Historical Images for Surface Topography Reconstruction (HISTORY)
Intercomparison experiment instructions

Last updated: 4 July 2025

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Objectives

- Compare and document photogrammetric processing chains applied to historical satellite and aerial imagery
- Evaluate residuals between experiment deliverables and with respect to validation data
- Centralize reproducible code/workflows to share knowledge and solve common problems
- Enhance interoperability between processing chains for the use and exchange of intermediate outputs
- Joint publication describing the different existing workflows and intercomparison.

Research Questions

- What is the spread between results (after rigid coregistration to reference terrain)?
    - Intercomparison
    - Comparison with reference terrain
- What is the difference in accuracy between products generated from synchronous KH-9 MC, KH-9 PC, and aerial acquisitions?
- Can we explain the spread by differences in preprocessing?
- Can we explain the spread by differences in photogrammetric processing?
- Which common problems (e.g. “doming” or “striping”) were encountered and how were they approached by different workflows?
- Is the gained accuracy worth the invested time of a given method that outperformed others?

- Does the spread matter for applications?
    - Coastal area
    - Glacier
    - Forestry
    - Tectonics (e.g., applying image correlation on ortho-images)
    - Cadastral mapping

Timeline and deadlines

4 July 2025	Instructions sent to participants
22 AUG 2025	Deadline to submit **preliminary results** (at least for test site **Casa Grande)**
31 OCT 2025	Deadline to submit **final results** for both sites
8-12 SEP 2025	Workshop, Grenoble

Data access

The data has been split into 14 zipped tar archives (.tgz) in total, with for each site:

- 1 archive for auxiliary data, i.e. reference DEMs (probably needed for all experiments): "*site_name_aux_data.tgz"*
- 2 archives for aerial images for preprocessed + associated files and raw images (optional): "*site_name_aerial_preproc.tgz"* & "*site_name_aerial_raw.tgz"*
- 2 archives for KH-9 MC images for preprocessed + associated files and raw images (optional): "*site_name_kh9mc_preproc.tgz"* & "*site_name_kh9mc_raw.tgz"*
- 2 archives for KH-9 PC images for preprocessed + associated files and raw images (optional): "*site_name_kh9pc_preproc.tgz"* & "*site_name_kh9pc_raw.tgz"*

The data can be viewed at the following link,
https://ige-meom-opendap.univ-grenoble-alpes.fr/thredds/catalog/meomopendap/extract/HISTORY/catalog.html
Each file can be downloaded by clicking on the file link, then selecting the "HTTPserver" access.
It can be downloaded programmatically with `wget` and using the same base url, e.g.:
https://ige-meom-opendap.univ-grenoble-alpes.fr/thredds/fileServer/meomopendap/extract/HISTORY/data/casa_grande_aux_data.tgz
A download bash script is provided at the above link.

Task

For each test site, choose at least one of the KH9-PC, KH9-MC, or aerial image datasets. Use the provided images, metadata, and auxiliary files to generate:

1. Georeferenced sparse point cloud
2. Georeferenced dense point cloud

3. Updated camera positions
4. Refined camera model parameters
5. Orthophotos and/or orthomosaic (optional)

For each site and dataset, we will provide a set of raw images and a set of preprocessed images. Processing the preprocessed dataset is mandatory, processing the raw dataset (with your own preprocessing) is optional.

Datasets

For each test site, the following files and folder structure will be provided as zipped directory.

Files and folder structure

site_name/

- aerial_images/
    - aquisition_date/
        - raw_images/
            - #.tif
            - …
                - quickviews/#.jpg
                - …
            - detected_fiducial_markers.csv
            - gcp.csv
        - preprocessed_images/
            - #.tif
            - …
                - quickviews/#.jpg
                - …
            - detected_fiducial_markers.csv
            - gcp.csv
            - image_mask.tif
        - camera_model_extrinsics.csv
        - camera_model_intrinsics.csv
        - images_footprint.geojson
        - calibration_report.pdf
    - aquisition_date/
        - …
- kh9_mc_images/
    - … (same structure as for aerial)
- kh9_pc_images/
    - … (same structure as for aerial)
- aux_data/
    - reference_dem_zoom.tif (1-2 m spatial res)
    - reference_dem_zoom_mask.tif
    - reference_dem_large.tif (30 m resolution)

    ○ reference_dem_large_mask.tif
- dataset_description_readme.md

File descriptions and content

img_#.tif
Both raw and preprocessed images are provided in TIFF format.

camera_model_extrinsics.csv
The estimated camera positions are provided with the following columns and units. If data are missing, they are unknown to the core team or not applicable to the dataset.

Column	Unit - Description
image_file_name	String - Name of the image file
lon	Degrees - Longitude in decimal degrees (WGS84)
lat	Degrees - Latitude in decimal degrees (WGS84)
alt	Meters - Altitude above the ellipsoid (WGS84)

camera_model_intrinsics.csv
The internal camera model parameters are provided with the following columns and units. If data are missing, they are unknown to the core team or not applicable to the dataset.

Column	Unit - Description
focal_length	Float - Focal length of the camera in mm
pixel_pitch	Float - Scanning resolution (square pixel) of the image in mm
midside_left_x_mm	Float - x distance to the origin in mm
midside_left_y_mm	Float - y distance to the origin in mm
midside_top_x_mm	Float - x distance to the origin in mm
midside_top_y_mm	Float - y distance to the origin in mm
midside_right_x_mm	Float - x distance to the origin in mm
midside_right_y_mm	Float - y distance to the origin in mm
midside_bottom_x_mm	Float - x distance to the origin in mm
midside_bottom_y_mm	Float - y distance to the origin in mm

corner_top_left_x_mm	Float - x distance to the origin in mm
corner_top_left_y_mm	Float - y distance to the origin in mm
corner_top_right_x_mm	Float - x distance to the origin in mm
corner_top_right_y_mm	Float - y distance to the origin in mm
corner_bottom_left_x_mm	Float - x distance to the origin in mm
corner_bottom_left_y_mm	Float - y distance to the origin in mm
corner_bottom_right_x_mm	Float - x distance to the origin in mm
corner_bottom_right_y_mm	Float - y distance to the origin in mm
principal_point_x_mm	Float - x distance to the origin in mm
principal_point_y_mm	Float - y distance to the origin in mm

gcp.csv
The ground control points are provided with the following columns and units.

Column	Unit - Description
gcp_label	String - Label of the ground control point
image_file_name	String - Name of the image file
x	Float - x coordinate of the GCP in the image pixel grid
y	Float - y coordinate of the GCP in the image pixel grid
lon	Float - Longitude in decimal degrees (WGS84)
lat	Float - Latitude in decimal degrees (WGS84)
elev	Float - Elevation above the ellipsoid (WGS84) in meters
lon_acc	Float - Accuracy of the longitude coordinate, in meters
lat_acc	Float - Accuracy of the latitude coordinate, in meters
elev_acc	Float - Accuracy of the elevation, in meters

detected_fiducial_markers.csv
The detected fiducial markers are provided with the following columns in raw image pixel coordinates. If data are missing, they are not applicable to the dataset.

Column	Unit - Description
image_id	String - Name of the image file
corner_top_left_x	Float - x coordinate of marker in the image pixel grid
corner_top_left_y	Float - y coordinate of marker in the image pixel grid
corner_top_right_x	Float - x coordinate of marker in the image pixel grid
corner_top_right_y	Float - y coordinate of marker in the image pixel grid
corner_bottom_left_x	Float - x coordinate of marker in the image pixel grid
corner_bottom_left_y	Float - y coordinate of marker in the image pixel grid
corner_bottom_right_x	Float - x coordinate of marker in the image pixel grid
corner_bottom_right_y	Float - y coordinate of marker in the image pixel grid
midside_left_x	Float - x coordinate of marker in the image pixel grid
midside_left_y	Float - y coordinate of marker in the image pixel grid
midside_top_x	Float - x coordinate of marker in the image pixel grid
midside_top_y	Float - y coordinate of marker in the image pixel grid
midside_right_x	Float - x coordinate of marker in the image pixel grid
midside_right_y	Float - y coordinate of marker in the image pixel grid
midside_bottom_x	Float - x coordinate of marker in the image pixel grid
midside_bottom_y	Float - y coordinate of marker in the image pixel grid
principal_point_x	Float - x coordinate of marker in the image pixel grid
principal_point_y	Float - y coordinate of marker in the image pixel grid

image_mask.tif
For preprocessed aerial images only. A binary raster of same dimensions as the preprocessed images, to optionally mask markings and film edges in the images.

images_footprint.geojson
A vector file containing polygons of the approximate image footprints, in geoJSON format. Following mainly the format of files provided by the USGS for satellite and aerial images. The data table also contains information on the footprint center location in lat/lon (same as in *camera_model_intrinsics.csv*).

calibration_report.pdf
A PDF of the calibration report available for that dataset. For aerial images only.

reference_dem_zoom.tif
The reference DEM provided in GeoTIFF format. Spatial resolution of 1-2 m over the area covered by aerial images. See details in the “experiment dataset” document.

reference_dem_zoom_mask.tif
A binary mask to separate assumed stable (value of 1) and unstable (0) pixels. In GeoTIFF format and on the same grid as the reference DEM. The mask tentatively excludes man-made infrastructure, vegetation, water bodies and glaciers, but is not very accurate. Can be used as a first basis for DEM co-registration. See details in the “experiment dataset” document.

reference_dem_large.tif
The reference DEM provided in GeoTIFF format. Spatial resolution of 30 m over the area covered by all satellite images. Same horizontal and vertical CRS as “reference_dem_zoom.tif”.

reference_dem_large_mask.tif
Same as “reference_dem_zoom_mask.tif” but on the extend and grid of the large, low resolution, DEM.

experiment_dataset.pdf
Contains all information on study site locations, CRS and data provided, as well as some quick figures.

Experiments and naming codes

MANDATORY
CHOOSE ONE OR MULTIPLE
OPTIONAL

Identifier	Option 1	Code 1	Option 2	Code 2	Option 3	Code 3
Site	Casa Grande	CG	Iceland	IL		
Dataset	Aerial	AI	KH-9 MC	MC	KH-9 PC	PC
Images	Raw	RA	Pre-processed	PP		
Use of Camera Calibration Information	Yes	CY	No	CN		
Use of Ground Control Points	Yes	GY	No	GN		
Point Cloud Coregistation	Yes	PY	No	PN		
Multi-temporal Bundle Adjustment	Yes	MY	No	MN		

Deliverables

Please define an “author tag” for your team, which you will use as a prefix for your submitted files. The tag should be a continuous alphabetical string without any separators.
Deliverable files:

- sparse_pointcloud.las
- dense_pointcloud.las
- camera_model_extrinsics.csv
- camera_model_intrinsics.csv

The camera CSV files should have the exact same columns, units, and data types as the provided input CSV files. **For the camera_model_intrinsics file**, additional columns may be added as needed to define each parameter of the lens distortion model (e.g. k1, k2 etc for a Brown Conrady model). The point cloud files are to be delivered in LAS format, in WGS84 (longitude, latitude, ellipsoidal height).

Note: The provided point cloud should be produced with camera parameters that match exactly the ones in the final camera_model.csv (camera position only, as orientation is not provided). This means that no post-processing should be applied to the point_cloud. It is however permissible to compute a co-registration to the reference terrain, apply this co-registration transform to the camera positions, and regenerate a final point_cloud with the updated camera positions.

Optional files:

- dem.tif
- orthoimage.tif

Deliverable code: (semi-optional)

- It is strongly encouraged to provide reproducible code if possible

File naming convention example for:

- Casa Grande (CG)
- Aerial (AI)
- Pre-processed images (PP)
- Using calibration information (e.g. focal length) (CY)
- Not using ground control points (GN)
- No additional point cloud coregistration (PN)
- No multi-temporal bundle adjustment (MN)

Example:

author_CG_AI_PP_CY_GN_PN_MN_sparse_pointcloud.las
author_CG_AI_PP_CY_GN_PN_MN_dense_pointcloud.las
author_CG_AI_PP_CY_GN_PN_MN_extrinsics.csv

author_CG_AI_PP_CY_GN_PN_MN_intrinsics.csv
author_CG_AI_PP_CY_GN_PN_MN_dem.tif (optional)
author_CG_AI_PP_CY_GN_PN_MN_orthoimage.tif (optional)

If you would like to submit additional experiments that are not captured by these codes, you may insert a version number after the final code. For example:
author_CG_AI_PP_CY_GN_PN_MN_v1_sparse_pointcloud.las
author_CG_AI_PP_CY_GN_PN_MN_v2_sparse_pointcloud.las
Please explain the differences of your versions in your final report.

Processing report

In addition to the deliverable products, please provide a preliminary processing report (in free format, a template is proposed here). It should include the following information:

- Team details
  - Author/team tag (same as above)

  For each member:
  - Name
  - Affiliation
  - Email
  - Role/contribution
- Software used
  - Software name and version number
  - Link to reproducible code/repository (optional but highly encouraged)
- Processing steps
  - Detailed description of processing steps and input information used and/or reference to publication.
  - If results are submitted with different versions of the same workflow, specify the differences here.
  - Details about lens distortion model used (e.g. Brown-Conrady), associated equations relating the parameters (as provided in the output camera_extrinsics.csv) and x/y distortion.
- Processing resources and compute time

  Experiment XX:
  - XX cpus (model XX) or XX GPUs (model XX) for XX hours
  - Memory requirements: XX GB
- Workflow diagram
- Any additional information that is relevant

Output data delivery

The output data should be provided as a tar/zip archive, uploaded to your preferred cloud/dropbox and the link sent to
amaury.dehecq@univ-grenoble-alpes.fr
fknuth@ethz.ch

Try not setting a short expiration date if possible, or contact us if not able to find a solution. Alternatively, we are working on setting up a dropbox where participants could directly upload their results. We will keep you informed if data delivery mode changes.

Evaluation criteria

The final products will be post-processed by the core team and evaluated as follows.

pointcloud.las

Post-processing steps (to be done by core team):

- Reprojected and rasterized on the same CRS and grid as the corresponding reference DEM.
- Apply the Nuth and Kääb co-registration to compute horizontal and vertical shifts. Rotation and scale corrections will be computed as needed, but will be treated separately to distinguish relative vs absolute accuracy.
- Compute the residuals over stable terrain after applying horizontal and vertical shifts.
- Compute the residuals between ~synchronous products
  - Over stable terrain
  - Over changing terrain
- Compute percentage of voids over land cover type
- Evaluation metrics and statistics are:

Column	Unit - Description
points	Integer - Number of points in the final point cloud
voids	Percentage - Fraction of voids/no-data by land cover type
x_shift	Float - x shift after co-registration with stable terrain
y_shift	Float - y shift after co-registration with stable terrain
z_shift	Float - z shift after co-registration with stable terrain
mean	Float - Mean of residuals over stable ground
std	Float - Standard deviation of residuals over stable ground
median	Float - Median of residuals over stable ground
nmad	Float - Normalized median absolute deviation of residuals over stable ground
range	Float - Range(s) of correlated errors from variogram analysis
sill	Float - Sill(s) of correlated errors from variogram analysis

camera_model_extrinsics.csv
The horizontal camera positions will be converted from WGS84 lon/lat in degrees to a local metric system x/y in meters before computing residuals. For each metric in the following table, the average (mean) residual will be computed.

Column	Unit - Description
x_r	Float - Mean of residuals in x
y_r	Float - Mean of residuals in y
z_r	Float - Mean of residuals in z

camera_model_intrinsics.csv
For each metric in the following table, the average (mean) residual will be computed.
Note that the lens distortion parameters will be used along with the distortion model equations provided in the report, to calculate the distortion on a regular grid, for intercomparison.

Column	Unit - Description
focal_length_r	Millimeters - Residuals between initial and final camera focal lengths
pixel_pitch_r	Millimeters - Residuals between initial and final pixel pitch
cx_r	Float - Residuals between initial and final principal point x coordinate
cy_r	Float - Residuals between initial and final principal point y coordinate

Questions and Answers

1. *Can I team up with others and share tasks?*

Yes, you can work in teams. Each member contribution must be clearly stated in the processing report

2. *Can we submit results from already published work?*

Yes, for the raw case, if the exact same dataset is used.

3. *Do we need to process both test sites?*

It is not mandatory but strongly encouraged.

4. *Do we need to process all image types (KH-9 MC, KH-9 PC, and aerial) for each site?*

No, you can process any of the dataset.

5. *Do we have to use the ground control points?*

No, but the use or not of the GCPs must be clearly stated.

6. *Can we use the raw images instead of the pre-processed images?*

You can additionally process the raw images, but working with the preprocessed images is mandatory.

7. *Can we co-register our final point cloud with the reference terrain and provide the co-registered product?*

Yes, you can optionally provide your best co-registered DEM, but we will evaluate in priority the DEM that will be post-processed with our default workflow from the raw point cloud.

8. *Can we compute our own stable ground mask?*

Yes you can compute your own stable mask, but a common mask (to be determined) will be used for the evaluation.

9. *Can we use additional image products to compute a multi-temporal camera model optimization?*

Yes, you can submit an optional result that makes use of additional products, but you must provide at least one result that only requires the provided data.