LiDAR sensor and system capabilities and issues

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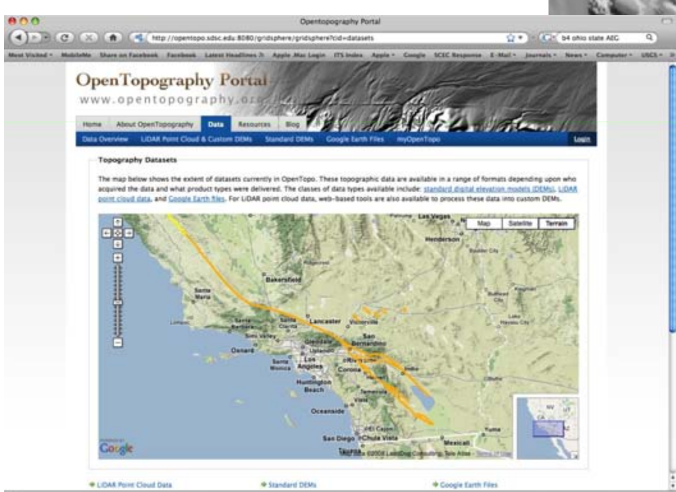

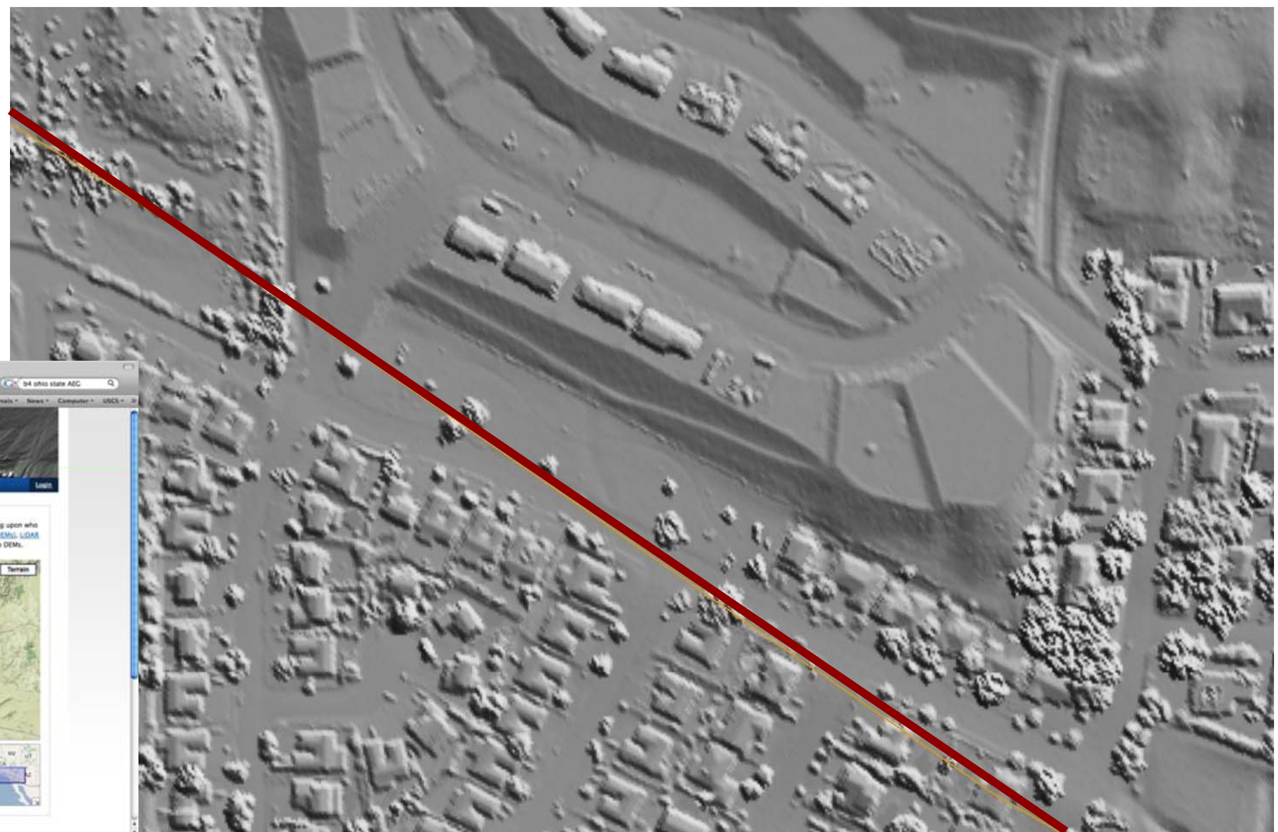

Main focuses of this presentation

GPS Positioning Errors and B4 Experiment Design

Why did we employ kinematic GPS base stations every 10 km along the flight segment? What can we learn from this unique GPS data set?

Some observations on Corduroy or Corn Row artifacts

And their possible relationship to GPS positioning and other errors

System issues – limitations to widespread geodetic use

data formats are not openly described; software is proprietary

no research community processing software (as for InSAR, GPS, etc.)

B4

Positional Accuracy Requirements

Paleoseismology and Geomorphology

Certainly it is necessary to geo-reference everything at the ~ 1 meter level. But groups looking for offset channels, for example, really do not care if the entire DEM in their study area has a systematic height error (bias) of 15 cm

Crustal Motion Geodesy

Groups intending to map surface displacements by comparing surveys performed at different times - by differencing them - need both 'before' and 'after' surveys to be positioned as well as possible in an *absolute* sense.

The B4 team is very interested in 'geodetic-grade ALSM' capable of mapping displacements with vertical accuracies of a few cm. Therefore we have tried to 'push the envelope' from the start. From the beginning we have suspected that the single largest error source in LIDAR is the GPS positioning of the aircraft.

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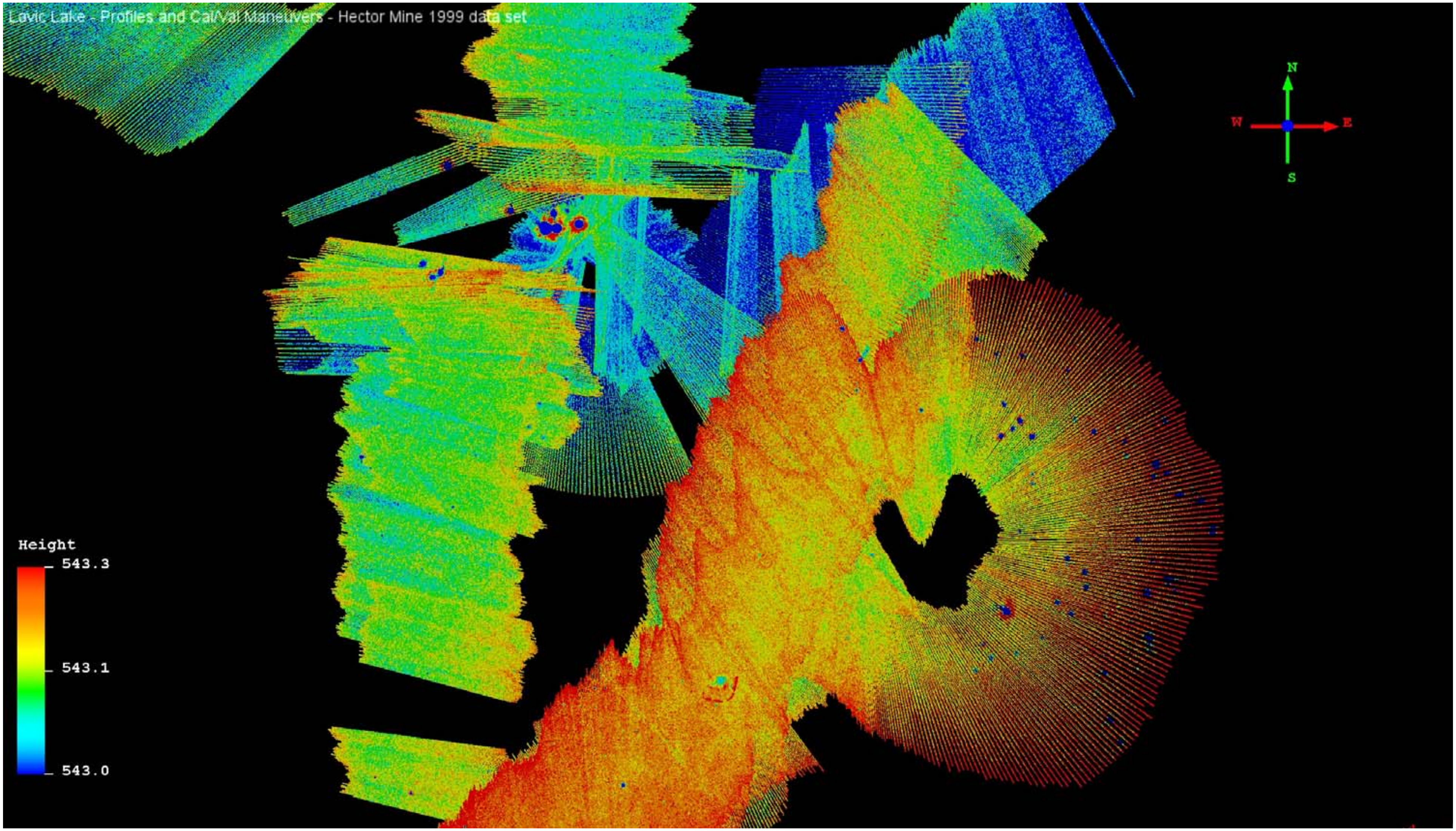
Positional Accuracy Requirements

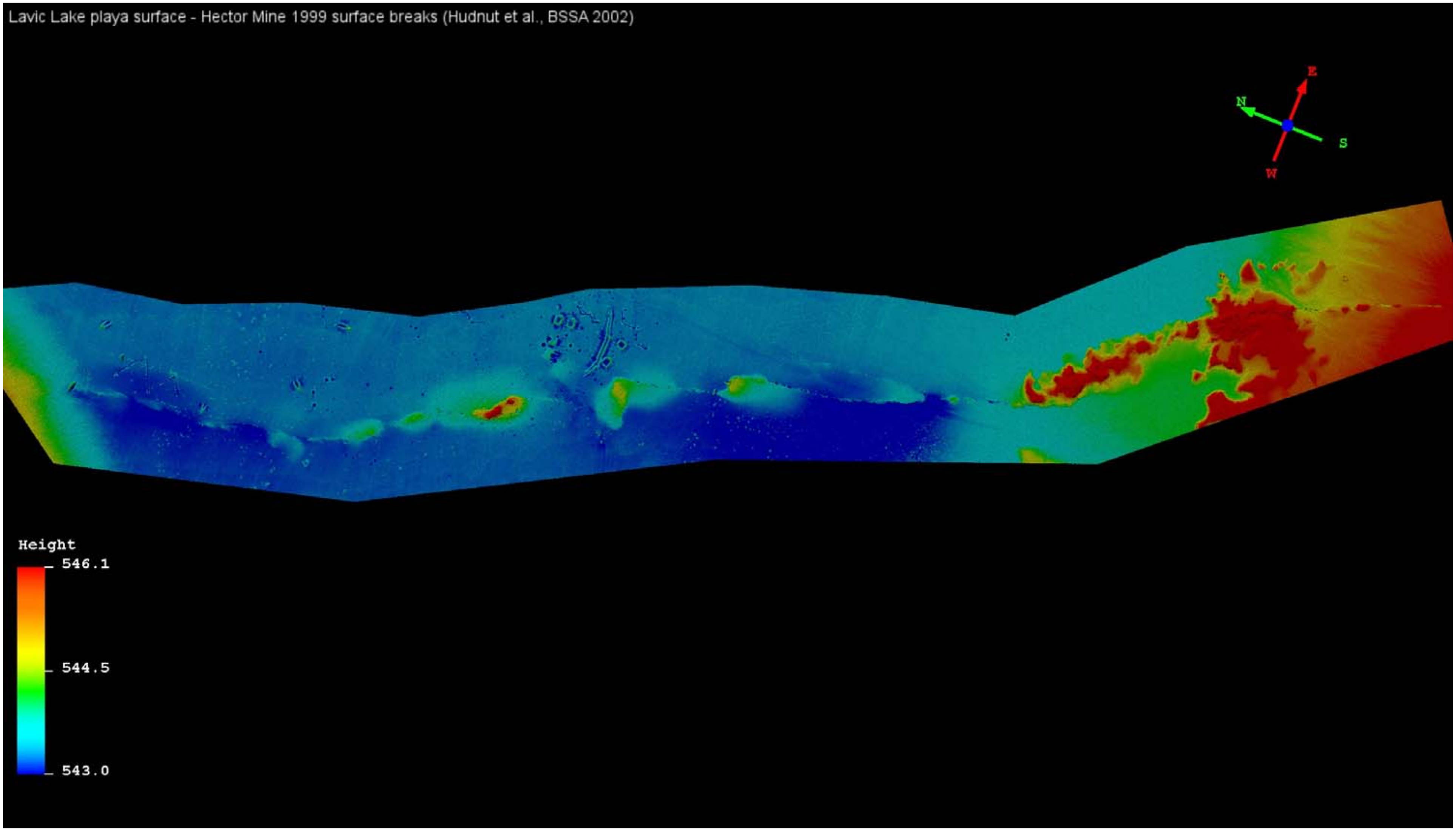
So can paleoseismologists and geomorphologists stop worrying about the role of GPS ground control and positioning?

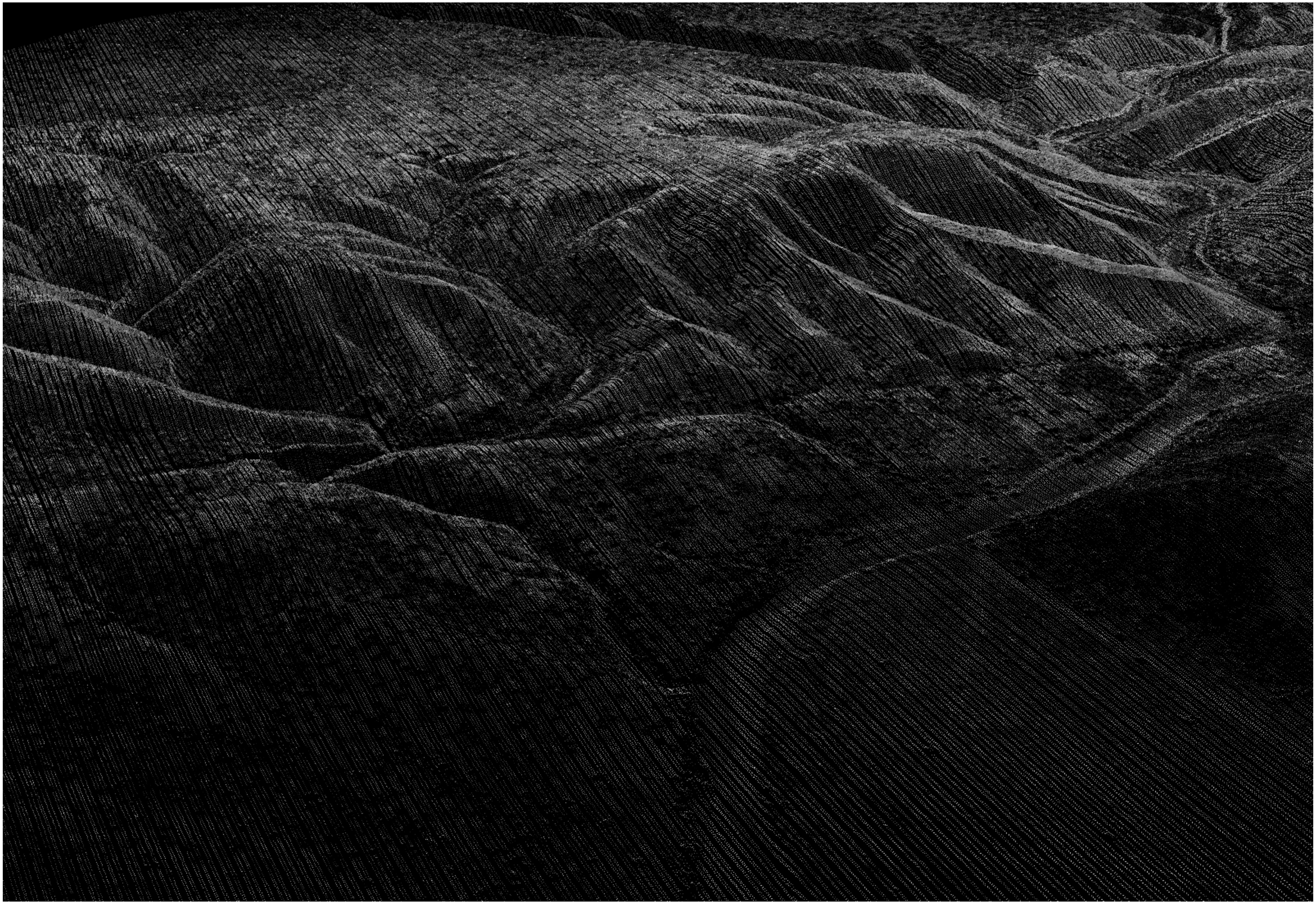
Not necessarily. Absolute height errors that vary between one swath and an overlapping swath may be contributing to ‘corduroy’

HM99 Lavic Lake cal-val



HM99 Lavic Lake cal-val





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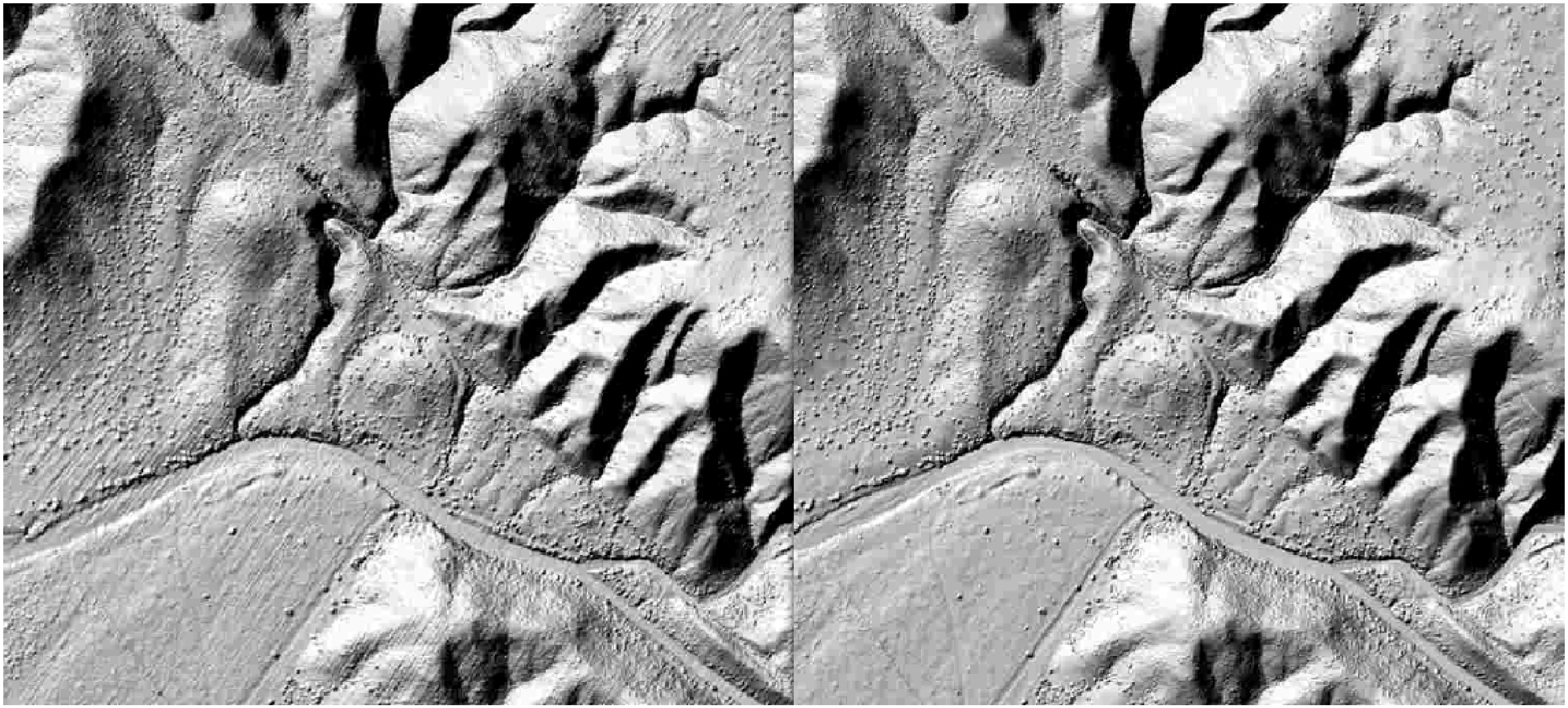
Corduroy

The B4 survey was supported by the loan of a 5100 unit from Optech to NCALM.



1233 5100

Carizzo Plain

Both models were used over the first few days of the May campaign. In general corduroy, though still present, is more subdued in the 5100 data, as illustrated in these DEM patches.

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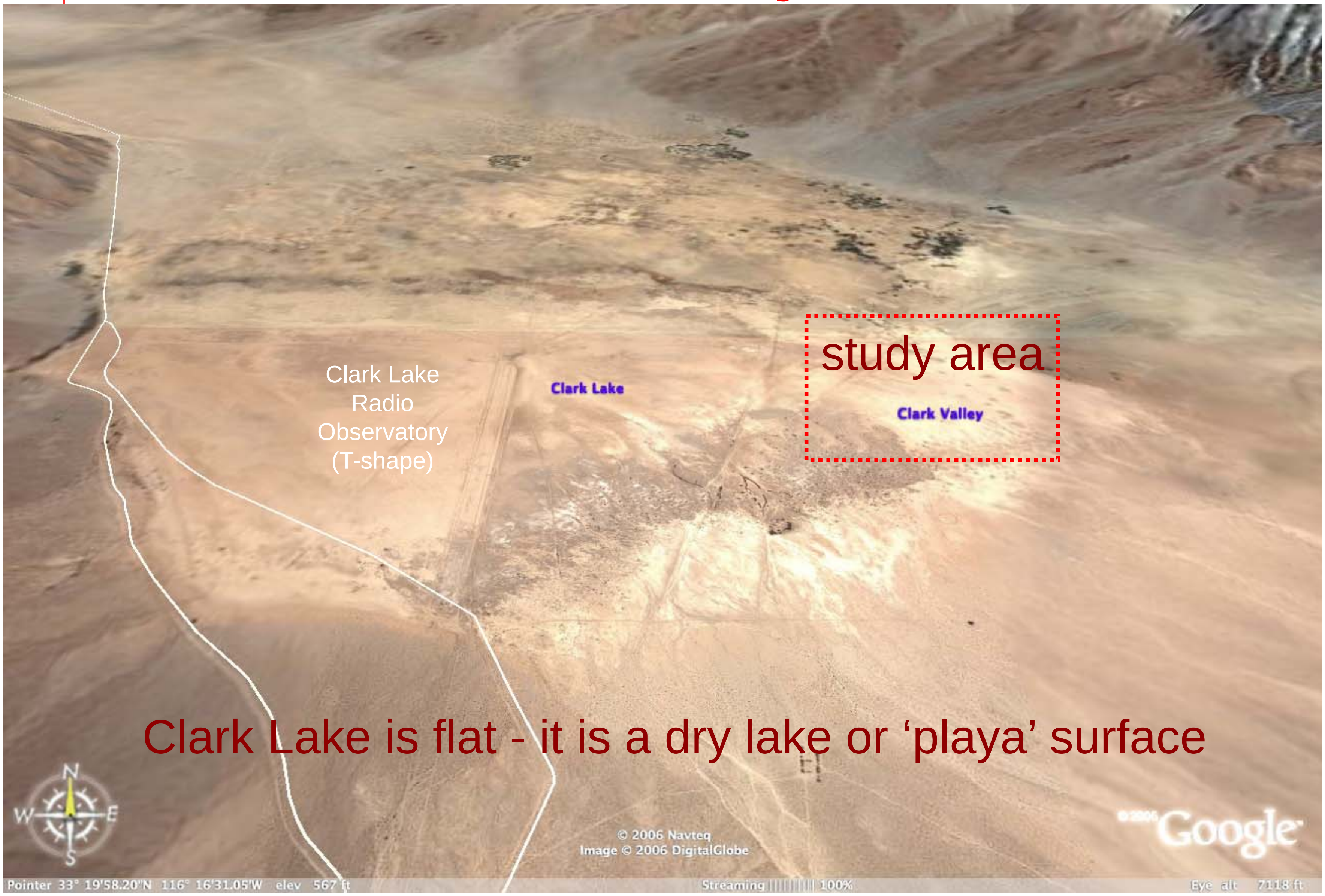
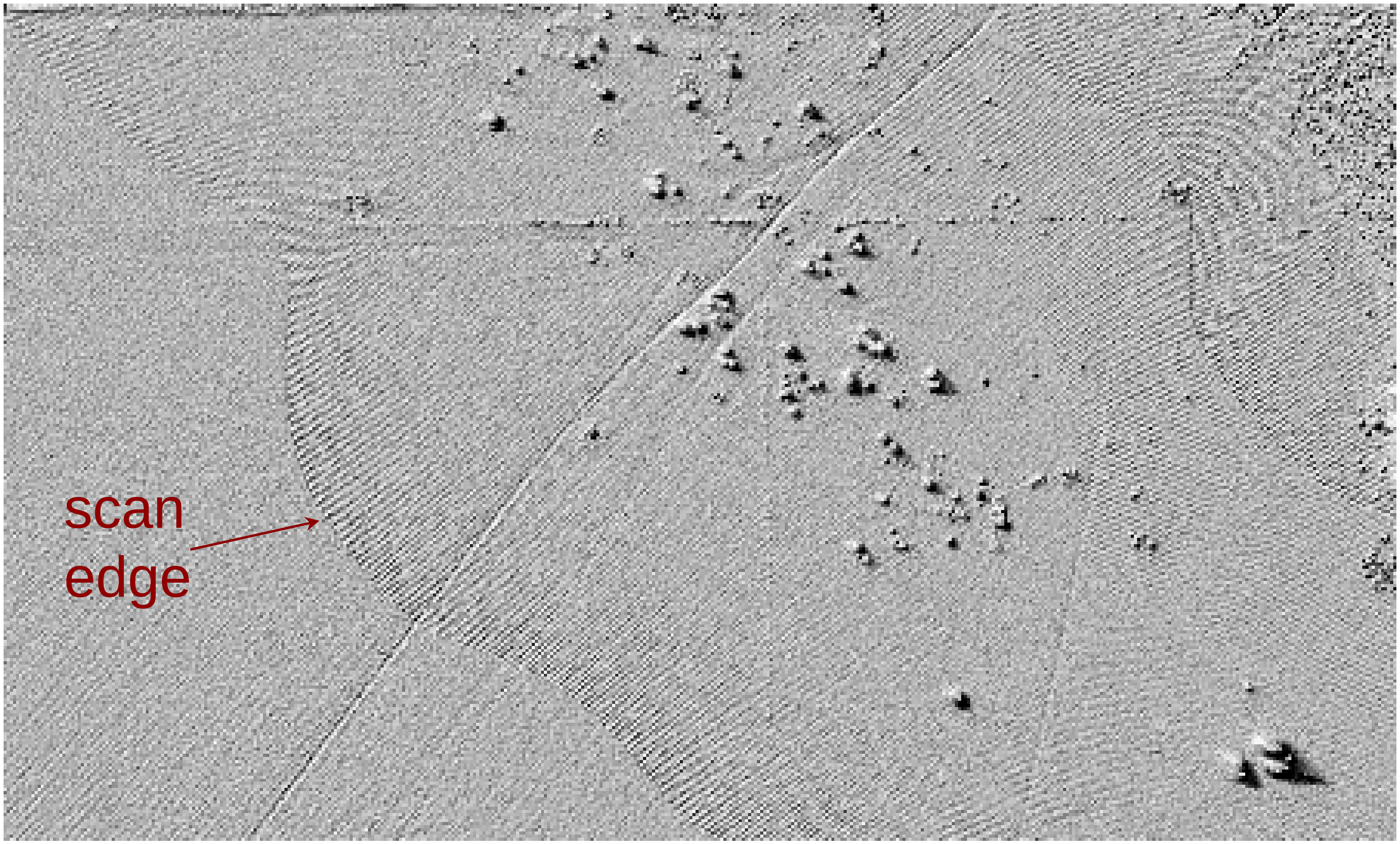
Corduroy


Clark Lake
Radio
Observatory
(T-shape)
Clark Lake
study area
Clark Valley
Clark Lake is flat - it is a dry lake or 'playa' surface
© 2006 Navteq
Image © 2006 DigitalGlobe
©2006 Google
Pointer 33° 19'58.20"N 116° 16'31.05"W elev 567 ft
Streaming |||||||||| 100%
Eye alt 7118 ft

Corduroy



SURFER 0.5 m DEM from NCALM - standard product

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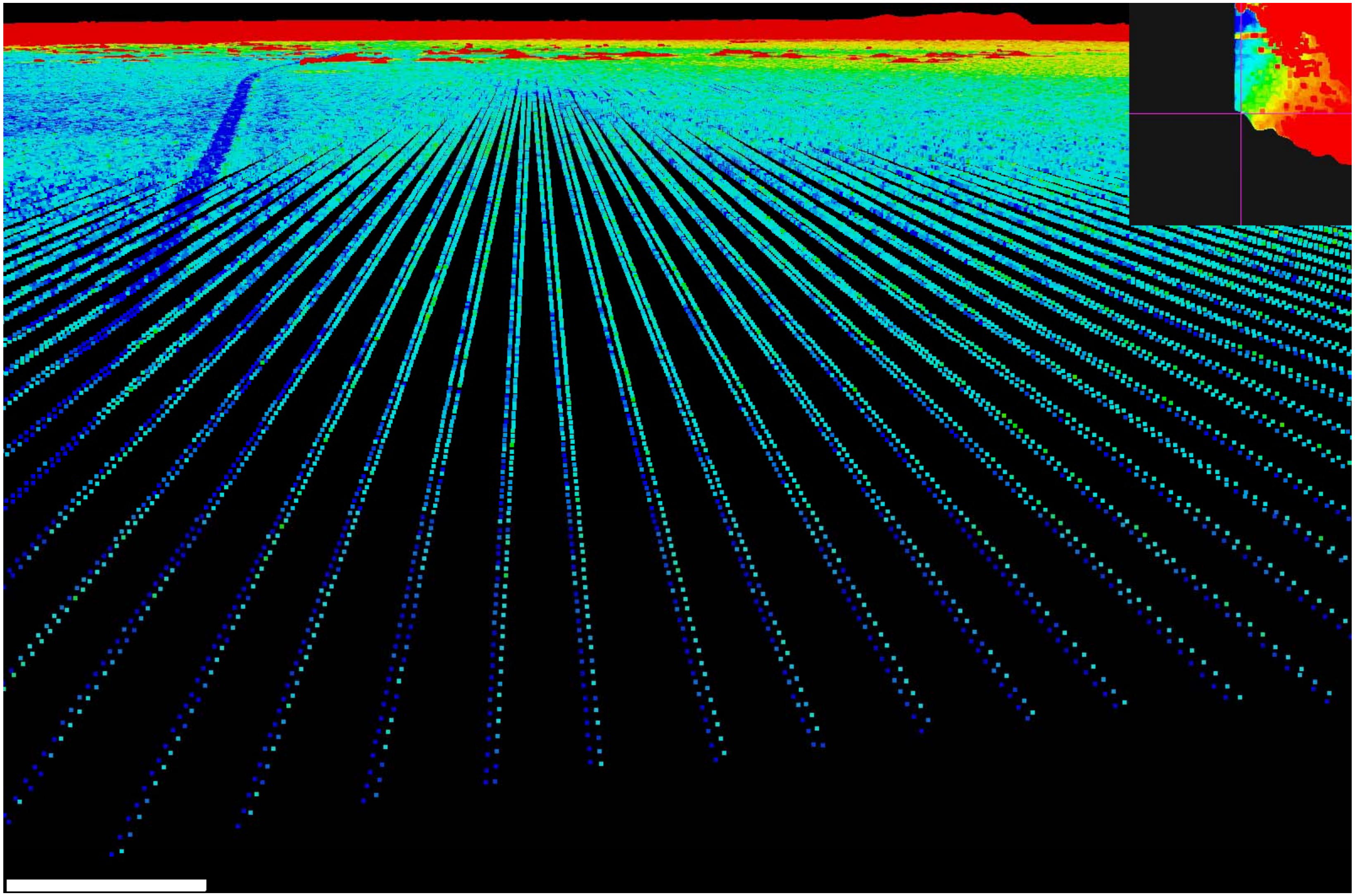
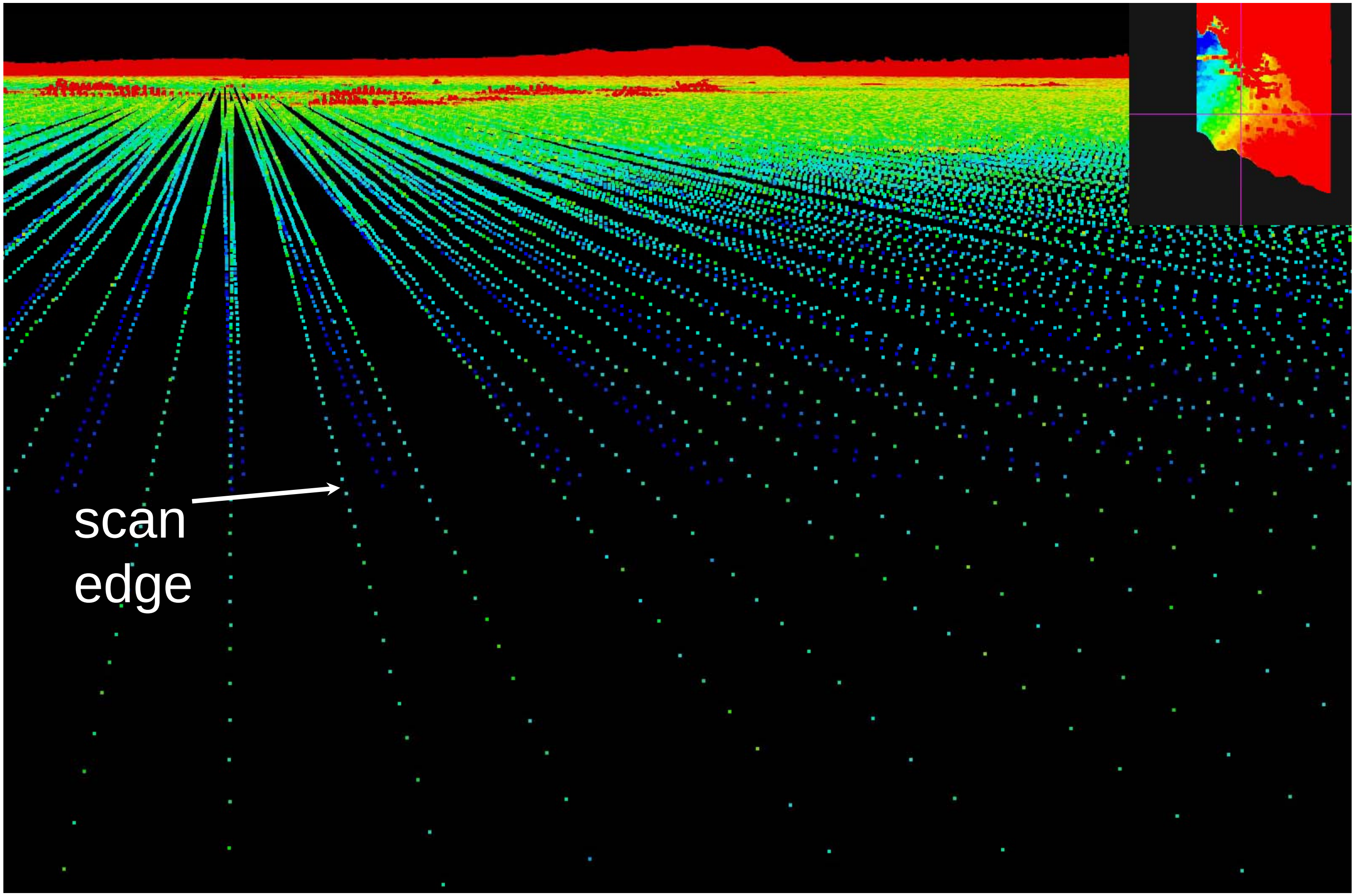
Corduroy - type 1



Scan artifact - at scan edge on dry lake one sees a pattern of up-down consistently; as mirror flips, height reads differently

Corduroy - type 2



The inner scan is consistently lower than the outer scan; this is a different source of 'corduroy,' the second type.

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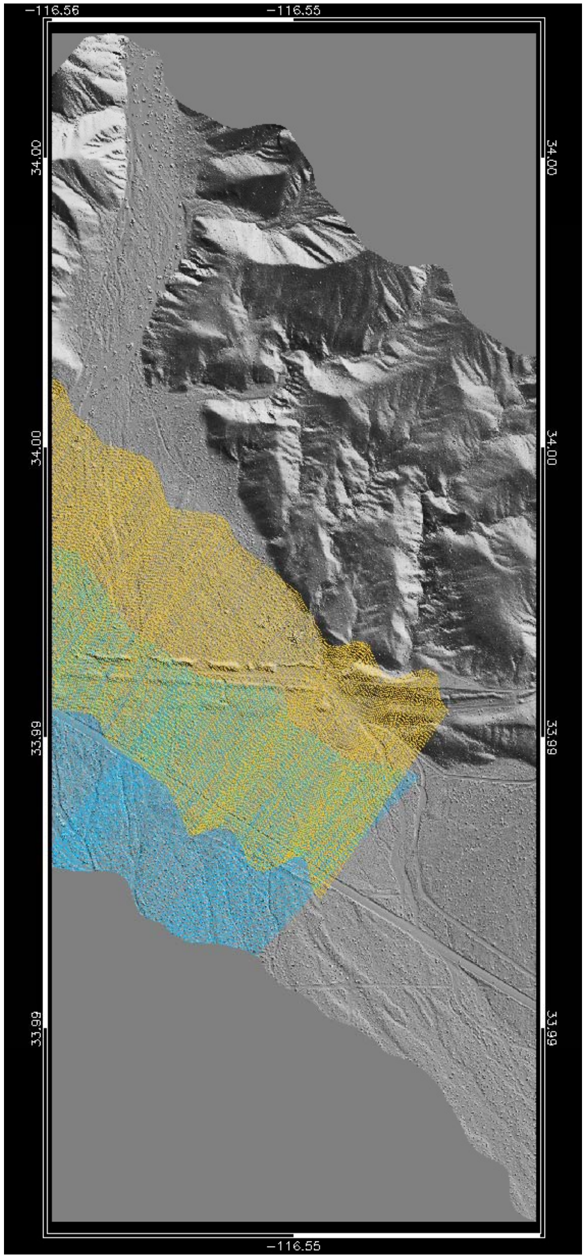
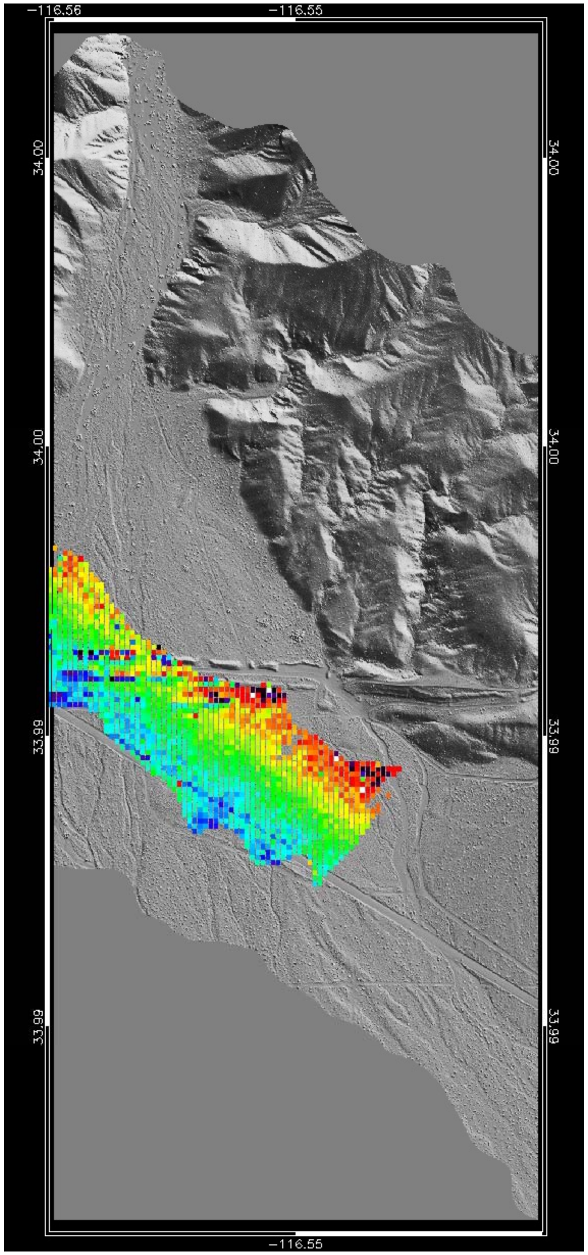
Swath comparisons





Courtesy of Adrian Borsa

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GPS Positioning Errors

Bill Elliott, USGS Volunteer

1 Hz GPS base station from UNAVCO pool

Mike Sartori and the NCALM crew

Surveying the B4 aircraft to determine the relative positions of the GPS antenna, the LIDAR, the IMU and the orientation of these vectors relative to the axes of the aircract.

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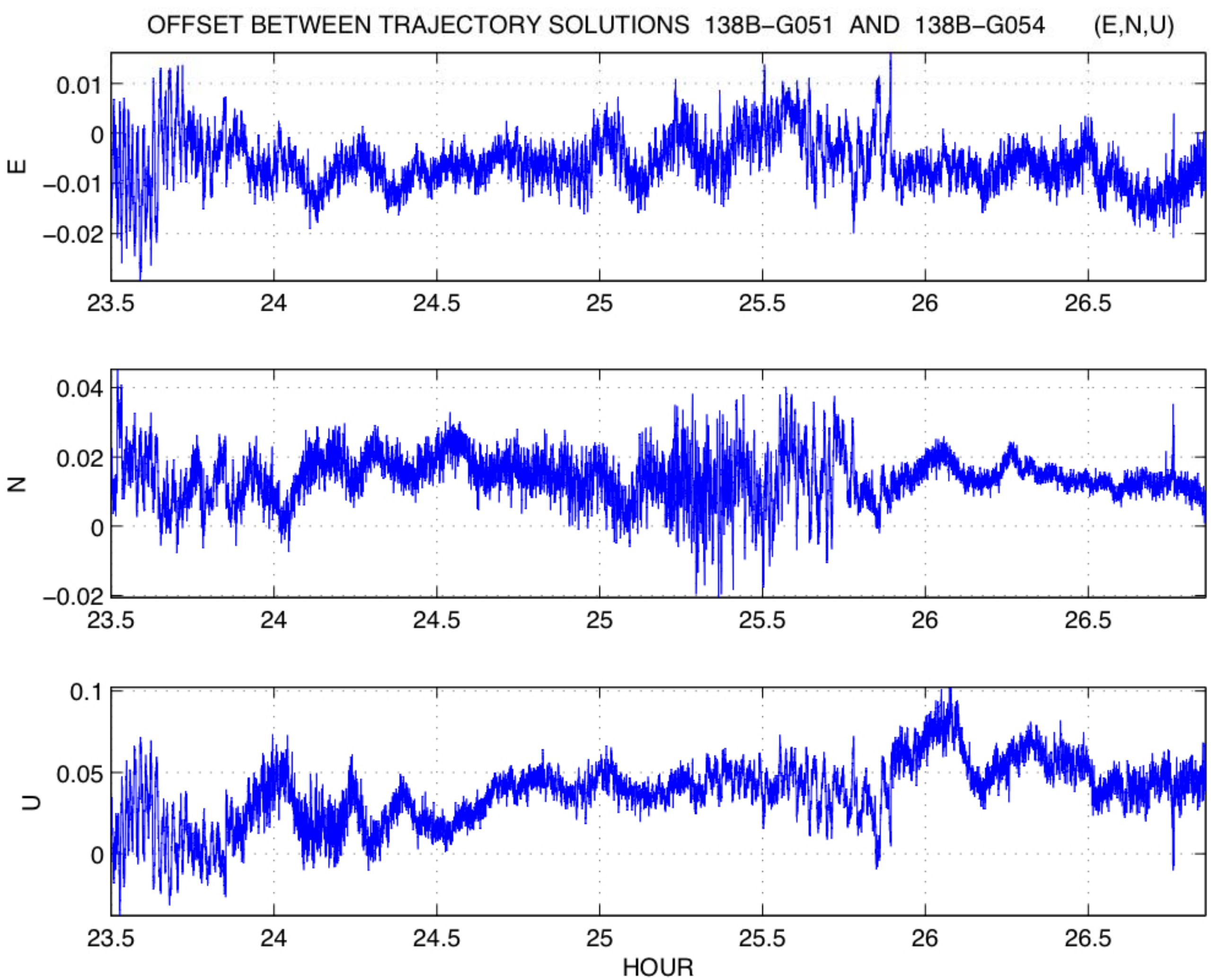
KARS Processing Strategy (Mader)



NCALM's standard procedure due to G. Mader: Estimate the flight trajectory for each flight segment using two KGPS base stations. Difference the solutions to identify problems (cycle slips), and edit the GPS data until all obvious jumps are gone.

NCALM will usually choose one of these solutions, and remerge with the IMU data using Applanix software. GPS baselines of 30 - 40 km are common.

OSU used KARS and Mader's processing strategy. But we estimated the flight trajectory against 6 or more base stations. We checked all pairs for position discontinuities. (Shan et al., GRL 2007)

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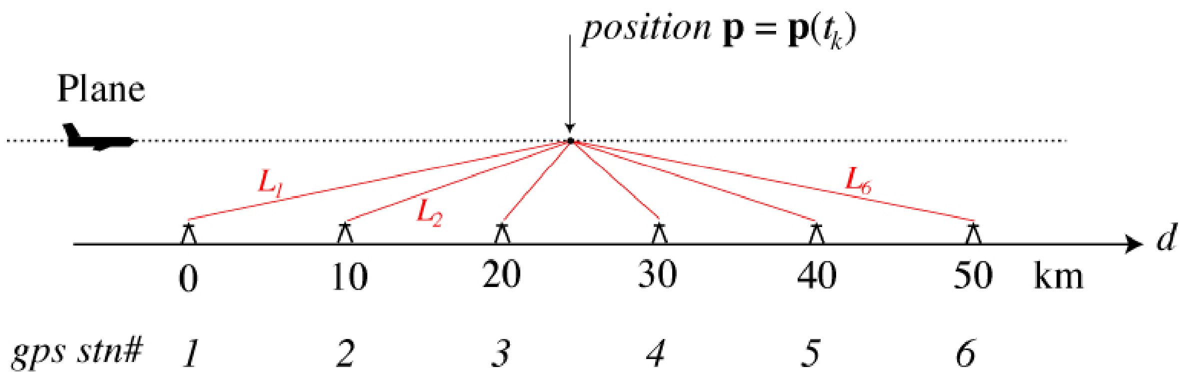
GPS Errors and Solution Blending 1



We have n estimates for the instantaneous position vector $\mathbf{p}$ *namely* $\{\mathbf{p}_i\}_{i=1,n}$ *(usually n = 6)*

Assume that in cartesian coordinates each estimate has a covariance matrix of form

$$\mathbf{C} = \begin{bmatrix} \sigma_e^2 & 0 & 0 \\ 0 & \sigma_n^2 & 0 \\ 0 & 0 & \sigma_u^2 \end{bmatrix}$$

where $\hat{\mathbf{u}}$ *is oriented very close to the average direction of ellipsoidal 'up'*

and that $\sigma_x = f(a_x, b_x, L)$ *for x = e, n or u*

We can experiment with different error models f(L)

Error Model A: $\sigma_x{}^2 = a_x^2 + b_x^2 L^2$

Error Model B: $\sigma_x = a_x + b_x\sqrt{L}$

Corduroy

There are *two* types of 'corduroy' in B4 data

type 1 - 'scan angle artifact'

scanner reads higher going one direction than it does in the other

type 2 - 'vertical swath offset'

aircraft first pass is vertically mis-aligned with second pass within a given area

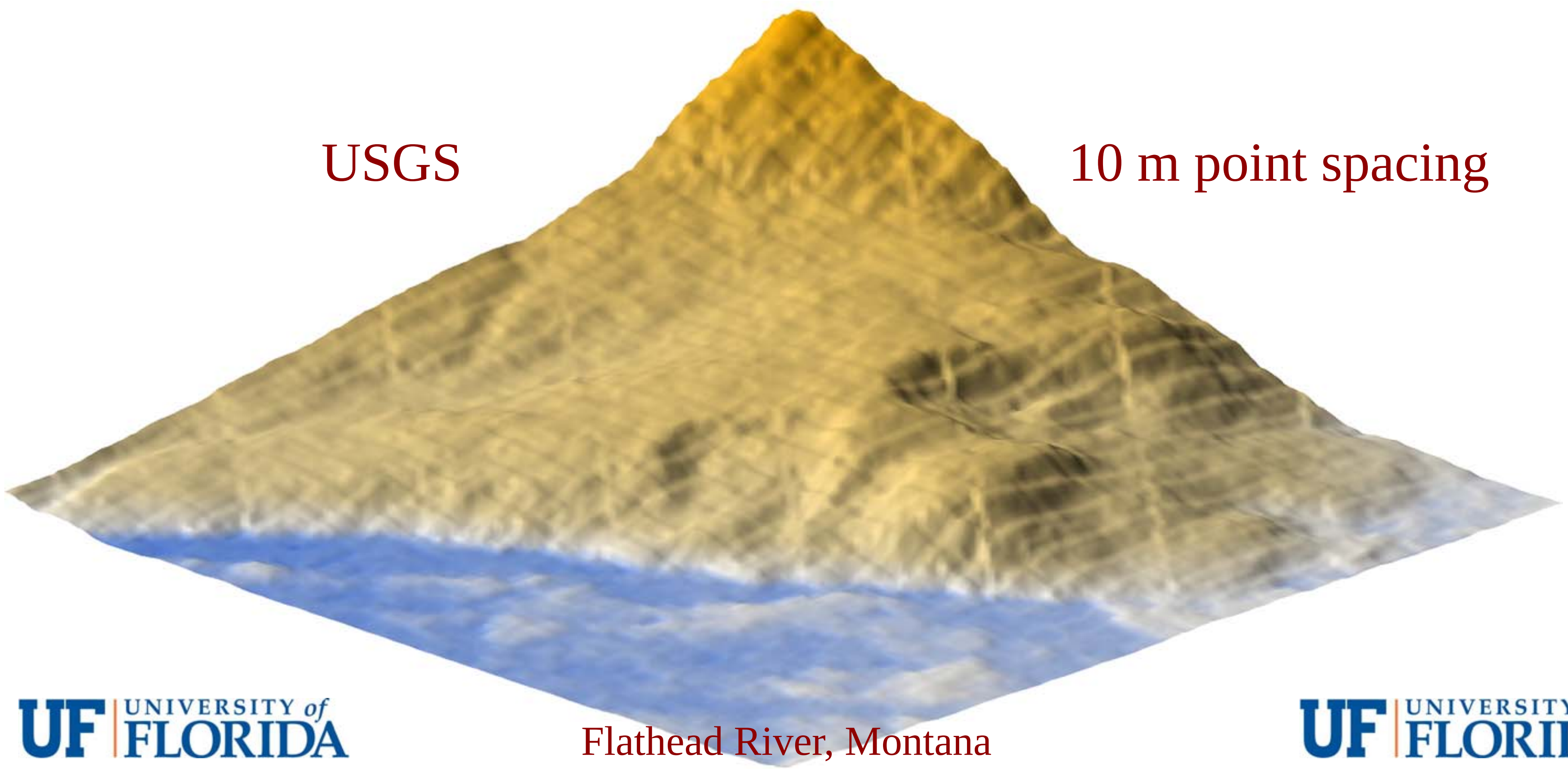
The second type, at least, can be mitigated or eliminated by increasing the accuracy of our GPS/IMU trajectories

NCALM

The National Center for Airborne Laser Mapping

USGS

10 m point spacing



Flathead River, Montana

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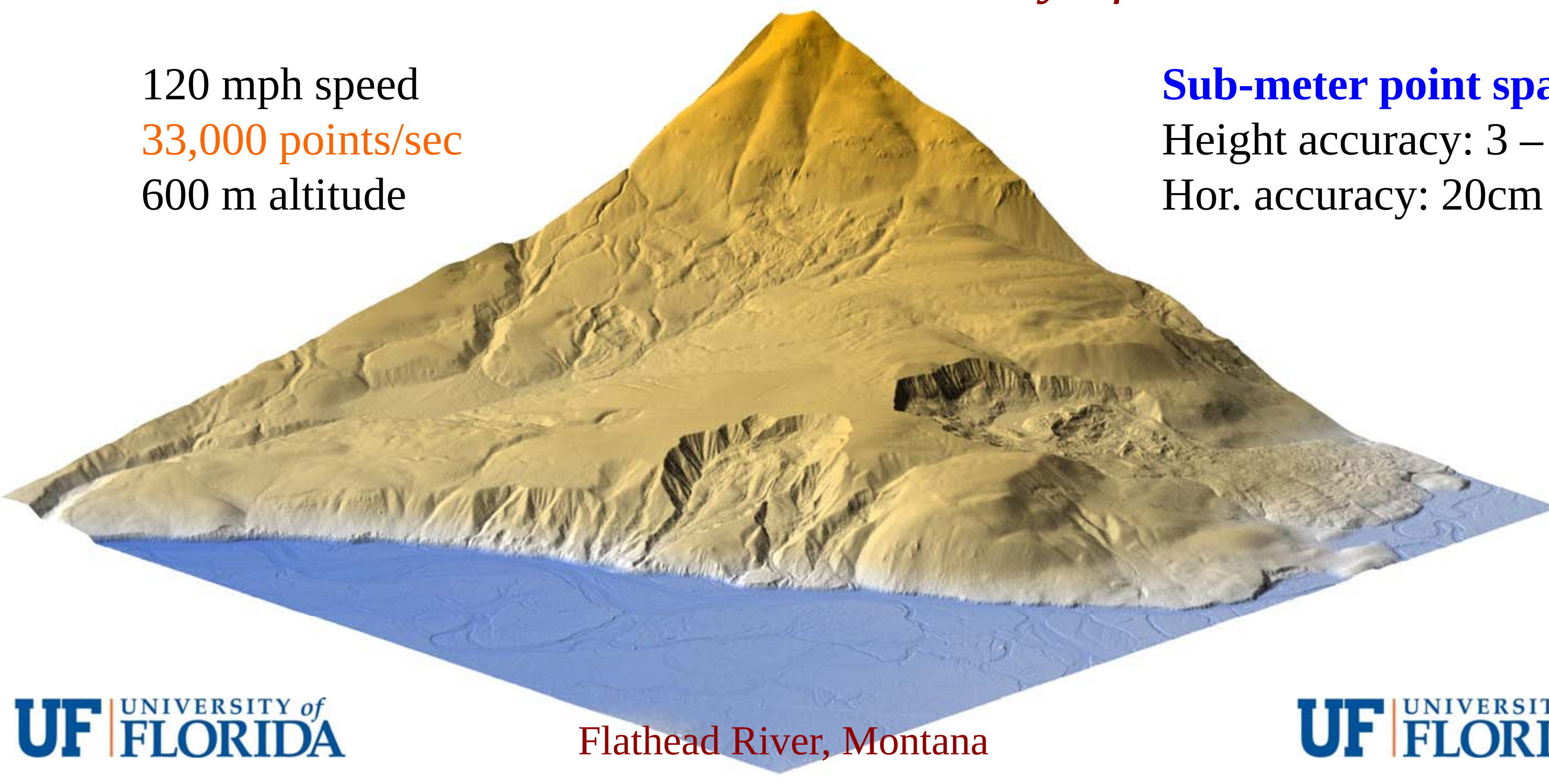
NCALM

The National Center for Airborne Laser Mapping

Courtesy of Ramesh Shrestha

120 mph speed
33,000 points/sec
600 m altitude

Sub-meter point spacing
Height accuracy: 3 – 8 cm
Hor. accuracy: 20cm



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conclusions

LiDAR artifacts causes are fairly well understood, but without open format descriptions for both scanner and GPS/IMU data most errors cannot be corrected and removed in a rigorous and satisfactory manner

Spaceborne platform - limitations for LiDAR:

- absolute positioning errors with GPS
- geometric errors increase with altitude
- laser power
- resolution and spot spacing