DATA PRODUCT DESCRIPTION FOR NASA-USGS LIDAR MAPPING PROJECTS: WEST RAINIER, NORTHERN SAN ANDREAS, DARRINGTON-DEVILS MOUNTAIN, AND MT. SAINT HELENS

INTRODUCTION

The airborne laser swath mapping data described here were acquired in support of collaborative research by members of the U.S. Geological Survey (USGS)and the National Aeronautics and Space Administration (NASA), with funding provided by NASA's Solid Earth and Natural Hazards (SENH) program. Data for the west Rainier seismic zone, WA and the northern San Andreas fault, CA were acquired and processed by TerraPoint, LLC under contract to NASA's Stennis Space Center. Data for the Darrington-Devils Mountain seismic zone and the Mount St. Helens volcano and seismic zone were acquired and processed by TerraPoint USA, Inc., a subsidiary of Mosaic Mapping Systems, Inc., under contract to NASA's Goddard Space Flight Center. Mosaic Mapping Systems subsequently became an operating unit of Pulse Data, Inc. and renamed Terrapoint. The specifications and deliverables for the Stennis and Goddard contracts are essentially identical, and the data were acquired and processed using the same instrumentation and processing methods (TerraPoint, 2004). The data was acquired under an unrestricted data use license in which all data products delivered became the exclusive property of NASA, and NASA has the right to publicly distribute the products.

The data were acquired by means of LIght Detection And Ranging (LIDAR) using a discrete-return, scanning airborne laser altimeter capable of acquiring up to 4 returns per laser pulse. Data were acquired at times when deciduous leaf cover was absent in order to maximize collection of laser returns from the ground surface beneath vegetation cover. Data acquisition was also restricted to be at times when snow cover was absent or minimal.

The majority of the Rainier data were acquired in November and December, 2002. Approximately 20 percent of the data, in the central part of the project area on the eastern side, were acquired in November, 2003. Data in the San Andreas area were collected in February, 2003. The majority of the Darrington-Devils Mountain data were acquired between late October and early December, 2003. Approximately 10 percent of the data, in the southeast corner of the project area, were acquired in October and November, 2004 and January, 2005. Data centered on the Mount St. Helens volcanic edifice were acquired on October 4 and 5, 2004 and repeated on November 20, 2004 for change detection purposes. Data extending to the NNE and SSW along the Mount St. Helens seismic zone were acquired in January, 2005.

The Rainier, Darrington-Devils Mountain and Mount St. Helens data sets (Figure 1) were collected in affiliation with the Puget Sound Lidar Consortium (PSLC), via a grant from the NASA SENH program (Documenting natural hazards in steep, densely forested regions using airborne laser swath mapping, western Cascade Range, Washington State, Sam Johnson, USGS, Principal Investigator). The PSLC is a cooperative effort involving county and municipal governments, the Puget

Sound Regional Council (PSRC), the USGS, and NASA (Haugerud et al, 2003) (http://www.pugetsoundlidar.org). Terrapoint is conducting extensive lidar mapping of the Puget Lowland, Washington, for the PSLC under a separate contract executed by Kitsap County, Washington, and managed by the PSRC. The northern San Andreas fault data set (Figure 2) was collected in affiliation with the USGS.

Data products delivered by TerraPoint consist of:
1) "bald Earth" ground topography Digital Terrain Model (DTM)
2) "full feature" highest surface Digital Surface Model (DSM)
3) classified “point cloud” ascii files with all laser returns
4) ascii files of aircraft platform flight trajectory

Data products produced at Goddard Space Flight Center consist of:
1) geotiff "bald Earth" ground topography elevation mosaics
2) geotiff "bald Earth" mosaic shaded relief images
3) geotiff "full feature" highest surface elevation mosaics
4) geotiff "full feature" mosaic shaded relief images

DATA USE ACKNOWLEDGEMENT

Please acknowledge any use of the Rainier, Darrington-Devils Mountain and Mount St. Helens data with the following statement:
These data were acquired by Terrapoint under contract to NASA, in collaboration with the Puget Sound Lidar Consortium, with funding from the NASA Solid Earth and Natural Hazards Program.

Please acknowledge any use of the San Andreas data with the following statement:
These data were acquired by Terrapoint under contract to NASA, in collaboration with the U.S. Geological Survey, with funding from the NASA Solid Earth and Natural Hazards Program.

PROJECTION, DATUMS, AND DATA DENSITY

Projection:	State Plane
Zone for Rainier:	Washington North
Zone for San Andreas:	California II
Zone for Darrington:	Washington North
Zone for St. Helens:	Washington South
Horizontal units:	US Survey Feet (= 1200/3937 meters ~ 0.30480061 meters)
Elevation units:	International Feet (= 0.3048 meters)
Spheroid:	GRS80
Horizontal Datum:	NAD83, 1991 Adjustment (HARN)
Vertical Datum:	NAVD88
	Orthometric elevations were derived from ellipsoidal elevations using National Geodetic Survey Geoid99.
Rainier data density:	averages 2 laser pulses per square meter
Data density elsewhere:	averages 1 laser pulse per square meter

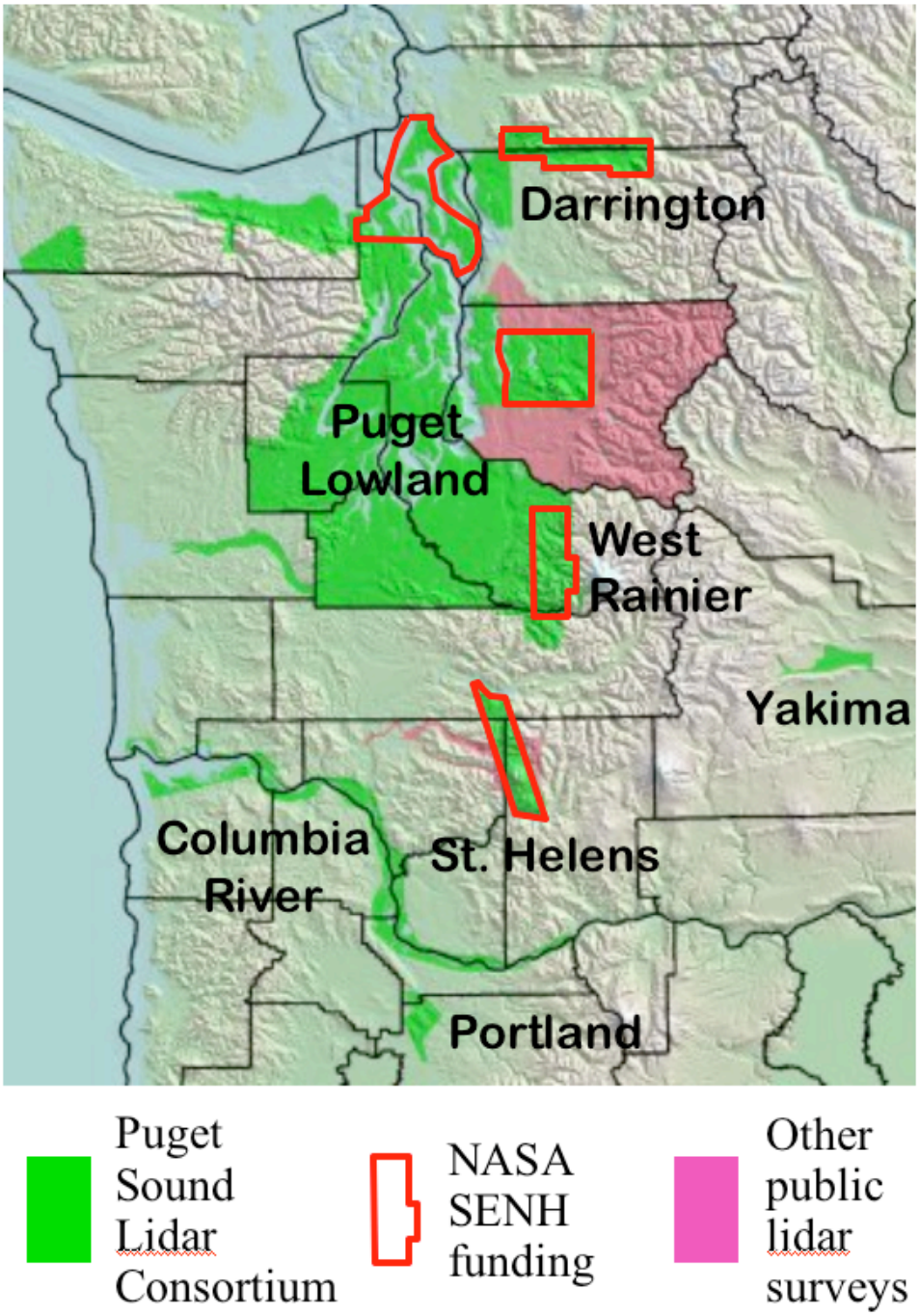

Figure 1. Location of lidar mapping in western Washington and northwestern Oregon as of January 1, 2005. County boundaries are outlined in black. The pink-shaded area was mapped by 3Di, Inc. for King County (http://www.metrokc.gov/gis/sdc/raster/elevation/index.htm); deliverables for this project were DTM and DSM grids and last return points (the classified point cloud of all returns and aircraft flight trajectory were not deliverables.)

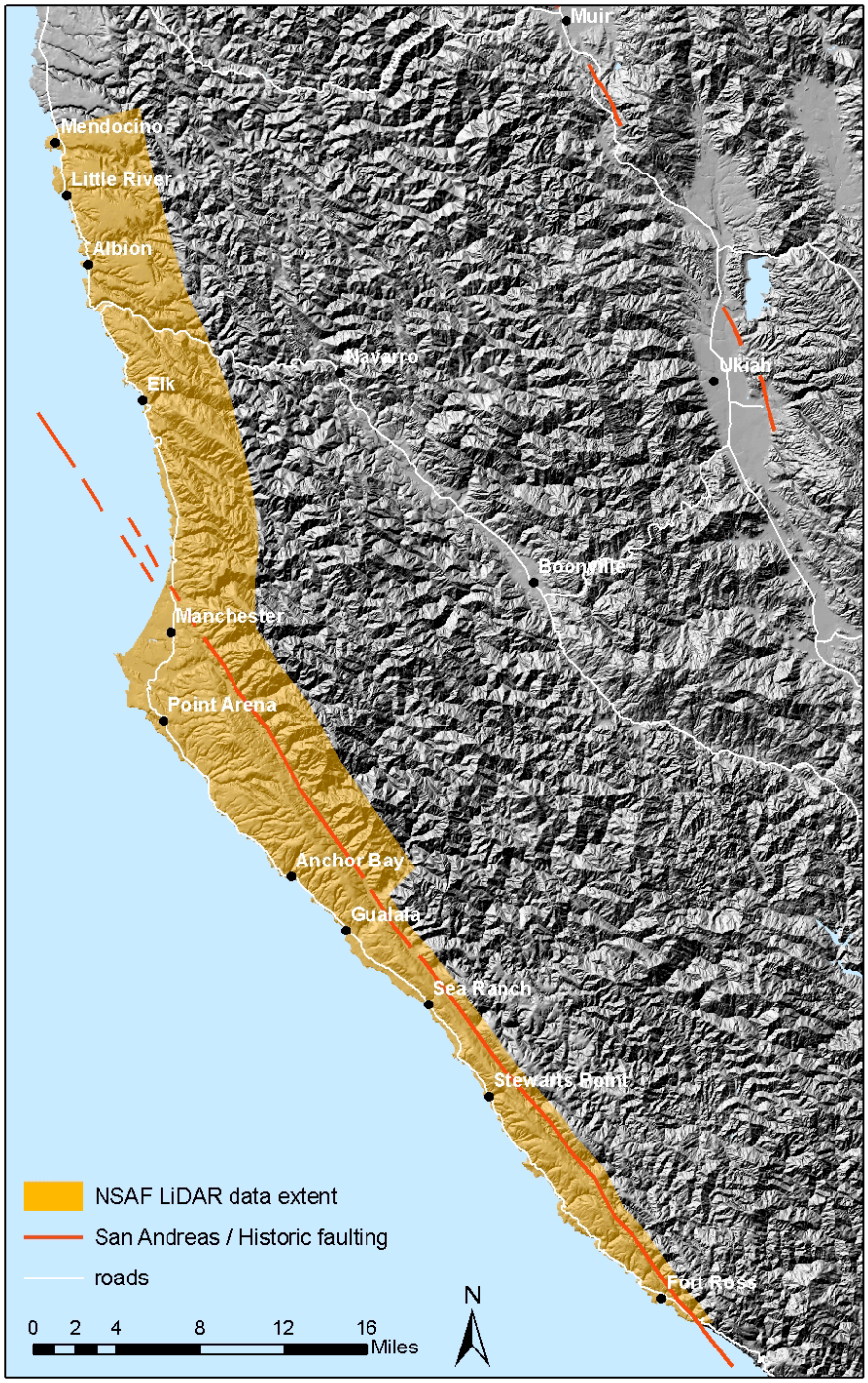

Figure 2. Location of lidar mapping along northern San Andreas fault (highlighted in orange).

FILE NAMING CONVENTION

DTM, DSM and point cloud data files are organized based on USGS quarter quadrangles which represents a 3.25 x 3.25 minute region.

The organization of the data files and the USGS quadrangle names are illustrated in Figures 2, 3, 4 and 5.

An example of the file naming convention is: q39123a14, in which

39 and 123 refer to the lower-right latitude and longitude of the 1 deg x 1 deg region in which the quarter quadrangle is located,

a1 refers to the USGS row and column index for quadrangles within 1 deg x 1 deg regions; row indices increase from south to north from a to h and columns indices increase from east to west from 1 to 8,

4 refers to the quarter quadrangle, where 1= NW, 2 = NE, 3 = SW and 4 = SE.

For the bald Earth DTM, be is appended to the end of the file name.

For the point cloud files of laser returns, each quarter quadrangle is subdivided into a 5 x 5 array of tiles organized from upper-left to lower-right as follows:

01	02	03	04	05
06	07	08	09	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

The two-digit tile number is appended to the end of the file name.

The GPS flight trajectory files are organized by flight mission. An example of the file naming convention is: u3030391.gps, in which

u3 is a two character sensor ID,
03 is the last two digits of the year,
039 is the Julian day at the beginning of the mission, and
a is the mission designation, incremented alphabetically for multiple missions in one day.

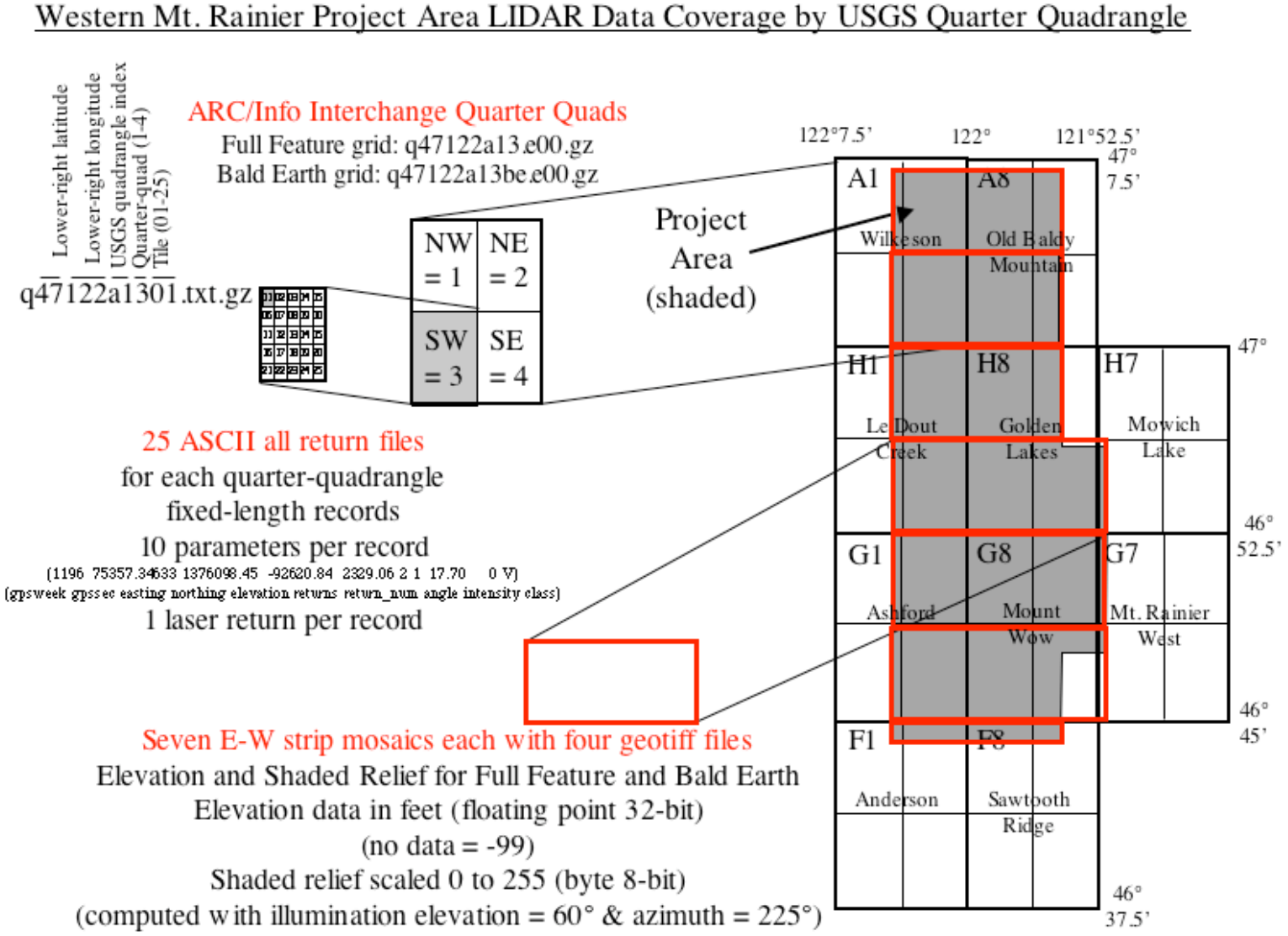

Figure 3. West Rainier seismic zone project area.

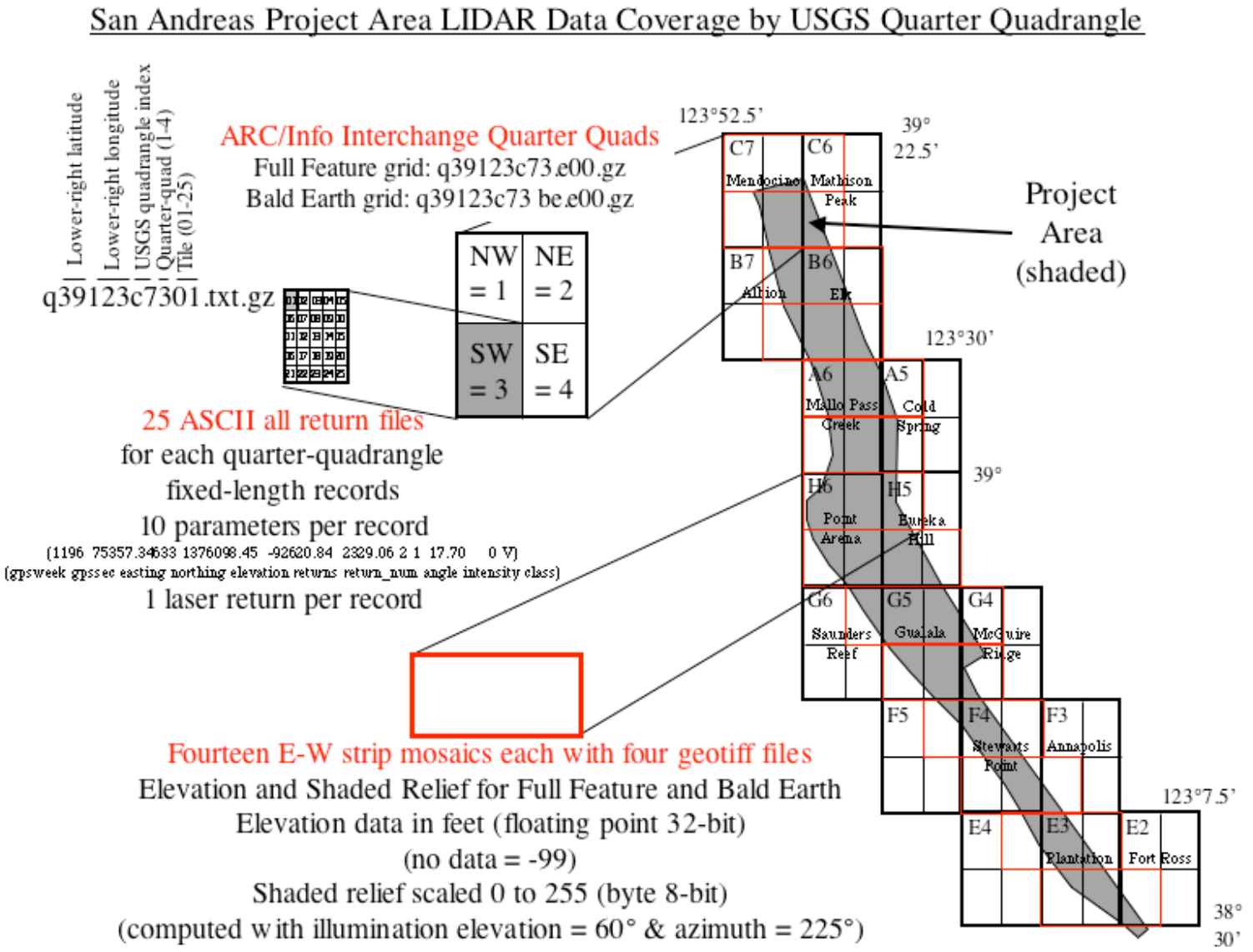

Figure 4. Northern San Andreas fault project area.

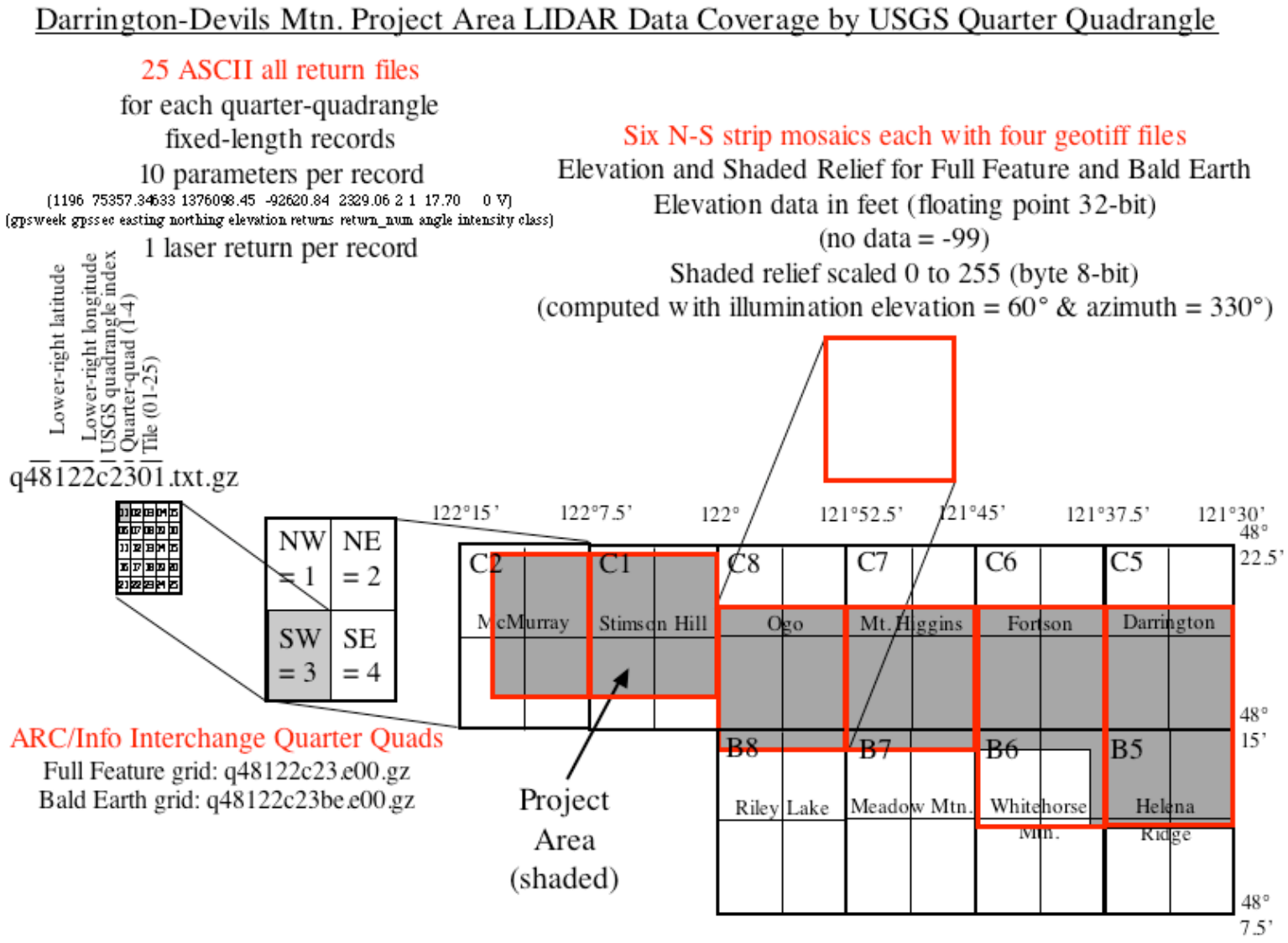

Figure 5. Darrington-Devils Mountain seismic zone project area.

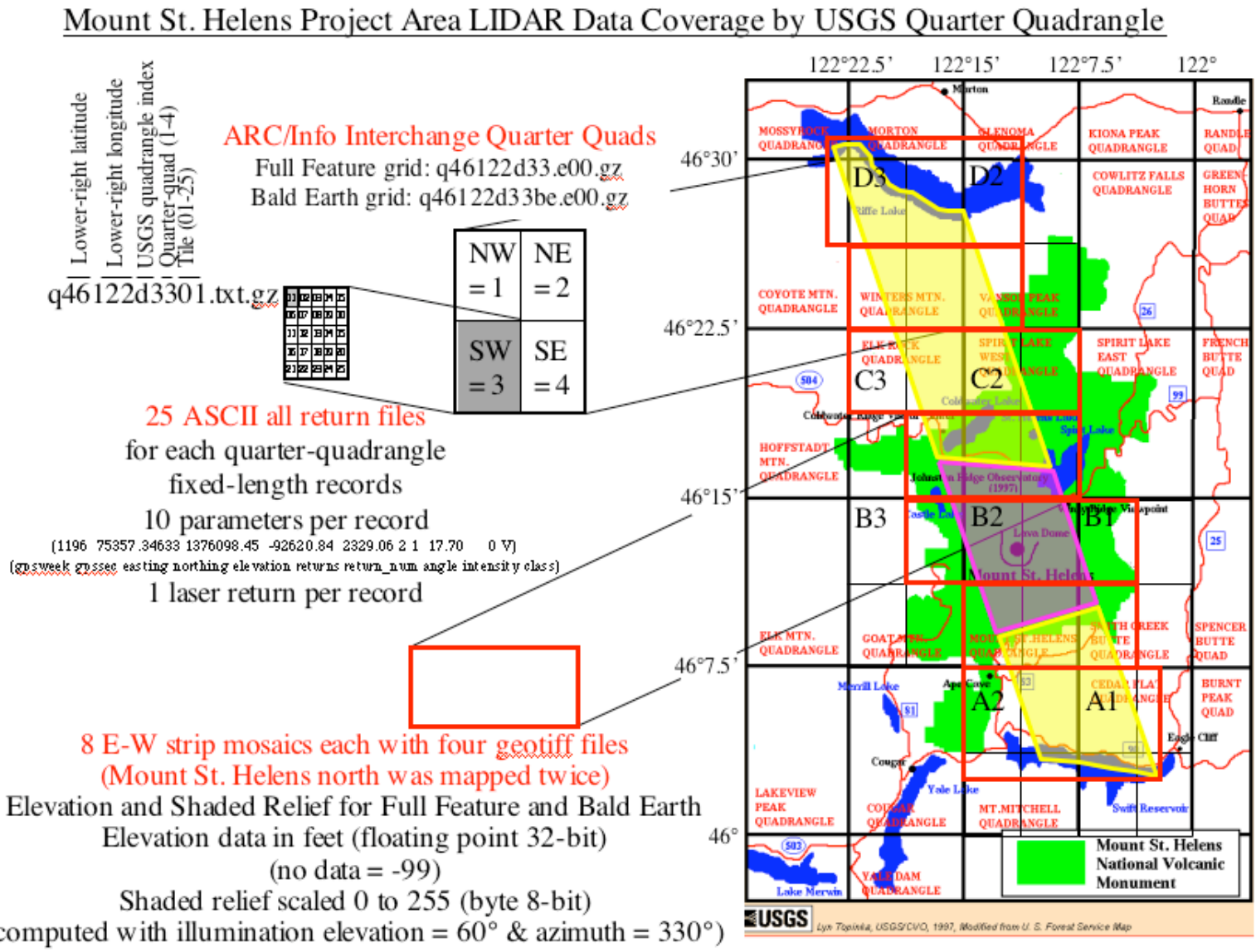

Figure 6. Mount St. Helens volcano and seismic zone project area. The purple shaded area was mapped on October 4-5, 2004, and the northern half of the Mount St. Helens quadrangle was remapped on November 20, 2004, for change detection purposes. The yellow shaded areas were mapped once, in January, 2005.

BALD EARTH DIGITAL TERRAIN MODELS

These are elevation grids distributed as gzipped ARC export files and have the extension e00.gz; be is appended to the quarter quadrangle file names to designate bald Earth files. They are derived by linear interpolation of a triangulated irregular network (TIN) built from those laser returns classified as being from the ground or water. The grid cell spacing is 6 survey feet. Cell easting and northing coordinates are integer multiples of 6, so that adjacent quarter-quadrangles can be merged without resampling or pixel-shift and so the cells align with those of the full feature digital surface model.

FULL FEATURE DIGITAL SURFACE MODELS

These are elevation grids distributed as gzipped ARC export files and have the extension e00.gz. Grid cell elevation value corresponds to the highest non-blunder laser return contained within the grid cell. Cells containing no laser returns are assigned a no data flag of -9999. The grid cell spacing is 6 survey feet. Cell easting and northing coordinates are integer multiples of 6, so that adjacent quarter-quadrangles can be merged without resampling or pixel-shift and so the cells align with those of the bald earth digital terrain model.

POINT CLOUD OF CLASSIFIED LASER RETURNS

Data files containing information about each laser return consist of gzipped ascii text files, with an extension of txt.gz.

Each file consists of one fixed length record for each laser return. There are no header records. The records each consist of 10 fields:

Parameter	Field Width	Read As
gps_week	4	long integer
gps_second_of_week	13	double precision float
easting	11	double precision float
northing	11	double precision float
orthometric_elevation	9	double precision float
number_of_returns	2	integer
return_number	2	integer
angle_off_nadir	7	float
intensity	6	long integer
classification	2	character

An example of a data record is:

```
1205 174436.50828 6151368.67 2011080.93     3.14 1 5  16.64    43 G
```

GPS_week and GPS_second_of_week refer to the time of the laser pulse transmission.

Easting, (in survey feet), northing (in survey feet), and orthometric_elevation (in international feet) refer to the location of the return.

Up to four returns can be recorded per laser pulse; number_of_returns is the total returns for a pulse (up to a maximum of 4). Return_number is assigned as a number from 1 to 7 in a scheme that identifies which return is the last return recorded for a pulse:
1 first return with subsequent returns detected
2 second return with subsequent returns detected
3 third return with subsequent returns detected
4 fourth return
5 first return with no subsequent returns detected
6 second return with no subsequent returns detected
7 third return with no subsequent returns detected

Angle_off_nadir refers to the orientation of the laser pulse vector, combining scan mirror and aircraft orientations.

Intensity is an uncalibrated measure of received energy for the return. Note that due to an instrumentation malfunction, intensity values for the Rainier dataset collected through gps_week 1200 are unreliable and the values can be large integer numbers. Data after and including gps_week 1201 are valid and are reported as byte values from 1 to 256.

Classification of each return was implemented by TerraPoint using the TerraScan software developed by TerraSolid. Returns are classified as:
B Blunder; anomalous return above or below return point cloud
G Ground or water; the "bald Earth" surface
V Vegetation
S Building/Structure

AIRCRAFT PLATFORM FLIGHT TRAJECTORY

Data files containing information the aircraft flight trajectory consist of ascii text files, with an extension of gps.

Each file consists of one fixed length record for each 1 second epoch of the GPS derived trajectory solution. There is one header record with parameter names for each column. The records each consist of 10 fields:

Parameter	Field Width	Read As
GPSWeek	4	long integer
SecofWeek	11	long integer
Easting (Ft)	15	double precision float
Northing (Ft)	13	double precision float
Height (Ft)	10	double precision float
Q	6	integer
StDev	7	float

VE	8	float
VN	8	float
VZ (velocity m/s)	8	float

An example of the header and one data record is:

GPSWeek	SecOfWeek	Easting(Ft)	Northing(Ft)	Height(Ft)	Q	StDev	VE	VN	VZ(velocity m/s)
1204	511502	6220315.27	2175661.94	626.32	2	0.002	0.001	0.001	0.003

GPSWeek and SecofWeek refer to the time of the GPS solution.

Easting (in survey feet), Northing (in survey feet), and Height (orthometric, in international feet) refer to the position of the GPS receiver on the aircraft.

Q is a quality factor, with 1 being best and 6 being worst.

StDev is the standard deviation of the position solution.

VE, VN, and VZ are velocities in the easting, northing, and vertical directions, in meters per second.

GEOTIFF MOSAICS

The highest surface and bald Earth .e00 quarter quadrangle files have been mosaiced together and output as geotiff elevation and derived shaded relief images. The grid cell values in the elevation images are orthometric elevations in international feet referenced to North American Vertical Datum 1988 (NAVD-88) stored as signed floating point values with undefined grid cells set to -99. The shaded relief images are byte values from 0 (shaded) to 255 (illuminated) computed using ENVI 4.0 shaded relief modeling with an illumination azimuth of 225 degrees (Rainier and San Andreas) or 330 degrees (Darrington and Mount St. Helens), an illumination elevation of 60 degrees, and a 3x3 kernel size.

The images are mosaics based on USGS 7.5 minute quadrangle boundaries. The Rainier, San Andreas, and Mount St. Helens mosaics are east-west strips covering the northern or southern half of adjacent quadrangles (Figures 3, 4, and 6). The Darrington mosaics are north-south strips covering adjacent quadrangles (Figure 5). File names include the quadrangle names, a northern (N) or southern (S) half designation (for Rainier, San Andreas, and Mount St. Helens mosaics), a bald Earth (BE) or highest-surface (FF) designation, and an elevation image (elev) or shaded relief image (SR) designation. FF refers to full-feature indicating vegetation and buildings have not been removed.

Files with .tif extensions are the geotiff images. Files with .txt extensions are header outputs providing the geotiff tag values for the mosaics. Files with .tfw extensions provide world file parameters used by some GIS software.

REFERENCES

Haugerud, R., D.J. Harding, S.Y. Johnson, J.L. Harless, C.S. Weaver, and B.L. Sherrod, 2003, High-resolution topography of the Puget Lowland, Washington - A bonanza for earth science, *GSA Today*, 13(6): 4 – 10.

TerraPoint, 2004, TerraPoint LIDAR Mapping Instrumentation and Methodology, D.J. Harding, ed., unpublished report available at http://core2.gsfc.nasa.gov/lidar/terrapoint/TerraPoint_System_Description.pdf, 22 p.

This documentation was prepared on 12/02/04, and updated on 6/30/05, by:

David J. Harding
NASA's Goddard Space Flight Center
Planetary Geodynamics Laboratory
Mail Code 698
Greenbelt, MD 20771
301-614-6503
David.J.Harding@nasa.gov