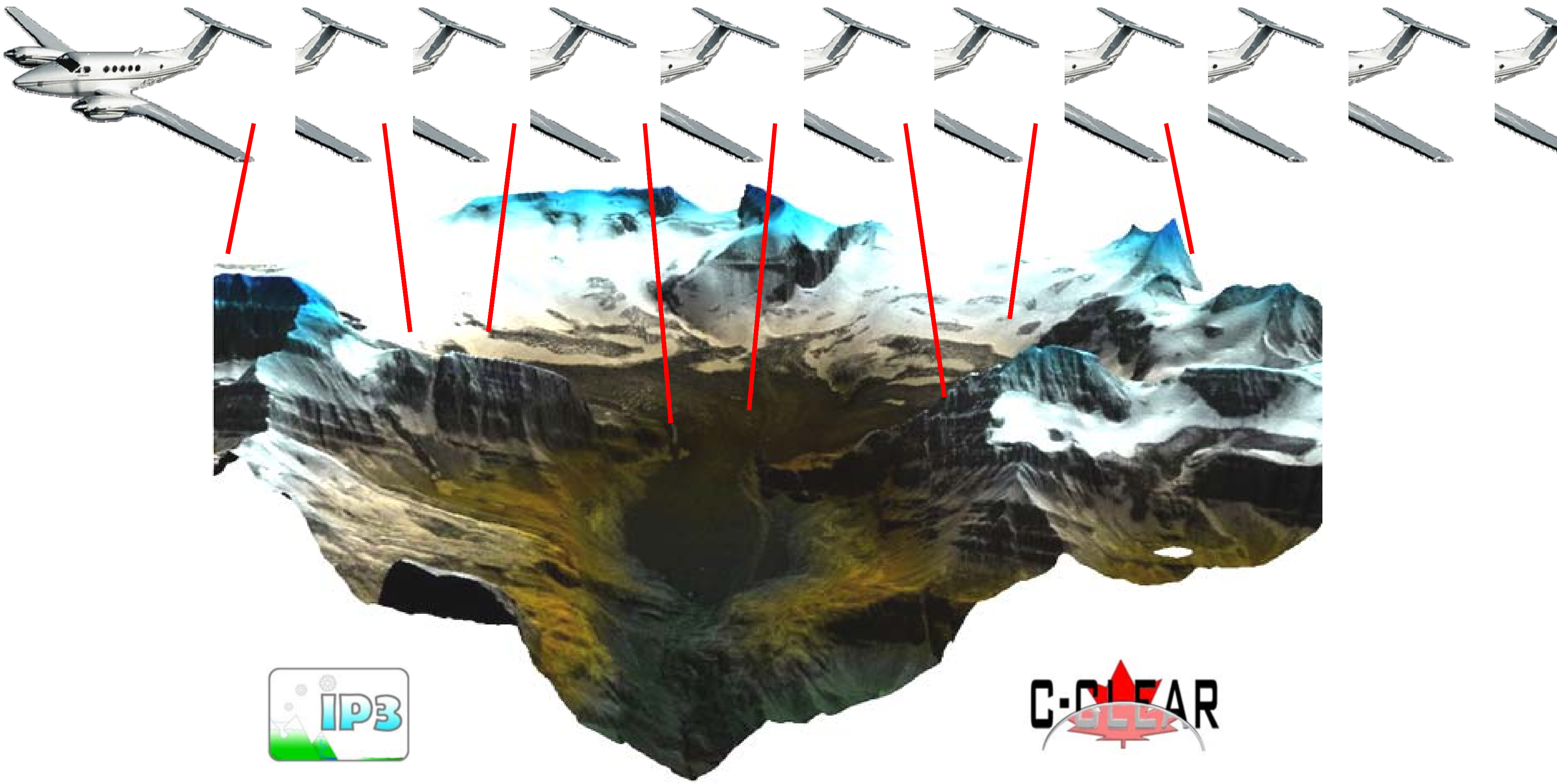
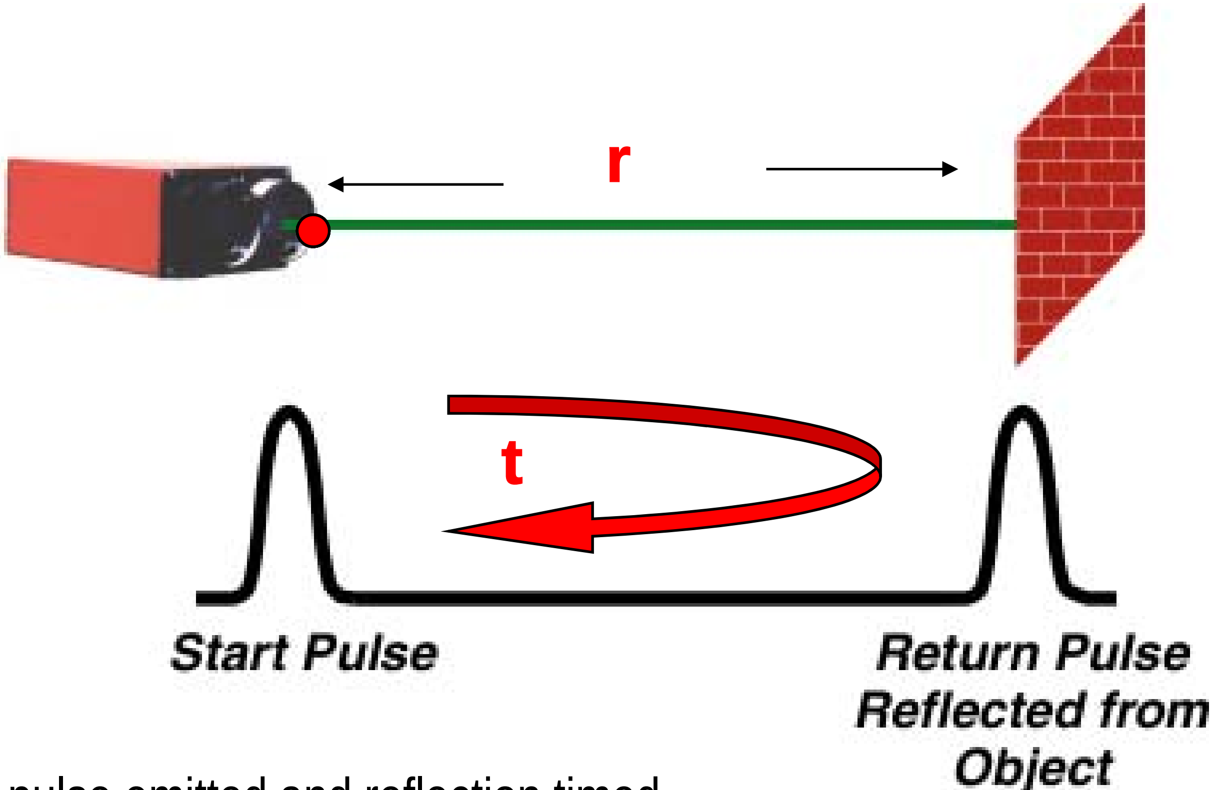
Using LiDAR to study alpine watersheds



Chris Hopkinson, Mike Demuth, Laura Chasmer, Scott Munro, Masaki Hayashi, Karen Miller, Derek Peddle

Light Detection And Ranging



LASER pulse emitted and reflection timed
Measures distance from source to object

$$r = (c \times t) / 2$$

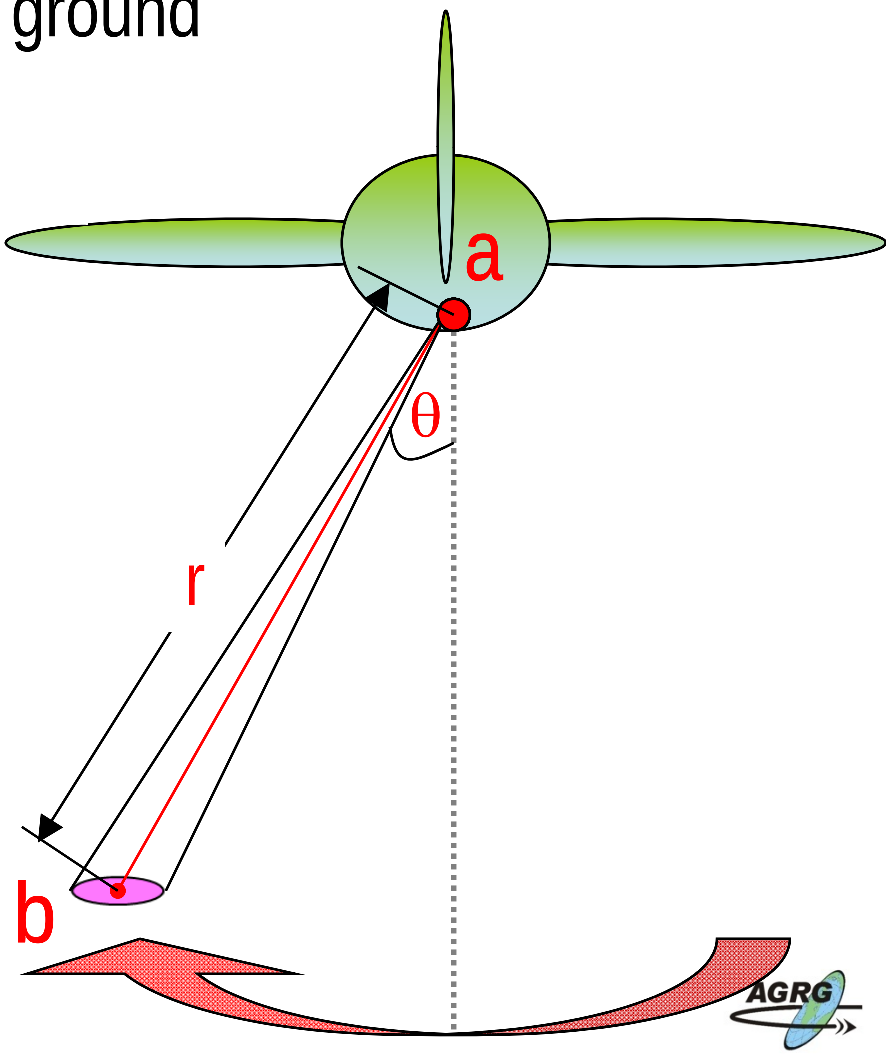
r = range
c = speed of light
t = time

Pulse origin & vector

To compute location (b) of point on ground need to know:

$$b = f\,(a, r, \theta, \omega)$$

1. position of pulse start (a)
2. laser pulse vector
   - Range (r)
   - Scan angle (θ)
   - Sensor attitude (ω)



Chris Hopkinson
2006

Comparison of watershed attributes derived from three DEM sources

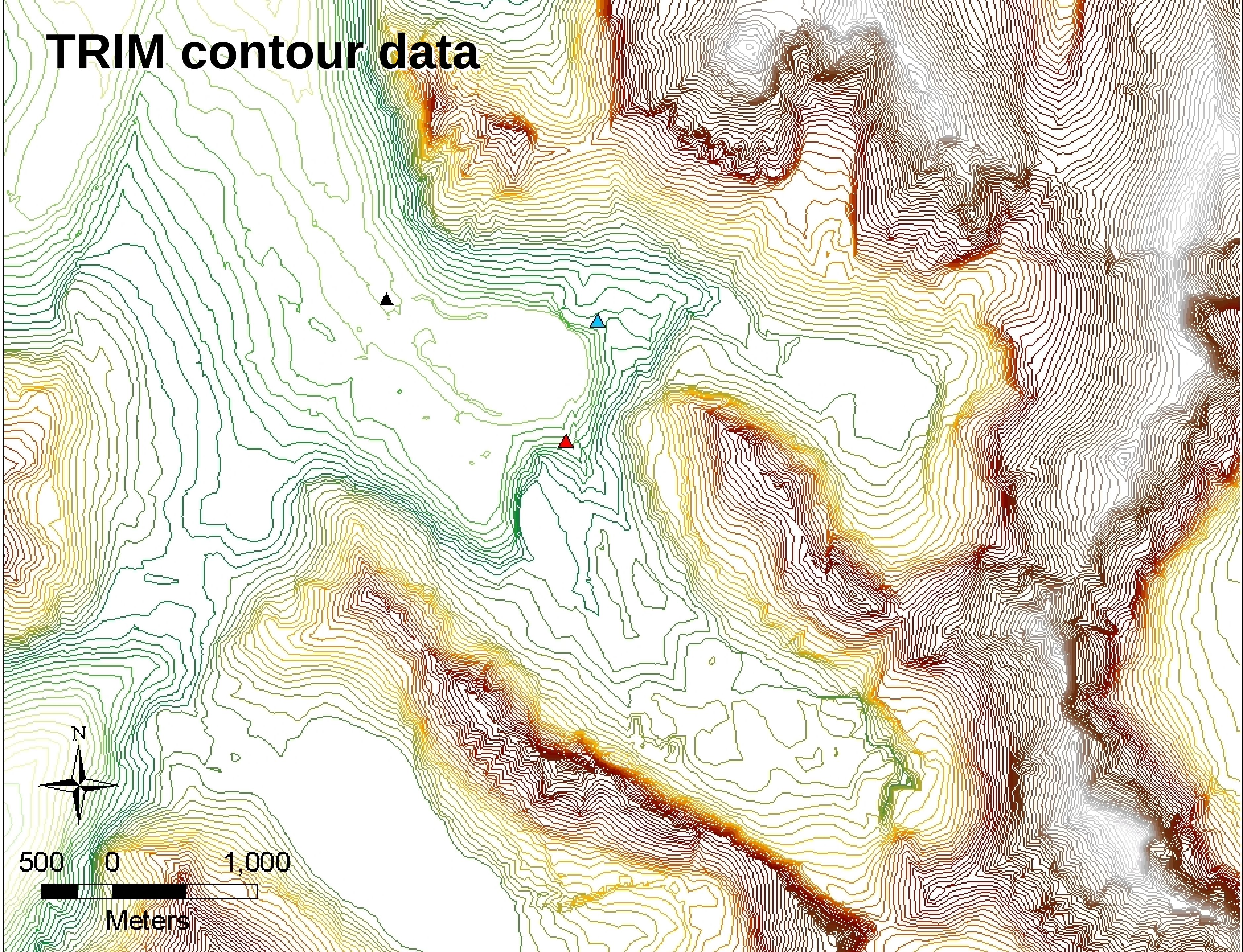
Chris Hopkinson, Masaki Hayashi, Karen Miller, Derek Peddle

To generate DEMs from three typical sources:

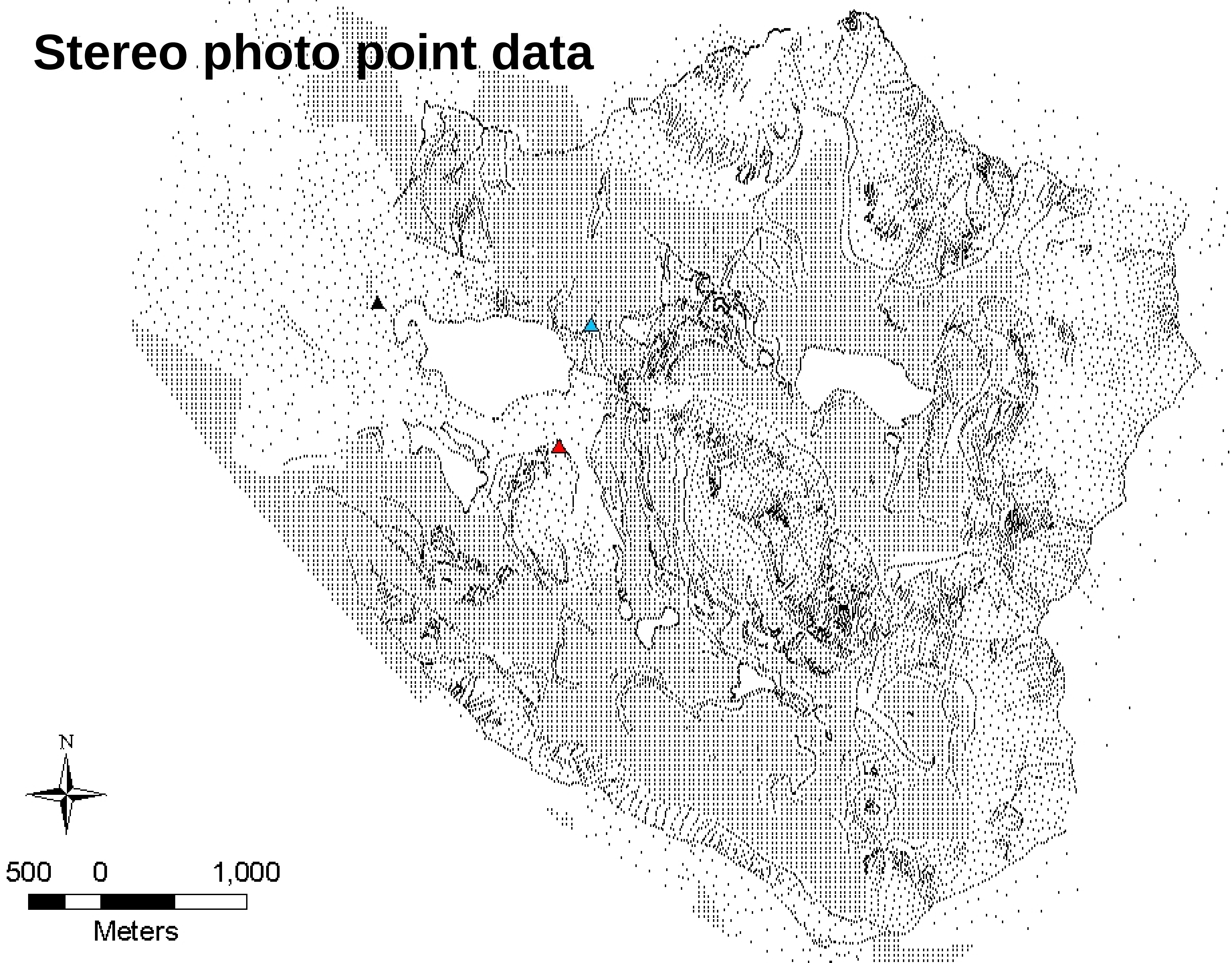
- BC TRIM
- Softcopy aerial photogrammetry
- Airborne lidar

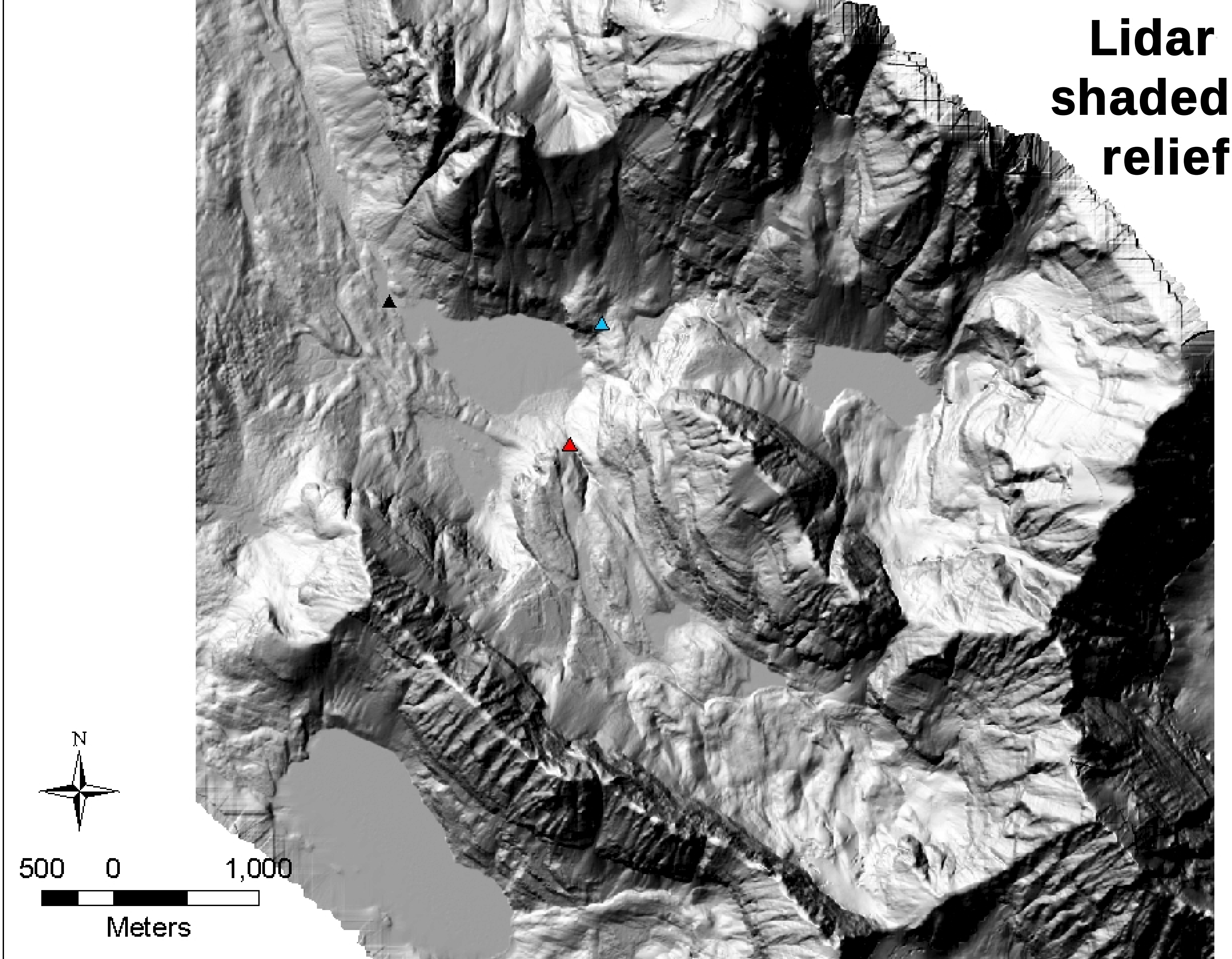
Compare derived GIS watershed attributes

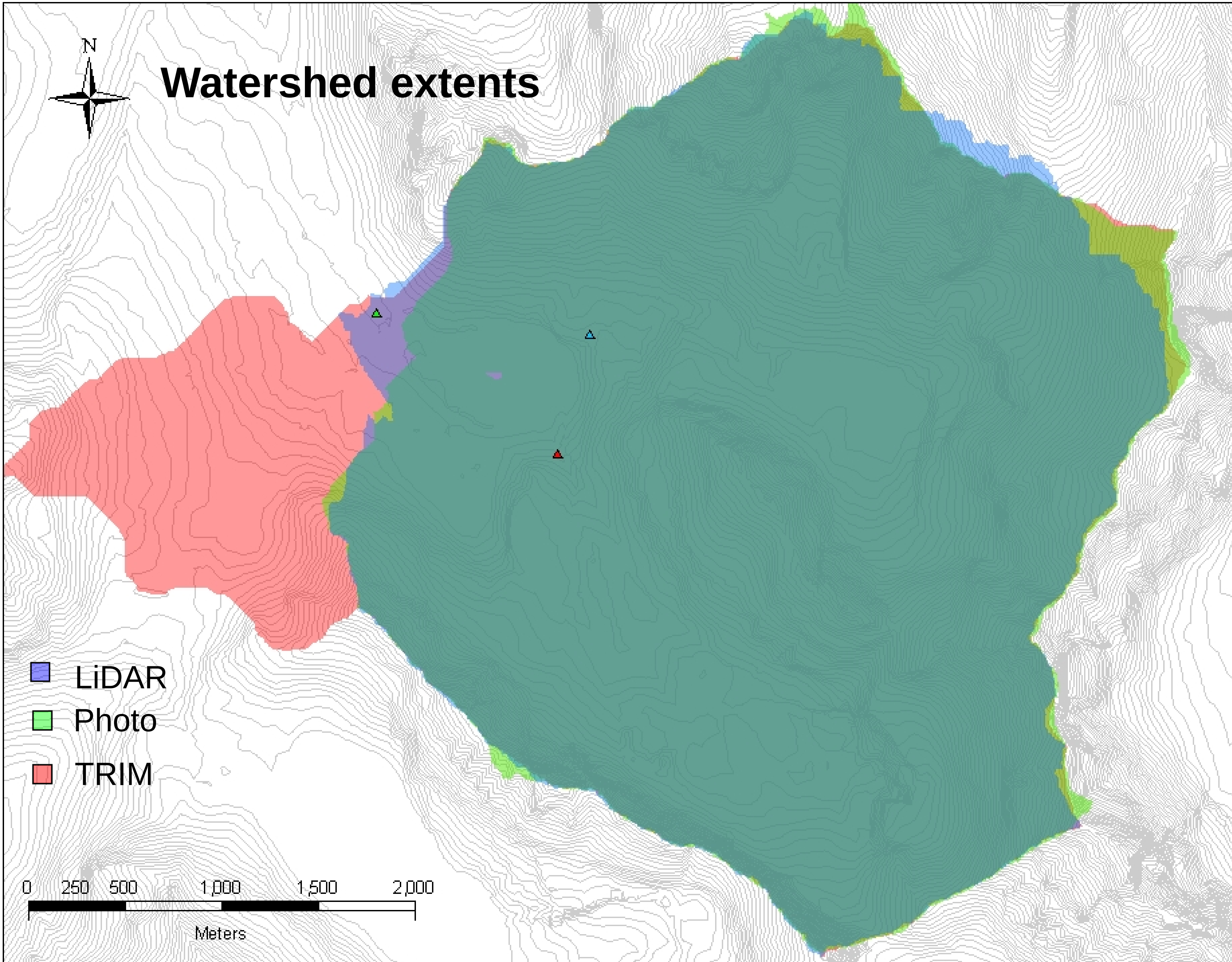
TRIM contour data



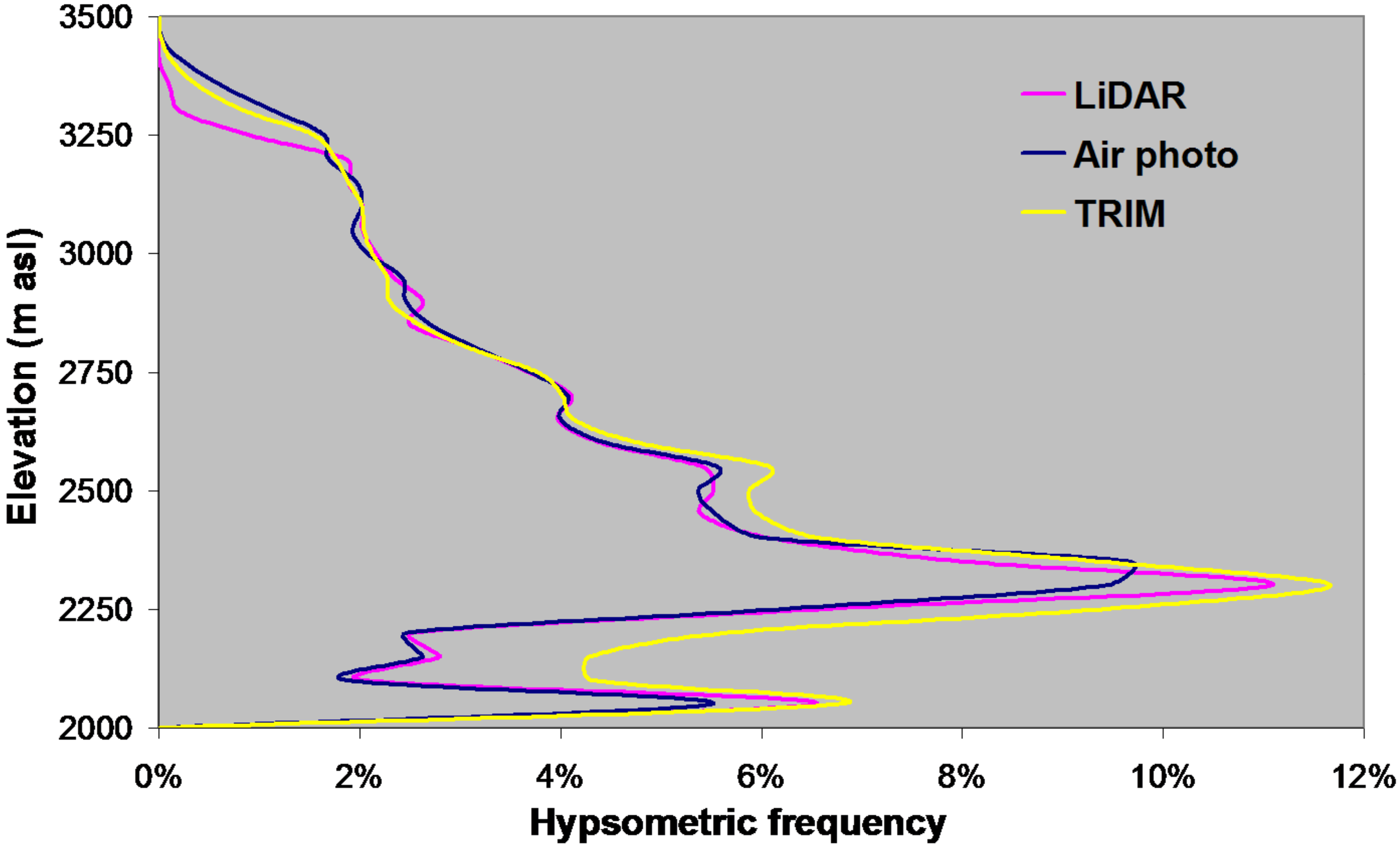
Stereo photo point data




Lidar shaded relief
N
500 0 1,000
Meters

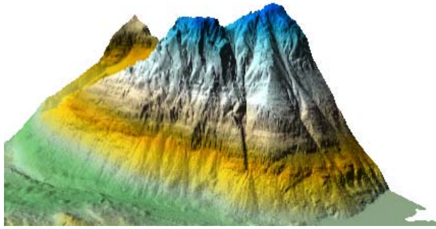

N
Watershed extents
LiDAR
Photo
TRIM
0 250 500 1,000 1,500 2,000
Meters

Hypsometry



3500
3250
3000
2750
2500
2250
2000
Elevation (m asl)
0%
2%
4%
6%
8%
10%
12%
Hypsometric frequency
LiDAR
Air photo
TRIM

Summary



Elevations/hypsometry:

- Photo / TRIM appear 'stretched'- Orientation control
- TRIM biased downwards - Watershed extent
- Photo/TRIM overestimate alpine - Gulleys invisible

Watershed extents:

- Photo slightly larger than Lidar – Terrain variation
- TRIM much greater than Lidar – Stream topology

Stream network:

- Topology problems with TRIM data – Contour spacing
- Photo ok but imperfect topology – Shadows/forests
- Lidar maps gulley water courses – Active illumination

Variations in GIS glacial melt prediction with terrain resolution

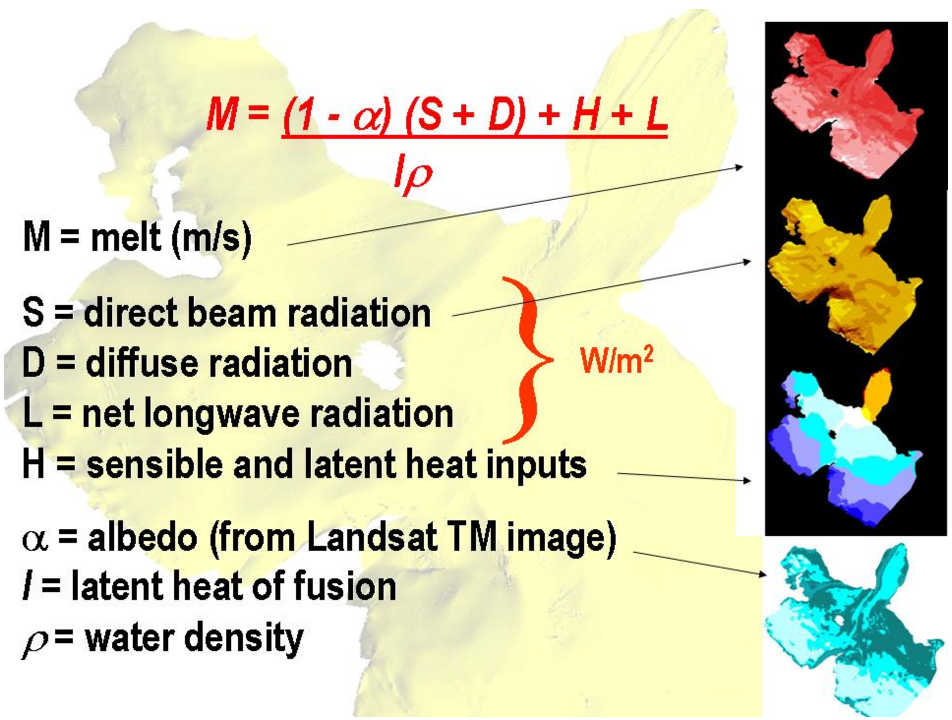
Chris Hopkinson, Laura Chasmer, Scott Munro, Michael N. Demuth

Assess impact of DEM resolution on melt prediction:

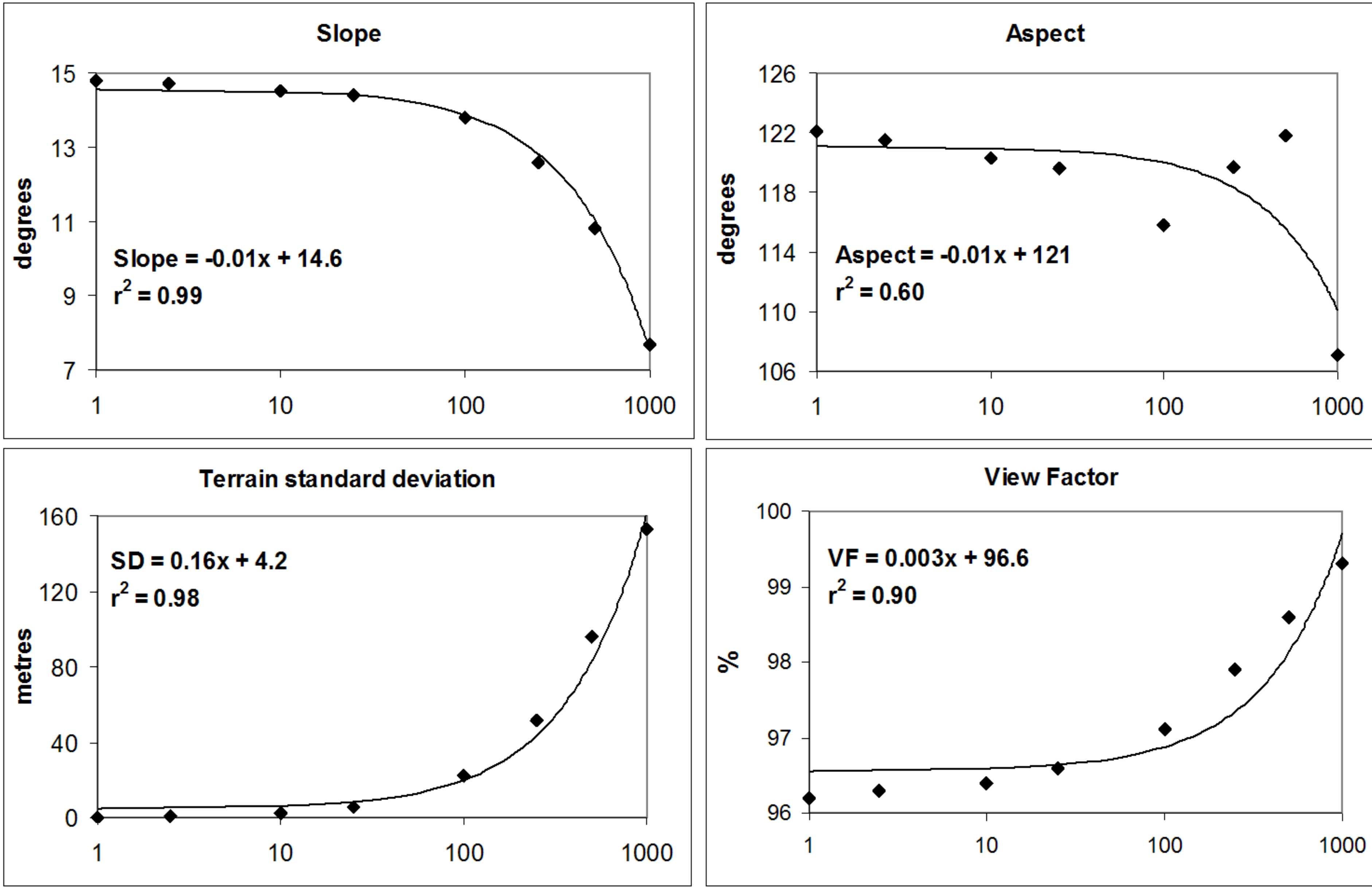
- Eight resolutions: 1 m to 1000 m
- Half hour time step

Compare:

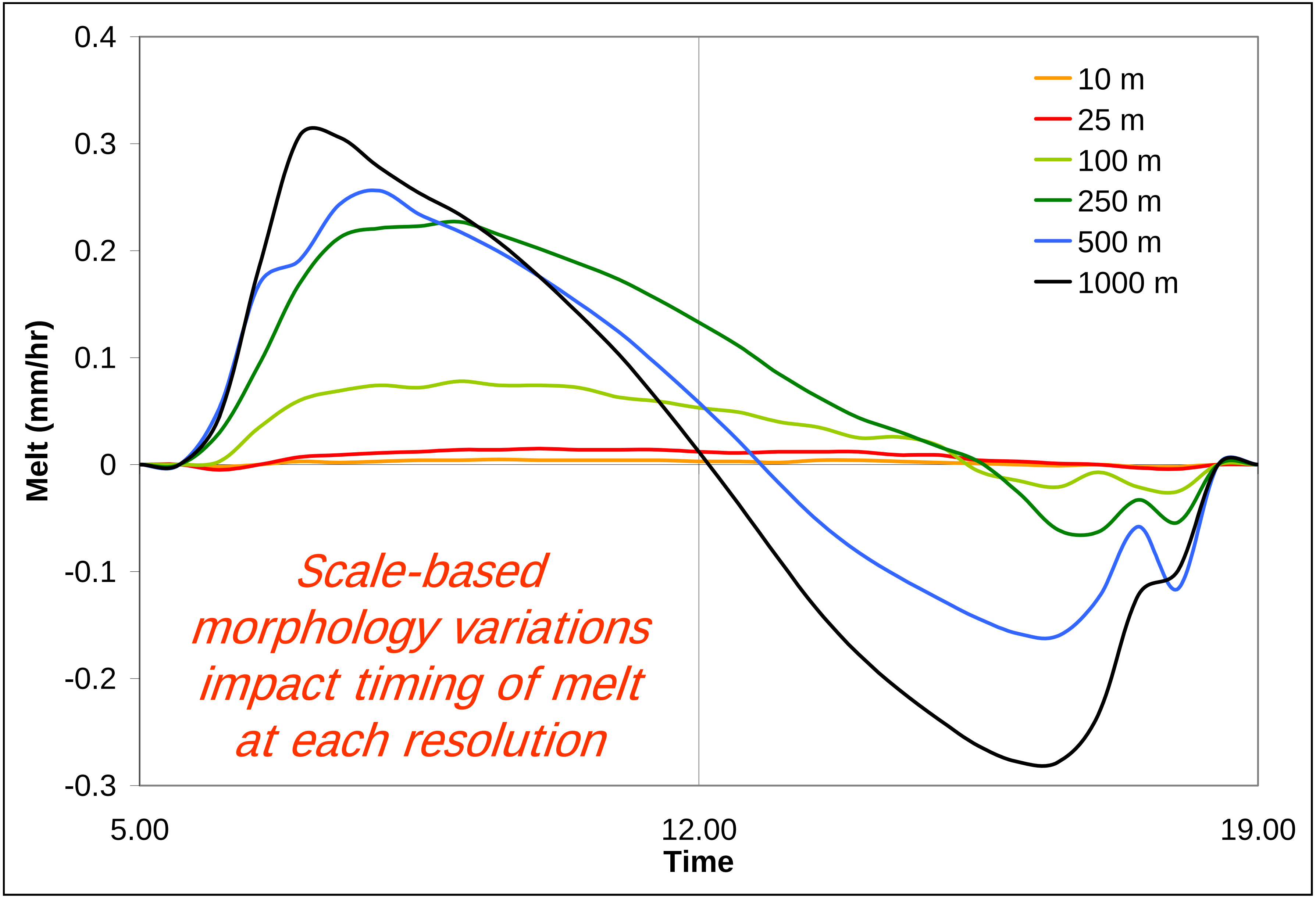
- Total melt
- Temporal distribution



Scale effects on Glacier DEM attributes



Δ Diurnal melt rate with resolution

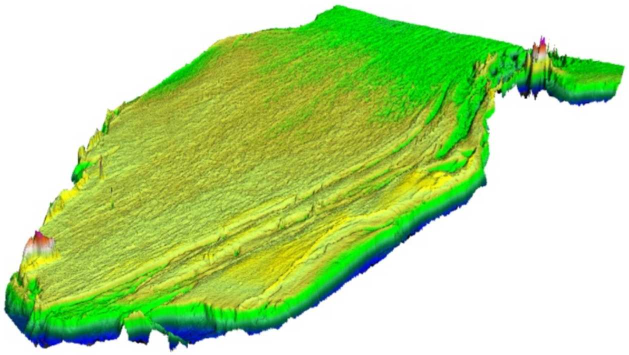


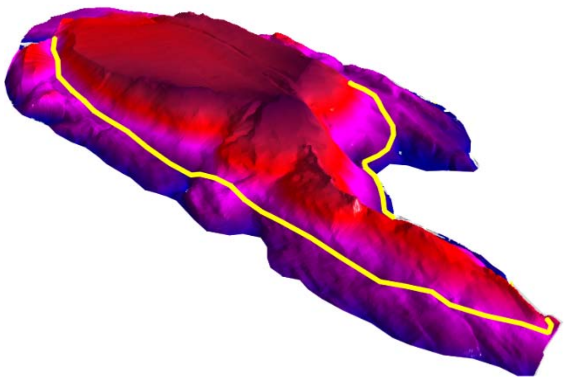
Assessing glacier dynamics from multitemporal lidar imagery

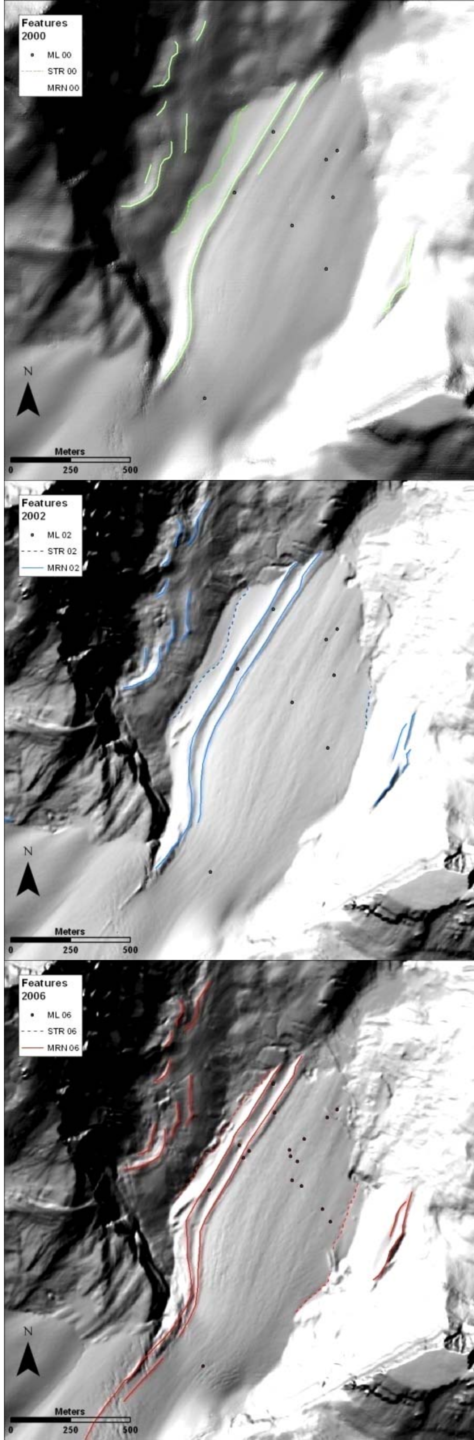
Chris Hopkinson & Michael N. Demuth

Assess glacial / periglacial rates of downwasting & motion

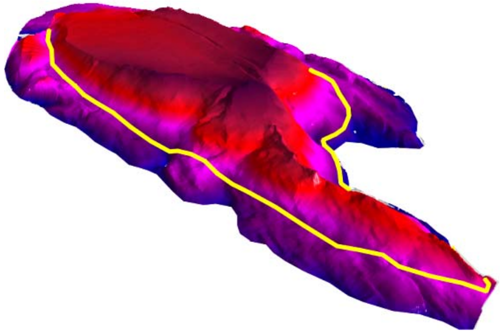
4 lidar datasets: 2000, 02, 06, 07



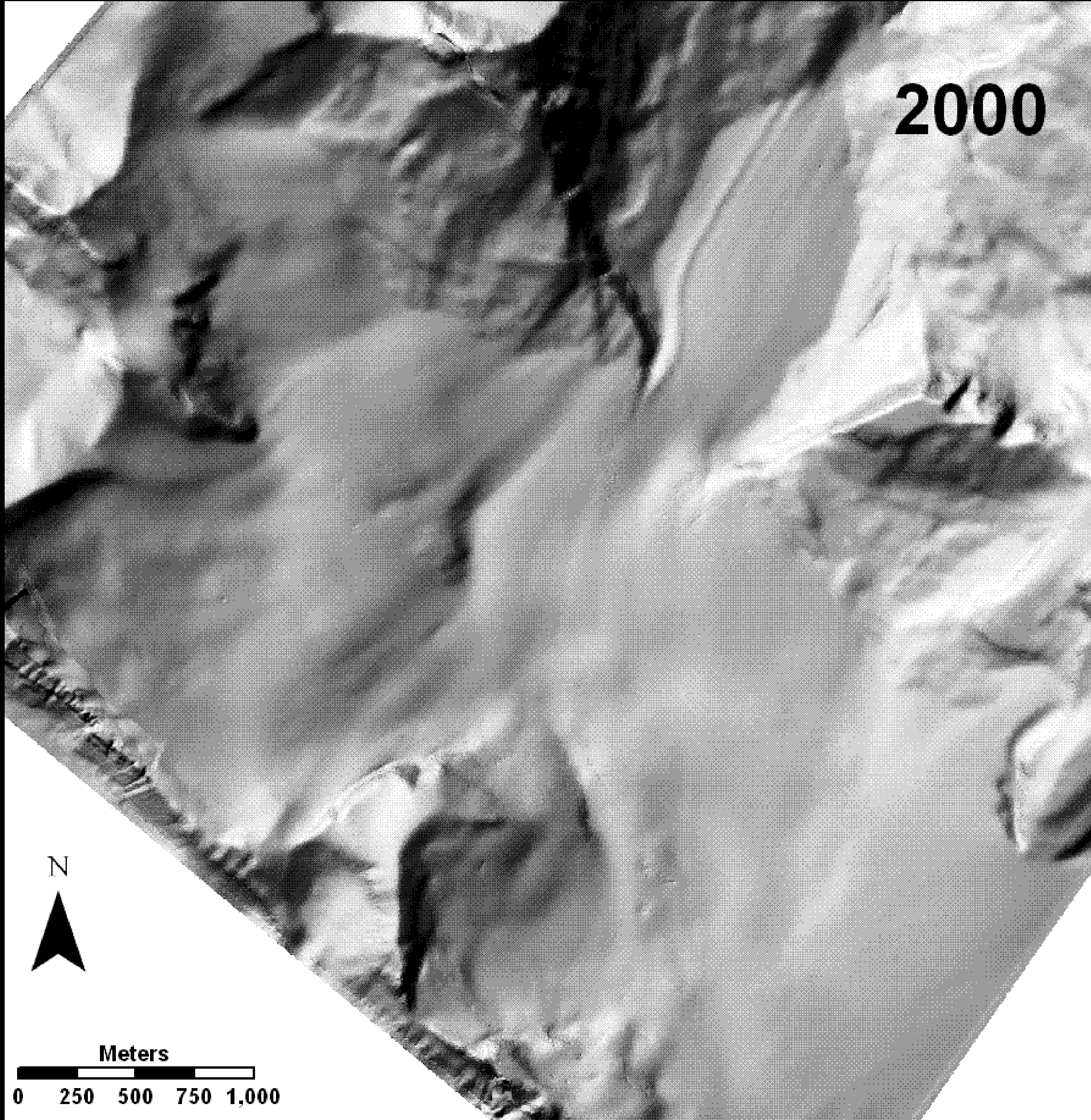


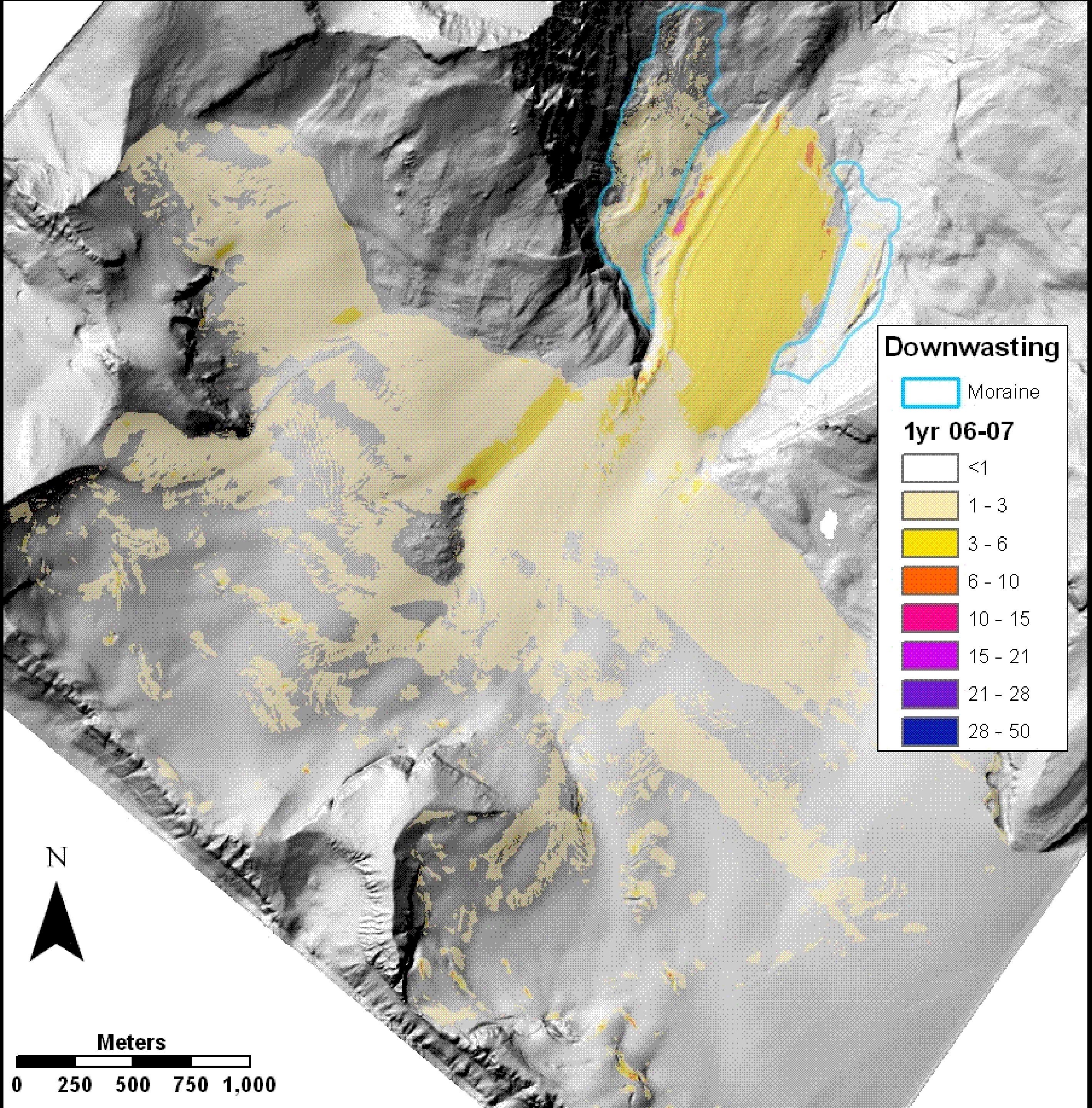


Local context

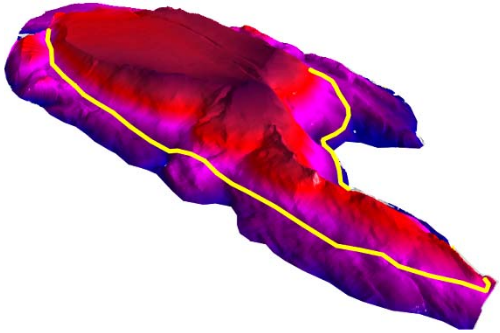


- Glacier wastage impacts water resources in western Canada
- Several studies suggest that mean annual contribution:
  - Is significant (1% to 12%)
  - Depends on size of basin & glacier cover
  - Will reduce as glacier sizes diminish
- Is wastage decreasing, leveling off or increasing?

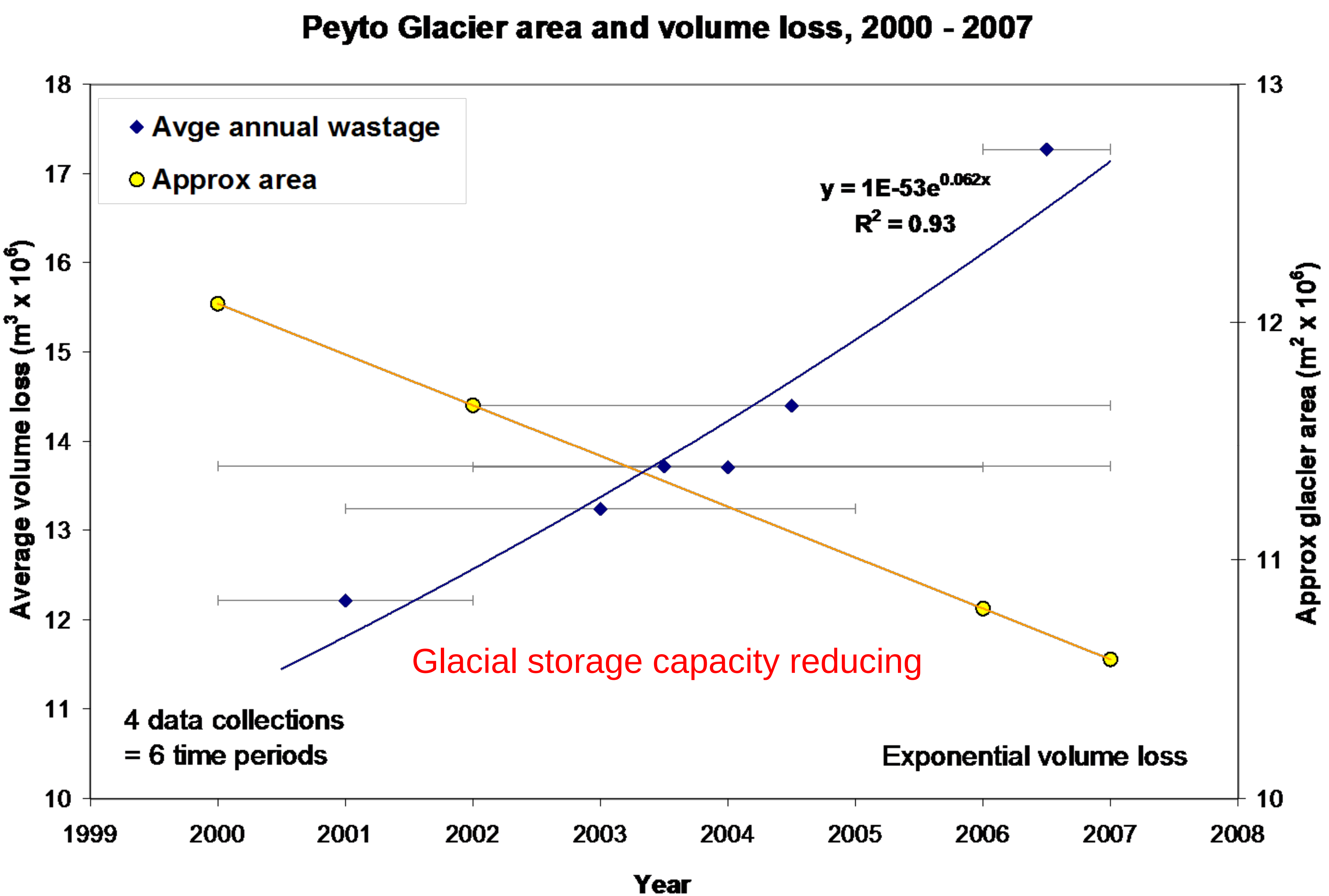

2000
N
Meters
0 250 500 750 1,000


Downwasting
Moraine
1yr 06-07
<1
1 - 3
3 - 6
6 - 10
10 - 15
15 - 21
21 - 28
28 - 50
N
Meters
0
250
500
750
1,000

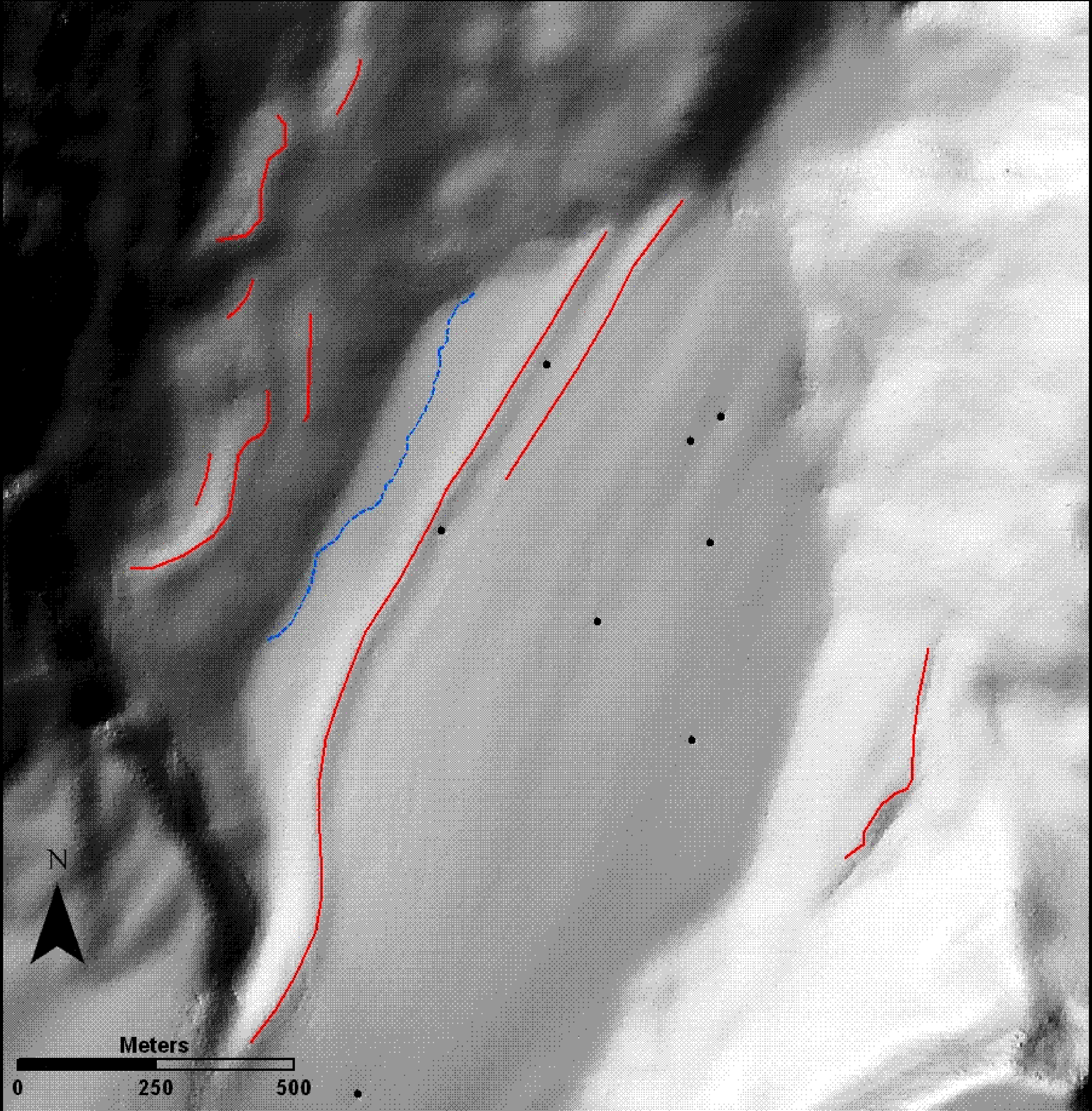
Observed glacial dynamics



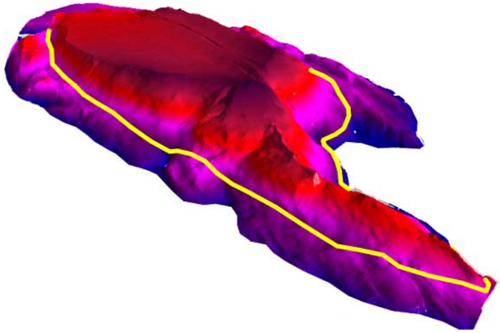
- Glacier area reduced by ~ 12% from 12.5 km^2 to 11.0 km^2
- Downwasting > 40 m in parts of the ablation zone,
- Mean melt depth increased from 1.0 m p.a. (2000) to 1.6 m p.a. (2007)
- Mean loss of glacial ice of 14.1×10^6 m^3 p.a.



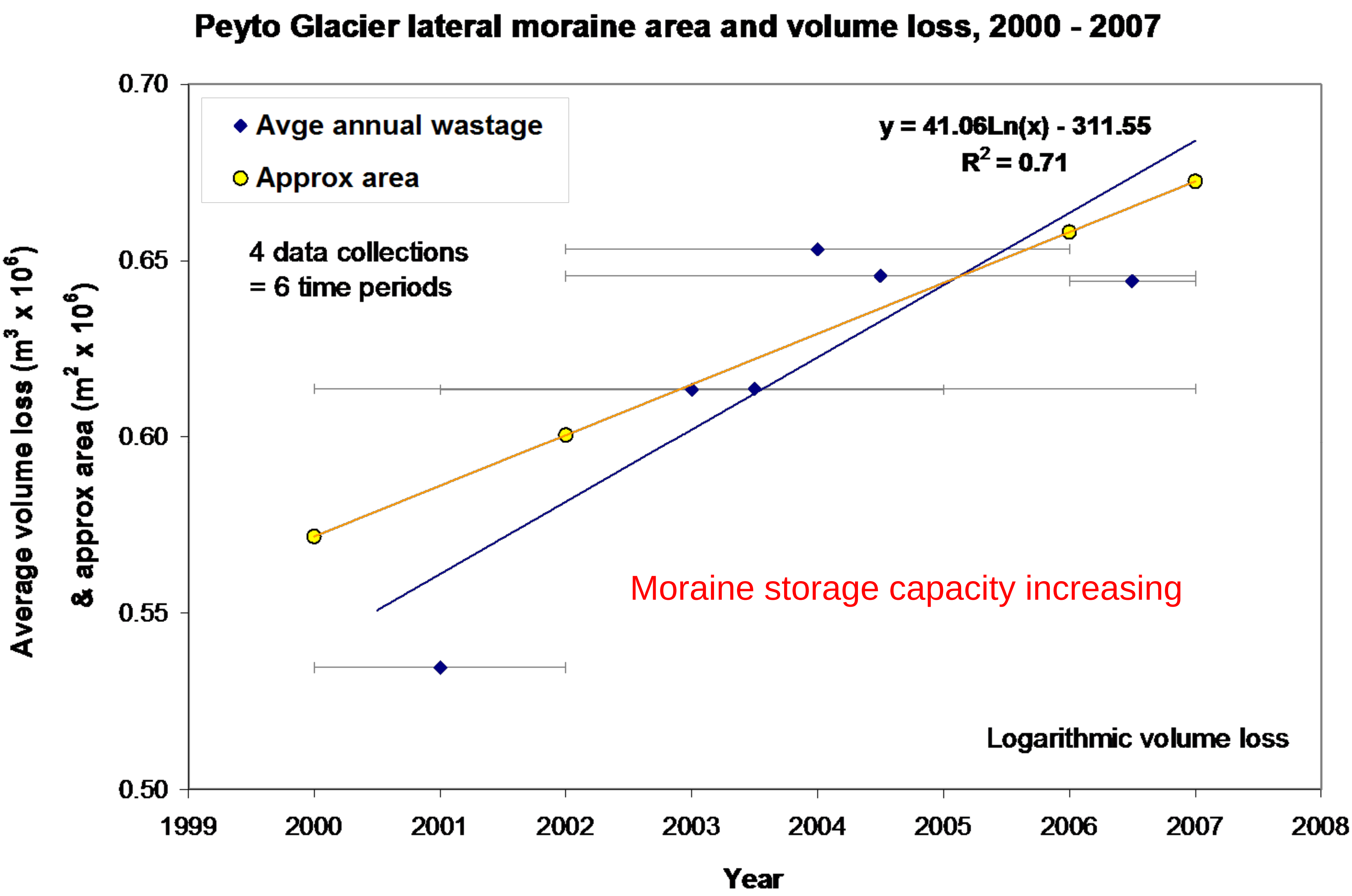
Peyto Glacier area and volume loss, 2000 - 2007
Avge annual wastage
Approx area
y = 1E-53e^0.062x
R^2 = 0.93
Glacial storage capacity reducing
4 data collections
= 6 time periods
Exponential volume loss
Average volume loss (m^3 x 10^6)
Approx glacier area (m^2 x 10^6)
Year
18
17
16
15
14
13
12
11
10
13
12
11
10
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008


N
Meters
0
250
500

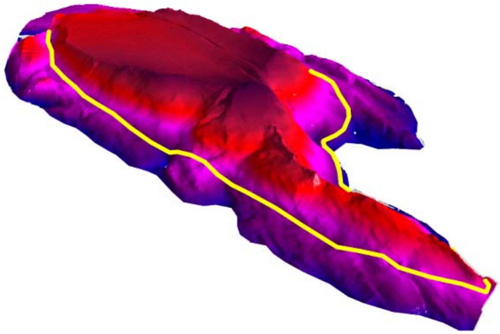
Observed glacial dynamics



- Lateral moraine downwasting ~ 1.0 m p.a
- Annual loss from moraines ranged from 3.7% to 4.8%
- Ablation zone moulin motion ~ 6 m p.a.
- Accumulation zone debris movement up to 15 m p.a.
- Constricted icefall motion up to 20 m p.a.
- Moraines moving up to 6 m p.a. laterally towards margins


Peyto Glacier lateral moraine area and volume loss, 2000 - 2007
Avge annual wastage
Approx area
y = 41.06Ln(x) - 311.55
R2 = 0.71
4 data collections
= 6 time periods
Moraine storage capacity increasing
Logarithmic volume loss
Average volume loss (m3 x 106)
& approx area (m2 x 106)
0.70
0.65
0.60
0.55
0.50
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Year

Summary



- Peyto glacier is rapidly losing mass
  - Rate of loss still increasing through time
  - Accumulation zone rapidly transporting mass to ablation zone
  - Ablation zone stagnating
- Glacial ice loss increasing at exponential rate as volume diminishes
- Ice cored moraine loss increasing at logarithmic rate as storage capacity increases

Ice cored moraine melt water production is increasing as glacier cover diminishes. Its contribution to the river water resource will become critical in the next few decades

Hydrological models need to explicitly account for this increasingly important alpine flow component

Thank you!