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Heights and UAVs

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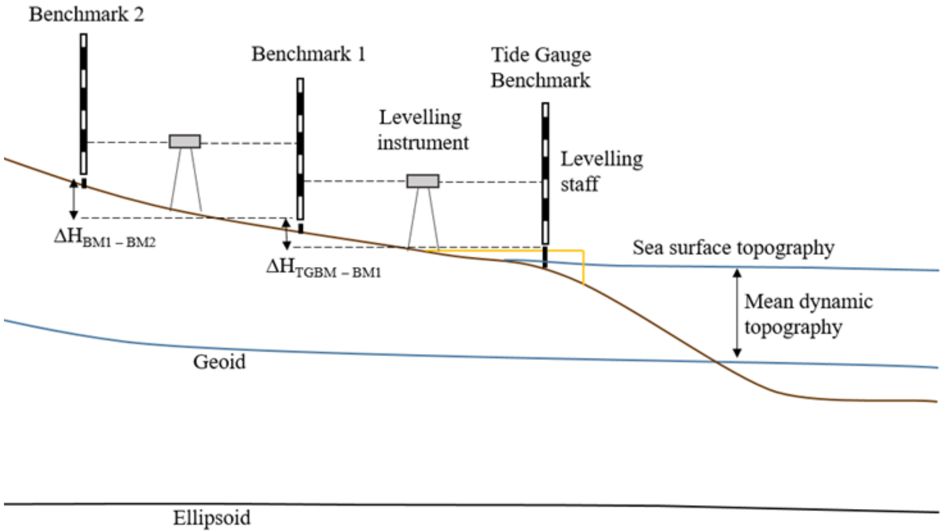
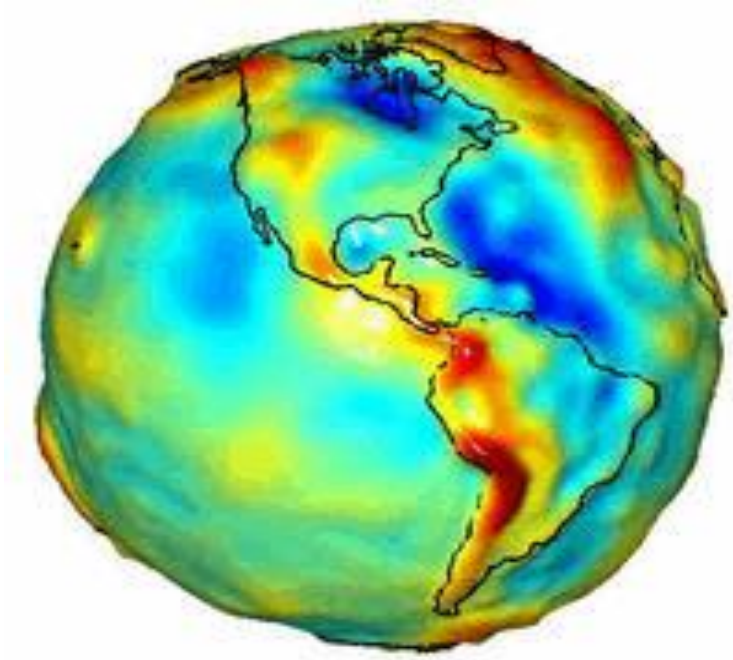
Water should run down hill….

Levelling


Benchmark 2
Benchmark 1
Tide Gauge Benchmark
Levelling instrument
Levelling staff
ΔH BM1 – BM2
ΔH TGBM – BM1
Sea surface topography
Mean dynamic topography
Geoid
Ellipsoid

Geoid

http://grace.jpl.nasa.gov/resources/6/



A surface on which the Earth's gravity potential is a constant (equipotential or level surface) and that closely approximates global mean sea level.

Height - from Tide Gauges

Mean Sea Level used as a proxy for the Geoid.

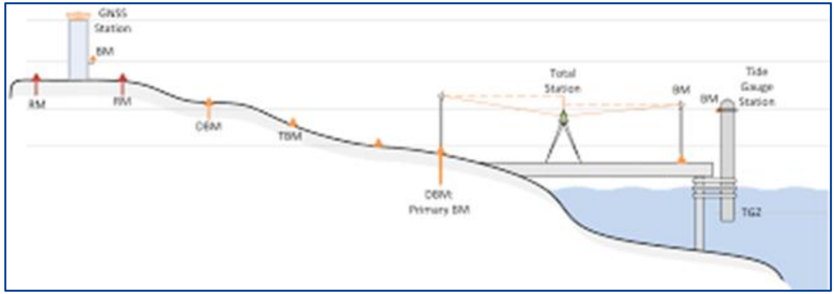
Tide Gauges

Newcastle East CORS (Courtesy Volker Janssen)

Tide gauge at Gandia, Spain. Courtesy

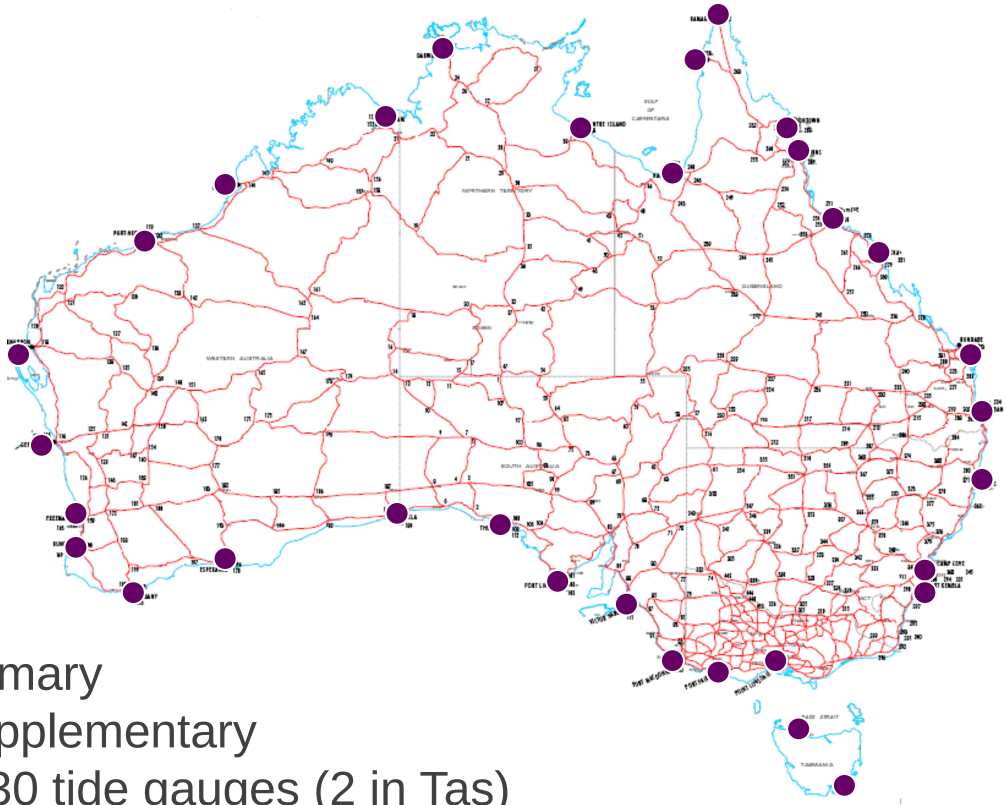
http://eurogoos.eu/tide-gauge-task-team/

- Tide gauges measure Mean Sea Level (MSL)
- Location of tide gauge important to avoid estuarine currents or tidal gradients.
- Height of tide gauge must be transferred carefully to the mainland
- Movement of tide gauge monitored regularly.



http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/pacificsealevel

Australian Height Datum (AHD71)

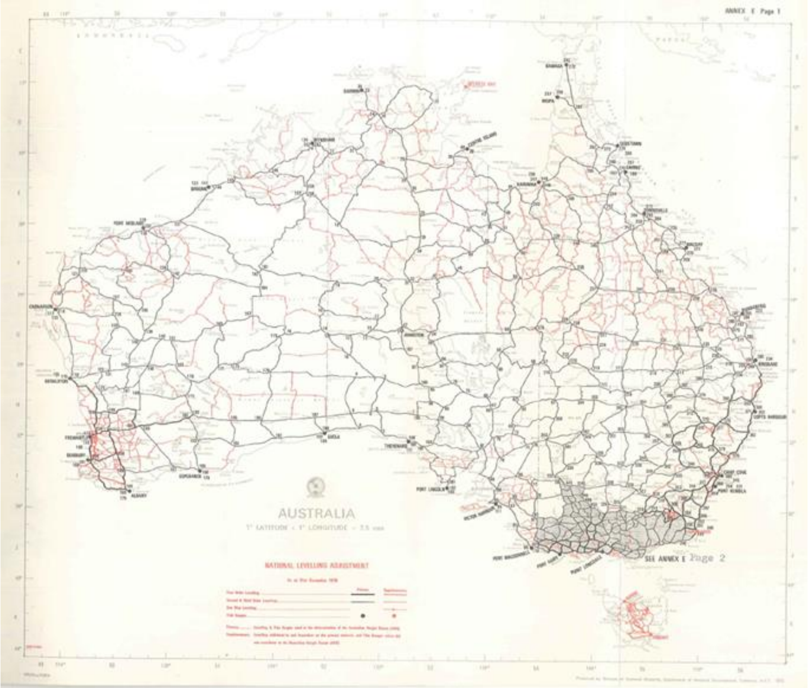


Based on levelling

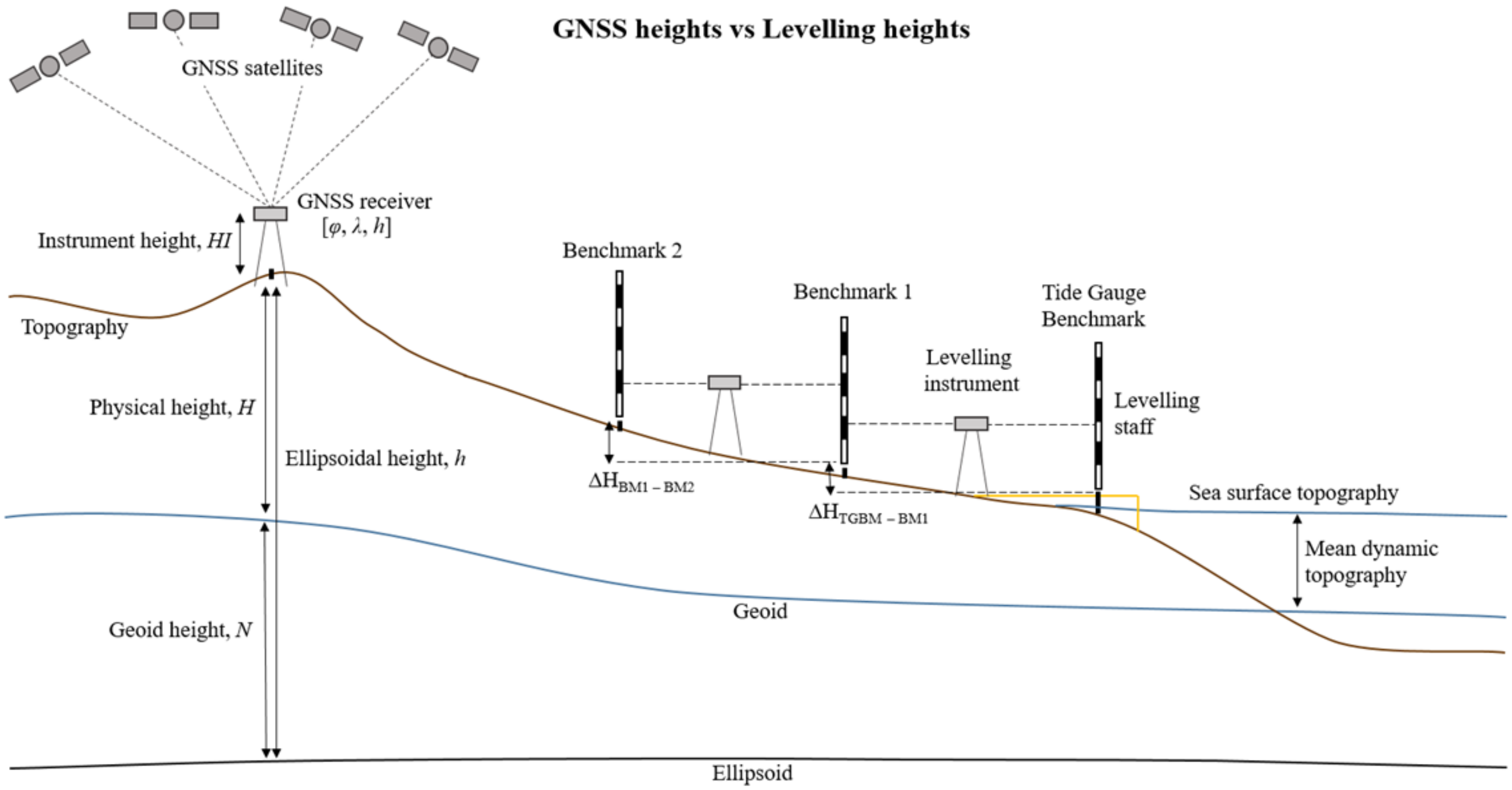
- 97,000 km primary
- 80,000 km supplementary
- Zero fixed at 30 tide gauges (2 in Tas)

Problems with AHD

- Based on tide gauge obs from 1966-68 - the full 18.6 year lunar cycle (*affects tides*) not considered
- 1+ m North-South tilt due to ocean temperature not considered
- 0.5 m regional distortions
- Hierarchical adjustment strategy
- ~50+ years old – *marks move*

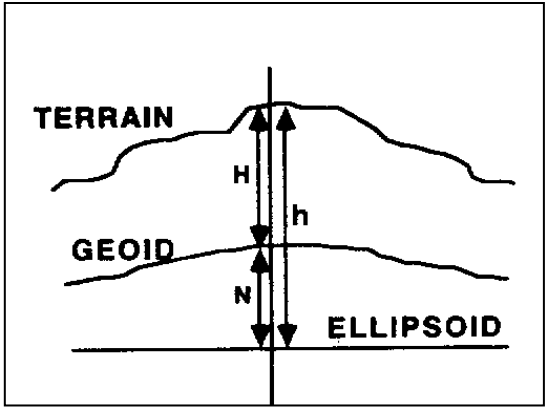


GPS for heights ?



GPS for Heights

- GPS gives ellipsoidal height (WGS84/ITRFxx)
- AHD heights refer to the MSL (approximates the geoid)
- Geoid/ellipsoid separation (N) must be determined and applied for GPS levelling

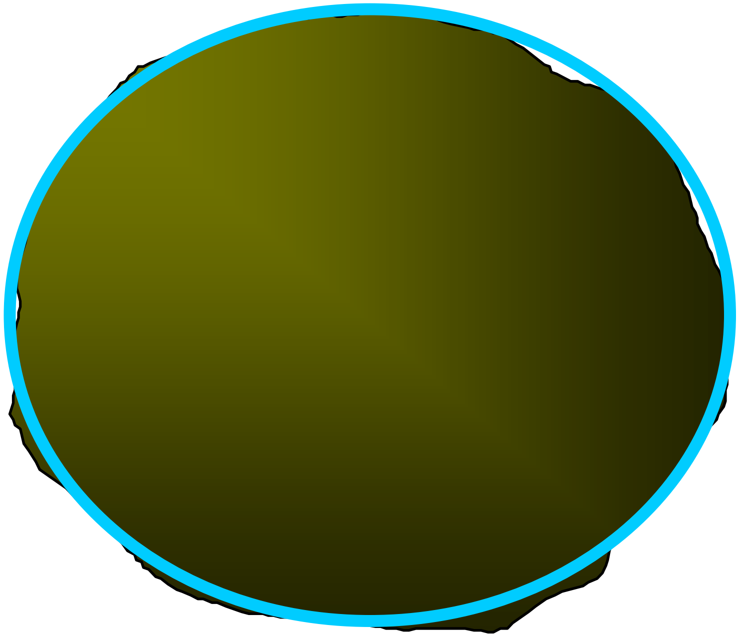


$$H = h - N$$

Physical ht (H) = ellipsoidal ht (h) – geoid/ellipsoid separation (N)

GPS is weak in height. Generally 2x worse than position

What is the Mathematical Shape of the Earth?



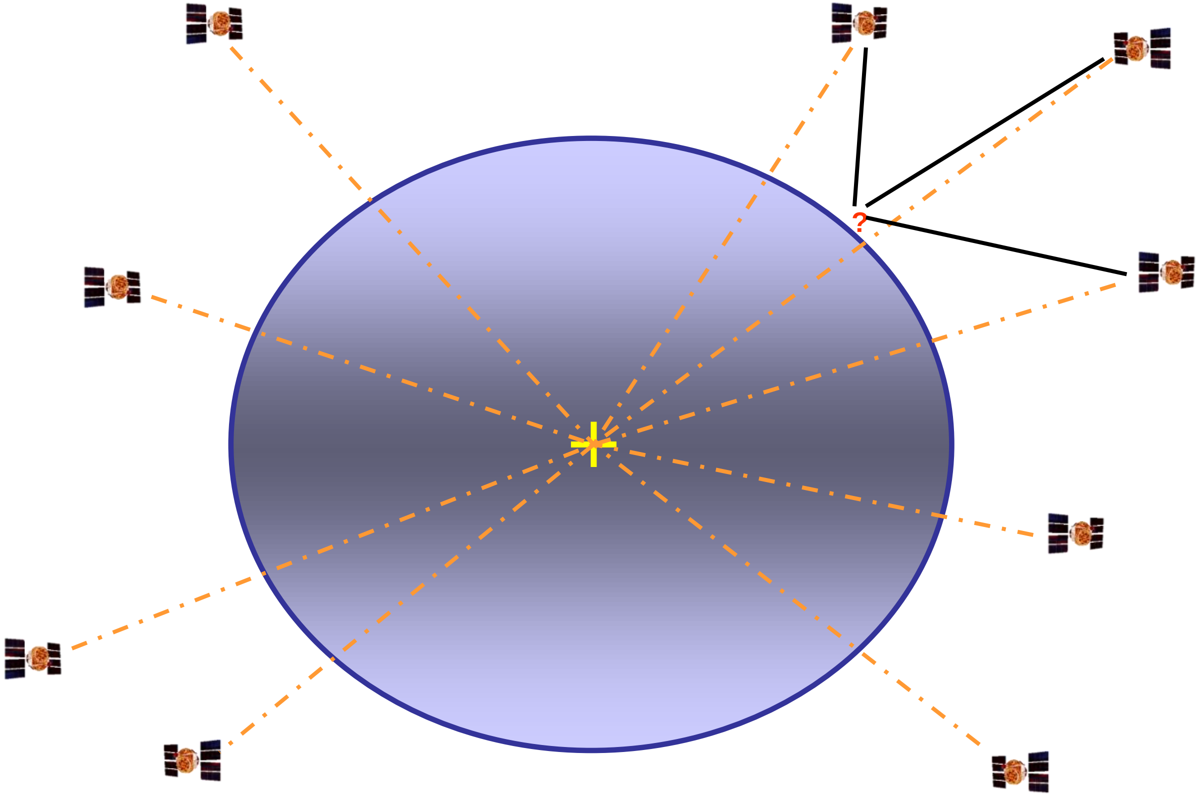
GPS coordinates (WGS84)

GDA94

GDA2020

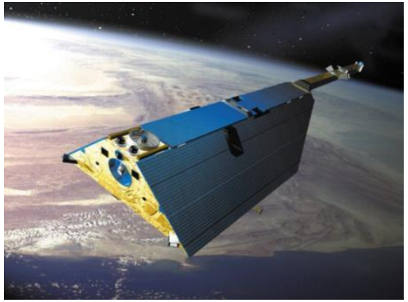
ITRF2014

All compatible with WGS84



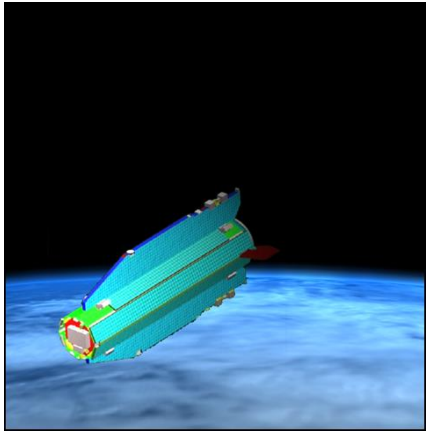
How do we compute N?

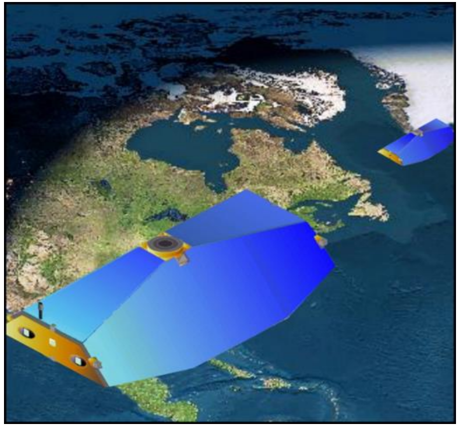
- Combination of historical astro-geodetic levelling, terrestrial gravity, airborne gravimetry and satellite geodesy.
- CHAMP, GOCE, GRACE & GRACE-FO provide data for new global geopotential models of the Earth.



CHAMP

GOCE

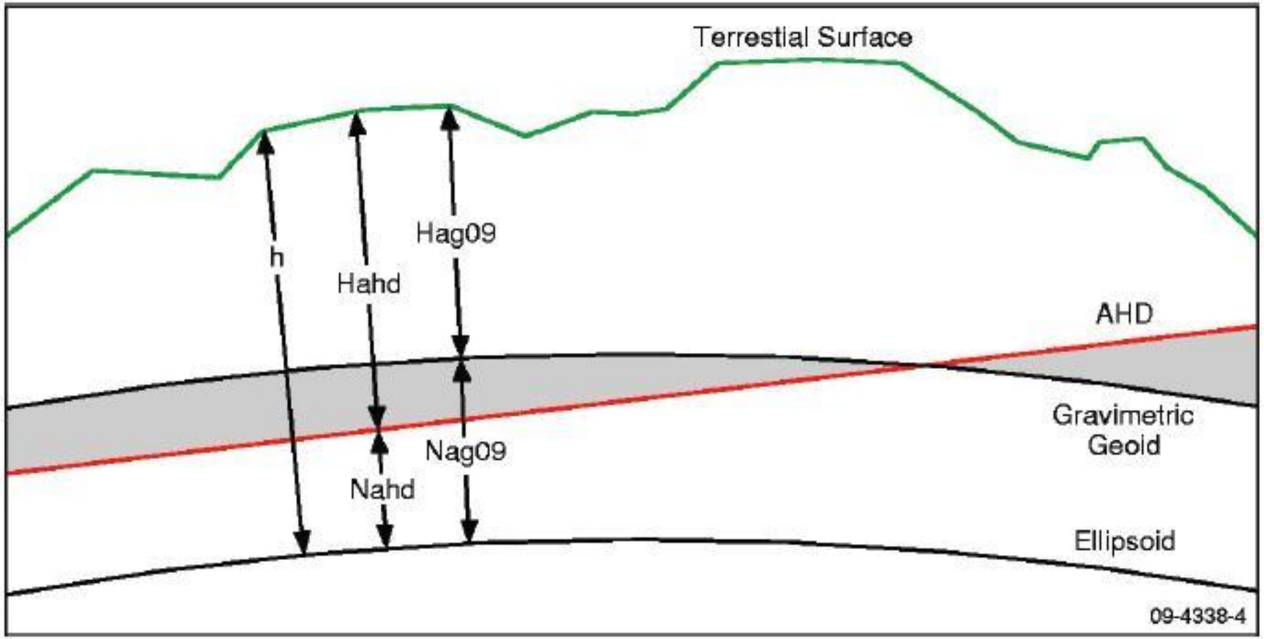




GRACE & GRACE-FO

AUSGeoid

AusGeoid09: Converting GPS heights to AHD heights.
www.ga.gov.au/webtemp/image_cache/GA16650.pdf



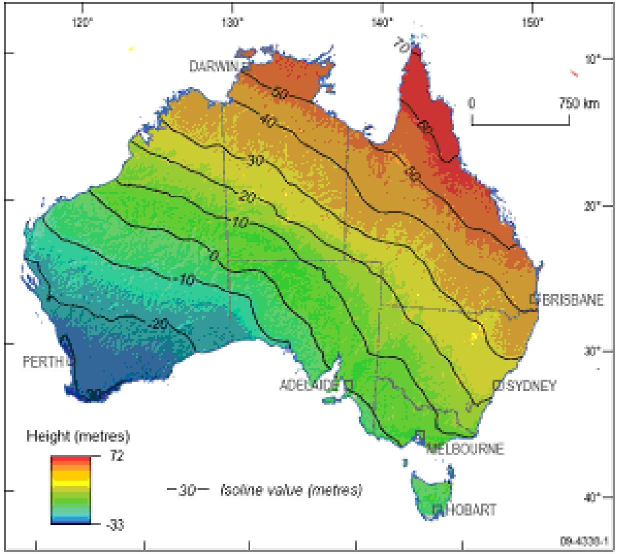


Figure 3. The different heights used to compute AUSGeoid09.

Estimated accuracy of Ausgeoid09 ±0.05m absolute

www.ga.gov.au/ausgeoid

AusGeoid2020

- AUSGeoid2020 will be the latest geoid model for use in Australia to convert between ellipsoid heights and the Australian Height Datum (based on MSL).
- AUSGeoid2020 is designed for use with the new national datum, GDA2020.
- AUSGeoid2020 model will also provide an uncertainty value.

- GDA94 + AusGeoid09 = Physical height (AHD)
- GDA2020 + AusGeoid2020 = Physical height (AHD)

- Approx. difference bet. AusGeoid's = 9cm in height across Australia **

http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/ahdgm/ausgeoid2020

** due in part to scale differences between ITRF92 and ITRF2014.

Why am I telling you all this?

Because water runs downhill on the geoid…

…. but not necessarily on the ellipsoid.

Be careful with which height system you are using.

UAVs

Fixed Wing vs. MultiRotor

Advantages
- Simple structure
- High speed
- **Long duration**

Disadvantages
- Large take-off & landing space
- Not able to hover
- Inflexibility to carry different sensors

Disadvantages
- High mechanical complexity
- Low speed
- Short flight time

Advantages
- Vertical take-off and landing
- Flexibility with different sensors
- Able to hover and stare

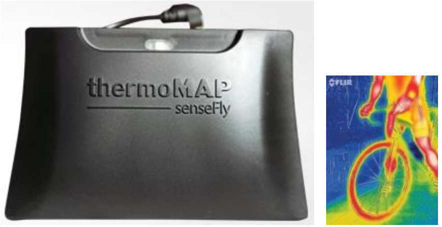
RPAs Imaging Sensors

(Remotely Piloted Aircraft)

RGB compact cameras

RGB DSLR cameras

NIR cameras



Thermal cameras

Multispectral cameras

Red edge

Image Distortion and Camera Selection

Distortion caused by lens:

- Consumer-grade cameras – large distortion
- Geometric-cameras – small distortion and geometrically stable

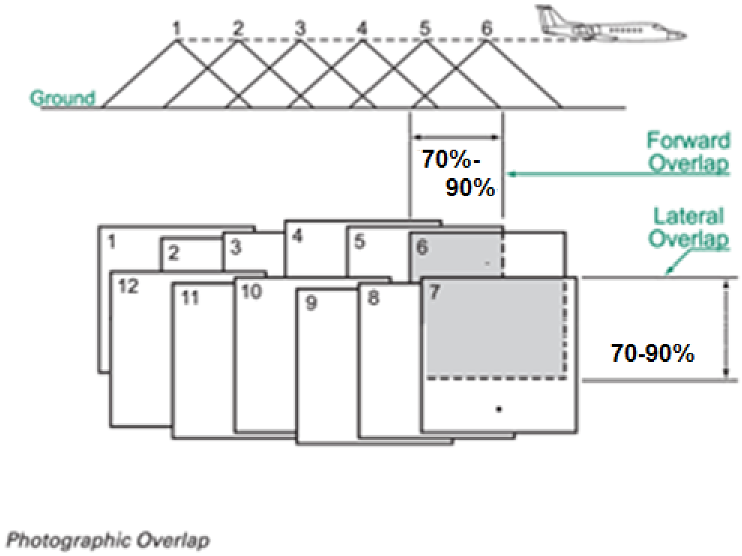
Distortion caused by moving camera:

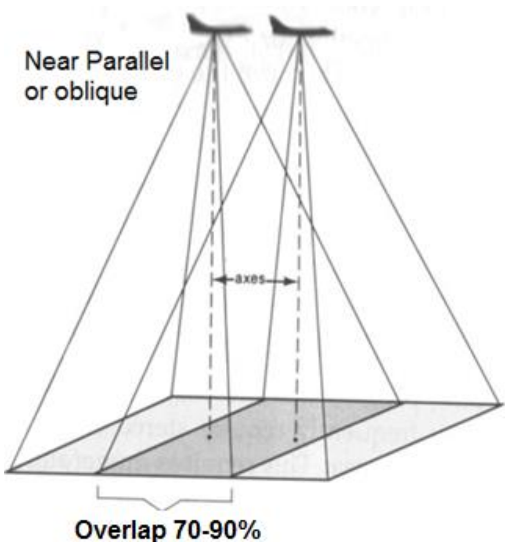
- Electronic (rolling) shutter – large distortion
- Focal plan (mechanical) shutter – small distortion
- Leaf (mechanical) shutter – no distortion (blurry?).

Camera selection:

- Avoid rolling shutter
- Leaf shutter right choice
- Focal plan shutter for low speed flight

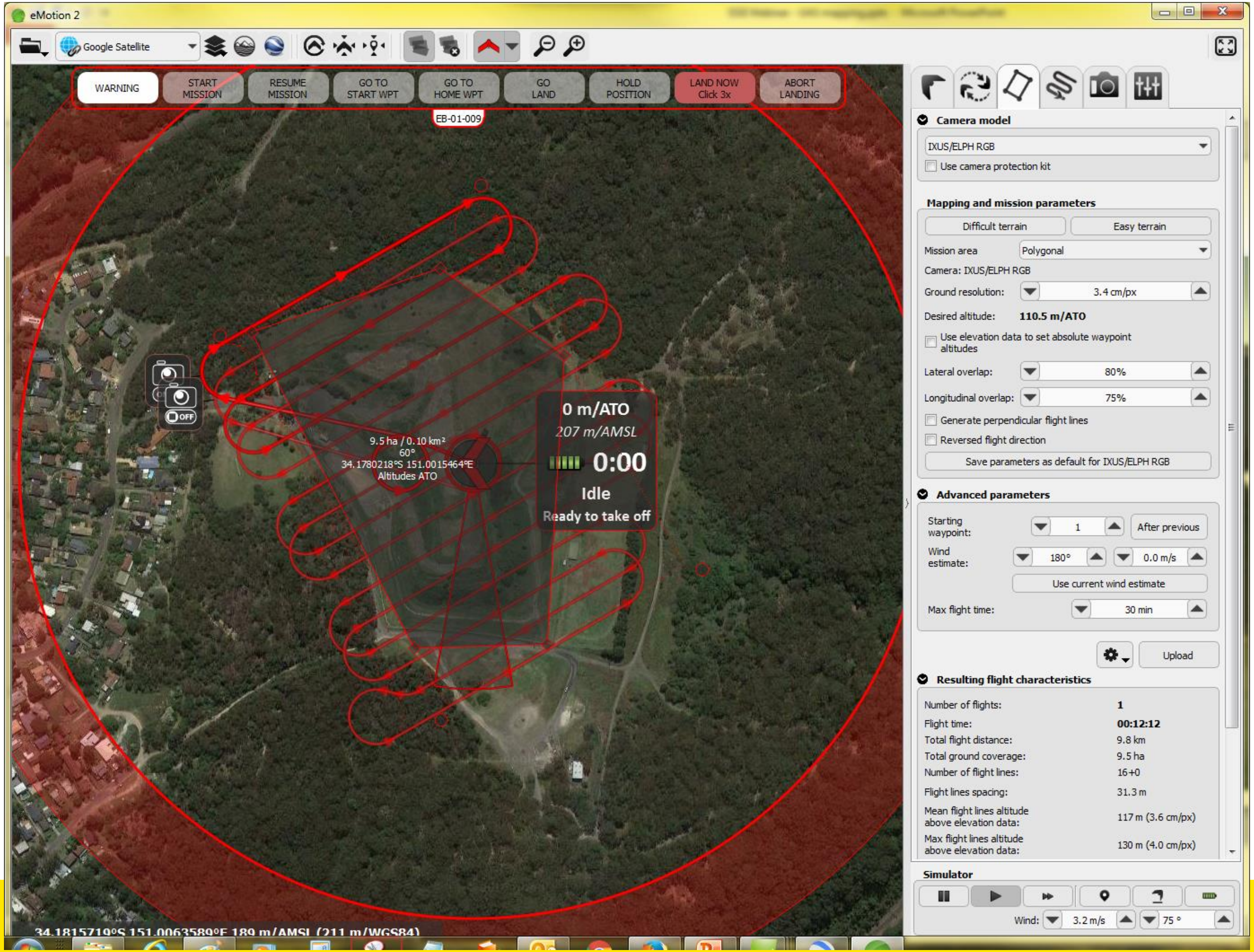
Flight Planning (1)





All photogrammetric measurements are based on overlapped images in order to obtain 3-dimensional object geometry

Flight Planning (2)



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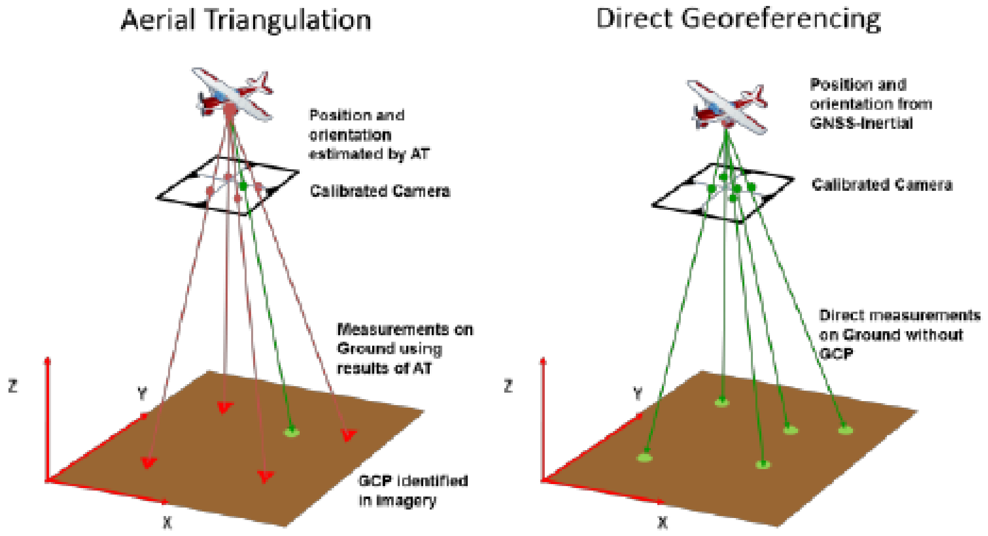
Indirect (aerial triangulation) vs Direct georeferencing

Indirect georeferencing (AT)

- Requires GCPs
- Post processing
- More time consuming
- Achieves higher accuracy in height

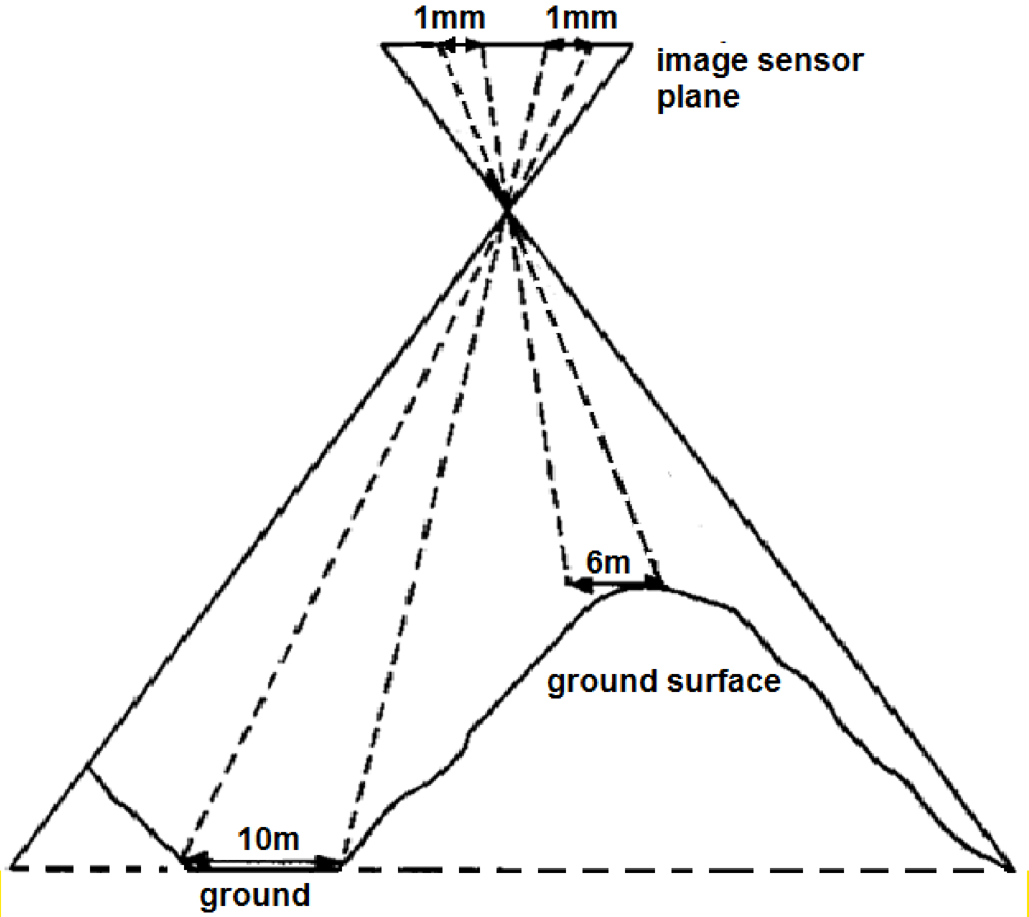


Courtesy Mian, Lutes et al, 2015

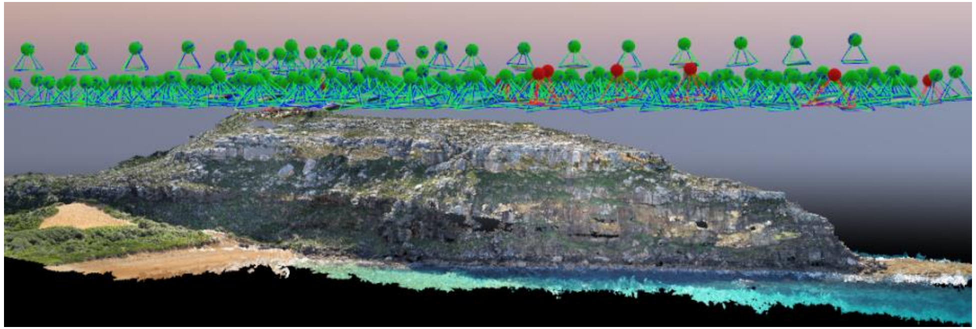
Direct georeferencing

- No GCPs
- GNSS-IMUs
- Faster field time
- Comparable height accuracy

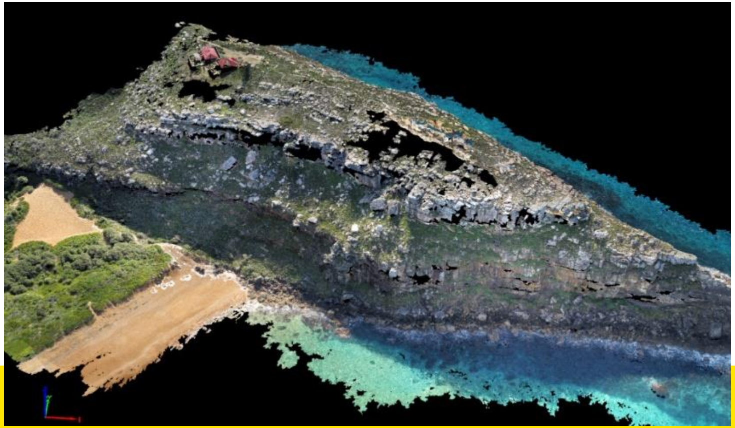
GSD variation due to terrain



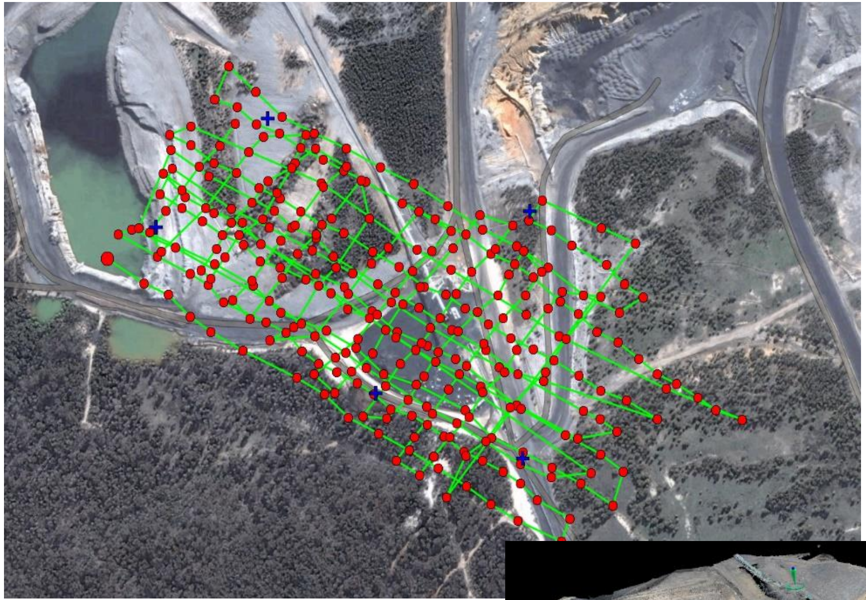
GSD variation due to terrain changes



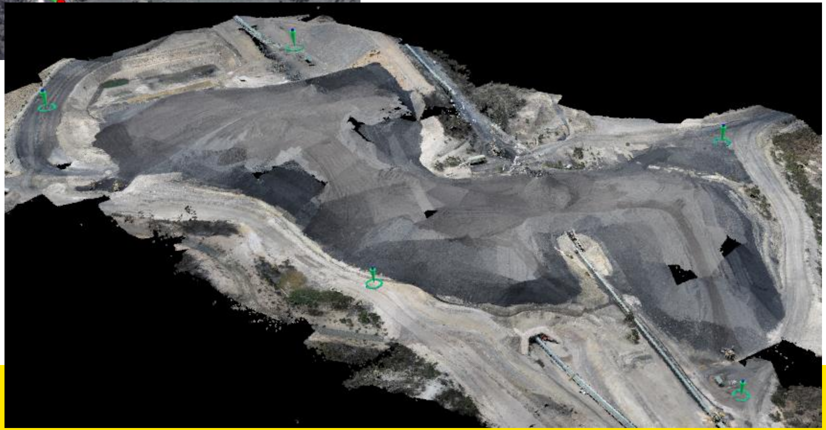
- Constant flight H above take-off location (120m)
- Different camera H above ground ΔH=80m (40m – 120m)
- Large GSD variation: 2cm at hill top, 6cm at bottom
- No oblique images



Windy condition affects accuracy



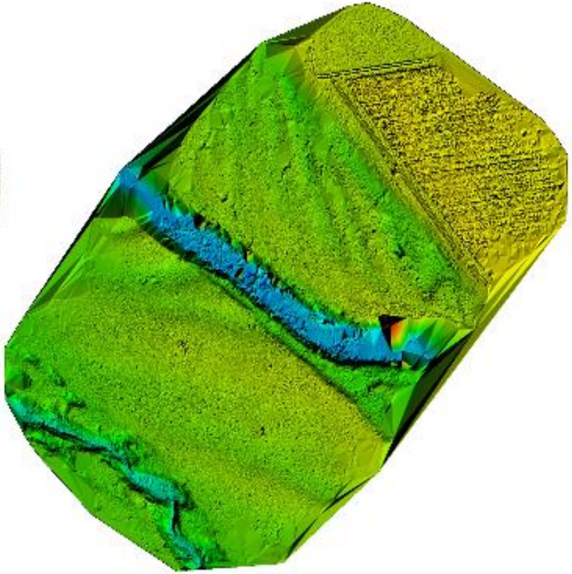
Flight tracks off designed paths due to strong wind.



Less matched feature points in some areas

Water surface

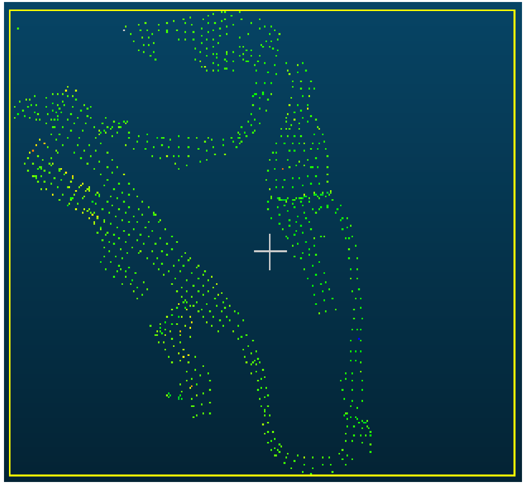
Water surface cannot be mapped or precisely surveyed photogrammetrically



Point cloud validation

500m

400m

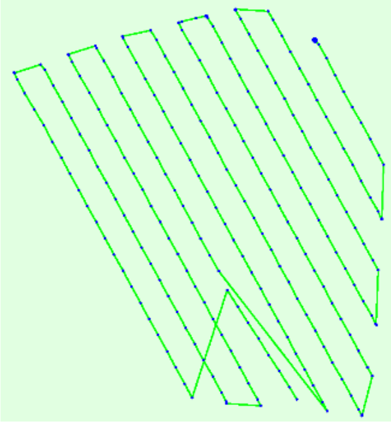


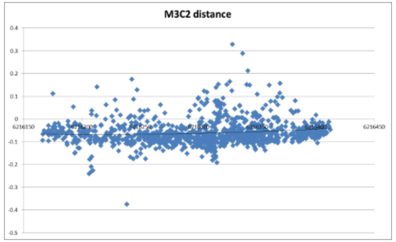
RTK (30 sec/epoch) check strings on hard surface areas

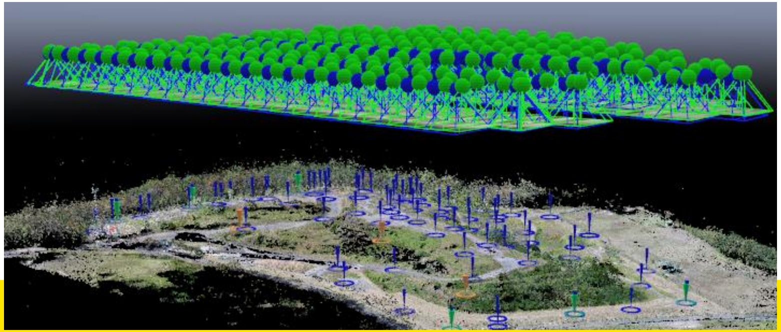
Point cloud validation (2)
– Single flight + Nadir images

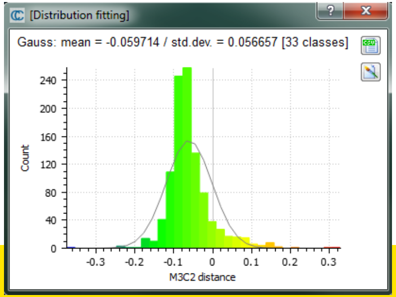
- Flight H = 120 m
- GCPs = 6
- Image overlaps = 80%
- Number of Images = 110

- Point cloud – RTK string points:
    - Mean = -6.0 cm
    - Standard deviation = ±5.7 cm





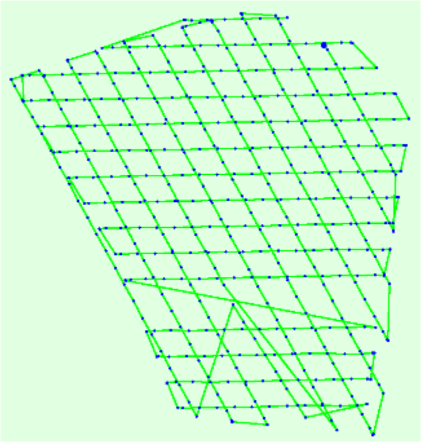


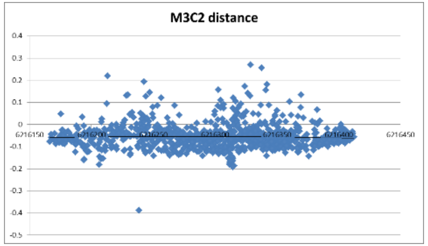


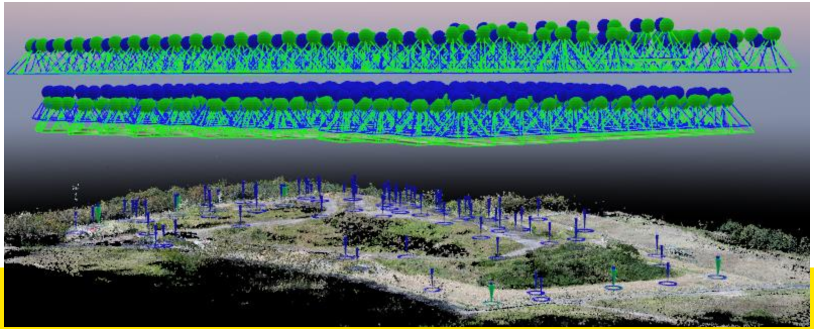
Point cloud validation (3)
– crossover flights + Nadir images

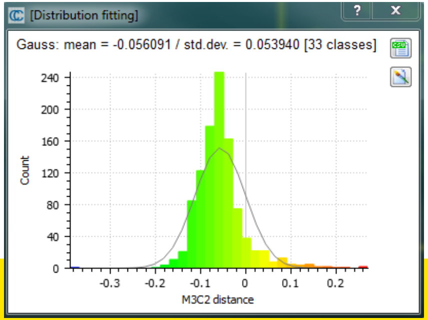
- Flight H = 80 m & 120 m
- GCPs = 6
- Image overlaps = 80%
- Number of Images = 220

- Point cloud – RTK string points:
    - Mean = -5.6 cm
    - Standard deviation = ±5.4 cm





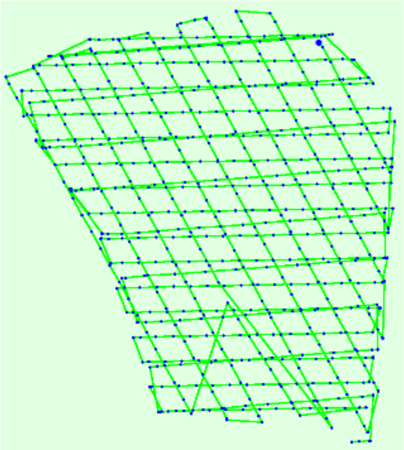


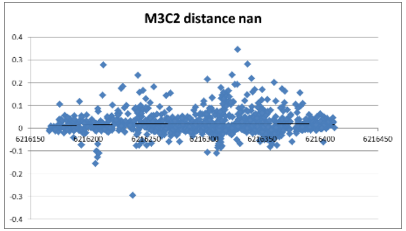


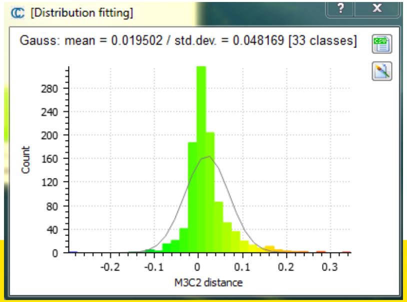
Point cloud validation (4)
– crossover flight (nadir) + Oblique images

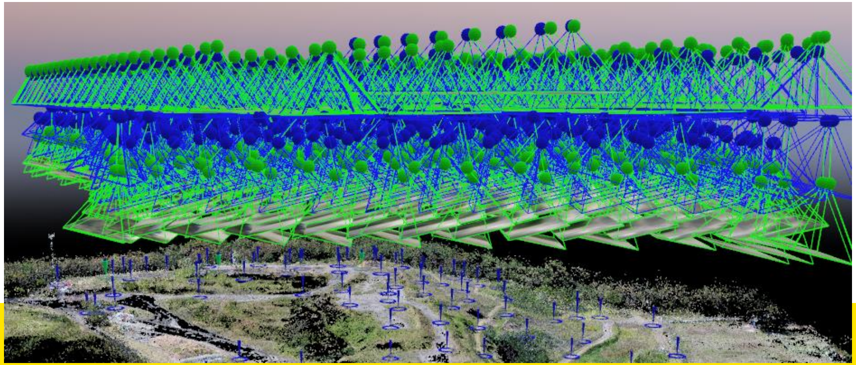
- Flight H = 120 m
- GCPs = 6
- Image overlaps = 80%
- Number of Images = 330

- Point cloud – RTK string points:
  - Mean = +2.0 cm
  - Standard deviation = ±4.8 cm









Considerations for best practice using UAVs aerial mapping.

- Accuracy depends on GSD: Optimal $\sigma_{xy} = \pm 1$ GSD; $\sigma_z = \pm 1.5$ GSD
- 70% ≤ Image overlaps ≤ 90% : Number of GCPs ≥ 5
- GCP survey use RTK-GNSS ≥ 30 epochs (best with bipod) – double occ
- Oblique Images improve accuracy significantly
- Time of the day = light cloudy or mid-day (less shadow)
- Large elevation variation = oblique images + variable flight H
- Slow ground speed (reduce motion blur)
- High resolution optical sensor (small GSD)
- Leaf shutter lens (avoid rolling shutter effects)
- High quality camera (less sensor or lens distortion)

Be careful with heights