Progress of positional accuracy of orthophoto maps based on GPS/INS systems

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Geometrical Accuracy of Orthophoto

Geometrical Accuracy of an Orthophoto depends of :

Absolute Orientation ⇒ Overall Accuracy

- Sensor (camera)
- GCP
- GPS
- IMU

Digital Terrain Model ⇒ Local Accuracy

Absolute Orientation of aerial images based on :

Aerial Images, sensor

Tie points & GCP ⇒ Aerial Triangulation, a lot of GCPs

Tie points & GCP & GPS ⇒ Aerial Triangulation, less GCPs

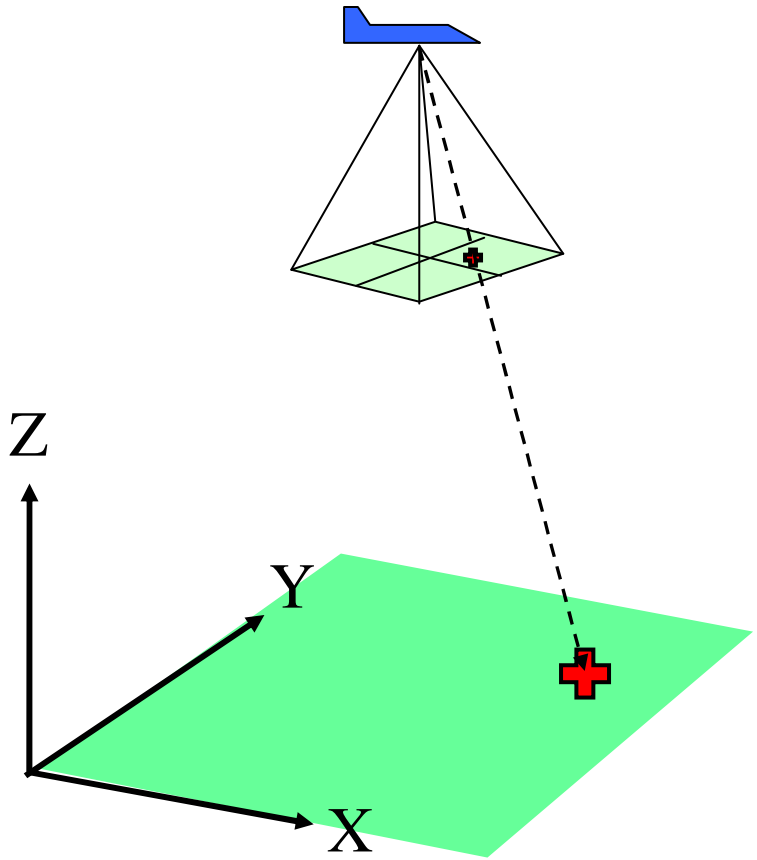
Tie points & GCP & GPS / INS ⇒ ISO, few GCPs

[Tie points & GCP] GPS / INS ⇒ Direct Georeferencing, no GCPs

Direct Georeferencing vs. „Indirect Georeferencing“

Georeferencing

connect information of an airborne sensor with a position in space



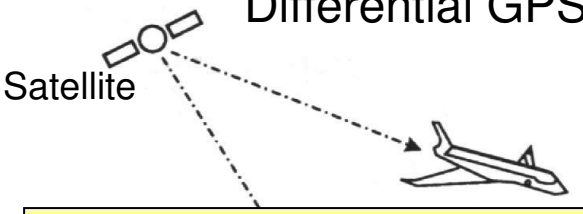
Indirect using the sensor data
Example: AT

Direct NOT using the sensor data

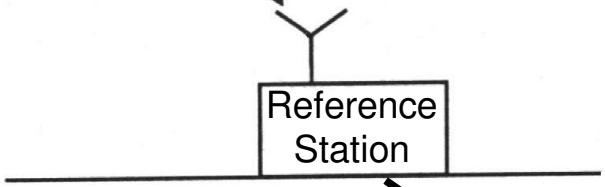
- position
- attitude
- velocity

GPS/IMU Integration

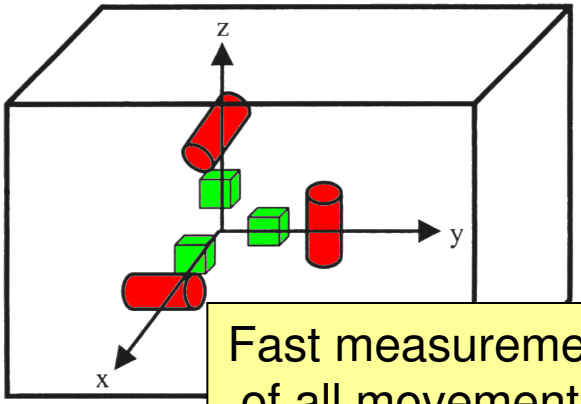
Differential GPS



Position and velocity with good long term stability



Intertial Measurement Unit



Fast measurement of all movements

Measurement of the attitude

Kalman Filter

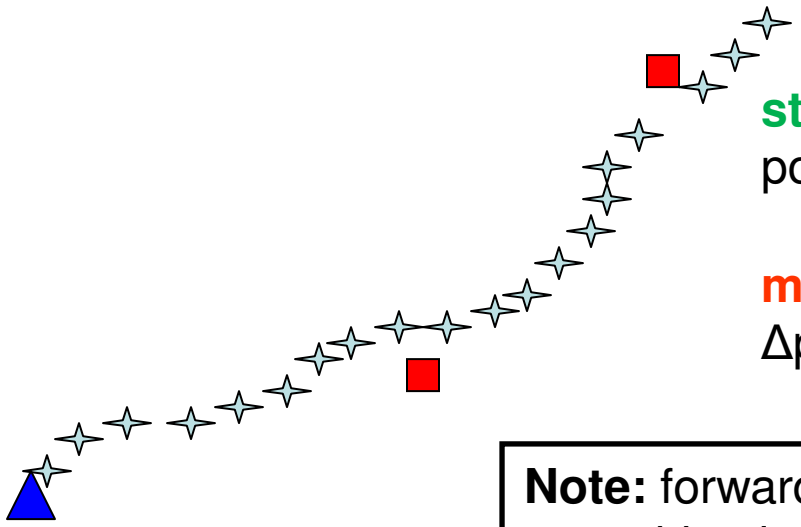
Position Velocity Attitude

GPS/IMU Integration

1. Calculate initial position, attitude and velocity (the **initial state**)

2. Calculate the **actual state** with the IMU data

3. When GPS **measurements** occur: use Kalman Filter to estimate **optimal state**, including IMU properties

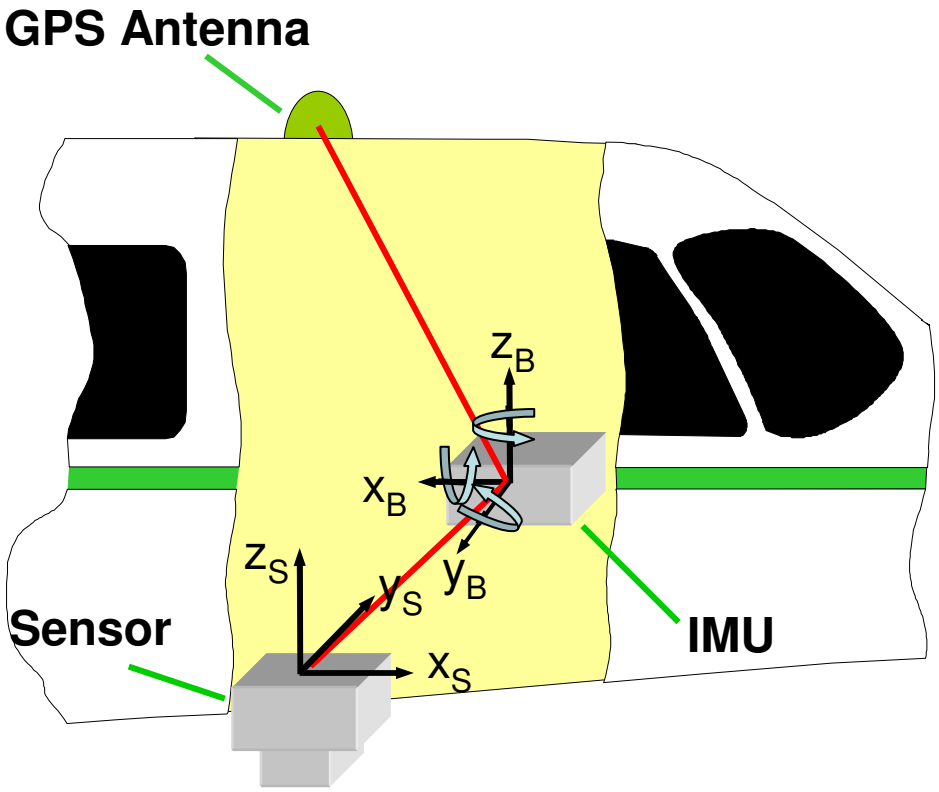


state vector
pos, att, vel, IMU properties

measurement vector
Δpos, Δvel

Note: forward-backward calculation and smoothing improve the result significantly

System Calibration



- Exact synchronization
- The lever-arms have to be taken into account
- Careful measurement of the attitude of the IMU
- Correct sensor model at the data collection time

Calibration:

IMU Calibration

Sensor Calibration

Misalignment Calib.

Direct Georeferencing / Integrated Sensor Orientation

Direct Georeferencing

No GCP's and no AT

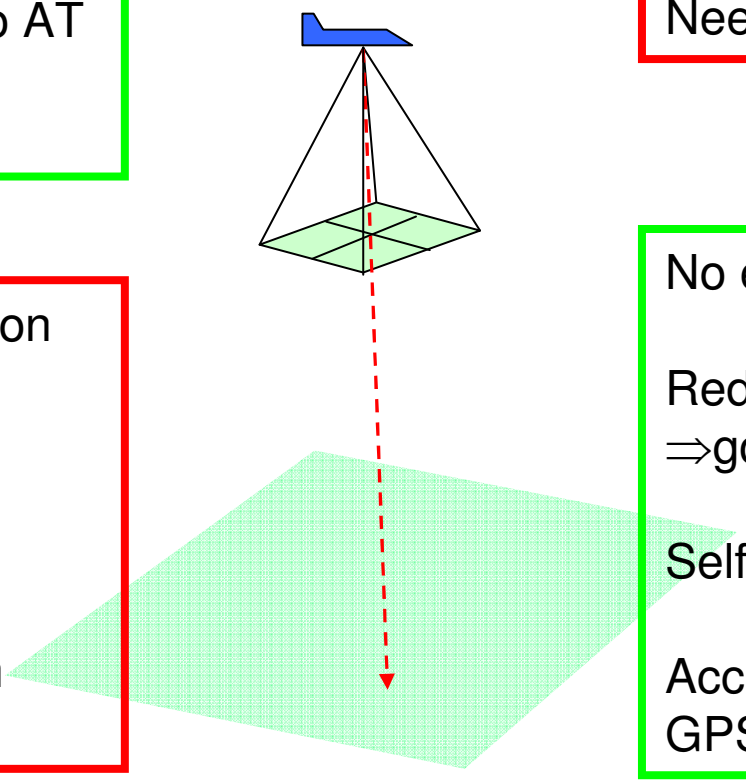
Very fast

Need for calibration

No redundancy
⇒ little error tolerance

No selfcalibration

Limited accuracy



Integrated Sensor Orientation

Need for AT

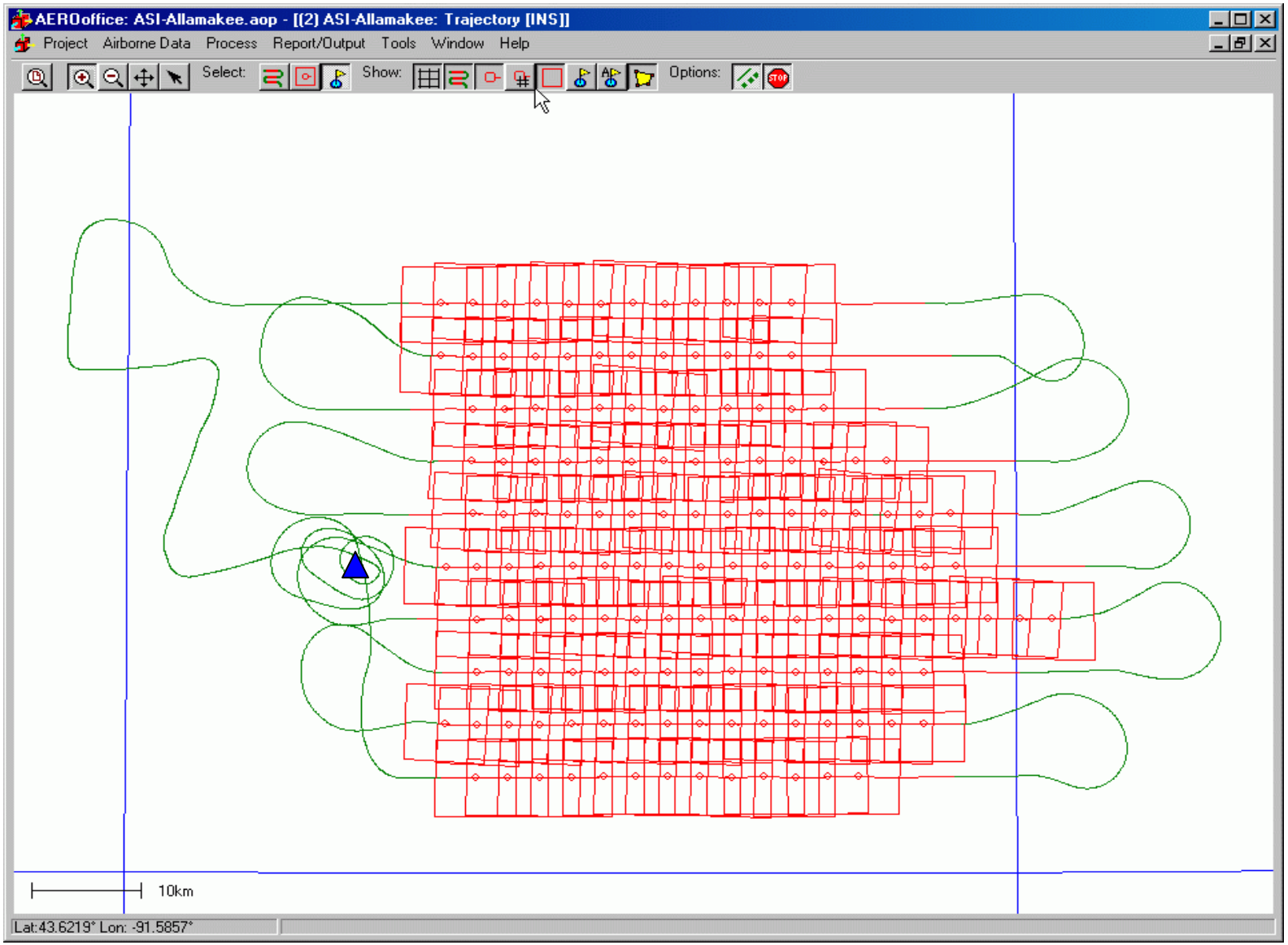
No extra calibration

Redundant measurement
⇒good error tolerance

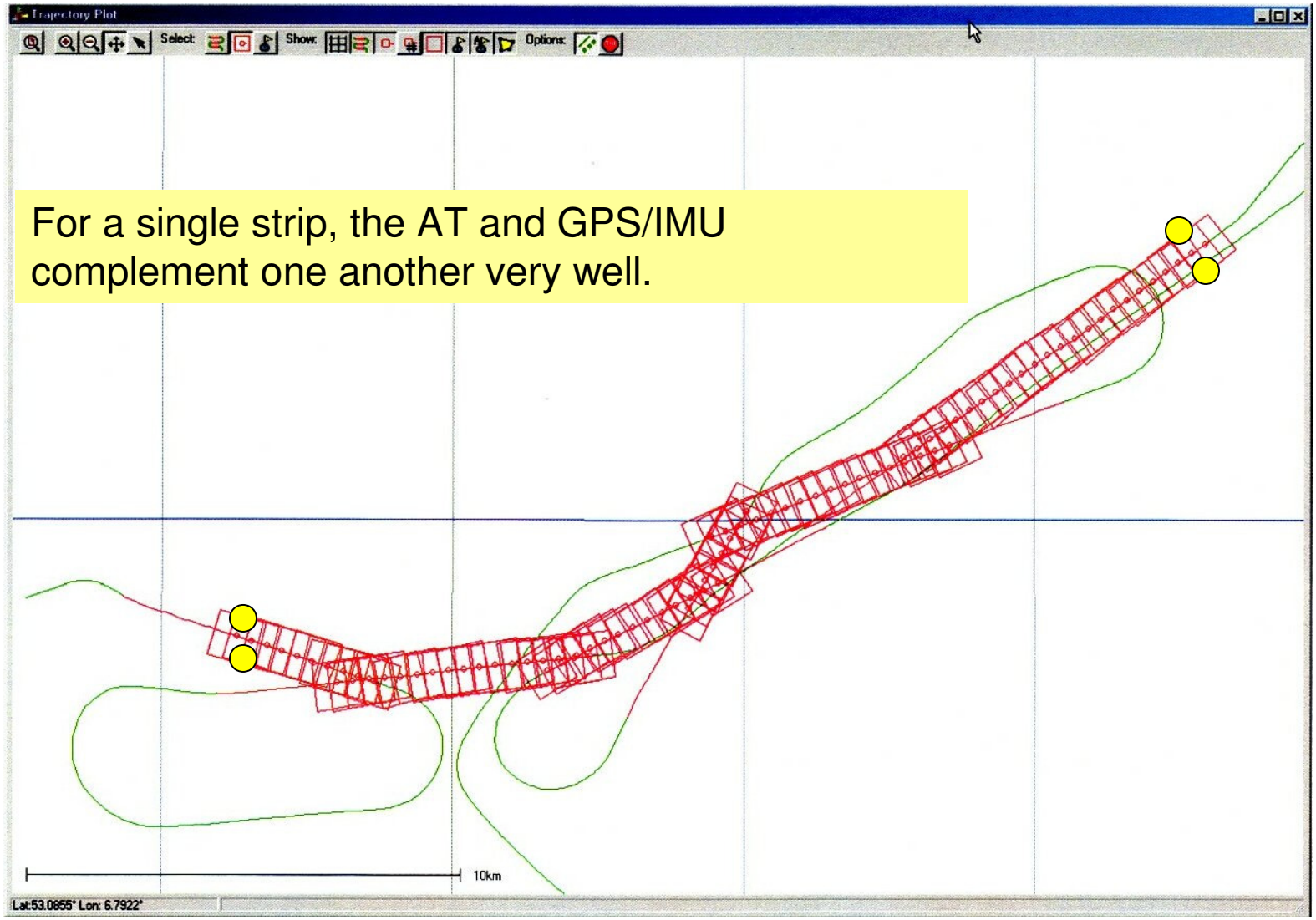
Selfcalibration possible

Accuracy not limited by GPS or IMU

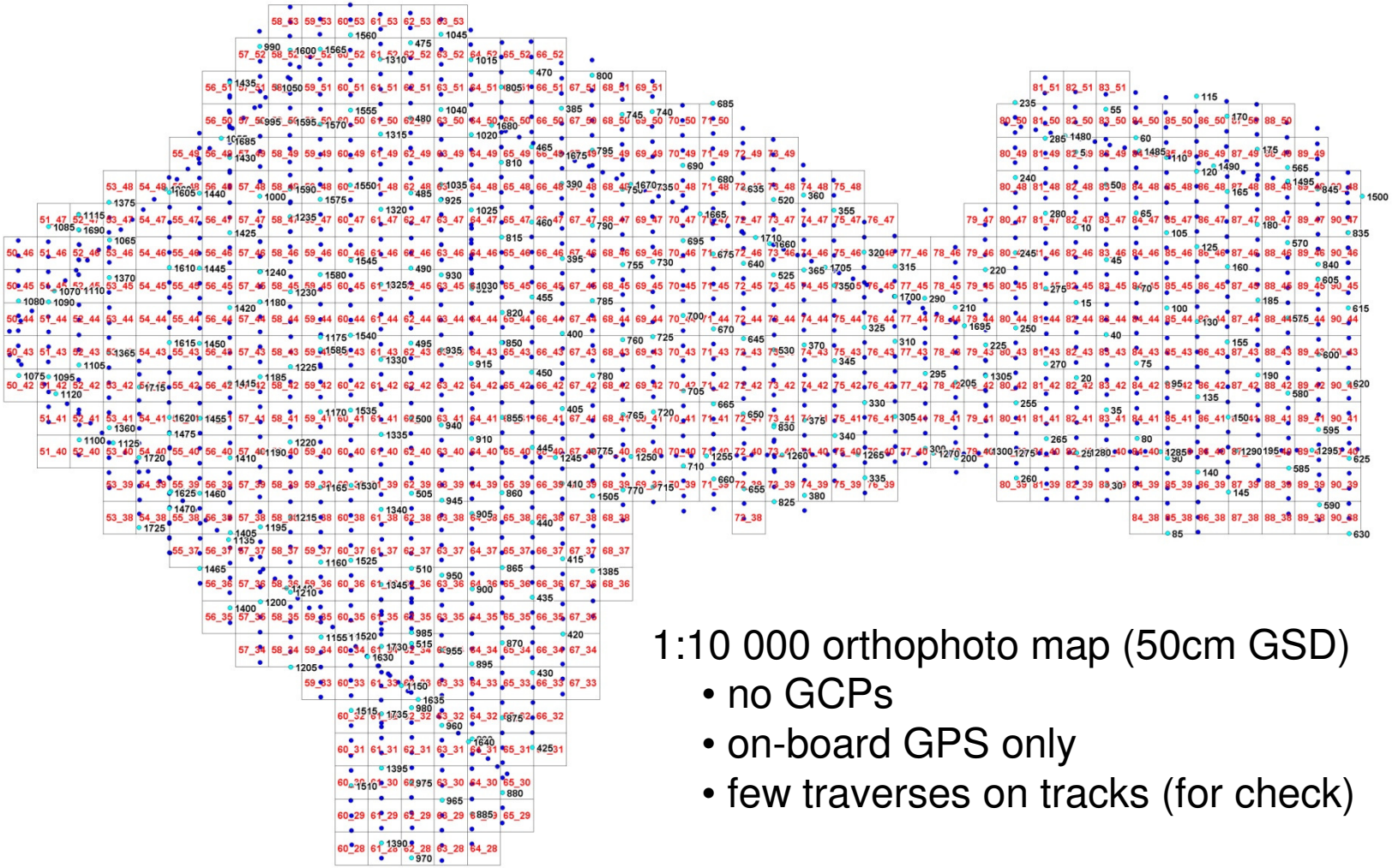
Example: Integrated Sensor Orientation, Block



ONLY 4 GCPs for blocks & strips



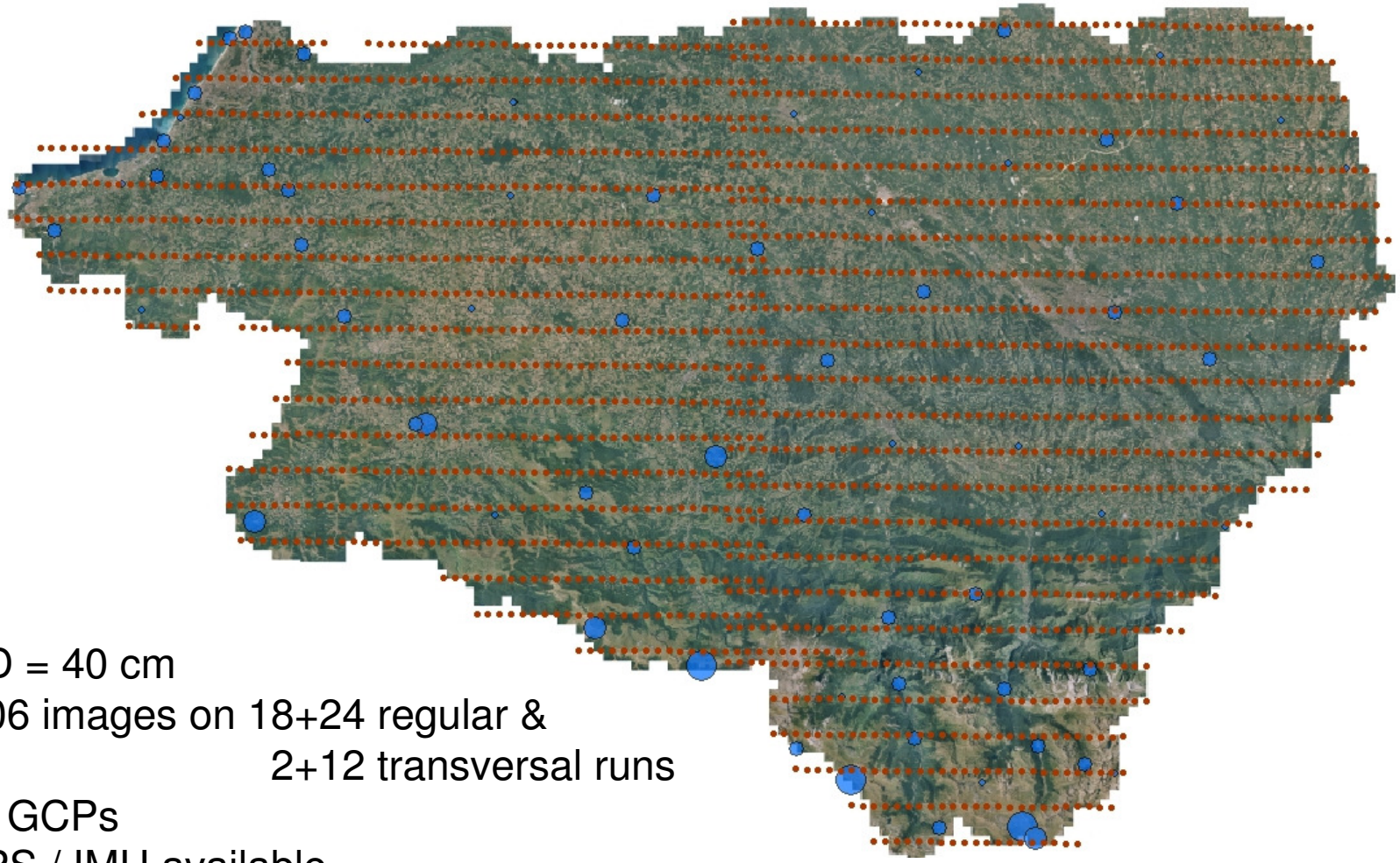
Example: Forest Project / Central African Republic



1:10 000 orthophoto map (50cm GSD)

- no GCPs
- on-board GPS only
- few traverses on tracks (for check)

Example: BD Ortho© / France



GSD = 40 cm

•2406 images on 18+24 regular &
2+12 transversal runs

• 85 GCPs

• GPS / IMU available

	RMSx	RMSy	RMSxy	RMSz	No pts
Control pts	0.32	0.24	0.40	0.26	67
Check pts	0.44	0.37	0.57	0.54	18

Example: BD Ortho / France

GPS / IMU accuracy:

$\mathbf{s}_X$ = 0.83m

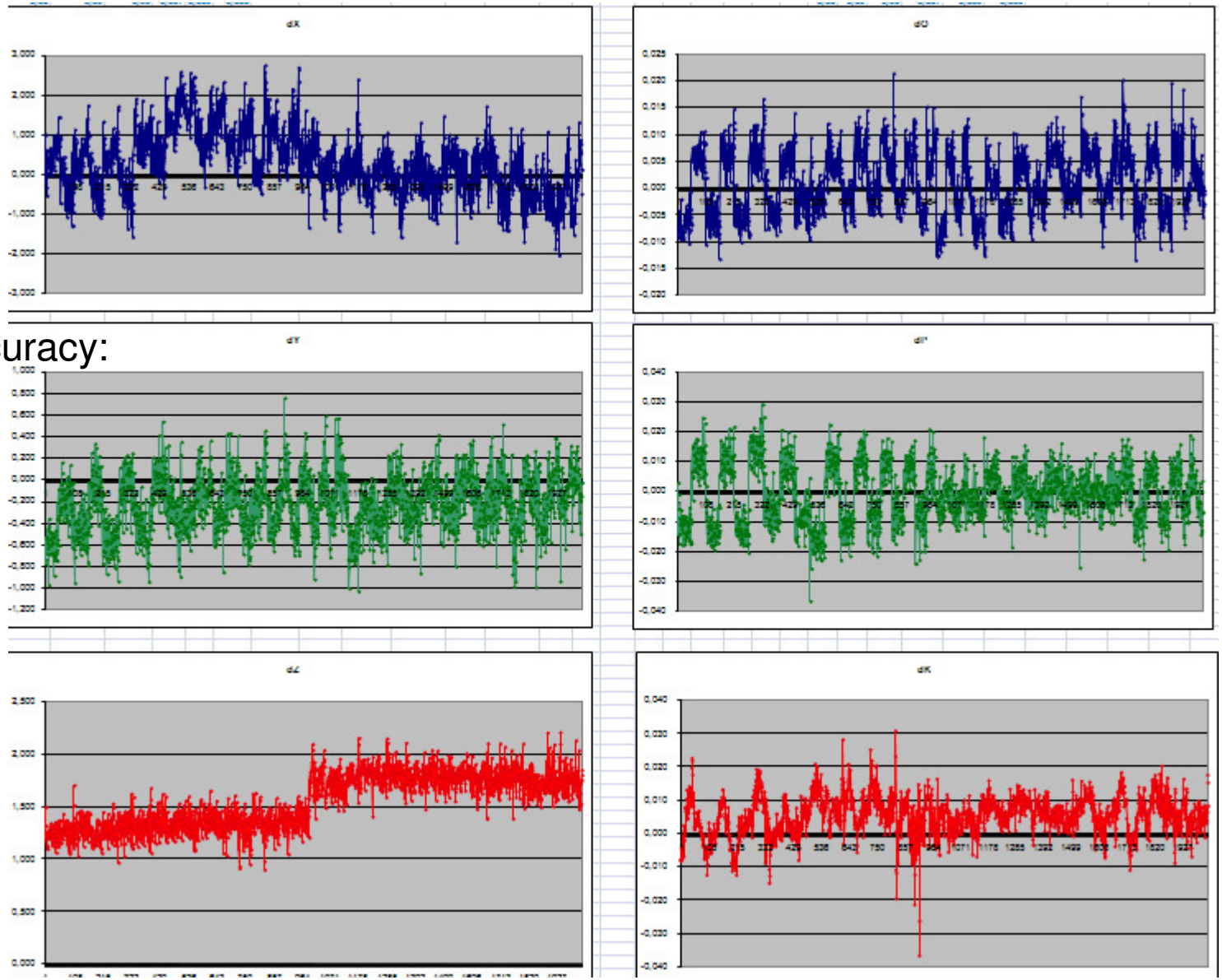
$\mathbf{s}_Y$ = 0.35m

$\mathbf{s}_Z$ = 1.57m

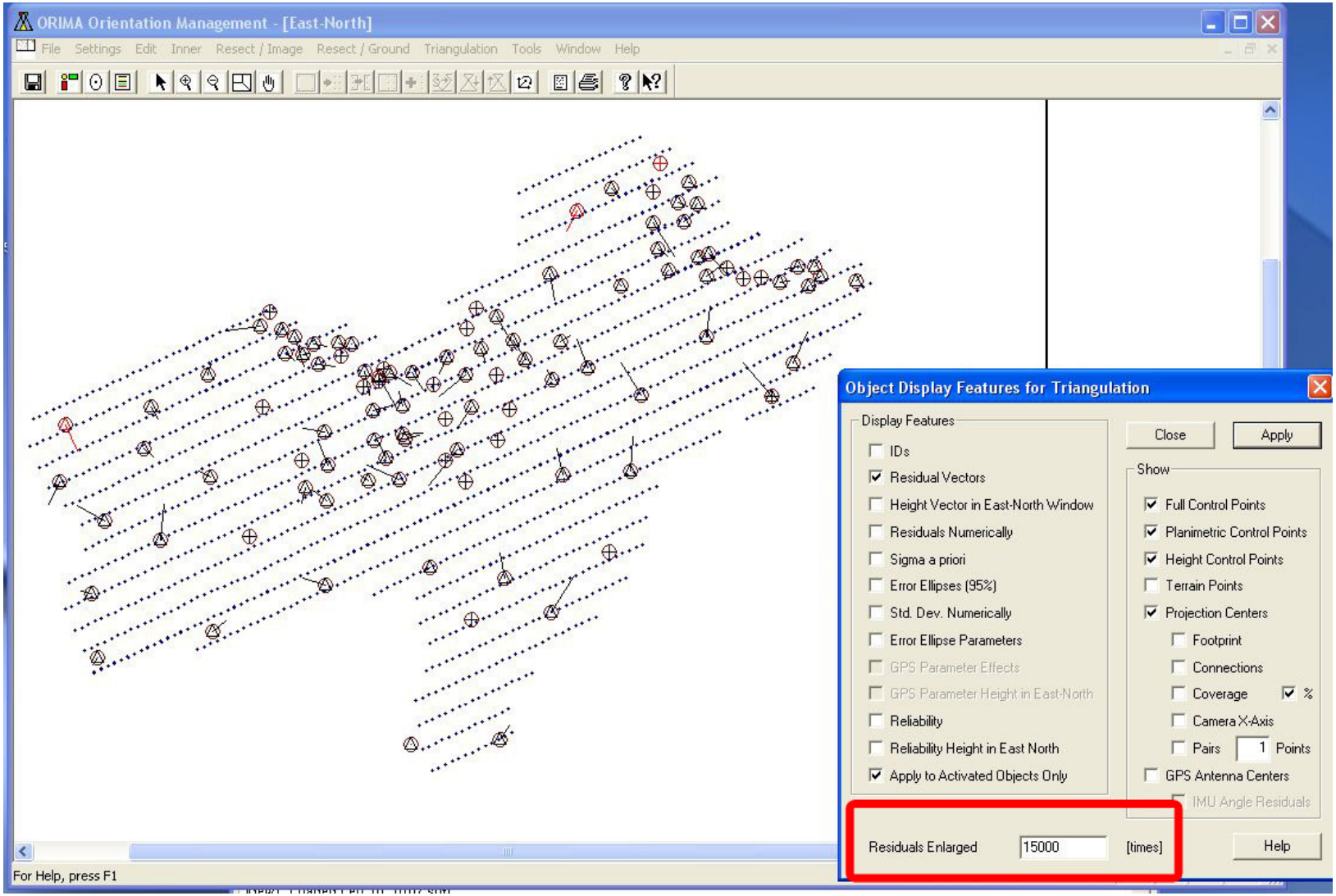
$\mathbf{s}_O$ = 0.006

$\mathbf{s}_P$ = 0.009

$\mathbf{s}_K$ = 0.008



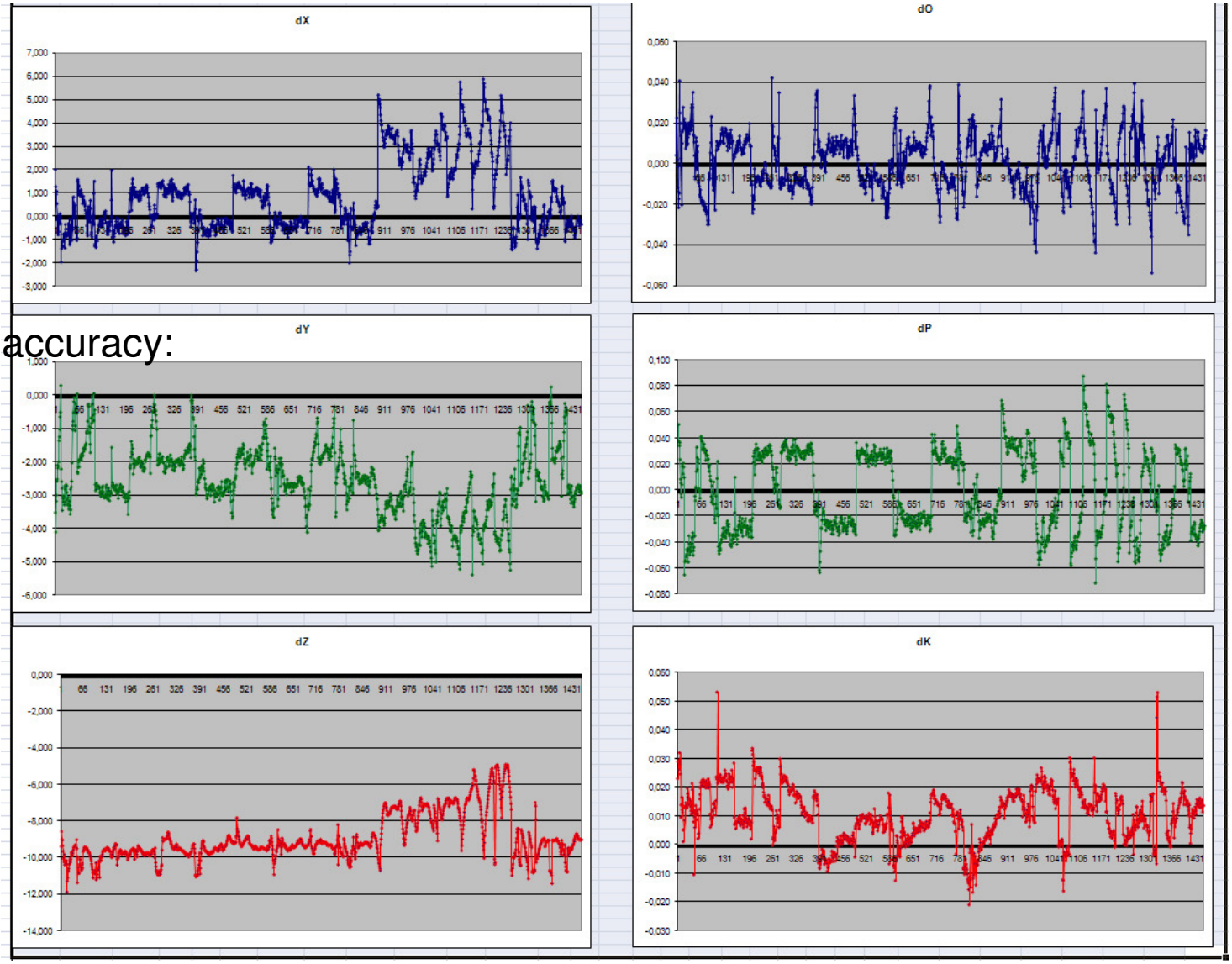
Example: AT for 25cm GSD / Alger



Example: GPS/IMU for 25cm GSD / Algeria

GPS / IMU (in)accuracy:

s_X = 1.75m
s_Y = 2.76m
s_Z = 9.06m
s_O = 0.014
s_P = 0.031
s_K = 0.014



Example: GPS/IMU for 12.5cm GSD / Algeria

GPS / IMU (in)accuracy:

s_X = 1.02m

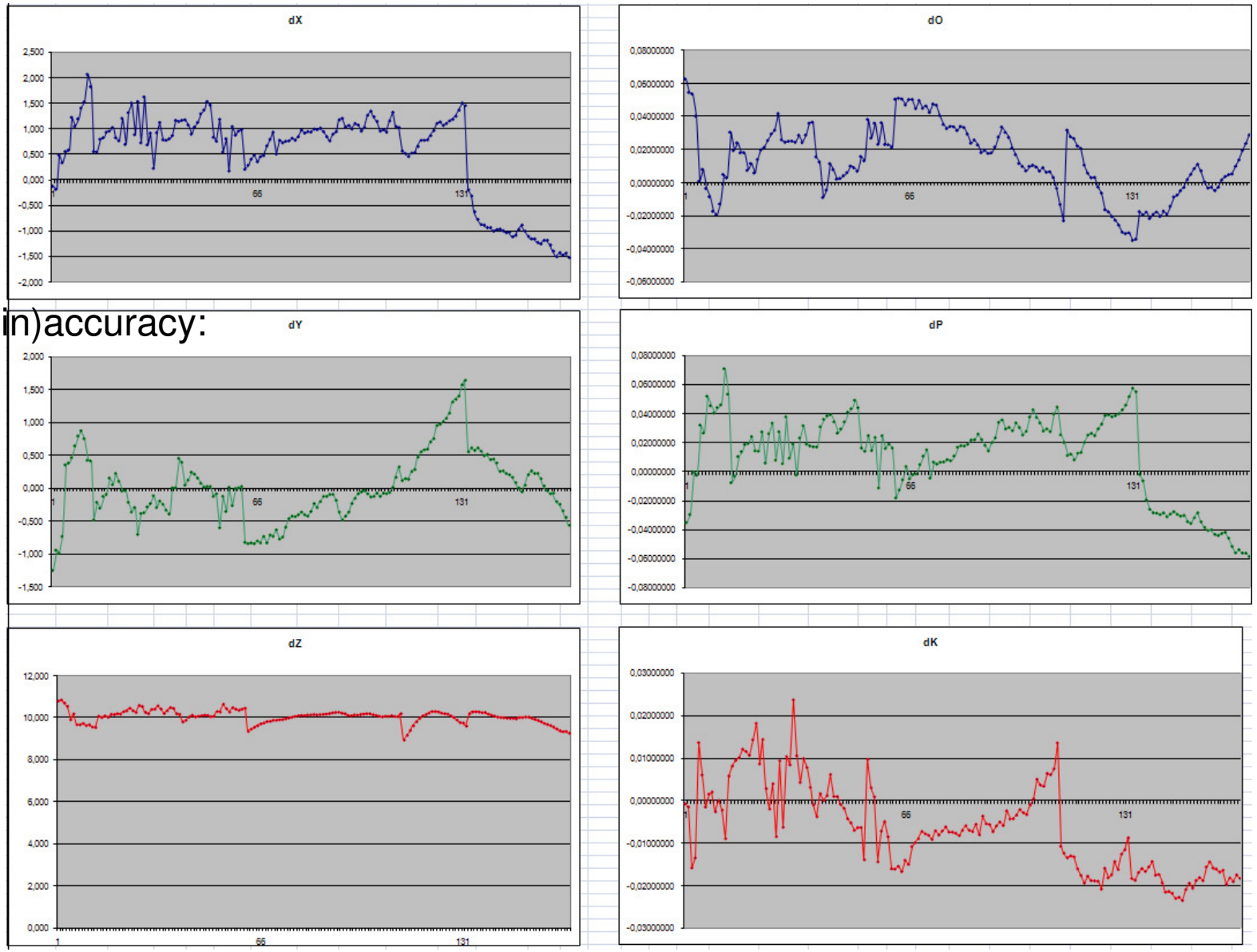
s_Y = 0.52m

s_Z = 10.05m

s_O = 0.025

s_P = 0.030

s_K = 0.012



Conclusion

- Georeferencing with GPS/IMU data is a well established method.
- The decision to use DG or ISO depends on the project parameters (scale, required accuracy ...).
- The proper use of GPS/IMU technology can save much time and money
- Improvements in GNSS will improve reliability and accuracy.
- The all digital workflow of the sensor orientation with GPS/IMU data together with automatic matching techniques speed up the processing times from years and months today to days and weeks.
- The use of GNSS/IMU systems for Direct Georeferencing and Integrated Sensor Orientation becomes a standard tool.