An open-source toolset for automated processing of historic spy photos: sPyMicMac

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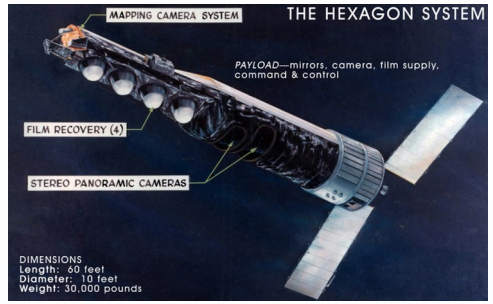
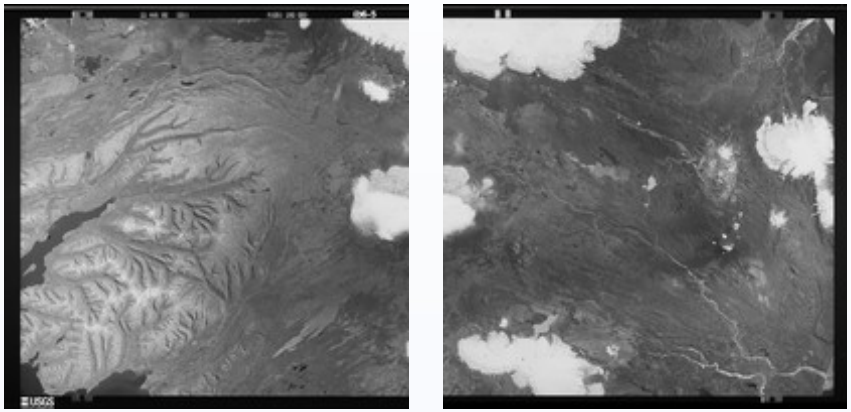
background/motivation

- Long-term (>20 years) spatially-resolved records of glacier change are important, but scarce
- Volume changes resolved for only ~10% of glaciers, mostly since 2000 (Zemp et al., 2019)
- De-classified photos from KH-9 Hexagon, historic air photos can help fill gaps, extend records
- Images are challenging to work with (and there's a lot of them)
- Goal: work on open-source tools that make this easier

KH-9 Hexagon mapping camera

- two camera systems:
  - panoramic (~0.6 m resolution)
  - mapping (~6-8 m resolution)
- 9” x 18” film (~23 x 46 cm)
  - images scanned as two halves
    - large files (>1 GB per half)
  - distortions due to storage, scanning
  - radiometric differences from scans
- Camera parameters still poorly known





MicMac

- Developed at IGN, ENSG, France (Rupnik et al., 2017)
- Cross-platform, free, open-source photogrammetry software:
  - workflows can be tailored for users of all levels
  - access to intermediary processing steps (modular)
  - applicable to modern (e.g., satellite, UAV) and historic datasets (e.g., air photos)
- Goal: provide tools that help simplify processing steps for datasets of interest

sPyMicMac modules

- `image_tools`:
  - pre-processing, image matching functions
- `micmac_tools`:
  - functions to interface with MicMac commands
- `usgs_tools`:
  - interface with USGS API
  - query USGS Earth Explorer to get image metadata, approximate georeferencing
- `ee_tools` (in progress!):
  - interface with Google Earth Engine API
  - produce, export cloud-free mosaics of area of interest
  - download DEM over area of interest

processing steps (simplified)

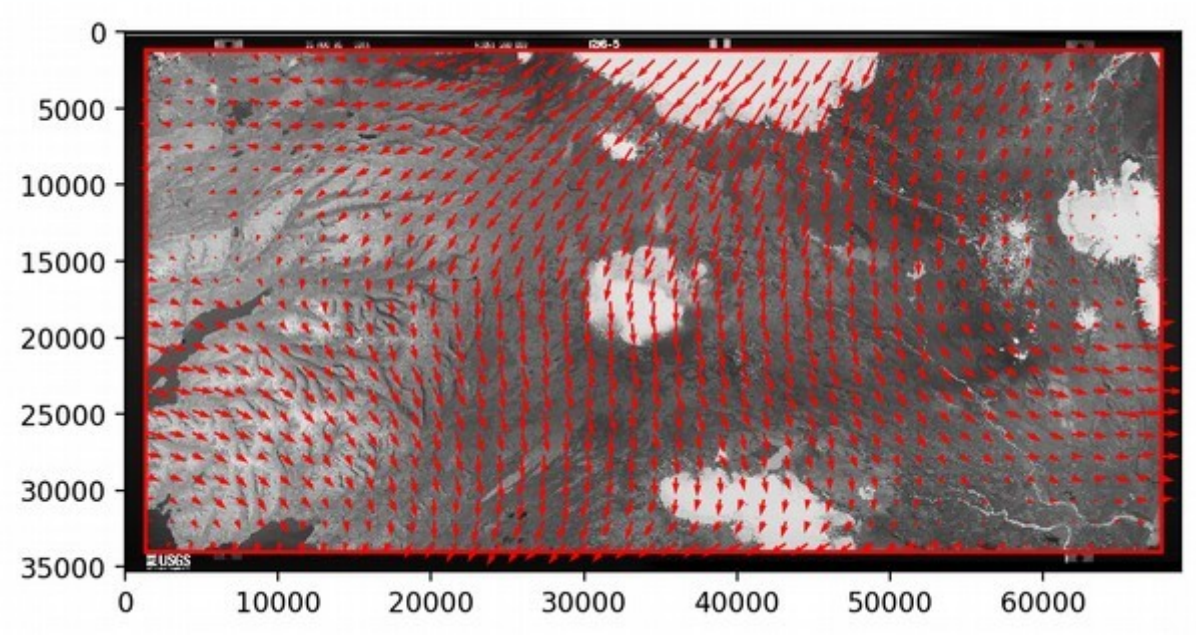
1. pre-processing (image joining, resample based on réseau grid)

   e.g., Surazakov and Aizen (2010); Maurer and Rupper (2015)

2. estimate relative orientation using tie points estimated with SIFT
3. generate relative (not georeferenced) orthoimage, DEM from internal orientation
4. find dense control points using relative orthoimage, satellite image
5. estimate absolute orientation, generate final DEM and orthoimage

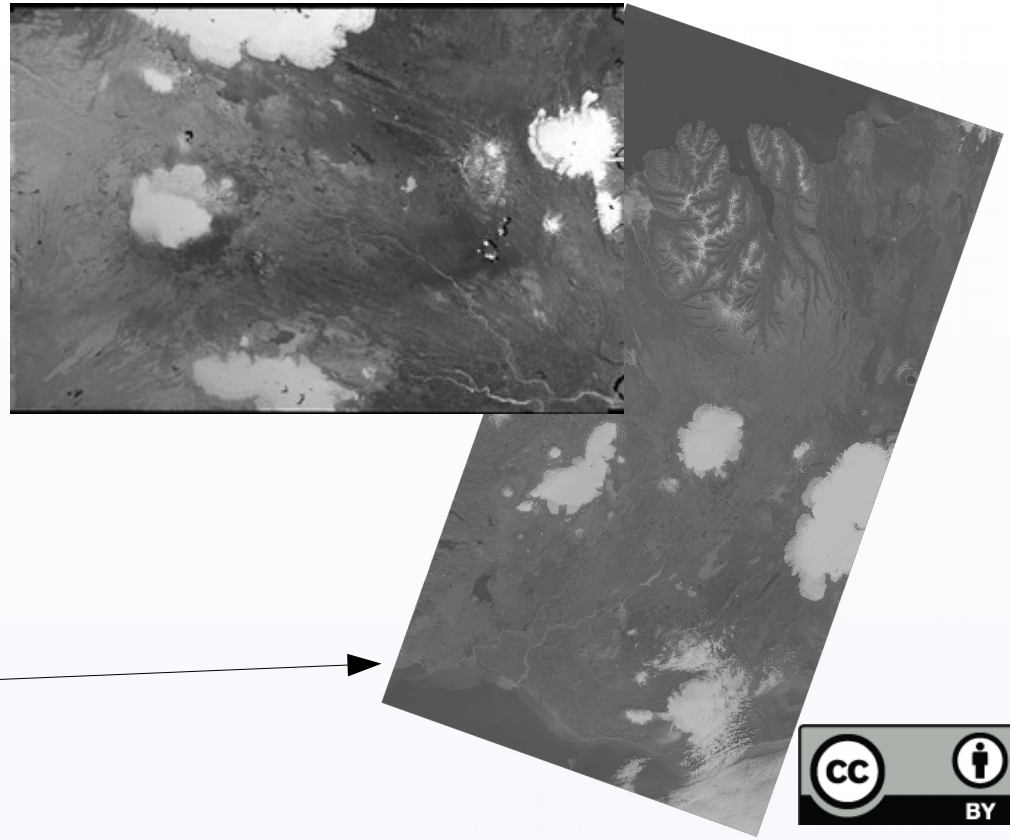
pre-processing: réseau grid

- Find image frame
- Search for corner réseau marks
- Search on a regular grid to save time
- Clear distortion patterns (see EGU2020-9153, this sesion, for analysis!)



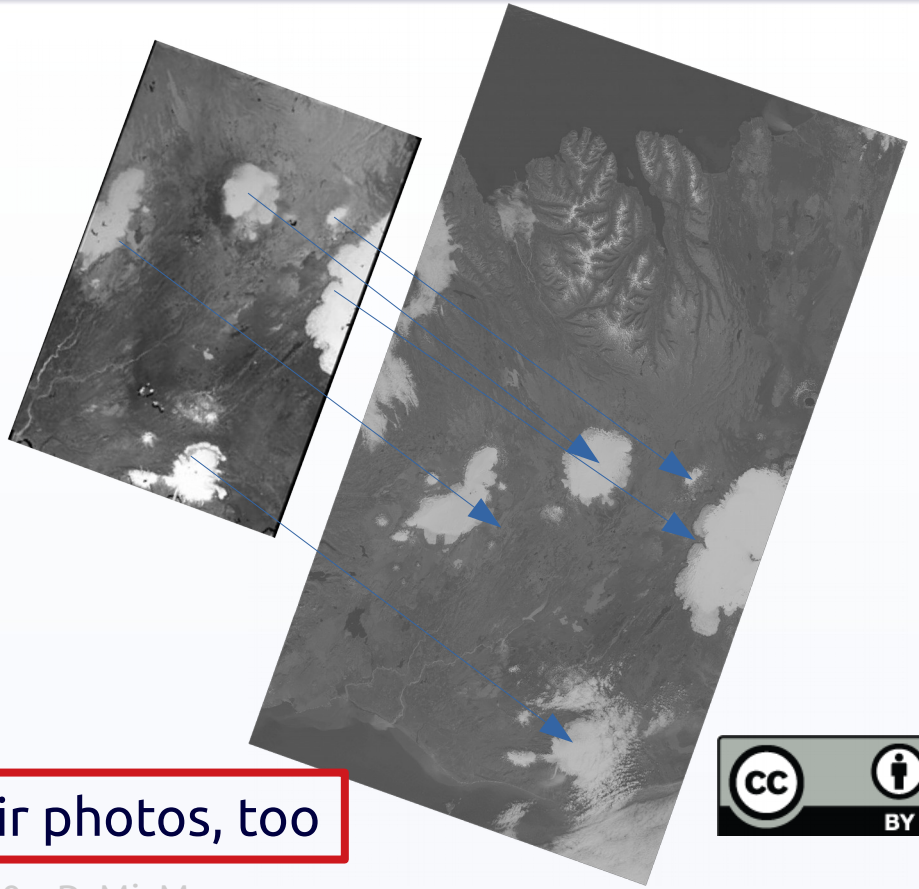
control point matching

- Images often remote areas w/ little to no ground control
- Residual warping requires large # of points to correct distortion
- Solution: use dense matching to orthorectified satellite imagery (e.g., Sentinel-2, Landsat 8)



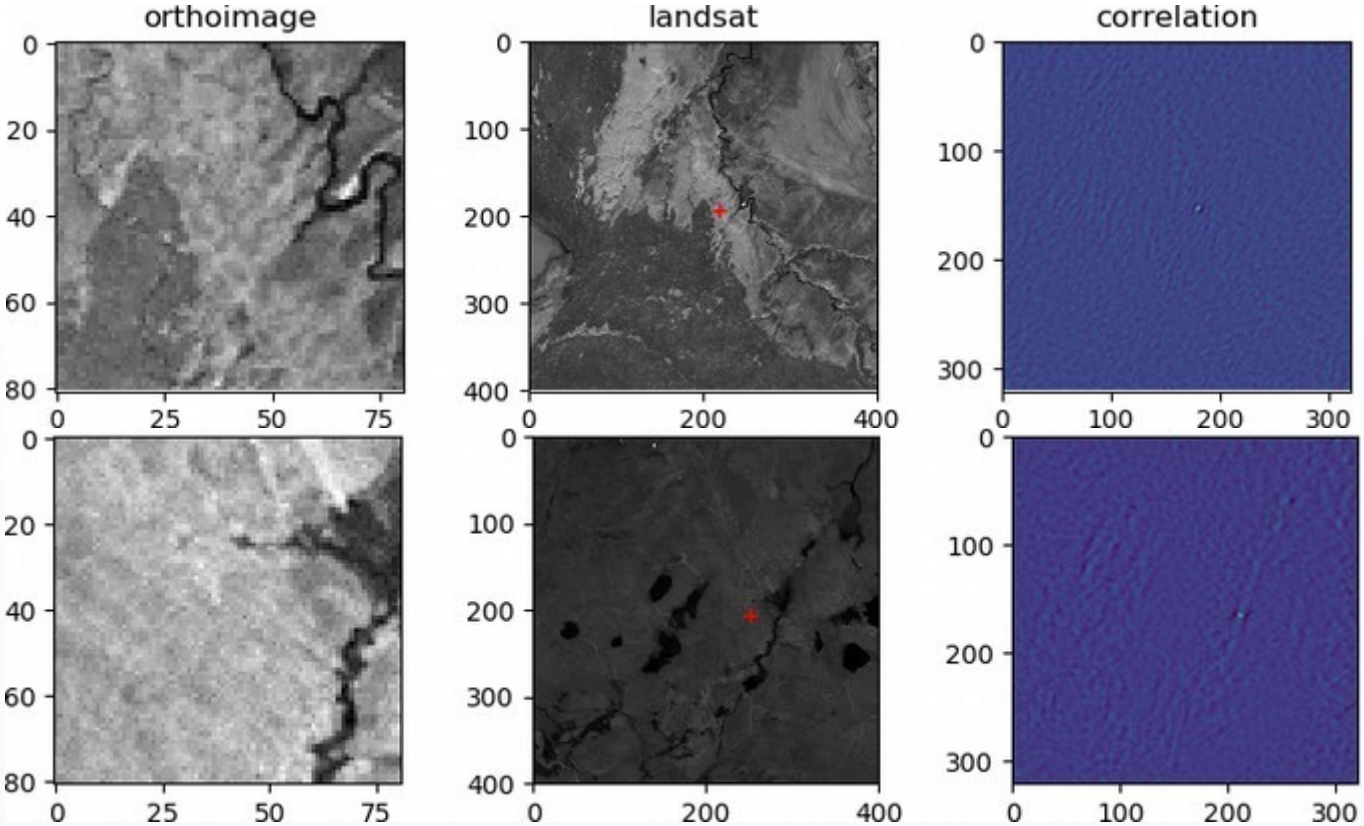
control point matching: steps

1. Roughly georeference low-resolution orthoimage using image coordinates
2. Refine georeferencing, find ‘control points’ using cross-correlation to orthorectified satellite image
3. Use ‘control points’ to refine camera parameters

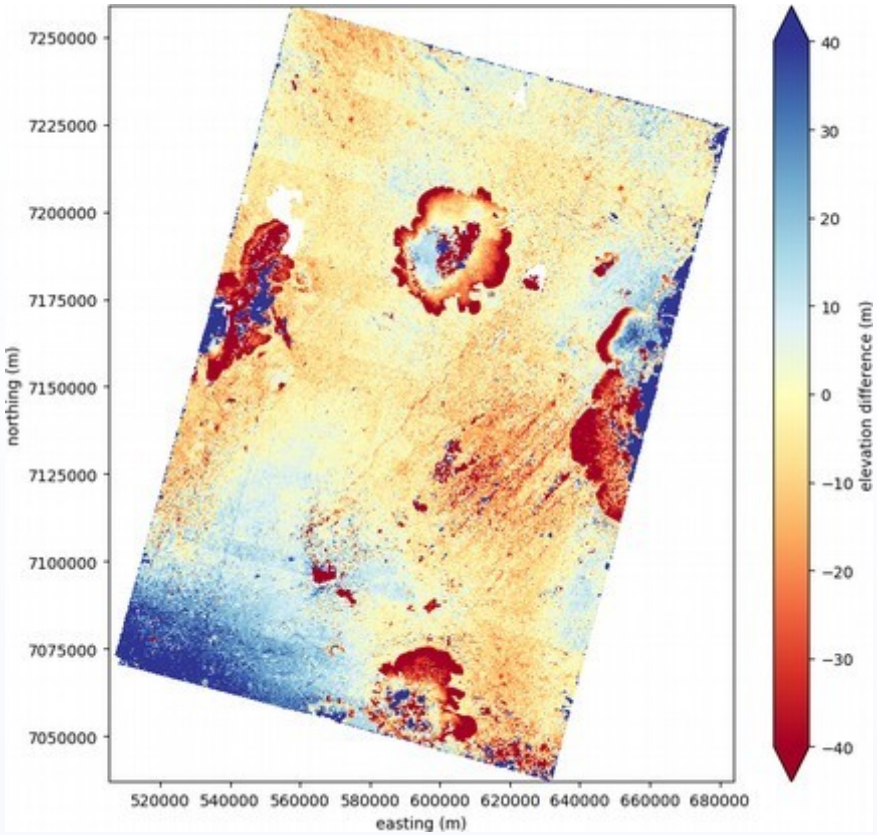


approach works well with historic air photos, too

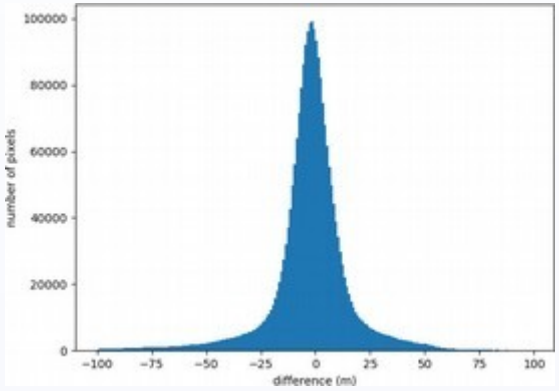
control point matching: examples



preliminary results: Iceland (1980.08.22)



- re-sample to 32m (from 8m)
- clear distortions remaining in DEM
- issues w/ image scans?
- overall agreement is good, “room for improvement”



links and future work

- MicMac: https://github.com/micmacIGN/micmac (-b Banana)
- sPyMicMac: https://github.com/iamdonovan/sPyMicMac
- tools for DEM co-registration, other things: https://pybob.readthedocs.io/
- further work to do understanding/removing distortions
- improve documentation
- clean up code, reduce memory/cpu use
- incorporate pre-processing steps into MicMac to improve speed
- add further support for historic air photos:
  - fiducial marker recognition

references/further reading

- Burnett, MG (2012) “Hexagon (KH-9) Mapping Camera Program and Evolution”. National Reconnaissance Office (NRO), Center for the Study of National Reconnaissance (CSNR), Chantilly, VA, USA. http://refhub.elsevier.com/S0924-2716(15)00166-5/h0030
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- Zemp, M., Huss, M., Thibert, E. et al. (2019) “Global glacier mass changes and their contributions to sea-level rise from 1961 to 2016.” *Nature* 568: 382–386. https://doi.org/10.1038/s41586-019-1071-0