Effects of Spatial Accuracy Uncertainty on Change Detection and Scientific Analysis
&
Lies, Statistics, and Spatial Data Accuracy

"Reliable and realistic accuracy determination for spatial data"

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Acknowledgements

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Joe Hazel, Matt Kaplinski, Rod Parnell

Northern Arizona University

GCMRC Objectives

- Provide credible, objective information to the GCDAMP
- Integrate physical, cultural, & biological resource sciences
- Make data and analysis available to stakeholders

Oracle database is THE tool that makes data integration and availability possible

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or·a·cle: A person, such as a priestess, through whom a deity is held to respond when consulted

- Reference good primary geodetic control
  - (National Spatial Reference System)
- Collect, check, evaluate, archive RS spatial data

  Establish geodetic control within CRE

  Primary – Secondary – Tertiary Levels
  - Ground Surveys
  - Photo Panels
  - Photo-identifiable hard-points
- Determine Accuracy
- Develop Database Layers
- Perform Analysis

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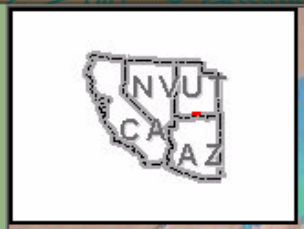
Grand Canyon Monitoring and Research Center



LAYERS

- All Layers
  - Lake Powell Navigation Aides
  - Lake Powell Water Quality Sta
  - Lake Powell Kilometer Tenths
  - Lake Powell Centerlines
  - Base Layers
  - Streams
  - Lakes
  - Lake Powell Bathymetry - 5 Mete
  - Color Shaded Relief Topography
  - USGS National Elevation Data

Refresh Map

Auto Refresh

Help:

- A closed group, click to open.
- An open group, click to close.
- A map layer.
- A hidden group/layer, click to make visible.
- A visible group/layer, click to hide.
- A visible layer, but not at this scale.
- A partially visible group, click to make visible.
- An inactive layer, click to make active.
- The active layer.

Tool Selected: Zoom In

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National Spatial Reference System

- is a consistent national coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the Nation, *as well as how these values change with time.*
- provides a highly accurate, precise, and consistent geographic reference framework throughout the United States.
- is the foundation for the National Spatial Data Infrastructure (NSDI)
- defined and managed by the National Geodetic Survey (NGS)
- Provides local and network accuracies

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NATIONAL GEODETIC SURVEY

Primary Control

1999

C-stability=“ May hold, but of type commonly subject to surface motion”

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Primary Control

2003

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Primary Control

2005

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The NGS Data Sheet

See file dsdata.txt for more information about the datasheet.

```
DATABASE = Sybase ,PROGRAM = datasheet, VERSION = 7.28
1        National Geodetic Survey,   Retrieval Date = OCTOBER 22, 2005
 DH5739 ***********************************************************************
 DH5739  HT_MOD      -  This is a Height Modernization Survey Station.
 DH5739  DESIGNATION -  HITE 1
 DH5739  PID         -  DH5739
 DH5739  STATE/COUNTY-  UT/SAN JUAN
 DH5739  USGS QUAD   -  HITE SOUTH (1987)
 DH5739
 DH5739                        *CURRENT SURVEY CONTROL
 DH5739
 DH5739* NAD 83(1994)-  37 52 24.71909(N)     110 23 40.91718(W)      ADJUSTED
 DH5739* NAVD 88     -      1133.86   (meters)     3720.0    (feet)   GPS OBS
 DH5739
 DH5739  X           -  -1,757,041.311 (meters)                       COMP
 DH5739  Y           -  -4,725,879.912 (meters)                       COMP
 DH5739  Z           -   3,895,056.072 (meters)                       COMP
 DH5739  LAPLACE CORR-           1.21  (seconds)                      DEFLEC99
 DH5739  ELLIP HEIGHT-        1112.72  (meters)          (05/31/05)  GPS OBS
 DH5739  GEOID HEIGHT-         -21.14  (meters)                       GEOID03
 DH5739
 DH5739  HORZ ORDER  -  A
 DH5739  ELLP ORDER  -  THIRD     CLASS II
 DH5739
 DH5739.The horizontal coordinates were established by GPS observations
 DH5739.and adjusted by the National Geodetic Survey in May 2005.
```

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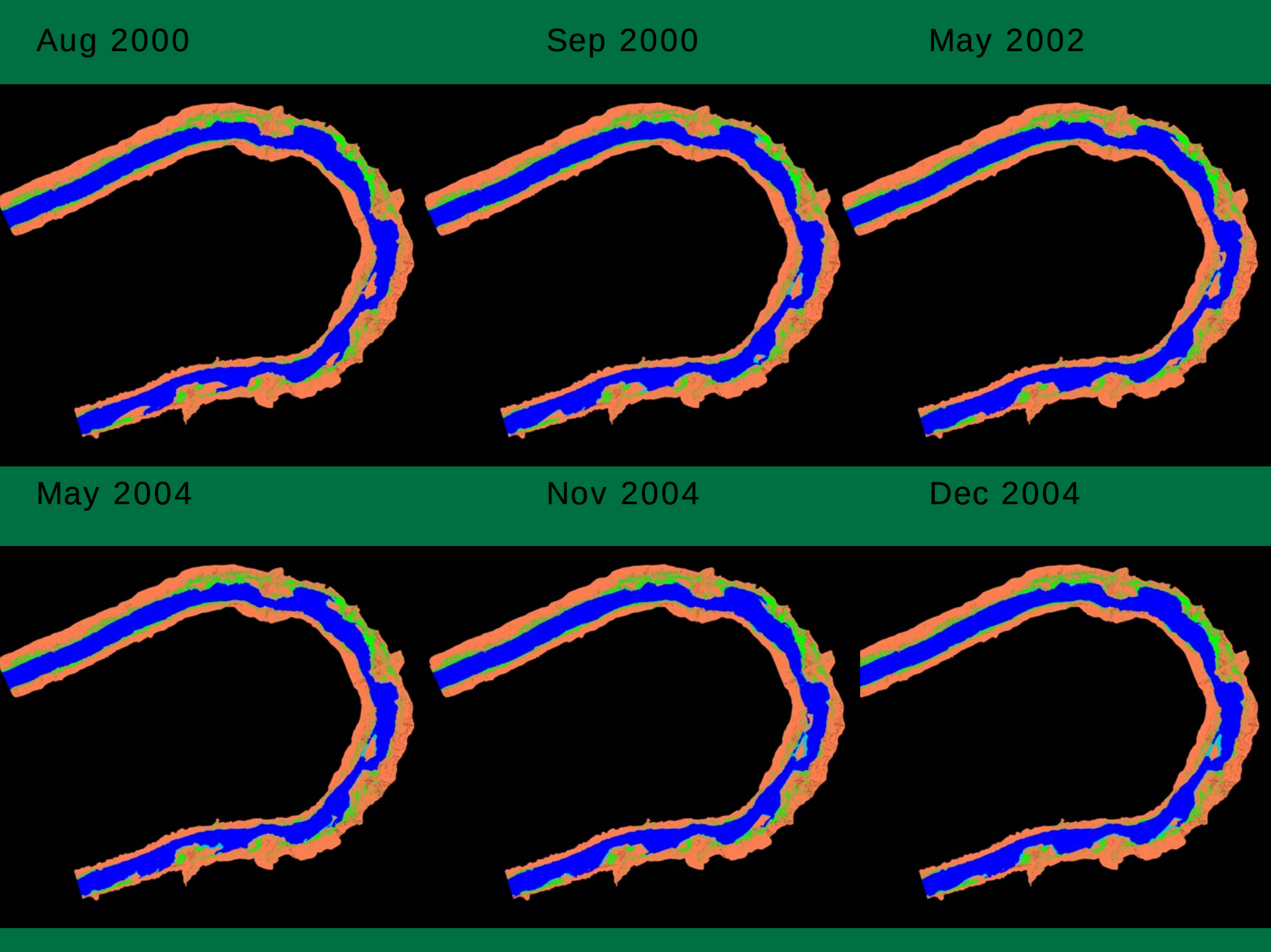
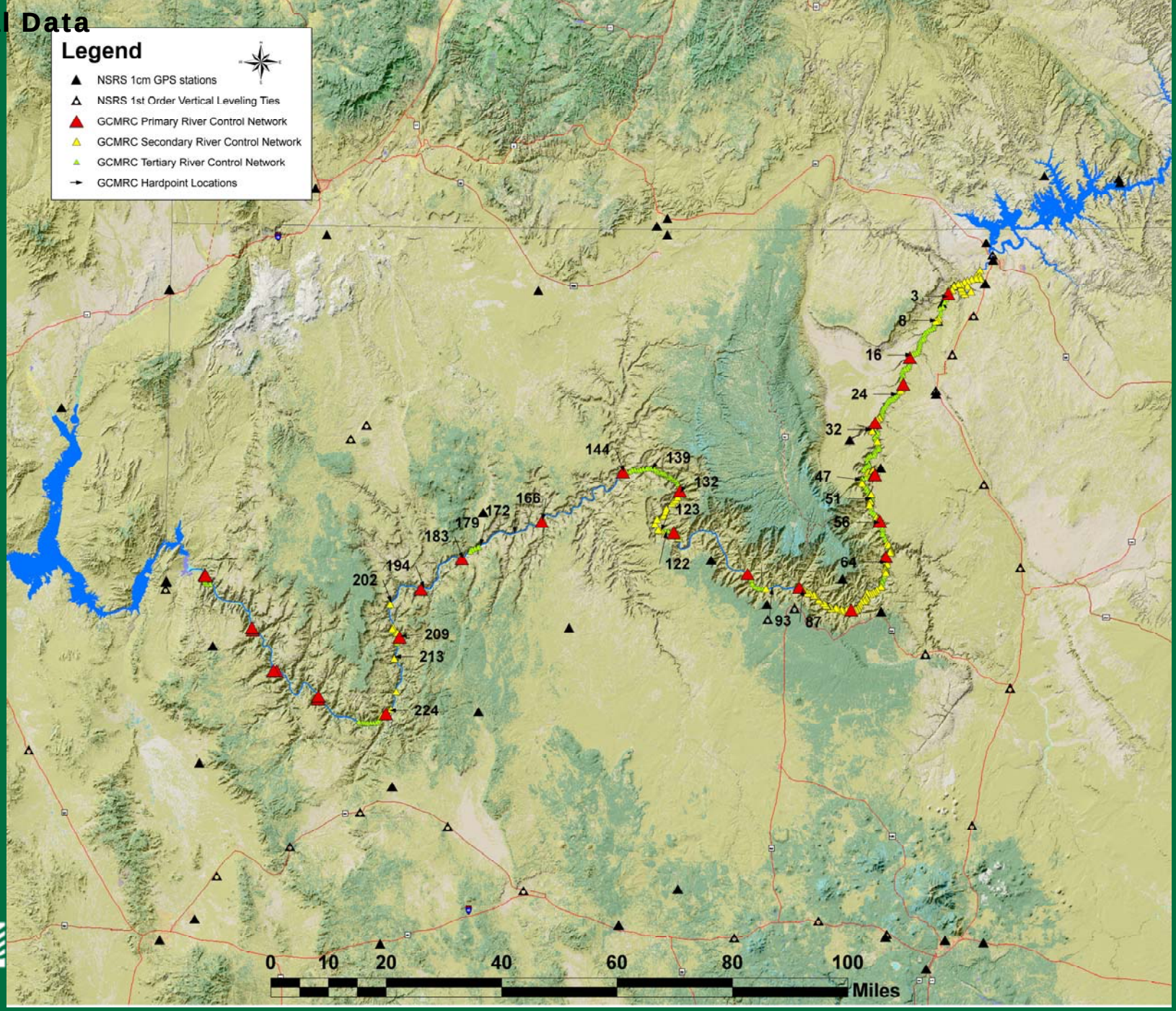
Remote sensing missions since 1999

Date of Acquisition	Contractor	Product
July 1999	Horizons	Lidar
September 1999	Bechtel	MSS Survey
September 1999	Horizons	B&W and Color film
September 1999	Horizons	Color Digital Imagery
September 1999	Horizons	CIR digital orthophotos
March 2000	Horizons	Film, scanned images
March 2000	Earth Data	Scanned CIR Orthophots, Lidar
May 2000	U.S.G.S.	Remote sensing agreement
July 2000	Horizons	CIR Digital images
July 2000	Bechtel	Digital ATM and thermal IR
August 2000	Enerquest	Digital *.TIFs, Lidar
September 2000	Enerquest	B&W orthophotos
September 2000	PWT	Color film photogrammetry
September 2000	Horizons	CIR film and scans
September 2000	Enerquest	B&W orthophotos, Lidar
September 2000	Enerquest	B&W High Gain Digital
April 2001	Enerquest	Lidar
July 2001	Enerquest	B&W Digital *.TIFs
September 2001	U.S.G.S.	Remote sensing agreement
February 2002	Bechtel	Photogrammetry of Arch sites
May 2002	PhotoScience	Unrectified imagery
May 2002	Istar	Digital Imagery (Pan, RGB and CIR)
May 2003	Chance Lidar	High density Lidar
May 2004	Horizons	CIR scanned orthophotos
May 2004	Airborne 1	LiDAR
November 2004	Spectrum Mapping	Pre-flood LiDAR
December 2004	Spectrum Mapping	Post-flood LiDAR
May 2005	3001, Inc.	Digital Imagery (Pan, RGB and CIR)
May 2005	Airborne 1	LiDAR


Aug 2000
Sep 2000
May 2002
May 2004
Nov 2004
Dec 2004

Spatial Data



Spatial Data

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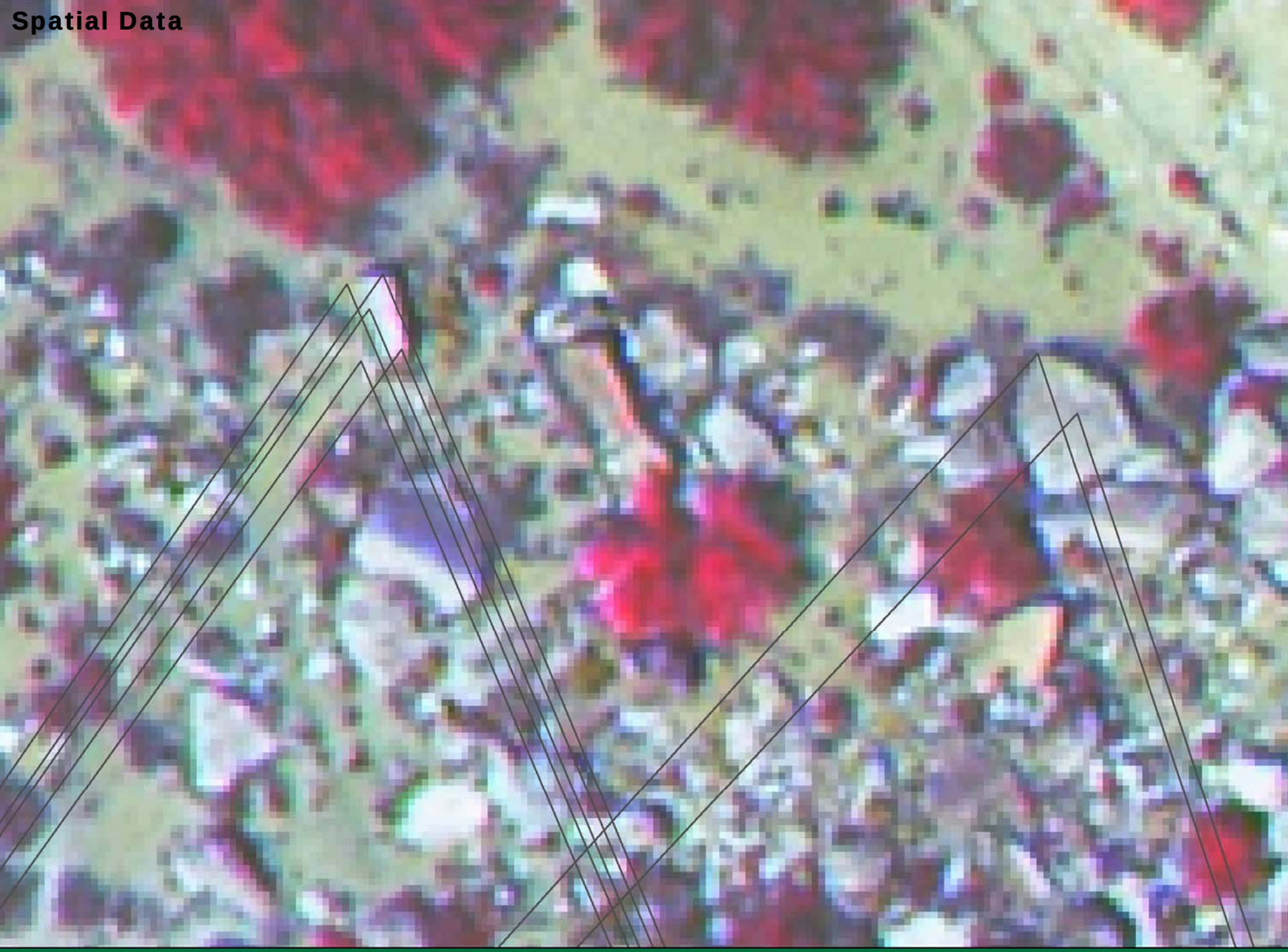
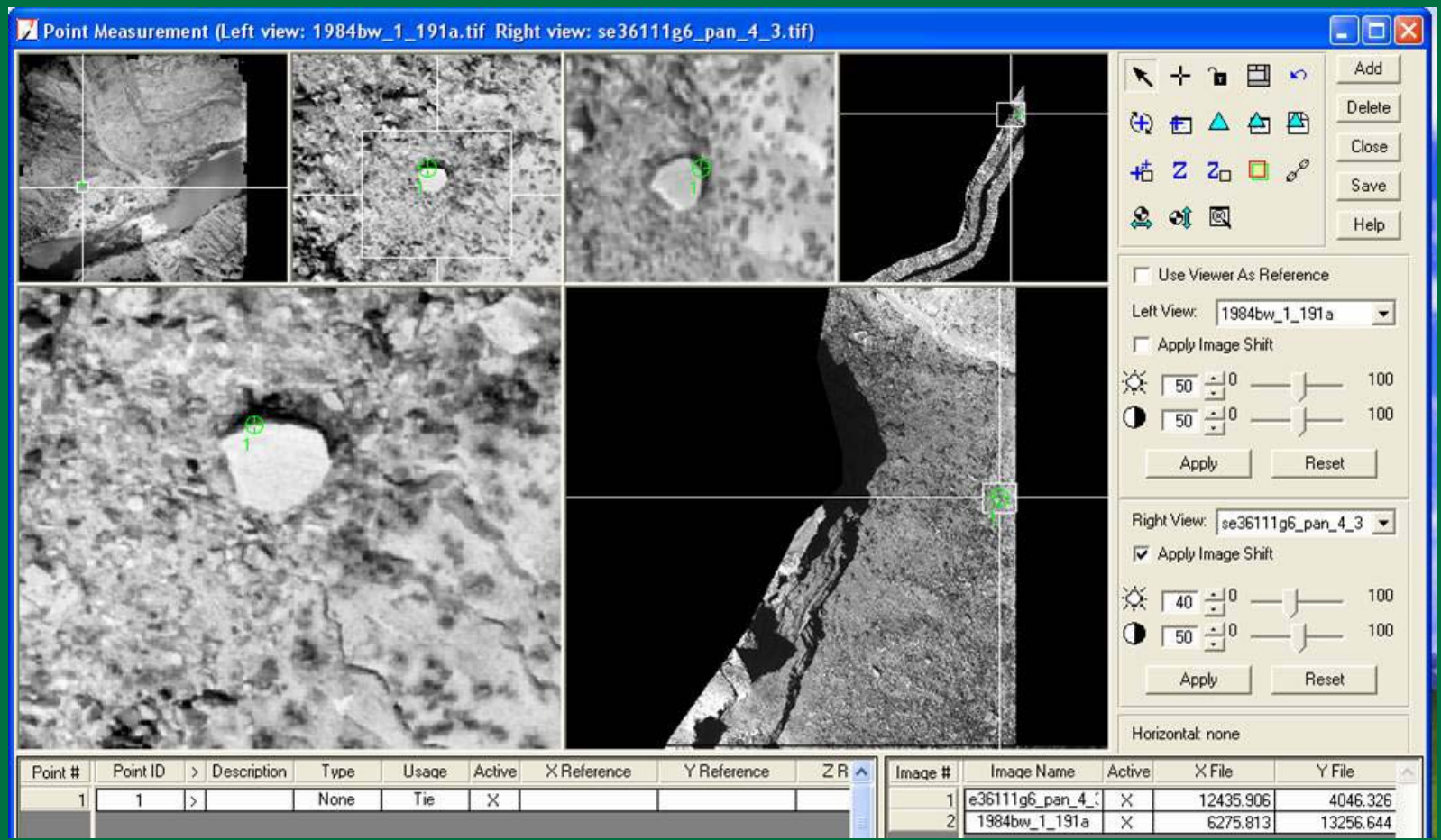


Spatial Data


Spatial Data

Historical Photos can then be scanned and referenced to the network for 2D and 3D analysis though the Oracle database



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Key Concepts Of Error Determination

- **All positioning is relative to something else**
  - ***National Spatial Reference System* (NSRS)**
- **All measurements contain error**
  - **Random, systematic, and gross ("blunders")**
  - **Accuracy = Precision + Bias**
  - ***Confidence level* of accuracy must be specified**
- **Standards and specifications are essential**
  - Standards **are based on *results***
  - Specifications **dictate *how* measurements are made**

Quote of the day:

"Accuracy is telling the truth . . . Precision is telling the same story over and over again."

— Yiding Wang

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National Standard for Spatial Data Accuracy (NSSDA)

- Provides method for estimating accuracy of spatial data
  - Specifies 95% confidence level
    - *Not* "root mean square error" (RMSE)
  - For both horizontal and vertical accuracy
- Required by Executive Orders 12906, 13286 for "*geospatial data produced, revised, or disseminated by or for the Federal Government*" (FGDC-STD-007.3-1998, p. 3-1)
- Promulgated by the Federal Geographic Data Committee (FGDC)

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Some ways to lie about accuracy

- Reporting accuracy using unscaled standard errors
  - Vertical: Gives accuracy at 68% confidence
  - Horizontal: Gives accuracy at 39% confidence
- Reporting accuracy using RMSE
  - Vertical: Gives accuracy at 68% confidence
  - Horizontal: Gives accuracy at ~65% confidence (varies, since covariance neglected)
- Using precision in data with systematic errors (bias)
- Ignoring non-uniform error distributions and error correlation (covariance)

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Some “accuracy” results to consider

(all from same airborne GPS photogrammetry & LiDAR data)

- Horizontal **“accuracy” computed as:**
  - **±34 cm**
  - **±38 cm**
  - **±49 cm**
  - **±55 cm**
  - **±82 cm**
  - **±92 cm**
  - **±121 cm**
  - **±135 cm**
- **Is it “accuracy” or is it “precision”?**
- **What is the “confidence level”?**

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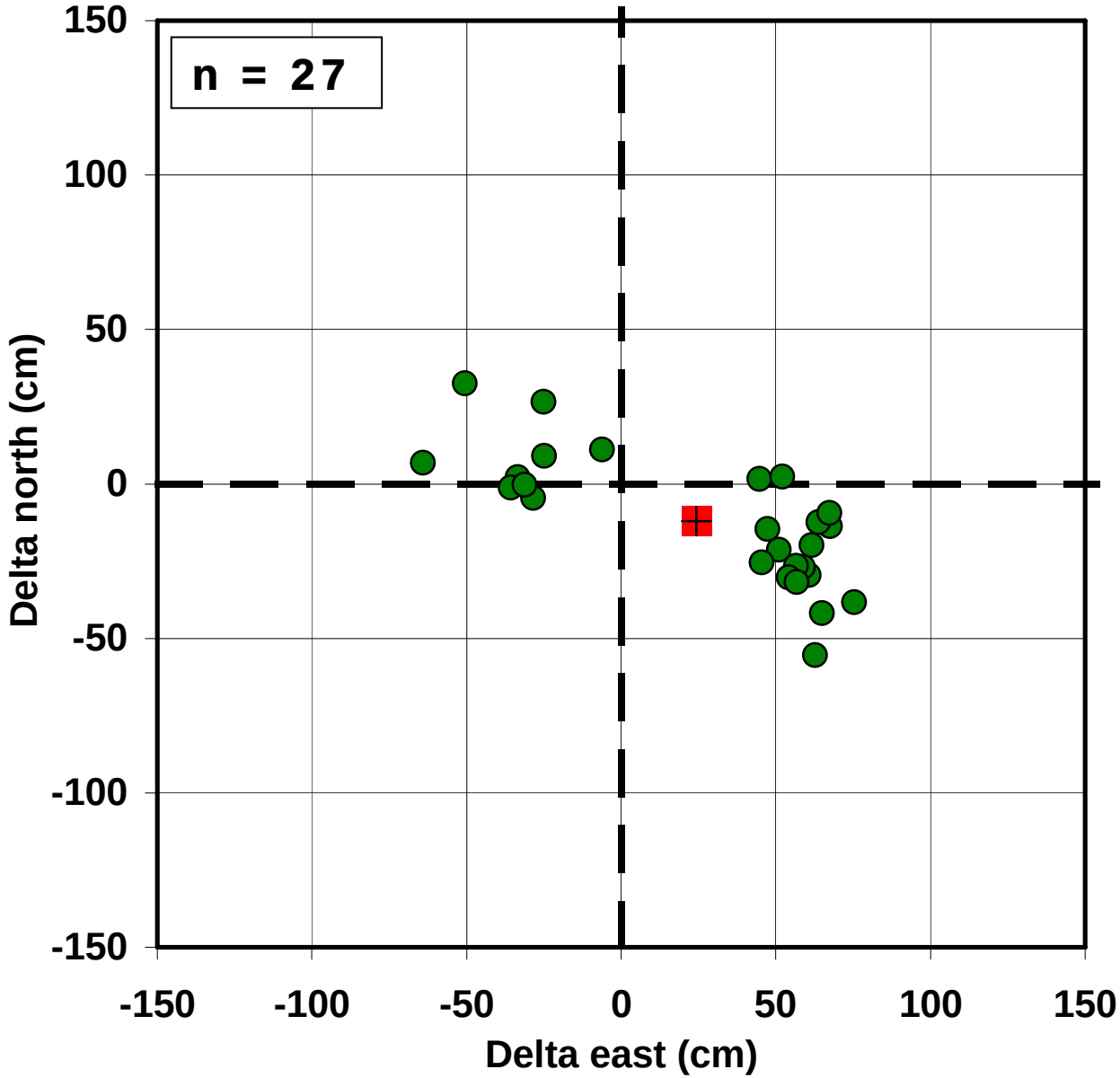
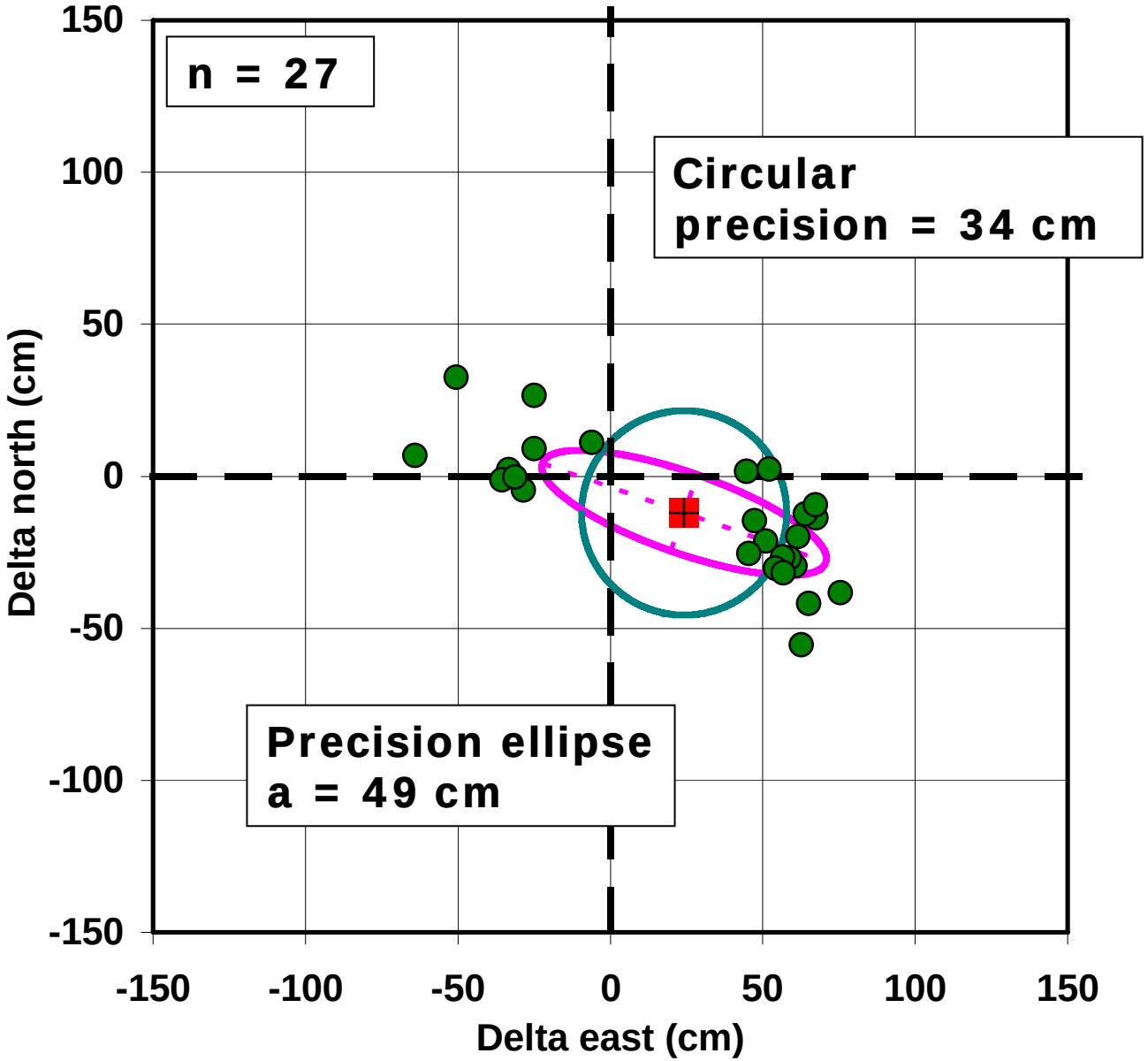
Horizontal data accuracy assessment

Scatter plot with respect to known control



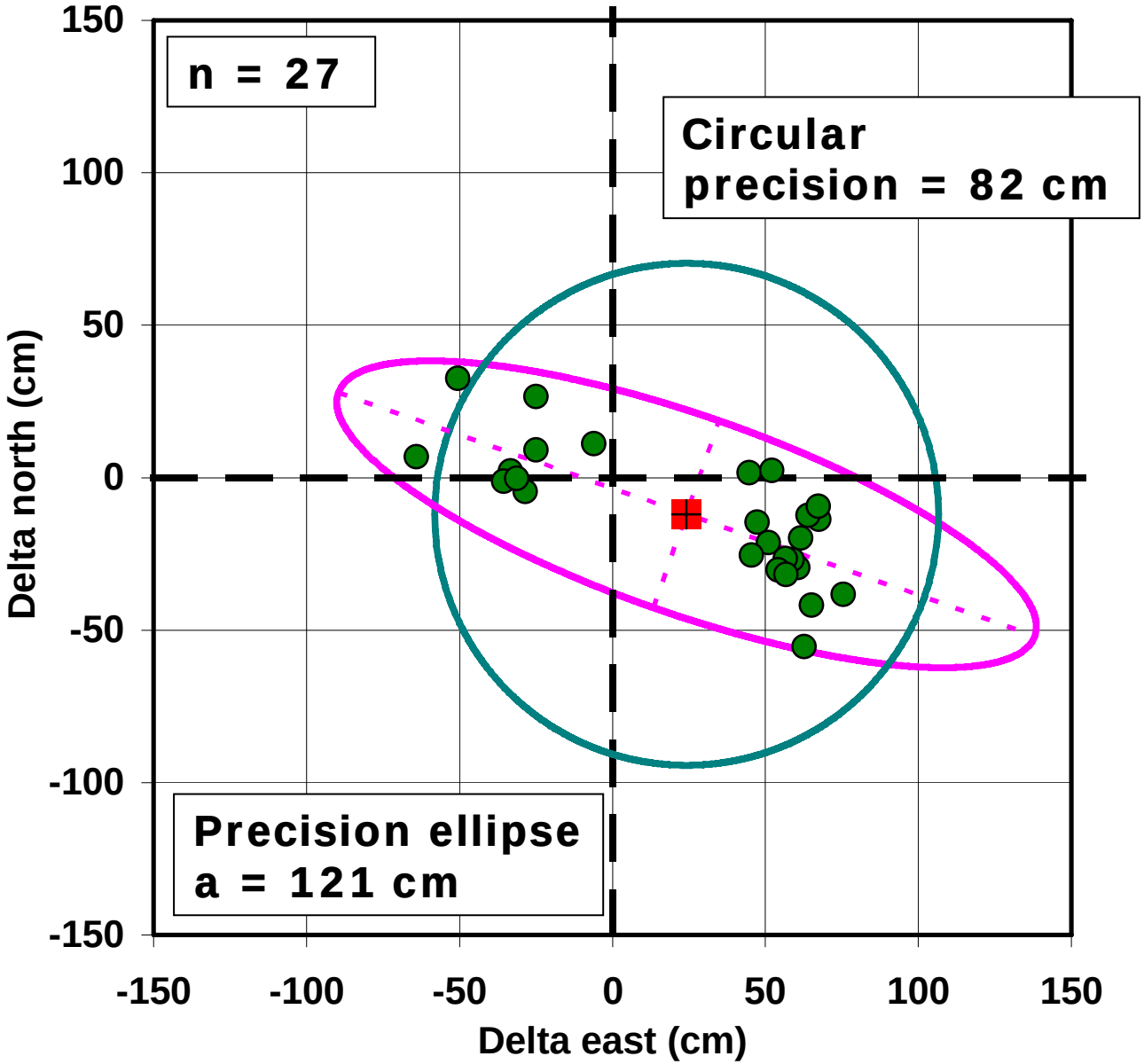
Horizontal data accuracy assessment

Scatter plot showing *standard* precision (39% confidence)



Horizontal data accuracy assessment

Scatter plot showing *scaled* precision (95% confidence)



Some "accuracy" results to consider

(all from same airborne GPS photogrammetry & LiDAR data)

- Horizontal "accuracy" computed as:
  - ±34 cm
  - ±38 cm (circular precision at 39% confidence)
  - ±49 cm
  - ±55 cm (precision ellipse at 39% confidence)
  - ±82 cm
  - ±92 cm (circular precision at 95% confidence)
  - ±121 cm
  - ±135 cm (precision ellipse at 95% confidence)
- Is it "accuracy" or is it "precision"?
- What is the "confidence level"?

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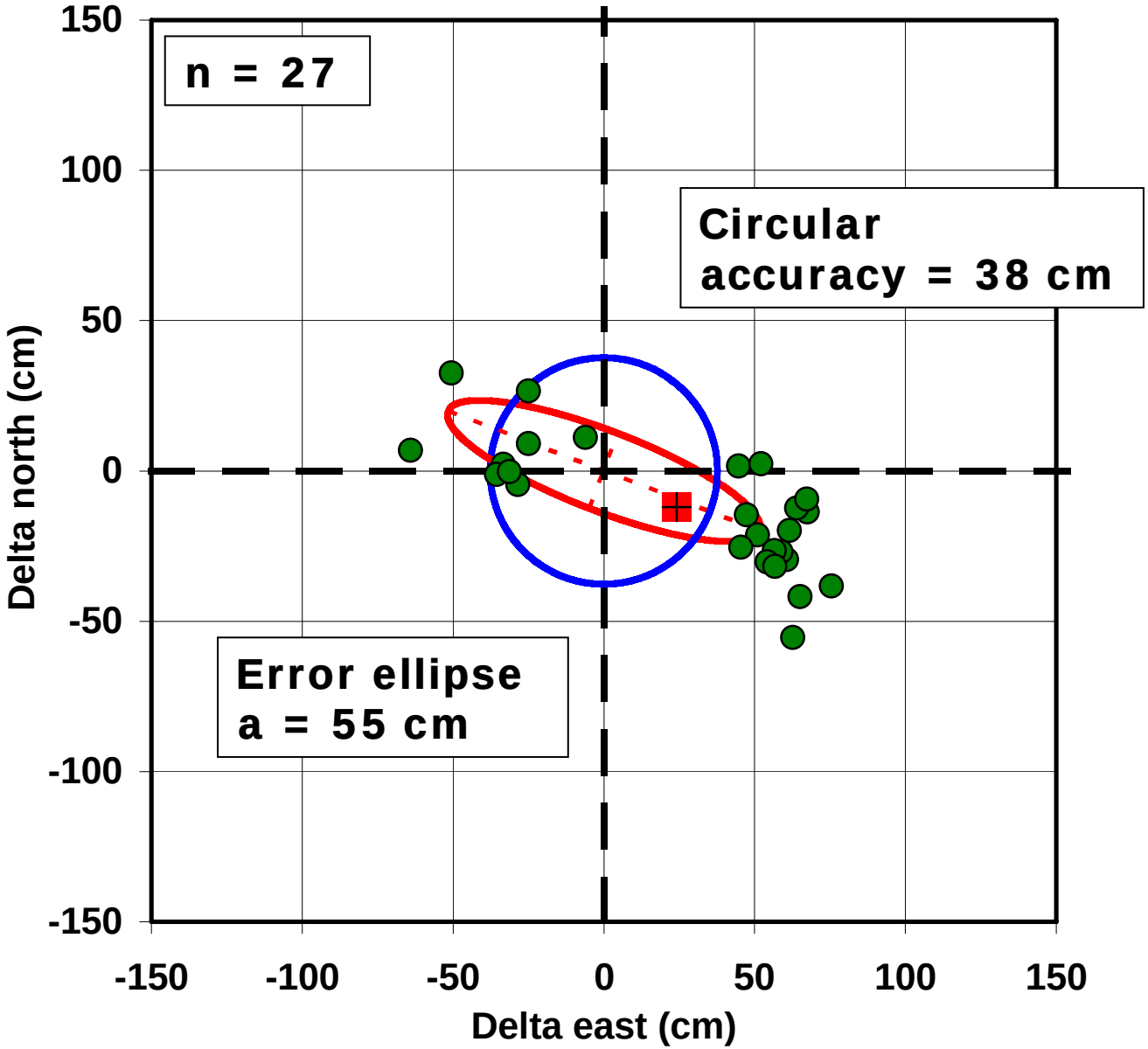
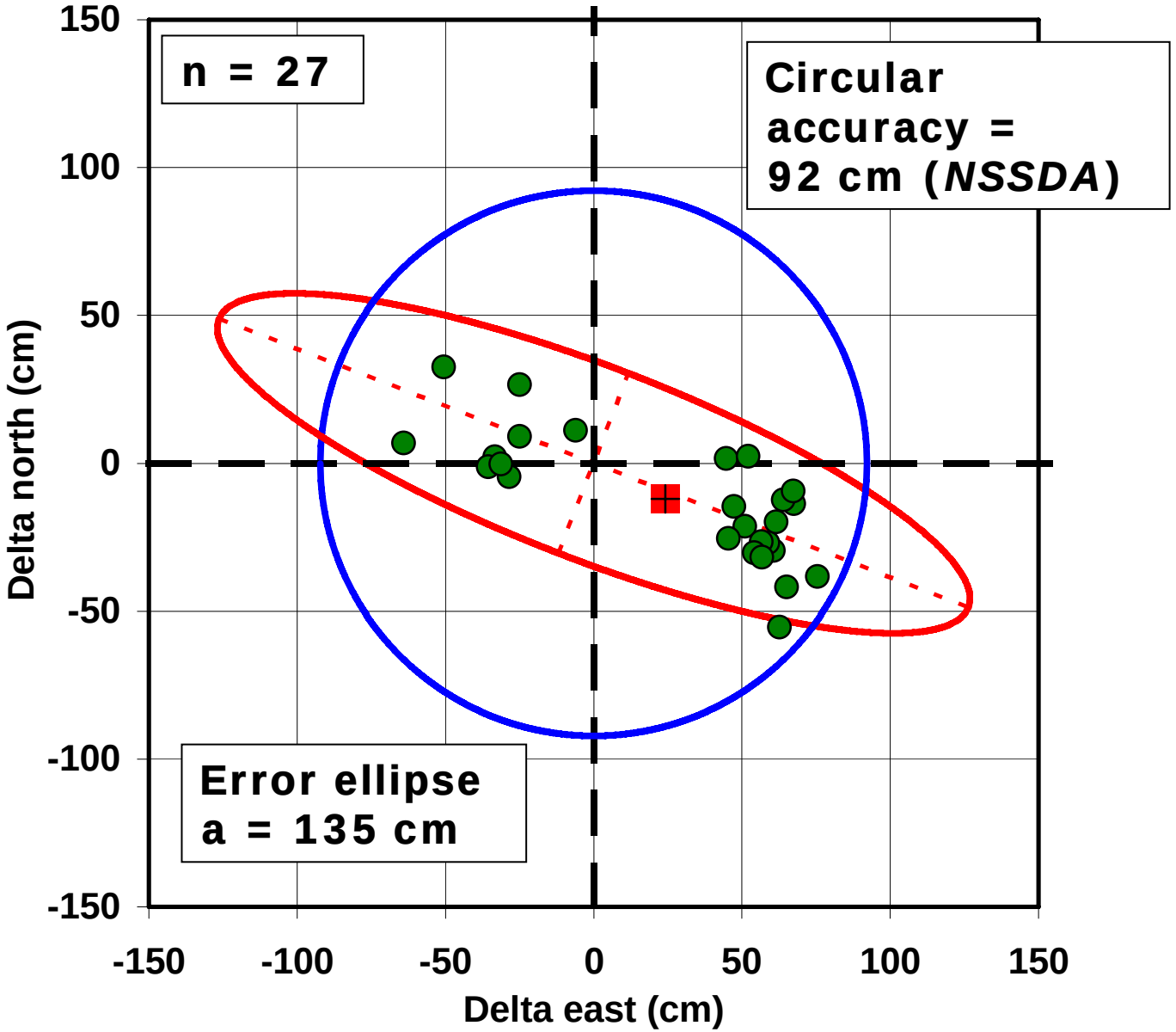
Horizontal data accuracy assessment

Scatter plot showing *standard* accuracy (39% confidence)



Horizontal data accuracy assessment

Scatter plot showing *scaled* accuracy (95% confidence)



Some "accuracy" results to consider

(all from same airborne GPS photogrammetry & LiDAR data)

- Horizontal **"accuracy" computed as:**
  - **±34 cm** (circular precision at 39% confidence)
  - **±38 cm** (circular error at 39% confidence)
  - **±49 cm** (precision ellipse at 39% confidence)
  - **±55 cm** (error ellipse at 39% confidence)
  - **±82 cm** (circular precision at 95% confidence)
  - ±92 cm ← **per NSSDA** (95% confidence)
  - **±121 cm** (precision ellipse at 95% confidence)
  - **±135 cm** (error ellipse at 95% confidence)
- **Is it "accuracy" or is it "precision"?**
- **What is the "confidence level"?**

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Some “accuracy” results to consider

(all from same airborne GPS photogrammetry & LiDAR data)

- Vertical **“accuracy” computed as:**
  - **±13 cm**
  - **±14 cm**
  - **±17 cm**
  - **±24 cm**
  - **±33 cm**
  - **±13 cm**
  - **±22 cm**
- **What if the data are biased?**
- **What if the data contain outliers?**

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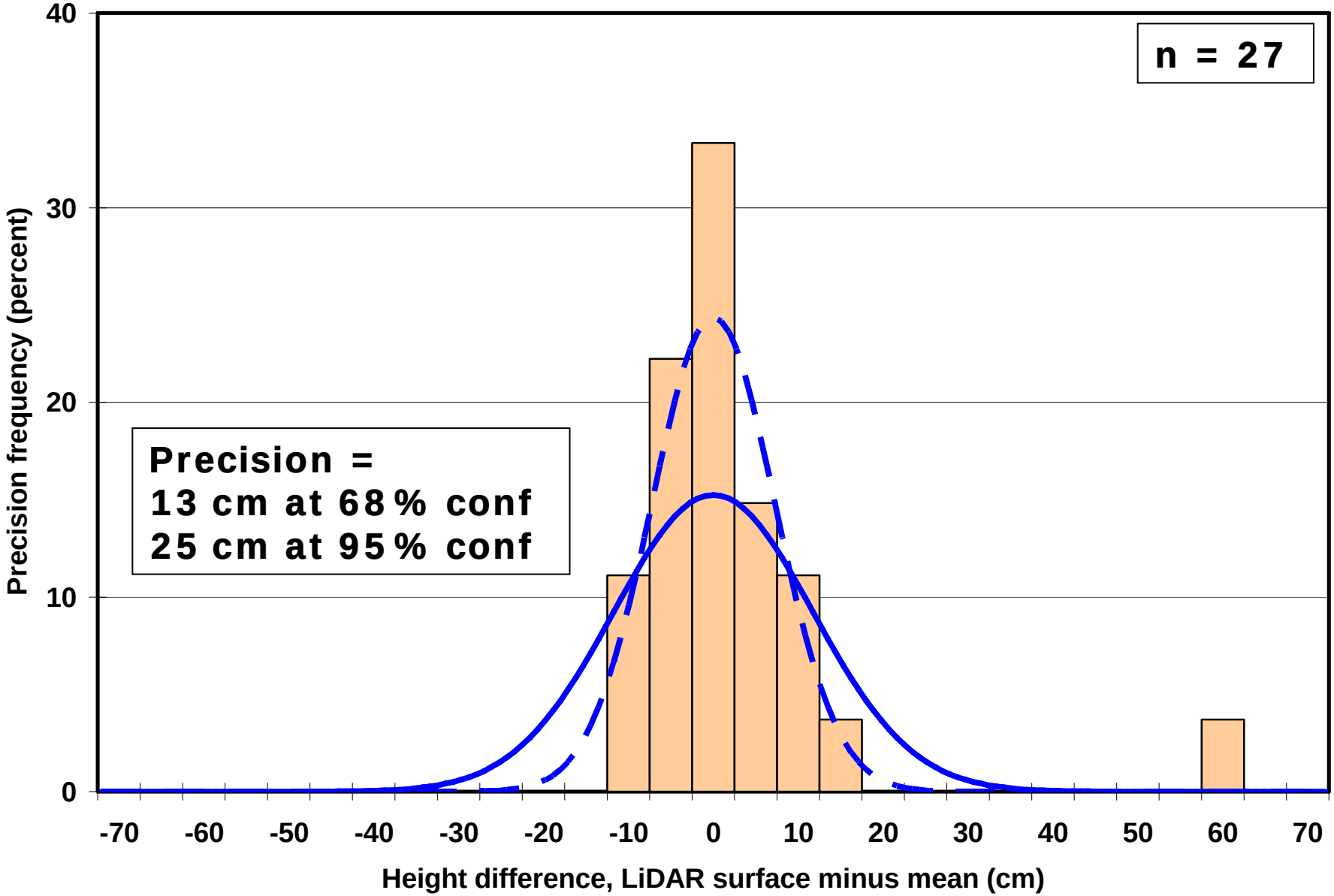
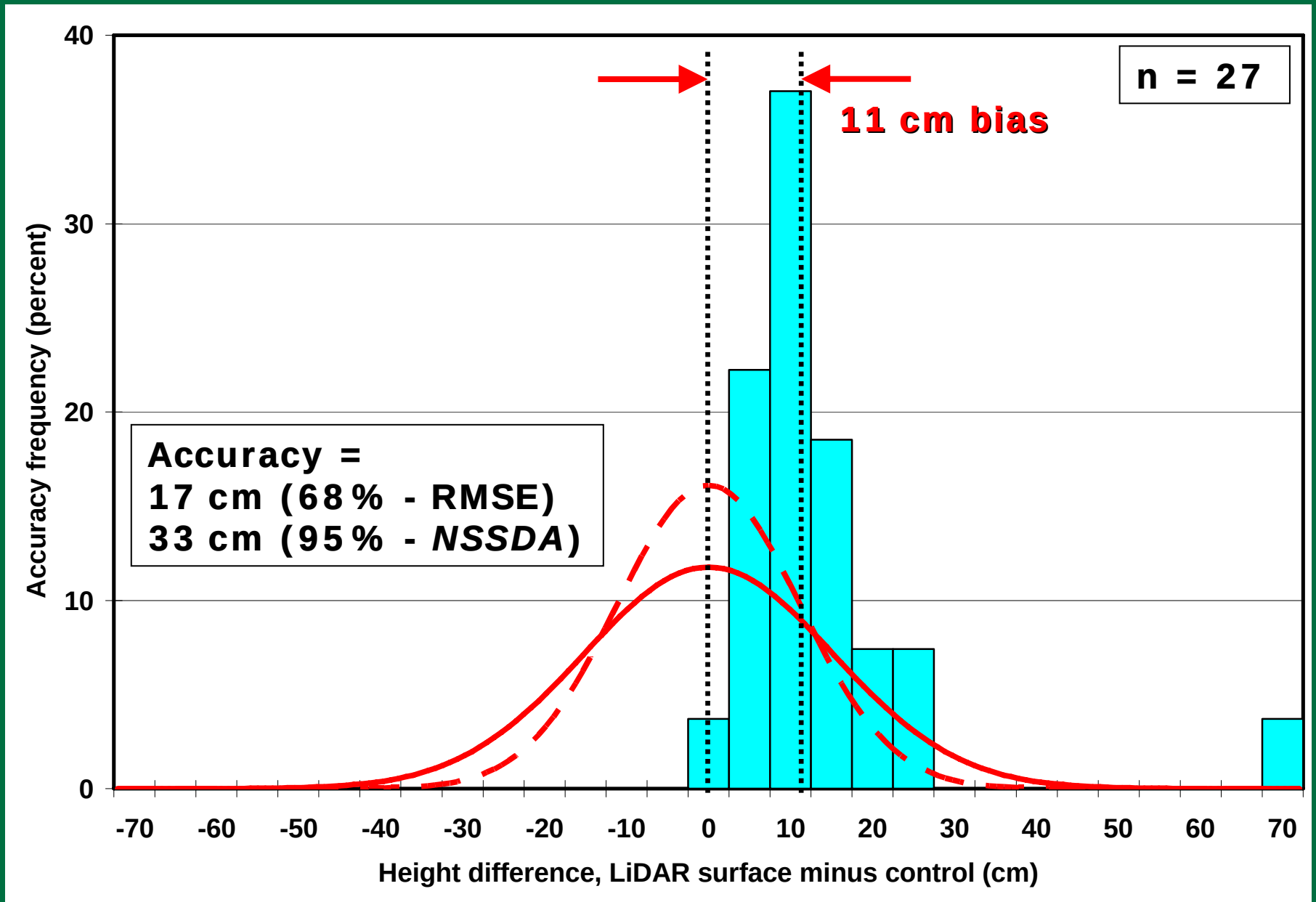
Vertical data accuracy assessment

Precision histogram (with respect to sample mean)



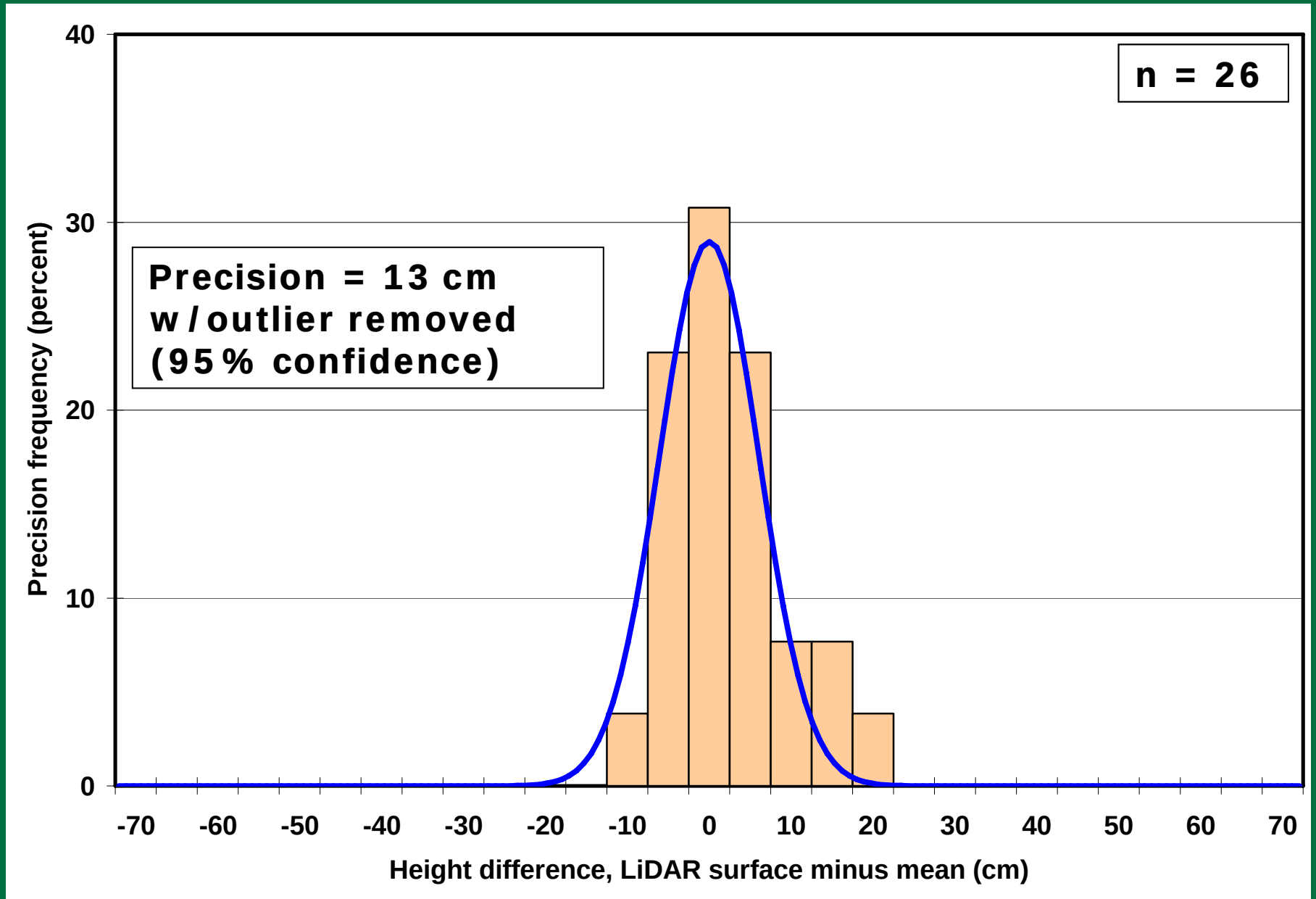
Vertical data accuracy assessment

Accuracy histogram (with respect to known control)



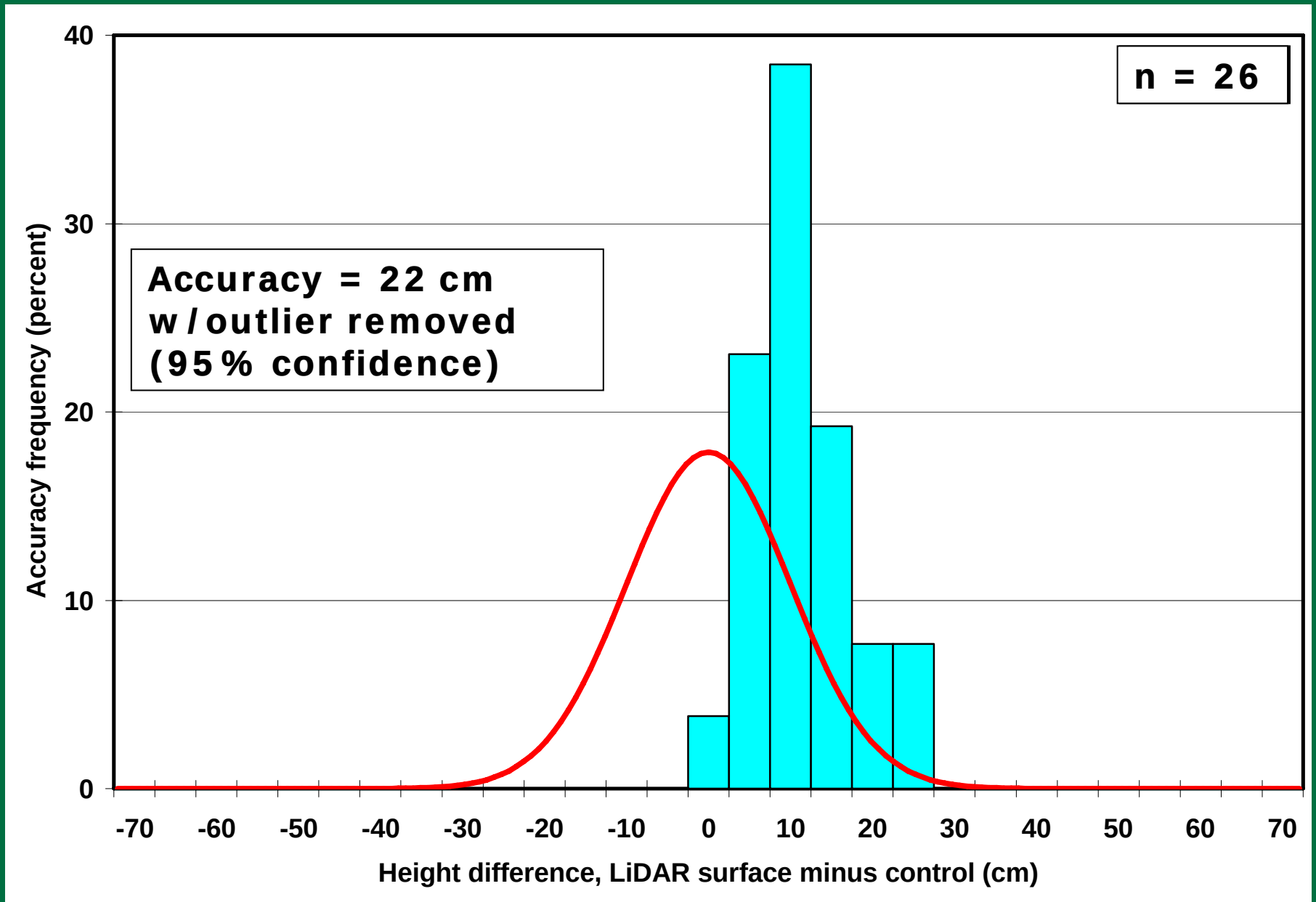
Vertical data accuracy assessment

Precision histogram (with outlier removed)



Vertical data accuracy assessment

Accuracy histogram (with outlier removed)



Some "accuracy" results to consider

(all from same airborne GPS photogrammetry & LiDAR data)

- Vertical "accuracy" computed as:
  - ±13 cm (linear precision at 68% confidence)
  - ±14 cm (95-percentile linear precision)
  - ±17 cm (linear error at 68% confidence)
  - ±24 cm (95-percentile linear accuracy)
  - ±33 cm **per NSSDA** (95% confidence)
  - ±13 cm (95% conf precision with outlier removed)
  - ±22 cm (95% conf accuracy with outlier removed)
- How do you deal with biased data?
- How do you deal with outliers?

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Limitations in NSSDA methods

- No requirement to plot error distribution
- No requirement to compute covariance in horizontal accuracy assessment
  - This necessary to compute error ellipse
  - Gives better indication of data uniformity
  - More rigorous, yet simple to compute
- Non-normal vertical errors
  - Commonly occur in LiDAR datasets
  - No restrictions on outlier removal

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Systematic errors

- Non-random
  - Must be removed or minimized
  - Compromises accuracy assessment
- Example: Determining “slope” using ellipsoid heights
  - Systematically differs from hydraulic slope
    - Difference accounted for in geoid heights
  - Total stations cannot measure change in ellipsoid height…
    - …unless deflection of the vertical is known

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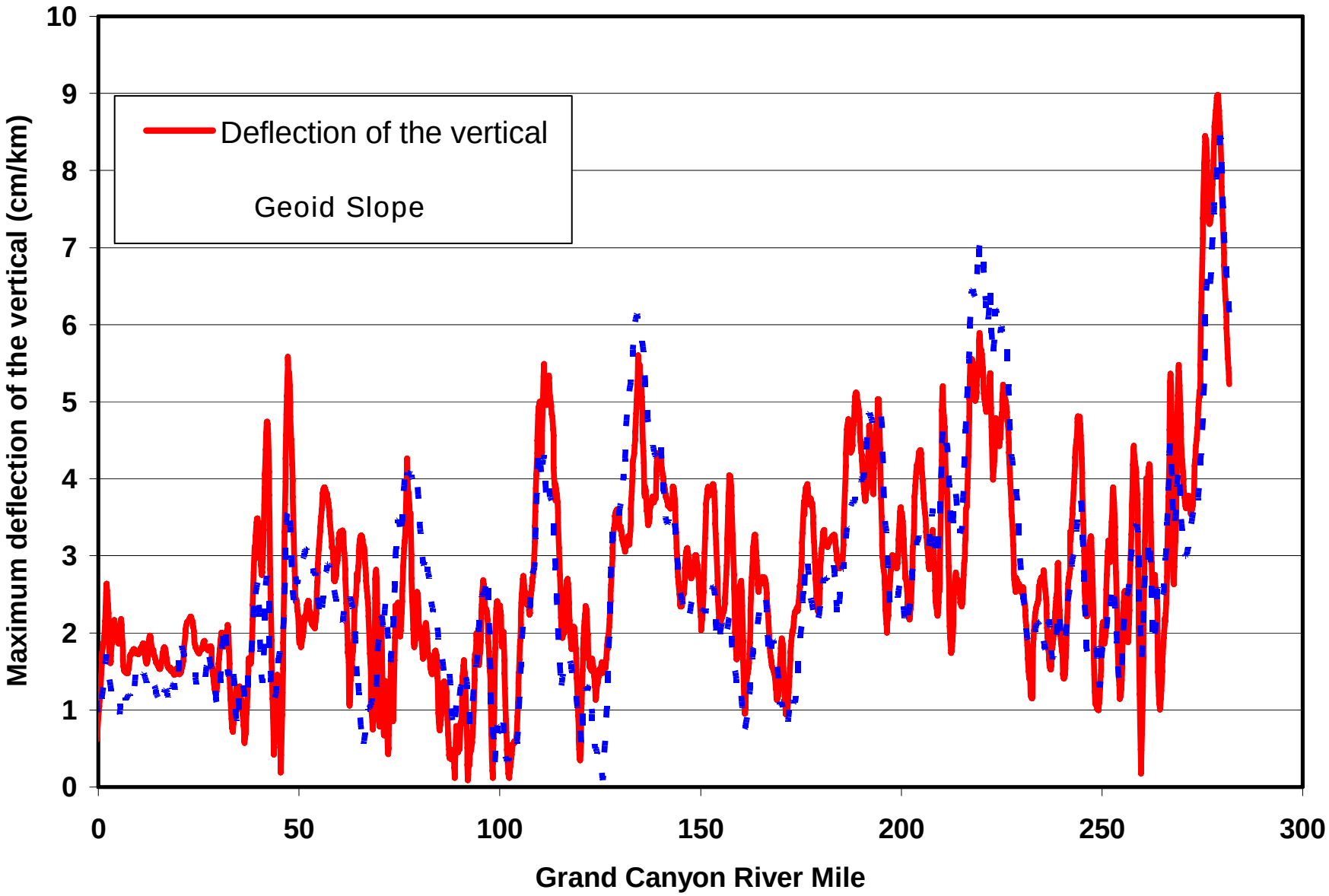
Systematic errors in ellipsoid height slope



Conclusions

- Spatial data *must* be evaluated for accuracy
  - Required by Executive Order for Federal spatial data
- Numerous ways to generate misleading accuracy estimates
  - Evaluating biased data (i.e., data w/systematic errors)
  - Providing results at a confidence level < 95%
  - Ignoring non-uniform and non-normal error distributions
  - Eliminate all (or many) outliers

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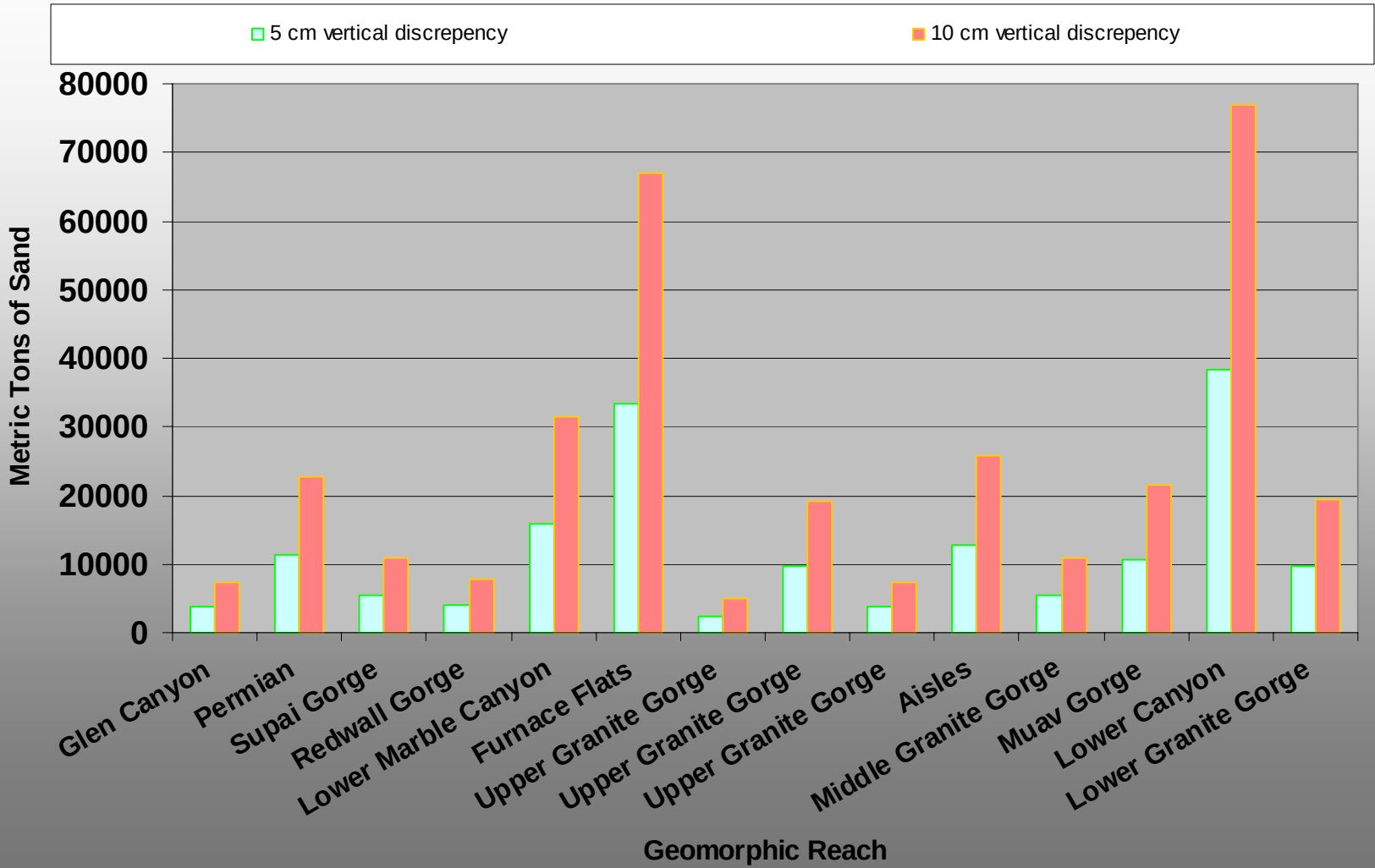
Vertical Discrepencies Vs Metric Tons of Sand



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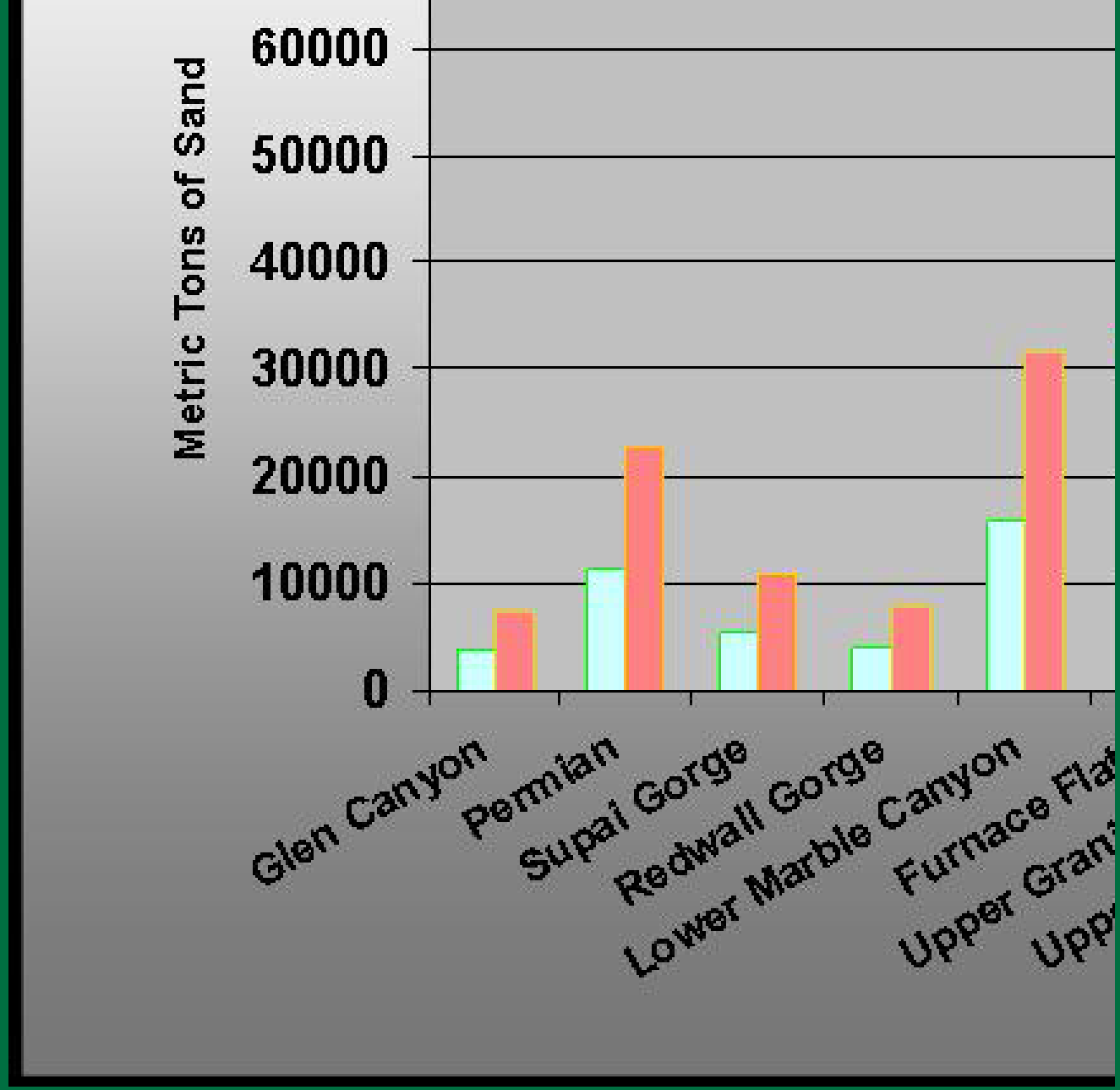
Metric Tons of Sand
60000
50000
40000
30000
20000
10000
0
Glen Canyon
Permian
Supai Gorge
Redwall Gorge
Lower Marble Canyon
Furnace Flat
Upper Granite

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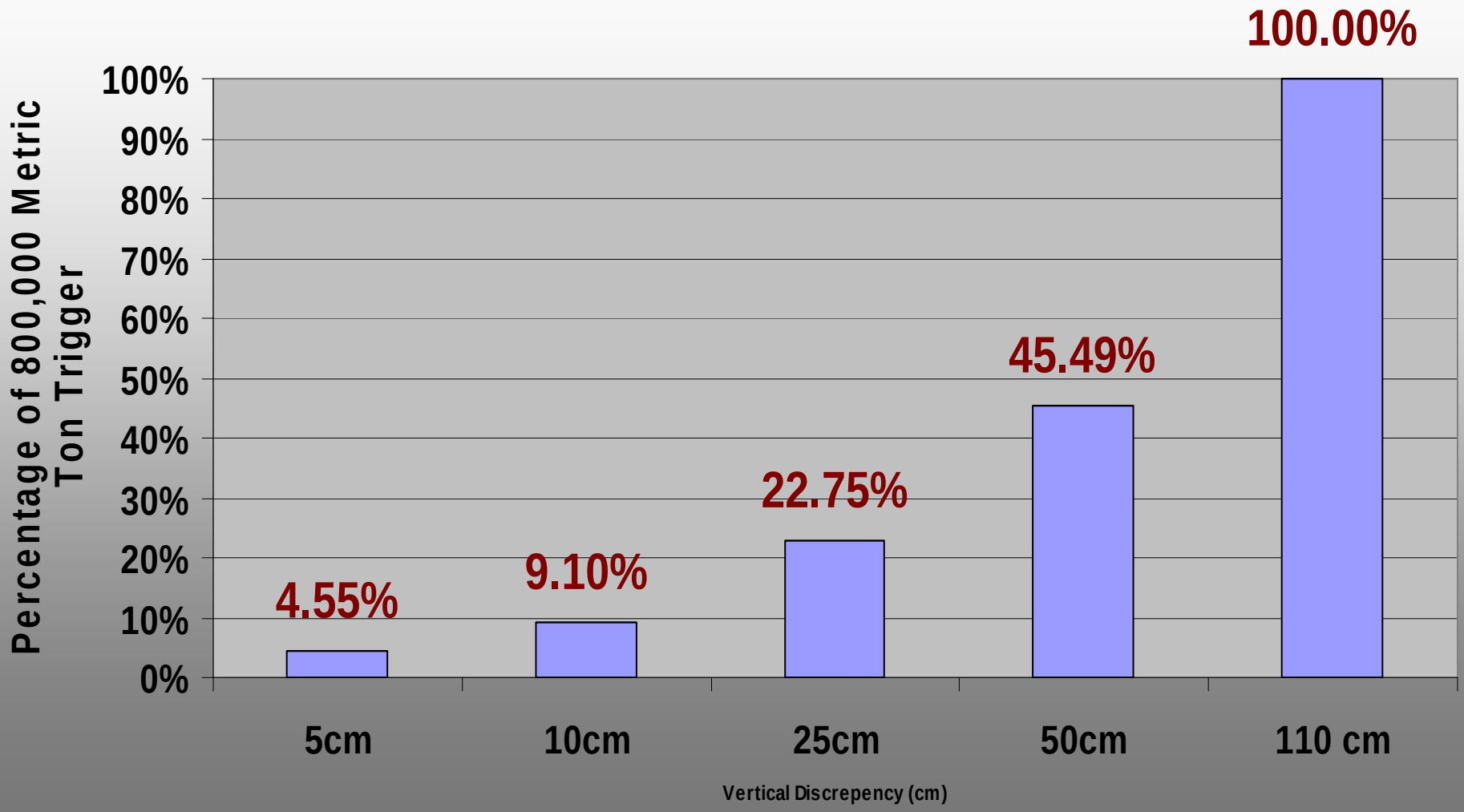
Percentage of Trigger Criteria Vs Vertical Discrepency (Marble Canyon)



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GCMRC_survey_control

Data format: Personal GeoDatabase Feature Class

File or table name: GCMRC_survey_control

Coordinate system: State Plane Coordinate System 1983

Theme keywords: Survey, Control, Network, Riparian

Abstract: This dataset represents locations of GCMRC's survey control network along th
(CRE) in Grand Canyon. These data are PROVISIONAL and should not be used for adjust
of existing data OR for the generation of new spatial datasets based on these values.

FGDC and ESRI Metadata:

- Identification Information
- Data Quality Information
- Spatial Data Organization Information
- Spatial Reference Information
- Entity and Attribute Information
- Distribution Information
- Metadata Reference Information
- Geoprocessing History

Metadata elements shown with blue text are defined in the Federal Geographic Data Committee's (
Digital Geospatial Metadata (CSDGM). Elements shown with green text are defined in the *ESRI Profile o*
with a green asterisk (*) will be automatically updated by ArcCatalog. ArcCatalog adds hints indicati
mandatory; these are shown with gray text.

Identification Information:

Citation:

Citation information:

Originators: Grand Canyon Monitoring and Research Center, Southwes
Geological Survey

***Title:**
GCMRC_survey_control

***File or table name:** GCMRC_survey_control

Data Quality Information:

Attribute accuracy:

Attribute accuracy report:

Prior to completion of the primary network adjustment, accuracy and precision for each subsequent level are estimated.

Logical consistency report:

Horizontal coordinates are referenced to 1983 Arizona State Plane Coordinate Central Zone 0202- defined as a Transverse Mercator projection (Latitude of grid origin, 31°00'00"N, Longitude of central meridian, 111° 55'00"W, False Northing = 0.000, False Easting = 213360.000). Vertical coordinates are referenced to NAD-83 (1992); GRS-80 ellipsoid. All coordinates are in meters. See www.ngs.noaa.gov

Completeness report:

The following coordinates are PRELIMINARY, and awaiting final results from a primary network adjustment. The National Geodetic Survey will validate local and network accuracies made possible through the National Spatial Reference System readjustment. Coordinates are of 3 types; SECONDARY, TERTIARY, UNKNOWN. These attributes are described below.

Positional accuracy:

Horizontal positional accuracy:

Horizontal positional accuracy report:

Horizontal coordinates are referenced to 1983 Arizona State Plane Coordinate Central Zone 0202- defined as a Transverse Mercator projection (Latitude of grid origin, 31°00'00"N, Longitude of central meridian, 111°55'00"W, False Northing = 0.000, False Easting = 213360.000).

Quantitative horizontal positional accuracy assessment:

Horizontal positional accuracy value: Secondary

Horizontal positional accuracy explanation:

Stations coordinates have been computed using static GPS survey methods, referencing the stations to Arizona Federal Base Network (FBN) stations, and subsequently projected into 1983-AZSPC. All calculations completed with Ashtech© SolutionsVer.2.60 then adjusted to NAD-83(1992) reference frame. Lack of antenna phase center height models, and unquantified sources and magnitude of multi-path errors are currently under review.

Horizontal Precision 0.05m
Horizontal Accuracy 0.10m

Quantitative horizontal positional accuracy assessment:

Horizontal positional accuracy value: Tertiary

Horizontal positional accuracy explanation:

Stations coordinates have been computed using least-squares adjustment practices within the AZSPC- planar projection. All calculations completed with Starnet©Ver6.0 by fixing conventional traverse measurements to the state plane projection of GPS results above.

Horizontal Precision 0.15m
Horizontal Accuracy 0.25m

Quantitative horizontal positional accuracy assessment:

Metadata – Metadata - Metadata!!!

Thanks to all for your Grand Canyon science efforts

USGS