A geoinformatics-based approach to the distribution and processing of integrated LiDAR and imagery data to enhance 3D earth systems research

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SDSC
SAN DIEGO SUPERCOMPUTER CENTER

GSA Penrose Conference – September 18, 2006, Durham, UK

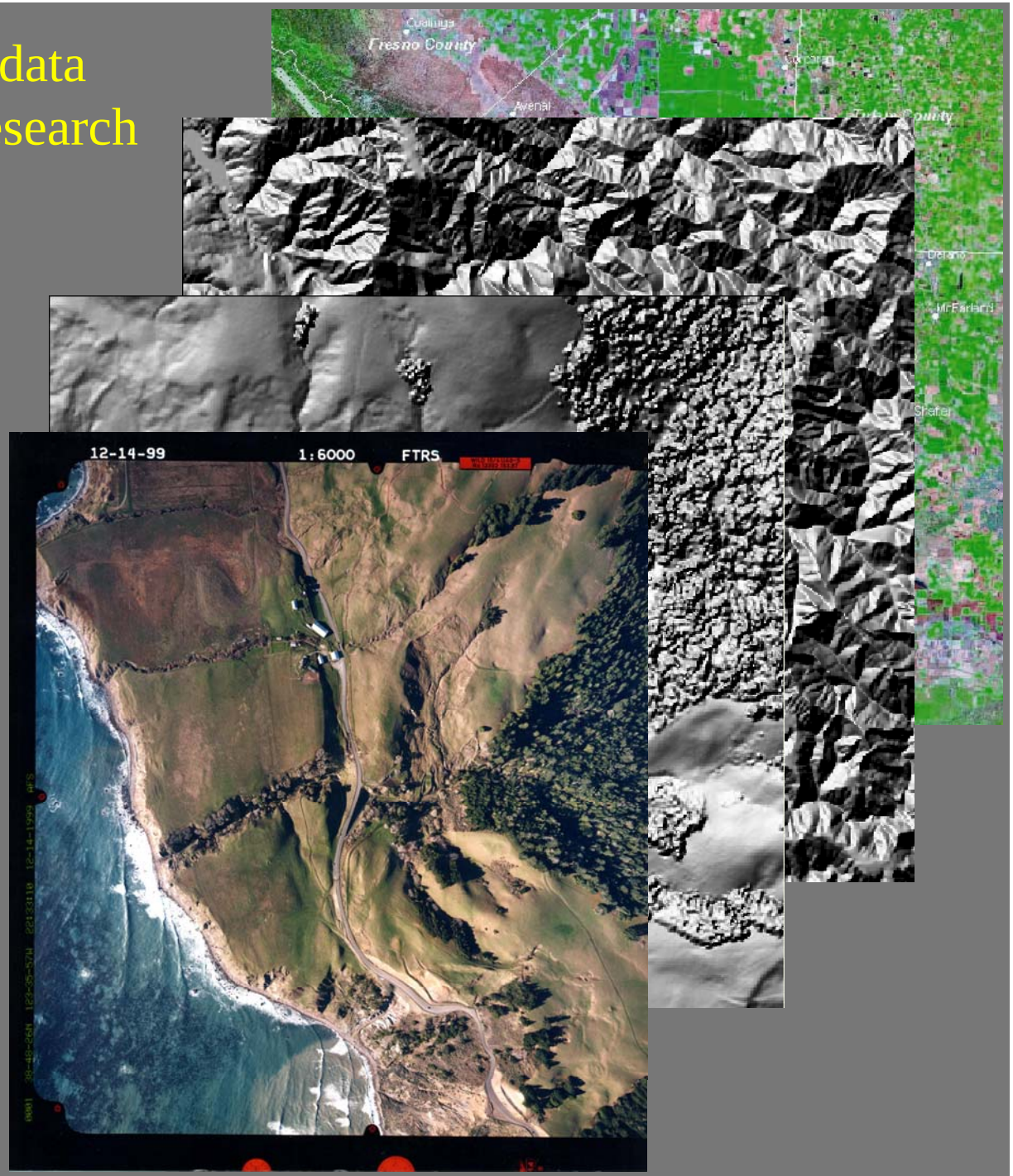
Imagery and topography data stack for earth systems research

Increasingly common for users to integrate various resolution DEMs and remotely sensed imagery to study landscape and geology at various spatial scales.

Datasets:

Landsat, ASTER, DOQQs, Hyperspectral, Aerial Photography

NED & SRTM: 90, 30, 10m + Aerial and terrestrial LiDAR datasets



Current Situation:

- Datasets publicly available but located on different servers and accessed through various web-based portals.
  - Requires projection and file format transformations as well as clipping to integrate datasets

- LiDAR and remotely sensed datasets often require specific processing knowledge and computing resources (hardware and software) to generate useful products.
  - Software packages and compute resources beyond the reach of many geoscientists.

The Vision: Utilize cyberinfrastructure to seamlessly integrate topography and imagery data access and processing from a central portal.

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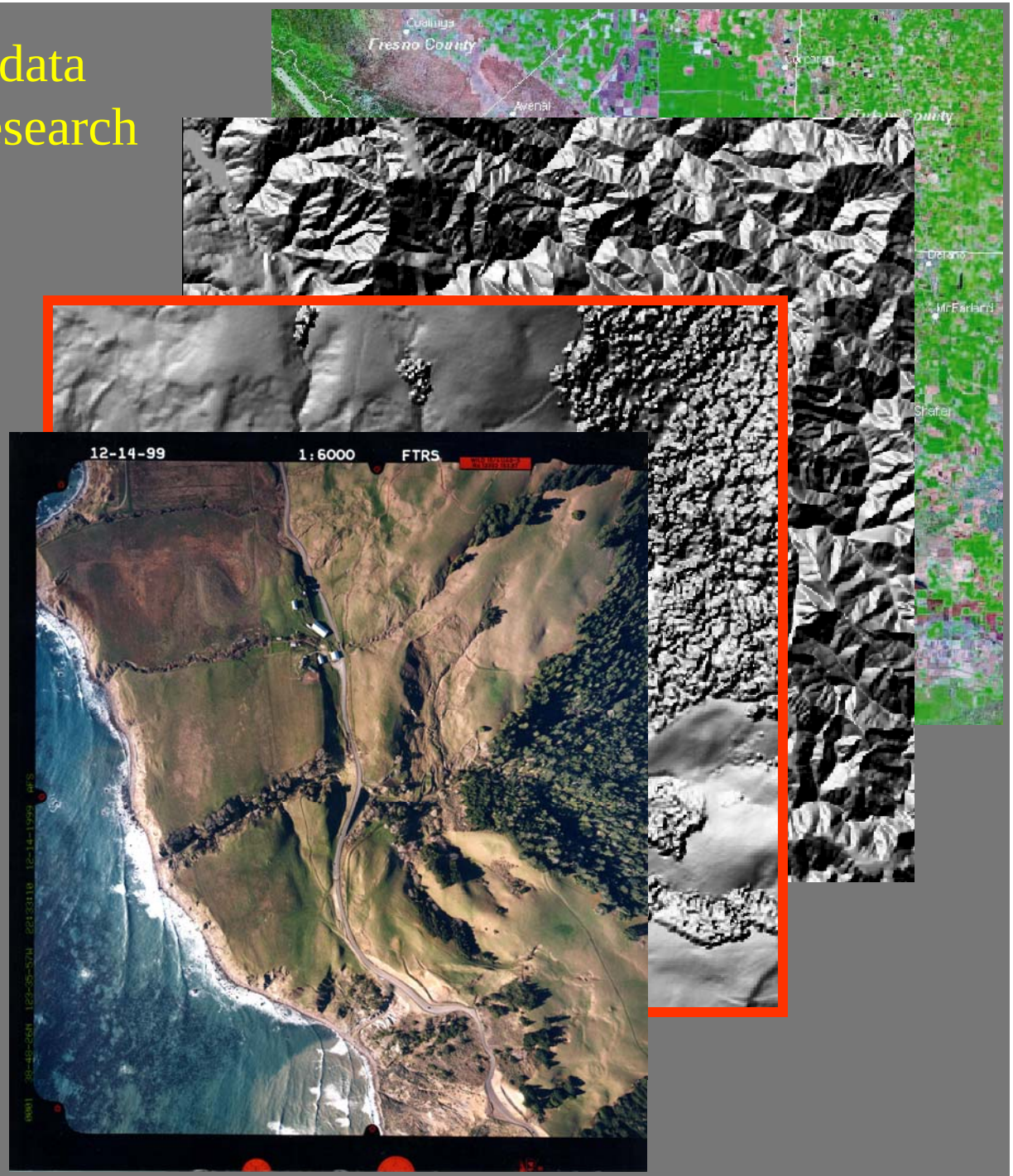
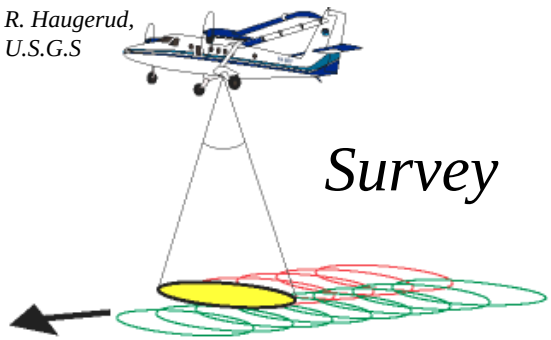


LiDAR Introduction

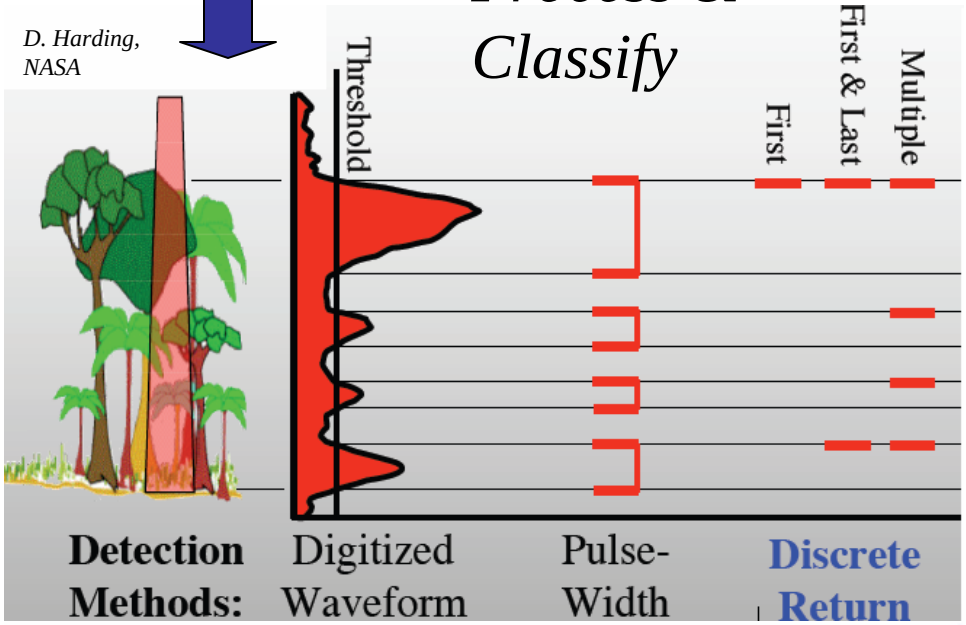
R. Haugerud, U.S.G.S

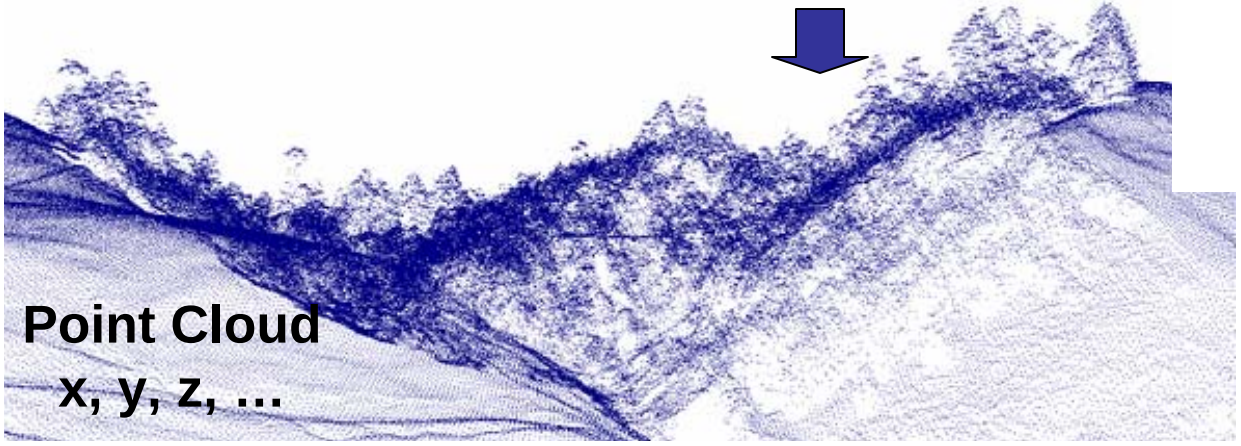


Survey

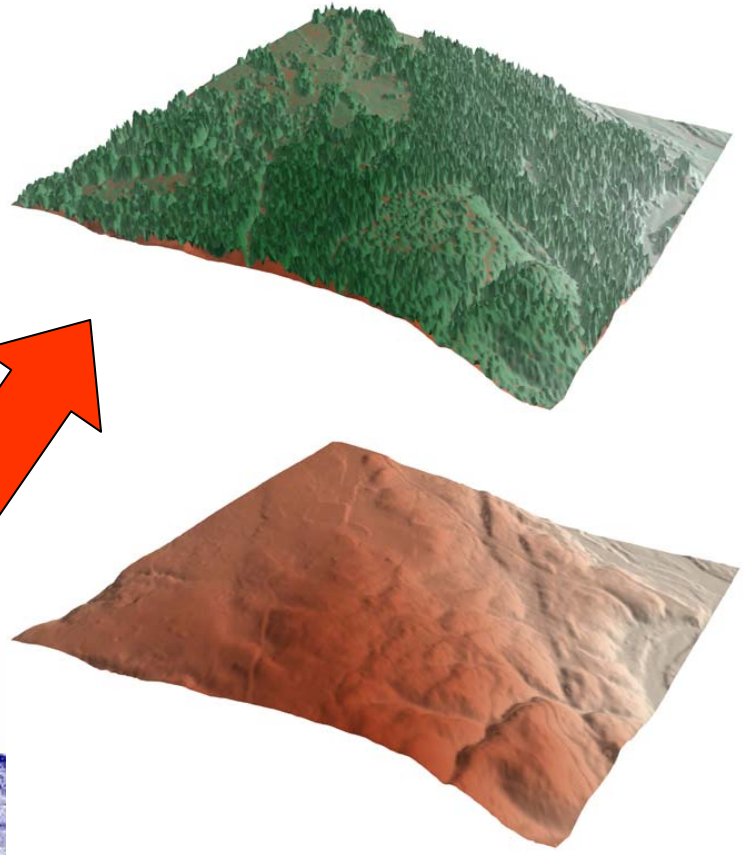
Process & Classify

D. Harding, NASA





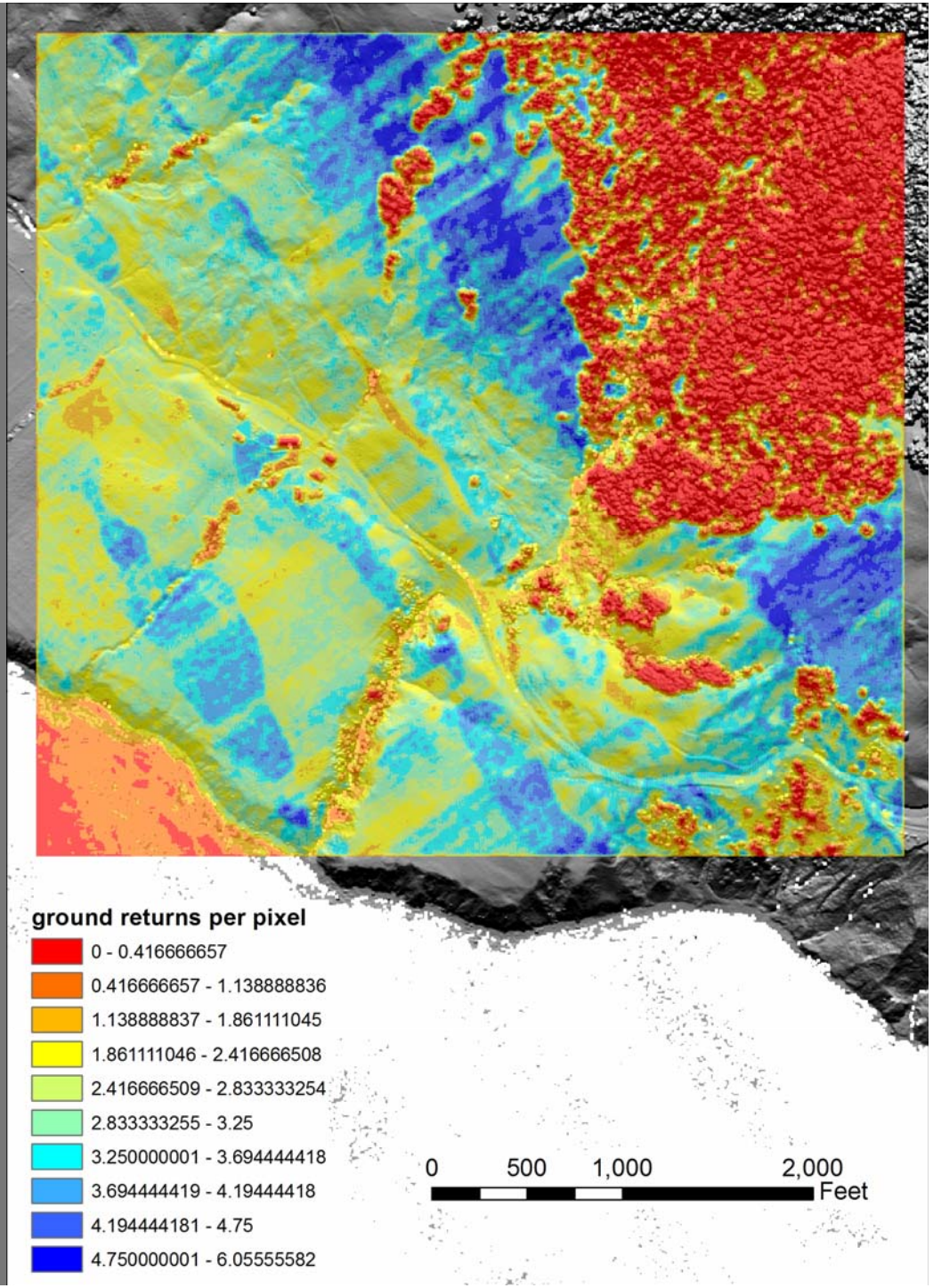
Interpolate / Grid



Analyze / "Do Science"

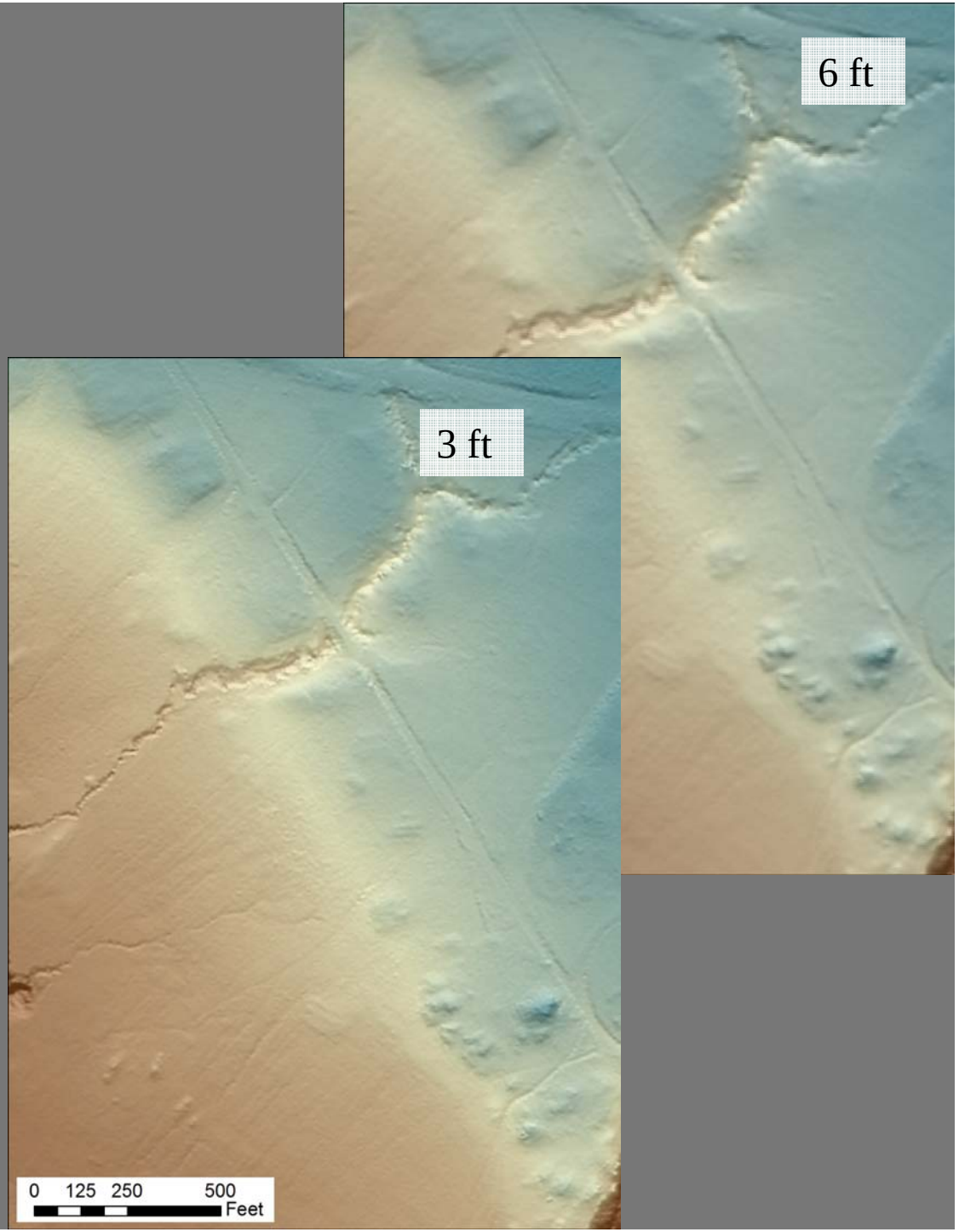
Why work from the point cloud?

- Understanding of data density and acquisition and processing artifacts.



Why work from the point cloud?

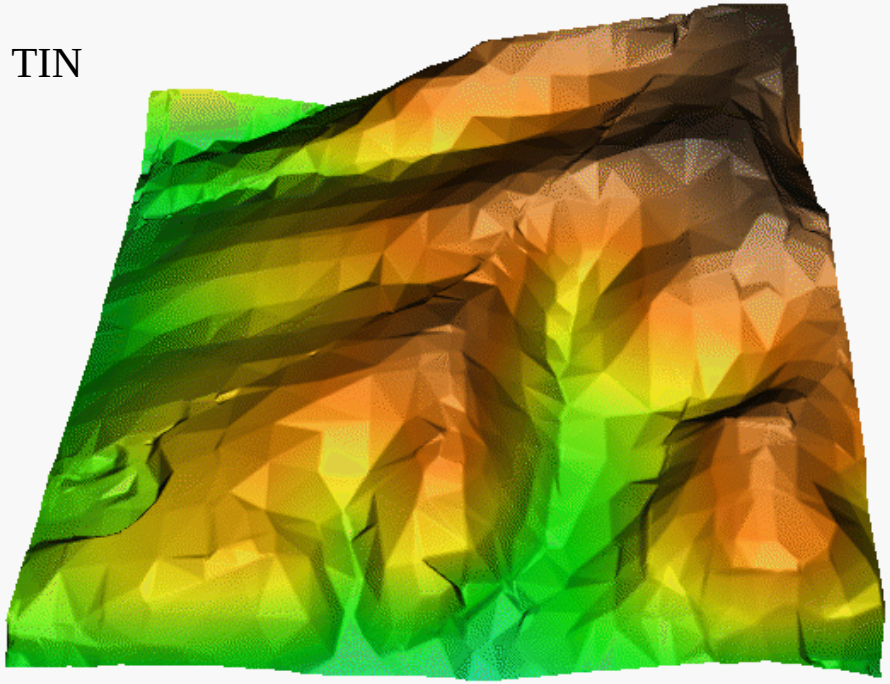
- User specified product (DEM) resolution



Why work from the point cloud?

- User control over DEM generation algorithms

TIN



Kriging

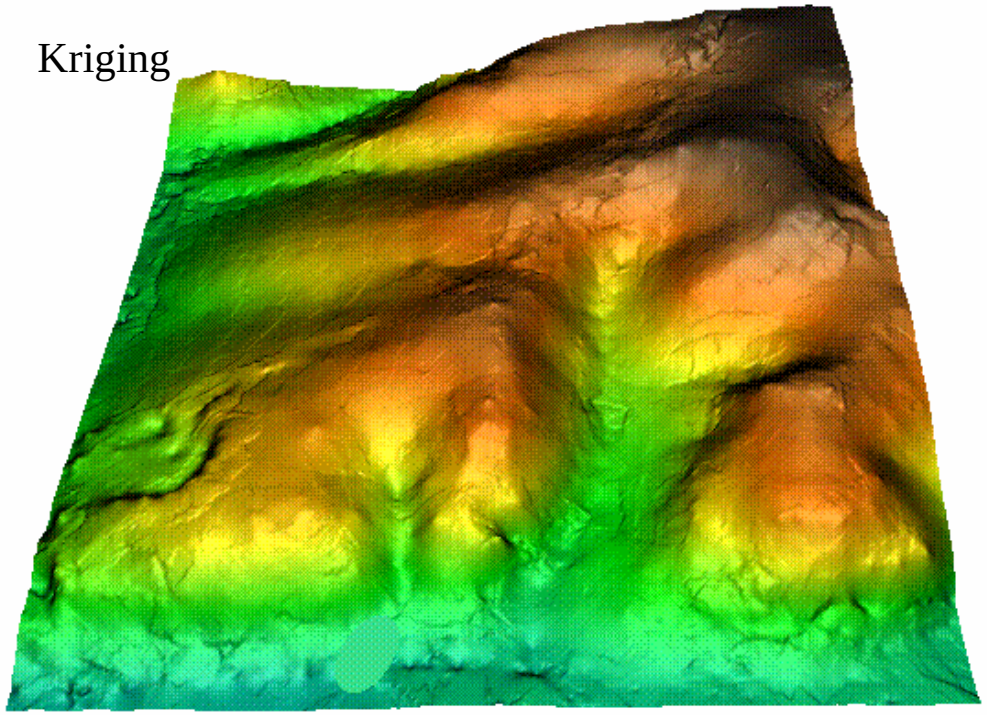
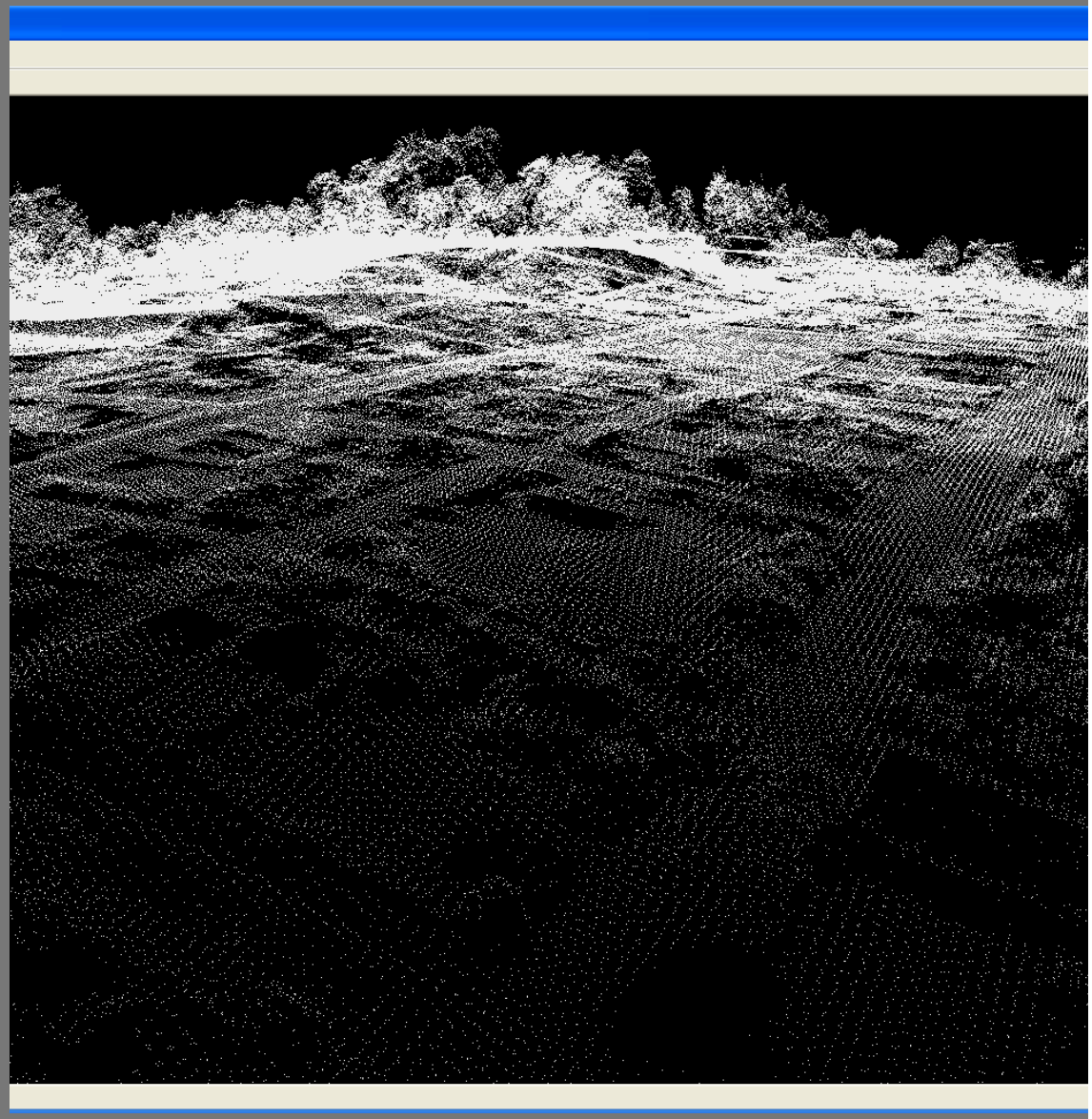


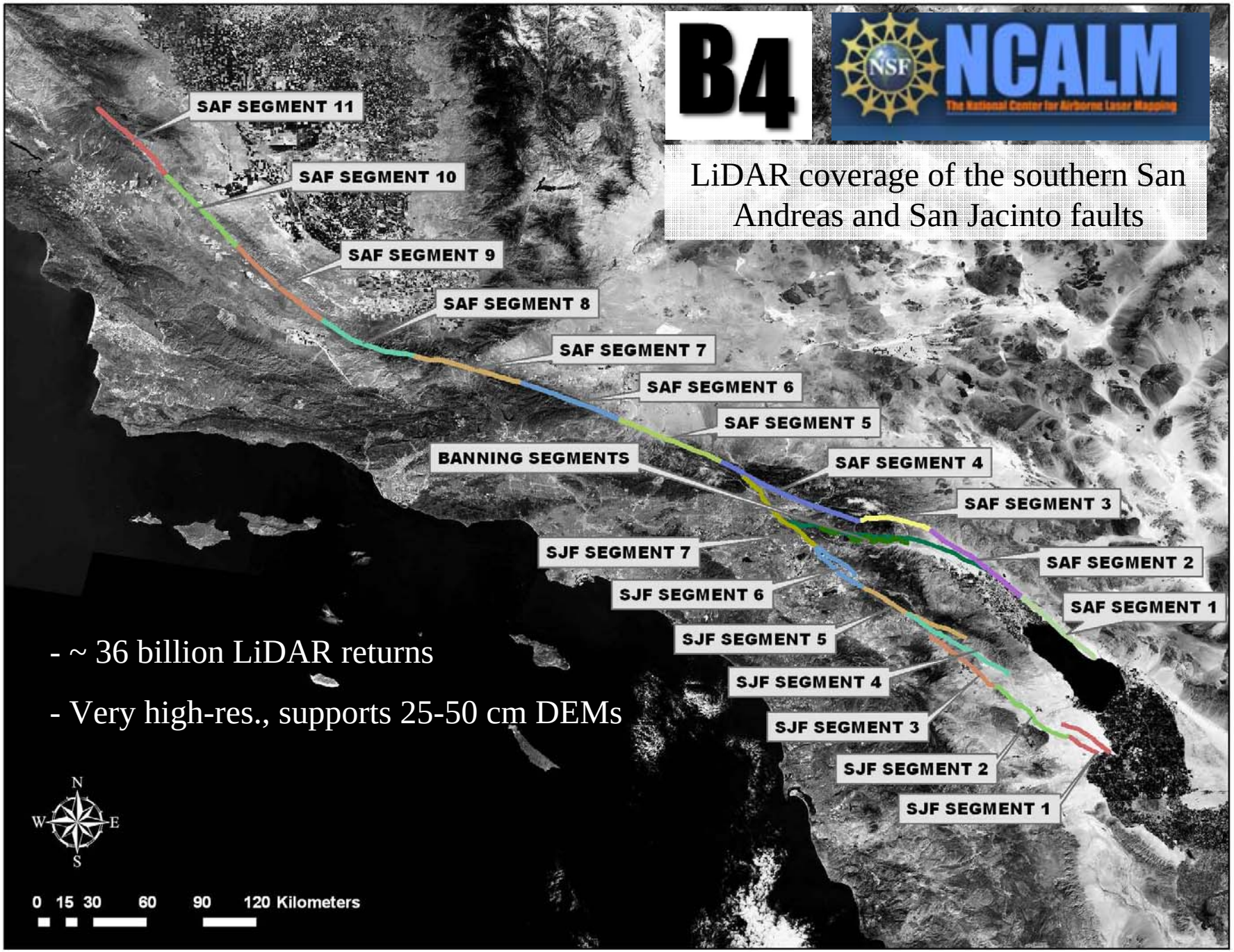
Figure from Helena Mitasova (NCSU): http://skagit.meas.ncsu.edu/~helena/gmslab/index.html

Why work from the point cloud?

- 2 & 3D visualization of point cloud data.



LViz – Free Download LViz version 1.2:
http://lidar.asu.edu/LViz.html


B4
NCALM
The National Center for Airborne Laser Mapping
LiDAR coverage of the southern San Andreas and San Jacinto faults
SAF SEGMENT 11
SAF SEGMENT 10
SAF SEGMENT 9
SAF SEGMENT 8
SAF SEGMENT 7
SAF SEGMENT 6
SAF SEGMENT 5
BANNING SEGMENTS
SAF SEGMENT 4
SAF SEGMENT 3
SAF SEGMENT 2
SAF SEGMENT 1
SJF SEGMENT 7
SJF SEGMENT 6
SJF SEGMENT 5
SJF SEGMENT 4
SJF SEGMENT 3
SJF SEGMENT 2
SJF SEGMENT 1
- ~ 36 billion LiDAR returns
- Very high-res., supports 25-50 cm DEMs
N
W
E
S
0 15 30 60 90 120 Kilometers

The Computational Challenge:

- Billions of returns per dataset are common.
- Internet-based distribution of these volumes of point cloud data to users represents a significant challenge.
- Processing and analysis of these data requires significant computing resources not available to most geoscientists.
- DEM generation from these data challenges typical GIS / gridding software.
  - our tests indicate that ArcGIS, Matlab and similar software packages struggle to grid even a small portion of these data.

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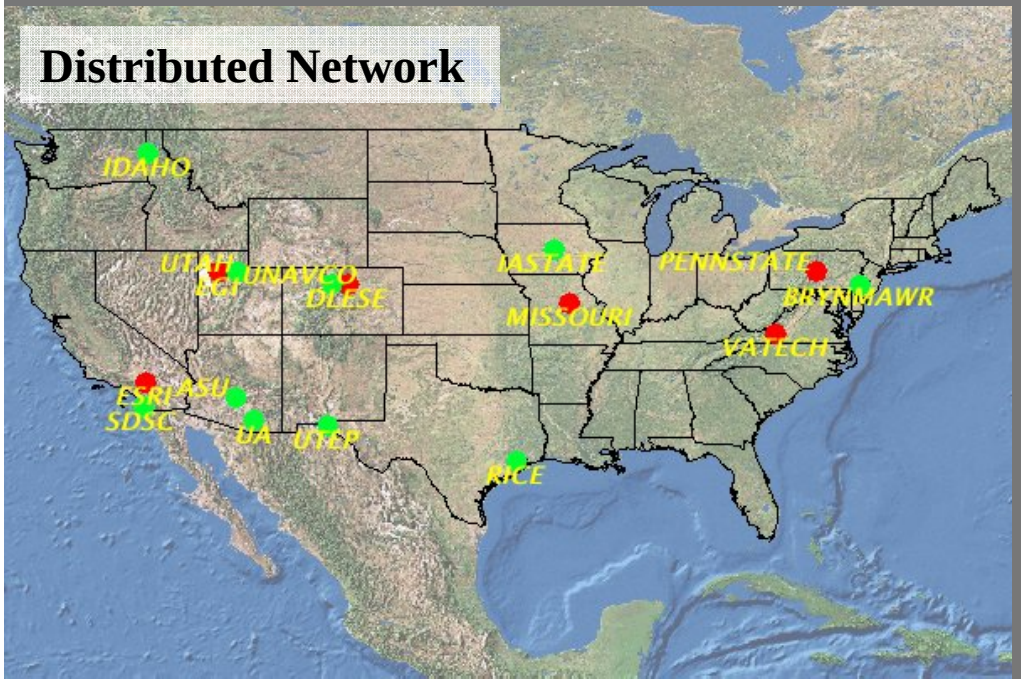
Enabling Scientific Discoveries and Improving Education in the Geosciences Through Information Technology Research

- Multi-institution collaboration between IT and Earth Science researchers
- Funded by NSF "large" ITR program

- GEON Cyberinfrastructure provides:
  - Authenticated access to data and Web services
  - Registration of data sets and tools, with metadata
  - Search for data, tools, and services, using ontologies
  - Scientific workflow environment
  - Data and map integration capability
  - Visualization and GIS mapping

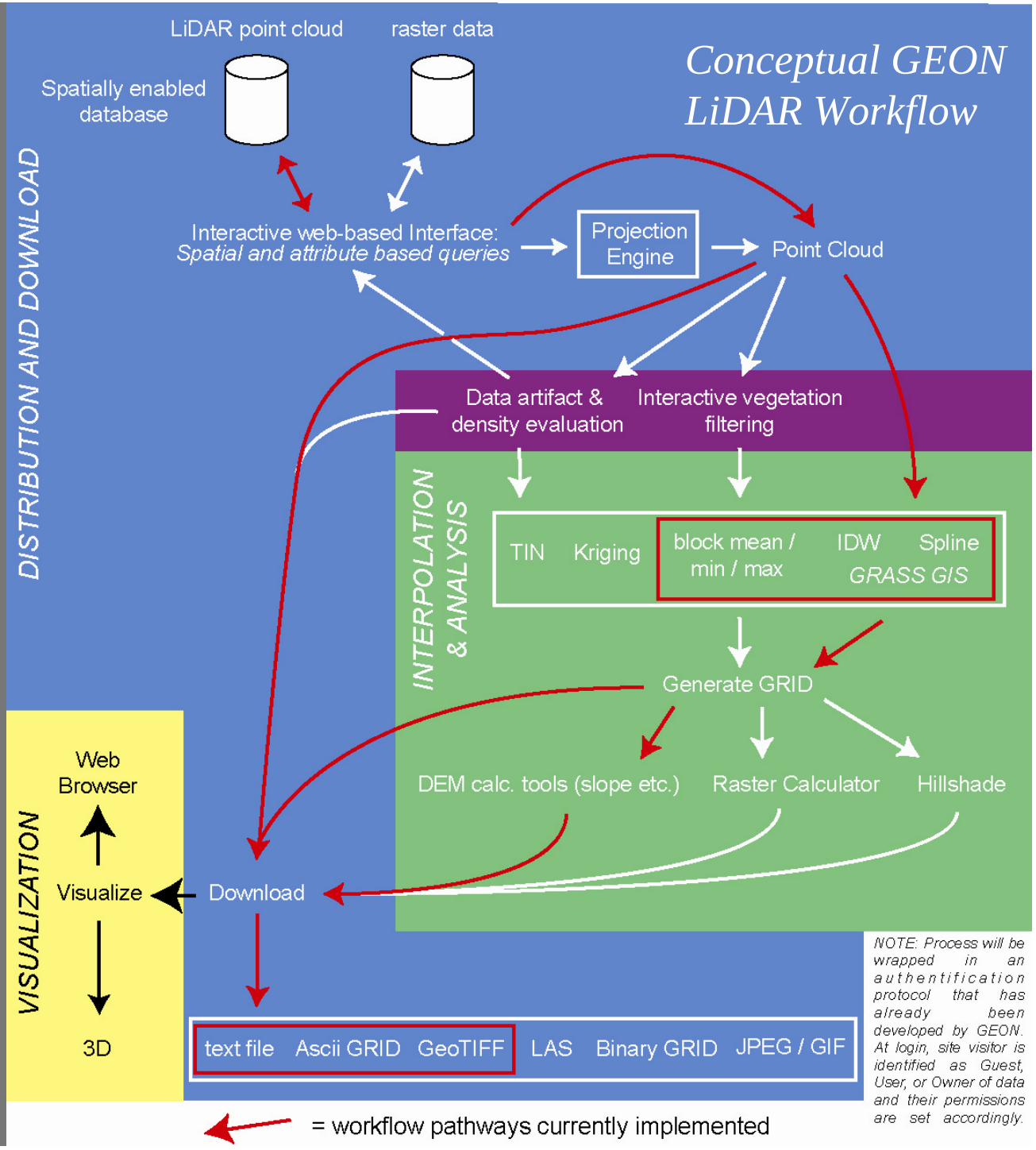
- "GEON was designed as an equal collaboration between Information Technology (IT) and Geoscience researchers, with the goal of developing an enabling IT platform to facilitate the next generation of Geoscience research."



GEON / ASU node "Agassiz":

The Vision:

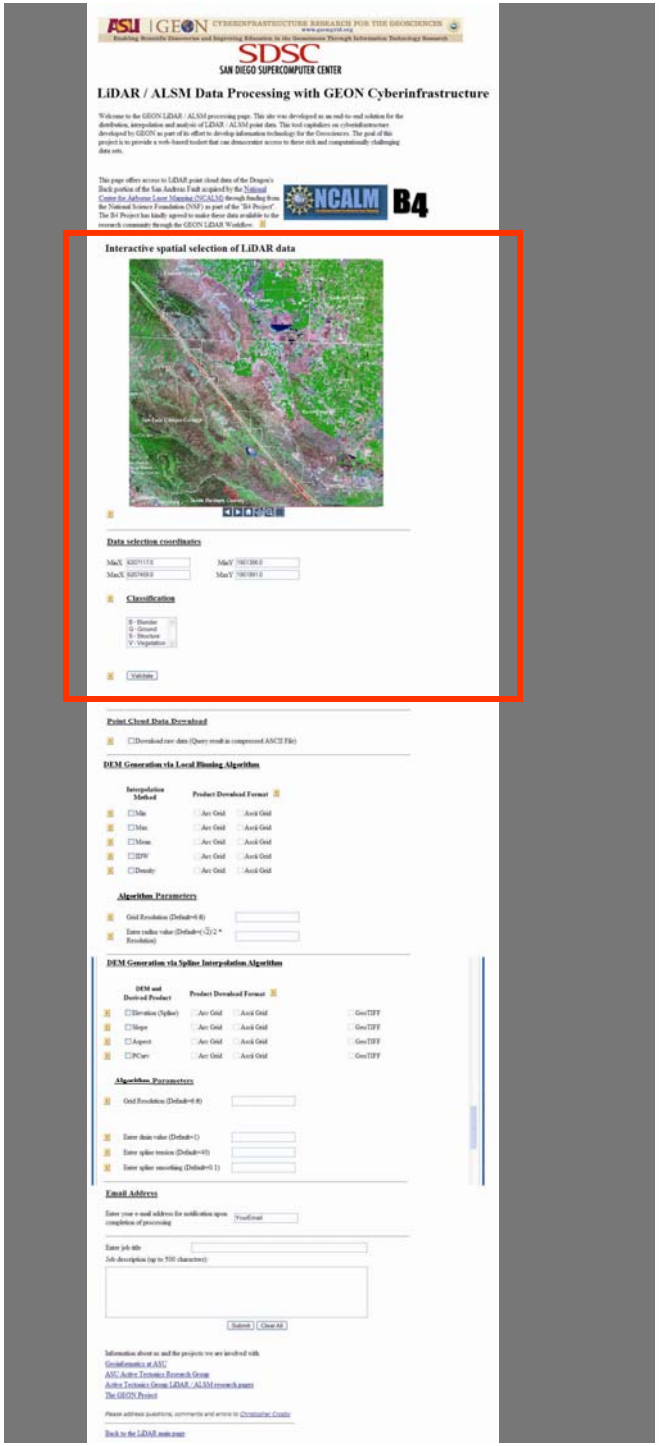
- Utilize the cyberinfrastructure developed by GEON to offer online data distribution, DEM generation, and analysis of large LiDAR datasets.
- Completely internet-based workflow:
  - **Point cloud to visualization**
- Utilize modular web services to complete a variety of processing and analysis tasks.
- Offer users control of interpolation and analysis parameters.



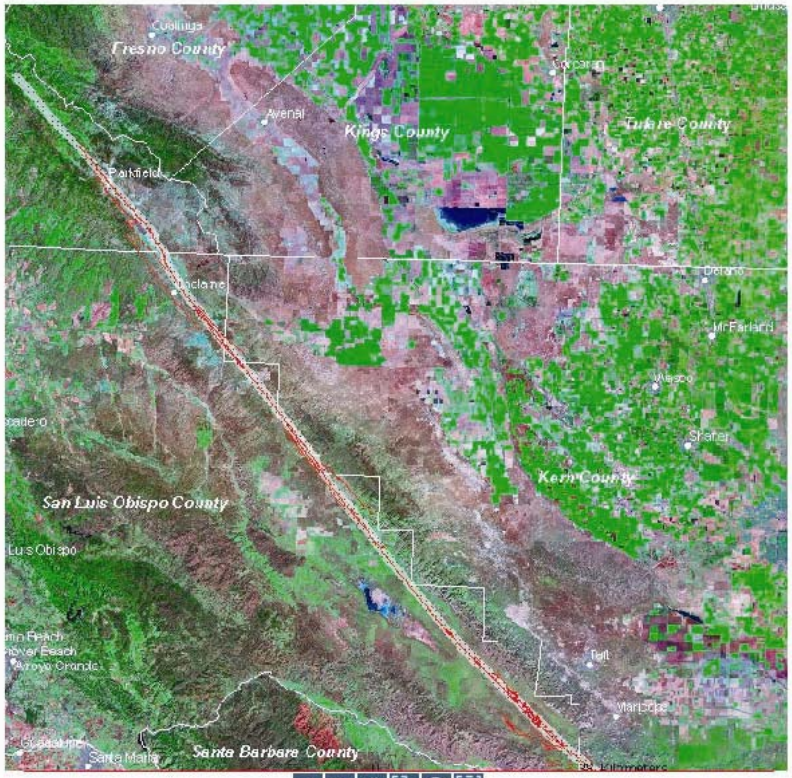
- Goal = interactive processing environment for iteration and exploration of various interpolation and processing options.
  - Optimize landscape representation based upon application of the data.

- By using distributed computing resources, user is able to quickly run multiple jobs and compare results.
  - Similar iteration may take days or weeks on a single local machine.

- Leave computationally intensive data processing to resources available through GEON and offer user downloadable products in common file formats.



Interactive spatial selection of LiDAR data



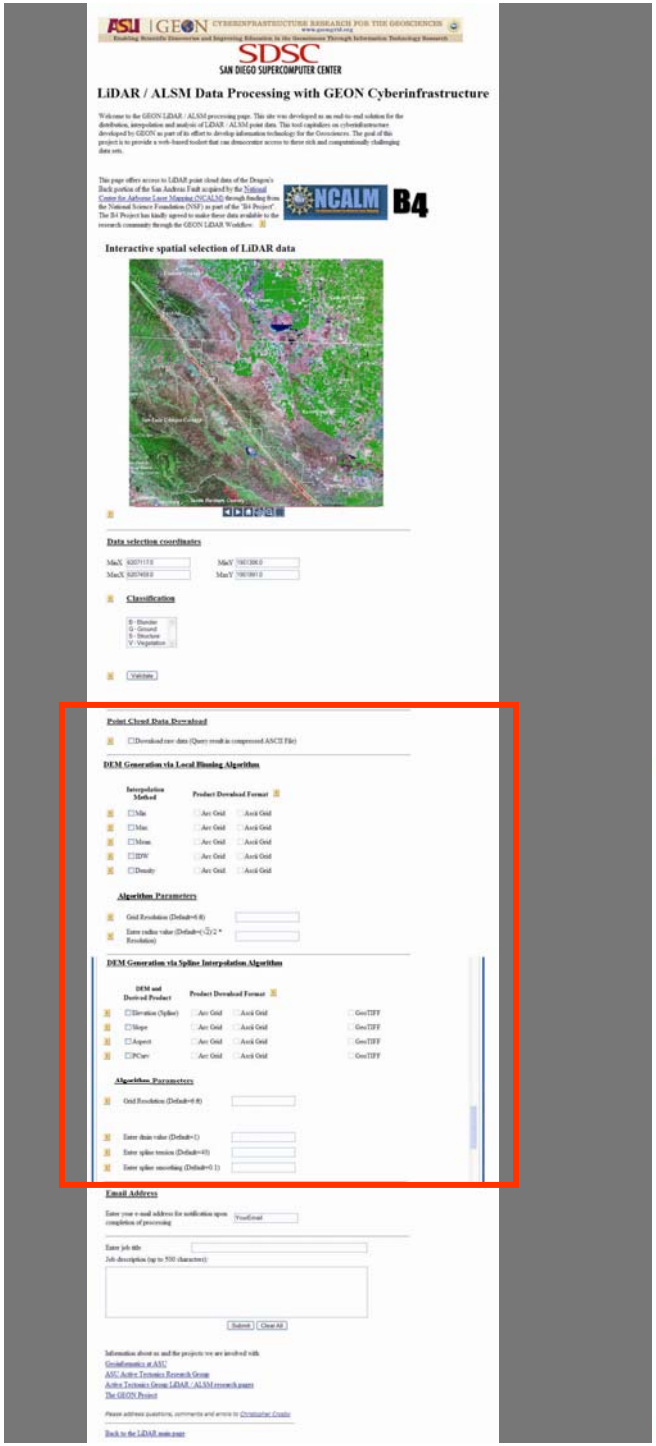
Data selection coordinates

MinX	6207117.0	MinY	1951306.0
MaxX	6207459.0	MaxY	1951991.0

Classification

- B - Blunder
- G - Ground
- S - Structure
- V - Vegetation

Validate



Point Cloud Data Download

Download raw data (Query result in compressed ASCII File)

DEM Generation via Local Binning Algorithm

Interpolation Method	Product Download Format	
Min	Arc Grid	Ascii Grid
Max	Arc Grid	Ascii Grid
Mean	Arc Grid	Ascii Grid
IDW	Arc Grid	Ascii Grid
Density	Arc Grid	Ascii Grid

Algorithm Parameters

Grid Resolution (Default=6 ft)

Enter radius value (Default=$(\sqrt{2})/2$ * Resolution)

DEM Generation via Spline Interpolation Algorithm

DEM and Derived Product	Product Download Format		
Elevation (Spline)	Arc Grid	Ascii Grid	GeoTIFF
Slope	Arc Grid	Ascii Grid	GeoTIFF
Aspect	Arc Grid	Ascii Grid	GeoTIFF
PCurv	Arc Grid	Ascii Grid	GeoTIFF

Algorithm Parameters

Grid Resolution (Default=6 ft)

Enter dmin value (Default=1)

Enter spline tension (Default=40)

Enter spline smoothing (Default=0.1)

LiDAR Processing Workflow Outputs - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://geon01.sdsc.edu:8405/lidar/data/tmp/output11375283168882084980797.html

Go

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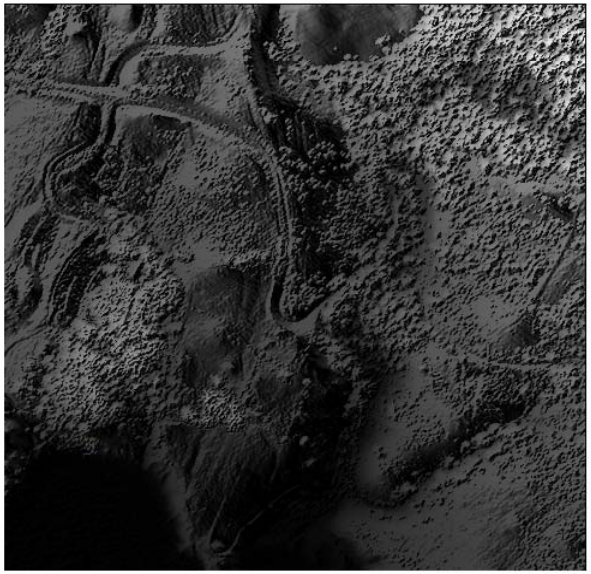
LiDAR Processing Workflow Outputs

Processing of 908930 points in Lidar point cloud.

Elevation (spline)



Below you can download an archive file (tgz format) with the results of your job

Results

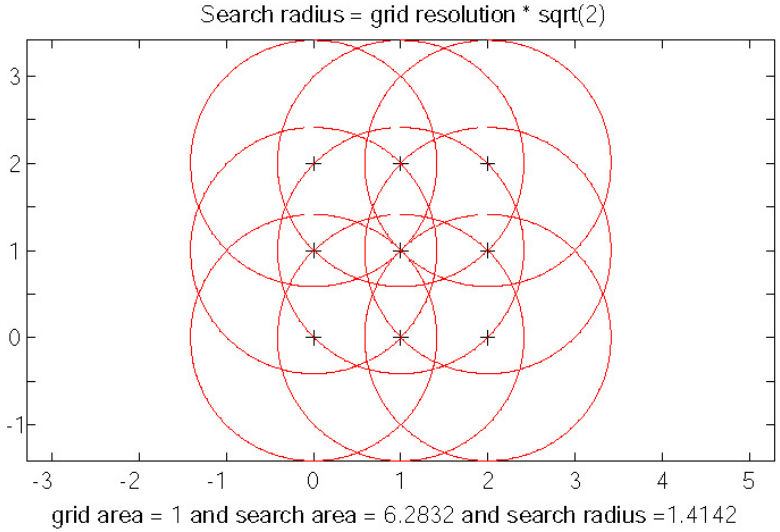
Raw data for bounding box selection: MinX = 6204521.346137968, MaxX = 6207425.849352351, MinY = 1950648.5712301359, MaxY = 1953553.0744445194 is available at

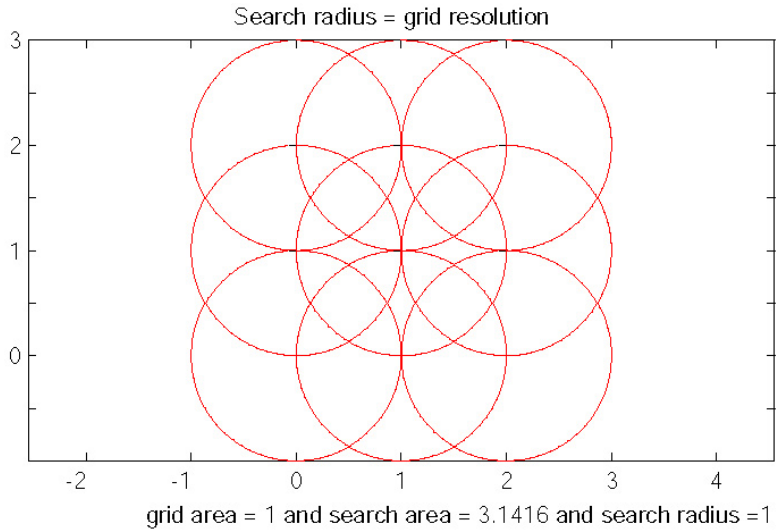
Results

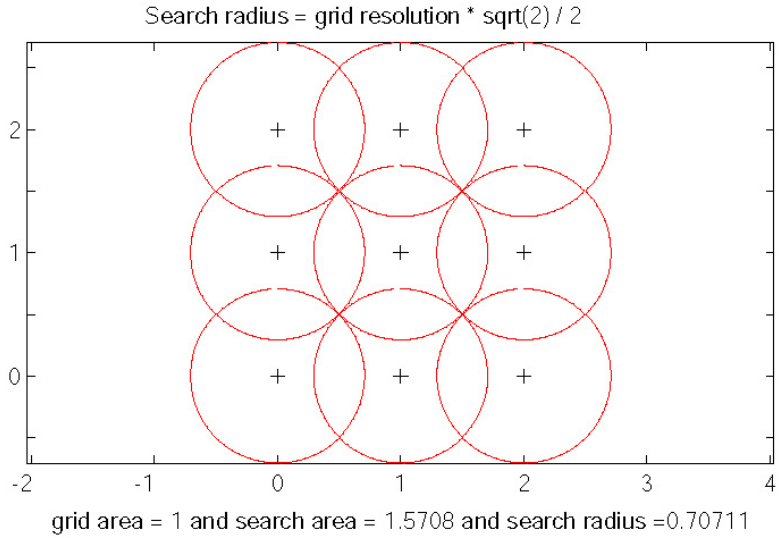
Download LViz - A free application for visualization of LiDAR point cloud and interpolated surface data developed in the Active Tectonics Research Group at Arizona State University.

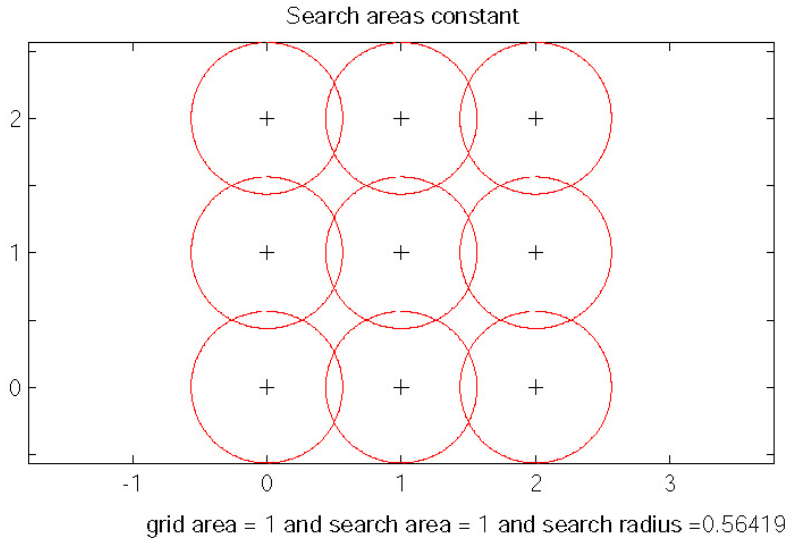
Done

DEM generation by local binning algorithm



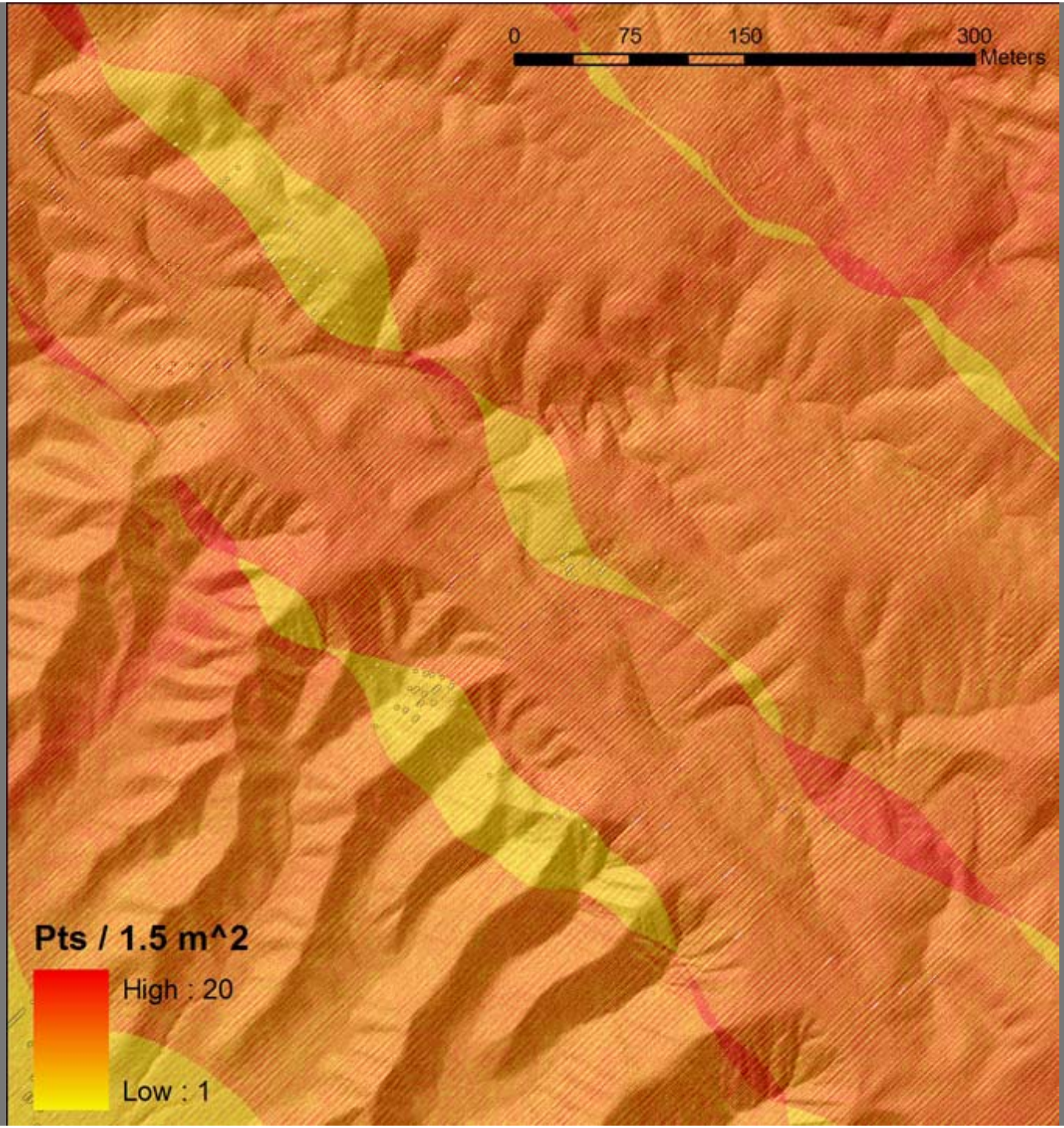




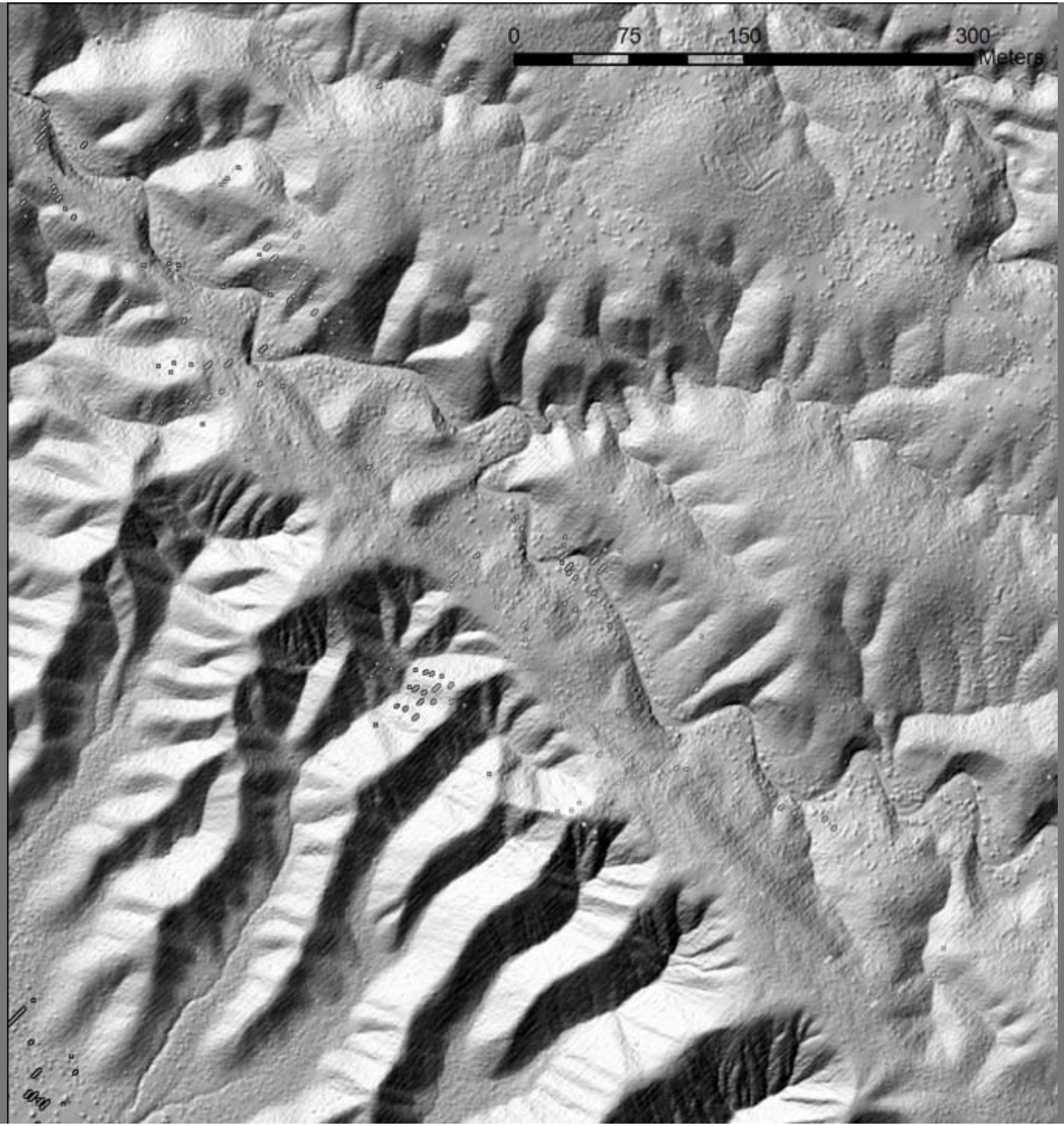


Possible DEM products: max, min, mean, IDW & points per search area at user defined resolution & search radius

Pts per search area
(1.5 m^2)

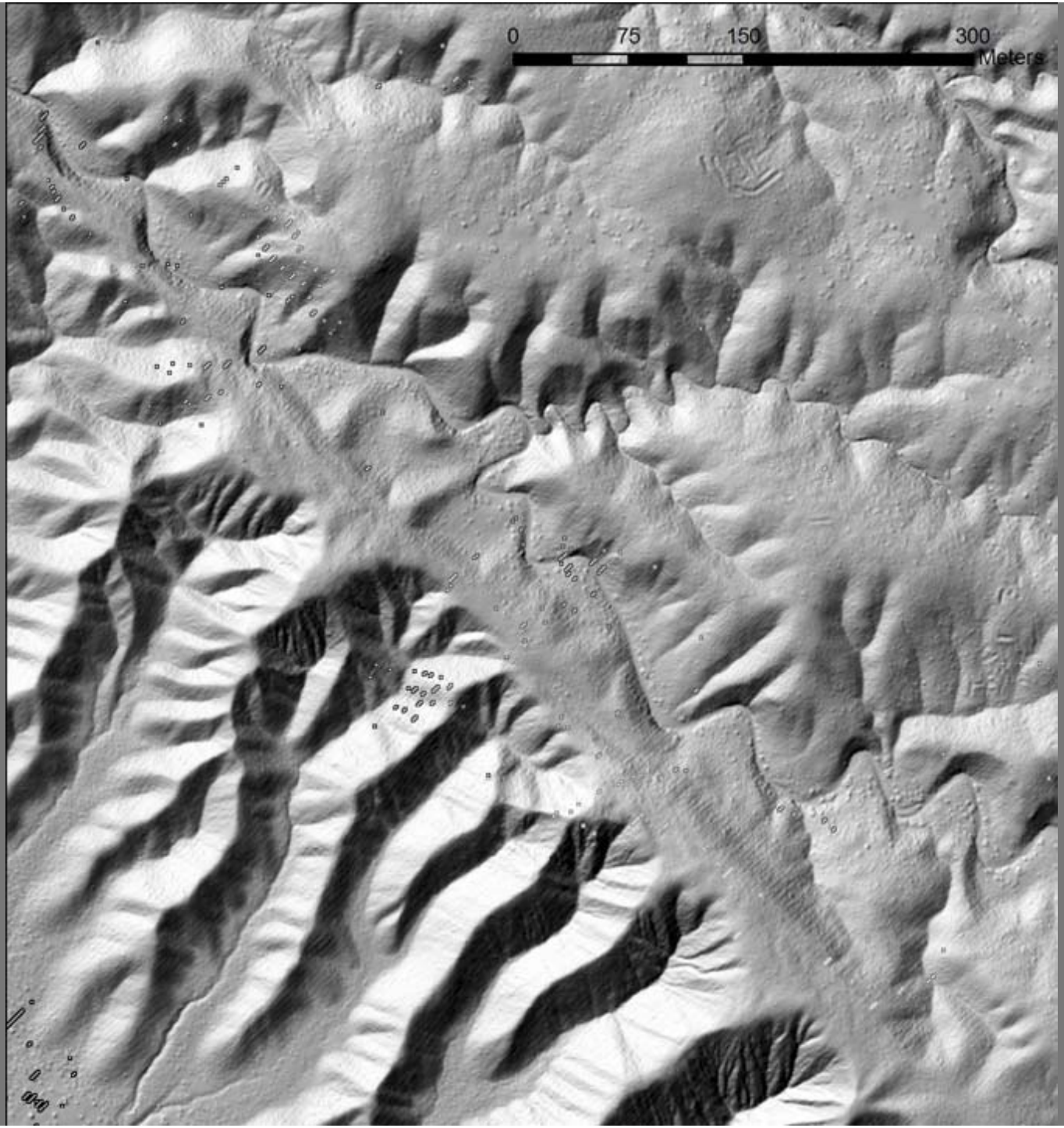


Max surface



Mean surface

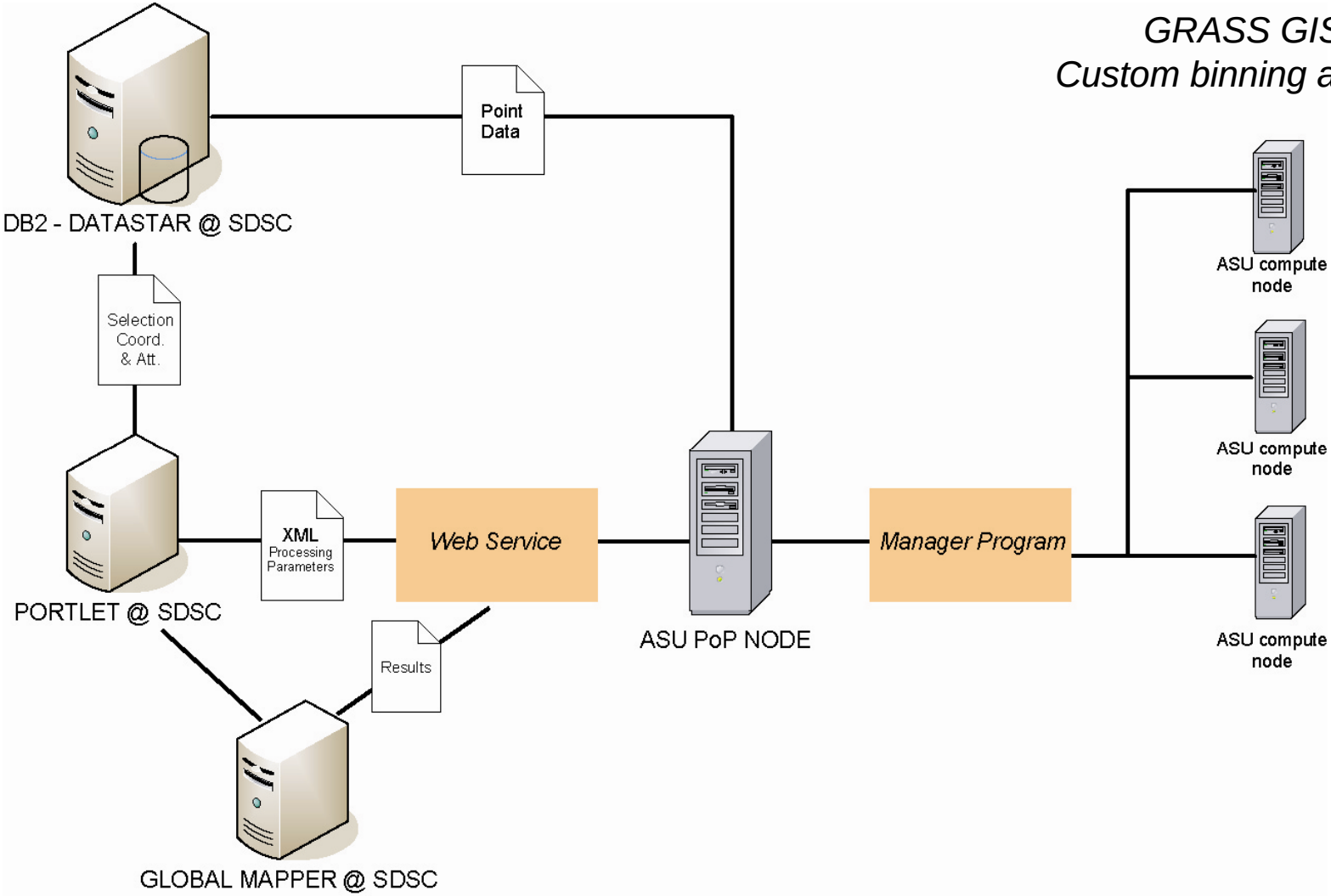
Inverse Distance Weighted (IDW) surface



Minimum surface

Implementation Overview:

The GLW utilizes advanced spatial databases (IBM DB2), GRASS Open Source GIS, custom DEM generation code, Kepler Workflow manager and web service technology to distribute, interpolate, and analyze LiDAR data.



Current GLW Status

Source:

Datasets online:

1. Northern San Andreas Fault
2. West Rainier Seismic Zone

3. Eastern California Shear Zone

(Mike Oskin PI)

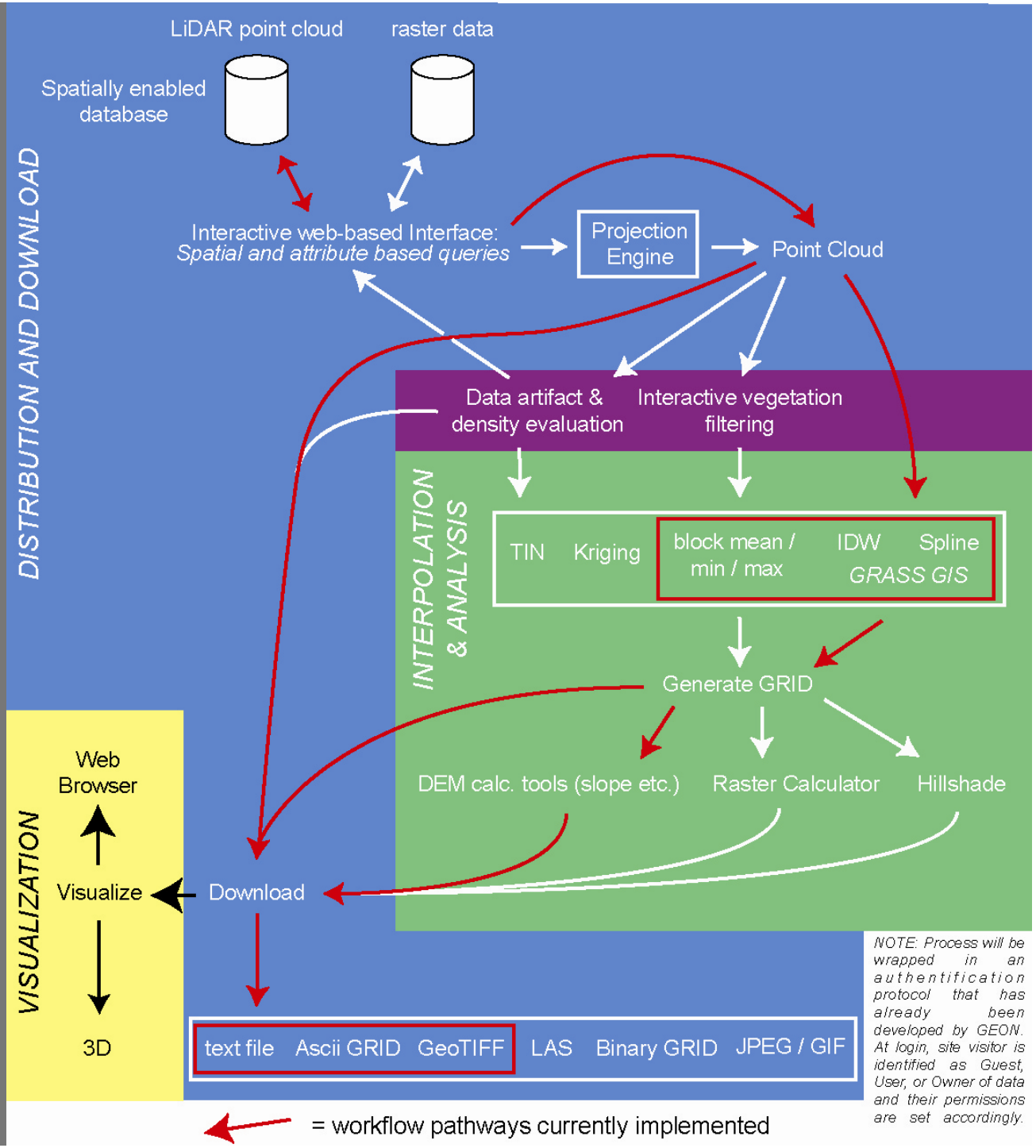
4. Dragon's Back portion of the SAF (B4)

5. Full B4 Dataset (Southern SAF and SJF)

Total of ~38 billion LiDAR returns available via GLW

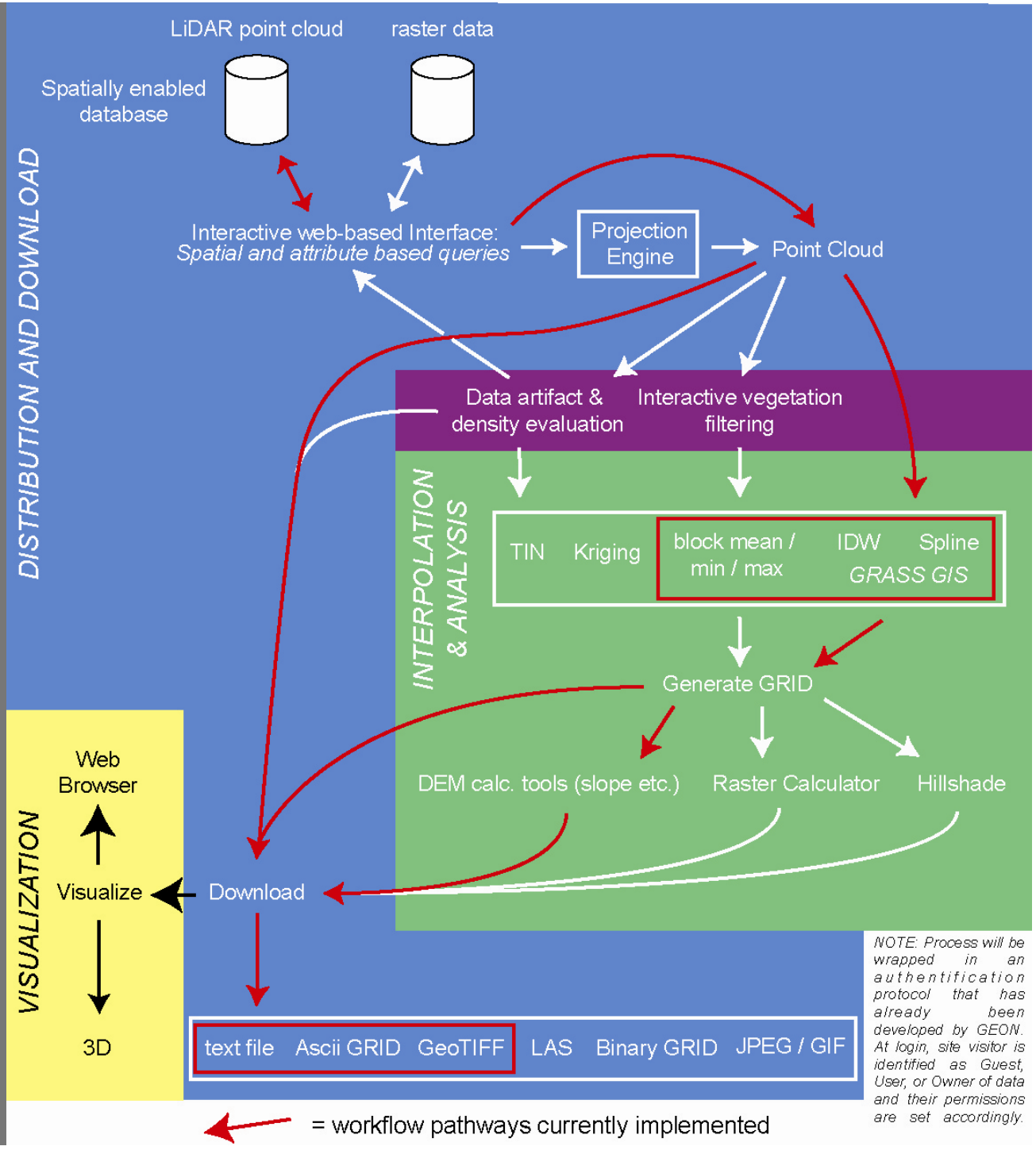
Future Functionality:

- Interactive vegetation filtering and feature extraction (implement open source algorithms)
- 2nd order products:
  - Filled and hydrologically corrected DEMs.
  - Derivative products



Future Functionality:

- TLS integration:
  - Seamless integration at 2.5 D
  - New tools and approaches for 3D
  - Nested resolution datasets.
- Raster imagery integration
- Web-based Viz:
  - Interface with GEON web-based mapping (2 & 3D)
  - Fledermaus or VRML web services

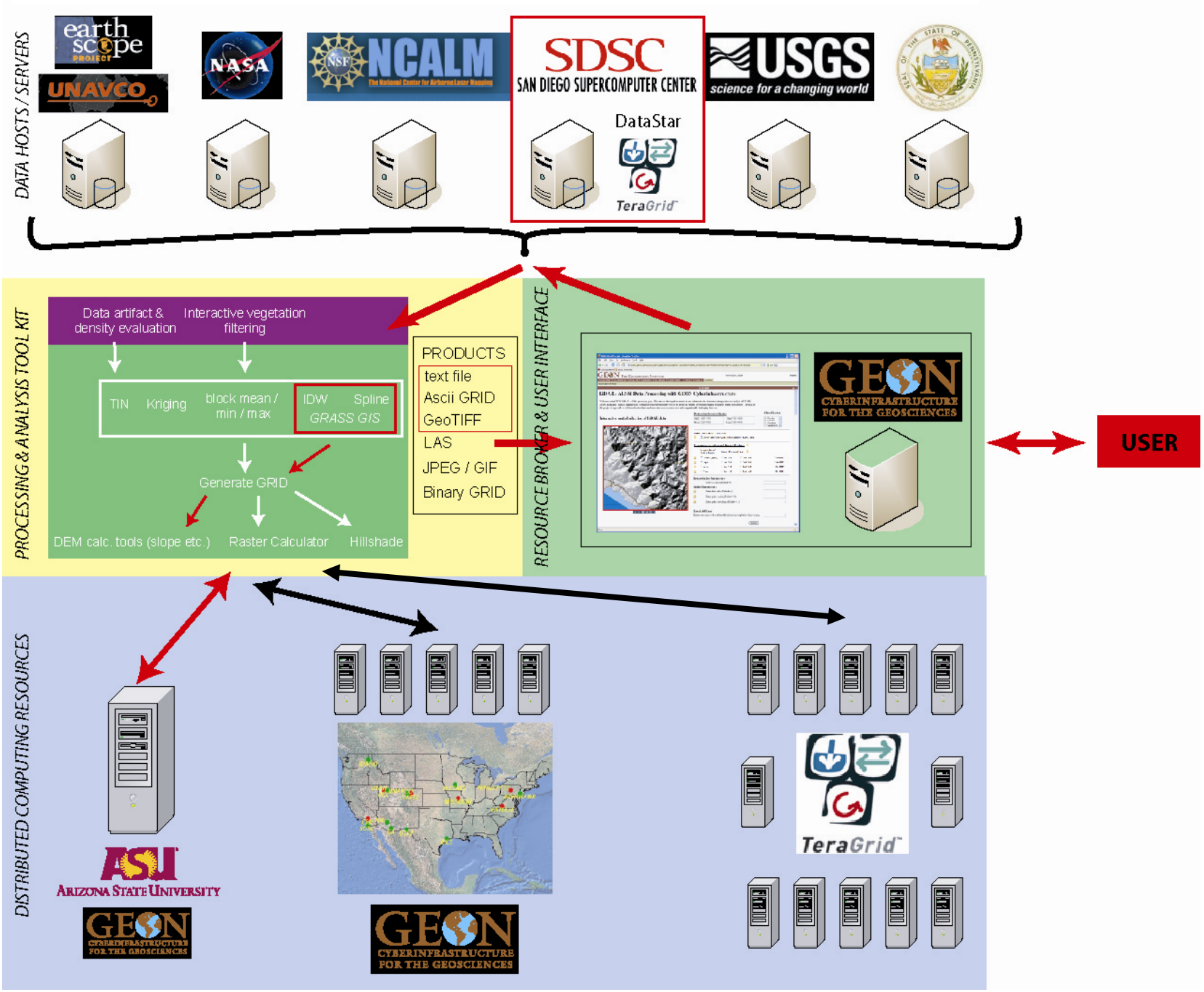


LiDAR/imagery fusion: 4 cm pixel balloon aerial photo merged with 25 cm B4 DEM.

Implications

- GLW likely distribution pathway for forthcoming GeoEarthscope LiDAR datasets
- Discussions underway with USGS EROS Data Center to expose their LiDAR archive (CLICK), NED and remotely sensed data (Landsat, ASTER, MODIS) via GEON portal – integrated access to nested resolution DEMs and imagery.
- GLW is a proof of concept for utilization of cyberinfrastructure to enhance access to the next generation geoscience datasets and processing tools.
  - Generic and scaleable GEON architecture applicable to numerous (geo) science datasets.

Proposed model for accessing and processing distributed topography and imagery data



GEON LiDAR Workflow Access Instructions:

http://www.geongrid.org/science/lidar.html

More information on the GLW:

Efrat Jaeger-Frank, Christopher J. Crosby, Ashraf Memon, Viswanath Nandigam, J. Ramon Arrowsmith, Jeffery Conner, Ilkay Altintas, Chaitan Baru, **A Three Tier Architecture for LiDAR Interpolation and Analysis**, *Lecture Notes in Computer Science*, Volume 3993, Apr 2006, Pages 920-927, DOI: 10.1007/11758532_123.

Crosby, C.J. et al., **A geoinformatics-based approach to LiDAR data distribution and processing** *in preparation.*

Abstracts, posters & powerpoints + LViz download:

http://lidar.asu.edu/