LiDAR for River & Coastal Managers
2. Planning & Practical Issues

Murray Hicks

m.hicks@niwa.co.nz

NIWA
Taihoro Nukurangi

Envirolink Workshop: Tasman District Council , 15 June 2006

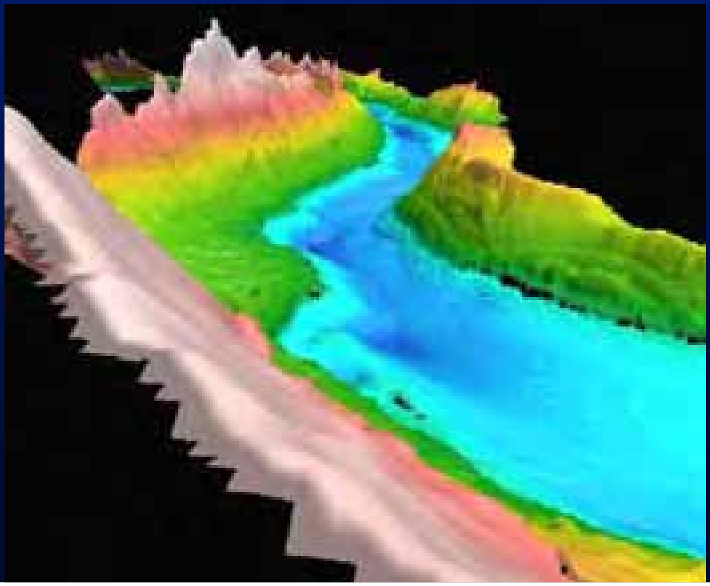
Outline

- Which system – terrestrial or bathymetry
- Operators
- Dealing with water with terrestrial systems
- Specification options
- Additional information
- Optimising environmental conditions
- Ground-truth & control data
- Geoidal adjustments
- Accuracy checks
- Post-processing
- Data management
- Case example of river bed-level monitoring
- Where are things going?

	Terrestrial (e.g. Optech 3100)	**New Dual-mode bathymetry** (e.g. SHOALS-1000T)
Cost	Lower	~ 3X?? Depends on density
Penetrates water	No	Yes to 0.2-50 m (2-3 X secchi depth)
Used in rivers	Yes (with other methods)	Yes (average depths <1 – several m)
Portable	~Yes	~Yes
Pulse rate	< 100 khz	1 khz / 10 khz
Footprint	0.2 - 0.9 m on ground	~ 1 m
Point spacing	~ <1-2 m	2x2 – 5x5 m bathy 2 x 0.7-3.2 m topo
Vertical accuracy	~ 0.15 m (0.03 m on flat)	~0.25 m
Horizontal accuracy	> ~ 0.2 m	~ 2 m
Intensity/backscatter info (e.g. for vegetation, substrate classn)	Intensity	Backscatter
Nearest operators	AAMHatch/Geosmart (Au,NZ) NZAM (NZ)	Fugro-Pelagos (US) ? AAMHatch soon

Shoals 1000-T in the Grand Canyon

"Clear" water at Lees Ferry Study Area



Check soundings

	All Soundings
Number of Samples	96
Mean difference	-0.0629m
Standard deviation	0.1676m
% of samples with <0.15m difference	68%

Graphics: Miller et al, 2005

Operators	AAMhatch	NZAM	Fugro-Pelagos
Location	Queensland (Geosmart in AKL, Nelson)	Hastings	San Diego
System	Optech 3025 Optech 3100 (100 khz)	Optech 3100C-EA	Shoals 1000-T
Additional info	Applanix 16Mp digital camera	Rollei 22Mp digital camera (colour or FIR)	Integrated digital camera Back-scattering

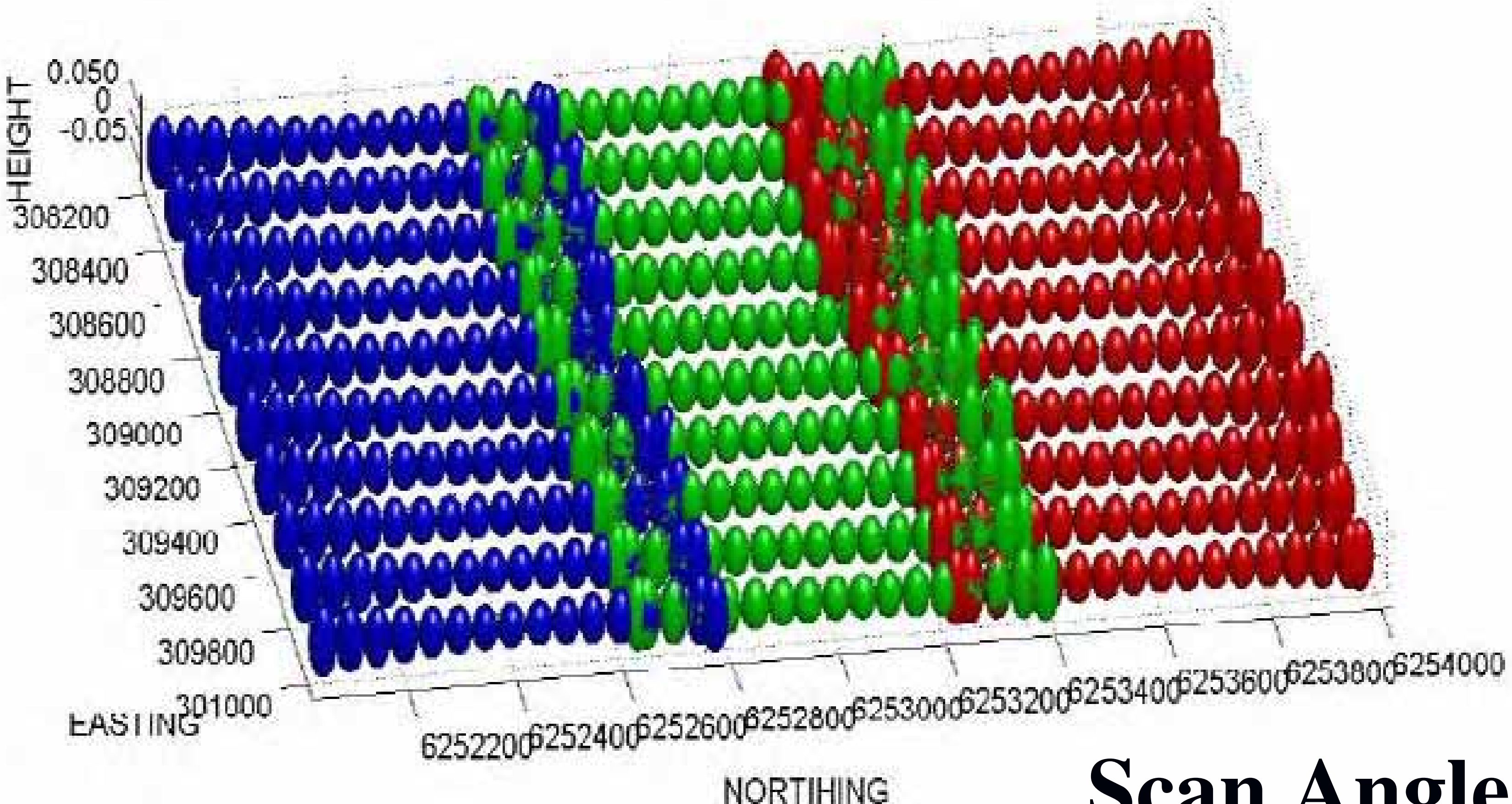
Options if you want wetted channels

System	Vert accuracy on land (rms)	Vert accuracy on river / sea bed (rms)	Limitations in water
Dual (e.g. Shoals)	0.25 m	0.25 m claimed (0.17 m SE , -0.063 m mean Grand Canyon)	Turbidity (2-3 x Sechhi depth No white-water
Terrestrial + bathy survey	0.15 m	0.05-0.1 m at-a-point	Point density Gaps (trees, un-navigable water) Slow
Terrestrial + colour imagery	0.15 m	0.25-0.3 m (Waimak)	Another plane (no more) Geo-syncing (no more) Turbidity optimum Calibration data Passive light, shadow, bottom effects
Terrestrial + MS imagery	0.15 m	0.23 m (Waitaki) (0.08 m mean)	

Specification options

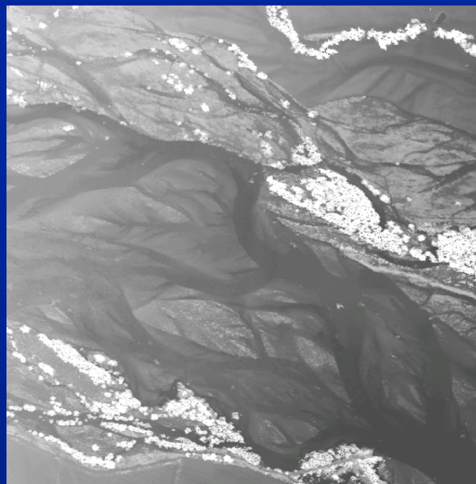
Controls / options	Issues
Scan rate, altitude	Point density, cost
Beam divergence angle (foot print)	Ground, non-ground surfaces
1st, last return, full wave form	Point classification, ground / non-ground surfaces
Scan angle	Accuracy
Intensity	Point classification
Digital imagery	Point classification, editing

In ALS, the Fundamental Errors can be determined by propagating the contributing errors of the GPS measurement of the air station, the IMU and the laser distance and angle. Clode (2003) has quantified these Fundamental Errors, concluding, "the accuracy is very dependent on the scan angle". This work is illustrated in Figure 5 which shows Fundamental Error ellipsoids along three swathes of ALS data, as generated by propagation of variances from the components of the ALS system.



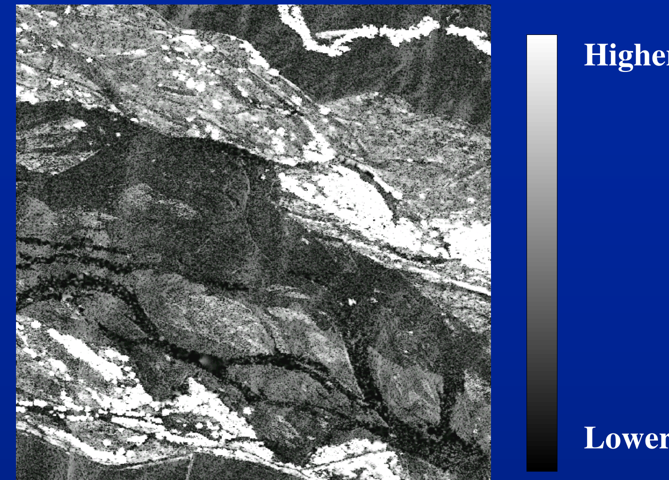
Scan Angle

Figure 5 – Error ellipsoids against position in the swathe (Clode, 2003)

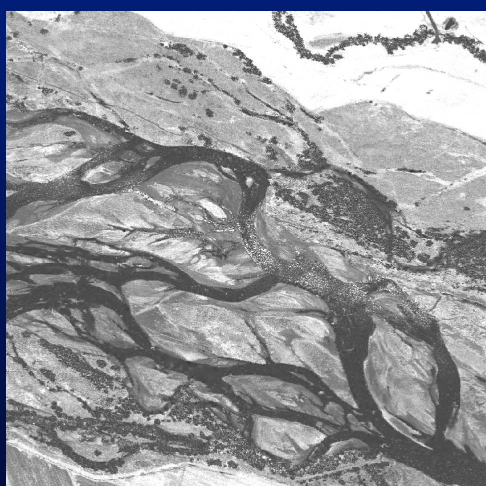


First return elevation

Last return elevation

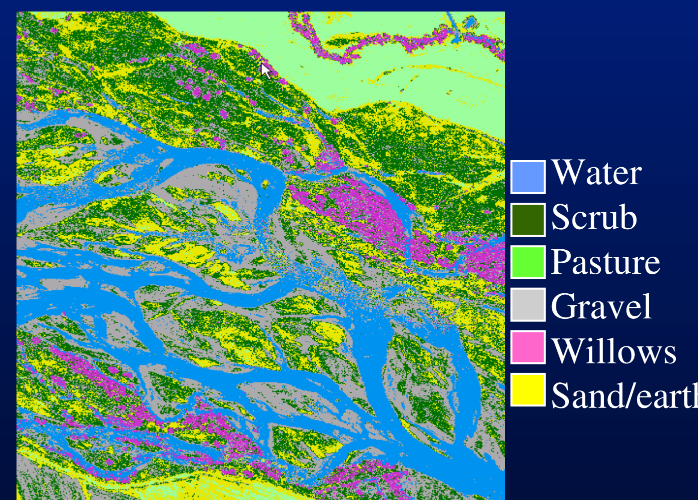


Elevation difference (~ veg height)



First-return intensity

Photograph



Ground classification

Supporting imagery

- Video
- Digital imagery

Optimal environmental conditions for river surveys

Condition	Terrestrial LiDAR	Bathymetric LiDAR
River flow	Very low	Low, minimal white water
Clarity	Slightly turbid	Clear
Season	Winter	Winter
Atmosphere	No cloud, smog no severe turbulence	No cloud, smog no severe turbulence

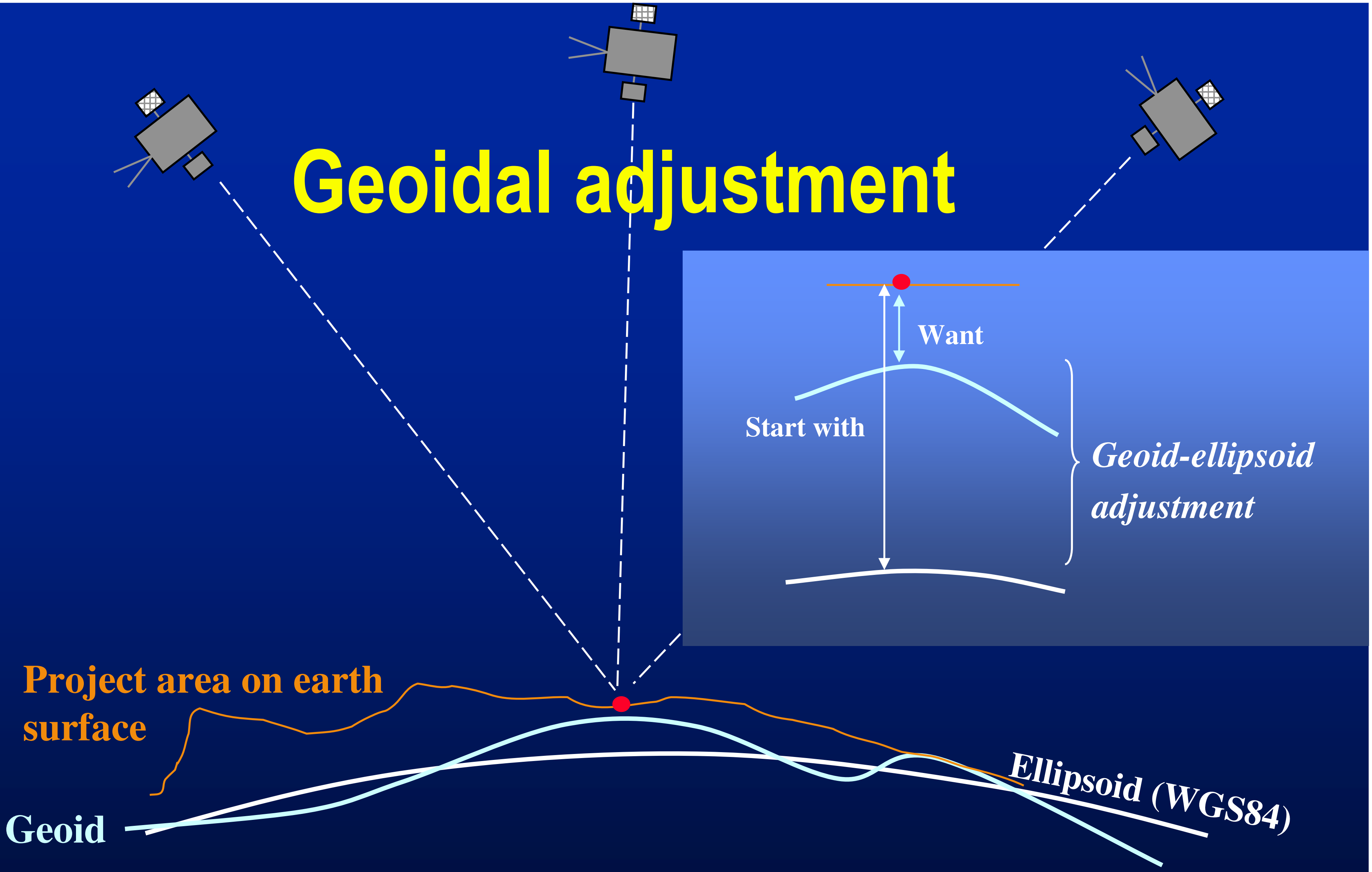
Ground control needs
(User usually provides)

- GPS base station – need 1 s logging of satellite data with dual-frequency receiver at known location (use two!!!)
  - Used for post-processing accurate locations

- Check data – several 100 check topo (x,y,z) points accurately surveyed over a flat sub-area in project area
  - Checks & correction of small systematic error
  - Provides RMSE for LiDAR strikes that “hit” check points (~ ± 5 cm) and “derived” elevation at other check points (~ ± 8-15 cm) as interpolated from LiDAR DEM

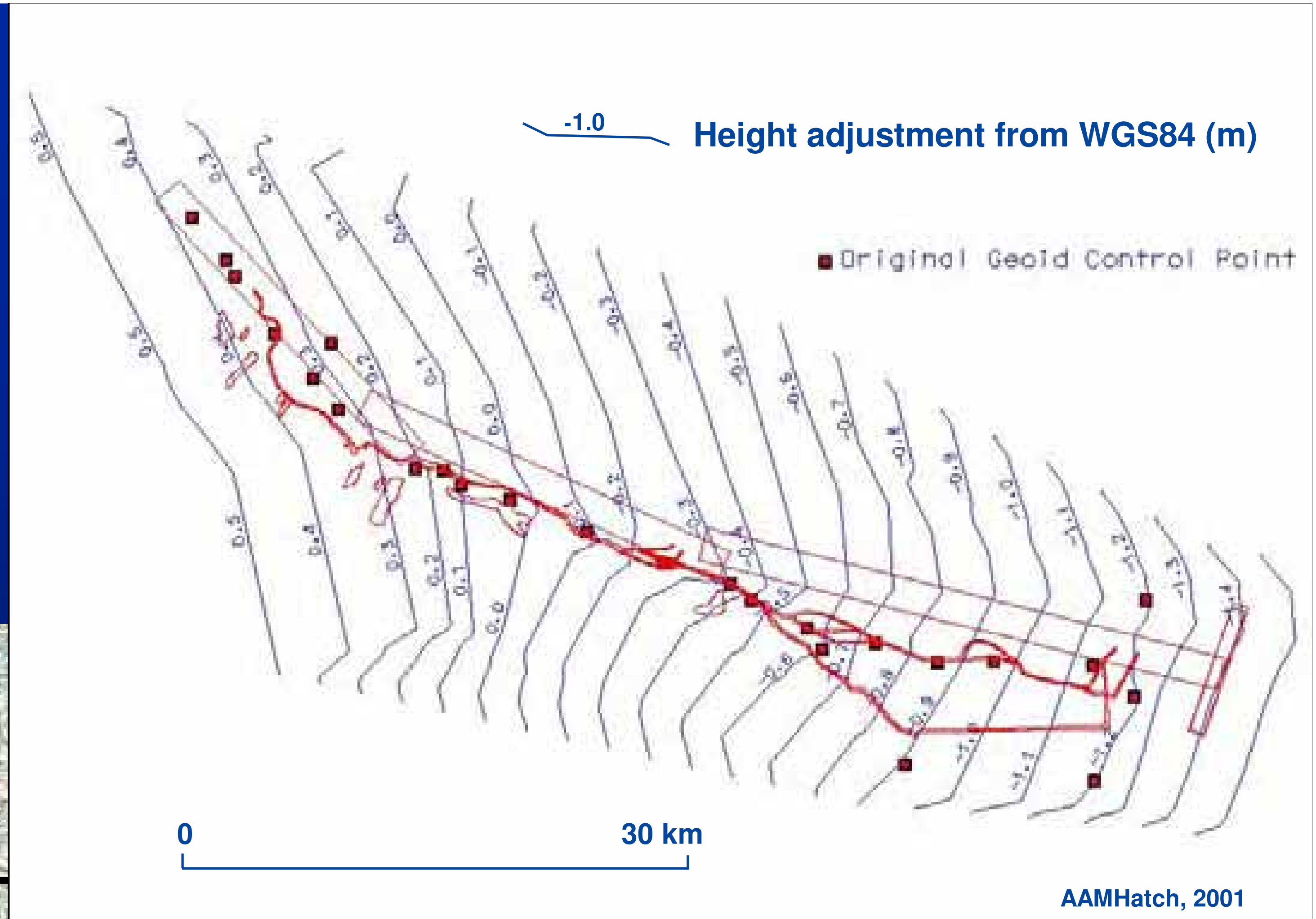
- Geoidal adjustment data or model – survey control data from around and within project area – to get true orthometric heights
  - Required for accurate survey in low gradient areas

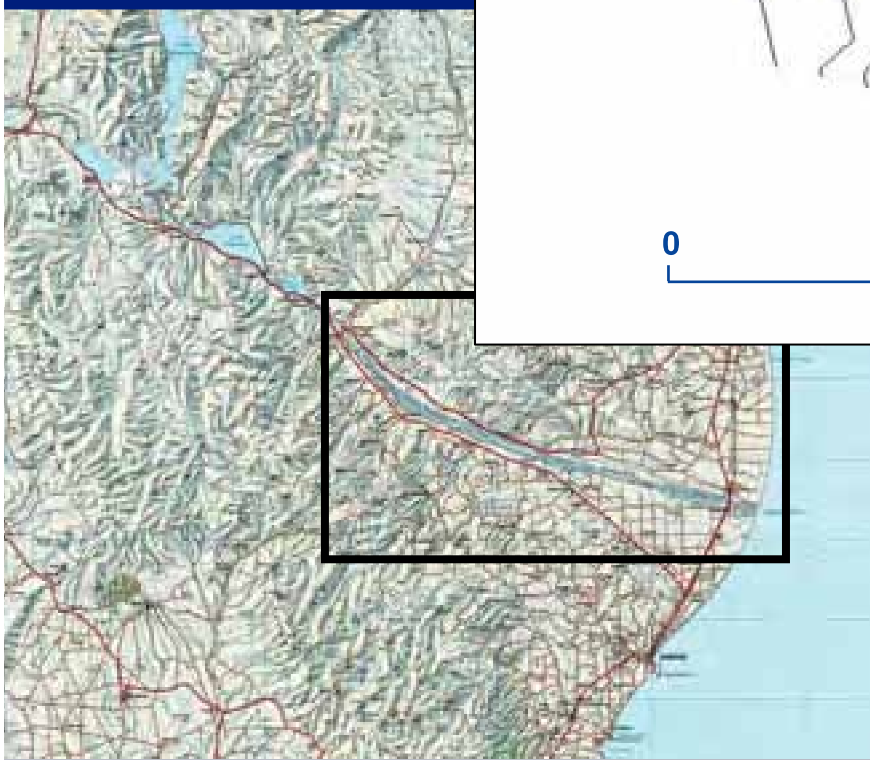
Geoidal adjustment



Need to define a geoidal adjustment surface for project area using surveyed control points

Example: WGS84 – Geoid adjustment Lower Waitaki Valley





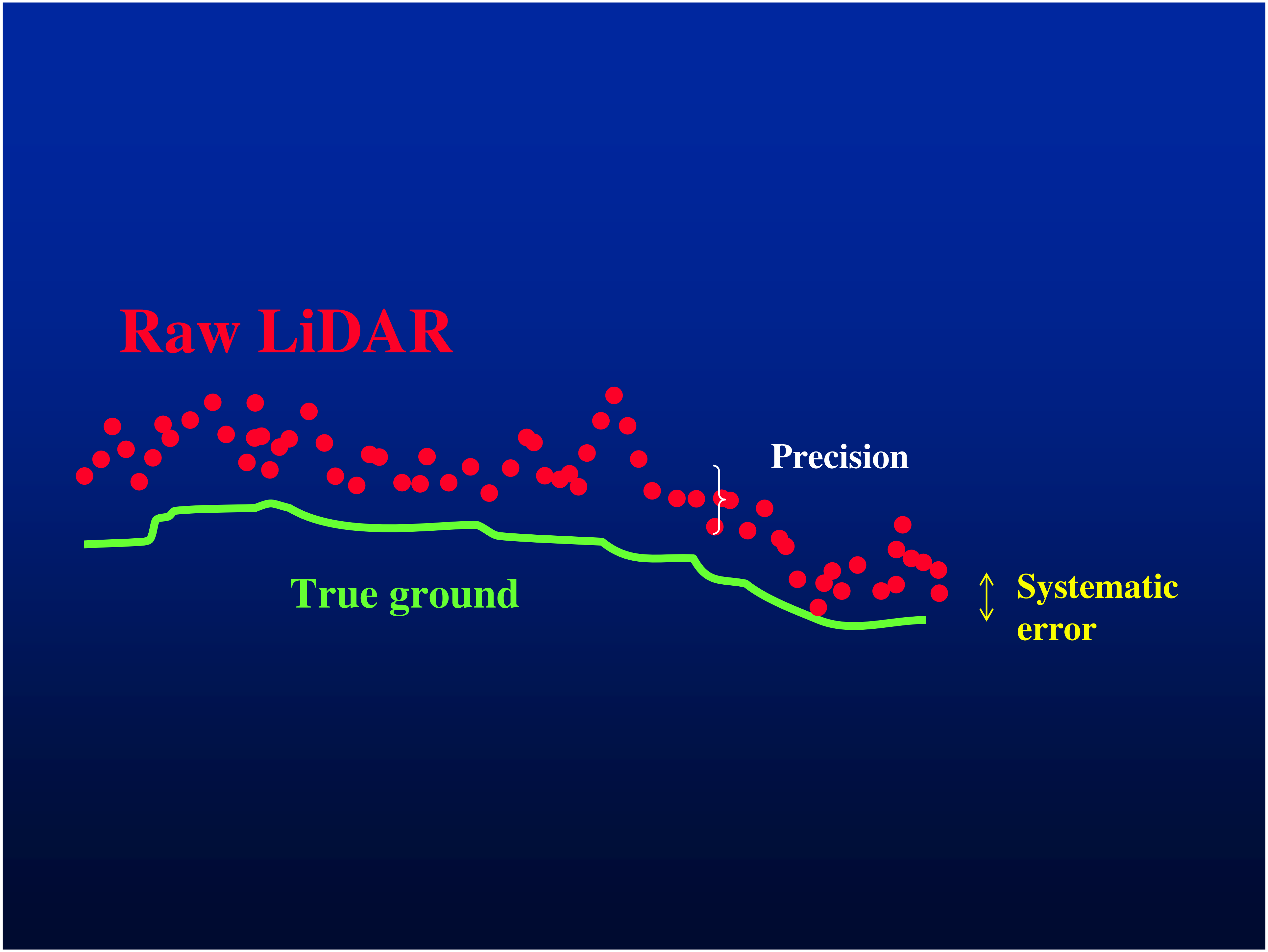
Down-valley trend ~4 cm/km

Waitaki slope: 3 m/km

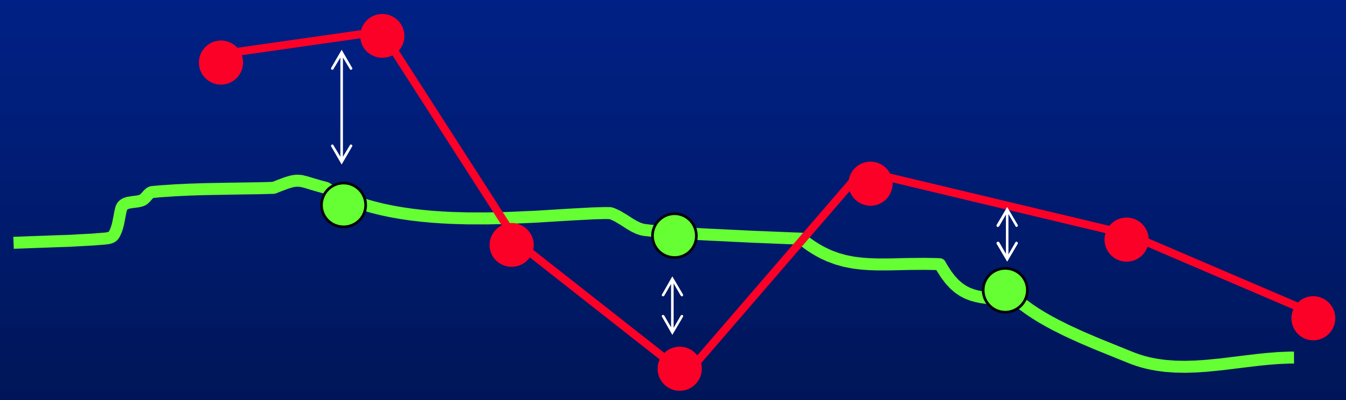
Lower (40 km of) Waikato slope: 4.3 cm/km

Error, Precision, and Accuracy

- Errors due to
  - Technology
  - Environment & atmospheric effects
  - Survey control
  - Point interpolation
- Errors are
  - Random : Precision
  - Systematic : Accuracy
  - Gross : Reliability


Raw LiDAR
Precision
True ground
Systematic
error

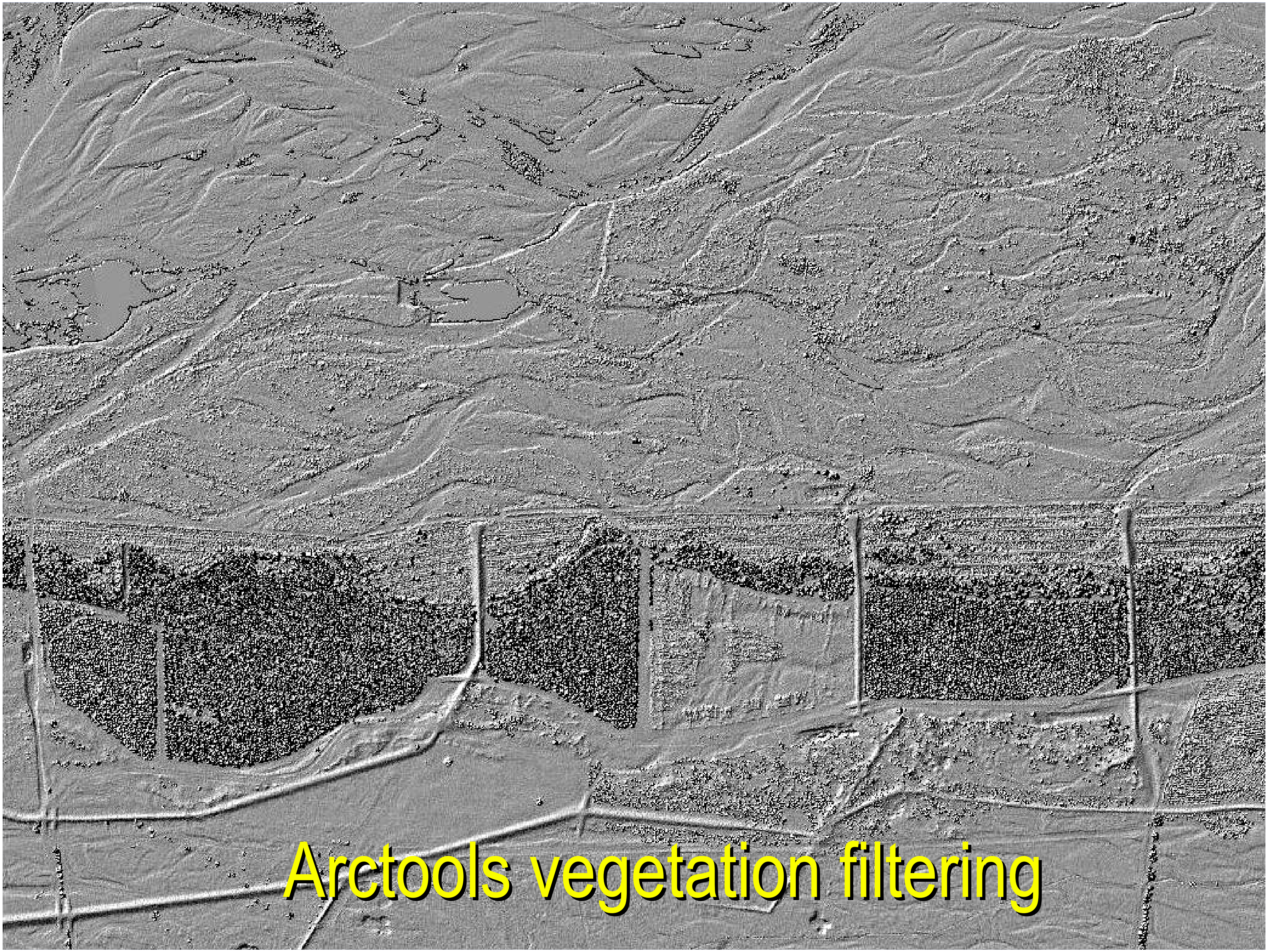
RMS Error (or standard error)
of check point elevation interpolated from DEM

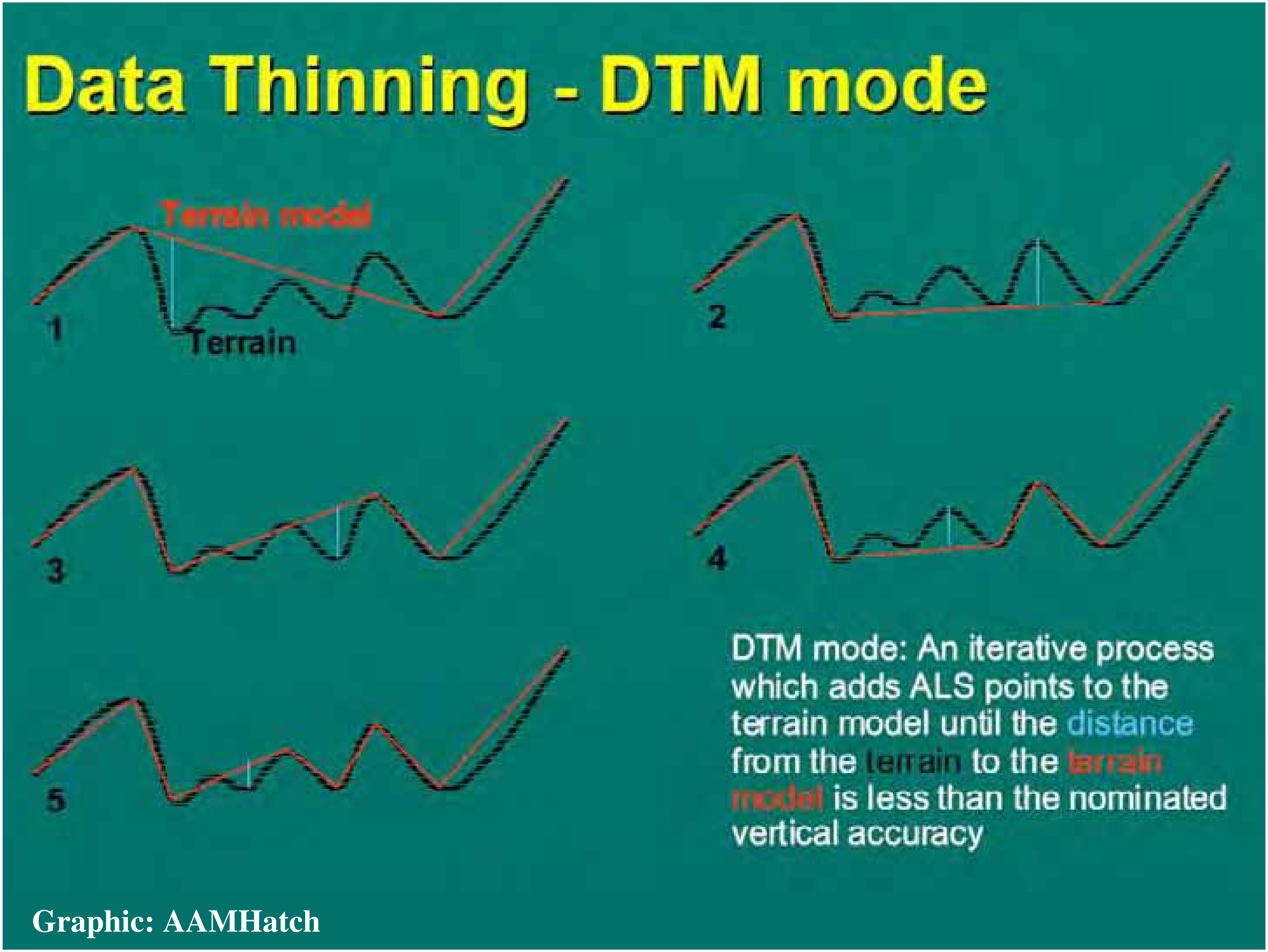


Typically ~ 0.10 – 0.15 m for terrestrial systems

Data processing

- Operator (usually system or own software)
  - Ground/non-ground classification of last return using numerical "morphological filter" ("burning off" vegetation)
  - Data thinning – numerical filtering of data that don't add to DEM
- User (or operator or intermediate party)
  - Refined numerical filtering to clear vegetation, buildings
  - DEM construction (grid or TIN) & sub-sampling
  - Merging bathymtery data
  - Manual editing of DEMs with various packages & tricks
  - Ground cover and roughness classification using altimetry, intensity, imagery data
- Some 3rd party software packages
  - ARC GIS suite (ESRI software) – general capapability
  - TerraScan (3DLM), Fledermaus – dedicated to LiDAR data processing


Arctools vegetation filtering



Graphic: AAMHatch

Further classification

- Ground cover
  - Hydraulic roughness
- Physical habitats

DEM / TIN sub-sampling

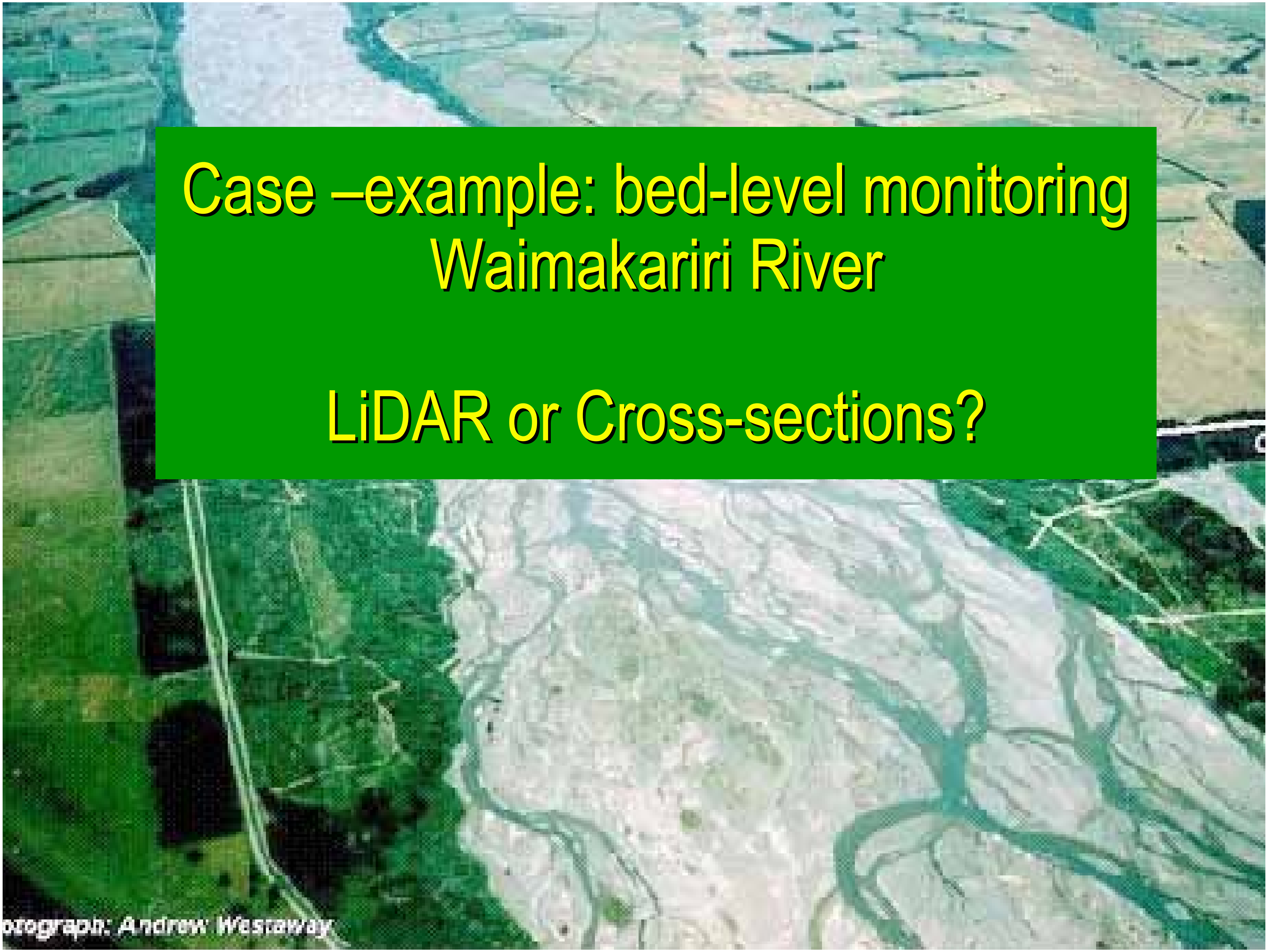
- **Need to sub-sample for numerical modelling**
  - **100's millions down to millions**
- **This can degrade topography**
- **Very important to correct along stopbanks!**

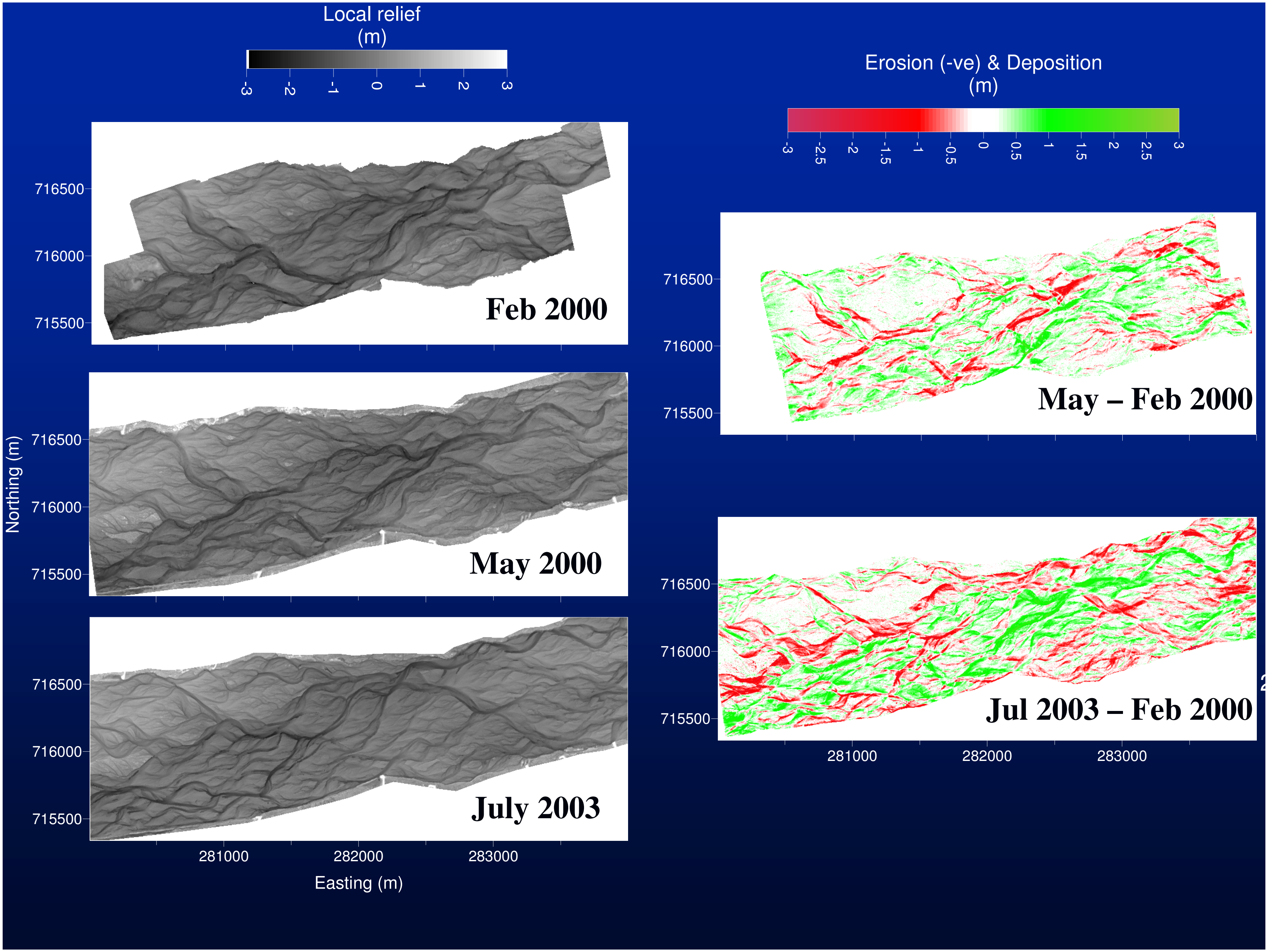
Data management

- Be prepared for *Gigabytes* of data
- Example: Lower Waitaki Valley
  - Project area: 70 km x 2 km
  - Last return data, unthinned, separated as ground/non-ground
  - 89 million points at ~ 2 m spacings
  - 49 tiles (4 km side), 98 files (49 ground, 49 non-ground)
  - Average file size: 24 Mb
  - Total size of files: 2.3 GB (zipped down to 600 Mb)
- Example: Lower Clutha
  - Project area: 17 km x 10 km
  - 45 tiles (2 km side)
  - 3 merged DEMs

Case –example: bed-level monitoring Waimakariri River

LiDAR or Cross-sections?

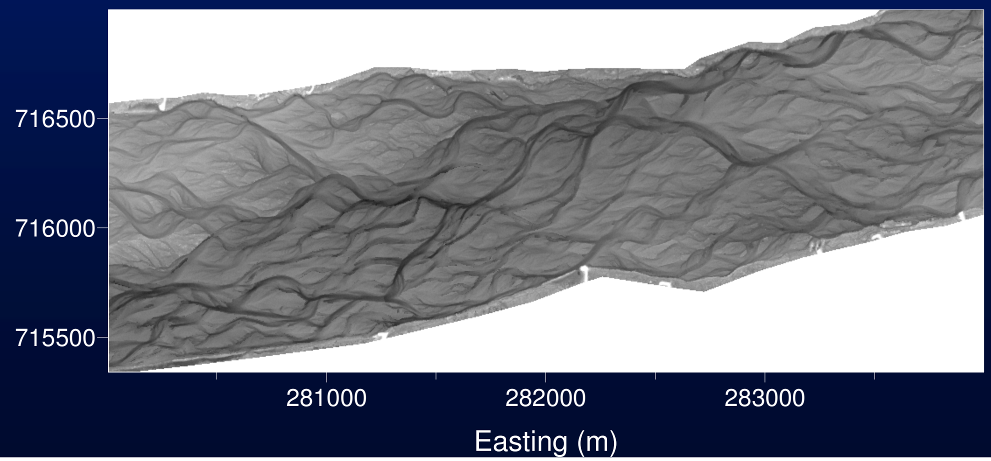




Local relief
(m)
-3 -2 -1 0 1 2 3
Erosion (-ve) & Deposition
(m)
-3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3
Feb 2000
May 2000
July 2003
May – Feb 2000
Jul 2003 – Feb 2000
716500
716000
715500
281000
282000
283000
Northing (m)
Easting (m)

DEM precision (m)

DEM	Check point precision: Dry	Check point precision: Wet	
Waimakariri - Feb 2000	± 0.137	± 0.239	Photogrammetry
Waimakariri - May 2000	± 0.105	± 0.217	LiDAR
Waimakariri - July 2003	± 0.105	± 0.3	LiDAR

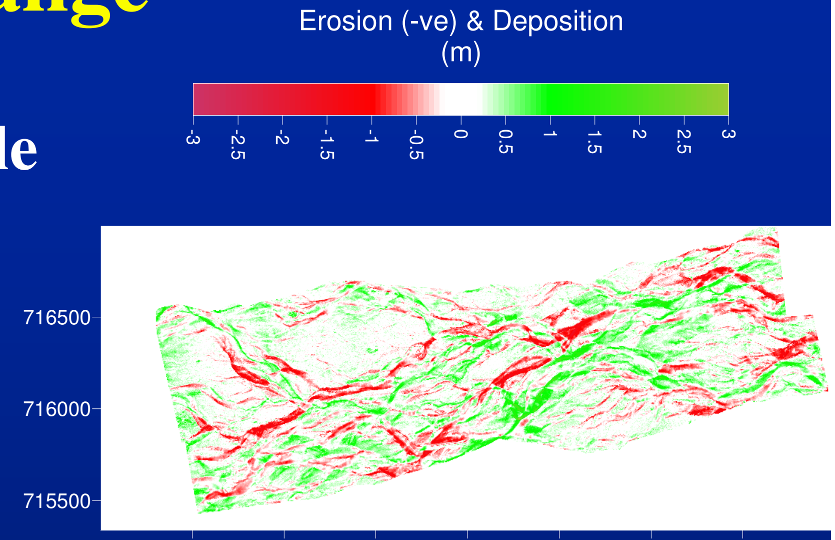


Accuracy of bed-level change

94 interpolated check points at stable locations on 2000 and 2003 DEMs:

Standard error = 0.19 m ~ $(SE_{surv1}^2+SE_{surv2}^2)^{0.5}$

Mean error = 0.038 m (just significant at 5% level)

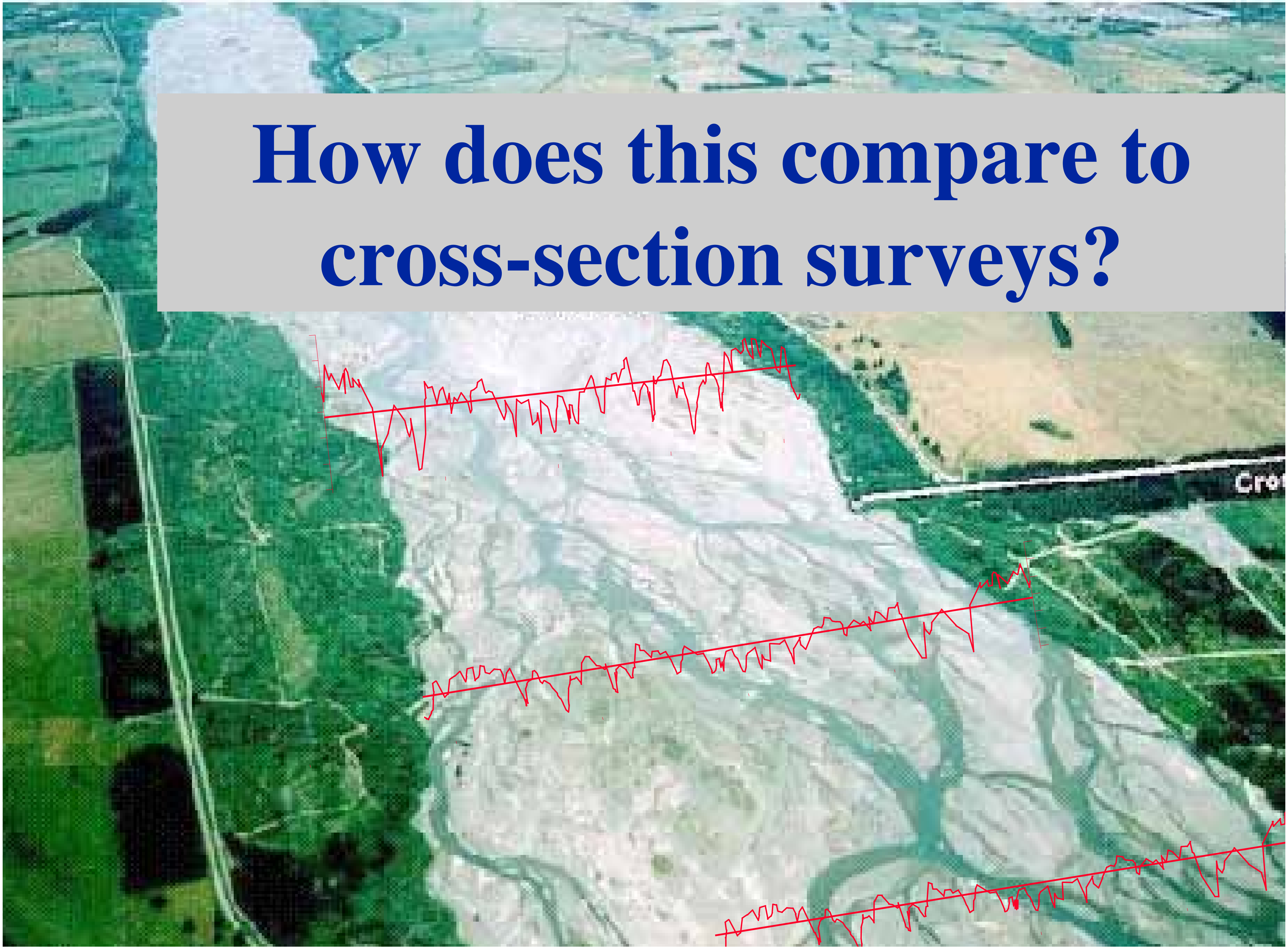


Conclude:

- Local (at-a-point) level-of-detection of change ~ 0.2 m

- There may be a systematic error of ~ 4 cm due to survey control /geoid model differences – this affects mean bed-level

How does this compare to cross-section surveys?



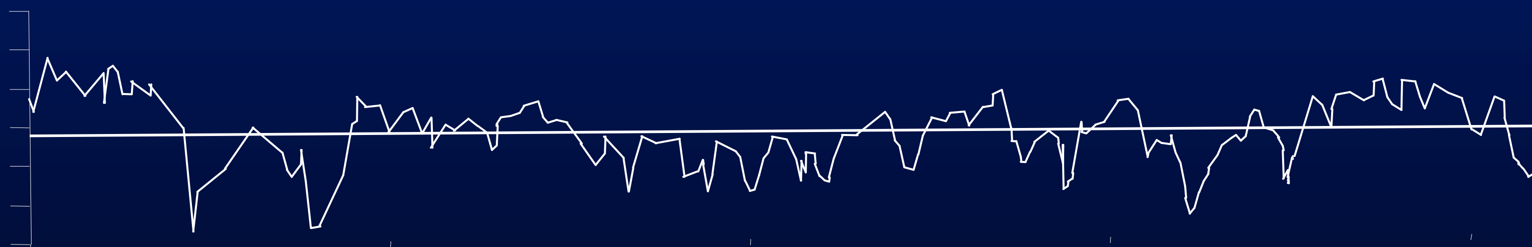
Cross-section networks

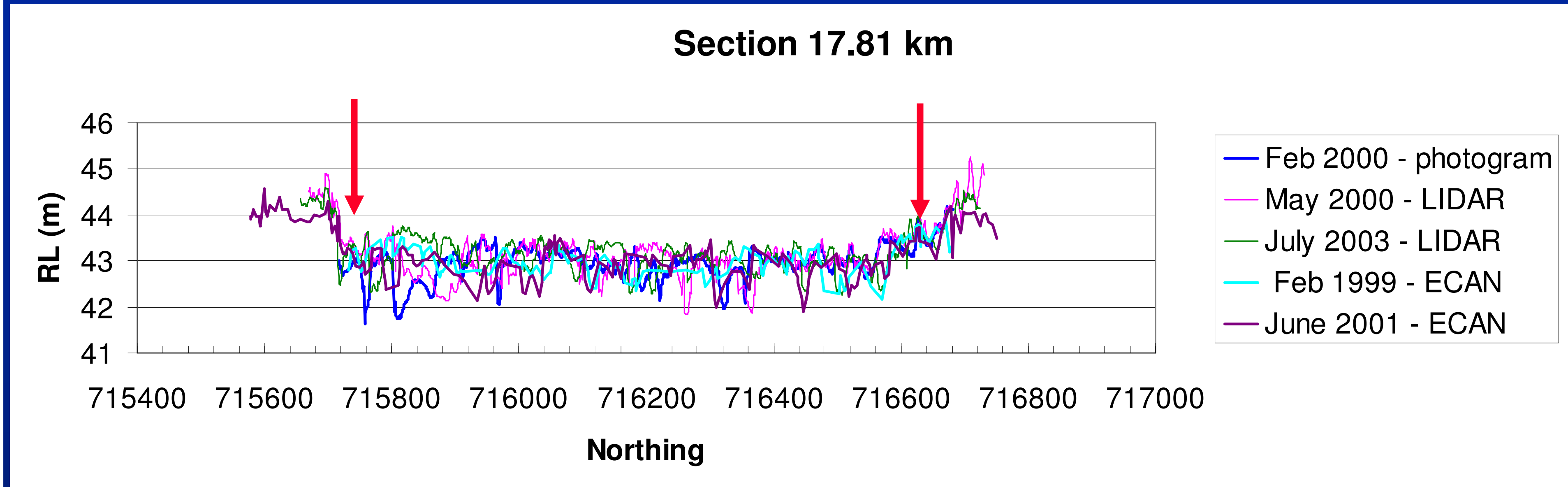
Pros

- Accurate on-line
- Equipment cheaper
- Can do in-house
- Can do most low-flow conditions

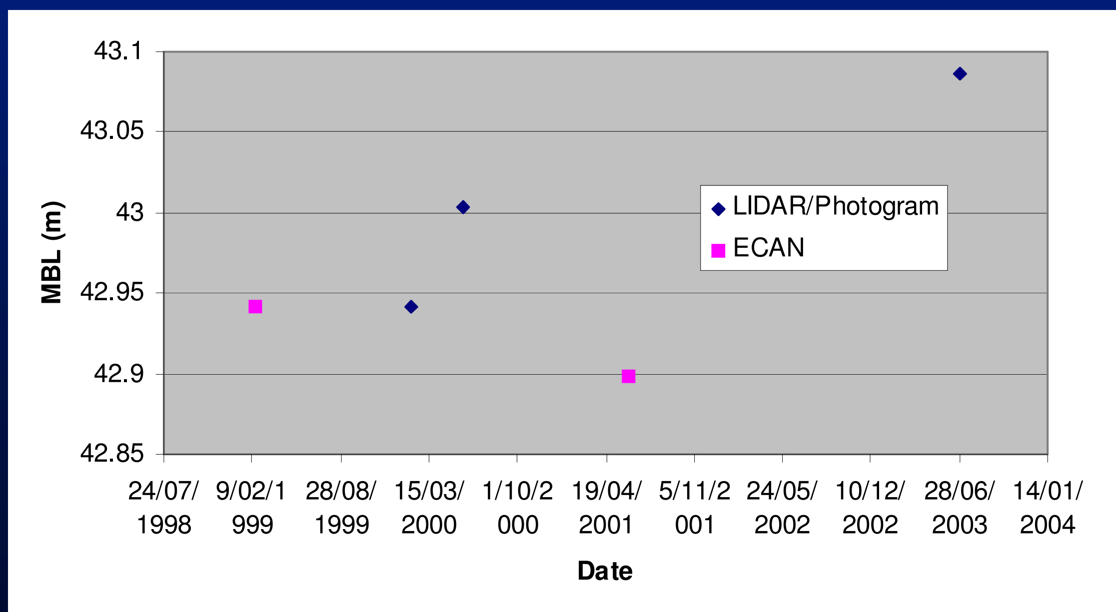
Cons

- Time and labour intensive
- Not synoptic (2 yr survey, 5 yr cycle)
- Spatial sampling error (between sections) - important if computing reach sediment budgets, yet section spacing often dictated by logistics & budgets, designed by “rules-of-thumb”





Section 17.81 km
RL (m)
46
45
44
43
42
41
715400
715600
715800
716000
716200
716400
716600
716800
717000
Northing
Feb 2000 - photogram
May 2000 - LIDAR
July 2003 - LIDAR
Feb 1999 - ECAN
June 2001 - ECAN



MBL (m)
43.1
43.05
43
42.95
42.9
42.85
24/07/1998
9/02/1999
28/08/1999
15/03/2000
1/10/2000
19/04/2001
5/11/2001
24/05/2002
10/12/2002
28/06/2003
14/01/2004
Date
LIDAR/Photogram
ECAN

Where are things going with LiDAR?

- Faster scanners (100 khz pulse rate now)
- More sophisticated post-processing (e.g. building definition, vegetation removal, ‘smart’ data thinning)
- Whole-wave-form analysis for surface classification (including substrate)
- Multi-sensor systems
  - Topography
  - Bathymetry
  - Digital imagery (visual & hyper-spectral)
- Local operators
- Better, cheaper (?)