National Elevation Dataset

Gayla Evans
U.S. Geological Survey
Earth Resources Observation and Science (EROS) Center
47914 252nd Street, Sioux Falls, SD 57198
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The National Elevation Dataset (NED)

- Seamless national coverage of “best available” raster elevation data
  - Geographic “projection”
  - 1-arc-second (30-meter), 1/3-arc-second (10-meter), and 1/9-arc-second (3-meter) grid spacing
    - Alaska: 2-arc-second grid spacing
  - Datum: NAD 83 horizontal; NAVD 88 vertical
  - Elevation units: decimal meters
  - Updated bi-monthly to incorporate all new USGS DEM production and other newly available source data

- NED is the elevation layer of *The National Map*
Large-Area Elevation Data Coverage

- **7.5-minute quadrangle tiled database**
  - Nearly 54,000 quad-based DEMs
  - Projected in 10 different UTM zones
  - Production artifacts (stripes), slivers of missing data, elevation value mismatches along quad boundaries
  - Metadata in individual files

- **The National Elevation Dataset (NED)**
  - Seamless raster mosaic
  - Consistent national coordinate system
  - Standardized datums and units
  - Filtered and edge-matched, where necessary
  - Spatially referenced metadata
<table>
<thead>
<tr>
<th>Area</th>
<th>Format</th>
<th>Projection</th>
<th>Elevation Units</th>
<th>Metadata?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Louisiana</td>
<td>5-m DEM (raster)</td>
<td>UTM</td>
<td>Feet</td>
<td>Yes</td>
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<tr>
<td>Hancock Co., Mississippi</td>
<td>LAS binary (points)</td>
<td>MS State Plane (m)</td>
<td>Feet</td>
<td>Yes</td>
</tr>
<tr>
<td>Harrison Co., Mississippi</td>
<td>ASCII XYZ (points)</td>
<td>MS State Plane (ft)</td>
<td>Meters</td>
<td>No</td>
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<tr>
<td>Jackson Co., Mississippi</td>
<td>LAS binary (points)</td>
<td>MS State Plane (m)</td>
<td>Feet</td>
<td>Yes</td>
</tr>
<tr>
<td>Mobile Co., Alabama</td>
<td>LAS binary (points)</td>
<td>AL State Plane (ft)</td>
<td>Feet</td>
<td>Partial</td>
</tr>
<tr>
<td>Baldwin Co., Alabama</td>
<td>Shapefile (MPBL)</td>
<td>AL State Plane (ft)</td>
<td>Meters</td>
<td>Partial</td>
</tr>
</tbody>
</table>
NED 1-arc-second
1-arc-second layer is approximately 30 meter resolution

- Processed as 1 degree titles and merged into a seamless mosaic
- Covers Conterminous U.S., Hawaii, small areas of Alaska, Territorial Islands of the US and Mexico
- Many applications are more suited for the 1-arc-second layer
  - Smaller size
  - Faster to download and process
- Relatively low cost to prepare and store
- Makes possible an inexpensive seamless continental view of North America
- Entire country of Mexico was added in 2009
- Negotiations are underway for the possible inclusion of part of Canada
NED 1/3-arc-second layer is approximately 10 meter resolution and is often referred to as 10 meter NED.

- Processed as 1 degree tiles
- Merged into two part seamless mosaic
- Covers conterminous US, Hawaii, and small areas of Alaska and the Territorial Islands
- 90% is 10 meter or better source
- High resolution or 1/9-arc-second data or approximately 3 meters dataset
  - Mostly of lidar source
  - Processed on a project basis and edge compared with other projects
  - Inserted into ArcSDE as areas or projects rather than one or two mosaics
  - Covers about 10% of the contiguous US
- 2-Arc-Second Resolution Approximately 60 meters
- The best available source for Alaska
- No update of 2-arc-second data
- Improvement through migration of higher resolution data
Possible NED 1/27-arc-second layer

- Much of the lidar source data would support a 27\textsuperscript{th} or approximately 1 meter dataset
- Customers are asking for it
- Present NED model was developed for the 1-arc-second and is being stretched by the NED 1/9 processing and is not appropriate the NED 1/27\textsuperscript{th} layer
- Storage for 1-arc-second layer of the contiguous US is about 45 GB for 1/27 would be about 33,000 GB
- Benefits of being uniform (standard projection and resolution) may be outweighed the possibility of data corruption at this high of resolution
- Research would be beneficial to determine pros and cons
NED 1/27-arc-second

- **Short term solution possibility:**
  - Load and serve this data in the original projection and resolution as a special collection

- **Forward looking possibility:**
  - Cloud Computing would be a better platform for future growth
Cloud Computing for National Lidar

- Flexible storage and processing solutions
- Direct access to ALL lidar source data
- Allow for customizable derivative creation from the source data on the fly
- Source data is read only & certified by USGS and partners
Create customized analysis-ready derivative model solutions on the fly, such as:

- Customized rasters with different resolutions, parameters
- Projection on the fly
- Slope and Aspect Grids
- Flow Direction Grids
- Flow Accumulation Grids
- Synthetic Flow Channels
- Canopy Height Models
- Canopy Density Models
- Height to Live Crown Models
- Intensity images
- Be flexible enough to allow for data innovations and partner ‘plug-in’ models to directly access all the source data
- Want your lidar processed a certain way?
- There’s an app for that
- * Corresponding fees may apply
- Based on ‘certified’ USGS point cloud source data
- Many opportunities to collaborate GEON, NRCS, GOOGLE, ESRI and USGS wide

3rd party Analysis algorithms

National Lidar
Migration of the NED Source Data

- Resampling higher resolution data and merging it into the lower resolution datasets
- This has been an automatic process as the 10 meter source has been included into the NED replacing the 30 meter source
- The NED 1 and 1/3 datasets are kept in sync having identical source data used to prepare them
- Originally there was a similar assumption for the inclusion of the higher resolution source data
Importance of improving the NED layers

30 meters Source

10 meters Source

1 meters Source
Elevation – 30m, 10m, & 1m
Higher resolution source migration

1-arc-second (30 meters)
1/3-arc-second (10 meters)
1/9-arc-second (3 meters)
Migration Continued:

- Unfortunately, the consistency of the high resolution datasets has not stabilized.
- Many of the high resolution datasets received are very useful for specific applications.
- However, the dataset may not meet the NED criteria to which the 1 and 1/3 layers are held to:
  - Flattened water bodies
  - Properly bare-earthed surface
  - Good resampling and minimal seam lines
  - Minimal TIN artifacts
Migration Continued:

- The National Elevation Team through the weekly telecons altered the migration policy
  - Higher resolution source datasets which do not meet the criteria of the NED 1 and 1/3 layers but support the NED 1/9 resolution and are the best available for that resolution will be accepted into the NED 1/9 layer
  - Datasets not meeting the criteria of NED 1 and 1/3 layers will not be migrated
  - Reasons for migration rejection of a dataset and example graphics of the issues are captured for future reference
  - New spatial metadata fields have been developed to support this change
The Traditional Topographic DEM

- Before lidar, DEMs were most recently created through stereo photogrammetry.
- In this method, 3D breaklines were generated along the banks of water bodies.
- The resulting DEMs therefore had “flat” water bodies.
- Bridges (raised spans) were not included in the DEMs because they are not the ground.
- Road fills over culverts WERE included in the DEM because they are on the ground.
- Depresssions (sinks) were mapped, like everything else.

- This is a traditional TOPOGRAPHIC DEM
Lidar DEMs

- Lidar does not inherently include breaklines
- Water bodies have uneven TIN’d surfaces
- Stream channels may contain elevation irregularities
- Bridges are usually removed during processing

- This is also a topographic DEM, though not of the same character of a photogrammetrically-derived DEM

- NED customers have expressed dissatisfaction with the appearance of lidar-only DEM surfaces.
Hydro-Flattened DEMs

- Hydro-flattening modifies lidar-only DEMs to resemble traditional photogrammetric DEMs
  - Water bodies are flat
  - Wide streams and rivers are flat bank-to-bank and follow downhill gradient
  - Bridge spans are removed
  - Road fills over culverts remain
Hydro-Flattening Examples

Lidar only

Hydro-flattened Lidar
Hydro-Flattening Examples

Lidar only

Hydro-flattened Lidar
Hydro-Flattened Examples

These examples show topographic handing of the road fills over culverts. This DEM is NOT hydro-enforced.
Hydro-Enforced DEMs

- In 2001 for the NC Floodplain Mapping Project, Watershed Concepts had their lidar subcontractor EarthData, develop “breaklines” (preferred term is “hydro-lines”) to support their modelling efforts

- The hydro-lines flattened water bodies, imposed smooth gradients on wider rivers, and forced streams to flow downhill.

- Hydro-lines forculverts were uniquely attributed so they could be included or excluded during DEM development.
  - If excluded, the resulting surface was a TOPOGRAPHIC DEM
  - If included, the resulting surface was a HYDROLOGIC DEM

- Most current hydro-enforced DEMs do not distinguish culvert segments from open channels
  - → Ground elevations are removed above culverts to allow the surface to reflect continuous water flow.
Hydro-Enforced Examples

Culvert cut open through the highway

Bridge Overpass properly removed

Culvert cut open through the highway
Hydro-Conditioning

- Hydro-conditioned DEMs are an extension of hydro-enforced DEMs
- In addition to representing water flow across the surface, they also have depressions (“sinks”) filled to the natural outlet elevation
- These are also HYDROLOGIC DEMs
“Best Available”

NED “best available” source data – decision rules

Reject for all NED layers

Use only in 1/3” and 1” layers

Use in 1/9” layer and migrate to 1/3” and 1” layers

Use only in 1/9” layer
Criteria for determining “best available” data for use as NED source data

- Reject from all NED layers
  - Water bodies higher than adjacent ground
  - Large number of data voids
  - Severe mismatches along tile edges
  - Poor bare earth processing (lots of residual vegetation and/or buildings)
  - Improper handling of overpasses
  - Excessive tinning
  - A cumulative effect caused by the above issues
  - No vendor metadata
Water bodies higher than land
Large number of data voids
Misalignment of data
Poor bare earth process
Improper handling of overpasses
Improper hydro handling
Excessive tinning

Excessive Tinning

Expected surface
Cumulative effect

Multiple voids

Excessive Tinning

Poor bare earthing
“Best Available” Criteria Continued:

- Use only in 1-and 1/3-arc-second layers
  - Nominal resolution is coarser than approximately 5 meters
“Best Available” Criteria Continued:

- Use in 1/9-arc-second, and migrated to 1- and 1/3-arc-second layers
  - Water bodies flattened
  - Very minimal TIN artifacts
  - Very minimal residual vegetation and/or buildings in bare earth grids
  - Replaces very poor source data (i.e., the worst MP or GPM quads)
  - Vender Metadata is available
“Best Available” Criteria Continued:

- Use only in NED 1/9-arc-second layer:
  - Water bodies not flattened
  - Large number of data voids
  - Moderate tinning and artifacts
  - Some residual vegetation and/or buildings in bare earth grids
  - Poor resampling and seam lines
  - A cumulative effect caused by one or more of the above issues
Unflattened water

Flattened water
Large number of data voids
Moderate tinning and artifacts

Tinning

Rough surface and unexplained tin artifact

Depressions caused by tree shadows
Residual buildings and vegetation
NED Spatial Metadata

Resolution

Date of Update

Production Method

10 Meter or Better Source

USGS
Over 30 metadata items are recorded for each DEM

- File name and quadrangle name
- Geographic location
- Horizontal and vertical resolution
- Summary statistics (min, max, mean, std dev)
- Horizontal and vertical datum, and adjustments
- Production site, method, and instrument
- Accuracy (C-record)
- Free text
- Source date and production date
- Date of addition to the NED (for status graphics)
- Contour interval of source map
- Others used internally during NED processing
Spatial Metadata

Polygon attributes store information about source DEM and NED processing.
Metadata attributes are associated with polygons in a GIS coverage, which can be used as an overlay on NED raster data.

- Co-generated with NED, every pixel can be traced back to its source.

- Completely updated with each NED release
  - Always in sync with NED rasters

- Separate metadata generated for 1 arc-second, 1/3 arc-second, and 2 arc-second (AK) NED.

- Separate “project level” metadata is available for most non-standard data sources.
Spatial metadata is supplied to customers with every NED Seamless delivery.

The NED Data Dictionary and the current Release Notes are also included in the delivery packages.

Spatial metadata shape files for each resolution are zipped and posted for customer download after each NED update.

A subset of these metadata files which reflects the changes since the last update are generated, zipped and posted as well.

These zipped files are available for every NED update since August 2001.
Spatial Metadata

- Using GIS functionality, NED metadata can be queried and analyzed in ways which would be difficult to accomplish with tables alone.

- For example, by intersecting NED metadata with other thematic polygon layers, subsets, such as individual states or federal lands, can be analyzed independently.
NED Accuracy Assessment

Reference data set for absolute vertical accuracy tests

National Geodetic Survey
GPS on bench marks for GEOID03

13,305 geodetic control points

Reference data set for absolute vertical accuracy tests
## Absolute Vertical Accuracy

Statistics of Errors (meters) vs. NGS GPS Benchmarks

<table>
<thead>
<tr>
<th>Version Date of the NED</th>
<th>RMSE</th>
<th>NMAS (90%)</th>
<th>NSSDA (95%)</th>
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<tr>
<td>September 1999</td>
<td>3.74</td>
<td>6.15</td>
<td>7.34</td>
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<tr>
<td>October 2001</td>
<td>3.13</td>
<td>5.15</td>
<td>6.14</td>
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<tr>
<td>October 2002</td>
<td>2.70</td>
<td>4.44</td>
<td>5.29</td>
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<td>June 2003</td>
<td>2.44</td>
<td>3.99</td>
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<tr>
<td>December 2005</td>
<td>2.34</td>
<td>3.81</td>
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<td>February 2009</td>
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<td>3.44</td>
<td>4.54</td>
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# NED Vertical Accuracy

<table>
<thead>
<tr>
<th>Production method</th>
<th>Number of reference GPS points</th>
<th>Minimum error (meters)</th>
<th>Maximum error (meters)</th>
<th>Mean error (meters)</th>
<th>Standard deviation (meters)</th>
<th>RMSE (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPM</td>
<td>809</td>
<td>-11.98</td>
<td>17.44</td>
<td>2.00</td>
<td>4.21</td>
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<td>MP</td>
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<tr>
<td>CTOG</td>
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<td>9.18</td>
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<td>LT4X</td>
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<td>-42.64</td>
<td>18.74</td>
<td>-0.47</td>
<td>2.12</td>
<td>2.17</td>
</tr>
</tbody>
</table>
NED Publishing Schedule

Gayla Evans
U.S. Geological Survey
NED Updates of NED 1 and 1/3 layers

- Bi-monthly Updates
  - NED updates are tentatively scheduled for the first Monday of Feb, Apr, June, Aug, Oct, and Dec
  - All standard 10m DEMs which reside in the GDA database 1 month prior to the release date are processed
  - Non-standard DEMs are worked into the schedule as time permits
    - These tend to be problematic
  - Migration of NED 1/9 data which were released during the previous update
NED Updates of NED 1/9

- Presently, we are coordinating the 1/9 releases with the NED 1 and 1/3
  - Due to the project-based processing it is possible to do out-of-cycle updates if a critical need arises
- NED 1/9 dataset are prioritized
  - Critical need such as hurricane or potential flood area
  - NGP priorities such as contour generation
  - Size of the dataset: bigger is better
  - Area is near other dataset which are in progress
  - USGS collaboration prior to over the fence data
NED Updates Continued:

- Other components of the NED Release
  - NED Release Notes generated, distributed to email list and posted for download
    - [http://ned.usgs.gov/download](http://ned.usgs.gov/download)
  - Spatial metadata for all three resolutions are zipped and posted for download
    - [http://ned.usgs.gov/download](http://ned.usgs.gov/download)
  - State liaisons are notified of NED 1/9 areas within their state which have been updated in the release
NED Delivery

- **Seamless Server (http://seamless.usgs.gov)**
  - Available for NED 1-, 1/3- and 1/9-arc-second
  - User defined area
  - ESRI ArcGrid, Float, GeoTIFF, BIL
  - Spatial and text metadata, current Release Notes and Data Dictionary are included in downloads
  - Customer selects size download packages
  - Method is good for small area

- **Bulk Data Delivery**
  - Available for NED 1-, 1/3- and 1/9-arc-second
  - Provide a hard drive or return a USGS drive
  - Delivered by resolution layer in 1 degree blocks
  - ESRI ArcGrid or Float
  - Spatial and text metadata, current Release Notes and Data Dictionary are included in downloads
  - Best method for large areas, however turn around can be up to 8 week depending on the demand
NED Delivery

- **Pre-packaged Tile Download**
  - Available for NED 1- and 1/3-arc-second
  - Delivered in canned 1 degree tiles
  - ESRI ArcGrid format
  - Spatial and text metadata, Data Dictionary are included in downloads
  - Viewer displays 1 degree blocks by state, county or user defined area
  - Downloads can start immediately
  - Method is good for large areas need immediately
  - However it requires a good connection and large band width

(http://gisdata.usgs.gov/webappcontent/neddownloadtool/NEDDownloadToolDMS.html)
Web Sites

- Elevation, Topographic Science, and Lidar Branch
- Elevation Derivatives for National Applications (EDNA)
- Light Detection and Ranging (Lidar)
- Topographic Change
Questions?