Introduction

Intended as the first in a series of workshops related to LiDAR and allied analyses, “Basics of LiDAR” will serve as both a prerequisite and jumping-off-point for other topics:

- Terrain Analysis
- Hydrologic Applications
- Engineering
- Wetland Mapping
- Forest and Ecological Applications

Introductions - Logistics

Course Instructor – Joel Nelson
Workbooks
Breaks
Restrooms

Introduction – Course Development

Course Development

- Previous Training Sessions
- Collective experiences of collaborators
- LiDAR Use Surveys
  - Spring 2011
  - Spring 2012

Introduction – LiDAR Use Surveys

LiDAR Use Surveys

- Spring 2011
  - LiDAR very important
  - Third – Third – Third
- Spring 2012
  - Data types, delivery

Introductions – Student Intros

Around the Room
Students

- Who uses ArcGIS 10?
- Who uses LiDAR data currently?
- Who calculates products or does raster processing from LiDAR data?
Course Objectives

Lecture and Hands-on Format
- Raster Data
- What is LiDAR?
- LiDAR Products

Raster Data
- Less used today than the vector data model
- Raster environment and principles not as well understood
- Most users familiar with aerial photos or satellite imagery

Lecture 1 – Raster Data

About Raster Data

Raster Data

Structure/Model
- Regular set of cells in a grid pattern
- Typically square
- Attribute values associated with each location (cell)
- Models “continuous” data well

Key features
- Cell size
- Units

Raster Data Analysis - Advantages

- History
- Flexible
- Data structure
  - Wide range of variables
  - Simple to complex – single cell, networks, groups of cells
- Well-developed
  - Wide variety of applications
- Continuous Data – i.e. elevation
Raster Data Analysis – Disadvantages
- Precision limited to cell size
  - Tradeoff – higher resolution comes at greater storage cost and speed of processing
- “Stairstep” edges
- Often assigned a single “value” for a single attribute rather than a host of attributes per cell

Raster Data Analysis
- Basic to complex
- Mathematical (Map Algebra), neighborhood (moving window) distance, surface, statistical, etc.

Neighborhood Functions
- Moving window of cells swept across all raster cells, typically multiplying values by data found around center cell
- Very common in raster analysis
- Slope, hillshade, filter, and kriging calculations for example, all employ a moving-window approach

Working with Raster Data

Raster Data Analysis - Map Algebra
Map Algebra – Raster Calculator
- Raster layers combined via mathematical combinations
- Cell-by-cell – added, subtracted, divided, or multiplied

Variety of uses
- Change detection – e.g. year 2000 data subtracted from year 2010 data
- Terrain attributes – e.g. SPI – multiply effect of one variable by another

Working in the Raster Environment
- Raster = Grid
- File Structure
- Grid Alignment
- Resampling
- Aggregation
File Structure

Arc GRIDS are not single files
- Several folders with associated files
- Linked – cannot work independent of one another
- Use ArcCatalog to copy, move or rename
- Can export into variety of single file types - .img, .e00, etc.

Aggregate/Resample

- Changing the resolution (Upscaling) – if cells evenly divisible, use AGGREGATE
- If not evenly divisible or changing the alignment, then use RESAMPLE
- You can downscale, but this does not create any new information

Grid Alignment

Proper Grid Alignment = Snap Raster Settings

Snap Raster Setting
- The cells in the output raster are aligned with the cells of the snap raster.
- The lower-left corner of the extent is snapped to a cell corner of the snap raster.
- The output cell size is same as the snap raster cell size.

Elevation Data - DEMs

Resolution

Cell size should be same for all inputs
If not →
- Nearest neighbor resampling automatically occurs
- Resampled to coarsest resolution of all inputs
- Esp. not recommended for continuous data – i.e. Elevation

Raster Elevation Data Sources

- Stereo photography
- Topographic maps (elevation contours)
- Ground survey (GPS, other)
- LiDAR
**Stereo Photography**
- View shape of topographic surface
- Overlapping photographs
- View from two perspectives (parallax)
- Old technology – has been used extensively in Soil Survey and forestry

**LiDAR**
- Aerial Survey
- Large (county-sized) or small areas
- Large areas processing-intensive
- Provides multiple formats and data-types from original data
- Very precise – not as precise as Survey

**Topographic/Contour Data**
- Also called contour maps
- Contour line joins points of equal elevation
- Can interpret slope, relief, shape/size of valleys and hills
- Paper and digital
  - Digital leaves visualization up to the user

**Raster Elevation Data Formats**
**Models of Topography**
- Multiple ways of representing elevation
  - Triangulated irregular network
  - Contours (Vector)
  - Digital elevation model (Raster)

Each has advantages and disadvantages

DEM is used most often for terrain analysis and watershed delineation

**Survey**
- GPS survey or Total Station
- Small areas
- Labor intensive
- Very precise

**Digital Elevation Model (DEM)**
**What is a DEM?**
- Digital file that:
  - Contains elevation of terrain over a specified area
  - Is arranged as a fixed-grid interval over the earth surface
  - Is geo-referenced
  - Can be manipulated to create other elevation-dependent data products
Digital Elevation Model (DEM)

- Consists of pixels or cells
- Value assigned represents average elevation of grid cell

DEM - Fast and Flexible

- Raster Pyramids - Fast Display
- Discrete or Continuous - Multiple Outputs

DEMs are a common way of representing elevation where every grid cell is given an elevation value. This allows for very rapid processing and supports a wide-array of analyses.

Effect of Cell Size - Resolution

- Coarse Resolution
- Fine Resolution

DEM Comparison

Why so much interest in LIDAR?
- Higher resolution data than we ever thought possible
- Opens up opportunities to describe and characterize landscapes in ways previously not feasible

Comparison to existing national standard product

<table>
<thead>
<tr>
<th></th>
<th>USGS DEM</th>
<th>LIDAR DEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal Resolution</td>
<td>30 meters</td>
<td>1 meter</td>
</tr>
<tr>
<td>Vertical Resolution</td>
<td>7-15 meters</td>
<td>~15 cm</td>
</tr>
<tr>
<td>Contour Interval</td>
<td>5-20 feet</td>
<td>1-3 feet</td>
</tr>
</tbody>
</table>
DEM Resolution Tradeoff
Lower resolution = faster processing
Higher resolution = more precision, maintains small features

Coarse to Fine

DEM Comparison
USGS 30m DEM  LiDAR 3m DEM

LiDAR Derived DEM
Cell Size: 1 meter sq
Vertical Error: 15 cm
1.5 mil points / sq mile

USGS Standard DEM
Cell Size: 30 meter sq
Vertical Error: "Equal to or better than 15 m." 
1600 points / sq mile

1 Varies based on project specifications
2 http://edc.usgs.gov/guides/dem.html

Credit – Tim Loesch - MNDNR
Hillshade DEM
3m vs 30m

Contour Comparison – Vector Product
2 ft contours created from LIDAR data
10 ft contours created from standard 30m DEM data

End of Lecture 1
Questions/Comments?

Lecture 2 – What is LiDAR?

LiDAR
What is LiDAR?
• Light Detection And Ranging – a remote sensing system used to collect topographic data
• Produces high-resolution, accurate, land-elevation information

LiDAR
How is LiDAR data collected?
Airborne survey:
• Covers the surface with multiple discrete laser pulses
  • Up to 150,000 per second
• Collects the returns
  Time = distance + GPS = Location

Credit – ESRI

LiDAR
What is LiDAR?

Credit – ESRI
LiDAR Survey Equipment

**Light Detection and Ranging**
- Laser Rangefinder
- IMU (INS)
- GPS
- On board computer

Produces accurate land elevation data

**LiDAR Survey Equipment**

Global Positioning System (GPS)
- Differentially corrected
- Provides cm accuracy of aircraft
- Allows cm accuracy of laser pulse

**LiDAR Survey Equipment**

Laser Rangefinder
- Records distance to target
  - Time * c / 2
- Wavelengths differ
  - 1064 nm
- Various scan rates

**LiDAR Survey Equipment**

Inertial Measurement Unit (IMU)
- Gyroscopes and accelerometer
- Records roll, pitch, yaw of aircraft
- .005 degree pitch & roll
- .008 degree heading

**LiDAR Survey Equipment**

On board computer
- Records data
  - Laser distance and intensity
  - IMU info
  - GPS info
- Converts into
  - X, Y, Z
  - Millions of points
  - On-board display

**LiDAR Data Resolution**

Based on collection density
- 1 point/meter to 8 points/meter with ground control point validation
- Supports 2 foot contours to sub 1-foot contours depending on collect

Credit – NASA

Credit - USGS

Credit - USGS

www.esri.com/library/userconf/proc00/professional/papers/Pap808/p808.htm
LiDAR Products

- End-product is accurate, with geographically registered longitude, latitude, and elevation \((x,y,z)\) for every data point
- Several file types and derivative products available to end-users
- LAS point cloud, DEM, contours, hydrologic breaklines

LiDAR Data Collection

LiDAR Returns: Multiple discrete return pulses
LiDAR Intensity: Magnitude or strength-of-return pulse
Metadata: Information about how data was collected—READ IT!

All returns can be used
- Forest canopy
- Intensity image
- Vegetation mapping

LiDAR Products

Returns

Single Return

Multiple returns

Waveform

Returns

LiDAR Data Collection

Returns

Single Return

Multiple returns

Waveform

Returns

Returns

Single Return

Multiple returns

Waveform

Returns
Intensity

- Intensity = amount of energy reflected for each return
- Different surfaces reflect differently based on wavelength of laser
- Example at 1064nm (NIR), water absorbs, vegetation highly reflective
- Can be used to build black and white near-IR images

Minnesota Mapping Initiative

Several unsuccessful attempts to secure funding at the state level
Worked with counties to ensure consistent data
- Technical advice and assistance
- Standards and accuracy

MN LiDAR Data

Clean Water Fund of the Legacy Amendment
- Citizens of the state have invested in Water Quality
- High Resolution Elevation data can be used for all future water quality projects
Secured $5.6 million in funding
- Funds in Division of Ecological Resources/Waters
- Project led by Management Resources/MIS

Multi-Government Partnership

- USGS, EPS
  - Technical Advice
  - Potential funding opportunities
- MnDOT, MnDNR, MnGEO
  - GIS technical expertise
  - Project management
  - Survey and Validation Coordination
  - Data Coordination
- County and Local Governments
  - Survey Points and Data validation
Statewide LiDAR Coordination and Collaboration

Two committees are tasked with LiDAR data development, management, and deployment

1. MN Digital Elevation Committee
   - http://www.mngeo.state.mn.us/committee/elevation

2. MN Digital Elevation Committee - Research and Education Subcommittee
   - http://www.mngeo.state.mn.us/committee/elevation/research_education
   - Mission Statement:
     - Design and promote best practices with LiDAR data for Minnesota
     - Ensure there is consistency in data development, application, and training.
   - Training:
     - Course Planning and Design
     - Survey

LiDAR Acquisition

Standards
- Defined by the MN Digital Elevation Committee
- Based on the recent USGS Base LiDAR Specification.
  - <=15 centimeter RMSEz.
  - 2-foot vertical accuracy (95% confidence).
  - 1-meter horizontal accuracy.

Coordinate system
- UTM Zone 15, NAD83 horizontal datum.
- NAVD88 vertical datum Vertical units in meters.

LiDAR Classification and Accuracy Assessment

LiDAR Classification
- Point Classification
  - Points are processed to determine what they bounced off of
    - Bare Earth
    - Buildings
    - Cars and other anthropomorphic things
    - Bridge decks
    - Vegetation (High, Medium, and Low)
    - Water
  - ASPRS has developed a set of standard classifications for LiDAR derived data

Credit – Tim Loesch - MNDNR
LiDAR Classification

Point Classification
- Automated Classification
  - Can identify features with 70-74% accuracy
- Manual Classification
  - Needed to get higher accuracies
  - Typically done with Air Photos and other sources of data
  - Typically the most time consuming portion of any project and the most likely to be farmed overseas

MN LiDAR Data Validation

Vertical Accuracy QA/QC
- Purpose:
  - Data Validation – we got what we bought
  - Data Integrity – we want people to trust the data
- Compare LiDAR elevations with Surveyed Points
  - 100 surveyed validation points per county
  - 20 points in each of 5 cover categories
  - Help from county surveyors

Error and Accuracy

Comparison of NDDSA and NMAS

<table>
<thead>
<tr>
<th>NMAS Contour Interval Equivalent</th>
<th>NDDSA RMSE (z)</th>
<th>NDDSA Accuracy (z²)</th>
<th>Required Accuracy for Tested Data for “Tested to Meet”</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.15 ft or 4.60 cm</td>
<td>0.30 ft or 9.10 cm</td>
<td>0.10 ft</td>
</tr>
<tr>
<td>1</td>
<td>0.30 ft or 9.25 cm</td>
<td>0.60 ft or 18.2 cm</td>
<td>0.20 ft</td>
</tr>
<tr>
<td>2</td>
<td>0.61 ft or 18.5 cm</td>
<td>1.19 ft or 36.3 cm</td>
<td>0.40 ft</td>
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<tr>
<td>4</td>
<td>1.22 ft or 37.6 cm</td>
<td>2.38 ft or 72.6 cm</td>
<td>0.70 ft</td>
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<tr>
<td>5</td>
<td>1.52 ft or 46.3 cm</td>
<td>2.98 ft or 90.8 cm</td>
<td>0.99 ft</td>
</tr>
<tr>
<td>10</td>
<td>3.04 ft or 92.7 cm</td>
<td>5.96 ft or 181.6 cm</td>
<td>1.98 ft</td>
</tr>
</tbody>
</table>

Types of Accuracy
- Validation Points
  - Level ground away from breaks in topography
  - Open, visible sky
- Five cover classes – 20 points per class (30 preferred)
  - L1O – Open terrain
  - L2T – Tall Grass
  - L3B – Brush
  - L4F – Forested
  - L5U – Urban

Error and Accuracy

What’s the value of your data?
How is accuracy measured?
- National Standard for Spatial Data Accuracy (NSSDA)
  - Addresses accuracy of the product at ground scale
  - Squared Root Mean Square Error (RMSE²)
- National Map Accuracy Standard (NMAS)
  - Accuracy based on Contour Interval at published map scale

Error and Accuracy

Types of Accuracy
- Fundamental Accuracy = Best Case Scenario
  - Open terrain tested to 95% accuracy
- Supplemental Accuracy
  - Accuracy for Cover Classes other than Open terrain
- Consolidated Accuracy
  - All Cover Class Accuracies Combined
Error and Accuracy

LiDAR points Interpolated Value 372.115
- Observe Interpolated value vs. Actual (Surveyed Point)

Error and Accuracy...

- Report Summary
  
<table>
<thead>
<tr>
<th>Name</th>
<th>Control X</th>
<th>Control Y</th>
<th>Control Z</th>
<th>Surface Z Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1O0</td>
<td>604760.340</td>
<td>4878787.629</td>
<td>201.217</td>
<td>201.389</td>
</tr>
<tr>
<td>L1O1</td>
<td>608921.294</td>
<td>4878065.350</td>
<td>201.488</td>
<td>201.806</td>
</tr>
<tr>
<td>L1O2</td>
<td>610991.353</td>
<td>4876621.369</td>
<td>200.214</td>
<td>200.397</td>
</tr>
<tr>
<td>L1O3</td>
<td>607292.402</td>
<td>4874401.804</td>
<td>233.428</td>
<td>233.606</td>
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<tr>
<td>L1O4</td>
<td>622397.772</td>
<td>4873262.387</td>
<td>207.292</td>
<td>207.356</td>
</tr>
<tr>
<td>L1O5</td>
<td>626922.206</td>
<td>4869248.810</td>
<td>202.936</td>
<td>202.969</td>
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<tr>
<td>L1O6</td>
<td>631669.497</td>
<td>4863815.331</td>
<td>200.254</td>
<td>200.333</td>
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<tr>
<td>L1O7</td>
<td>635439.901</td>
<td>4857649.190</td>
<td>375.011</td>
<td>375.070</td>
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<td>L1O8</td>
<td>625518.897</td>
<td>4864620.123</td>
<td>385.756</td>
<td>385.722</td>
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<tr>
<td>L2T9</td>
<td>621174.012</td>
<td>4864494.226</td>
<td>388.359</td>
<td>388.470</td>
</tr>
<tr>
<td>L2T10</td>
<td>620283.975</td>
<td>4857065.579</td>
<td>386.810</td>
<td>387.048</td>
</tr>
</tbody>
</table>

LiDAR Project Activities

- Winona County Validation Report

Error and Accuracy...

- RMSE Calculations
  - \( \text{RMSE}_{(z)} = \sqrt{\text{sum}(Z_{\text{data}(i)} - Z_{\text{check}(i)})^2 / n} \)
  
  - Vertical Accuracy 95% Rate = 1.96 * \( \text{RMSE}^2 \)

LiDAR Project Activities

- Winona County Validation Report

Error and Accuracy...

- Vertical Error Distribution

Credit – Tim Loesch - MNDNR
Accuracy and What it Means...

National Accuracy Standards Specifications

- USGS Base LiDAR Specifications V13
- NDEP Guidelines For Digital Elevation Data

LiDAR System Limitations

- Cannot penetrate:
  - Water (near-infrared Lasers)
  - Heavy canopy cover
  - Rain, snow, clouds
- Limited window of opportunity to collect
  - Vegetation and snow free periods in the spring and fall
  - Flooding is bad too!
  - High winds hinder collection

Potential LiDAR Applications

Water Resources
  - Floodplain mapping
  - Storm water management
  - Drainage basin delineation
  - Shoreline erosion

Geology
  - Sinkhole identification
  - Geologic/geomorphic mapping

Transportation
  - Road and culvert design
  - Cut and fill estimation
  - Archaeological site identification

Agriculture
  - Erosion control structure design
  - Soils mapping
  - Precision farming

Water Quality
  - Watershed modeling
  - Wetland reconstruction
  - Land cover/land use mapping

Forestry
  - Forest characterization
  - Fire fuel mapping

Fish and Wildlife Management
  - Drainage and water control
  - Walk-in Accessibility

Habitat Management

Emergency Management
  - Debris removal
  - Hazard Mitigation

End of Lecture 2
Questions/Comments?
LIDAR – Emergency Management

- How much debris and where?
- Volume cut/fill statistics
- Aid Debris Removal

LIDAR

- September 2004 – Post-Ivan

LIDAR

- August 31st, 2005 – Post-Katrina

LIDAR

- May 2004 – Pre-Ivan

LIDAR
Bare Earth, Vegetative, and Structural Applications

Bare Earth Analysis

- Buildings and trees removed
- Automatic and manual filtering
- Shows bare earth surface DEM
- Provides elevation “base layer” for further calculations

Bare Earth –
Top: Digital Surface Model (DSM)
Bottom: Digital Elevation Model (DEM)

Bare Earth – Example of Removing Artifacts
Initial Bare Earth Surface from LiDAR

4/1/2015 MN GIS/LIS Fall Workshops Slide courtesy of Sanborn
Bare Earth – Contours - Initial Bare Earth Surface

Bare Earth – Contours - Filtered Bare Earth Surface

Terrain Analysis
Model real landscape processes
Utilize base layer DEM

Hydrologic Modeling
- Identify appropriate water conveyance
- Watersheds

Vegetation – Canopy Height

Vegetation - Hillside with deciduous vegetation
Vegetation - Profile of points

- Deciduous
- Coniferous

Credit – Tim Loesch - MNDNR

First Return Digital Surface Model (DSM)

Bare Earth DEM
(no vegetation or buildings)

Length of live crown
Crown base height

Structures - Lidar Point Cloud

Difference Image
- height of buildings and trees

Credit – Tim Loesch - MNDNR
Hardware and Software

Hardware - Getting Ready for LiDAR
- Bigger is better
- Workstations
  - Duo or Quad Core
  - > 3.0ghz
  - > 4Gb RAM, more is better
  - 256 RAM Display OPEN GL
- High Speed disks – storage is cheap
- External hard drive for backup

Software
- ArcGIS, Whitebox, Saga, IDRISI, Open Source GIS viewers
- ArcHydro
- TauDEM
- LAS Reader
  - LiDAR Analyst, LP360, etc
  - Stand-Alone Programs
    - MARS
- AutoCAD
- Civil 3D
- Stand-Alone Viewers (free)
  - Qcoherent (www.qcoherent.com)
  - Fugro EarthData (www.fugroviewer.com)
  - Sanborn (http://www.sanborn.com/technologies/lidar.asp)

Software – Training Purposes
ESRI – ArcGIS
- Spatial Analyst
  - Hydrologic modeling
  - Raster analysis
- 3D Analyst (ArcScene, ArcGlobe)
  - Cut/Fill
  - Line of Sight
  - 3D Perspective

Spatial Analyst
ESRI Extension – Additional cost
- Fairly robust set of general raster processing tools
  - Surface (Slope, Curvature)
  - Reclassify
  - Zonal Statistics
  - Conditional
  - Neighborhood
  - Raster Calculator
- Some specialized tools
  - Hydrology
  - Groundwater

3D Analyst
- ESRI Extension – Additional cost
- Specifically designed for elevation data
- 3D visualization
- Creating & working with TINs
- Cross-section tool
ArcHydro
- Free Extension for ArcGIS (Maidment)
- Suite of tools for geospatial hydrology
- Semi-complicated install
- Terrain analysis focused on stream and watershed delineation
- Tools for analyzing sinks and reconditioning DEM
- AGRE

Saga GIS
- Free stand alone program
- Open source
- Very robust suite of terrain analysis and hydrology tools
- D-infinity Flow Routing, as well as upslope area ID
- Proprietary File Format
  - Can be difficult to use in conjunction with ArcGIS

Tau DEM
- Free toolbox for ArcGIS 9.3 (Tarboton)
- Easy install
- Specialized terrain analysis tools focused on stream and watershed delineation
- Tools not found in the standard ArcGIS extensions or ArcHydro
- D-infinity flow direction

Whitebox GAT
- Free stand alone program (Lindsay)
- Open source
- Fairly robust suite of terrain analysis tools
- Handles LAS data (LiDAR)
- Many hydrologic analyses
- Uses Python as native language
- Proprietary File Format
  - Can be difficult to use in conjunction with ArcGIS

LiDAR Representations

Point Cloud/LAS
Raster – DEM
Vector – Contours
Triangulated Irregular Network (TIN)
Terrain
Point Cloud/LAS Files

LAS – Common LiDAR Data Exchange Format
- Industry Standard
  - Easily transferred from system to system
  - Less volume and more easily transferred than ASCII
- Retains flight information and instrument parameters
  - GPS, IMU, Laser Pulse Range
- Current version is LAS 1.1 (5/05)
  - 1.2 has been proposed and in final review
  - 2.0 has been proposed


Point Cloud/LAS Files

LAS files
- Stores a variety of point information
  - Number of returns
  - Return Number
  - Intensity
  - X,Y, Z values
  - Scan Direction
  - Classification
  - Scan Angle Rank
  - GPS Time

LAZ files = Compressed LAS files

LAS Files

- Source data for other products
- Can be manipulated to represent elevation as well

LiDAR Representations

Point Cloud/LAS
- Raster – DEM
- Vector – Contours
- Triangulated Irregular Network (TIN)
- Terrain

Bare Earth Filtering

Bare Earth vs. First Return

LiDAR Representations
Digital Elevation Model

DEM Creation
- Interpolation process
- Derived from source files (LAS)

LiDAR Representations

Point Cloud/LAS
Raster – DEM
Vector – Contours
Triangulated Irregular Network (TIN)
Terrain

LiDAR Representations

Point Cloud/LAS
Raster – DEM
Vector – Contours
Triangulated Irregular Network (TIN)
Terrain

TIN Triangles Hillshaded and Colored by Elevation

Vector Contours

Contour Creation
- Interpolation process
- Derived from source files (LAS)

TIN – With Breakline enforcement
LiDAR Representations

Point Cloud/LAS
Raster – DEM
Vector – Contours
Triangulated Irregular Network (TIN)

Terrain Data Structure

- Data structure specific to elevation data
- TIN model represents surfaces
- Terrains use pyramids to represent multiple levels of resolution
- Data Inputs
  - Mass Points – TIN
  - Breaklines
- Data Outputs
  - TINS
  - Rasters

LiDAR Additional Products

Breaklines

- Breaklines identify changes in landscape elevation
  - Too small or continuous to be reliably recorded with LiDAR
  - Stream banks, curbs, centerlines, water/land interface
  - Used to influence interpolation for contours
  - Can help enforce stream and lake elevations

Generated from
- Air Photos
- LiDARGrammetry

LiDARGrammetry

- Classify points by intensity
- Trace around water intensity values to create a contour
MN LiDAR Data Delivery

What Data Do People Use?

- Primary use products
  - Raster Digital Elevation Model
  - Contours
- Most consumers don’t bother with the raw LiDAR data
  - Not a lot of tools available but this list is growing
  - ArcGIS extensions are now available to read LAS format LiDAR data
- Derived products from LiDAR is a growing research field

MN LiDAR FTP Data Delivery Format

Things to know…

- Use third party FTP Software - Filezilla
- Know what you want before you download
- Interactive web download page coming in near future
- RTM – Read the Manual!
  - Several helpful Readmes

MN LiDAR Interactive Data Delivery Format - NEW

- Multi-view
- Air Photos
- Streets
- Terrain
- AOI Download
- Mobile App?
Visualization

Lidar data can be visualized in a number of ways:
- Shaded Relief images can reveal very subtle relief
  - Especially with high detail data
  - Helpful for data validation and looking for anomalies and errors in the data
- 3-Dimensional viewing
- Cross-sections
- Contour generation
- Triangulated Irregular Networks (TIN)

Visualization - Interactive

Great templates/ideas available on web-based viewer
Visualization – Natural Features

Natural Features
- Watercourses
- Floodplains
- Glacial Geology

2006 color NAIP airphoto

Sinkhole

Sinkhole – Cross-section
Visualization – Manmade Features

Manmade Features – Angular, linear, continuous

- Hydrologic manipulation
- Mining
- Transportation
- Utilities
- Structures
Credits/Acknowledgements

- Tim Loesch – MN Dept. of Natural Resources
- Sean Vaughn – MN Dept. of Natural Resources
- Steve Kloiber – MN Dept. of Natural Resources
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- Dr. Jay Bell – University of Minnesota
- Ann Lewandowski – University of Minnesota
- Les Everett – University of Minnesota