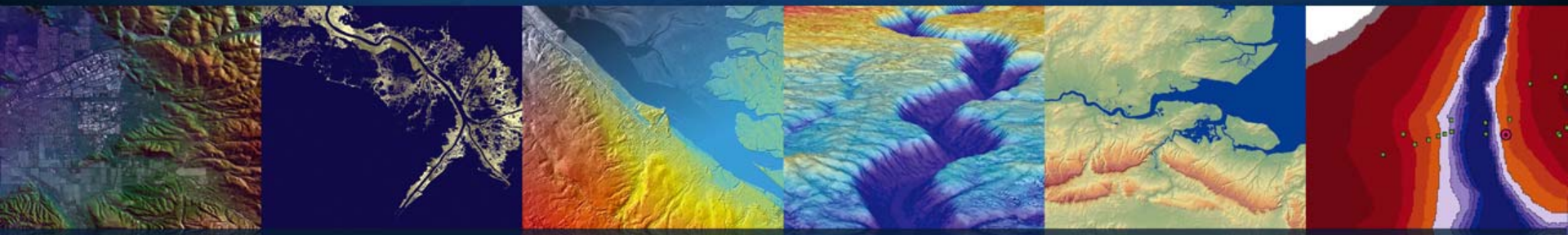

National Digital Orthophoto Program (NDOP) Meeting October 6-8, 2008

M. Lorraine Tighe PhD Candidate

3:15 – 3:45 pm October 7th

Agenda

- IFSAR Technology (X/L/P Band)
- X-Band DTM Improvements
- Orthorectification using IFSAR
- IFSAR derivative datasets
- Discuss Licensing of IFSAR Data and DEM derivative datasets

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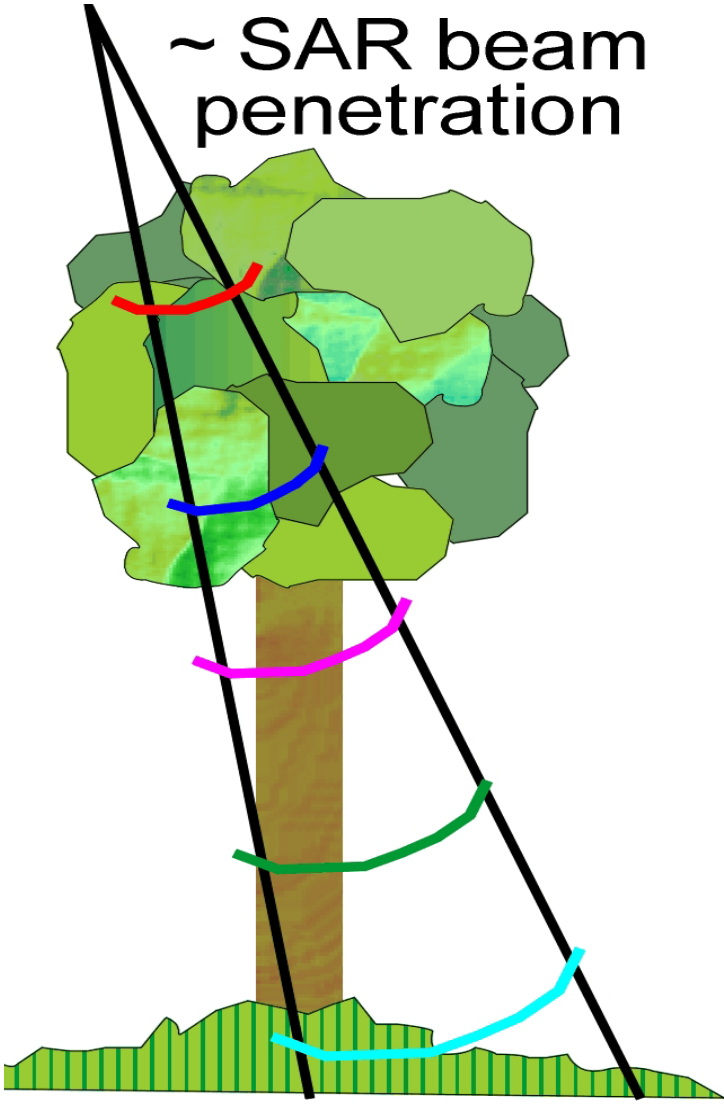
IFSAR Technology (X/C/P Band)

- Penetration of radar microwaves into a forest canopy depends on the wavelength of the microwave system.

- Rule of thumb for the same forest conditions, flying height and viewing geometry, is as follows:

  - K-Band Leaves
  - X-Band Leaves, twigs, small branches
  - C-Band Leaves, secondary branches
  - L-Band Primary branches, trunk, ground
  - P-Band Primary branches, trunk, ground, below the ground



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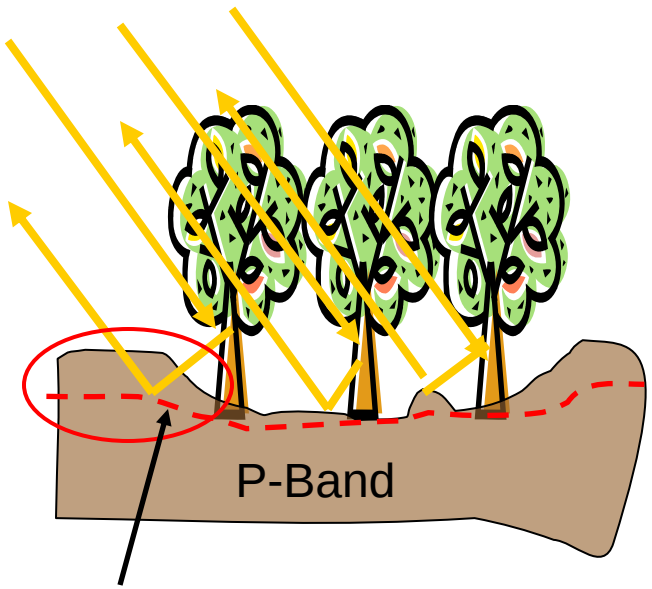
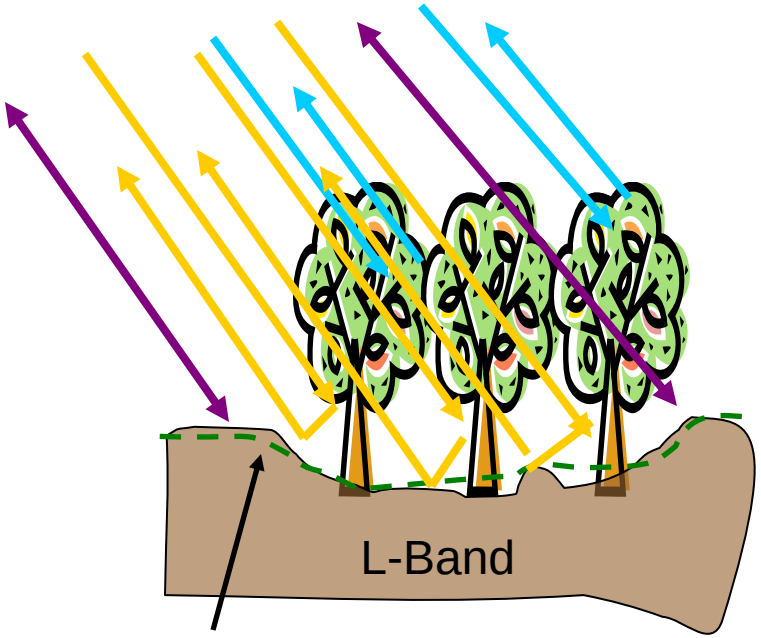
P-Band – Not usually at the bottom of the canopy

P-Band Dual-Pol utilizes 'double bounce' to extract terrain using tree trunks as corner reflectors



- P-Band often penetrates more into soil due to longer wavelength
- P-Band Dual-Pol 'double bounce' approach often results in erroneous terrain measurements

L-Band Quad-Pol utilizes Pol-InSAR to *fully characterize all scattering mechanisms*



- L-Band penetrates less into soil
- L-Band PolInSAR Random Volume over Ground (RVoG) approach provides more accurate measurement for terrain

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Why L-Band and not P-Band (Collection)

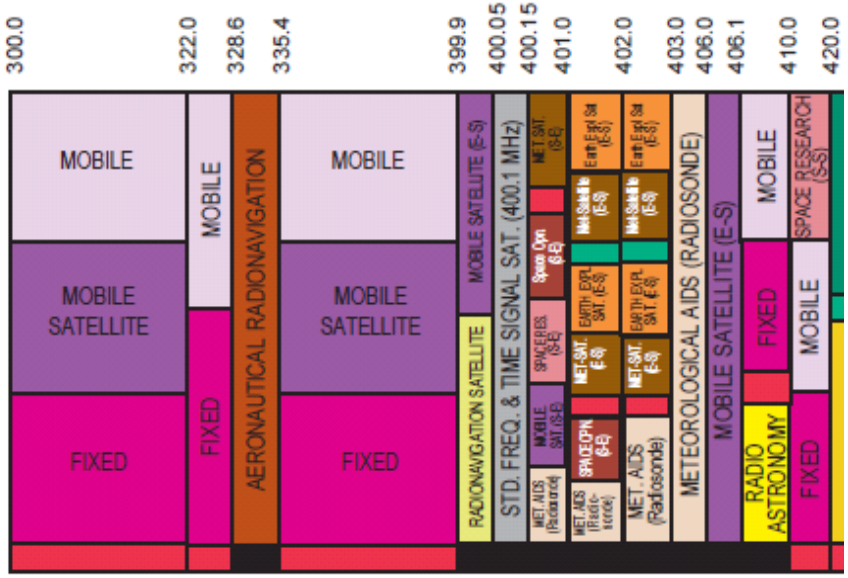
- Radar systems are classified as *'radiolocation'* equipment by US NTIA and other international organizations

Latest spectrum allocation chart from:

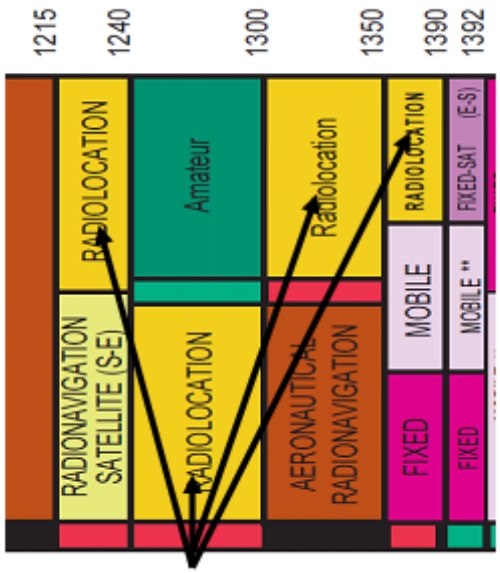
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

October 2003

P-Band



L-Band



- P-Band does NOT have any allocation for radiolocation (cannot be licensed operationally)

- L-Band has 125+ MHz allocated for radiolocation (can be licensed for operations)

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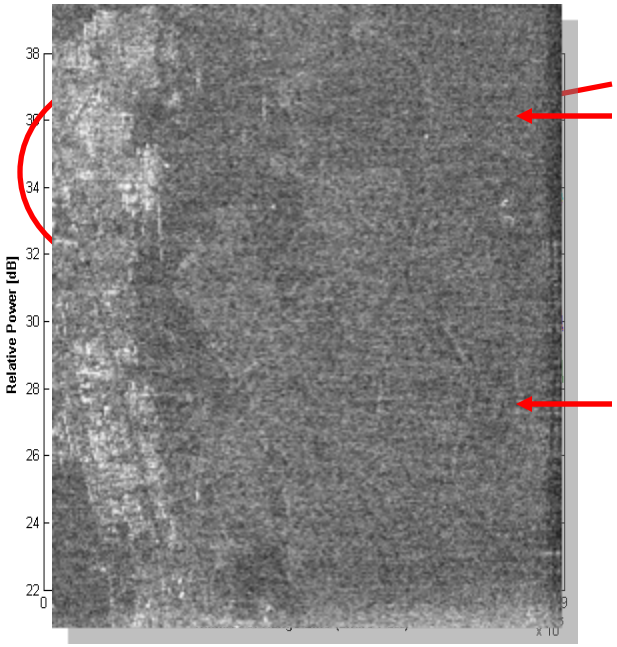
Why L-Band and not P-Band (Interference)

Since P-Band utilizes the same frequencies used by terrestrial communication and navigation systems, ***interference*** *between the systems is very* ***common***.



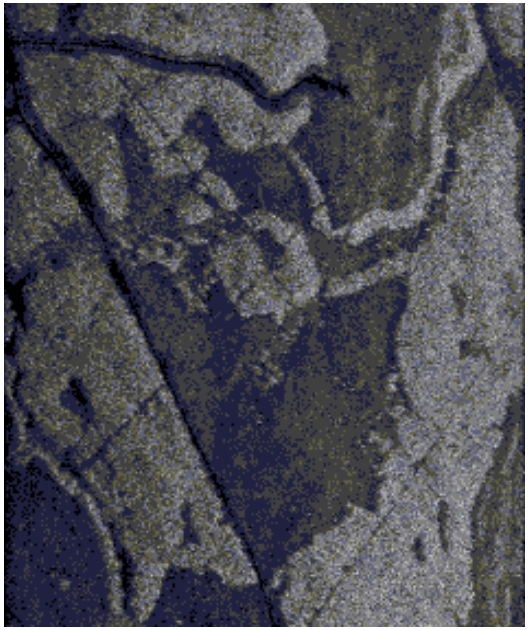
Interference experienced in Intermap's early P-Band repeat pass system

Interference resulted in very **poor signal and image quality**

To reduce effects in imagery, *extensive filtering in the radar receiver is required*.

Extensive filtering on transmit is required even for special R&D operating permit to reduce interference with communications devices.

L-Band *does not share* frequencies with navigation and communication systems, so *interference is* ***not present***



Since L-Band has broad radiolocation frequencies allocated, full bandwidth is available for **full resolution imagery**.

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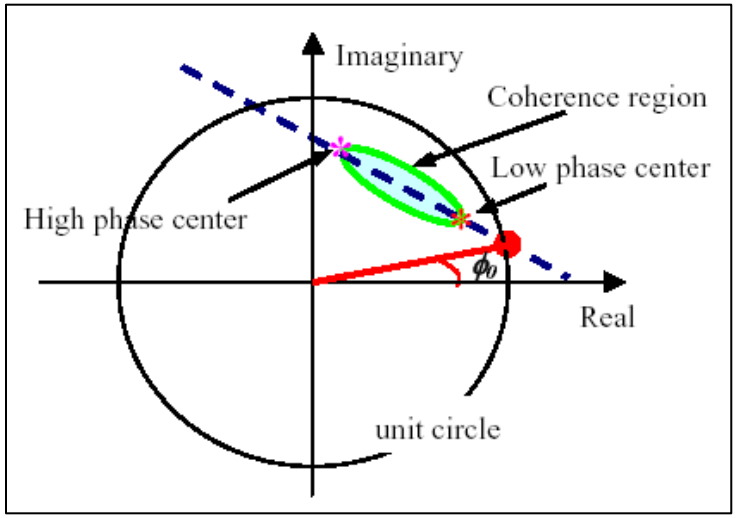
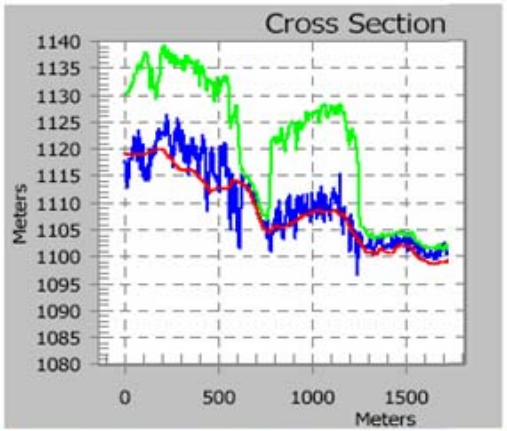
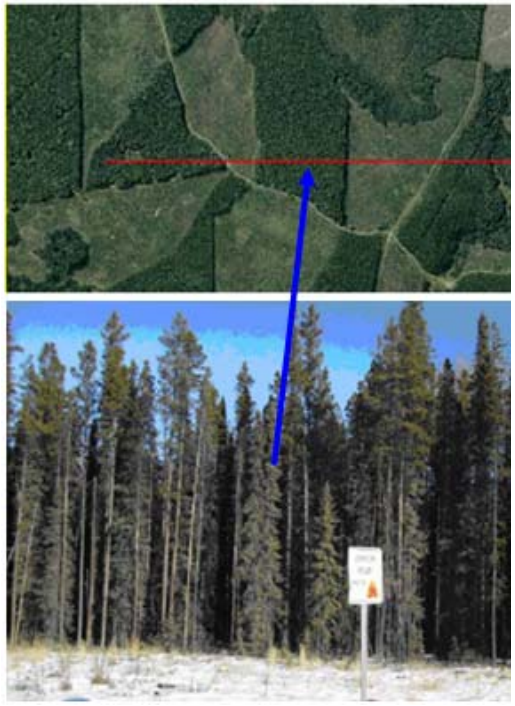
We have opted for PolInSAR L-Band

- World's first single pass L-Band PolInSAR system.







- Phase optimization approach for topographic phase estimation.
  - The green ellipse is the estimated coherence region. The straight line (blue dashed) passes through two ends of the coherence region. The ground topographic phase centre is estimated from one of the line-circle intersection points (red circle).

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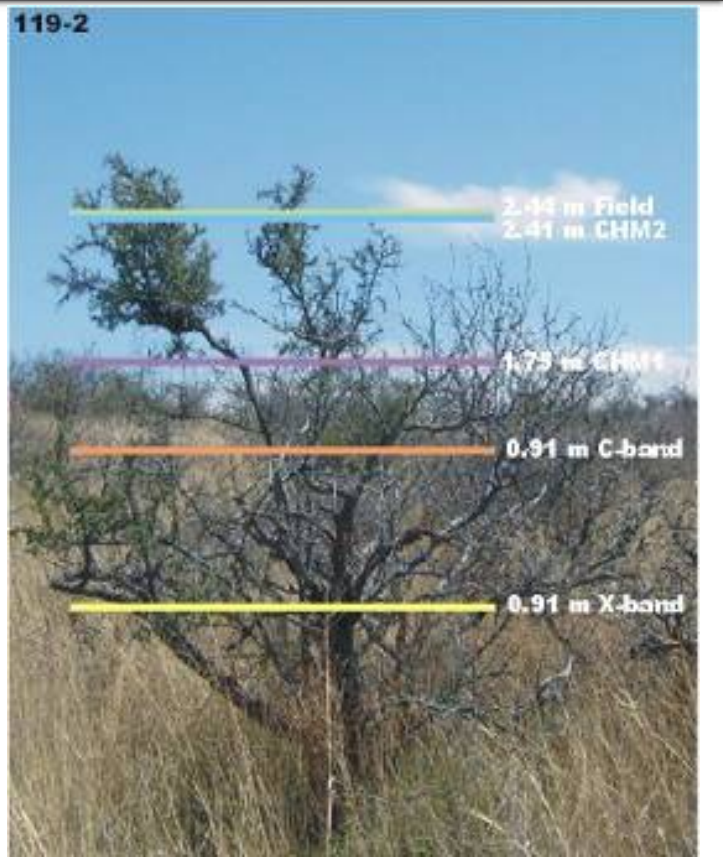
X-Band – Not usually at the top of the canopy

- Intermap has created a canopy height model to retrieve tree heights to within 1.5 m.
- Example here is shrub. We have also looked at evergreen, deciduous, wetlands, and mixed trees.



Site #	Photo #	Site Location (x, y, z geographic coordinates)			Site Type	# Trees 100" Radius Circle	Field Height (ft)	Field Height (m)	DSM-DTM (m)	DSM-DTM (m)	X-band BIAS	C-band BIAS	X-Band Canopy Models		Delta CHM1 - DSM	Delta CHM1 - DSM
		Latitude	Longitude	Height									CHM1	CHM2		
new119	n/a	31.54489812	-111.336571	**1157.9**	Base Station	124	na	na								
	119-1	31.54481639	-111.336773	n/a	Shrub		8	2.44	0.63	1.55	25.94%	63.52%	1.77	2.13	0.67	0.31
	119-2	31.54479947	-111.33679	n/a	Shrub		8	2.44	0.91	1.56	37.34%	63.93%	1.75	2.41	0.69	0.03
	119-3	31.54518881	-111.336587	n/a	Shrub		7	2.13	1.03	1.44	48.50%	67.61%	2.02	2.53	0.11	-0.40

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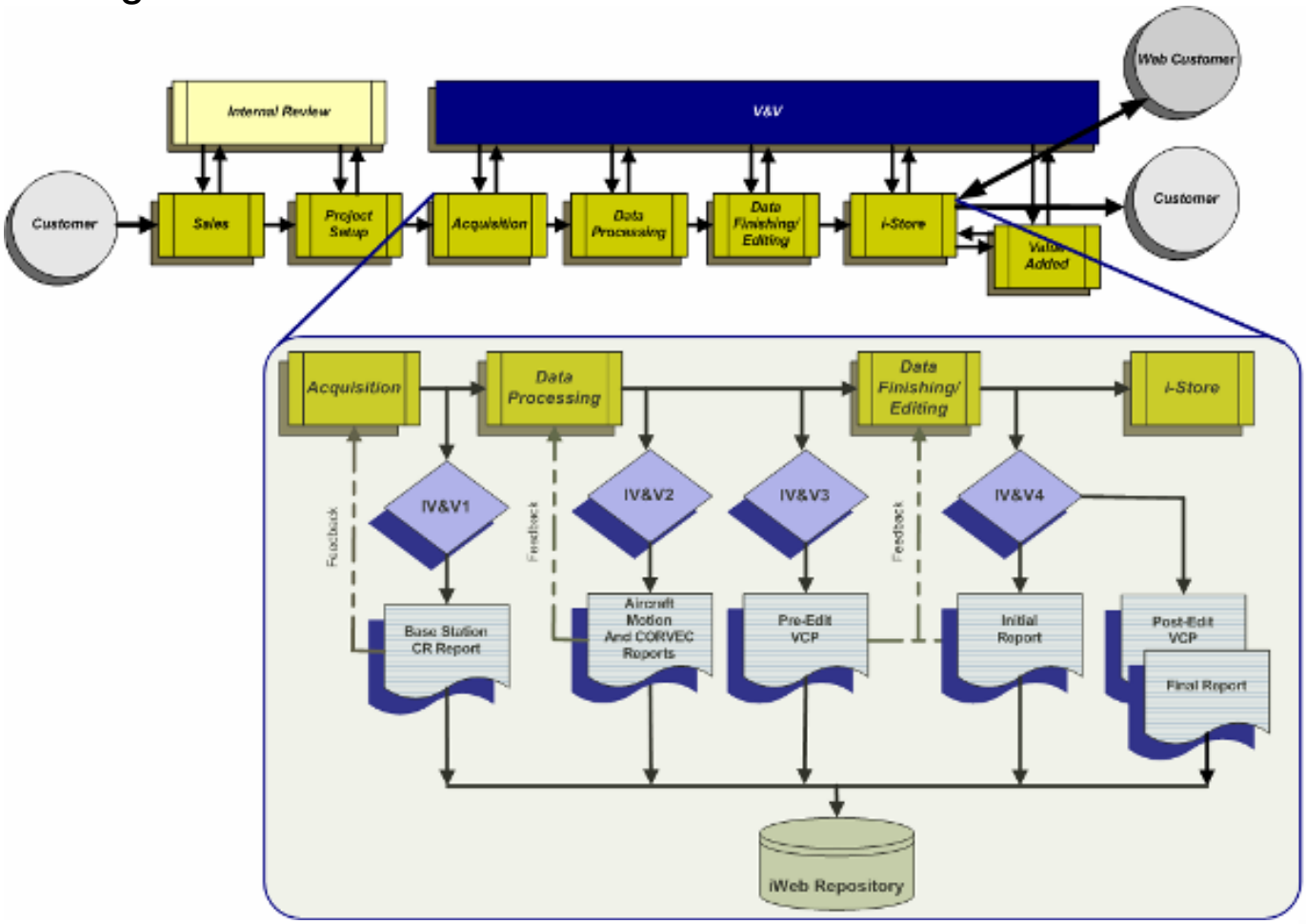
X-Band Enterprise Workflow

- Workflow dedicated to deriving high quality elevation data and customer satisfaction. All aspects of production are managed with rigorous QC checks throughout and within the framework of ISO9000 certification.



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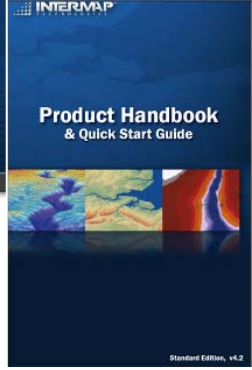
Newest DTM Product



- 480 Editors working in a semi-automated 3D editing system

Feature	Description	DTM v1.0	DTM v1.5	Benefit
Streams	Single Line Drains	No interruption of monotonicity greater than 2 meters shall be present in single line drains	No interruption of monotonicity greater than 1 meter shall be present in single line drains	Further supports flood modeling applications
Buildings	All man-made dwellings	Built-up areas greater than 100 meters across are smoothed but will contain some remnant building elevations	Buildings are removed regardless of magnitude of built-up area using best technology and ability (see section *6.2.2 FITS Editing Process*).	Further supports flood modeling and contour applications
Forests	All trees and groupings of tree canopy heights	Tree stands greater than 100 meters across remain in DTM	No magnitude criteria – all trees / forests are removed from the DTM	Further supports flood modeling, contour, forestry applications

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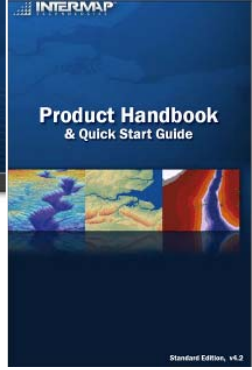
Newest DTM Product



- Moved from Socet Set to our IES Proprietary Editing system based on Autometrics to allow better alignment between edit rules and editors to provide seamless data

Feature	Description	DTM v1.0	DTM v1.5	Benefit
Crops	All field crops detectable in the radar data greater than 1 meter in height	Crops are smoothed to bring their elevation closer to surrounding ground elevations	Crops are removed when detected within radar sensed data	Further supports agricultural applications such as precision farming and flood modeling applications
Major Roads and Railroads	Highways, major roads, and railroads	Highways, major roads, and railroads were flattened so as to be more aesthetically pleasing	Highways, major roads, and railroads are left as sensed by radar	Flattening major roads did not provide an appreciable benefit from an analytical perspective.

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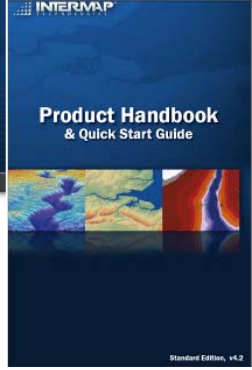
Newest DTM Product



Feature	Description	DTM v1.0	DTM v1.5	Benefit
Bridges	Bridges over water features, roads and railroads	Bridges remain in the DTM and were edited to the road elevation	Bridges are removed from the DTM	Bridge removal is necessary when doing flood modeling applications
Voids	Data gaps due to radar anomalies (See section *5.3 IFSAR Artifacts*)	Interpolated using available seed points across void areas	Ancillary data augments our radar data as one infill component to radar void areas (See section *6.2.2 FITS Editing Process*)	Further supports applications such as contour generation, forestry, biomass analysis, environmental assessment, etc.

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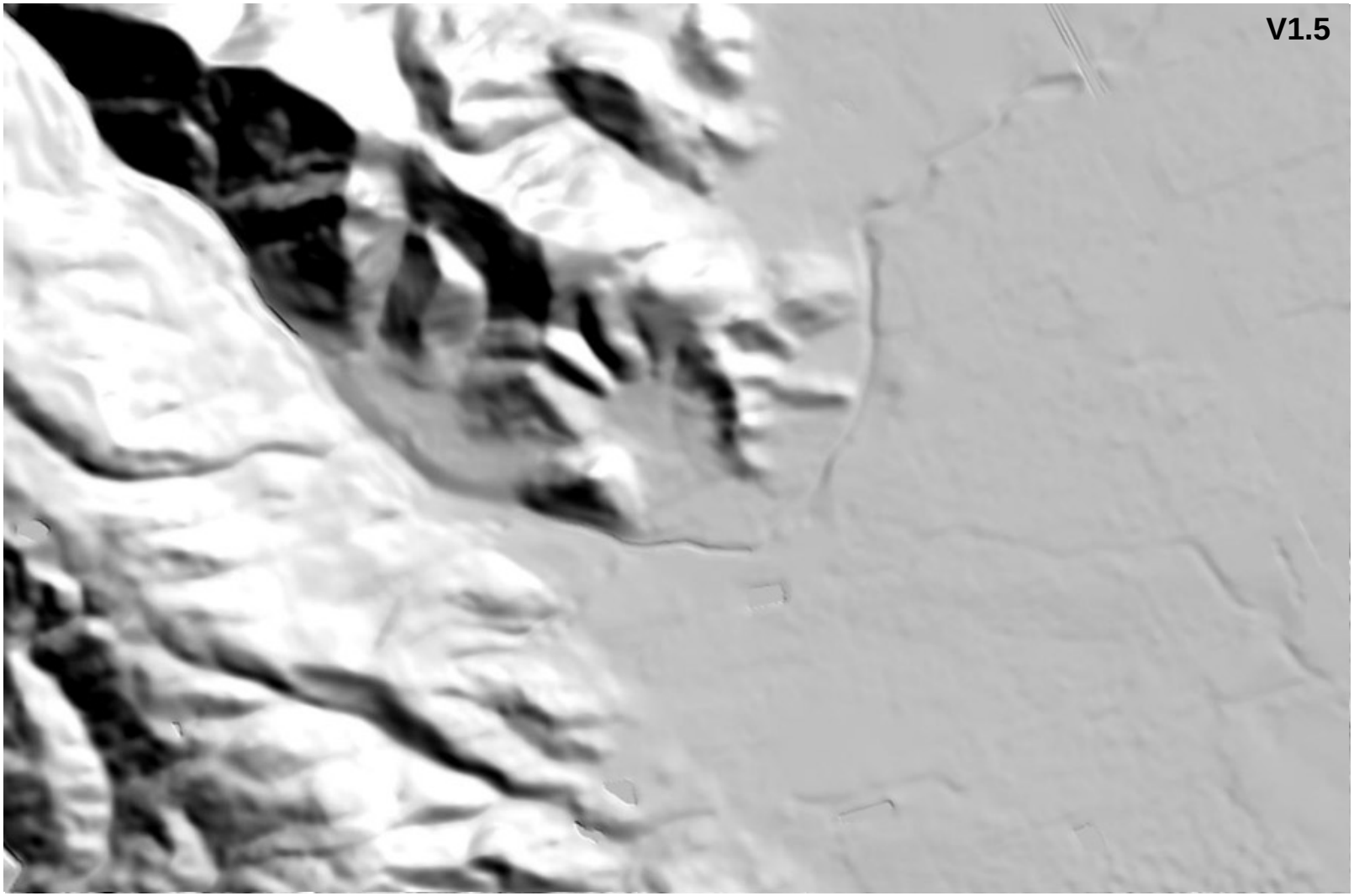
Old Versus New DTM Product



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Orthorectification

- Orthorectification of IKONOS and QuickBird images at off nadir viewing angles to 23 degrees, has been demonstrated using a Rational Functions method.
- CE(90) values better than 4 meters were obtained when compared to independent check points over full image scenes.
- The method utilized external IFSAR-derived DTMs and associated ORIs as prolific sources of GCPs.

ORTHORECTIFICATION OF SATELLITE IMAGES USING EXTERNAL DEMS FROM IFSAR[1]

J. Bryan Mercer, Jeremy Allan, Natalie Glass, Johnathon Rasmussen, Michael Wollersheim

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Commission II, Working Group II/2

KEY WORDS: Mapping, Orthorectification, SAR, Interferometer, DTM/DEM, IKONOS, Quickbird

ABSTRACT:

Images from high-resolution satellites are now in relatively wide use for a variety of applications. For use in most medium and large-scale mapping applications, it is desirable that the imagery be orthorectified. While this may be accomplished by utilizing stereo pairs acquired from these agile-pointing systems, the price and delivery schedule may be significantly impacted by this requirement. On the other hand, savings of time, resources and cost may be realized through use of an external Digital Elevation Model (DEM) of appropriate quality to perform the orthorectification on single, non-stereo, images. The quality of the DEM is a key factor in the ultimate accuracy and robustness of the orthorectification. DEM quality in this sense is equated to vertical accuracy and to sample spacing (posting). It has been shown that as the off-nadir viewing angle increases, the vertical accuracy required must improve for any given horizontal accuracy requirement. DEMs created by the STAR-3*i* IFSAR system have been used to test and demonstrate orthorectification of IKONOS, QuickBird and EROS-A1 images in addition to aerial photography. Several methodologies have been used including that of a simple Rational Functions approach. Together with input of GCPs (Ground Control Points) taken from the STAR-3*i* Orthorectified Radar Images (ORIs) that accompany the DEMs, mapping scale accuracies suitable for 1:4800 and larger have been achieved. In this presentation we demonstrate several examples of orthorectification performed with single images from IKONOS and QuickBird. Quantitative and visual results are presented.

1. INTRODUCTION

In order for imagery to be utilised in GIS and other applications for which pixels must be correctly geo-located, image orthorectification is a necessity. The particular application determines the factors required – specifically the image resolution and horizontal accuracy. These are often defined in terms of desired mapping scale. Orthorectification implies that both sensor system and terrain-related errors are reduced to some specified level and that the image pixels are resampled to a particular projection and reference system.

Aerial photography and satellite images exhibit certain similarities and differences in terms of the parameters and issues to be dealt with during orthorectification. In both cases, the horizontal pixel displacement caused by off-nadir viewing increases with viewing angle Θ. Specifically, $\Delta = h \tan\Theta$ for aerial photography, as a back-of-the-envelope calculation shows, where Δ = the terrain displacement and h = the terrain height of the pixel. For typical high-resolution satellites, Δ increases somewhat faster than $\tan\Theta$ as shown by Zhang, *et.al.* (2000). This parallax displacement error is usually corrected in a pixel-by-pixel manner during orthorectification, provided the elevation, h, of the ground pixel is known. However, the consequence of the viewing angle dependence is that the displacement correction required depends more critically on the vertical accuracy of the elevation information as Θ increases. A second elevation-related factor impacts the accuracy of the orthorectification: the spatial frequency of the terrain relief drives the requirement for spatial sampling density of the terrain elevation. For example, elevations sampled at 30 meter spacing would be inappropriate for retaining orthoimage accuracy along ditches or other land features that change more rapidly.

Traditional orthorectification involves the use of stereo pairs from which elevation is extracted directly to be used for production of contours and DEMs in addition to orthorectification of the images. However the cost of acquiring and processing stereo may not be justified if the purpose is to do orthorectification only. In the case of the high-resolution satellites, there is also an opportunity cost for stereo acquisition: the time spent in acquiring the stereo partner is time lost in acquiring additional primary images. Given the small footprint, (100-200) km^2 per image, this is a serious cost factor. Provided a suitable DEM is available from external sources, it seems plausible and cost-effective to acquire single images and perform the orthorectification without invoking stereo requirements.

The purpose of this paper is to demonstrate orthorectification results achievable using external DTMs derived from airborne IFSAR – specifically the Intermap STAR-3*i* system. We provide visual examples and quantitative accuracy results relating to the orthorectification of IKONOS and QuickBird images. Aside from the technical merits we also address the cost benefits of the process.

We provide a brief review of the IFSAR data in section 2, describe the orthorectification methodologies used in section 3, and the data sets in section 4. We then present the results of the accuracy analysis along with visual examples in section 5. A demonstration of comparative cost is provided in section 6 followed by concluding remarks section 7.

2. THE IFSAR DATA

STAR-3*i* is an X-band interferometric SAR (IFSAR) carried in a Learjet (Mercer and Schnick (2000)) and has been operated commercially by Intermap Technologies since 1997. The core products generated include a Digital Surface Model (DSM) and an Orthorectified Radar Image (ORI). A Digital Terrain Model

[1] Published in: *Proc. Joint ISPRS Workshop "High Resolution Mapping from Space 2003", Hannover, Germany, October 6-8th, 2003*

http://www.intermap.com/uploads/1170362785.pdf

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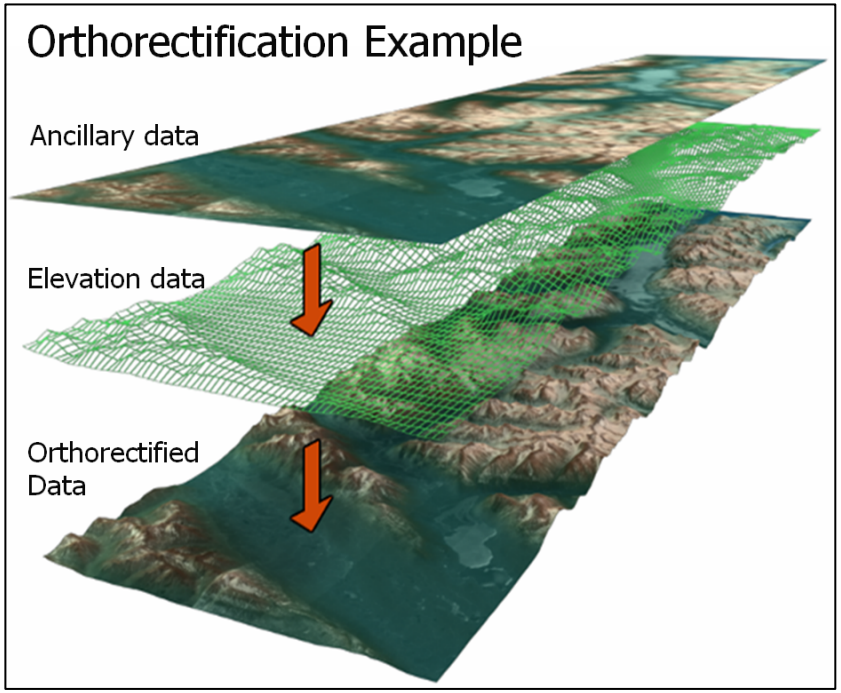
Imagery Orthorectified Using IFSAR

- How IFSAR DEM's can be used to make Orthoimagery that meets NMAS at 1:24K in Alaska?
  - Require set of specifications, orthorectified imagery, elevation data and software.
  - Orthorectification: existing data may need to be orthorectify (correct for horizontal and vertical distortions) ancillary data



- Input:
  - Ancillary data
  - Elevation data
  - Ground Control Points (GCPs)
  - Commercial software
- Output:
  - Orthorectified data layer

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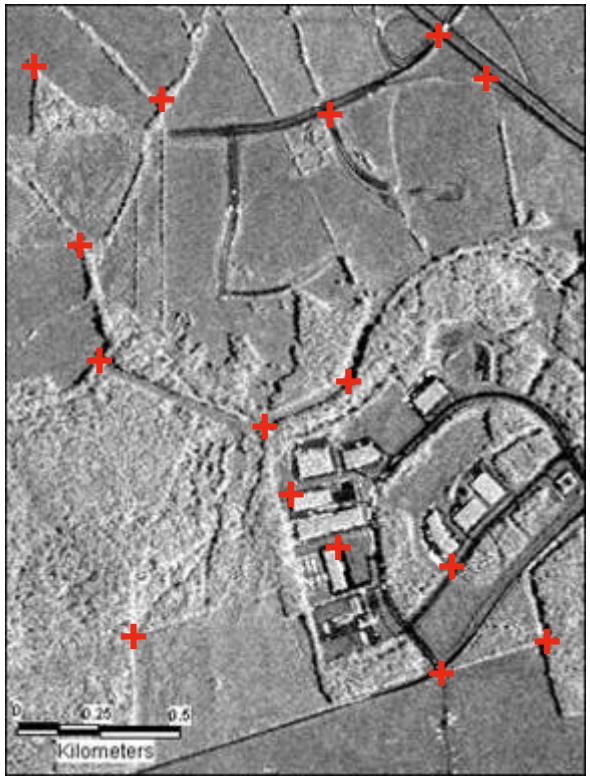
Data Orthorectification – IFSAR Example

- Use radar imagery as a source of GCPs (+)
- Using GCPs + Optical imagery + DEM + Commercial software = orthorectified product



ORI

Landsat 7 (7,4,2)

SAR-sharpened Landsat 7 (7,4,2)

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USGS vs. Intermap DTM (Orange County, California)

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USGS vs. Intermap DTM (Orange County, California)

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Accurate and Quality data

- Data Quality and Data Accuracy
  - Improved with higher resolution data (smaller posting)
  - Google example using USGS 30 m DEM compared to Intermap's 5 m DEM draped on an orthorectified image

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High-Quality Orthorectification

- First Image orthorectified with a **30 m posted USGS** elevation data – note vertical error in road (Red circle).
- Second Image orthorectified with a **5 m posted Intermap** elevation data – note a better rendition of the roads, buildings and mountains.

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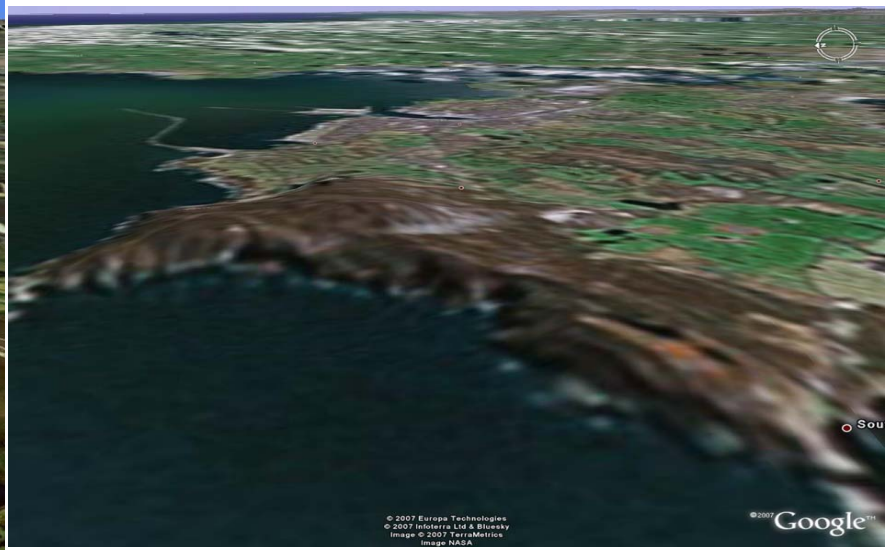
Holyhead, Wales

- Virtual Earth higher resolution images (aerial) provide more “crisp” detail about the landscape then Goggle Earth’s spaceborne “blurred” image over Holyhead, Wales



- Elevation data provided by Intermap’s NEXTMap® data (10-m posting) provide a more accurate rendition of the landscape over the coarser SRTM data (30 m posting) used by Google Earth.

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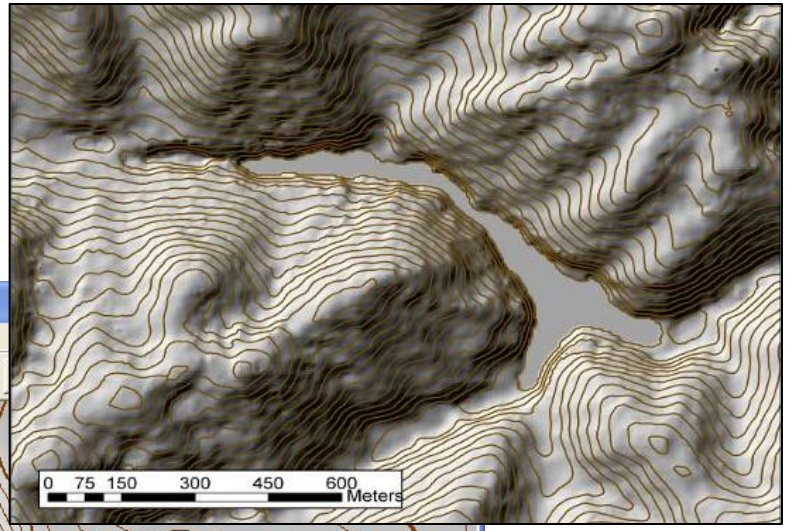
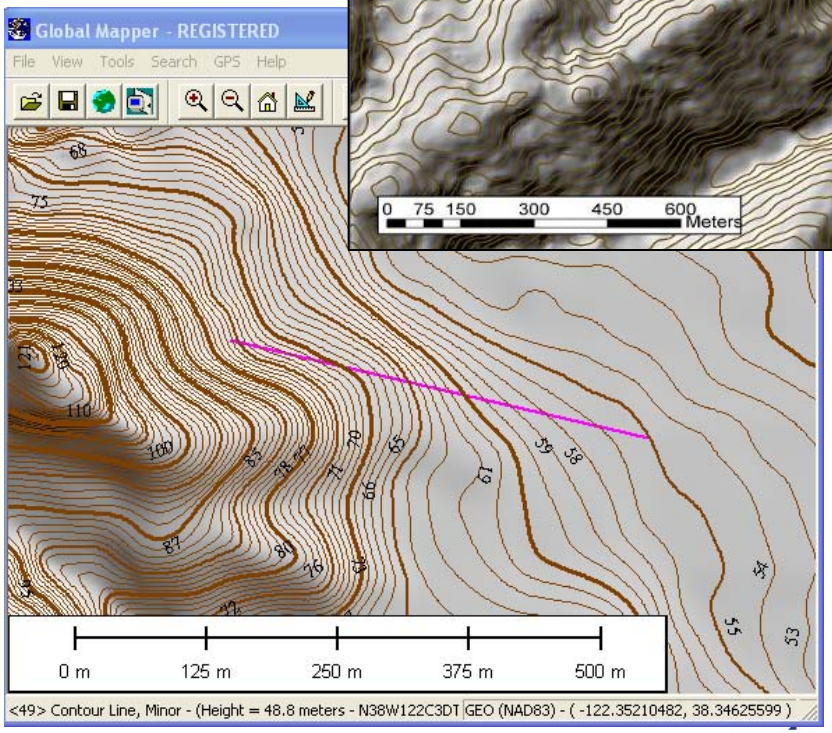
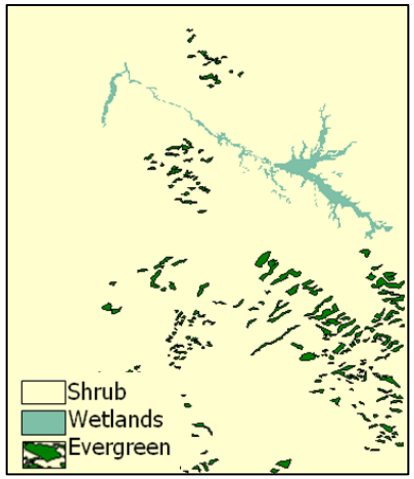
DEM derivative datasets

- Intermap has two divisions (Professions Services & Solutions) to assist in creating and supplying DEM derivatives such as:
  - Contours
  - Topographic/Geology Maps
  - LANDFIRE
  - Canopy Height Models
  - Hillshades
  - Slope and Aspect Maps
  - Reprojected Data
  - Orthorectification
  - **Technology Transfer**







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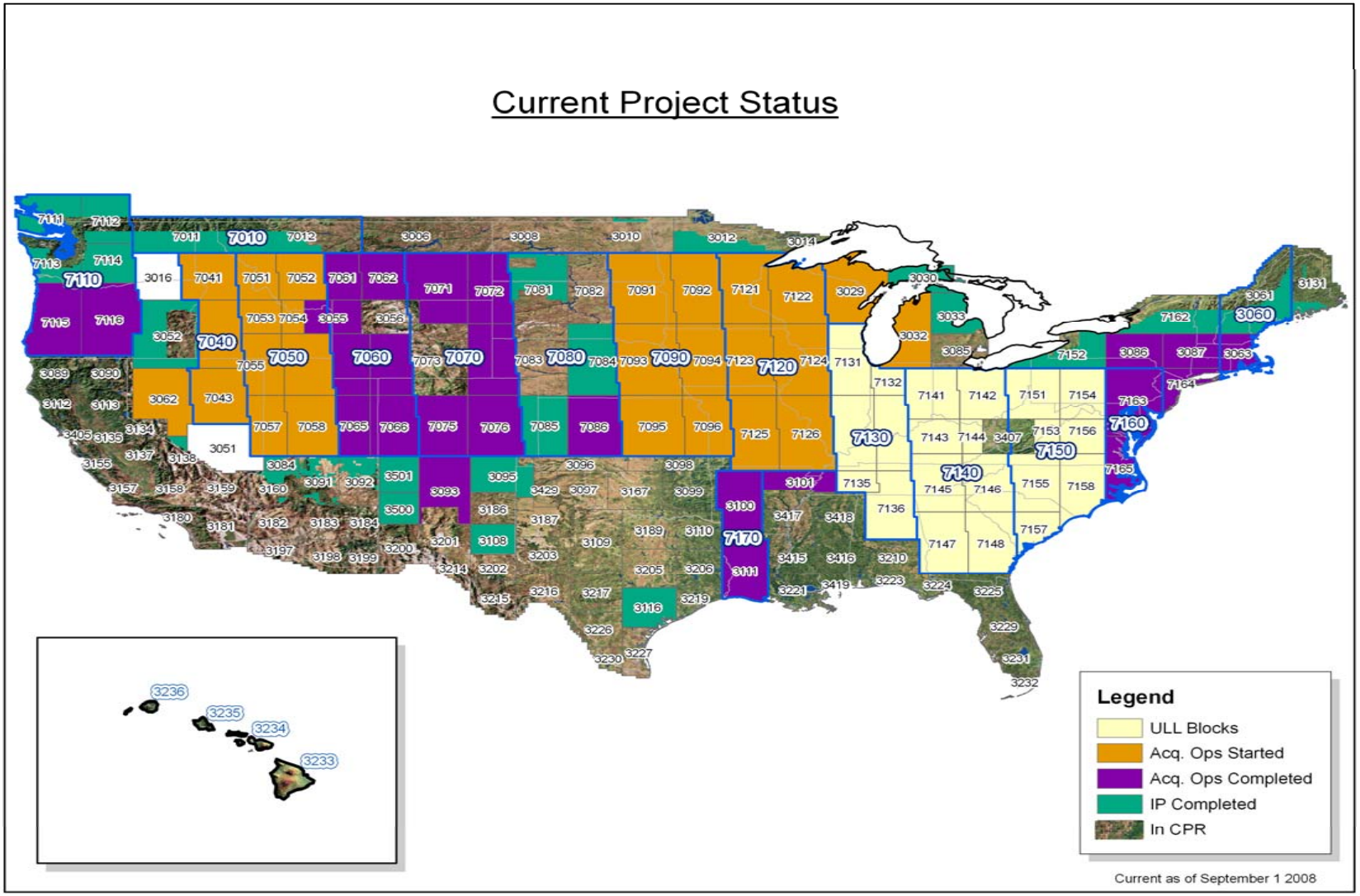
NEXTMap USA Status September 2008



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Intermap Licensing Tiers

- **Licensing Tiers as Described in USGS contract 08CRCN0037**

- Single Organization - This license permits unlimited use of source data and derived products within a single organization of the United States Government, specified at the time of purchase.

- Federal Civil Department Tier- This license permits the unlimited use of the source data and derived products within a single civilian department of the United States Government, specified at the time of purchase.

- Federal Civil -This license permits unlimited use of the source data and derived products within all U.S. Federal Government Organizations excluding DoD and Title 50 organizations.

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- Federal Civil & State/Local Governments - This license permits all uses covered by the Federal Civil license. In addition, this license permits use by State and local governments. All source data and derived products shall be retained by the State and local governments.

- Additional licenses may be negotiated as the need arises on terms mutually agreeable to the parties (e.g. Alaska – public domain).

- DEM derivative products licensing may be negotiated as the need arises on terms mutually agreeable to the parties.

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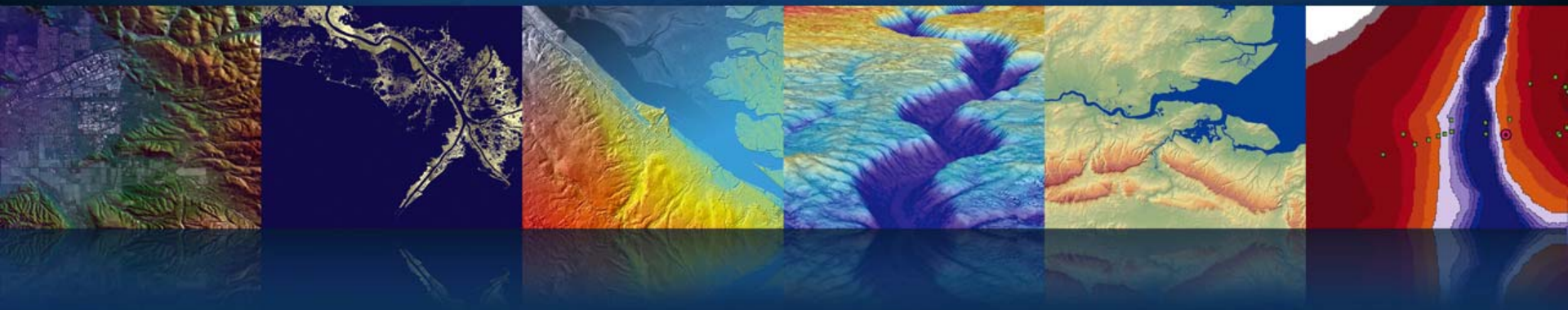

Questions

gbuckman@intermap.com