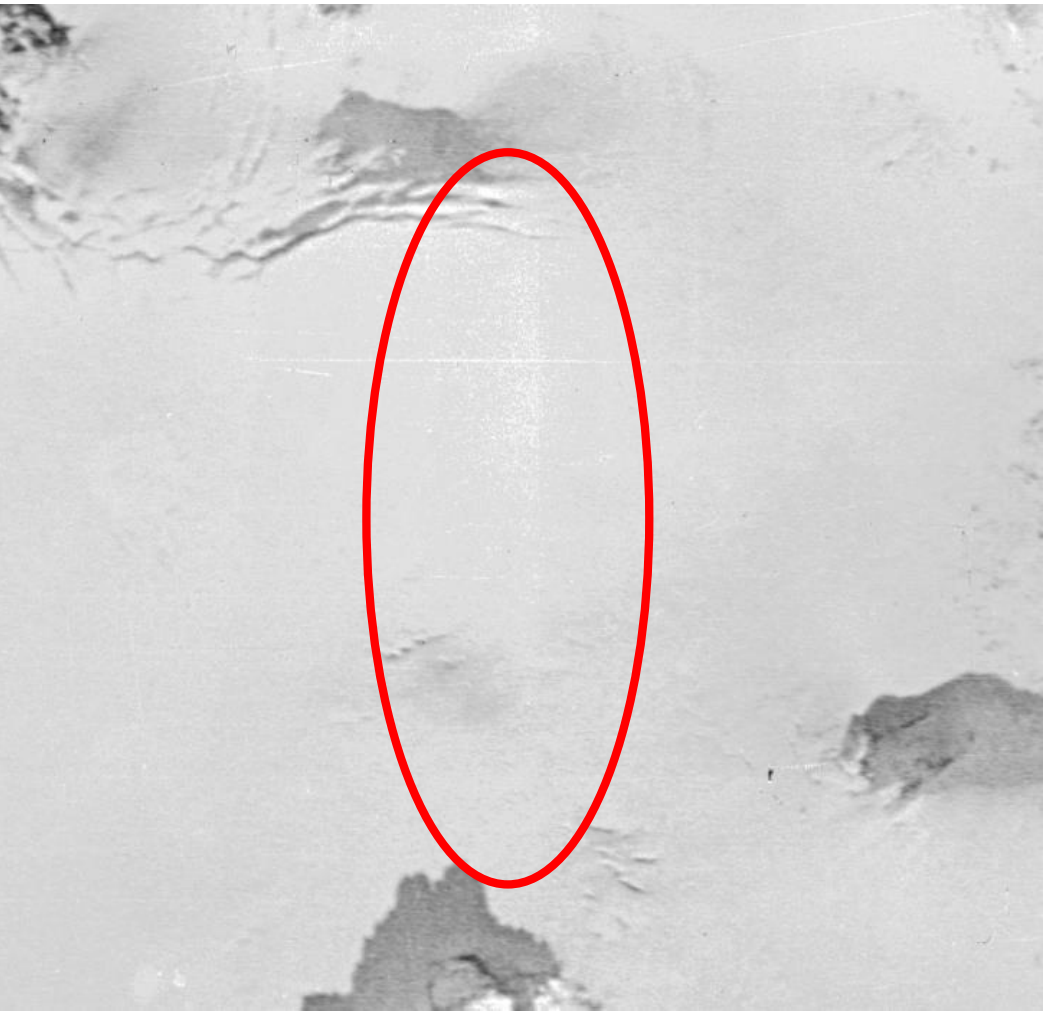



**Scanning errors**

**Scratches**

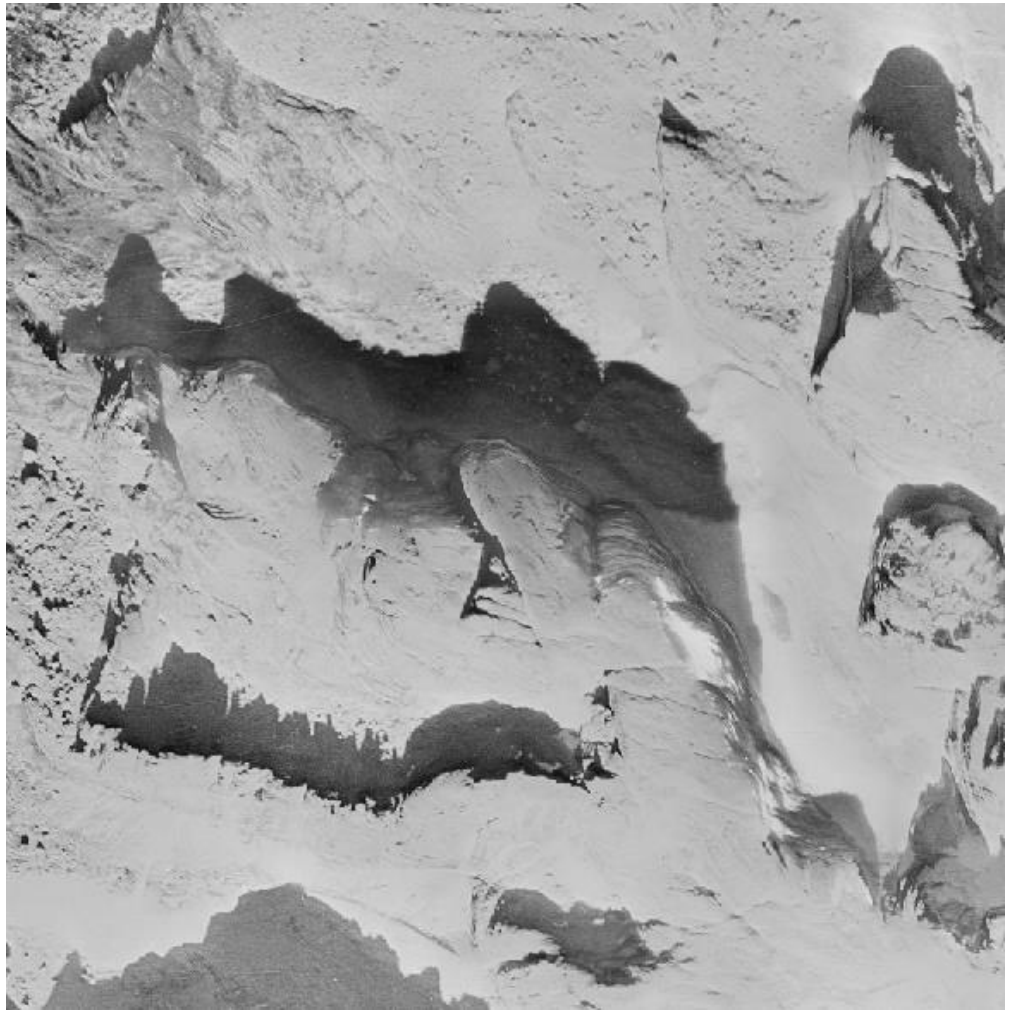
*Source: PAT / AVT*

# SCANNING ISSUES



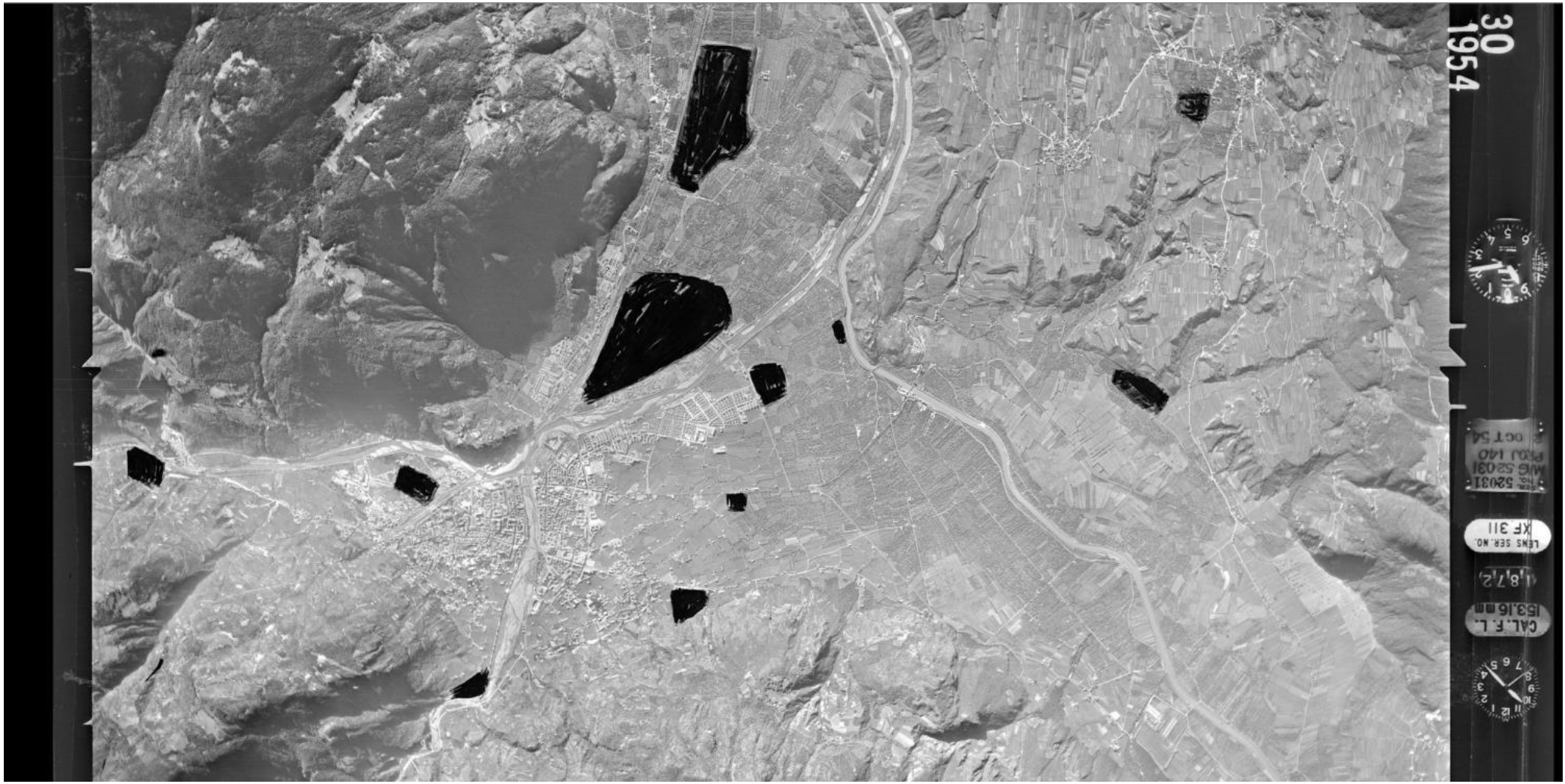
**Saturation**

*Source: PAT / AVT*



**Dark shadows**

# SCANNING ISSUES




**Masks**

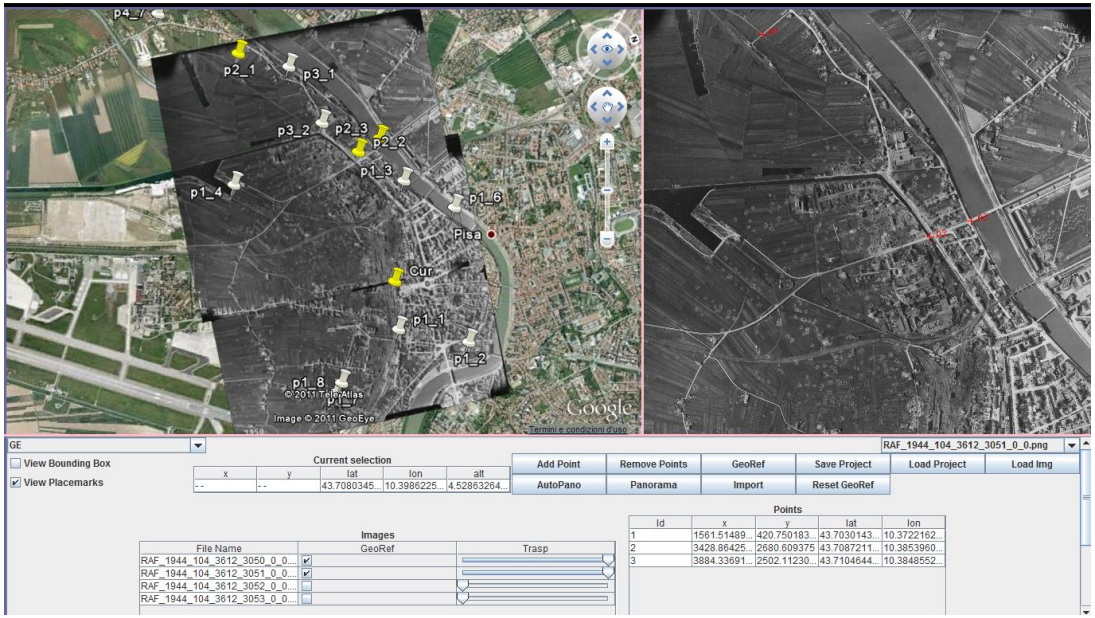
# GEO-PROCESSING

**SCANNING / DIGITIZATION**

**GEO-REFERENCING**

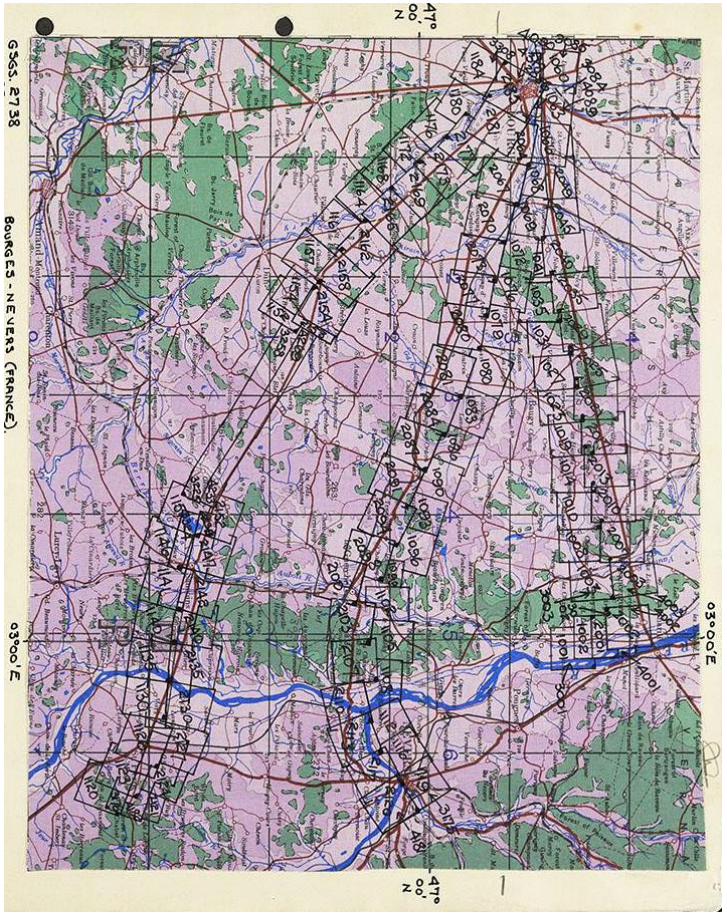
**GEO-PRODUCTS**

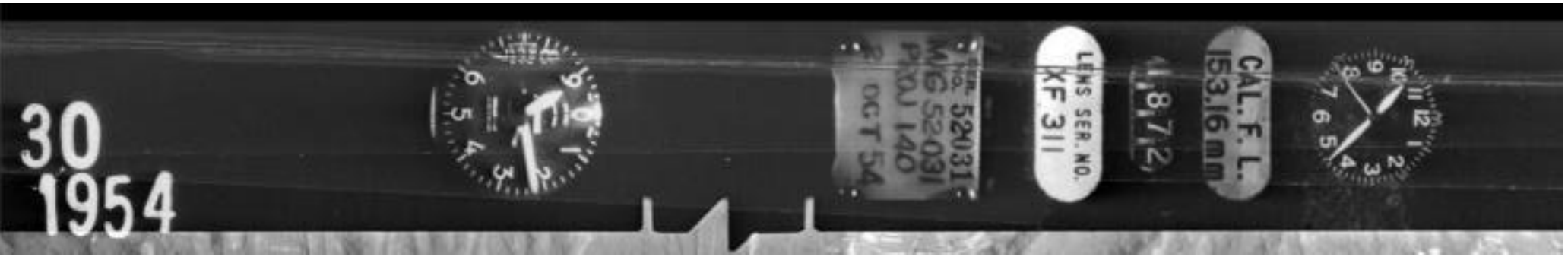
**VISUALIZATION**



# GEO-REFERENCING

- Find the camera (interior and exterior) parameters
  - Interiors: info on camera borders might help
  - Exteriors: flight plans / plots might help
- Bad conservation (e.g. scratches), low res, scanning misalignments and lack of metadata or multi-temporal series do not facilitate automated geo-referencing procedures
- 4D GCPs mandatory
- Geo-referencing accuracy is required to
  - perform comparison analyses
  - store images in webGIS portals

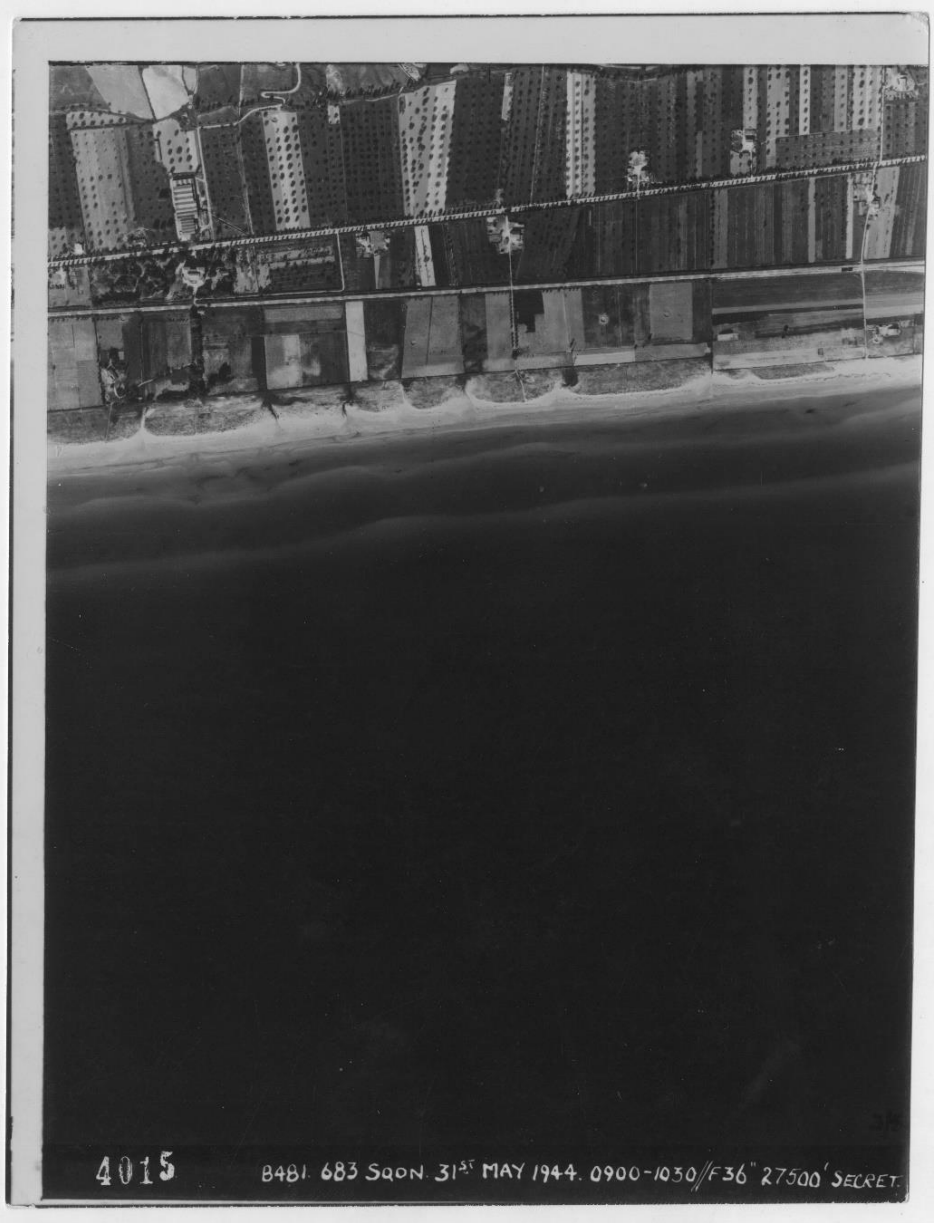


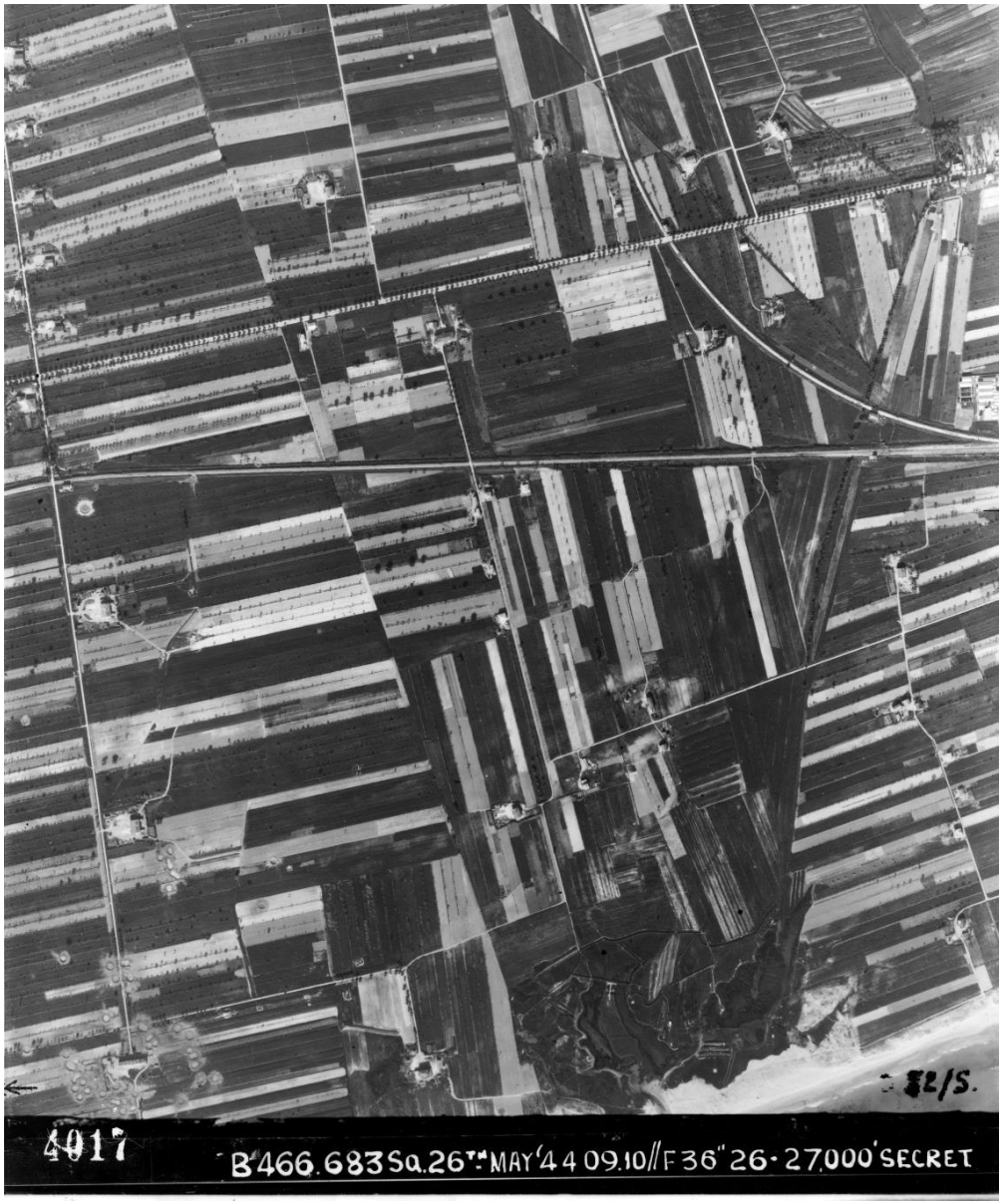
# 4D GCPs for GEO-REFERENCING

*City details can help*

# 4D GCPs for GEO-REFERENCING




*Shoreline could be useful*

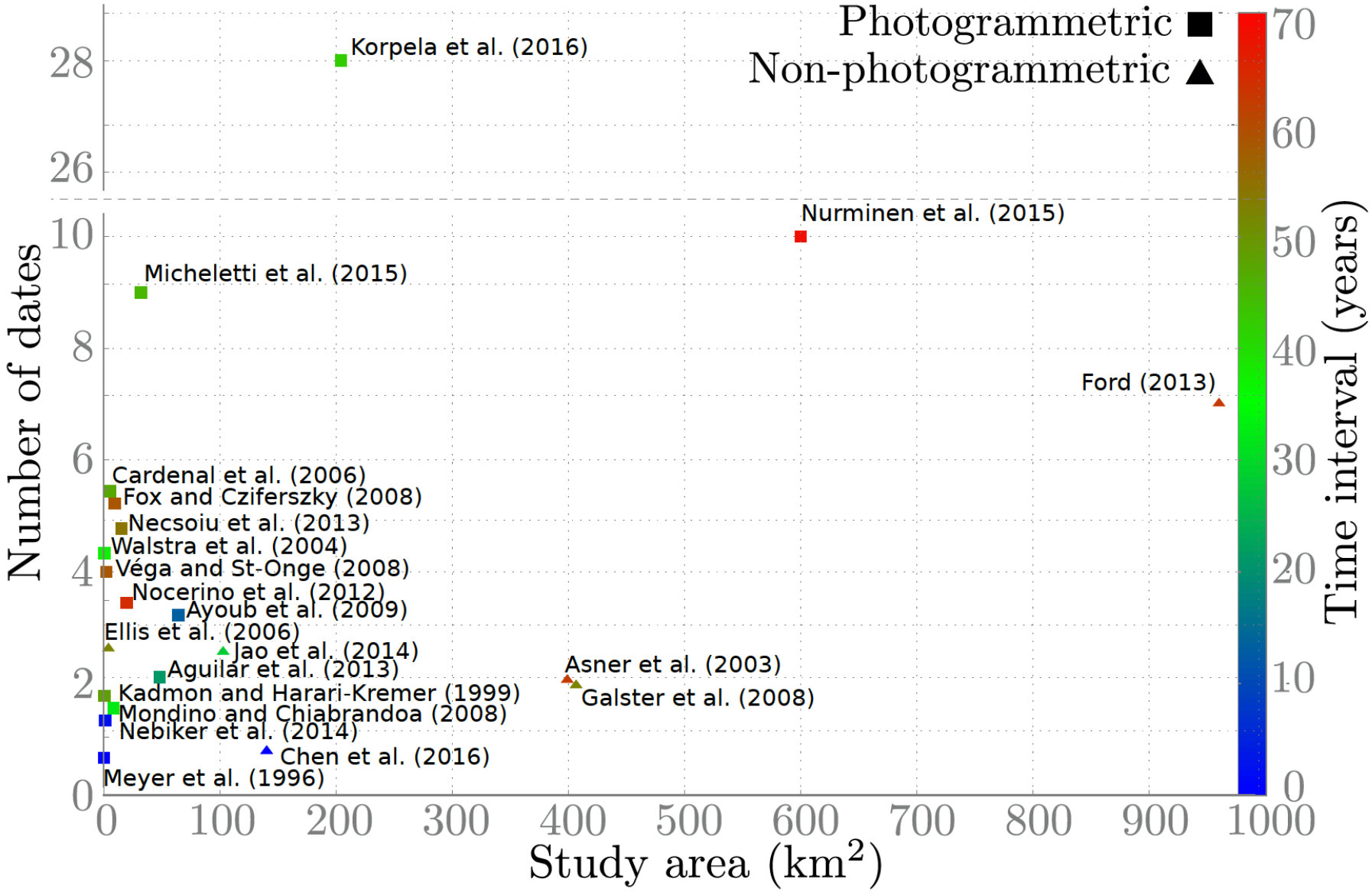



*…good luck…*

# GEO-REFERENCING METHODS

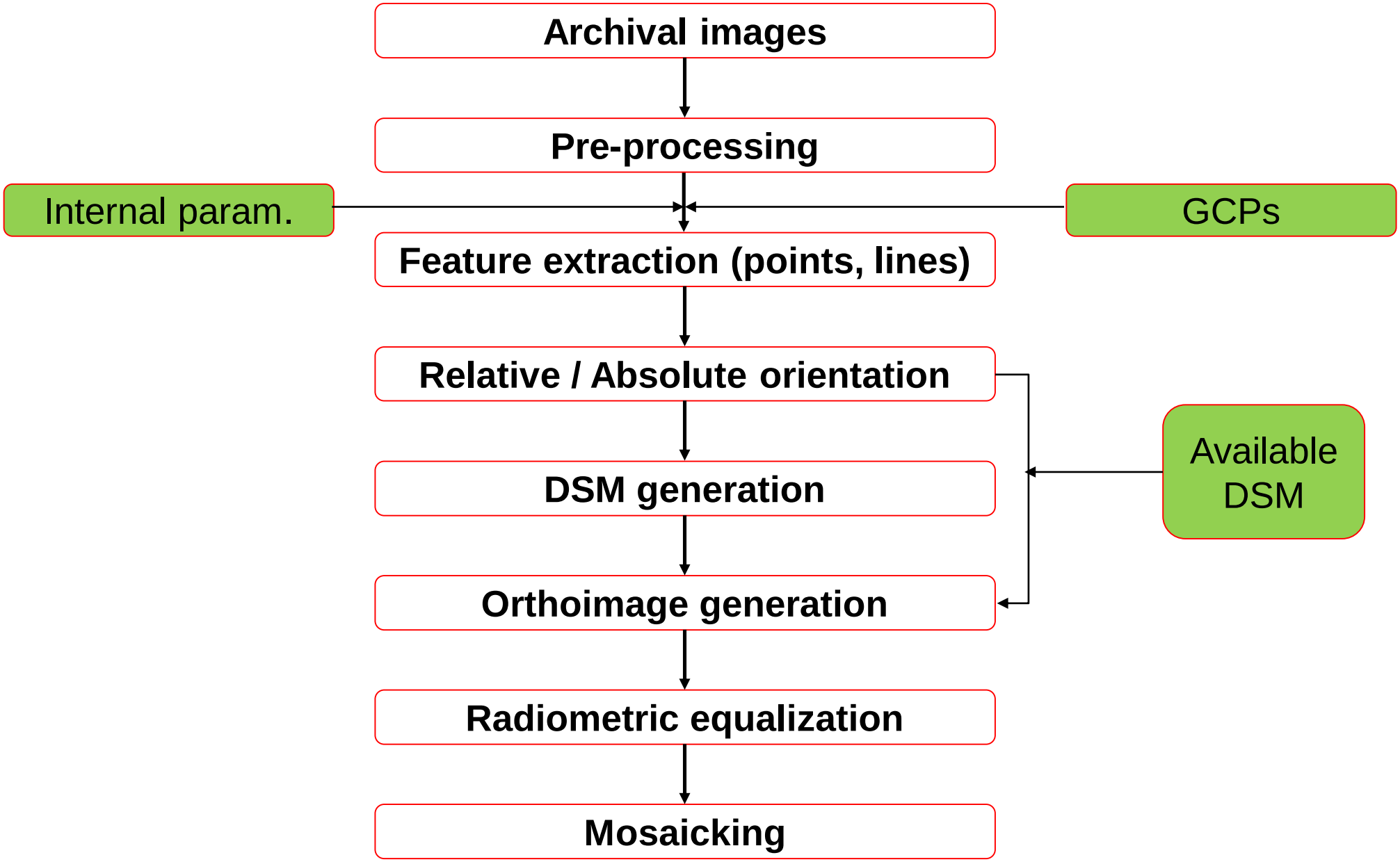
- Proposed approaches varies a lot:
  - Coarse image location available (Giordano et al., ISPRS Annals 2018) vs no metadata available (Nocerino et al., ISPRS Archives 2012)
  - Photogrammetric methods - modelling the geometry of all images (Micheletti et al., Photogrammetric Record 2012) vs non-photogrammetric methods - find an empirical transform that gives the best match between images (Zambanini and Sablatnig, 2017)
  - Use of dense multi-temporal series (Korpela, 2006) vs large time interval (Nebiker et al., Remote Sensing 2014)
- Automated georeferencing methods need a lot of coarse / initial information and dense time series to be effective, reliable and applicable at country-scale
- Could learning methods support automated geo-referencing procedures for historical aerial images?

# GEO-REFERENCING METHODS

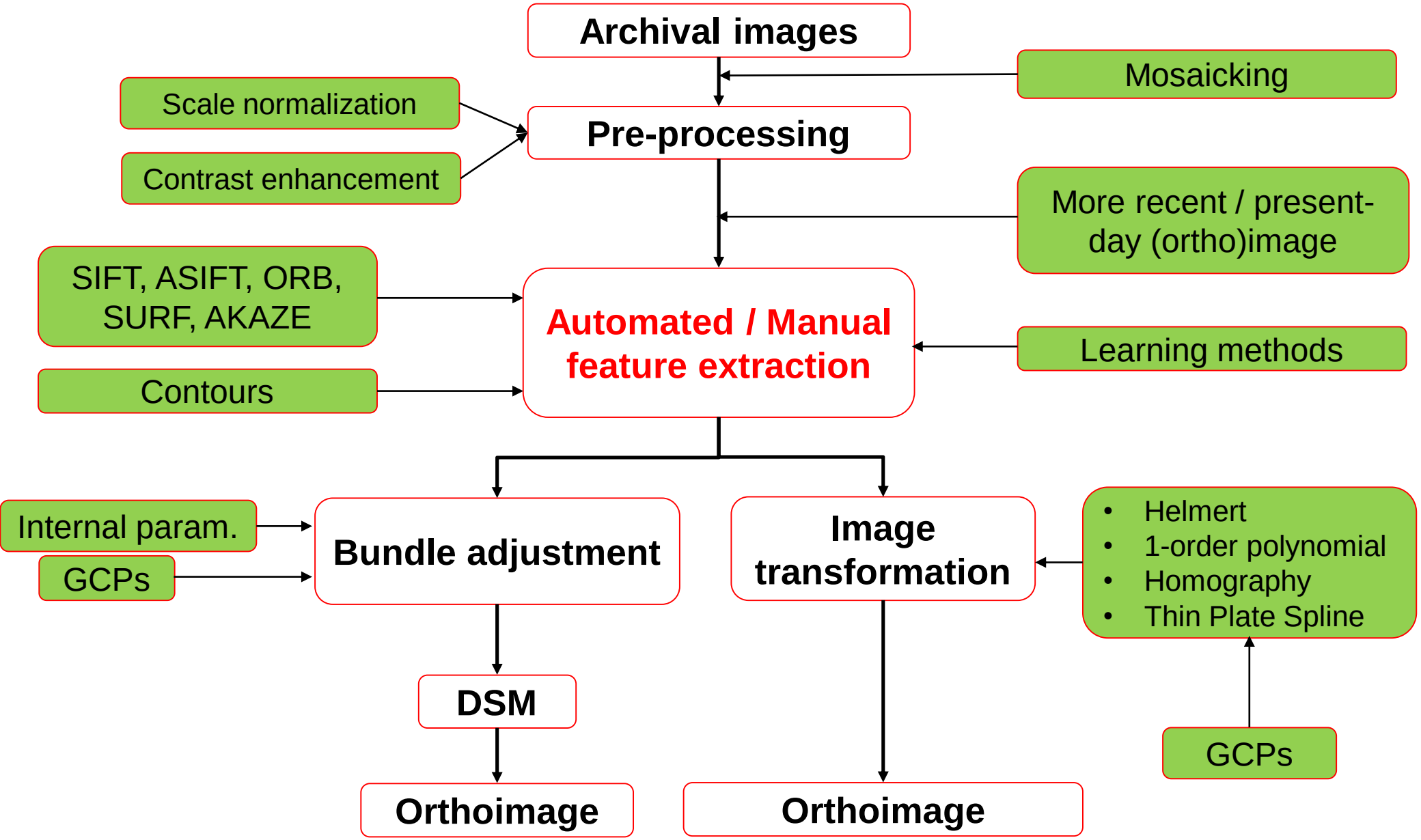



[Giordano, S., Bris, A. L., & Mallet, C., 2018. **Toward Automatic Georeferencing of Archival Aerial Photogrammetric Surveys**. ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences, Vol. 4(2).]

# GEO-REFERENCING, DSM & ORTHO GENERATION



# GEO-REFERENCING, DSM & ORTHO GENERATION

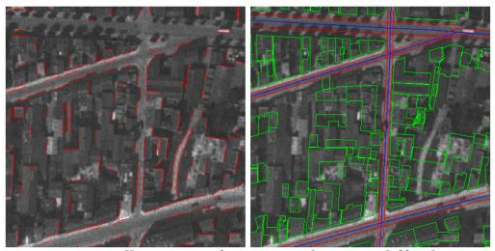


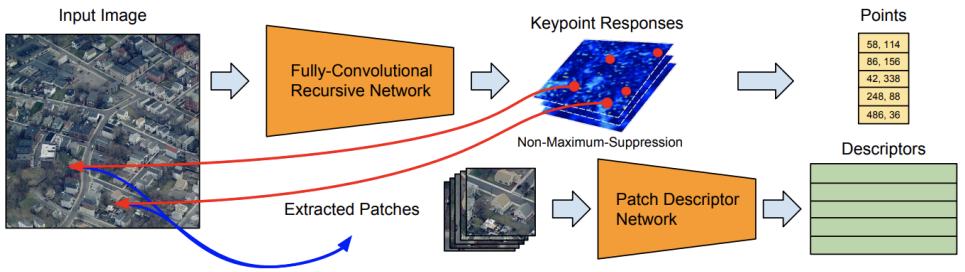
# FEATURE EXTRACTION APPROACHES

- **Points**
  - automated detectors/descriptors like SIFT, ASIFT, ORB, SURF, AKAZE, MSER, etc.
  - Not always reliable due to low radiometric resolution, rotations, large temporal differences and landscape changes

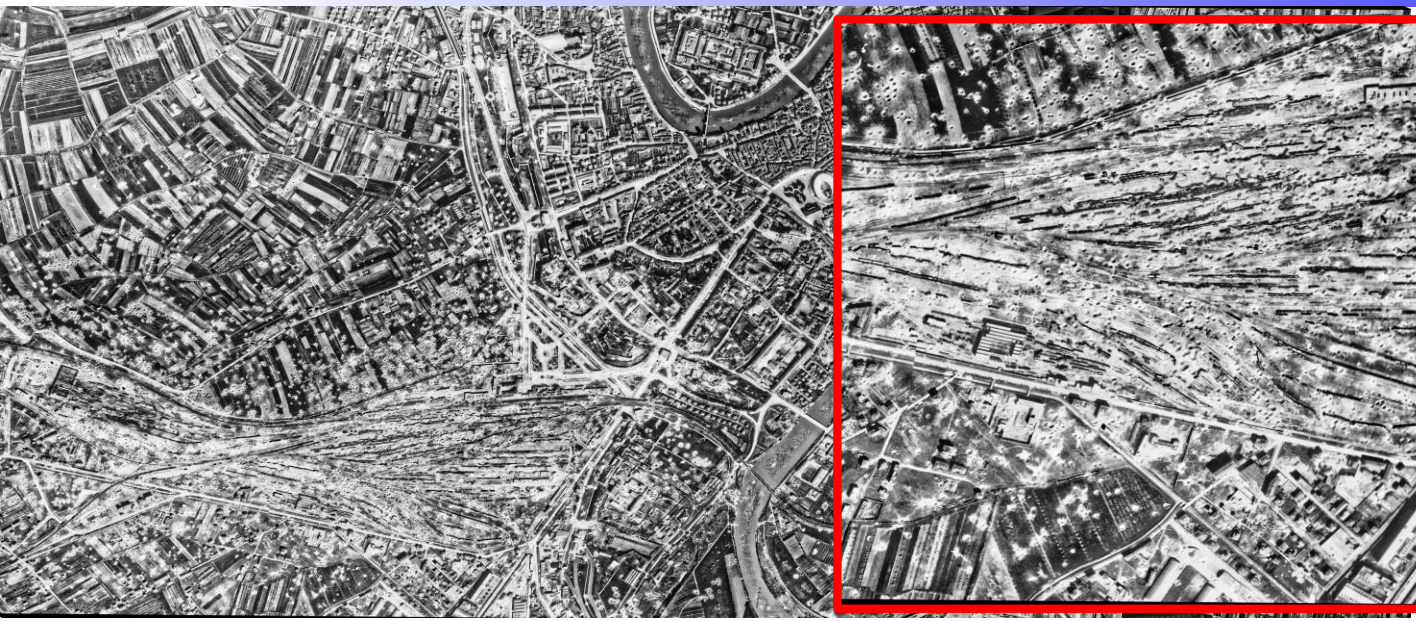
- **Contours and lines** (e.g. Clery et al., 2014)
  - Topographic DB necessary
  - Coarse geo-referencing necessary

- **Learning-based methods to detect repeatable keypoints**:
  - MatchNet (Han et al., CVPR 2015), TILDE (Verdie et al., CVPR 2015), LIFT (Yi et al., ECCV 2016), PN-Net (Balntas et al., arXiv, 2016), LF-Net (Ono et al., CVPR 2018), UnSuperPoint (Christiansen et al., arXiv, 2019), etc.
  - Deep Network architecture that combines 3 components: detection, orientation estimation and feature description) for keypoints extraction into a unique network
  - Only tested on “simple” terrestrial datasets, so far



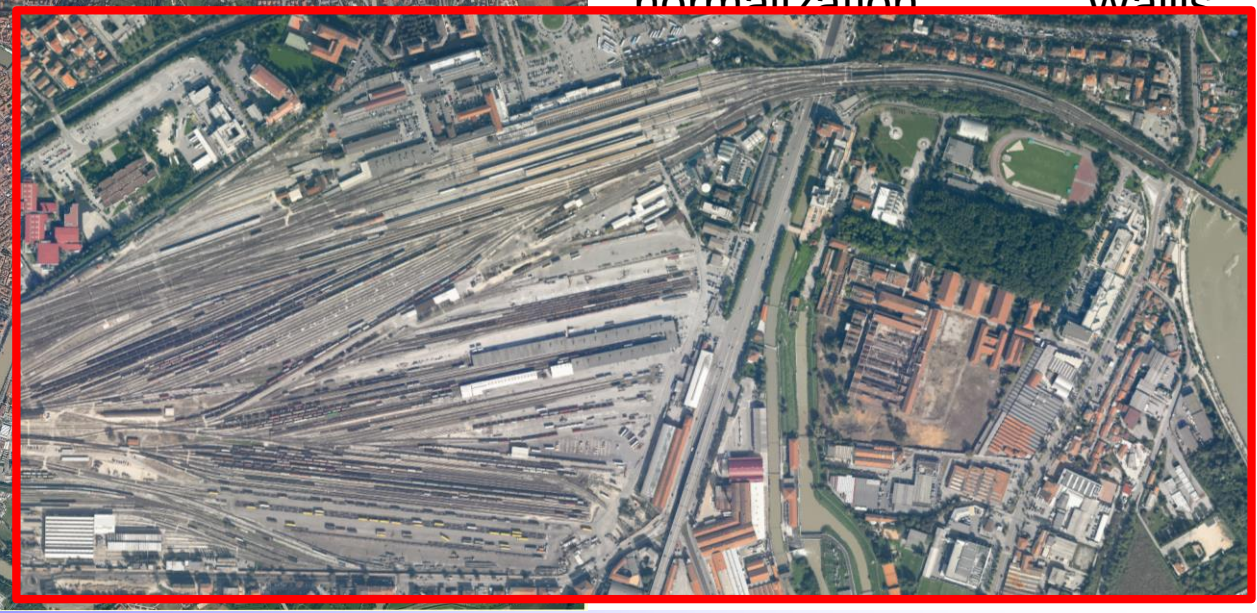


# GEO-REFERENCED IMAGES



*Verona (Italy) – April 1945 vs today*

present-day ortho (scale normalization Wallis



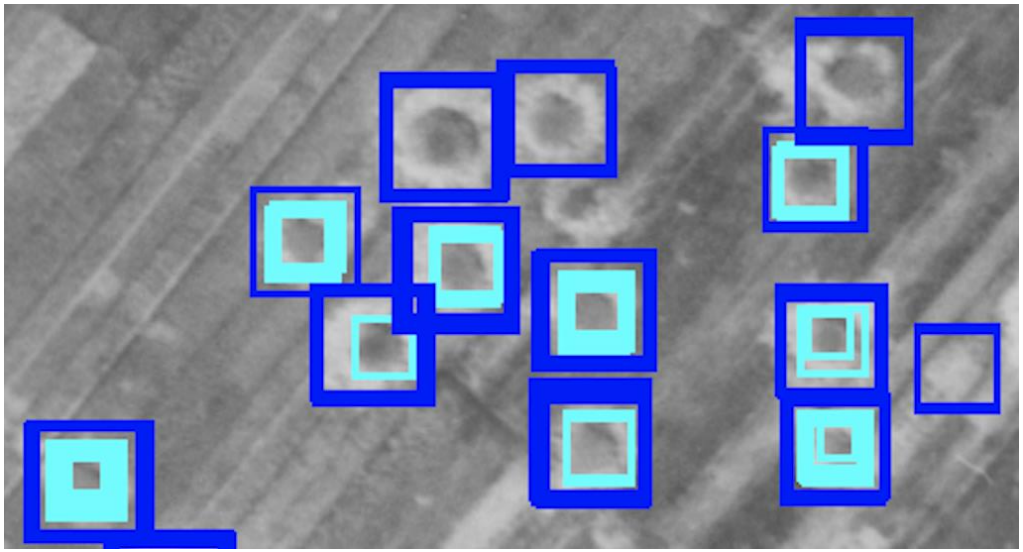
# GEO-PROCESSING

SCANNING / DIGITIZATION

GEO-LOCALIZATION

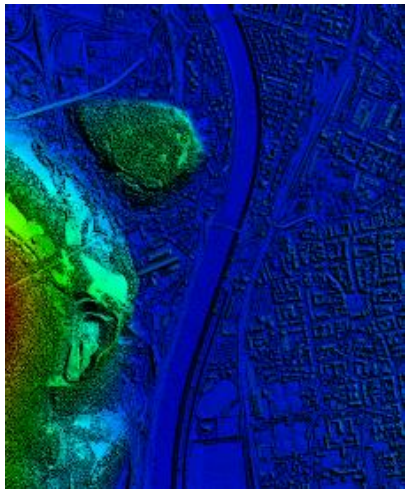
GEO-PRODUCTS

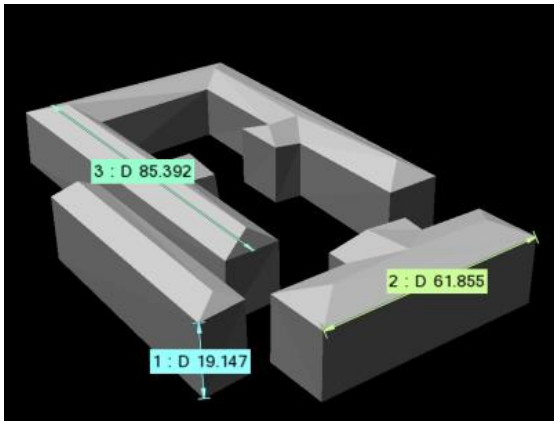
VISUALIZATION

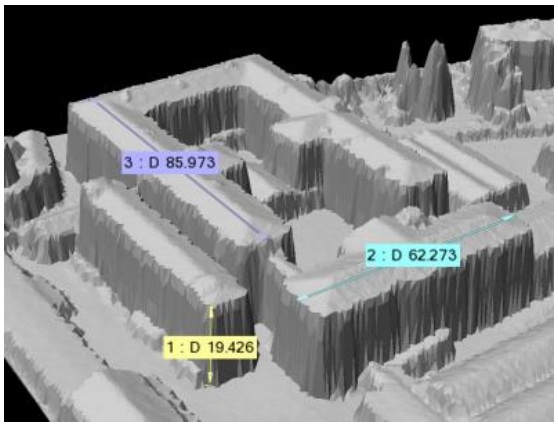


# DENSE IMAGE MATCHING

- Often skipped ☺
- Performed in case of volumetric analyses of past scenarios (e.g. glaciers)
- Super good AT, large overlap, high radiometric quality needed
- **Alternative**:
  - Stereo manual measurement by an expert operator (more reliable, although time consuming)
  - Digitization of historical map in GIS environment
- For ortho generation, more recent / existing DSM are generally employed



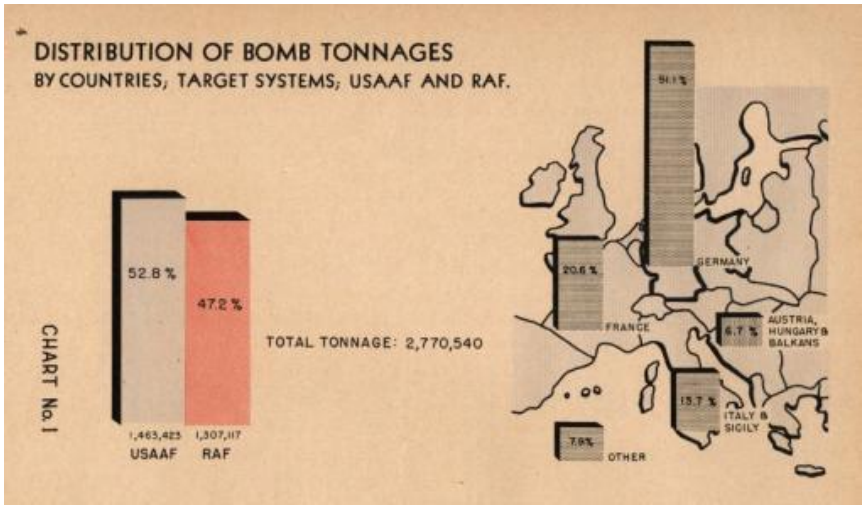



*[Nocerino, E., Menna, F., Remondino, F., 2012: **Multi-temporal analysis of landscapes and urban areas**. Int. Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 39(4), pp. 85-90]*

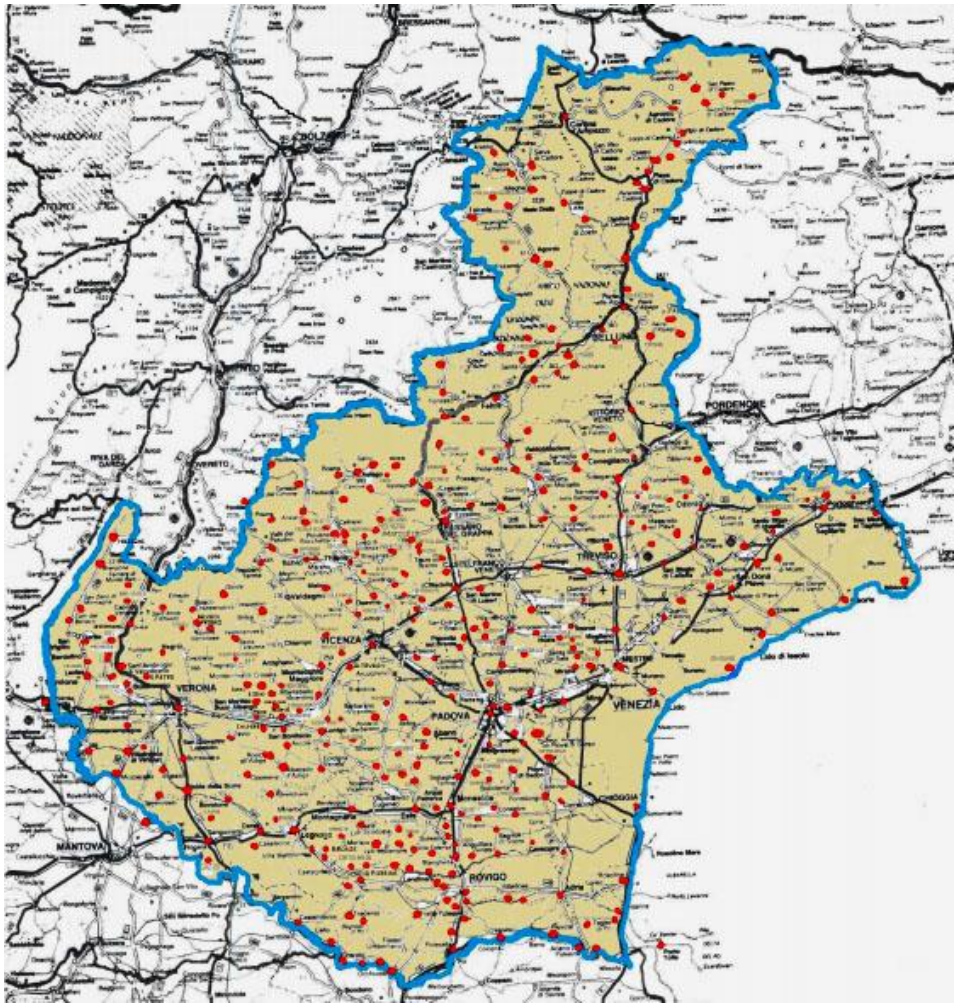
# CRATER DETECTION (UXO)

- Millions of bombs (2.7 mil tons) were air-dropped by the Allied Forces during WWII over EU
  - ca 1 million bombs / ca 380K tons over Italy
  - ca 1.5 million bombs / ca 1.3 mil tons over Germany
  - ca 30K tons over UK
- According to recent studies, some 8%-10% did not explode (UXO / UXB)
- Many found / disposed every year, others are still there lying below the ground
  - Hundreds UXO every year found in Italy
  - Ca 15K UXO removed in construction sites between 2006 and 2008 in UK
- Every found UXO, normally, causes mass evacuations of citizens for disposal procedures (e.g. 16K evacuated in Frankfurt in July 2019)

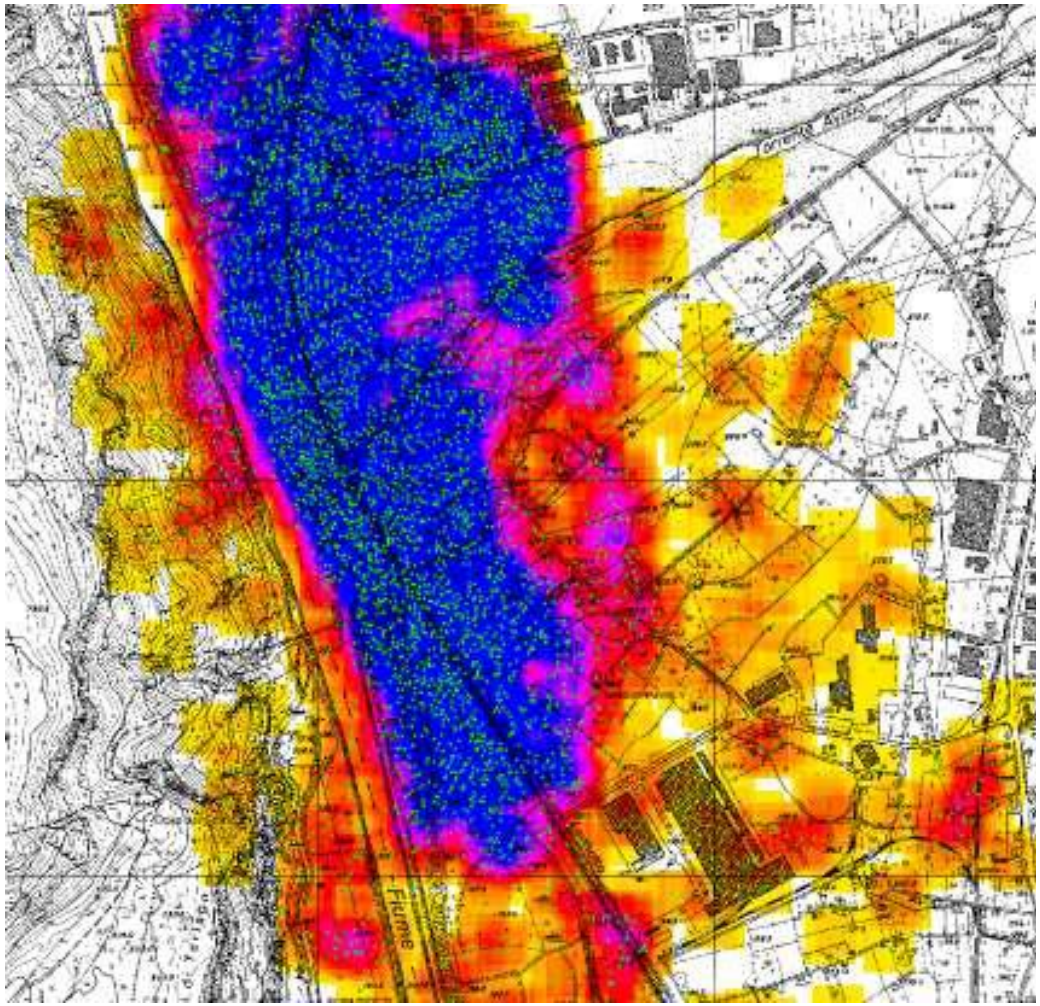


Ahlbach (Germany) June 2019: self-detonated WWII bomb, 10 m wide, 4 m deep crater

# RISK MAP GENERATION



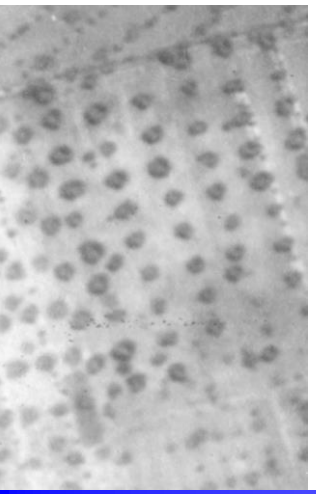
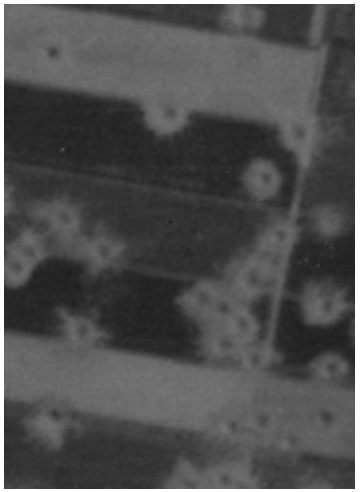

UXO found in the Veneto region (Italy) between 1980 and 2010 *(Gironi, 2011)*

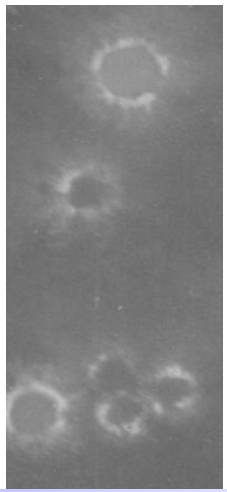
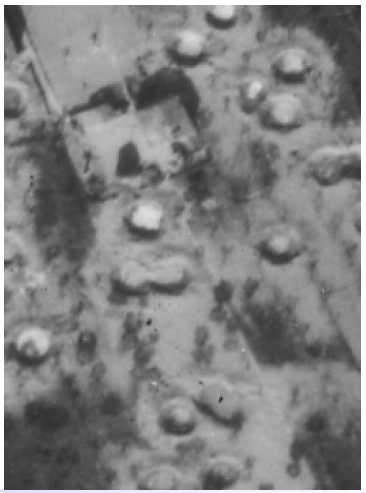
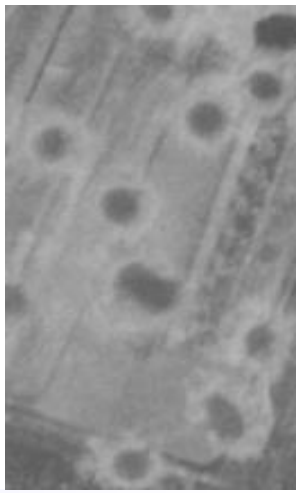



Risk map for the Trentino Province, Italy *(Furlanello et al., 2004)*

# UXO ANALYSIS / CRATER DETECTION

- **Aim**: produce risk maps
- Image interpretation to detect craters and, eventually, unexploded bombs (UXO)
- Visual check of an expert operator vs automated (learning-based) interpretation
- Are actual machine/deep learning methods reliable for automatic crater detection?
- Extra-planetary mapping methods not really successful
- **Challenges**:
  - Many types of craters with various textures, shapes, size (varying GSD), depths, etc.
  - Very similar to tree plantations
  - Shadows and b/w images
  - Different types of terrain generated different types of craters

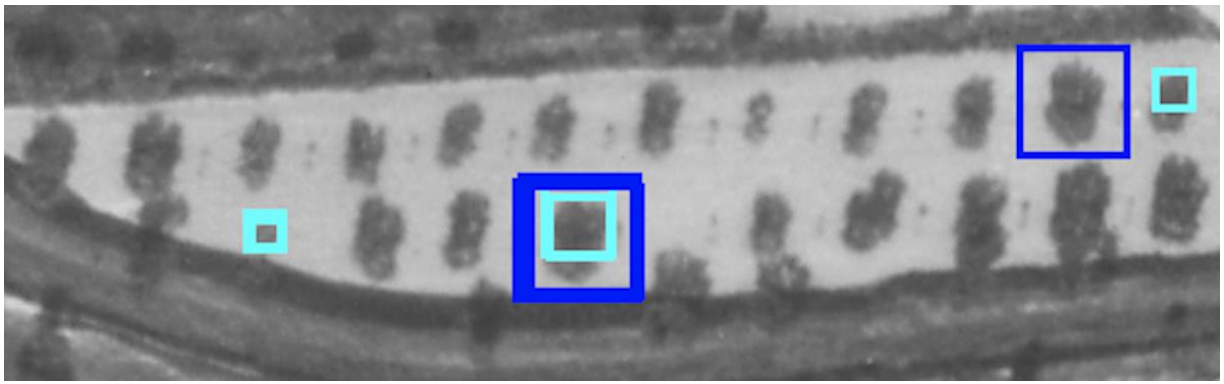



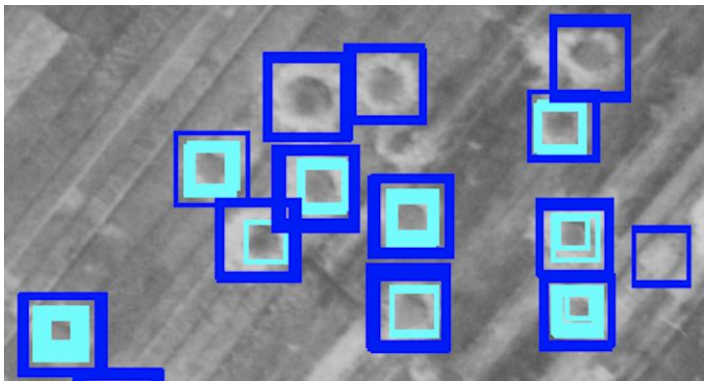




# CRATER DETECTION WITH DL

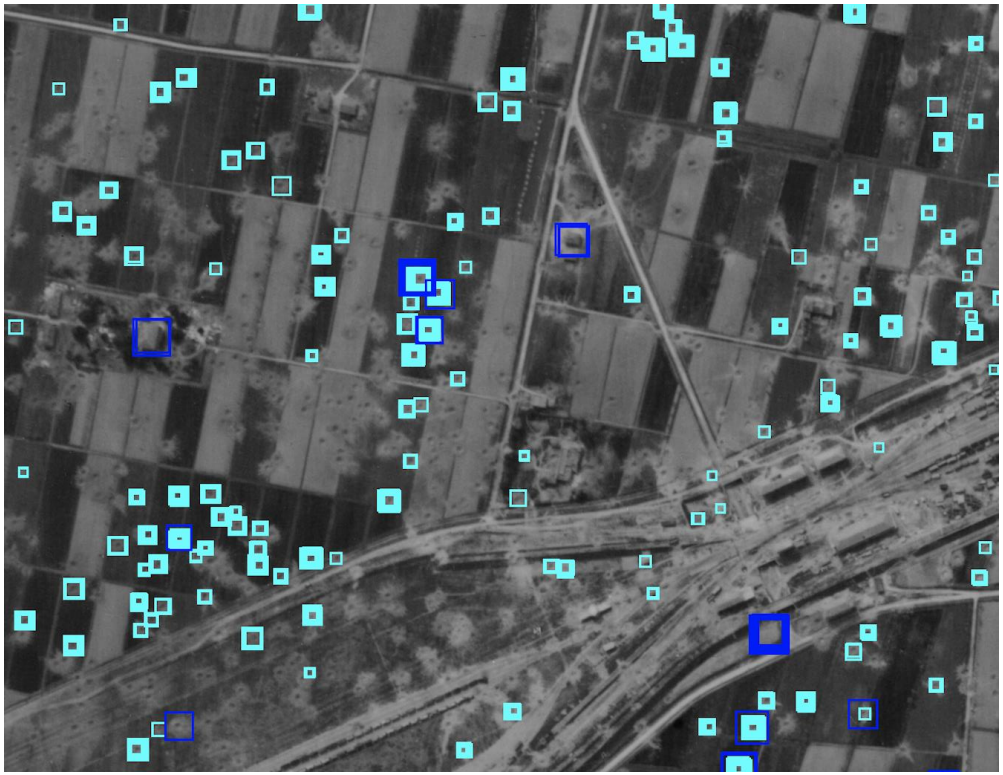
DNN:

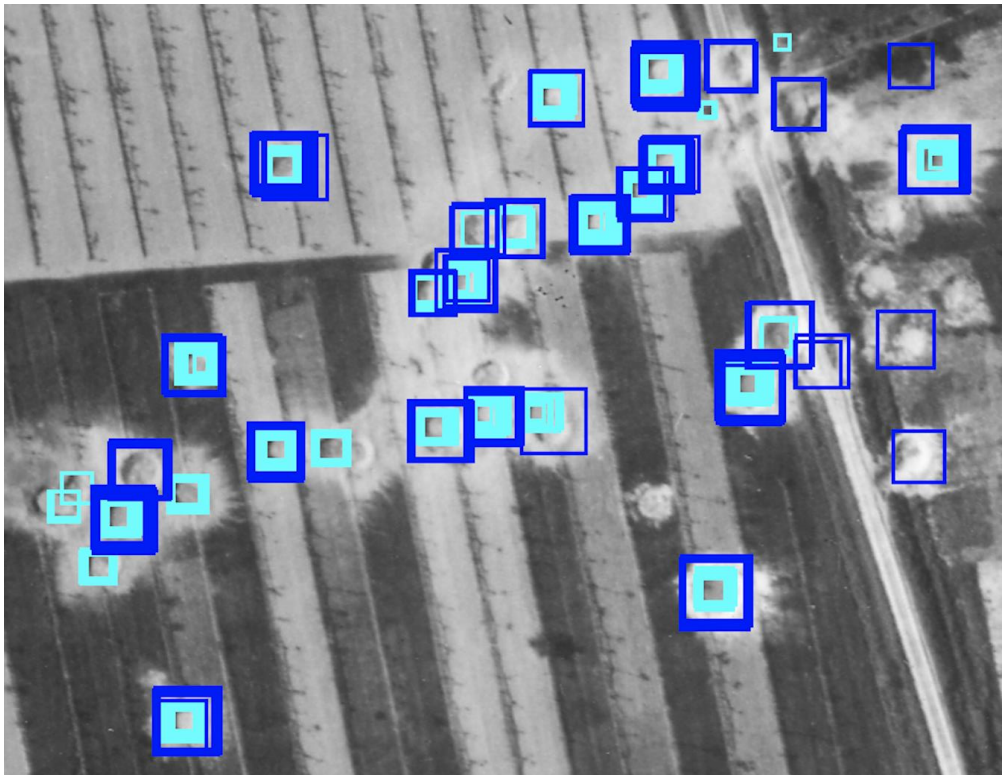
- 21 Serially Connected Layers (Sequential Network)
- 32x32 image input
- Images processed with sliding windows in different dimensions
- Trained with ~3500 manually labelled craters
- Automatic detection of craters, although trees are not helping…
- Training set is very important

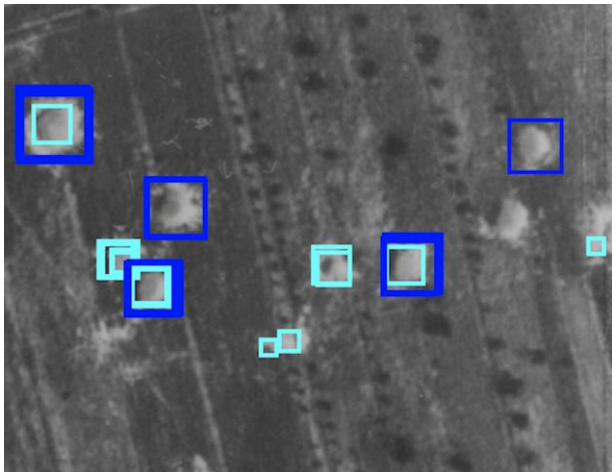


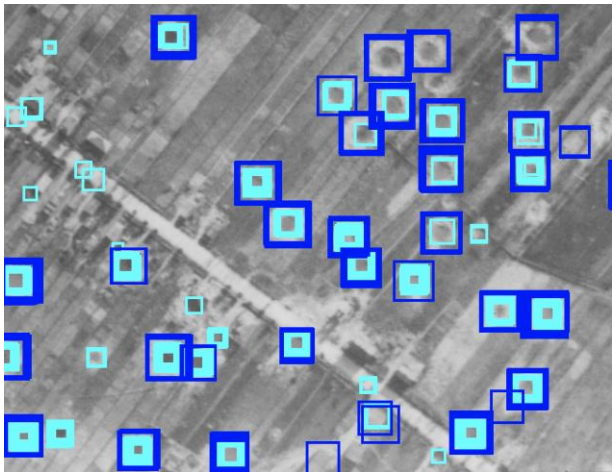


# CRATER DETECTION WITH DL



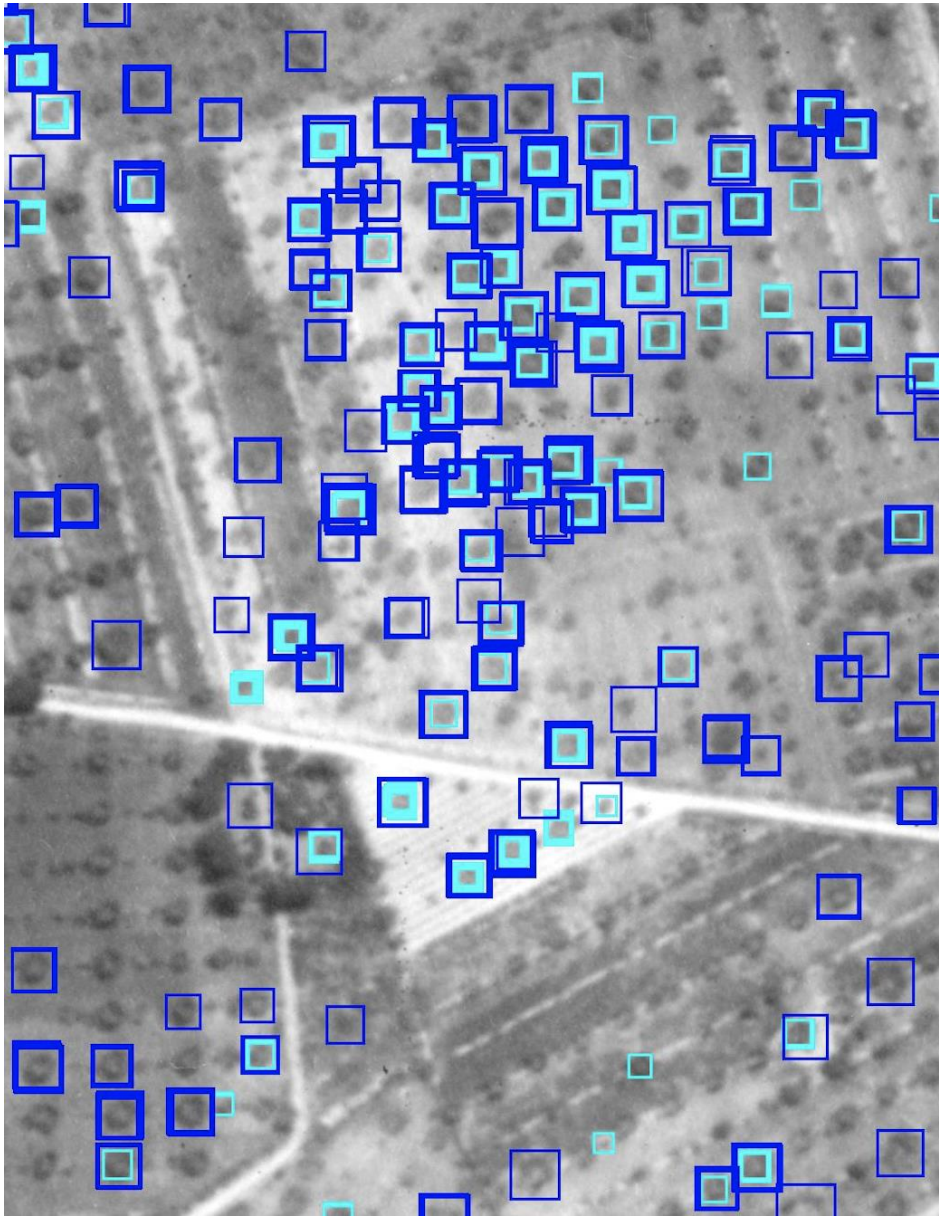






- Most of the craters are detected
- Too bright craters are not spotted
- First results, no accuracy numbers

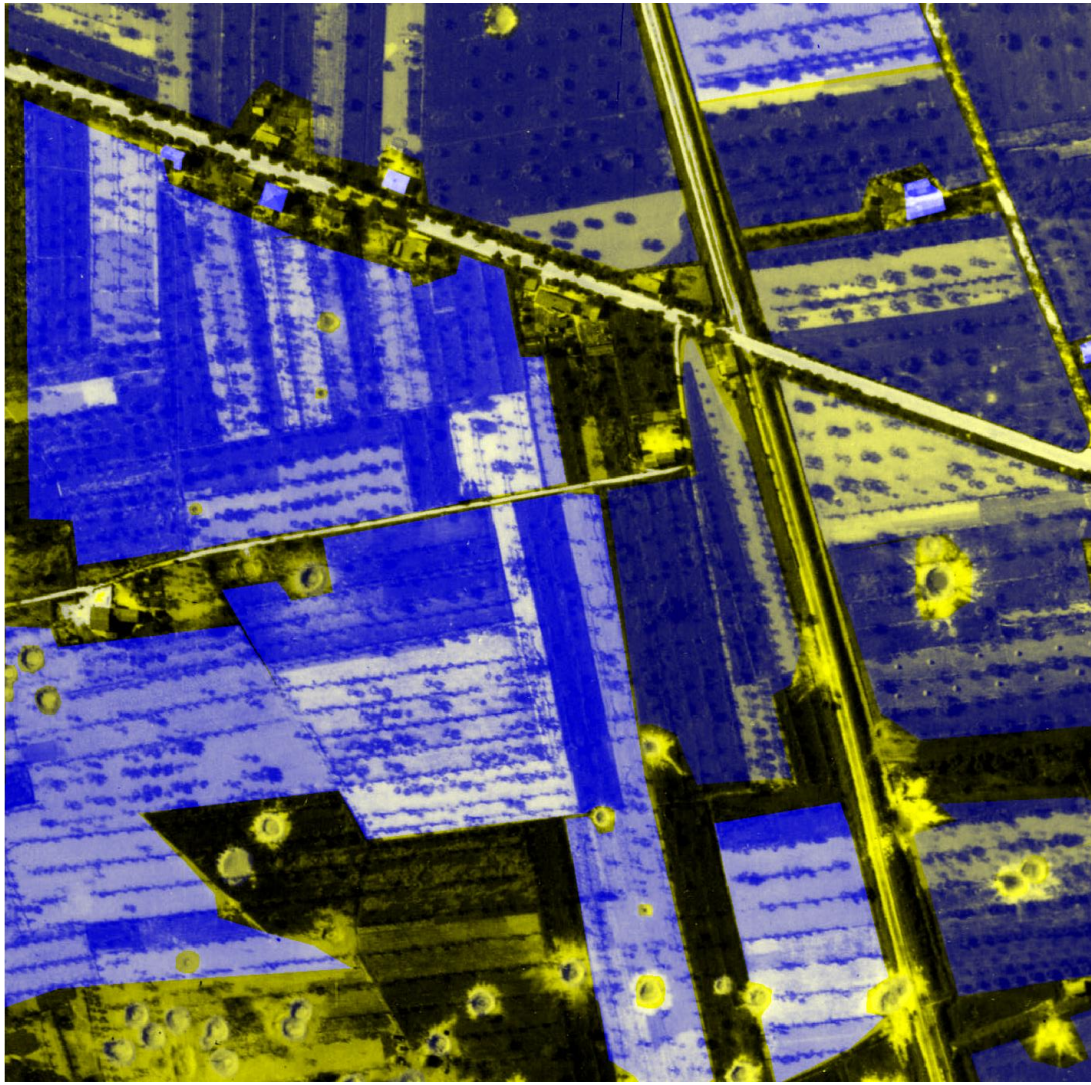
# CRATER DETECTION WITH DL



Various false positives

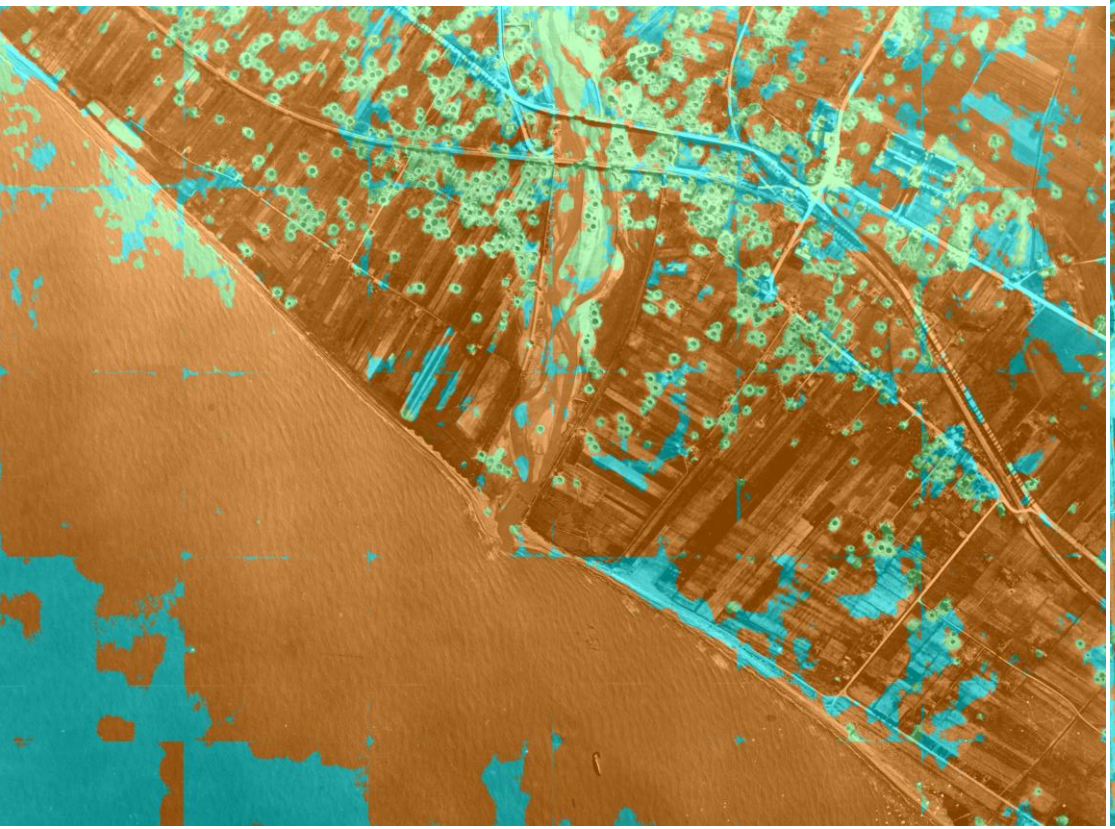
# CRATER DETECTION WITH SEMANTIC SEGMENTATION

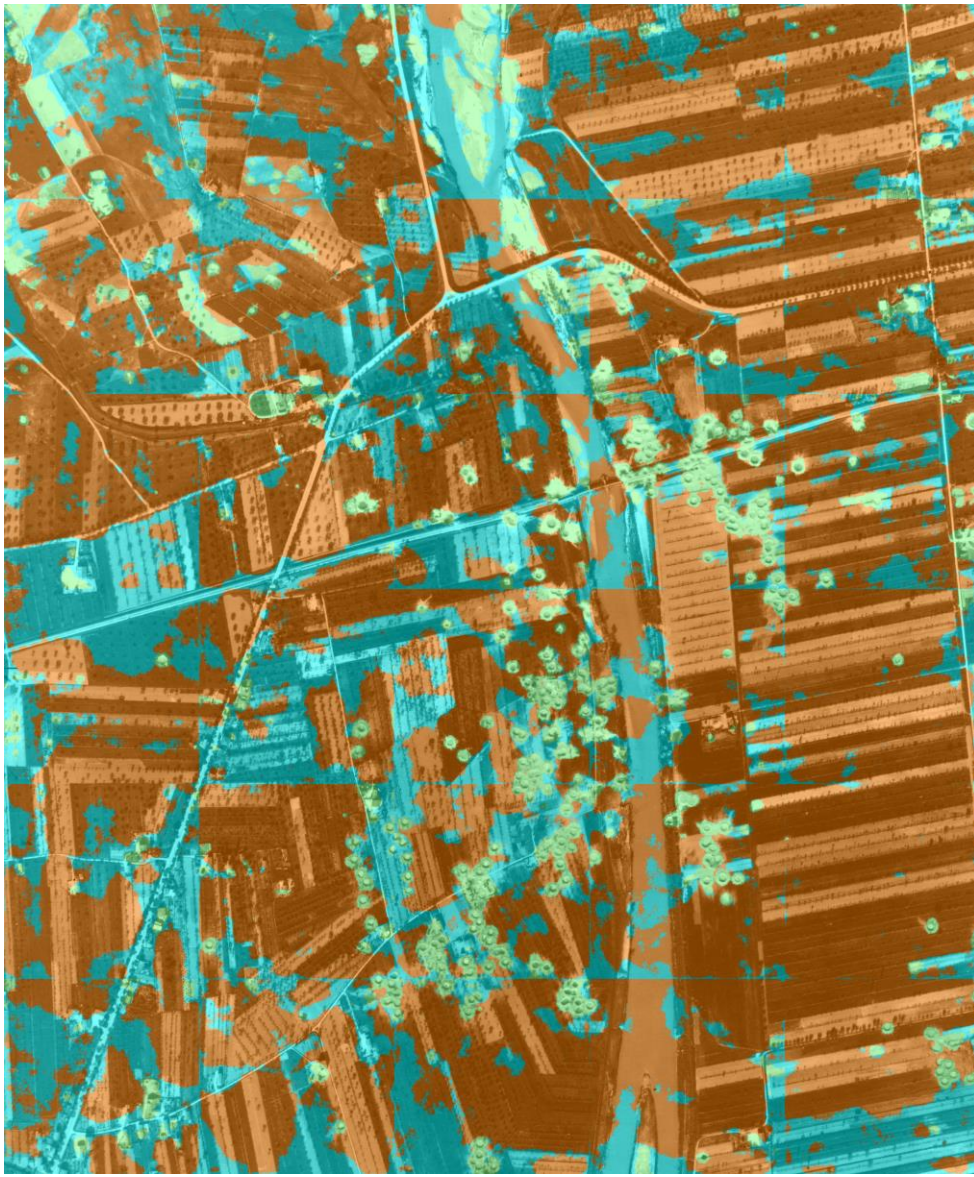
- SegNet Layers with VGG16 model (Russakovsky et al., IJCV 2014)
  - 91 layers, 100 connections
- Focus on rural areas close to urban environment (i.e. very new constructions mainly take place)
- 5 Classes:
  - Craters
  - Farms
  - Vineyards
  - Buildings
  - Flat-white surfaces
- Very large images (~8,000 x 8,000 px) for DL approaches
- Training & evaluation on 1000 x 1000 px regions



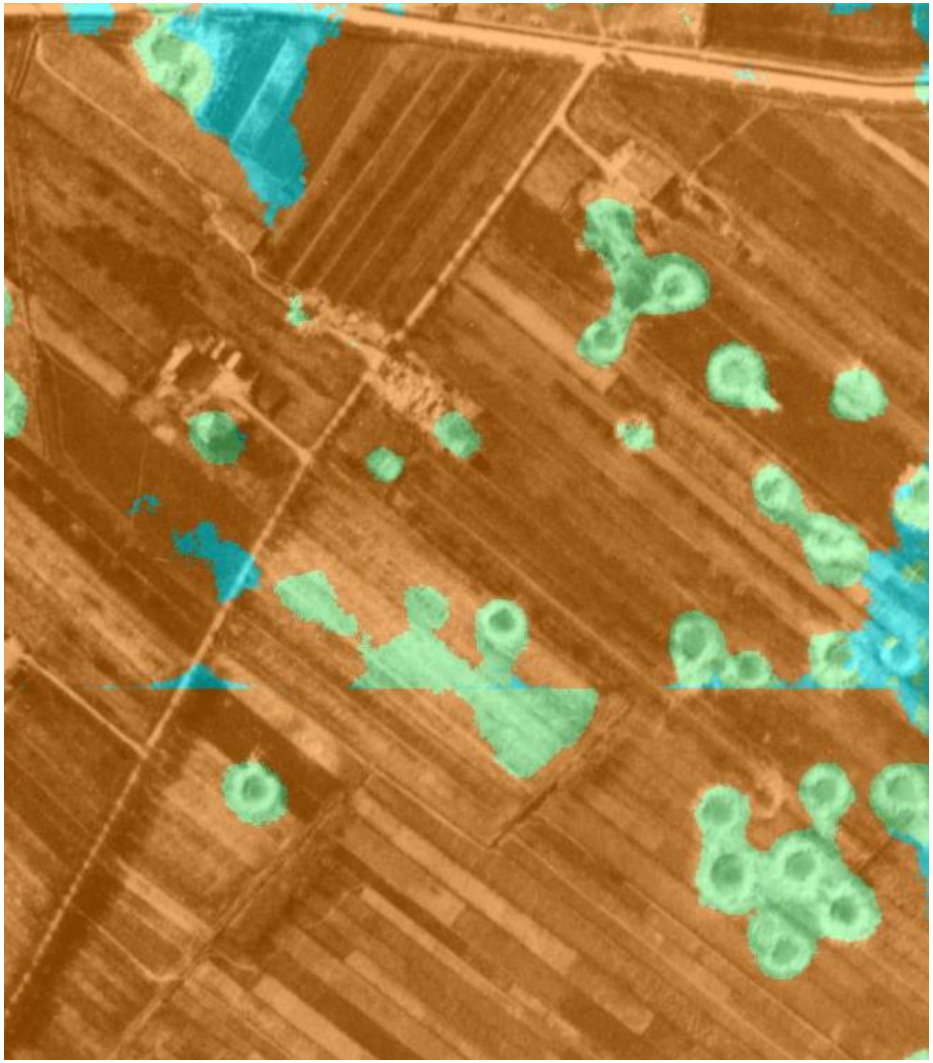
# CRATER DETECTION WITH SEMANTIC SEGMENTATION

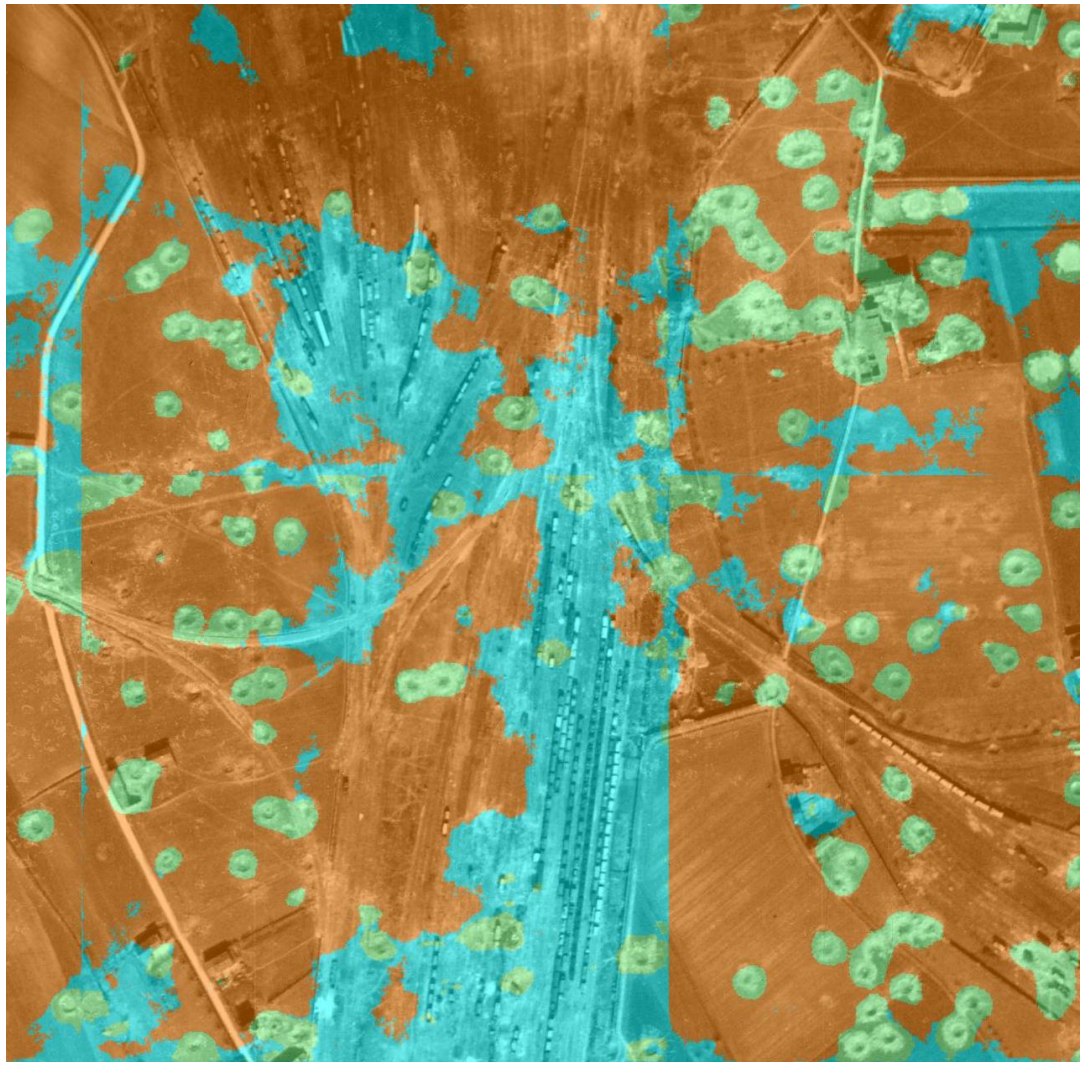
- Results suffer of limited training data
- Some trees look like craters
- Changes in crater size is not helping





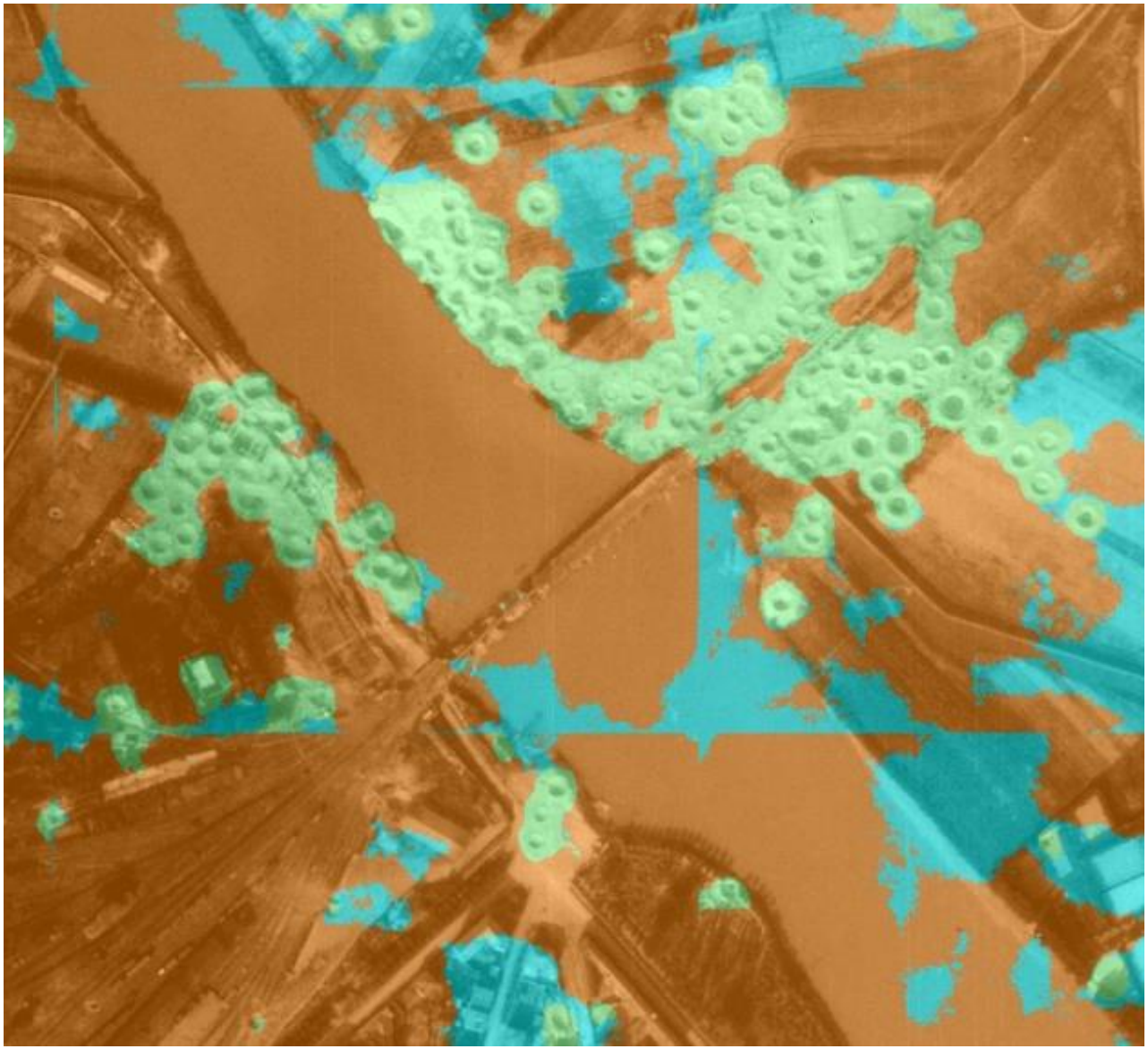
# CRATER DETECTION WITH SEMANTIC SEGMENTATION

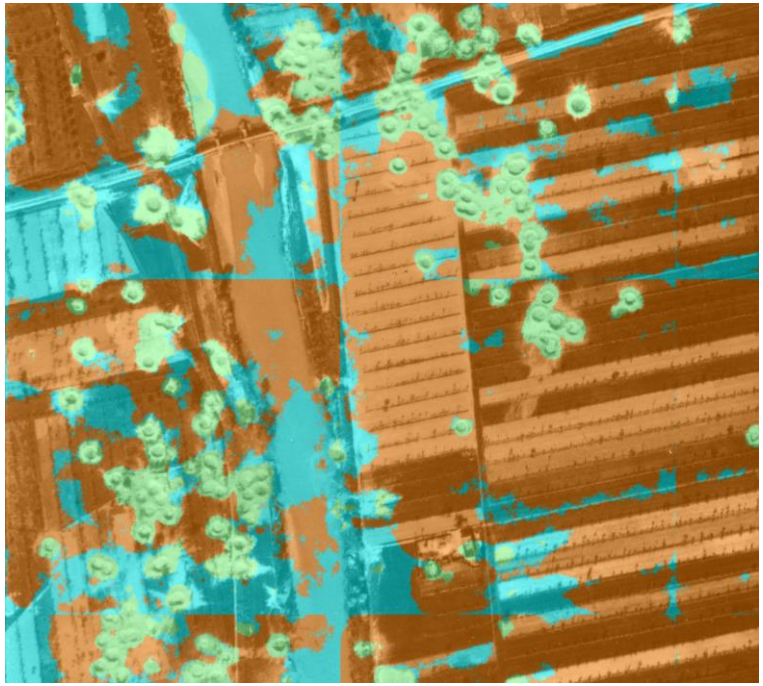


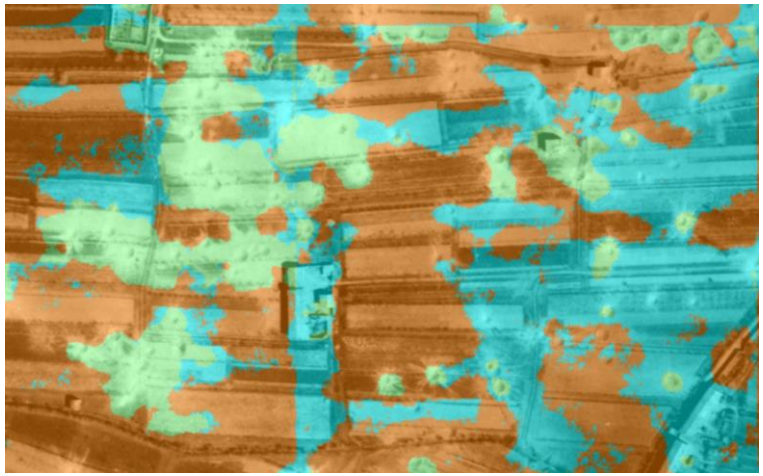


Accuracy of the classification varies wrt the GSD of the images

# CRATER DETECTION WITH SEMANTIC SEGMENTATION







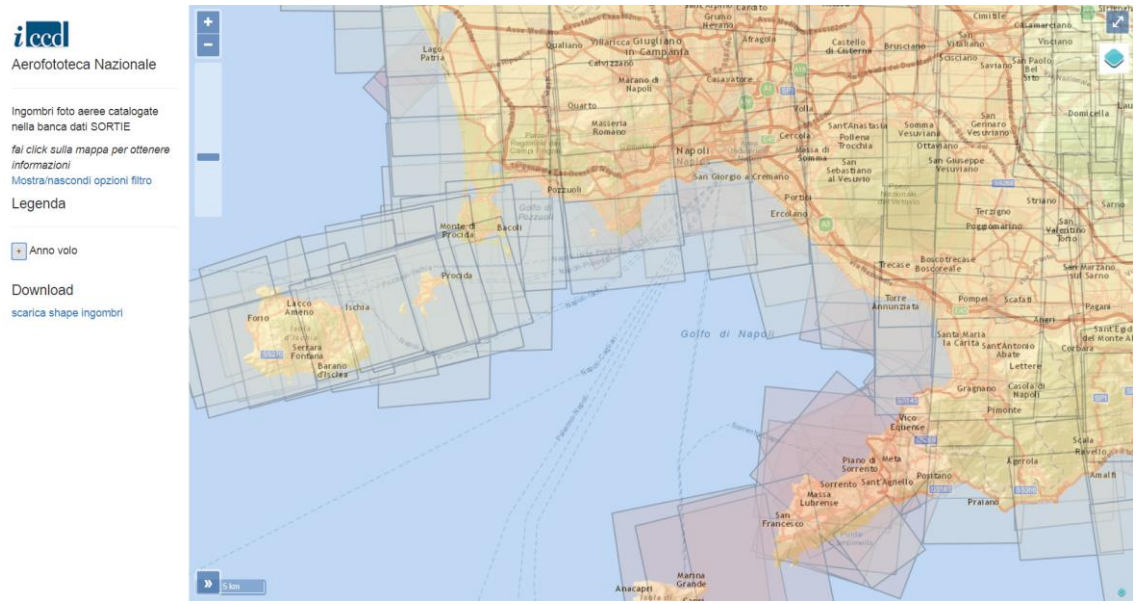
# GEO-PROCESSING

**SCANNING / DIGITIZATION**

**GEO-LOCALIZATION**

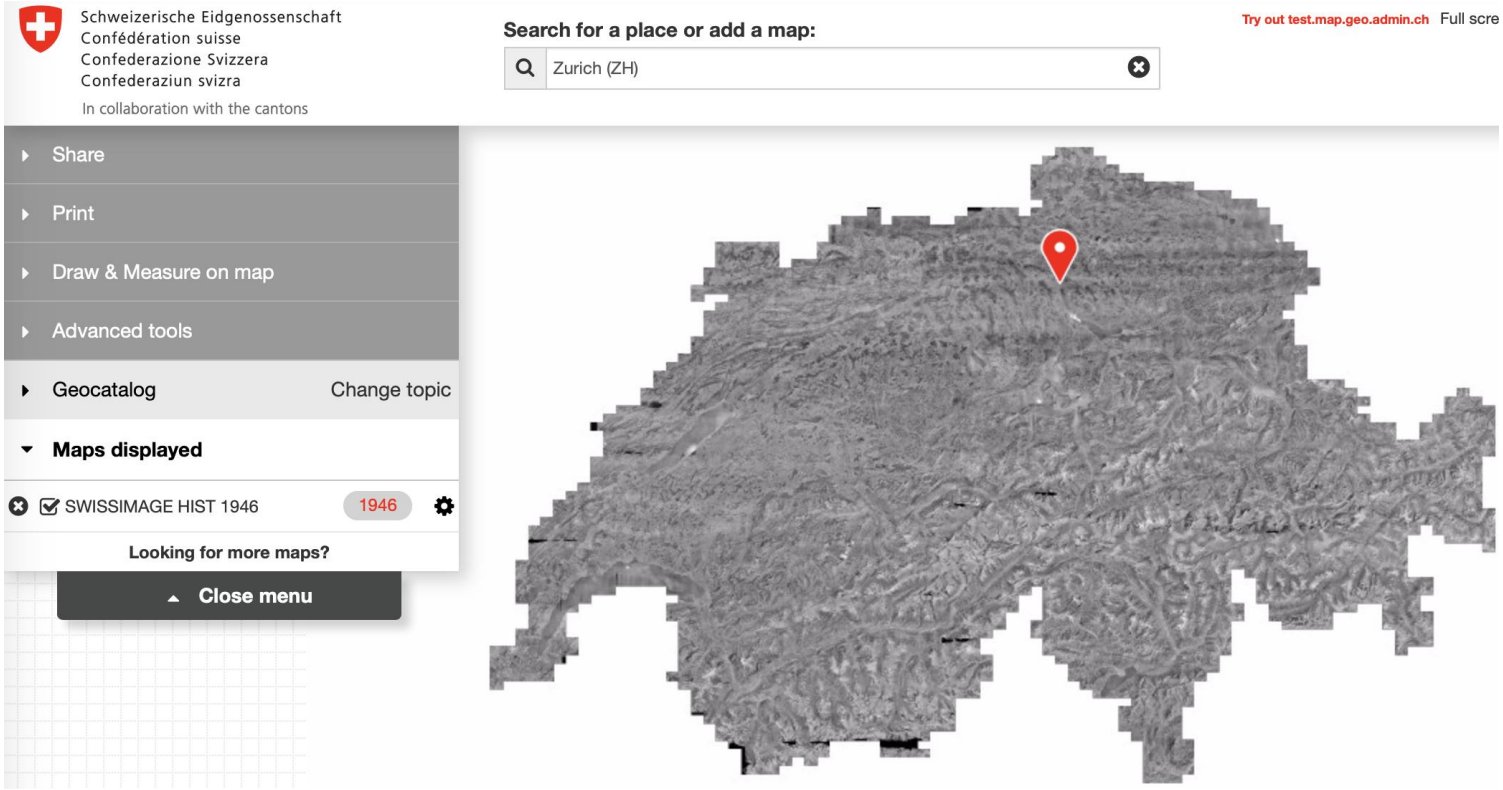
**FEATURE EXTRACTION**

**VISUALIZATION**



# VISUALIZATION & DISTRIBUTION in EU

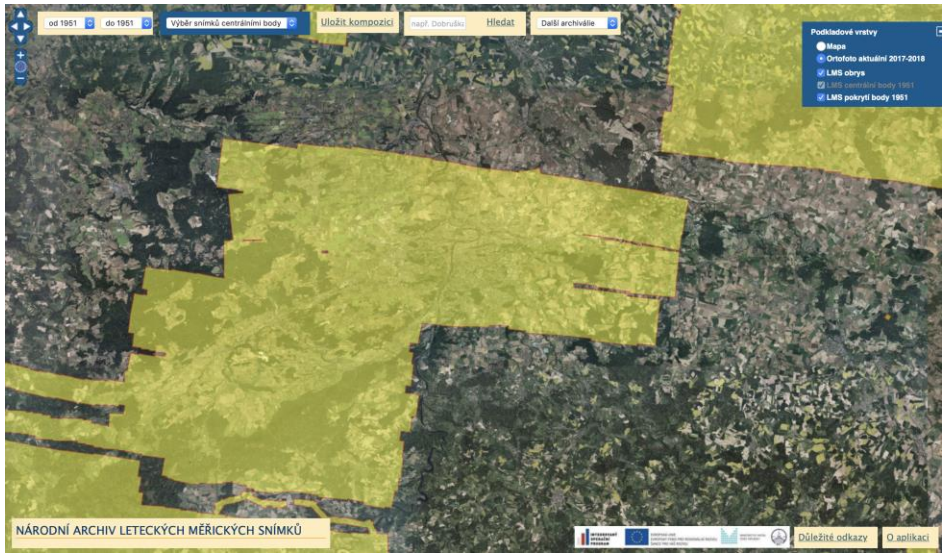
- Online access to historical digital images for consultation & purchasing
- Different business models: free of charge download vs 5-25 Eur/photo
- Some EU countries have produced historical nation-wide orthos for particular years using digitized archive images (e.g. Swissimage 1946, Sweden 1960 and 1975, etc.)

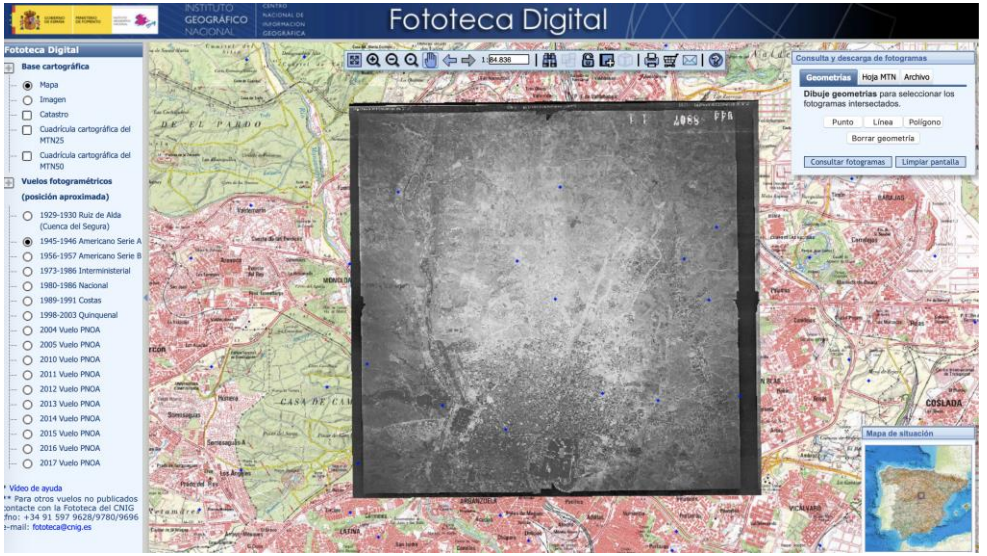



*4117 photos digitized, oriented with PCA Historical Air Photo module, orthorectified and moisaicked in Inpho*

# VISUALIZATION & DISTRIBUTION in EU

- Example of visualization and distribution web-platforms in EU countries:
  - Norway: www.norgeibilder.no
  - Sweden: https://geolex.etjanster.lantmateriet.se
  - Austria: www.bev.gv.at
  - Spain: http://fototeca.cnig.es
  - Cyprus: https://eservices.dls.moi.gov.cy/
  - Czech Republic: https://lms.cuzk.cz/
  - Switzerland: https://www.swisstopo.admin.ch
  - France: http://remonterletemps.ign.fr
  - etc.

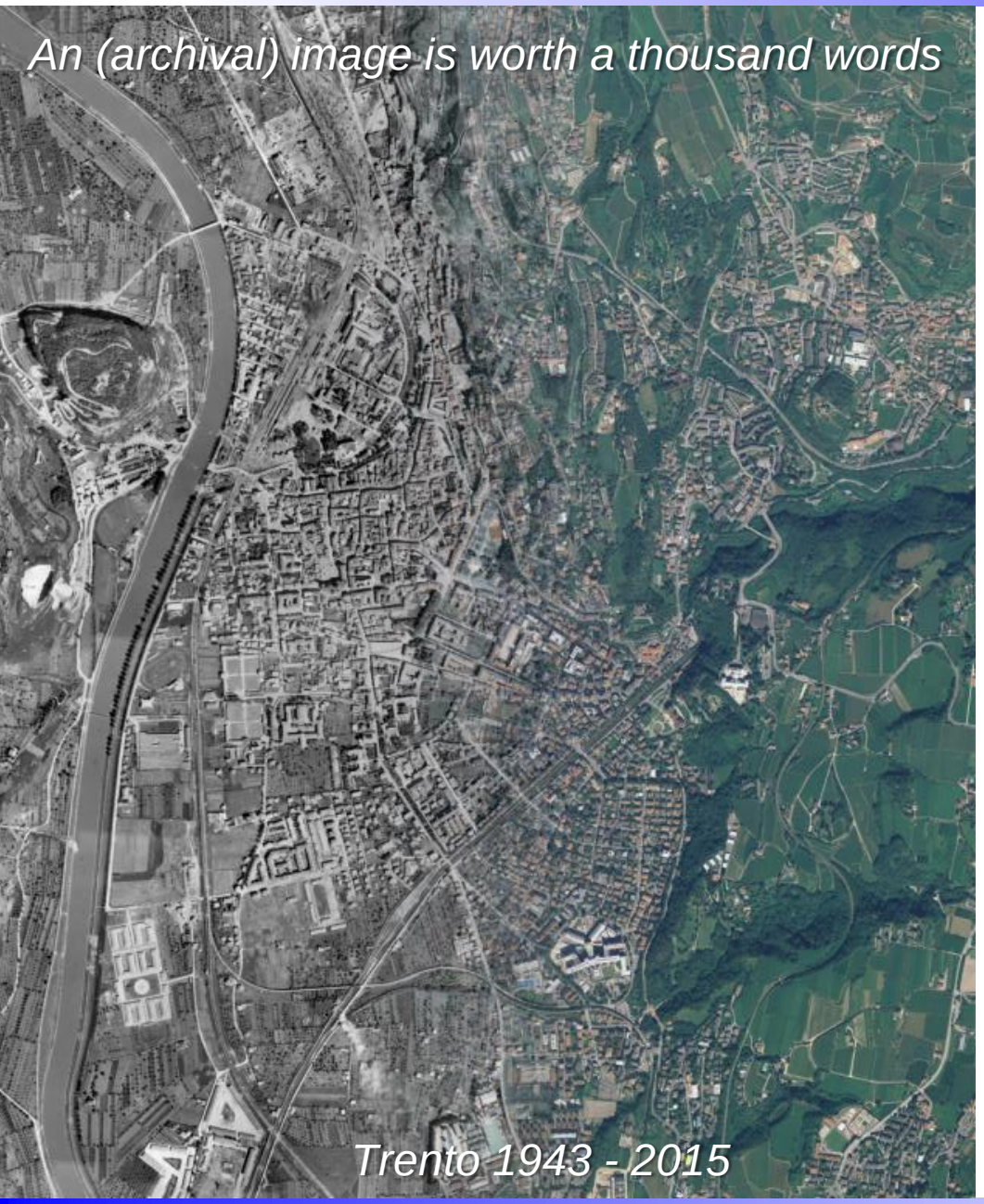


# CONCLUSIONS

- Key value and importance of historical aerial images
- Lot of interest in geo-community thanks to recent progresses in geo-processing algorithms and the availability of digital images
- Many possible applications but still many open issues for automated processing
- Potential for learning methods (tie point extraction, crater detection), but a lack of training data still blocks the fully deployment of these methods to historical aerial images
- Preparation of an EuroSDR benchmark for automated georeferencing, crater detection, change detection, etc.

# THANK YOU

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and various NMCAs in Europe