INTERMAP®

Product Handbook

& Quick Start Guide

Edit Rules Edition, v4.5

INTERMAP®

Product Handbook

& Quick Start Guide

Edit Rules Edition, v4.5

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Corporate Information

Intermap Technologies® has offices at the following locations:

Denver – International Headquarters

Intermap Technologies, Inc.
Phone: 303-708-0955
Fax: 303-708-0952
info@intermap.com
8310 South Valley Highway, Suite 400
Englewood, CO United States 80112

439015 ISO 9001: 2008
Intermap Technologies, Inc.

Prague – Czech Republic Office

Intermap Technologies s.r.o.
Phone: +420 261 341 411
Fax: +420 261 341 414
info@intermap.com
Zelený pruh 95/97
140 00 Prague 4 Czech Republic

421330 ISO 9001: 2008
Intermap Technologies s.r.o.

Calgary – Alberta, Canada Office

Intermap Technologies Corp.
Phone: 403-266-0900
Fax: 403-265-0499
info@intermap.com
840 – 6th Ave SW, Suite 200
Calgary, AB Canada T2P 3E5

10009138 ISO 9001: 2008
Intermap Technologies Corp.

Jakarta – Asian Office

PT. ExsaMap Asia
Phone: +62 21 719 3808
Fax: +62 21 719 3818
info@intermap.com
Wisma Anugraha, 2nd Floor
Jl. Taman Kemang No. 32B
Jakarta, Selatan – 12730
Indonesia

20003832 ISO 9001: 2008
EXSAMAP ASIA

Corporate Information

Product information

United States and Canada: +1 877-837-7246

Outside the United States, Canada and Europe: +1 303-708-0955

Email: info@intermap.com

Product Support

Please visit our Support page on www.intermap.com or call +1 877-837-7246.

Additionally, you can email support.nextmap@intermap.com for data assistance and questions.

The information in this document is subject to change without notice as Intermap® continues to improve its processes, technologies, and product offerings. To ensure you have the latest version of the Product Handbook, visit our Web site at www.intermap.com.

Overview 1.0

Welcome to the Intermap Technologies® Product Handbook.

This handbook is intended to provide you with an introduction to Intermap® and our high-quality digital elevation data products. It includes an overview of Intermap's products, specifications and uses, a description of how we acquire data and validate the accuracy of our products, a Quick Start Guide, and much more.

We hope you will find this handbook to be a useful resource, whether you are a new user of Intermap products or simply want a better understanding of how our products are developed and used. Either way, the content provided in this handbook will give you the information you need.

1.1 How This Handbook Is Organized

The handbook is divided into 10 sections, allowing you to quickly find the information you need.

Section 2.0, *Introduction to Core Products*, describes our three core products: two types of digital elevation models and an orthorectified radar image.

Section 3.0, *Purchasing Intermap Products*, explains how you can order our products. Through its NEXTMap® programs, Intermap has data archives for Europe, the United States, and other areas that can be purchased off the shelf or through our sales team (see Section 6.3.1, *Product Type Availability*). If the data you require is not in the archives, custom products can be purchased through our sales team.

Section 4.0, *Training*, contains descriptions of the various training programs available to help you to increase your understanding of Intermap products in order to optimize their use.

Section 5.0, *Understanding IFSAR,* contains detailed information on IFSAR technology as well as information on artifacts inherent to data captured with IFSAR systems.

Section 6.0, *Core Product Specifications,* contains specific information relating to accuracy, file types, file size, and more to help you understand what you can expect when you place an order with us.

Section 7.0, *Understanding Accuracy,* contains an in-depth description of the statistics and methods used in assessing the accuracy of Intermap data. It also discusses some of the issues that affect the accuracy of our data and how we address those issues.

Section 8.0, *Product Validation,* discusses the processes Intermap has in place to verify the accuracy of our data products.

Section 9.0, *Introduction to Applications,* provides an overview of various uses for both our core products and our value-added products.

Section 10.0, *Quick Start Guide,* provides step-by-step instructions on how to load our products into many popular software packages on the market today.

Appendix A, *Product Licensing,* provides Intermap's end-user license agreement outlining the terms of use for Intermap's products.

Appendix B, *Core Product DEM Edit Rules*, provides a description of the characteristics found in the raw elevation data and the rules used by the editors to edit that data and create the final DSM and DTM products.

1.2 Fast Facts About Intermap

Tracing its legacy back almost 100 years, Intermap is a worldwide leader in providing geospatial solutions that allow customers to make better location-based decisions. Intermap enables commercial enterprises and government agencies to build a wide variety of innovative geospatial applications and efficiently perform analyses.

- Intermap and its world-wide offices are audited annually by Underwriter Laboratories. The processes in the following offices are Certified under our ISO 9001:2008 Quality program: Denver, Calgary, Jakarta, and Prague.
- Our fixed-wing aircraft images the earth's surface using interferometric synthetic aperture radar (IFSAR), which can operate day or night, in clear or cloudy conditions.
- Intermap has acquired and processed over 14 million square kilometers of data in over 54 countires that comprise our NEXTMap® archives.
- Our proprietary and patent-pending data fusion process blends data collected from various sources creating a more accurate and useful end product. Sources we work with include, but are not limited to: IFSAR, customer- or partner-supplied light detection and ranging (LiDAR) technologies, spaceborne SAR, and spacebornce optical remote sensing platforms.
- Intermap's vast experience with elevation data led to involvement in flood modeling projects more than a decade ago.

To find out more about data products or to purchase data online, visit our online Data Store at https://store.intermap.com. You can also contact us directly to place an order or inquire about having a custom project flown to meet your unique needs:

- +1 877-TERRAIN (1-877-837-7246), toll-free within the United States and Canada
+1 303-708-0955 (United States)
+1 403-266-0900 (Canada)
+42 (0) 261 341 411 (Europe)
+62 21 719 3808 (Southeast Asia and Australia)
- E-mail: sales@intermap.com

The most current version of the Product Handbook is available at www.intermap.com.

Introduction to Core Products 2.0

Intermap Technologies® offers three core products, each created from our high-quality IFSAR[1] data. This section briefly describes these products and the innovative IFSAR technology used to capture the raw data.

Our core products include an orthorectified radar image (ORI) and two digital elevation models (DEMs): a digital surface model (DSM) and a digital terrain model (DTM).

ORIs look somewhat like a black and white aerial photo. DSMs, created by capturing radar signals from two antennae and measuring the phase difference between them, contain location and elevation information. DTMs are created by digitally removing, to the extent possible, the cultural features contained in a DSM, exposing the underlying terrain. Both ORIs and DSMs display the first surface that the radar strikes, whether it is bare earth, vegetation, or cultural features such as buildings and utility features.

Intermap® is unique in that we create our products proactively and make them available off the shelf. Our core products are created according to tightly controlled specifications, resulting in consistent, seamless data that span entire land masses. These products vary only when the specifications are upgraded – to reflect improvements in our equipment, for example.

Off-the-shelf products have two advantages – they are highly cost-effective and can be delivered to you very quickly, assuming no custom processing is required. If we have not yet acquired data in your area of interest, please contact us to find out when it will be available. If you prefer, the data can be collected for you as a custom project.

In addition to these primary products, Intermap also provides a variety of value-added products and solutions, some of which are described in Section 3.0, *Purchasing Intermap Products*.

For a more detailed description of our core products and their specifications, see Section 6.0, *Core Product Specifications*.

[1]IFSAR: Interferometric synthetic aperture radar, also known as InSAR, is a type of radar that creates images by combining signals received from two antennae. Intermap uses X-band IFSAR to capture its core product data. X-band refers to the particular wavelength of the radar pulse, which is approximately 3 centimeters.

Introduction to Core Products

2.1 Core Products

This section explains the key features of our core products and provides examples of various applications for their use.

2.1.1 Orthorectified Radar Image (ORI)

The ORI is a grayscale image of the earth's surface that has been corrected to remove geometrical distortions that are a normal part of the imaging process. This product appears similar to a black-and-white aerial photograph. What differentiates an ORI from a photograph is that an ORI uses radar signals, not visible light, to produce images. As the radar waves strike the ground and return to the antennae, they also provide distance and intensity measurement data.

The key feature of this product is that it provides a means of viewing the earth's surface in a way that accentuates features far more than is possible with aerial photography. The radar pulses are transmitted at an angle from the side of the aircraft, which casts "shadows" that enable the user to visually perceive the elevation information in the image, which appears similar to a shaded relief.

The ORI has many applications in value-added products. For example, it can be used to extract cultural features, such as road networks and buildings, and it lends itself readily to terrain, land cover, and geological analyses. Figure 2.1 is an example of an ORI from San Luis Obispo County, California.

Figure 2.1: Example of an orthorectified radar image (ORI) from San Luis Obispo County, California, USA.

2.1.2 Digital Surface Model (DSM)

The DSM is a topographic model of the earth's surface that can be manipulated using a computer. Surface elevation models play a critical role in applications such as biomass studies, flood analysis, geologic and topographic mapping, environmental hazard assessment, oil and gas, and telecommunications – to name a few. The DSM comprises elevation measurements that are laid out on a grid. These measurements are derived from the return signals received by two radar antennae mounted on Intermap's aircraft. The signals bounce back from first surface they strike, making the DSM a representation of any object large enough to be resolved, including buildings and roads, as well as vegetation and other natural terrain features.

In the case of vegetation, the derived elevation data represents the scattering phase center heights. The scattering phase center height over vegetated land cover is located below the true surface height, and consequently, the surface elevation is bias downward. An understanding of the bias is required when utilizing the DSM data in, for example, biomass and canopy height calculations. The key feature of this product is that it provides a geometrically correct reference frame over which other data layers can be draped. For example, the DSM can be used to enhance a pilot's situational awareness, create 3D fly-throughs, support location-based services applications, augment simulated environments, and conduct viewshed analyses. It can also be used as a comparatively inexpensive means to ensure that cartographic products, such as topographic line maps or even road maps, have a much higher degree of accuracy than would otherwise be possible. Figure 2.2 is an example of a DSM from San Luis Obispo County, California.

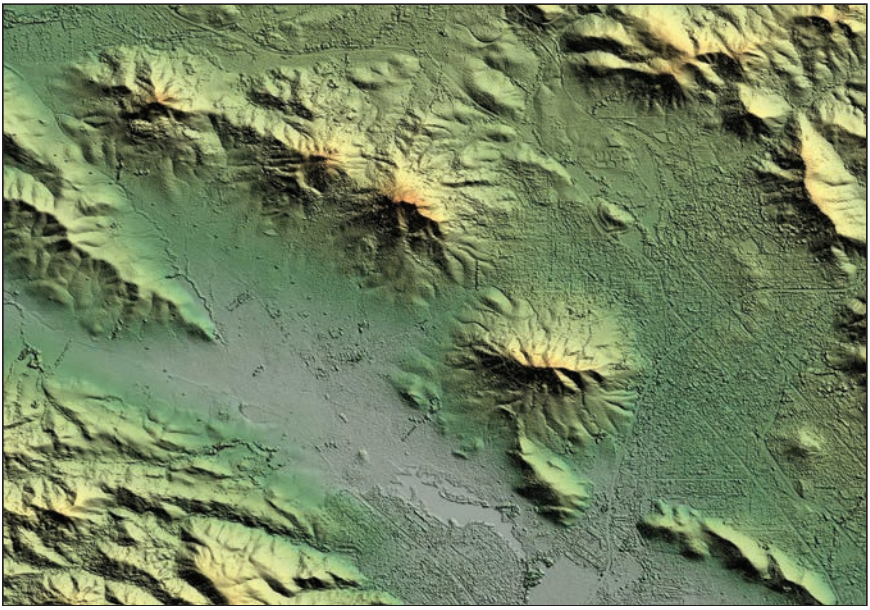


Figure 2.2: Example of a digital surface model (DSM) from San Luis Obispo County, California, USA.

2.1.3 Digital Terrain Model (DTM)

The DTM is a topographic model of the bare earth that can be manipulated using a computer. Vegetation, buildings, and other cultural features have been digitally removed from the DTM, leaving just the underlying terrain. This is achieved using our proprietary software, which derives terrain elevations based on measurements of bare ground contained in the original radar data as well as by manually reviewing and editing every tile.

The key feature of the DTM is that it infers the terrain characteristics that may be hidden in the DSM. Figure 2.3 illustrates that the buildings and trees evident in the previous figures are no longer visible. See Section 6.2, *Product Characteristics*, for a sample list of applications that can use the DTM v1.0 and DTM v1.5 data.

Intermap has two versions of the DTM, based on when the data was collected and how it was processed. The differences between the two versions, DTM v1.0 and DTM v1.5, are described in Section 6.2, *Product Characteristics*. When the DTM is mentioned in this product handbook and no version is stated, the implication is that the data being referred to is DTM v1.5. If you have specific questions about Intermap's DTM data and which DTM is best for your particular applications, please contact an Intermap sales representative.

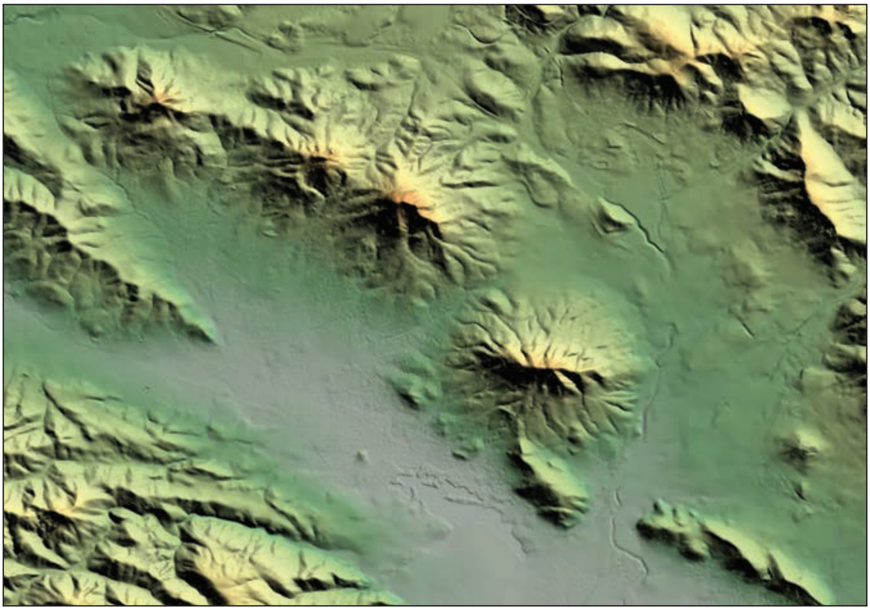


Figure 2.3: Example of a digital terrain model (DTM) from San Luis Obispo County, California, USA.

2.2 IFSAR Technology

Interferometric synthetic aperture radar (IFSAR) is a well-established remote sensing technology for obtaining high-resolution elevation data and corresponding orthorectified radar images of the earth's surface from airborne and spaceborne platforms.

IFSAR remote sensing systems are capable of generating topographic data with accuracies measured in centimeters. These systems rely on electromagnetic energy of a specific wavelength to collect information about their targets or the terrain they image. Remote sensing systems are defined as being either active or passive, and the distinction is important. Passive systems use energy that is naturally available, such as energy from the sun; active systems use energy that is generated by a human-made source, such as a radar antenna. Aerial photography, for example, is generated by passive remote sensing systems that require the sun to illuminate the terrain they image. By contrast, IFSAR systems, as well as LiDAR systems, are active systems and generate their own source of illumination, in the form of radar pulses, when imaging the terrain. Figure 2.4 provides a conceptual view of Intermap's IFSAR system process flow.

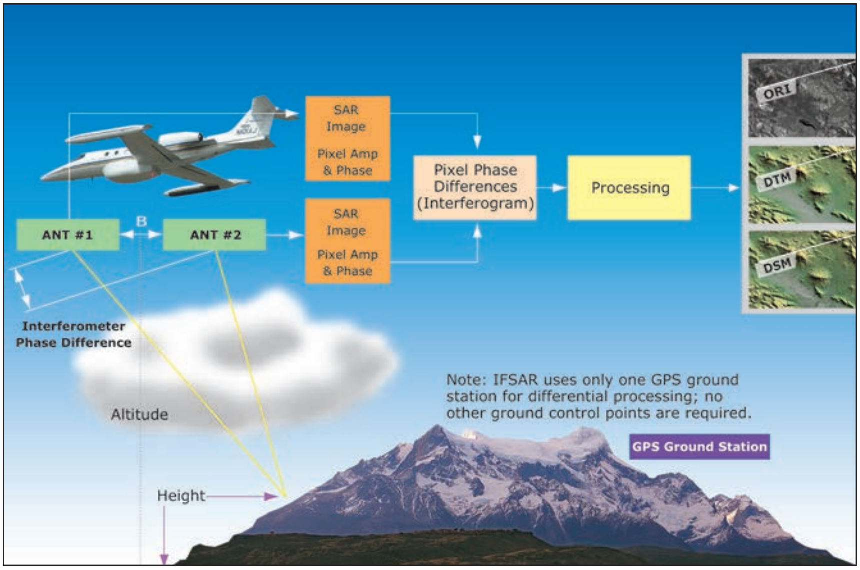


Figure 2.4: Conceptual view of Intermap's IFSAR system process flow.

Intermap's IFSAR systems use two antennae separated by an interferometric baseline (B) to image the earth's surface by transmitting radar pulses toward the terrain. The reflected energy, represented by the lines from the two antennae to the terrain below, is recorded by both antennae, simultaneously providing the system with two SAR images containing amplitude and phase of the same point on the ground, separated only by the phase difference created by the space between the two antennae. In addition, as the aircraft passes over the terrain, global positioning system (GPS) data from both aircraft- and ground-based GPS devices as well as navigation data from an inertial measurement unit

(IMU) onboard the aircraft are collected. This navigation data is then processed to provide the precise position of the aircraft.

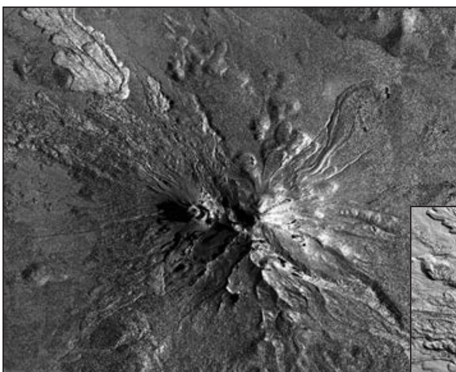
The phase difference between the antennae for each image point – along with range, baseline, GPS, and navigation data – is used to infer the precise topographic height of the terrain being imaged. This enables us to create an interferogram (depicting the phase difference) from which we derive our DSMs and ORIs. Through additional processing, we generate our DTM and other products.

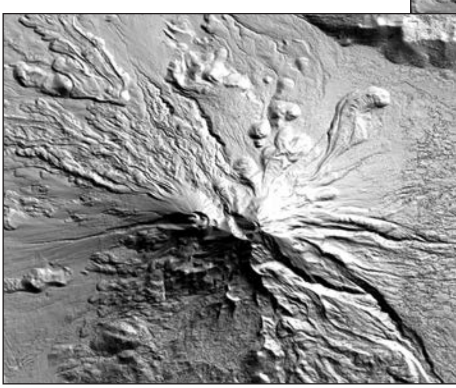
For a complete discussion of IFSAR technology, see Section 5.0, *Understanding IFSAR*.

2.3 Core Products Gallery

In this section, we have selected a few examples of our core products that accentuate different types of features. In these examples, the ORIs have a pixel resolution of 1.25 meters, while the DSMs and DTMs have 5-meter posted intervals with 1-meter RMSE vertical accuracy.

Figures 2.5 through 2.7 depict Mount Shasta in Northern California, with Lava Park lava flow to the northwest.





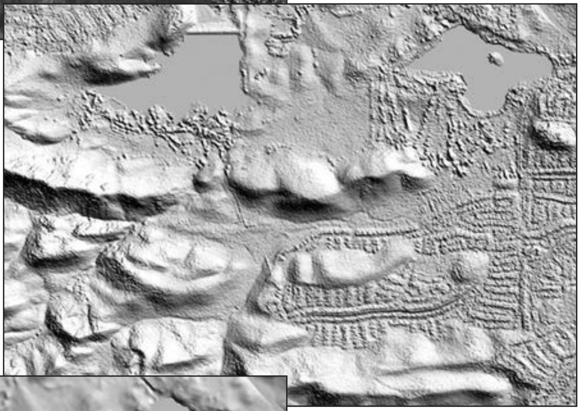
Clockwise, from upper left:

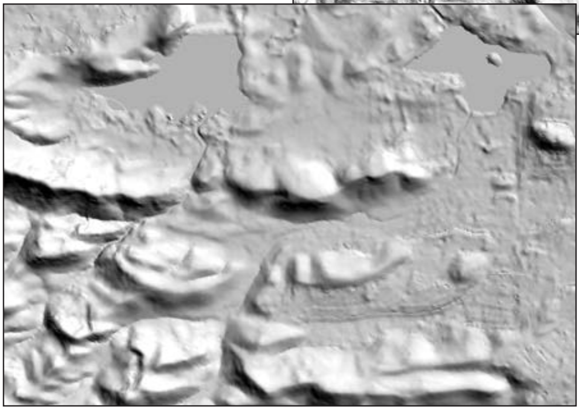
Figure 2.5: ORI example.

Figure 2.6: DSM example depicted with shaded relief.

Figure 2.7: DTM example depicted with shaded relief.

Figures 2.8 through 2.10 depict an area in California east of San Francisco Bay, just south of the city of Antioch, showing Contra Loma and Antioch Municipal Reservoirs.





Clockwise, from upper left:

Figure 2.8: ORI example.

Figure 2.9: DSM example depicted with shaded relief.

Figure 2.10: DTM example depicted with shaded relief.

Introduction to Core Products

This digital surface model shaded relief of Great Britain was created by mosaicking about 2,850 tiles and resampling them from 5m posting or pixel size to 30m posting.

Figure 2.11: Digital surface model shaded relief mosaic – Great Britain.

Purchasing Intermap® Products 3.0

At Intermap Technologies®, we work hard to understand your expectations as a client – and we do everything we can to meet them. That is why we make it easy for you to find the solution that best suits your needs. We offer high-quality products in a range of choices that will fit both your particular application and your budget. You can order products right off the shelf or arrange for a custom acquisition in your specific areas of interest.

3.1 Purchasing Off-the-shelf Data

Intermap® has off-the-shelf data available from its NEXTMap® USA and NEXTMap® Europe programs. In addition, off-the-shelf data is available for Indonesia, Puerto Rico, the Philippines, and other international locations. Intermap's online data store, https://store.intermap.com, allows you to browse the off-the-shelf products and determine the availability of data for your area of interest.

There are several ways to purchase licenses for Intermap's off-the-shelf data:

- Purchase the data at Intermap's online data store, https://store.intermap.com, with a credit card.
- Contact an Intermap sales representative:
    - Toll-free: 1-877-TERRAIN (1-877-837-7246), within the United States and Canada
    - Phone: 303-708-0955 (United States and Canada)
+42 (0) 261 341 411 (Europe)
+62 21 719 3808 (Southeast Asia and Australia)
    - Email: sales@intermap.com
    - Contact an Intermap data distributor. Data distributors are listed at www.intermap.com within the Partners section.

The following section presents answers to frequently asked questions about off-the-shelf orders. For general product inquiries, please email info@Intermap.com.

What, exactly, can I select when I place an order for off-the-shelf data?

You can choose which of our core or value-added products you would like to have delivered. Talk to one of our sales representatives for details and suitability. For more information, please see Section 9.2, *Value-added Products*.

How do I know that Intermap products will suit my needs?

Our elevation and image products have been used successfully in numerous applications across a wide range of industries. The actual suitability to your specific purpose, however, is best determined by discussing your exact needs with an Intermap sales representative, who will recommend the most suitable products. For additional information on applications of Intermap data, see Section 9, *Introduction to Applications*, and Section 6.2, *Product Characteristics*.

How long does it take to obtain off-the-shelf data?

The amount of time it takes to obtain off-the-shelf data depends on several factors, which are not mutually exclusive:

- The size (in square kilometers) of the project
- Any additional processing that may be required
- Our current production backlog

Off-the-shelf data has been acquired and processed to defined standards. In many cases, small projects involving areas less than 500 square kilometers can be acquired the same day. Larger project areas may take longer to deliver.

How much does an off-the-shelf order cost?

Intermap's online data store, https://store.intermap.com, provides an estimate of the cost of our core products. For orders greater than 1,000 square kilometers, contact an Intermap sales representative.

What are the specifications of the data?

Refer to Section 6.0, *Core Product Specifications*, for detailed information about Intermap's core products.

Does Intermap have an ISO 9001:2008 certified Quality Management System?

Yes – Intermap's Quality Management System (QMS) is ISO 9001:2008 certified. Our QMS and product realization processes are audited on a regular basis by both Intermap's internal auditors and Underwriters Laboratories, Inc. (UL).

UL is an independent company that examines our QMS to ensure that it conforms to the requirements of ISO 9001:2000. In addition, these audits enable us to determine if our QMS is effectively implemented and maintained, thus providing Intermap with opportunities to continually improve our processes and products.

3.2 Ordering a Custom Data Project

This section details the difference between an off-the-shelf order and a custom order by presenting answers to frequently asked questions.

How is a custom project different than buying a product off the shelf?

With a custom project, you get exactly the coverage areas you need – with the added assurance that the data is completely up to date. However, because you are directing the resources of our aircraft, the price of a custom project is higher than if you were to purchase the same data off the shelf, assuming it is available.

In spite of the higher cost of a custom acquisition project, it is important to bear in mind that Intermap's products represent a tremendous value. On a per-dollar basis, no other company can cover the vast areas that we can – and as accurately as we do.

What, exactly, will I receive when I place a custom order?

Aside from selecting the precise coverage area you need, you can choose which of our core or value-added products you would like to have delivered. Talk to one of our sales representatives for details and suitability.

How long does it take to complete a custom project?

The time required to complete a custom project depends on several factors, which are not mutually exclusive:

- Your urgency in acquiring the data
- The size (in square kilometers) of the project
- Our current backlog
- The location of the aircraft
- The weather, especially if there are seasonal considerations

Because of the popularity of our products, our acquisition teams are typically booked several months in advance. However, depending on the itineraries of the acquisition teams, it may be possible to expedite your order. Please contact us to see if we can accommodate your request. Bear in mind that snow and ice on the ground may hamper the radar's ability to pick up an adequate signal, so projects in higher latitudes should be booked to account for seasonal variability.

Depending on the size of the project, acquisition can take anywhere from a few days to a few weeks; processing the data can take weeks or months. Specific timelines will be established when the order is finalized.

Purchasing Intermap® Products

Who retains the intellectual property rights to the data?

Intermap retains all rights to the data, which becomes part of our product inventory.

What are the specifications of the data?

Refer to Section 6.0, *Core Product Specifications*, for detailed information about Intermap's core products. Talk to one of our sales representatives if you have unique requirements, such as a specific resolution.

How much does a custom acquisition order cost?

Intermap's custom acquisition projects are the most cost-effective way to collect high-accuracy elevation and orthorectified image products. They are much less costly than those obtained by other types of sensors because our proprietary technology allows us to cover large areas very efficiently. The cost of a project varies according to a number of factors:

- The size of the project area (a minimum order is 3,000 square kilometers)
- The shape of the area (flight lines can be hundreds of kilometers long, and long lines facilitate efficient collection)
- The nature of the terrain (rugged areas require more effort to ensure coverage is as complete as possible)
- The type of products to be generated from the data
- Any incidental charges, such as aircraft ferrying

Once these factors have been determined, your Intermap sales representative will give you a detailed price analysis of your project.

How do I order a custom data project, and what is involved in seeing it through to completion?

To order a custom data project, simply follow these steps:

1. Determine your area of interest as well as your resolution requirements. Having the exact geographic coordinates helps, but it is not essential at this point.
2. Contact an Intermap sales representative in your area, or call 1-877-TERRAIN (1-877-837-7246) in the United States and Canada, +42 (0) 261 341 411 in Europe, or +62 21 719 3808 in Southeast Asia and Australia.
3. The sales representative will discuss your plan and obtain additional information from you. This information is then used to prepare a Preliminary Flight Plan (PFP). The PFP shows a map of your area of interest, estimates the number of days required to collect the data, and provides an approximate cost for the project.
4. If the plan meets your technical and budgetary requirements, the sales representative then orders a Detailed Flight Plan (DFP). This builds on the information contained in the PFP and specifies actual flight lines for the aircraft.

If you wish to change the coverage area or scale the project back to make it more affordable, the sales representative submits a request for a modified PFP, which is presented to you for your consideration before going to the DFP stage.

5. Once the DFP details have been finalized, the sales representative orders a Contract Flight Plan (CFP). This document contains all of the previous information and includes technical details related to the aircraft flight lines and radar operation. The project is flown according to the specifications defined in the CFP, which you will be asked to formally approve. It becomes the basis for all of the logistical and technical planning that is subsequently undertaken to ensure the project is a success.
6. Once you have signed the CFP, a project manager is assigned to oversee the administration of your work. An Acquisition Manual is then created. This document is used by everyone involved in your project to ensure that the planning is complete in every detail.
7. At the appointed time, the aircraft is ferried to the project area. A GPS base station network is established to help pinpoint the aircraft while it is collecting data and provide independent check points throughout the processing tasks.
8. The aircraft begins flying the lines that were defined in the CFP. At the end of each day, the data undergoes a field quality check to ensure it is within specifications, particularly in regard to the motion and navigational parameters.
9. At the end of the project, the data tapes are shipped to the Processing Center, where they are used to create mapsheets from the project flight lines.
10. The mapsheets are used to create mosaics, edited to remove artifacts, and then cut into tiles.
11. The tiles are saved as core products. If required, value-added products are then produced using the specified core products as input. They are checked a final time to ensure they conform to the terms of the contract, and then shipped to the address you have provided.

Can I make changes to the project once I sign the Contract Flight Plan?

Changes will be considered, assuming they are logistically possible. They become more difficult to implement as the deployment date nears. Your sales representative will advise you of any additional charges, which will vary according to the nature of your request.

How do I contact Intermap?

- Toll-Free: 1-877-TERRAIN (1-877-837-7246), within the United States and Canada
- Phone: 303-708-0955 (United States and Canada)
  +42 (0) 261 341 411 (Europe)
  +62 21 719 3808 (Southeast Asia and Australia)
- E-mail: sales@intermap.com

Training 4.0

Intermap Technologies® offers specialized training solutions and learning services that are designed, developed, and delivered by experienced learning professionals and subject-matter experts. These programs enable you to increase your understanding of our innovative data products and optimize their use within your organization.

Intermap® offers a series of comprehensive and outcome-based training programs. These programs include relevant theory as well as practical, real-world applications supporting client use. Detailed datasheets for each training program are available at www.intermap.com within the Products & Services section, under Training.

Below is a list of the training programs currently available.

4.1 Application Training

Global Mapper: An Introduction

This program provides comprehensive, practical training to introduce new users to Intermap's powerful and easy-to-use Global Mapper GIS software.

Intermap Data: Practical Application

This program provides participants with background information on Intermap's proprietary IFSAR technology, data acquisition, processing methodology, the Intermap Product Handbook, detailed reviews of contour generation from Intermap data, data merge techniques, and orthorectification of optical data using Intermap data.

3D Topographic Map Compilation: Operational

This program provides participants with an overall methodology to build topographic digital map layers based on traditional 1:50,000-scale map specifications.

2D Topographic Map Compilation: An Overview

This program provides participants with an overall methodology to build topographic digital map layers based on traditional 1:50,000-scale map specifications.

4.2 Image Interpretation for Operational Mapping

Road and Railroad Identification and Extraction

This program summarizes Intermap's proprietary IFSAR technology and data products and demonstrates how the data can be used to interpret and extract roads and railroads.

3D Topographic Map Compilation: Operational

This program provides participants with an overall methodology to build topographic digital map layers based on traditional 1:50,000-scale map specifications.

4.3 Image Interpretation Basics

3D Intermap Data Interpretation

This program summarizes the end-to-end Intermap data products and demonstrates how the data can be used for feature identification.

2D Intermap Data Interpretation

This program summarizes the end-to-end Intermap data products and demonstrates how the data can be used for feature identification.

4.4 Technology Overview

Intermap's Technology Fundamentals for New Users

This program provides a fundamental overview of Intermap's proprietary IFSAR technology and data products for new users.

Intermap's Product Handbook

This program provides a comprehensive review of Intermap's Product Handbook and includes discussions on Intermap's proprietary IFSAR technology and the edit rules used for producing our data products.

4.5 Customized Training Solutions

The standard training programs may be customized to best suit your needs. Intermap will work with you to ensure that content, duration, location, and delivery strategies are appropriate and that the training delivers expected results. Customization may affect pricing.

Training and support is available onsite or delivered online via collaborative Web conferencing tools, depending on your needs and training requirements.

To request more information, please contact Intermap's Learning and Skills Development team at info@intermap.com.

Understanding IFSAR 5.0

Intermap Technologies® uses a type of radar sensor called interferometric synthetic aperture radar (IFSAR). This section explains how IFSAR works and some of the attributes that are specific to IFSAR data products. For information on the specifications of our data products, see Section 6.0, *Core Product Specifications*.

5.1 Synthetic Aperture Radar

Before jumping into what IFSAR is and how it works, it is worth taking some time to first understand synthetic aperture radar (SAR). Conventional SAR, a form of radar that allows for higher resolution than typical types, has been used as a mapping tool since the 1950s. Radar is an acronym formed from the term "radio detection and ranging," which describes the principle of radar in its simplest form. The basic principle is that radio waves are transmitted as high-power pulses of microwave energy. The radar antenna, or sensor, then receives a portion of the transmitted energy as it is returned from any target it strikes. Figure 5.1 illustrates how a radar system operates. The radar sensor transmits electromagnetic (EM) pulses (in the microwave portion of the EM spectrum) at a target area at regular intervals (Figure 5.1, left image). The radar system's sensor then records energy that is returned back towards the sensor, referred to as radar backscatter (Figure 5.1, right image). Due to the characteristics, frequency, and wavelength of microwave pulses, energy is generally reflected from the first surface it contacts, whether it is foliage, a human-made structure, or bare earth. The radar processor measures the intensity of the transmitted energy from the target. Ranging is accomplished by measuring time delay between transmission and reception of the radio signals. All that is needed to measure the distance to the target is to measure how long it takes for a radio pulse to travel from the sensor, bounce off the target, and come back. Divide the time by two (to measure the distance one-way instead of round trip) and multiply the result by the speed of light (3 x 108 m/sec) to get the answer. Once this data is processed, the result is a digital radar image.

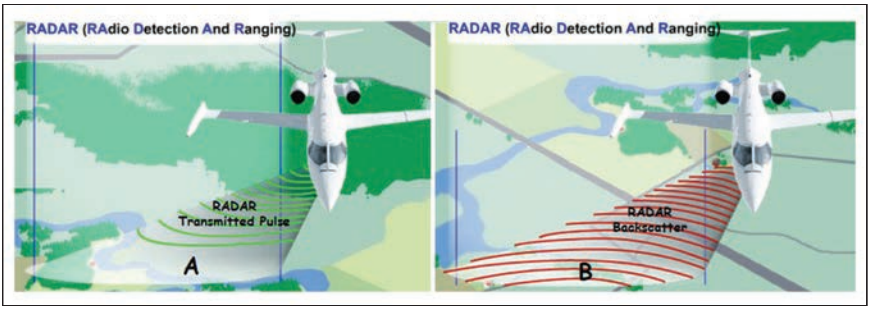


Figure 5.1: Schematic illustrating how radar works.

Radar azimuth resolution is limited to the aperture of the physical antenna, which varies with range. However, the aperture can be improved through signal process, and that is where the term synthetic aperture comes into the description of this type of radar. It refers to the manner in which image resolution is enhanced in the direction that is parallel to the track of the aircraft. Any device designed to use optical principles to form an image has an opening that collects incoming radiation. This opening is called an aperture; common examples of devices with apertures are cameras, telescopes, and eyes. Resolution is determined by the ratio of the wavelength of light being observed to the length of the aperture being used to collect it – the larger the aperture, the better the resolution. Intermap uses radar antennae that are only about a meter in length, because designing them any larger creates problems relating to the airframe and antenna stability.

To compensate for this comparatively small aperture, Intermap works to combine the multiple overlapping signal returns collected during flight. As the aircraft moves across the target, the radar sensor will record the same location multiple times. Through standard SAR processing, we digitally combine the overlapping return signals. By doing this, each point on the ground can be observed from a much wider angle. This amounts to increasing the length of the antenna, without the additional processing, and provides a resolution that is far greater than could be achieved by simply using the 1-meter aperture aboard the aircraft. Radio astronomers frequently use the same principle to enhance stellar observations by coordinating data acquisition from dishes that are separated by many kilometers.

5.2 Interferometric Synthetic Aperture Radar

Interferometry as a measurement technique was first developed through experiments performed by Albert Michelson and Edward Morley in 1879. In the years since these experiments, the fundamentals for the interferometric technique have been used in countless areas of scientific investigation, from deep-space astronomy to fine-scale precision measurement, including differential global positioning system (DGPS) processing techniques. The first reported experiments to determine terrain elevations of the earth were by L.C. Graham in 1974. It took an additional 10 years before SAR interferometry was being extensively researched for non-military applications by various groups, including the Canada Centre for Remote Sensing (CCRS), the U.S. Jet Propulsion Laboratory (JPL), the Environmental Research Institute of Michigan (ERIM), and others. These investigations used many airborne platforms, including the CCRS CV-580 and the JPL DC-8, and space platforms such as Seasat, ERS-1/2, and the shuttle SIR-A-C radar. In 1996, Intermap Technologies applied the world's first commercial implementation of a high-performance airborne single-pass across-track interferometer, called STAR-3i. Since then, Intermap's® fleet of airborne IFSAR systems continues to provide highly accurate elevation data and orthorectified radar images around the globe.

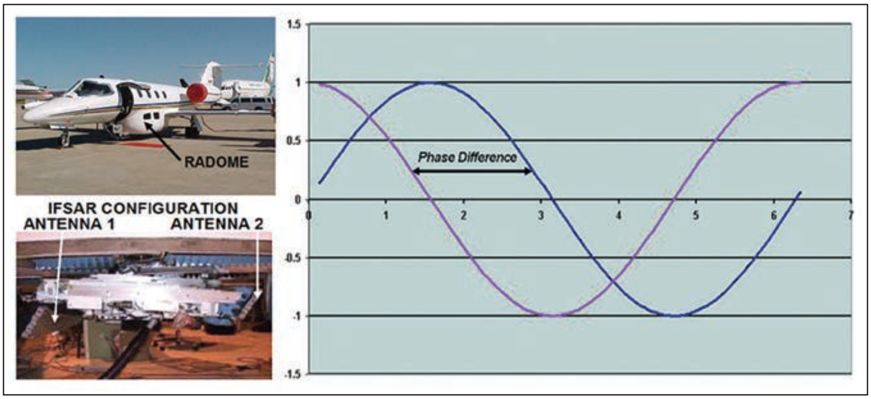


Figure 5.2: Top left image: The IFSAR antennae are housed in the radome. Bottom left image represents the IFSAR configuration of the two antennae. The right image provides a schematic of two identical waves that are out of phase.

Digital elevation information about the earth's surface are derived from the phase content of two SAR signals through IFSAR techniques. The basic idea is that the height of a point on the earth's surface can be reconstructed from the phase difference between two SAR signals arriving at two antennae housed in a radome (Figure 5.2). This is because the phase difference is directly related to the difference in path lengths traversed by the signal between the point on the earth's surface and the two antennae.

The waves that are received in antenna A shift in and out of phase with respect to those received at antenna B, depending on where the point is located from which they are being reflected. This is illustrated in Figure 5.3, which shows two cutaway views of the antennae in the radome under the aircraft's fuselage.

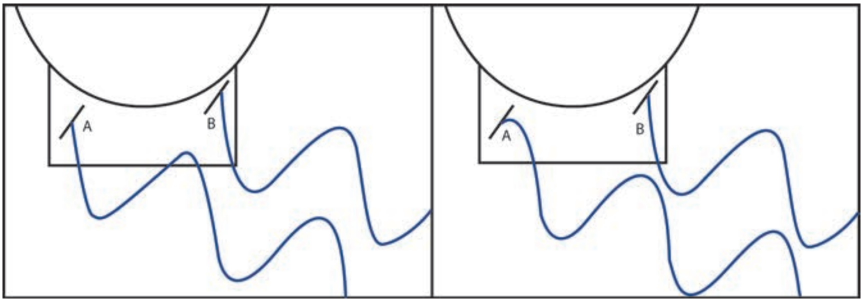


Figure 5.3: In the left example, a radar pulse is reflected back to antennae A and B in phase from the same point on the ground, whereas in the right example, the radar pulse is slightly out of phase from a nearby point. The rate at which the phase changes occur is used to measure changes in terrain elevation. The waves are not shown to scale.

For example, if a point on the ground is an integer number of wavelengths away from each antenna, then those waves will be exactly in phase. If the point is slightly closer or farther away from the aircraft, then the waves will be out of phase. On flat terrain, these changes in phase will occur at a certain rate. When phase changes occur more quickly than normal, this indicates an increase in terrain elevation. Conversely, when the phase changes occur more slowly, this indicates a decrease in elevation (from the previously measured point). This phase difference result and the geometry formed by the positioning of separation of the antennae viewing across the imaging dimension provide all the information required to derive the height, as well as corresponding x and y position, of any target that interacted with the broadcast energy.

Each of Intermap's aircraft contains a one-pass IFSAR system consisting of two physical SAR antennae, each with an independent coherent receiver. Each antenna independently receives echo data and forms a complex SAR image of the terrain. In two-pass systems, the platform requires only conventional radar with a single receiver, but makes two flights past the area of interest. The advantage of one-pass operation is the ability to compensate for motion, since the two apertures are physically coupled. Additionally, there is no temporal decorrelation between the two images. Decorrelation in phase can result in an unreliable measurement of height variation and a potential loss of data. If the IFSAR baseline (separation between the two antennae) is large enough, the reflectivity of corresponding pixels in the two SAR images will decorrelate. A small baseline is preferred for avoiding baseline decorrelation and for reducing height ambiguities. For examples of phase decorrelation in data from Intermap's one-pass IFSAR system, see Section 5.3.2.2, *Phase Decorrelation*.

5.3 IFSAR Artifacts

To ensure our products are of the highest possible quality, Intermap puts them through numerous quality assurance checks as part of our standard production process as well as an independent verification and validation process. This is not a completely intuitive task, because we do not interpret the world around us using ranging devices and signal processing. Our eyes operate in the visible portion of the electromagnetic (EM) spectrum, much like optical sensors, while IFSAR sensors operate in the microwave portion of the EM spectrum. It means that some of the attributes of radar are not as familiar as those associated with photography, for example, which uses many of the same principles of the human eye. Certain characteristics that exist in IFSAR data, therefore, require close attention to ensure the final products are not adversely affected.

Table 5.1 identifies artifacts first by class and then by type. It describes many of the IFSAR artifacts we look for and explains how we address them. The goal is to produce the best possible data that meets our core product specifications.

Artifact Class	Definition	Type
Geometry	Related to the viewing geometry of the IFSAR sensor	Layover
		Shadow
Sensor	IFSAR sensor parameters	Signal Saturation
		Decorrelation
		Motion Ripples
Processor	Related to the post processing of the IFSAR data	Missing Data
		Image Tone Brightness

Table 5.1: Artifact classification and type.

The following sections provide examples of each artifact, how we try to reduce their effects, and how the artifact is manifested in the orthorectified radar imagery and digital elevation data.

5.3.1 Geometry Artifacts

Geometry artifacts result from the viewing geometry of IFSAR sensors. Unlike some optical sensors that look directly below the imaging platform, radar and IFSAR sensors "view" the ground according to a perspective beam that looks out to the side of the platform. See Figure 5.4 for an illustration of this principle. The beam shown in yellow in Figure 5.4 corresponds to the line between the radar antenna and the target on the ground. The radar sensor points the radar beam out to one side of the aircraft, defining an incidence angle range. This configuration is an optimized viewing geometry for an IFSAR topographic mapping system. As the aircraft flies over the terrain, an image strip or swath is collected. This beam, called the slant range, is the distance as measured by the radar directly, in effect along each line perpendicular to the flight vector and directly with the radar and each scatter. The slant range is further defined by two terms: near range (NR) and far range (FR). A target located in the NR is closer to the antenna than a target positioned in the FR location. This viewing geometry creates distortions radiating out from the NR to the FR, rather than radiating out from nadir, as with aerial photography data collections. Two types of distortions are common: layover and shadow.

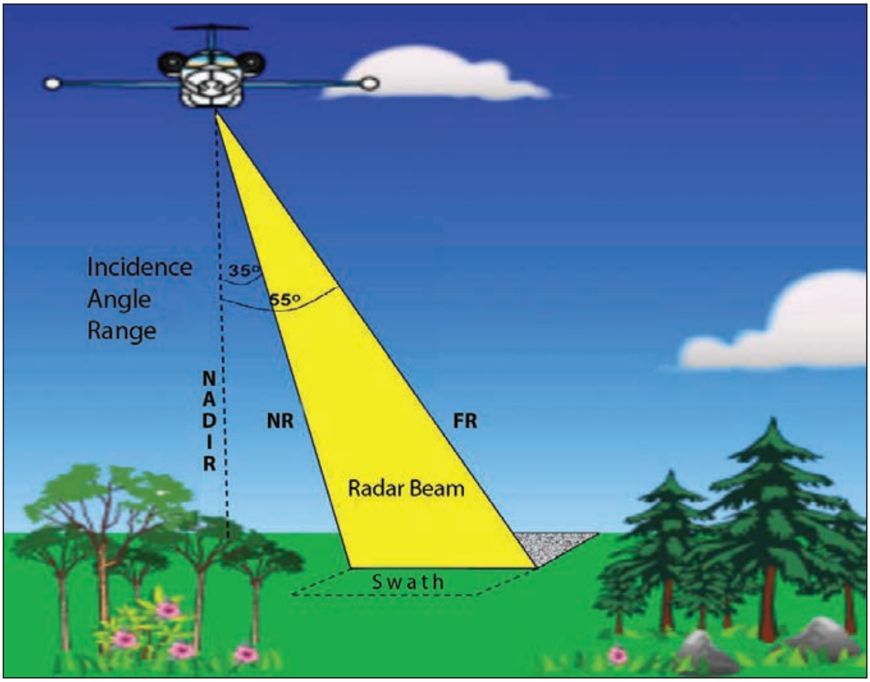


Figure 5.4: Radar sensor geometry example of our system configuration in which the radar beam (in yellow) has an incidence angle range from 35° to 55°. The location of the near range (NR) and far range (FR) and swath width are also indicated. At a flying height of 10.4 km (34,000 feet), our swath width is approximately 11.5 km in width. A typical flight line can be as long as 1200 km.

5.3.1.1 Layover

Layover results from the side-looking nature of the radar with respect to the ground it is imaging. Geometric viewing of the sensor can cause objects to look shorter than in reality, because of the viewing angle of the observer. For example, a pencil tipped toward your eye appears shorter than when it is held upright. Layover, which occurs when the top of the object is recorded before the bottom of the object, takes place most frequently in the extreme near range, where the peaks of mountains are nearer to the sensor than the bases. Therefore, the peak gets imaged first, and none or little of the information on the face of the mountain that looks toward the aircraft can be recovered. The effect of layover is most noticeable in mountainous areas and tends to make them appear to be closer to the radar antennae than they actually are.

Figure 5.5 illustrates the geometric relationship that must exist between the ground and the radar for layover to occur. The strip along the top of the figure is the view of the scene looking down from above. The lower portion is a front view of the aircraft and the mountain it is imaging. The dotted yellow lines connect corresponding points in each representation. They are key to understanding layover, because they show the time that the radar pulse takes to reach various parts of the mountain. Because the top of the mountain (B) is closest to the aircraft, it is imaged ahead of everything else (B'). The effect is to eclipse the view of the front of the mountain (in red).

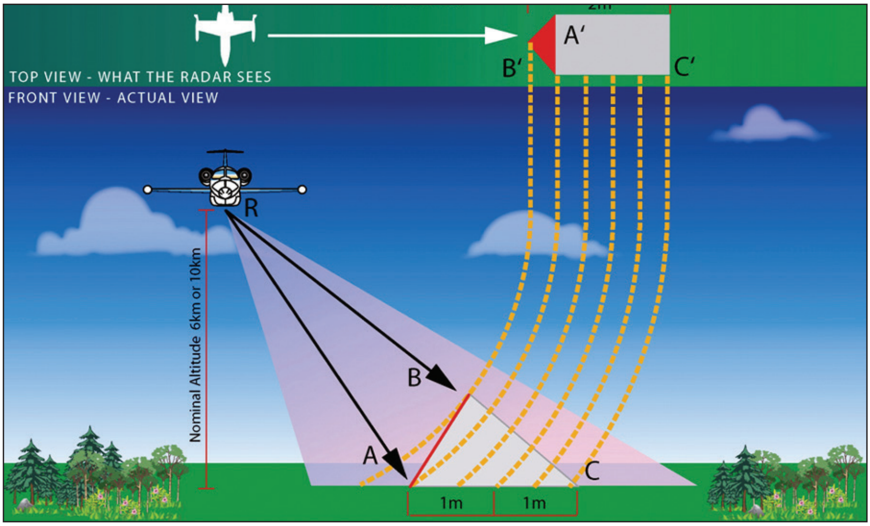


Figure 5.5: The geometry of layover. The perceived effect is that the red area is smaller than it actually is. In the top view, it appears as less than ½ meter, but in the front view, you can see that the red area actually covers more than ½ meter.

Through flight planning and data processing, we try to reduce the amount of layover that occurs in our data products. However, depending on the type of terrain type and where it is located within the swath, layover may still occur. As part of the production process, layover is corrected so that all image pixels can be used as a map output (orthorectified). Previously compressed regions are "stretched" to cover the true terrain. This correction (stretching) is illustrated in Figure 5.6.

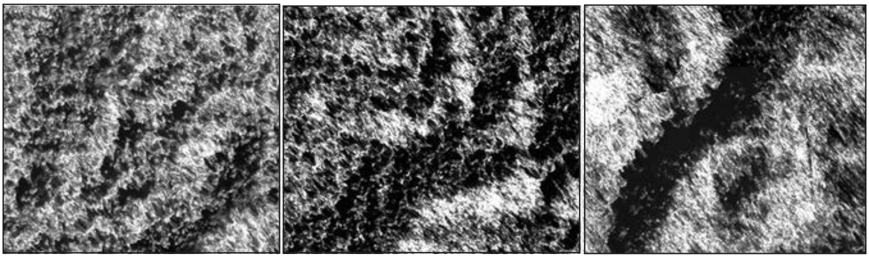


Figure 5.6: Layover effect illustrated.

All three images in Figure 5.6 are of a jungle and mountainous terrain in northern Sulawesi, Indonesia. The left image represents a mid-swath data collection, in which little or no layover anomalies are present. This gives way to the homogenous tone and texture of the forest canopy. The middle and right images were collected in the NR, where the sides of the mountains appear to be leaning toward the radar illumination beam, thereby resulting in layover anomalies.

The layover is manifested as blurred or stretched regions because the radar processor has tried to "pull" or "stretch" areas of higher terrain back to their correct position. In some cases, the layover portion may be represented as a white band, as illustrated in the ORI (Figure 5.7, left image) where the edge of the forest canopy is white in image tone due to a strong return from the edge of the forest canopy. Notice how the corresponding elevation data (DSM, middle image; DTM, right image) is not adversely affected in the region containing layover.

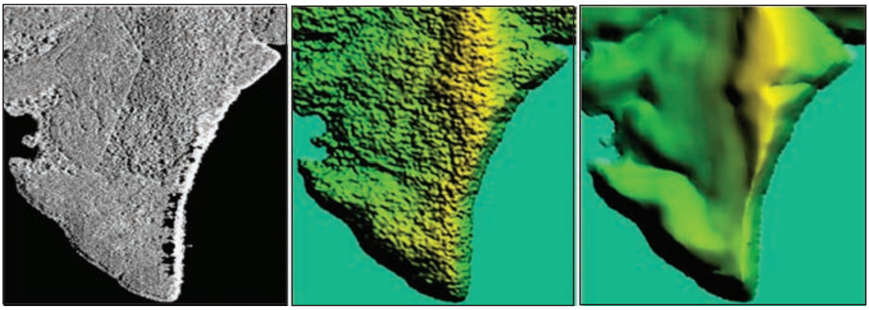


Figure 5.7: Layover illustrated.

Layover causes mountains to resemble shark fins (Figure 5.8, red arrow), due to the visual compression of the near slopes. As part of the production process, the data is corrected. The previously compressed regions are effectively stretched to better represent the terrain. Thus, layover often appears as a blurred region, because the processor has tried to "pull" areas of higher terrain back to their correct position. The DTM (Figure 5.8, right image) has valid elevation data in the region of layover due, in this case, to overlapping elevation data from an adjacent flight line. If overlapping data is not available, areas of layover would be filled in either through interpolation or using ancillary data.

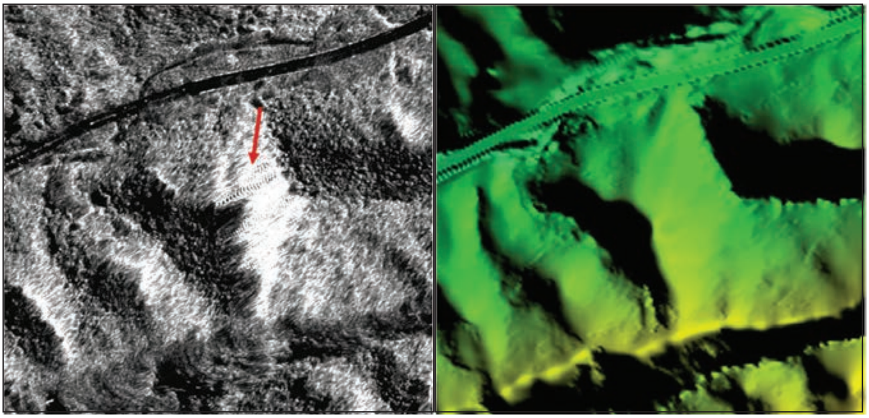


Figure 5.8: Layover illustrated.

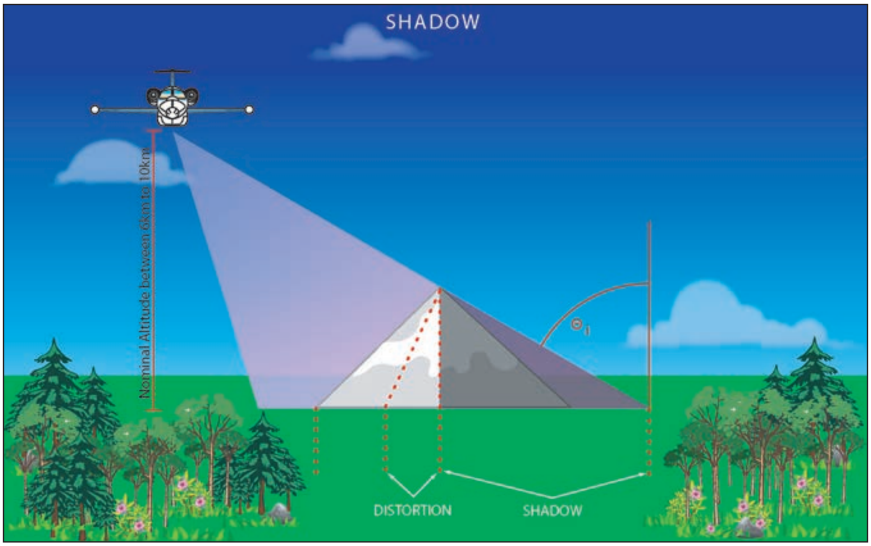


Figure 5.9: Radar shadow illustrated.

5.3.1.2 Shadow

Radar shadows represent an absence of data – regions from which no information was returned to the sensor. Such shadows are not the result of sunlight that is being blocked by higher objects, although they often appear that way. Instead, they are caused by the radar's side-looking signal being eclipsed by various terrain features – just as the flash on a camera creates shadows that are evident in the photograph of the subject. Therefore, if one thinks of the radar as a camera that images an area by illuminating it with a flash of radio waves, then shadows occur in regions where the flash cannot reach. SAR sensors, however, are active sensors continuously collecting snapshots of the terrain. Thus, the amount of shadow is generally less than what is presented in data collected by optical sensors. Figure 5.9 illustrates the geometric relationship that must exist between the terrain (for example, a mountain) and the radar sensor for a shadow to occur. The back slope of the mountain is facing away from the radar look direction, which will result in a region of shadow on the radar image.

Shadow is a geometric artifact that cannot be eliminated. Through flight planning and data processing, however, Intermap does try to minimize this effect. For example, if an adjacent pass covers the shadow area, it is possible that the area will be filled with data during the merge. If a large part of the pass is affected by shadow, an additional sensor look may need to be acquired to fill these areas in the DEM. The additional look may come from an orthogonal tie line or a secondary look. In the case of the tie line, it would be positioned through the area where we would expect to have shadow – for example, in areas of steep terrain. As for a second look, it could come from a flight pass that is parallel to the original one, only looking in the opposite direction.

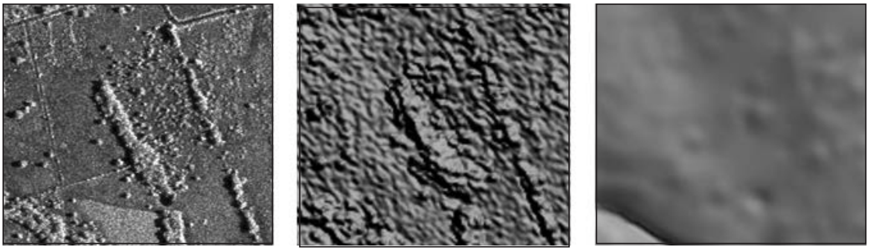


Figure 5.10: Dark regions behind trees; ORI left image, DSM middle image, DTM right image.

Figure 5.10 illustrates tree shadows. In much the same way as we would see a tree cast a shadow as the sun goes down, shadows behind trees will be depicted as dark spots in the imagery and missing information in the elevation data. The amount of elevation data lost due to this type of shadow is minimal, and the affected areas can be filled in by interpolating elevation information from nearby areas. Note that the location of the shadow gives an obvious clue as to the look direction of the radar. In this case, the radar is looking from the right to the left. As a result, areas of shadow are on the left sides of the trees, denoted by the yellow arrows in the ORI. Conversely, the right side the radar return is strongest and appears brighter in the ORI. Notice that the shadows do not present a problem for the DSM (middle image) or DTM (right image).

While small shadows can accentuate terrain features and help form a better impression of the landscape – which can be helpful in confirming or eliminating certain characteristics of the data – large shadows may be problematic. Large shadows may require the re-acquisition of data from a better flight angle (recall, tie line or secondary look options). Large shadows are evident in Figure 5.11, located northeast of Pearl Harbor, Hawaii, USA.

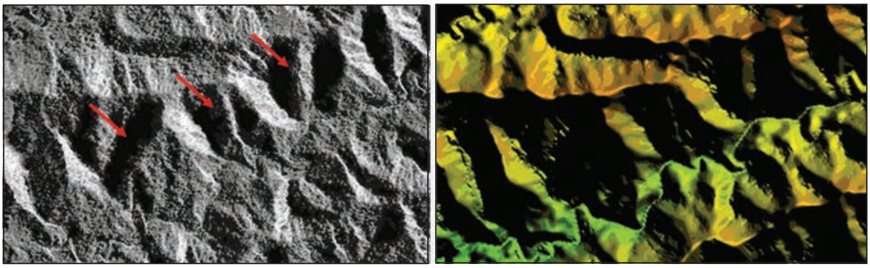


Figure 5.11: Dark region (indicated by red arrows in the ORI, left image) are regions of shadow where the radar pulse was not able to reach. The corresponding elevation data is illustrated in the right image.

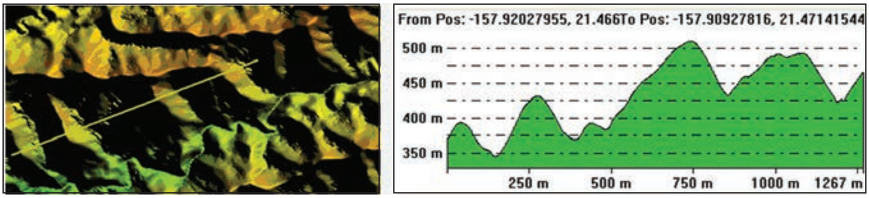


Figure 5.12: A profile through the shadow regions, indicated by the yellow line in the DTM image on the left, is presented in the chart to the right to demonstrate that there is elevation data in areas of shadow regions.

A profile (yellow line and graph, Figure 5.12) through the region of shadow areas reveals that there are elevation data in those areas. In regions of shadow, elevation data can be retrieved from an overlapping flight line, a secondary flight line, ancillary data, or through interpolation. Intermap endeavors to have less than 5 percent of our elevation data derived through interpolation.

5.3.2 Sensor Artifacts

5.3.2.1 Signal Saturation

Signal saturation in radar is similar to taking a picture with a flash camera while standing too close to the subject. Too much light is returned to the camera and image detail is lost. The same principle applies to radar. A return signal that is too strong can result in data loss. Ideally, the gain control will be set to a level that is appropriate for a particular mission. That level is monitored by proprietary Intermap IFSAR data collection software, but it is not always easy to maintain a balance. The change in levels can cause loss of detail in the low return areas, for example.

Signal saturation occurs most often over urban areas because of the strong return from buildings. Buildings and surrounding pavement may act as corner reflectors, which is caused by the combination of two orthogonal intersecting reflecting surfaces that combine to enhance the signal back in the direction of the radar. Essentially, as the radar signal interacts with a building, the entire radar signal is sent back to the sensor, resulting in a bright smeared appearance in the radar image. This can also result in elevation data being lost in these areas. Thus, as with shadow regions, the elevation data for a building may be interpolated if a secondary source of elevation data is not available from a secondary look flight line, overlapping flight line, or from ancillary data.

Figure 5.13: Building saturation example; ORI left image, DSM right image.

Figure 5.13 shows where signal saturation has occurred over buildings, represented by bright white image tones in the ORI.

5.3.2.2 Phase Decorrelation

As described in Section 5.2, decorrelation in phase results in a loss of data. That data loss is manifested as data dropout in the imagery and as areas requiring interpolation in the elevation data. Data processing techniques are implemented to mitigate the effects of phase decorrelation.

Figure 5.14 shows a region in Arizona where decorrelation exists in areas of steep terrain.

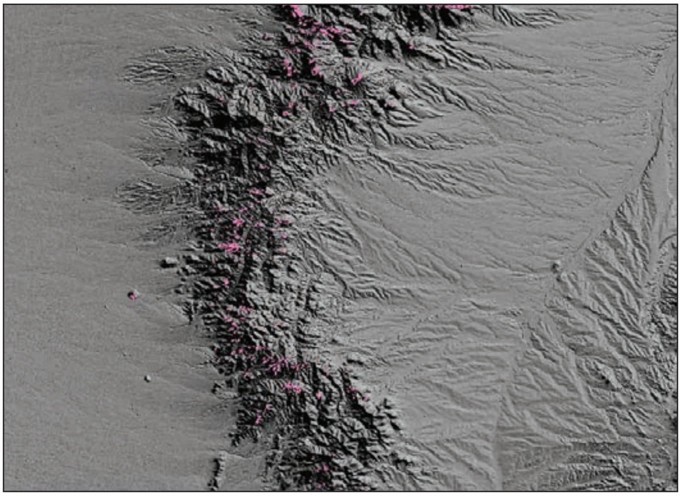


Figure 5.14: Areas of data loss due to phase decorrelation.

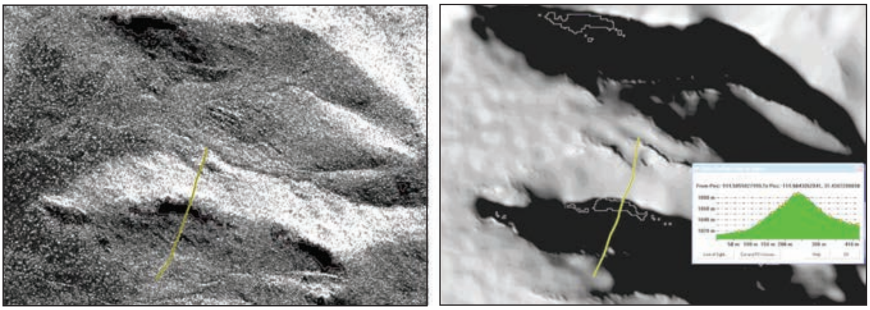


Figure 5.15: Areas of data loss due to phase decorrelation; ORI left image, DTM right image.

Similar to Figure 5.14, Figure 5.15 shows an ORI and DSM in which data decorrelation (region within the pink vector) has occurred. In these areas of decorrelation, the missing data was filled in either by using ancillary data or by using Intermap's proprietary interpolation software, which can result in slightly degraded vertical accuracies in those regions. In the profile shown for the right image, it can be seen that one of the areas of data loss in the DTM has been effectively filled in.

5.3.2.3 Motion Ripples

Motion ripples are the result of aircraft turbulence that creates a frequency of motion that is beyond the bounds for which the processor is designed to compensate (Figure 5.16). They can appear as height ripples in the elevation data and as dark bands in the imagery in the across-track direction. Motion ripples usually appear squinted, or narrower at the edges, as opposed to being perfectly parallel. Motion ripples cannot be eliminated completely, but Intermap makes every effort to address them in different ways, including additional flights, so that the data meets our core product specifications.

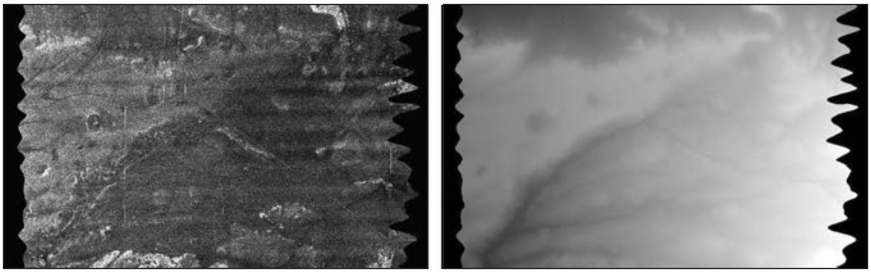


Figure 5.16: This example shows excess motion ripples (dark bands) in the radar image (left image). In the corresponding elevation data (right image), the appearance of motion ripples is less obvious.

5.3.3 Processor Artifacts

5.3.3.1 Missing Data

Sometimes small regions of data loss occur because of a processing problem in regions in which the terrain is particularly steep. Interferometry relies on picking up the return signal using antennae at two different locations; the phase differences are used to detect changes in elevation. Because of the way these phase differences are processed, it is possible that small islands or peninsulas could drop out of an image. This can also occur with river bends and along coastlines or in regions in which there is low coherence between the phase measurements.

Intermap's airborne radar systems have two antennae that face sideways, parallel to each other and separated by 1 meter (the interferometric baseline). Each antenna collects data independently of the other, and the images each receives are almost identical, except for the slight difference in the ranges to any specific target. Therefore, changes in phase difference between the two antennae and the same points on the ground make it possible to calculate the different elevations of those points. However, if the data processor is unable to predict confidently where certain areas are located against an absolute reference frame, it will leave them blank until it receives more information. To solve the problem, the operator gives the processor more seed points from surrounding areas to build a better elevation framework for placing the data that had previously dropped out.

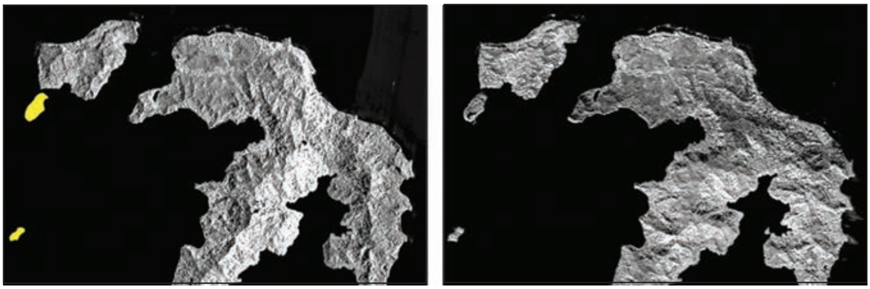


Figure 5.17: Missing island example.

Figure 5.17 illustrates islands missing in the left image, as indicated by the yellow polygons. One of the steps in the production process involves checking the raw image data against processed image data to ensure that no data are lost. The data was reprocessed to capture the islands, as shown in the right image.

5.3.3.2 Image Tone Brightness

During data collection, the aircraft flies in long parallel lines over the ground. The footprint of the radar beam on the ground defines what is called the swath. The height of the aircraft, to some extent, determines the width of the swath – the higher the aircraft flies, the wider the swath. During the planning process, the swath layout is designed to include overlap between adjacent swaths to ensure complete coverage of the terrain being imaged. In addition, the overlap is used during the mosaicking process (stitching flight line data together into a single, seamless dataset) to ensure that the amount of distortion associated with side-looking radar may be trimmed. Each swath is collected with the same look direction, within a given study area (Figure 5.18), and then they are stitched together with orthogonal tie lines.

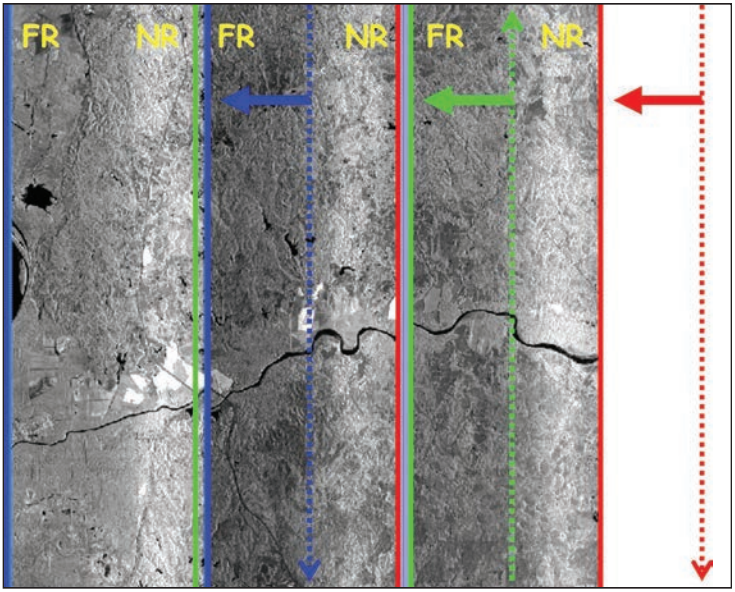


Figure 5.18: IFSAR data flight lines are represented by the dotted arrows.

To accomplish the same radar look direction countrywide, the radar sensors are rotated as the aircraft turns around to collect the next flight line. The result is a near-range (NR) edge of one flight line overlapping with a far-range (FR) edge of the adjacent flight line. The NR and FR edges are indicated for each flight line. Every effort is made to minimize the effect of NR to FR variation in image tone brightness by radiometrically balancing the imagery. It is not always possible, however, to remove this effect completely.

Figure 5.18 illustrates three flight lines with the radar looking to the west. Within these flight lines are raw data that have yet to be orthorectified and radiometrically balanced; consequently, the NR–FR tonal variation across the swath is present. Notice that the NR edge of each of the three swaths is brighter than each of the FR edges. This is a result of the NR side of the swath being closer to the radar sensor than the FR of the swath.

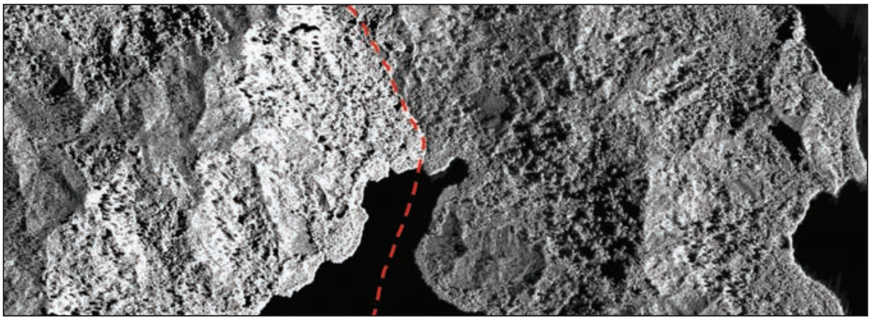


Figure 5.19: Seam line as a function of near range merged with far range strips.

In Figure 5.19, a forest canopy is imaged by two flight lines that are mosaicked together, as indicated by a seam line shown here as a dashed red line. There is a tonal change from the NR (steep incidence angle) of the left flight line (brighter image tone, left of dashed line) to the FR (shallow incidence angle) of the right flight line (darker image tone, right of dashed line). With this knowledge, the editor can anticipate where to find changes in tone resulting from variations in incidence angle as opposed to variations in land cover. This effect, however, becomes difficult to mitigate in regions of steep terrain.

Product Specifications 6.0

This section describes Intermap Technologies®' ORI, , DSM, and DTM core product specifications. The specifications in this section are organized as follows:

General specifications:

- Datums
- Projections
- File origin definition
- Metadata
- Data delivery, including naming conventions and file size

Product Characteristics:

- DTM Version Comparison
- FITS (Fully Integrated Terrain Solution)
- Editing Process
- NEXTMap® Britain v2.0

Product Accuracy:

- ORI
- ESI, DSM, and DTM
- Product Quality

Feature Content:

- ORI
- DSM and DTM

While reviewing the specifications for products developed by Intermap Technologies, it is important to note that the NEXTMap® DEM product accuracies correspond to the Type II specifications mentioned in Section 6.4.2, *DSM and DTM Accuracy*.

Product Specifications

6.1 General Specifications

The geodetic specifications that are part of our core products are described below.

6.1.1 Definitions

A reference ellipsoid is a geometric approximation to the surface of the earth. It is defined as an ellipsoid of revolution (obtained by rotating an ellipse about its shorter axis), with parameters that are selected such that it best fits the shape of the earth for use as a convenient reference surface.

A global geodetic datum is a framework that enables us to define the location of points anywhere on the earth. The framework can be thought of as the combination of a reference ellipsoid and of some parameters that define the spatial relationship of that ellipsoid with respect to the earth.

The coordinate is an expression of location. When expressed in a useful datum, it provides a unique and meaningful statement of the position of a topographic feature. When a global geodetic datum is used, the coordinate is expressed as latitude, longitude, and ellipsoidal height.

It is also possible to express the horizontal coordinates in a two-dimensional representation, known as a projection. Projected coordinates are used to specify position with respect to a map, and usually as a northing and easting.

The term horizontal datum is often used synonymously with the horizontal components of a geodetic datum, corresponding in coordinate space to the latitude and longitude.

A vertical datum can be thought of as a reference surface for the height component of a coordinate. Although a geodetic datum defines a reasonable vertical datum (e.g., via the ellipsoid), the height reference at Intermap is defined by a surface known as a geoid. The resulting height is known as an orthometric height, which, as shown in Figure 6.1, is more physically meaningful than the corresponding ellipsoidal height.

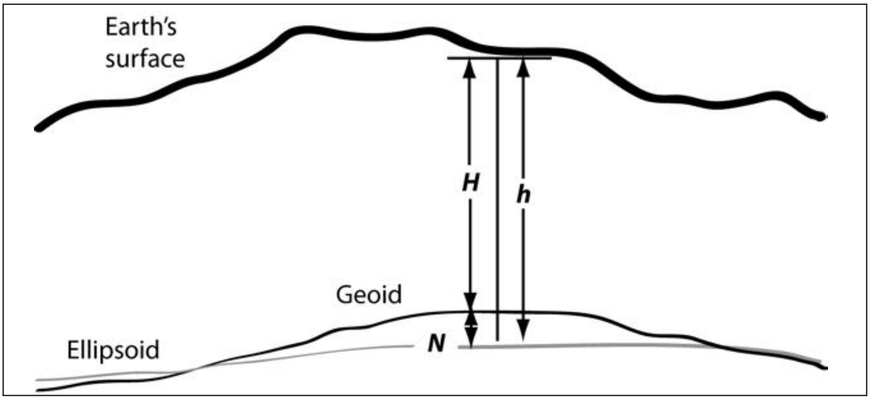


Figure 6.1: The elevation or orthometric height *H* above the geoid, the ellipsoid height *h*, and the geoid height (undulation) *N* above the ellipsoid.

6.1.2 Datums

The vertical datums and corresponding horizontal datums used by Intermap are listed in Table 6.1.

Region	Vertical Datum (Geoid Model)	Corresponding Horizontal Datum (Geodetic)
UK	ODN (OSGM91)	OSGB1936
USA	NAVD88 (Geoid99)	NAD83
Canada	CGVD28 (GSD95)	NAD83
Australia	AHD (AUSGeoid98)	GDA94
Europe	EVRS2000 (EGG07)	ETRS89
Elsewhere	(EGM96)	ITRF2000

Table 6.1: Vertical and horizontal datums.

Because of the importance of height information, the selection of datums is driven by criteria in the vertical. These include the need for a physically meaningful vertical datum, the vertical accuracy requirements and that the datum is realizable and accessible across the region of interest. As such, a geoid model gives the vertical datum for all core products. Further, preferred are regional or national standard geoid models that meet the above criteria.

The selection of geodetic (horizontal) datum is driven by the requirements to:

- Be consistent with the selected vertical datum
- Be geocentric, accessible, realizable and consistent across the region of interest
- Be tectonic plate-fixed

As such, the geodetic datum is realized via the terrestrial reference frame that best meets the above criteria.

It should be noted that in the absence of suitable regional or national datums, the vertical datum is realized through the use of the globally applicable geoid model that best meets the above criteria, and the geodetic datum is realized through a compatible terrestrial reference frame.

The GeoTIFF file specification allows for the definition of the horizontal datum, including ETRS89 (Europe) and ITRF2000.

These horizontal datums are identified as such in Intermap's ORI files. However, many standard applications that read GeoTIFF files may not be able to recognize these datum specifications. Intermap can supply modified GeoTIFF files to meet specific needs as a value-added service.

6.1.3 Projections

The NEXTMap core products from Intermap® are delivered in geographic coordinates (longitude, latitude), with units in decimal degrees. Other projections are available upon request. The vertical reference of the core product is orthometric height, derived by applying standard geoid models. Elevation units are measured in meters.

6.1.4 File Origin

Knowing the file origin of our products will help ensure that your software correctly interprets and positions our data. The file origin for Intermap products varies depending on the product; the file origin for the DSM and DTM products (and the ESI product derived from the DTM)is different than the file origin of the ORI. This section describes the different file origin locations.

The coordinates for the file origin of a DSM or DTM, when delivered as a BIL (*.bil) file, are found in the corresponding header (*.hdr) file. The coordinate provided is the center of the lower left cell of the file. This is depicted by the red star in Figure 6.2.

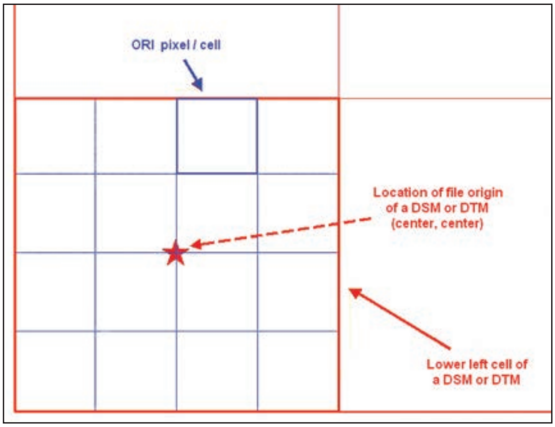


Figure 6.2: File origin for Intermap DSM and DTM products.

Product Specifications

The coordinates for the file origin of an ORI, when delivered as a GeoTIFF (*.tif) file is inherent to the file and located in the center of the upper left cell of the file. This is depicted by the blue star in Figure 6.3.

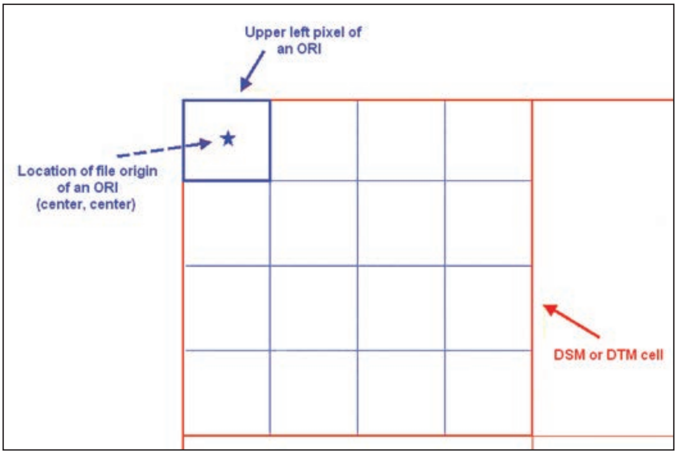


Figure 6.3: File origin for Intermap ORI product.

6.1.5 File Metadata

Standard formats for metadata files are supported; they include HTML, XML, and flat ASCII. These formats can be generated so they comply with a number of widely recognized standards, including those set by the Federal Geographic Data Committee (FGDC).

The following is a list of core product attributes that Intermap stores in the database:

- Intermap project number
- Project manager
- Country
- Task order number
- Project area
- Version (issue identification)
- Product level
- Product level accuracy (meter RMSE)
- Acquisition start date (YYYYMMDD)
- Acquisition end date (YYYYMMDD)
- Publication / process date (YYYYMMDD)
- Horizontal accuracy (meters [1 sigma])
- DSM vertical accuracy (meters [1 sigma])
- DTM vertical accuracy (meters [1 sigma])
- Flight height
- Primary look
- Secondary look
- Mission number(s)
- Phase unwrapper
- Look (primary or secondary)
- Horizontal datum
- Vertical datum
- Projection
- Ellipsoid
- Spheroid
- Alternative / forced zone
- End User License Agreement (EULA)

Product Specifications

Metadata files are created separately for each data layer. The metadata file naming convention is the same as the corresponding data file, but with an extension designating the format of the metadata file. These extensions are listed in Table 6.3.

6.1.6 Data Delivery

This section describes the file naming conventions, file sizes, and file formats of our core products.

6.1.6.1 Delivered File Naming Conventions

Orders are delivered in either a database or file containing the complete area of interest (AOI) or in a tiled format. For orders that are requested in tiled format, the naming convention is based upon a 1° x 1° block of tiles. The name contains the latitude and longitude at the lower right-hand corner of the block, followed by row (letter, increasing north) and column (number, increasing west). Tile width is doubled to 15' above 56° latitude to compensate for the convergence of the lines of longitude as they approach the poles. This is illustrated in Figure 6.4. Table 6.2 shows how the area of the tiles varies as a function of latitude.

(Note: Intermap's data is priced per square kilometer, not per tile.)

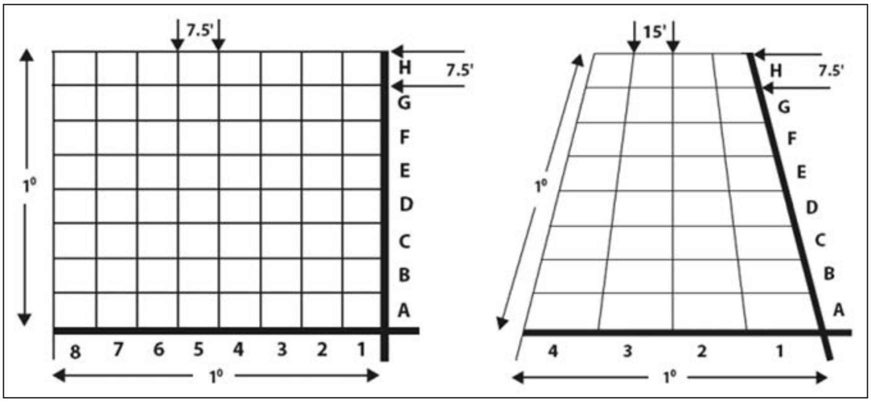


Figure 6.4: Blocks are 7.5' wide below 56° latitude (left) and 15' wide above 56° latitude (right).

Product Specifications

Latitude (North or South)	Average Tile Size (sq km)
0° to 8°	193
8° to 16°	189
16° to 24°	181
24° to 32°	170
32° to 40°	156
40° to 48°	139
48° to 56°	119
56° to 64°	96
64° to 72°	72
72° to 80°	47

Table 6.2: Average tile size in square kilometers with respect to degrees of latitude, north or south.

A folder is created for each tile that is delivered, and each folder contains all files pertaining to the tile. The files are named according to the standard format and type of delivery, with an extension that indicates the contents of the file. These extensions are listed in Table 6.3. Alternative file formats for our DEMs and radar images are available upon request.

(Note: the .dem file format for digital elevation data is supported by many applications, but it does not have the same precision as other file formats. While the data may appear to be representative of the terrain, our analysis has shown that the reduced precision of .dem files can adversely affect analysis performed with the data. As an example, the creation of contour data from .dem-formatted data results in contours that are very angular or coarse. These contours would not be sufficiently representative of the terrain.)

Extension	Contents
*.BIL	DSM or DTM data in 32-bit floating point binary grid format
*.TIF	ORI in 8-bit grayscale unsigned GeoTIFF format
*.html	Metadata in Hypertext Markup Language (HTML) format — FGDC-compliant standard
*.xml	Metadata in eXtensible Markup Language (XML) format — FGDC-compliant standard
*.txt	Metadata in ASCII text

Table 6.3: Intermap data file extensions.

If you were to order the tile named n32w117g3, you would find a folder of that name created on the delivery medium. The folder would contain all the files related to the tile, named as follows:

- n32w117g3dsm.bil – for the DSM product
- n32w117g3dtm.bil – for the DTM product
- n32w117g3ori.tif – for the ORI product

Delivery of any dataset comprised of a specific area of interest (not comprised of standard tiles) will follow a customer-derived or operator-derived naming convention that provides a descriptive reference to the source area.

6.1.6.2 File Sizes

While data is processed in production units called blocks and tiles, products are sold based on the number of square kilometers in an order. The combined file size for the DSM, DTM, and ORI, is approximately 1.5 MB per square kilometer.

The breakdown, per 150 square kilometers (approximate size for an average 7.5' x 7.5' tile), is as follows:

- DSM and DTM products are approximately 35 MB each
- ORIs are approximately 140 MB

Intermap supports the following standard data delivery media based on file size:

- FTP for files less than 100 MB
- CDs for files less than 4 GB
- DVDs for files greater than 4 GB but less than 20 GB
- USB hard disk for any file greater than 20 GB

Product Specifications

6.2 DTM Product Characteristics

Intermap endeavors to provide customers with the highest-quality products available and follows strict ISO certified processes in creating our data products.

Since the inception of our NEXTMap® program, we have solicited significant customer feedback on our core elevation products and their utility to a variety of applications. Intermap feeds this vital information back into our production processes to ensure that we continue to satisfy the needs of our customers.

The core DTM is one specific product that customer feedback has allowed Intermap to improve through updated editing processes, both automated and manual. These improvements have also expanded the uses of the DTM to include newer customer applications. As a result of these improvements, Intermap has two versions of the DTM product within the NEXTMap® USA dataset. Our DTM v1.0 elevation product is suitable for more traditional elevation applications, whereas our DTM v1.5 elevation product satisfies a more extensive list of product application for our customers.

Working closely with our customer base, we have found that the DTM v1.0 product offering is well suited for the following applications:

- Topographic base mapping
- Image orthorectification
- Acoustic modeling (noise abatement analysis)
- Radio propagation modeling (tower placement analysis)
- Vehicle navigation systems
- GPS / consumer electronics devices
- Slope and aspect analysis
- Surface mining

In extending the scope of utility for our core products, Intermap has found that the DTM v1.5 product offering is more suited to the following applications on top of the ones listed for v1.0:

- Storm surge analysis
- Watershed and drainage applications
- Floodplain analysis (flood modeling applications)
- Contour generation
- Preliminary engineering planning (site location analysis)
- Canopy height modeling*
- Biomass studies*
- Forestry applications*
- Wildlife habitat applications*
- Topographical mapping*
- Geological applications*
- Transmission line corridor planning*
- Environmental applications*

* in conjunction with the DSM and / or ORI

Product Specifications

For your project requirements, our DTM v1.0 product may be the most appropriate and cost-effective solution. For some of your more specific applications, Intermap offers you a DTM v1.5 product that undergoes an extended scope production process.

Due to the vast size of our NEXTMap USA program, and to ensure that we are expedient to market in offering you the best possible product solution, not all areas of the USA are available in both DTM products. Figure 6.5 shows those areas of NEXTMap USA where DTM v1.0 data is available. In addition to these areas, and because it was one of the first datasets captured by Intermap, NEXTMap Britain also has the DTM v1.0 product. The rest of NEXTMap Europe and NEXTMap USA will have a DTM v1.5 product. DTM v1.5 was available in 2010.

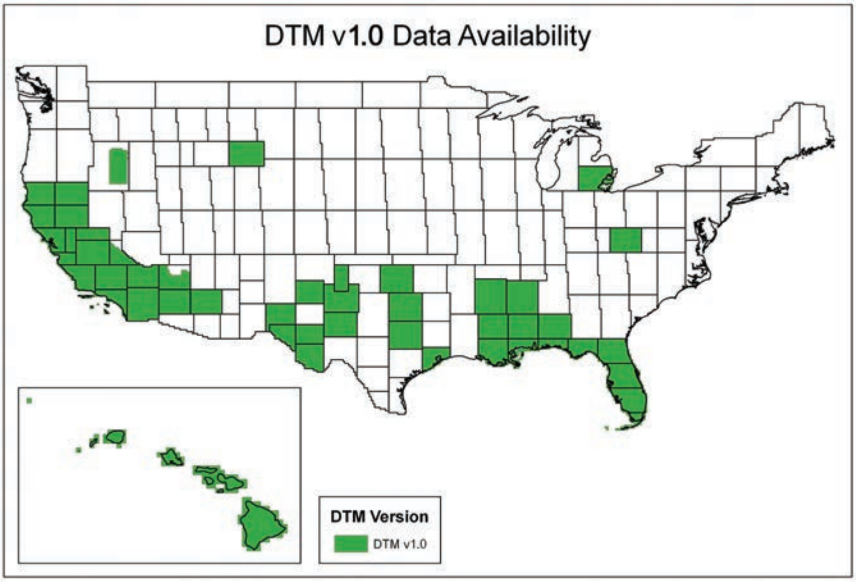


Figure 6.5: DTM v1.0 availability.

Because of its increased post-production processing and editing, the DTM v1.5 data has a higher price per square km than the DTM v1.0 data. When the DTM v1.5 data is available in areas covered by DTM v1.0 data, it will be made available as an optional upgrade for customers who previously purchased the DTM v1.0 data.

If you are interested in the cost of upgrading from DTM v1.0 to DTM v1.5 or you are interested in an area where our DTM v1.0 is currently available but your application is more suited to DTM v1.5, contact an Intermap sales representative.

Product Specifications

6.2.1 DTM Version Comparison

To facilitate easier decision-making in your DTM choice, the following table highlights the distinctions between our DTM v1.0 and DTM v1.5 datasets. As Intermap updates DTM v1.0 data to DTM v1.5, v1.0 data will no longer be available for purchase.

Note: As a result of software limitations, bare ground elevations in urban areas (downtown cores) may not be as expected due to remnants of first-surface features.

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
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.
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.

INTERMAP

6.2.2 FITS (Fully Integrated Terrain Solution) Editing Process

Intermap's proprietary FITS process (or Fully Integrated Terrain Solution) is a key contributor to the nuances in our DTM v1.5 product. FITS utilizes existing ancillary data from many sources as an input to the DTM editing process. The practice reduces any bias, tips, and / or tilts in the ancillary contribution using better accuracy seed points from the radar data. The ancillary data are adjusted appropriately based on the higher accuracy radar elevations. This process is performed in a localized manner to ensure a best fit adjustment. The FITS steps are carried out in an automated session prior to the data review by one of our trained 3D editing staff members.

As mentioned in Section 5.2, *Interferometric Synthetic Aperture Radar*, radar data has elevation "noise" of approximately 30 cm in magnitude. This noise is left in the DSM and represents the first surface data that we capture. Note that noise is dependent on type of data. Type I data will have less noise than Type II data. For more information about types of products, please see Section 6.3.1, *Product Type Availability*.

When editing the DTM v1.5 data, every effort is made to smooth this noise so that our DTM product not only exceeds Intermap's accuracy requirements, but also provides a more aesthetically pleasing mapping product and meets the requirements of the expanded list of applications. Our experienced 3D editing staff works extensively with the best technology available to digitally remove vegetation, buildings, and other cultural features in order to produce a best approximation of bare earth. This interactive process also takes into consideration the use of the most current ancillary data available and reduces or eliminates remnant anomalies and artifacts.

The results of this process can be seen in the DTM v1.5 product in Figure 6.6. The same area with the DTM v1.0 product can be seen in Figure 6.7. Both have the same vertical accuracy specifications as described in Section 6.4.2, *DSM and DTM Accuracy*.

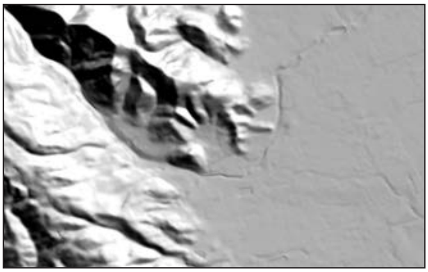


Figure 6.6: DTM v1.5 data example.

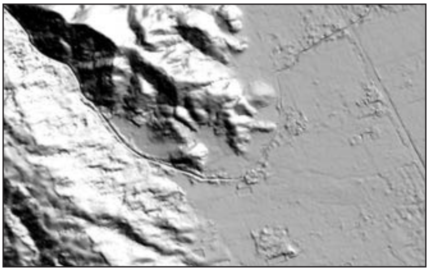


Figure 6.7: DTM v1.0 data example.

During the smoothing process undergone by the DTM due to radar noise, there are areas in which the DTM will be higher than the DSM. In addition to rounding off bumps, the smoothing process fills small dips in the terrain. It is in these dips where the DTM elevations will be higher than the DSM elevations. The height difference and the area it covers depend on the height of the noise. Radar interacts with different types of terrain and produces different degrees of noise in the data. For example, radar that hits an area of mud flats will have more noise than a flat inland area in the central United States. In areas of greater radar noise, the elevations of the DTM can be expected to be higher than those of the DSM on a larger scale.

6.2.3 NEXTMap® Britain v2.0

Another area where Intermap's NEXTMap data products vary is in Great Britain. NEXTMap® Britain v2.0 is a fused data product comprising IFSAR-generated and other elevation products. This fused data was used to create the new DSM and DTM products. The fusion process improves both the content and the accuracy of the resultant products relative to the original NEXTMap Britain products.

The updated data covers about 60,000 sq km primarily in England and Wales (see Figure 6.8). The new data was captured using different technologies with better accuracy and resolution specifications. All of the new data was decimated to a 2m grid as input to the fusion process, where it was further resampled to the final 5m resolution.

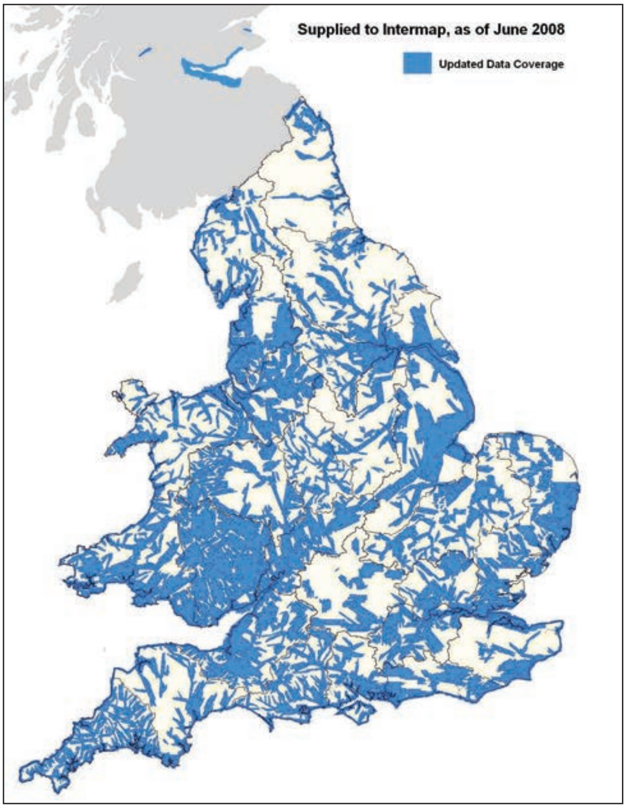


Figure 6.8: Approximate coverage of the new data used in the NEXTMap Britain v2.0 data products.

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The fusion process effectively substitutes the updated elevation data for the original IFSAR data. The products are blended together to form a smooth transition between the two. The original edited water surfaces from the NEXTMap Britain product are used to preserve the same flat surfaces on lakes, canals, and reservoirs, and to preserve the monotonic flow along watercourses.

The nominal vertical accuracy of the original NEXTMap Britain is 1 m RMSE, except in southeast England where it is 0.5 m RMSE. The nominal vertical accuracy of the NEXTMap Britain v2.0 data in areas of new coverage is estimated to be 25 cm to 40 cm RMSE. The vertical accuracies of the new data itself range from 15 cm to 30 cm, depending on the age and location. The new data has not been adjusted within the NEXTMap Britain v2.0 products except to blend it with the IFSAR elevations in the areas of transition. The only degradation in accuracy of the new data is a function of the decimation to the 5m resolution of the final product. It is impossible to accurately quantify the degradation in accuracy except by empirical means as the degradation is a function of surface roughness.

When using this data, the user will appreciate enhanced detail and accuracy in the elevation models, particularly along water courses and in urban areas where the increased sampling density of the new data contributed to a better representation of the terrain in comparison to areas using the IFSAR elevation model alone.

Figures 6-9 and 6-10 below illustrate a comparison between IFSAR and the new elevation data. The enhanced level of detail inherent in the new elevation model is apparent despite the decimation to 5m resolution.

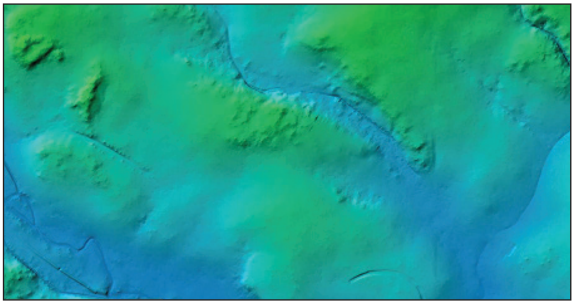

Figure 6.9: IFSAR DTM, 5m resolution.

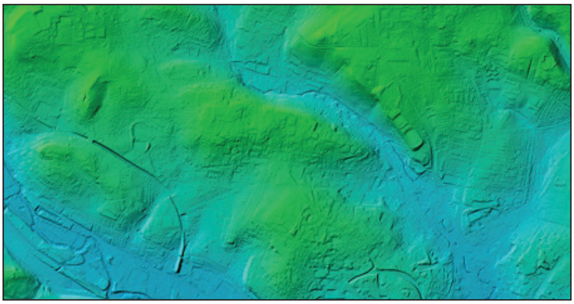

Figure 6.10: DTM of the new data, 5m resolution.

Product Specifications

Figure 6.11 below illustrates the detail of the new data coverage area (the valley bottom) contrasted with the detail associated with the IFSAR elevation model in the upland areas. The smooth transition between the two products is readily apparent in this example.

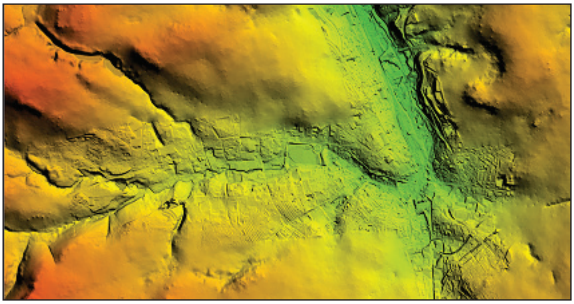

Figure 6.11: An example of IFSAR data fused with the new data.

Intermap continually looks at new ways to improve the products we provide to our customers, and the creation of the NEXTMap Britain v2.0 products is one more way we have found to do that.

6.3 Product Types

Intermap Technologies' data products are processed and stored as different product "types" based on the radar settings and equipment used and the ability to tie that data to ground control. The three product types are Type I, Type II, and Type III. The primary difference between these products is the vertical RMSE accuracy of the DEM data; the accuracies of these product types are listed in Section 6.4.2, *DSM and DTM Accuracy*.

With improved radar technology, Intermap also has the ability to create higher-resolution image products. Many of Intermap's more recently collected areas are available with a 0.625m image resolution; all older coverages are at 1.25 m. These variations provide improved ORI pixel size or resolution (see Section 6.4.1, *ORI Accuracy*).

6.3.1 Product Type Availability

The geographies that are currently available from Intermap, listed by product type, are as follows:

Type I:

- Some portions of the UK

Type I with 0.625m image:

- Northern Ireland
- Republic of Ireland
- Portions of Australia

Product Specifications

Type II:

- North America
  - United States including Hawaii and portions of Alaska
  - Portions of Alberta and British Columbia, Canada
  - Areas of Mexico and Canada bordering the United States
- Great Britain
- Western Europe
  - Portugal
  - Spain & Gibraltar
  - Andorra
  - France and Monaco
  - Belgium
  - Netherlands
  - Germany
  - Denmark
  - Luxembourg
  - Liechtenstein
  - Switzerland
  - Italy & Vatican City
  - San Marino
  - Malta
  - Austria
  - Czech Republic
  - Areas of Slovenia, Hungary, Slovakia, and Poland bordering Italy, Austria, the Czech Republic, and Germany

Type II with 0.625m image:

- Malaysia

Type III:

- Portions of Alaska
- Puerto Rico
- Jamaica
- Central America
  - Portions of Belize
  - Portions of Guatemala
  - Portions of El Salvador
  - Portions of Honduras
  - Portions of Nicaragua
  - Portions of Costa Rica
  - Portions of Panama
- South America
  - Portions of Colombia
  - Portions of Ecuador
  - Portions of Peru
- Portions of the Philippines
- Solomon Islands
- Vanuatu

Product Specifications

6.4 Product Accuracy

6.4.1 ORI Accuracy

Table 6.4 provides the horizontal accuracy specifications for the ORI data. Since an ORI is an image, it has no elevation component.

Product Type	Pixel Size	RMSE[1]	CE95[2]
I	0.50 m	2.0 m	4.0 m
II	0.625 m	2.0 m	4.0 m

Table 6.4: ORI accuracy specifications.

6.4.2 DSM and DTM Accuracy

Table 6.5 provides the accuracy specifications for Intermap DSMs and DTMs. The values in the tables are depicted graphically in Figure 6.12. Note that the horizontal accuracies of the DSM and DTM core products are inferred from the horizontal accuracy of the corresponding ORI (see Table 6.4, above).

DSM / DTM	Measures of Accuracy Specifications		Pixel Size / Post Spacing
Product Type	RMSE[1]	LE95[3]	
I	0.5 m	1.0 m	5 m
II	1.0 m	2.0 m	5 m
III	3.0 m	6.0 m	5 m

Table 6.5: DSM vertical accuracy specifications

[1] RMSE: The Root Mean Square Error is derived from a statistical formula for measuring the accuracy of our data against independently obtained "truth" data. The resulting RMSE value is a measure of the difference between these two sets of data. The stated value for ORI, DSM, and DTM RMSE is in unobstructed areas with slopes less than 10 degrees.

[2] CE95: The Circular Error 95 methodology is a spatial accuracy assessment, which requires that 95% of the horizontal data measurements fall within the specified distance of their true positions.

[3] LE95: The Linear Error 95 methodology is a spatial accuracy assessment, which requires that 95% of the vertical data measurements fall within the specified distance of their true positions.

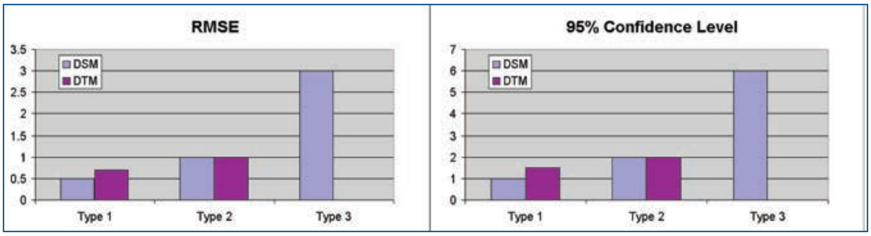

Figure 6.12: Vertical accuracy measurements for core products, grouped by type.

For more information on product accuracy, see Section 7.0, *Understanding Accuracy*.

6.5 Product Quality

There are a number of factors that affect the quality and accuracy (RMSE) of the DSM and DTM products. These factors fall into three primary categories:

- Slope
- Obstructed Areas
- Artifacts

Slope: Slope is defined as terrain slope in the traditional sense. Slopes greater than 10 degrees cause reduced accuracy. How much that accuracy is reduced depends on the magnitude of the slope, whether the slope is positive or negative, the aspect angle, and where it lies in the radar swath (look angle). As a general rule, the RMSE will increase in areas with slopes above 10 degrees. In areas with slopes of 20-30 degrees, the RMSE can be expected to double, and it will continue to increase as the slope increases. Additional information on slope and how slope affects the DSM and DTM can be found throughout Section 7.0, *Understanding Accuracy*.

Rapid changes in terrain from features such as ridgelines, tree lines, or other pronounced features can also cause a similar increase in error. When these instances are identified, measures are taken to isolate the problematic areas so that surrounding areas are not adversely affected.

Obstructed Areas: Obstructed areas are areas where ground control points cannot be used to verify elevation accuracy to the degree that we are confident the data meets the accuracy specifications listed in Table 6.5. This applies to the DSM as well as the DTM.

In cases where the obstructed areas are relatively small, it is reasonable to extrapolate the ground beneath based on surrounding, unobstructed terrain so that it meets our DTM product specifications.

In large, heavily obstructed areas (developed or forested areas), our editors estimate the ground surface using our proprietary Fully Integrated Terrain Solutions (FITS) software (See Section 6.2.2, *FITS Editing Process*). This software derives terrain elevations using our IFSAR data in conjunction with the best available ancillary elevation data for the obstructed areas. In many of these obstructed areas, national datasets are used to supplement Intermap's data. Some of these datasets contain anomalies, such as stepping effects, which can translate into our NEXTMap DTM data. Depending on how pronounced the anomalies are, remnants of those anomalies may appear in our data. After the ancillary datasets are incorporated, they are subjected to the same interactive three-dimension edit process as the rest of the data. While the resulting DTM is a good representation of the bare-earth in the obstructed areas, we are not able to use the same processes as we do in other areas to verify its accuracy. See Section 7.2.1, *IFSAR Features that Affect the Accuracy of DSMs and DTMs*, for more information.

Another anomaly that may be visible in obstructed areas is the occurrence of seam lines, or creases, along tile and project boundaries. Intermap's datasets are homogeneous and continuous across land masses, but editing is done at the tile level (7.5 minute quads). While the editing within tiles is done to our defined product specifications and according to strict editing processes, minute variations may occur at tile or project boundaries. Within a project area, variations from tile to tile may be due of slight differences in how individual editors handle obstructions. Across project boundaries, there may be the added affect of differences in vegetation as a result of seasonal changes between the times when the project areas were flown. As with all anomalies, every effort is taken to minimize these effects, though some evidence of creases may still be visible in the DSM and DTM data.

Artifacts: Due to the nature of IFSAR technology and how data is captured, there are a number of artifacts that may affect product quality and accuracy (See Table 6.6).

These artifacts occur for different reasons and affect the data in different ways. For a thorough description of these artifacts, see Section 5.3, *IFSAR Artifacts*.

Artifact Class	Definition	Type
Geometry	Related to the viewing geometry of the IFSAR sensor	Layover
		Shadow
Sensor	IFSAR sensor parameters	Signal Saturation
		Decorrelation
		Motion Ripples
Processor	Related to the post processing of the IFSAR data	Missing Data
		Image Tone Brightness

Table 6.6: Artifact classification and type.

6.6 Feature Content

6.6.1 ORI Feature Content

The ORI feature content is identified in Table 6.7.

Feature	ORI Characteristics
Dynamic range	The pixel values in the ORI will be optimally dispersed along a grayscale ramp to take advantage of 254 gray levels based on a standard histogram of the entire acquisition area.
Specific pixel values	"0" is reserved for NULL data where original radar imagery was not acquired — typically water areas that were not imaged by the sensor. "1" is reserved for those pixels where the sensor imaged data but could not resolve the returned signal.
Radiometric balance	An antenna pattern correction will be applied and an image tonal balance (gain and contrast) will be achieved for overall "acquisition boundary" areas. Adjacent swaths and segments will be balanced so that apparent radiometric differences across seam lines are minimized.

Table 6.7: ORI feature content.

6.6.2 DSM and DTM Feature Content

Fully populated raster files represent the elevation models. If the target could not be resolved by the sensor, the values in that area are set to -10,000, otherwise known as the NULL data value. Where the sensor was targeted at the ground but no return signal was received, the elevation is infilled with ancillary DEM data, if available. If there is none, elevations are interpolated from the surrounding terrain. The location of these areas of ancillary infilled data or interpolated areas are identifiable in a proprietary correlation file.

Due to the nature of radar, certain features must be edited in the DSM and the corresponding DTM. To ensure our products are consistent, well-defined rules have been established and are abridged in Table 6.8 (which begins on the facing page). These correspond to the manner in which the DTM v1.5 data is edited. For more information on the differences between DTM v1.0 and DTM v1.5, see Section 6.2, *Product Characteristics*. The abridged version of the edit rules below does not include all exceptions and is provided only as a guide. In some cases, ancillary data is required to aid in feature identification. The comprehensive edit rules indicate where and how ancillary data is used to support the elevation model editing.

(Note: Features are edited to the resolution of the DEM post spacing or pixel size, so an 18m runway in the ORI will be represented as a 20m runway in the DEM.)

Product Specifications

Feature	Definition	Characteristics	Core Product Type I & II	Core Product Type III
Lakes	Greater than 400 square meters in area	DTM: Lakes will be leveled to a single elevation (expressed to the nearest decimeter) based on the water elevations and the surrounding shoreline.	√	√
		DSM: Extents and elevations of lakes will be the same as those in the DTM.	√	√
Rivers	Double Line Drain (DLD) greater than 20 m in width and greater than 400 m in length	DTM: Rivers will be flattened to the nearest decimeter with monotonic flow based on the water elevations and the surrounding shoreline. Water elevation stepping will not exceed 50 centimeters unless supported by the data (e.g., waterfalls, rapids).	√	√
		DSM: Extents and elevations of rivers will be the same as those in the DTM.	√	√
Streams	Single Line Drain (SLD) less than 20 m in width and greater than 1 km in length	DTM: Elevations along the stream will be modified to maintain the monotonic flow within the vertical accuracy limit of radar elevation data.	√	√
		DSM: Streams will not be delineated in the DSM.	√	√
Oceans	All oceans and tidal water bodies	DTM: Extents and elevations of oceans will be the same as those in the DSM.	√	√
		DSM: Oceans will be flattened at 0-m elevation. Ocean shoreline will be delineated at the water shoreline visible in the ORI.	√	√
Islands	Land greater than 400 square meters surrounded by water (Smaller islands visible in the ORI may be included in both the DSM and DTM.)	DTM: Elevations will be derived from the DSM with first-surface feature elevations removed.	√	√
		DSM: Elevations will remain as sensed by the radar.	√	√
Bare ground	Unobstructed terrain	DTM: The elevations of unobstructed terrain will be smoothed to remove radar noise. The smoothing process both lowers and raises individual posts.	√	√
		DSM: Bare ground will remain as sensed by the radar.	√	√

Product Specifications

Feature	Definition	Characteristics	Core Product Type I & II	Core Product Type III
Bridges	Bridges over water features Bridges over roads and railways Bridges holding water (aqueducts)	DTM: Elevations of all bridges will be removed in the DTM.	√	√
		DSM: Bridges over edited ocean, lakes, and rivers (DLDs) are flattened as water. Bridges in the DSM not flattened as water will be left as sensed by the radar.	N / A	√
Cultural obstructions	Villages, towns, and cities	DTM: Cultural features will be removed from the DTM.	√	√
		DSM: Cultural features will exist in the DSM as sensed by radar. However, due to the nature of IFSAR, features such as buildings (heights and edges) may not be well defined.	√	√
Isolated cultural features	Buildings, water towers, pylons, poles, and other manmade structures	DTM: Isolated cultural features will be removed from the DTM.	√	√
		DSM: These feature elevations will be in the DSM as sensed by the radar.	√	√
Trees	Isolated trees, clumps of trees, tree rows, and forests	DTM: Vegetation elevations will be removed from the DTM.	√	√
		DSM: Vegetation elevations will be in the DSM as sensed by radar.	√	√
Crops	Agricultural crops	DTM: Crops that can be detected above bare ground will be removed from the DTM.	√	√
		DSM: Crops will be in the DSM as sensed by radar.	√	√
Airports	All airports supported by ORI	DTM: Runways, aprons, and taxiways will all be edited and flattened. Runways will follow the lay of the land.	√	√
		DSM: Extents and elevations of airports will be the same as those in the DTM.	√	N / A
Manmade features affecting water	Includes dams, embankments, commercial piers and docks, breakwalls, causeways, canal locks, berms, weirs, and spillways	DTM: These features will not be removed from the DTM. Where features were altered as a result of obstructions being removed, they will be added back to the DTM as best possible.	√	√
		DSM: These features will remain in the DSM as sensed by the radar.	√	√

Table 6.8: DSM and DTM feature content.

Understanding Accuracy 7.0

To select the Intermap product that best matches your needs, it is important to understand how we arrive at the accuracy figures mentioned in Section 6.0, *Product Specifications*. The purpose of this section is to provide a better understanding of some of the statistics behind these accuracy figures and to describe some of the things that Intermap takes into consideration when compiling the statistics.

The vertical accuracy of the DSMs and DTMs, and the horizontal accuracy of the ORIs described in this document are specified in statistical terms. However, the conditions under which these specifications apply must be carefully defined.

Several types of products and associated accuracy specifications are created by Intermap's IFSAR systems. Trade-offs occur between desired accuracy and cost. In general, better accuracy implies greater cost, as it is associated with shorter GPS baselines, more stringent QC criteria, lower flight altitudes and possibly the introduction of additional vertical check points (VCPs). The table in Section 6.0, *Product Specifications*, displays the vertical accuracy specifications associated with our DSM and DTM products. Two points should be noted:

- These specifications represent upper limits on the achievable accuracy for the ORI, DSM and DTM when tested in unobstructed areas with slopes less than 10 degrees.
- They should be interpreted in the light of the explanatory information below which describes the statistical measures (next section) and the conditions under which they are valid as well as the particular terrain and terrain-cover situations that may lead to larger errors (see 7.2, *Validation Criteria*).

7.1 Statistical Measures

In this section, we provide some background on statistical measures. Every measurement of height 'h' has an error '˜ø' associated with it and a common assumption is that these errors are normally distributed with zero mean. Under these assumptions, the standard deviation 'σ' of the observed error distribution may be related to the probability that any single measurement will lie within +/– ˜ø (or some multiple of it) of the true elevation.

For example, if it turns out that σ = 1 meter, then we would expect that ~68% of all measurements would be within +/– 1 meter of the true elevations or equivalently, that 95% of all measurements would lie within +/– 2 meters of the true elevations. Often the RMSE (Root Mean Square Error) is used as an approximation to σ, although as noted below this is only valid in the case of zero (or sufficiently small) mean error. RMSE is calculated as RMSE = SQRT $(\Sigma \tilde{ø}_i^2)/N$, where $\tilde{ø}_i = (h - h_{true})_i$ and the summation is done over the N measurements. Under these assumptions, the mean error 'm' is defined as $m = \Sigma \tilde{ø}_i/N = 0$.

Often, however, the governing assumption that the error distribution is normally distributed with zero mean is invalid. This is due to the presence of systematic errors that have not been totally removed, and/or due to slowly varying errors over the area that is being sampled. Such an error could be caused, for example, by GPS errors either constant or variable. These can contribute to a 'mean offset,' or 'bias,' as they are sometimes referred to, in the statistical results over the sample area in question. In other words, the mean offset $m = \Sigma\tilde{ø}_i/N$ is non-zero, as illustrated in Figure 7.1. Using vertical check points, the mean offset can be removed from the data set or at least reduced in magnitude. It should be noted, however, that the magnitude of such an offset would likely be dependent upon the extent of the area being sampled.

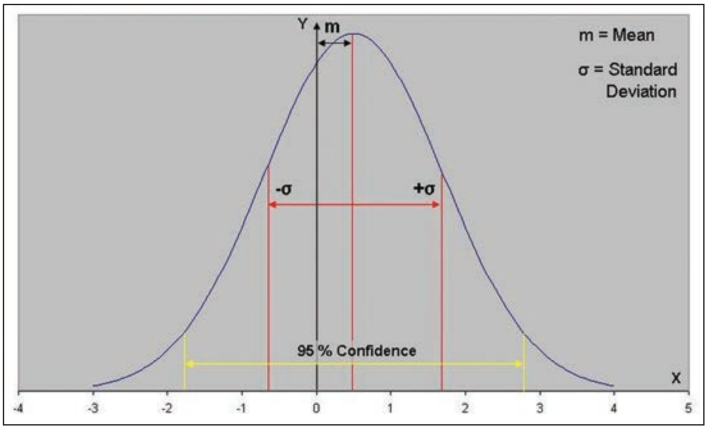

Figure 7.1: Error distribution with mean offset (m).

The standard deviation is more generally calculated as $\sigma = SQRT\ (\Sigma(\tilde{ø}_i - m)^2/N)$ and represents the relative part of the observed errors. As can be immediately noted, in the absence of any mean offset it becomes the same as the RMSE defined above. In fact, it can be easily shown that $RMSE2 \approx \sigma^2 + m^2$ where the approximation is very good for large N. It should also be noted, that the assignment of probability is with reference to σ, not to the RMSE, so that attributing a 95%, 90%, or 68% confidence level, based upon computed RMSE, which is the norm for the mapping industry, is not valid unless the mean offset, 'm,' is zero, or at least small compared to σ. Internal studies of our DSMs indicate that the two error indicators are often of comparable magnitude and, depending on the size of the area being sampled, either one may be dominant. Moreover, the distribution may not be normal as assumed.

This creates a dilemma when reporting accuracy. In the technical literature, σ, m and RMSE are often reported without reference to standard confidence levels. However, from a user's perspective, the notion that X% of the error measurements are within some specified upper limit is of particular interest. We address this dilemma in the following section.

7.1.1 Parameters Specified

In order to overcome this difficulty with respect to the specifications quoted in this document, we are reporting both RMSE and the 95% (percentile) confidence level value, where the latter has been computed not from the probability distribution but simply as a percentile. For example, in a sample of 100 measurements, five or fewer measurements should be found with absolute errors larger than the error corresponding to the 95%, provided the tests are performed according to the rules described below. This quantity turns out to be very close to 2 * RMSE for offsets in the range usually observed, although it varies depending on the particular values of σ and m (See Figure 7.2). In Section 6.0, *Core Product Specifications*, we also provide the upper limits of the mean offset 'm', and the standard deviation 'σ' that may be observed in any test situation.

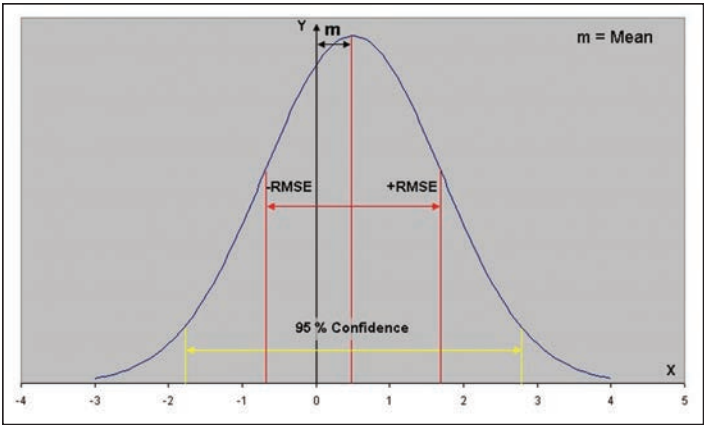

Figure 7.2: Error distribution with RMSE and 95% confidence level.

7.1.2 Scale Effects in Statistical Sampling

Provided the particular error distribution remains the same over the total area of interest, the same statistical results should be observed irrespective of the size of the area sampled. This implies that intensive sampling of a unit as small, for instance, as 100 m x 100 m would generate the same results as those from an area 100 km x 100 km or larger. However, over small areas, the distribution may depart from that experienced on average over the larger area. This may occur because of spatially limited motion effects experienced by the aircraft, or perhaps small areas in which the terrain reflectivity is exceptionally low. While it is possible to correct these problem areas in principle, it would obviously counter the economic benefits gained by having the large-area data capture capability. Therefore, the specifications reflect the fact that, over the smallest mapping unit or tile delivered, the error distribution may differ from that of the project area as a whole.

NEXTMap Britain is an example. The mapping unit we created is a 10km x 10km tile over a project area totaling more than 150,000 sq km. Where highly accurate ground-truth data was available, 17 random test sites each of 2 km in extent were intensively sampled across the region (according to the rules described in Section 7.2, *Validation Criteria*) and comparative statistics generated. In 16 of 17 test sites, the resulting RMSE results were well within the Type I specification. In one test site, however, the results were outside the specification in a localized sub-area owing to a platform motion error. This would be viewed as a statistically satisfactory outcome. Figure 7.3 is a graphical representation of a group of test sites falling within the 95% confidence level, in spite of a single test site falling outside.

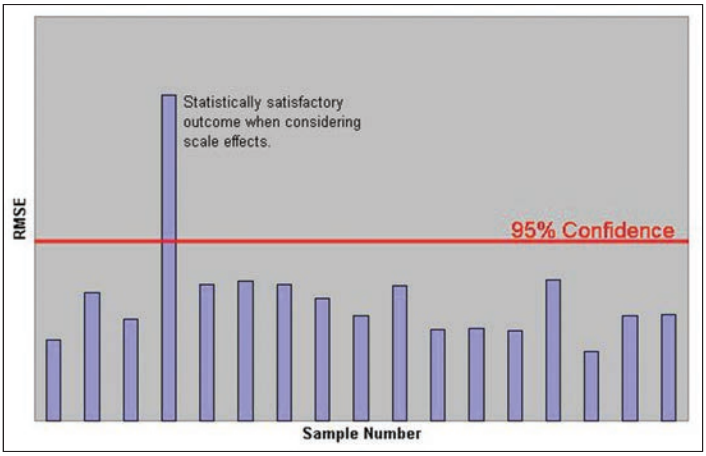

Figure 7.3: Small samples from a larger area show that scale can affect localized results, but the overall results for the entire area are still within the 95% confidence level.

7.2 Validation Criteria

Section 7.3, *Test Rules for IFSAR DSM and DTM Validations*, below, describes the conditions under which the stated specifications are valid. These may be thought of as a statement of the fundamental accuracy of the system and the associated processes. It is important to understand the circumstances under which errors may be generated that are outside the stated specifications. Then a set of 'validation rules' may be generated, which describe the allowable circumstances under which testing or validation of the fundamental product accuracy may occur.

7.2.1 IFSAR Features that Affect the Accuracy of DSMs and DTMs

A DSM represents the scattering surface observed by the radar – the first surface encountered by the radar pulse that returns a signal. This scattering surface may include buildings and other structures, as well as vegetation and bare ground. IFSAR sensors retrieve the mean height of the main scattering elements in a resolution cell, known as the scattering phase center height. Thus, it is worth noting that the radar return from trees and vegetation usually penetrates to some level lower than the true vegetation surface or height. The DTM is derived from the DSM using a semi-automated process that classifies areas as obstructed (buildings and vegetation) and unobstructed (bare earth, roads, and water). The obstructed areas are then processed to approximate bald earth. A DEM editor then modifies the derived bald earth using a 3D interactive editing process to create the final DTM. See Section 6.2, *Product Characteristics*, for more information.

Understanding Accuracy

There are several potential sources of error that can exist in the DSM and DTM. Some of the most common are:

- Radar 'integration footprint'
- Side-viewing geometry
- DTM-related issues
- Slope effects
- Rapid changes in terrain
- Phase decorrelation effects

Radar 'integration footprint': The radar integrates (or averages) over a square footprint, therefore the DSM sample or representative elevation for that square footprint area will contain the effects of all the scattering objects within it. For example, if it contains bare ground and a raised object such as a structure or tree, both will contribute to the sample elevation. Similarly, if the sample is at the edge of a road, it may also be affected by the ditch at the side of the road. If the DSM sample elevation is being compared with a vertical check point (VCP) somewhere in the square footprint, it may be an over-estimate or under-estimate of the elevation. It is important, therefore, that the VCP be in an unobstructed region with modest and constant slope, such as an open field or park (see Figure 7.4).

Figure 7.4: Unobstructed regions of modest and constant slope (yellow polygons) are suitable locations in which to test the data.

Various types of terrain features make areas unsuitable for validating accuracy. As a rule, areas with unobstructed terrain of moderate slope less than 10 degrees are suitable for validating accuracy, but areas with the following characteristics are unsuitable for validating our product accuracy.

- **Urban areas:** Some open residential, commercial, and industrial areas may appear to be suitable for validating accuracy in the data, but the proximity of cultural features such as buildings, houses, cars, light standards, and utility lines, as well as roads, bridges, and parking lots, can reduce the absolute accuracy in the data. This is because these features can block or otherwise interfere with the returned radar signal. As such, these areas are not suitable for validating the accuracy of our data.

- **Dense tree cover:** Areas of dense tree cover, where the IFSAR technology does not penetrate the canopy well, prevents us from capturing ground elevation information. Consequently, these areas are not suitable for validating the accuracy of our data.
- **Scrub brush and scattered trees:** Areas of scattered trees or extensive scrub brush, where the spacing among them within our ORI appears to indicate sufficient open area, may still pose a problem for validating accuracy. This is because the ORI has a 1.25m resolution, whereas the DEM data has a 5m resolution or cell size. Combined with the effects of the viewing geometry in these areas, these features can affect the accuracy of our DEM data enough that these areas are excluded as areas suitable for use in validating the accuracy of our data.
- **Areas near water bodies:** Because radar signals respond to water bodies in a similar manner to how they respond to parking lots, open areas that would otherwise be suitable locations for validating accuracy could be affected because of their proximity to water. Additionally, these areas are subject to the effects of temporal changes – changes in shoreline location – so we cannot expect consistency in the elevation readings in these areas. Consequently, these areas are not suitable for validating the accuracy of our data.
- **Construction sites:** Areas under construction should not be used as locations for validating accuracy. While at the time of the survey the land may be an open, low-slope area, if there is any evidence that may change then a more suitable location should be chosen to validate the accuracy of our data.
- **High-slope areas:** Areas of high slope, along with factors such as the magnitude of the slope, whether it is positive or negative, where it lies in the radar swath, and the aspect angle relative to the look angle, can cause reduced accuracy in elevation. As a result, areas with slope greater than 10 degrees are not suitable for validating the accuracy of our data.

Side-viewing geometry: The radar views to the side of the aircraft with local incident angles of about 35 to 55 degrees. Therefore, in the direction perpendicular to the flight path, there are shadow effects behind tall structures and layover effects in front. For example, a 10-meter vertical structure could affect the terrain as far as 17 meters away from the structure. This has two consequences in urban areas:

- These areas often contain voids, and using ancillary DEM data, elevations are infilled into the product. If ancillary DEM is unavailable, interpolation is used to compensate for data loss.
- In areas with narrow streets parallel to the flight line, the buildings may obscure the streets, so there may be no sampling of the bare earth in the street itself.

Understanding Accuracy

Slope effects: Slopes greater than 10 degrees cause reduced accuracy. (Slope may be terrain slope or it may also be localized slopes caused by first surface features.) The impact depends on the magnitude of the slope, whether the slope is positive or negative, aspect angle, and where it lies in the radar swath (look angle). As a general rule, the RMSE will increase in areas with slopes above 10 degrees. In areas with slopes of 20-30 degrees, the RMSE is estimated to double, and it will continue to increase as the slope increases.

Rapid changes in terrain: Rapid changes in terrain from features such as ridgelines, treelines or drainage embankments can cause a similar increase in error. Additionally, the DTM interpolation process may generalize the terrain, creating local errors. Elevations in the DTM may not be completely preserved as in the DSM. Utilizing breaklines during the interactive editing stage reduces these effects. These breaklines are only used during the editing process and are not maintained or deliverable with the final product. Similarly, the transition zone between obstructed and unobstructed areas (usually less than 25 meters) may have edge-effects.

DTM-related issues: The process for creating a bald-earth DTM (using proprietary software developed by Intermap) attempts to remove the first surface features in the DSM (e.g. buildings, utility features, trees and forest, etc). Obstructed areas, although processed and interactively edited to lessen the effects of first surface features, may not meet the same vertical accuracy as unobstructed areas with slopes less than 10 degrees. Consequently, these areas must be excluded from any validation testing.

Phase decorrelation effects: As the data is being gathered, a decorrelation of phase between the two antennae can occur. This is more common with radar systems that require two passes over a target area, but it can occur, to a lesser extent, with one-pass systems such as those used by Intermap. The result of phase decorrelation can be an unreliable measurement of height variation and a potential loss of data. That data loss is manifested as data dropout in the imagery and as areas requiring interpolation in the elevation data. Data processing techniques are implemented to mitigate these effects.

7.3 Test Rules for IFSAR DSM and DTM Validations

There are different ways to create vertical accuracy validation statistics for radar-derived DTMs. Each has advantages and disadvantages, as discussed below:

Individual VCPs: The advantage is that these VCPs are usually high-precision points (typically 5-25 cm RMSE) in (x,y,z), tied in to first-order benchmarks. The disadvantage is that they are often relatively few in number and may not represent the spatial variability of the subject DTM over a range of conditions. Industry practice usually specifies a minimum of 25-30 VCPs uniformly distributed over the test area. Often the test area size is not referenced, so the remarks in Section 7.1.2, *Scale Effects in Statistical Sampling*, are worth noting. Figure 7.5 contains stars that represent a typical scattering of VCPs in part of a collection area.

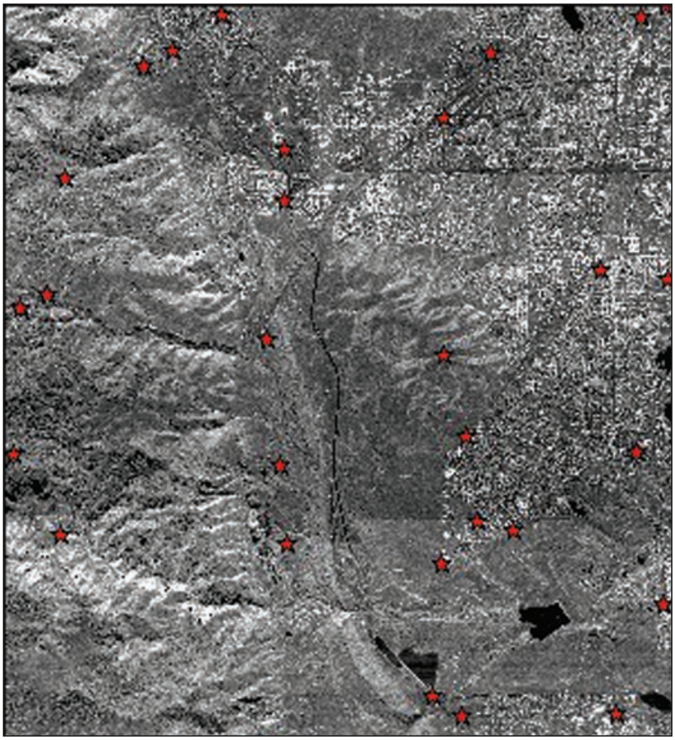

Figure 7.5: Red stars indicate a typical scattering of VCPs in a collection area.

Higher Accuracy DSM/DTM: If an independent DSM or DTM is available that has a suitably high sampling density and accuracy, the comparative accuracy over larger, continuous areas of the Intermap product can be obtained. Several of the validation exercises conducted by Intermap have used LiDAR-derived DSMs and their associated point sets as comparative 'truth.' Of course, these systems have their own errors and anomalies so care must be exercised. Also, if the comparison is used to validate accuracy of the IFSAR DSM or DTM, this comparison must be restricted to unobstructed areas as previously defined.

Test Site Selection Rules: The main rule is that the site on which test points will be acquired (whether individual VCPs or LiDAR ground points) must consist of unobstructed, low-slope terrain. All test points should not be horizontally (d) within 1.7 times the height (h) of a vertical obstruction (d=h/tan30°). Any area where interpolation has been required in the DSM due to low correlation will not provide representative statistics.

7.4 ORI Accuracy

The ORI is produced as part of the interferometric process and conditions that introduce errors into the associated DSM will affect the ORI as well. Therefore, many of the remarks of the previous sections apply also to the ORI. For example, the edges of buildings will not present the same level of horizontal accuracy that would be measured through use of a bright, point-like target such as a corner reflector (trihedral). Since the ORI is a 2D image product and doesn't contain elevation information, only horizontal or planimetric accuracy can be assessed.

The validation method of choice is through the use of corner reflectors, which appear to return all the scattered energy from a single 'point' (and can be surveyed to within a few cm). These are also used for validation of the spatial resolution of the system. This enables the horizontal location of the reflector to be checked to sub-pixel accuracy. Under test conditions in which corner reflectors are deployed in flat, unobstructed areas, the horizontal accuracy has been validated at the 2.0 meter RMSE level, where in this instance we refer to the circular error, which accounts for errors in the two-dimensional horizontal sense. If RMSE is calculated as RMSEr = SQRT($RMSE_x^2$ + $RMSE_y^2$), where the x and y refer to the orthogonal spatial components of the error (for example, in conventional Easting and Northing units), then we can also calculate a 95% probability, similar to that for the vertical errors. The circular case is more complicated, but it can be shown to be CE(95) = 1.73* RMSEr. That is, CE(95) represents the radial distance within which 95% of the errors may be found. The problem related to offsets that was discussed in Section 7.1, *Statistical Measures*, also applies in this case. Experience indicates that simply approximating CE(95) as 2 * $RMSE_r$ is adequate, and we do so in the specifications table.

The star in Figure 7.6 denotes the center of a typical corner reflector as it appears in an ORI that has been enlarged 10 times.

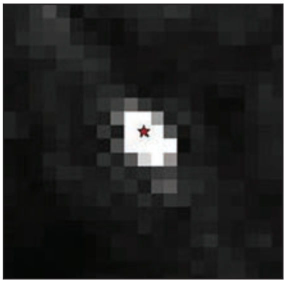

Figure 7.6: Corner reflector in an ORI, magnified by a factor of 10.

It should be noted that an alternative validation method often employed is to use visible features such as road intersections that have been surveyed at their intersecting centerlines. While this is a useful approach, it will tend to overstate the apparent error. Or rather, the observed error is really a combination of the uncertainty associated with the identification of the centerlines and the fundamental ORI pixel position error. The former uncertainty is dependent upon the nature of the features chosen and the feature-matching method chosen. Typical uncertainties of this nature are 2-3 pixels in magnitude. For this reason, the specification relates to the underlying accuracy derived from reflector tests.

7.5 Vertical Resolution

As mentioned previously, Intermap periodically compares its DSMs and DTMs to high-accuracy samples of elevation data that have been independently collected. These samples are taken from within larger areas that we have also flown. Using them, we are able to calculate the relative noise in our data and determine the smallest possible changes in elevation that can be identified when using our products. The threshold at which these changes are verifiable is defined as a difference in elevation that is equal to the apparent elevation differences caused by the relative noise of the data.

So from this it follows that, if you can measure the relative noise in the data, you are, in effect, measuring its vertical 'resolution' – the precision with which the data can be used to identify the vertical relationship of one point relative to another. Any change in elevation that is greater than the threshold described above will be detectable in the data. A change that is less than the threshold will not be distinguishable from the relative noise. (By comparison, the vertical accuracy refers to how well the data conforms to an absolute frame of reference.)

In determining the relative noise level with respect to vertical accuracy of the DSM and DTM surfaces, the assumption is made that the "truth" data has a relative noise level of less than 10 centimeters (that it does not contribute significantly to the overall relative noise), and the difference histogram (between the truth data the Intermap data) is approximately normally distributed. The different histograms in Figure 7.7 and Figure 7.8 show typical results with Intermap DSM and DTM data when referenced against sample data, confirming that the second assumption is valid.

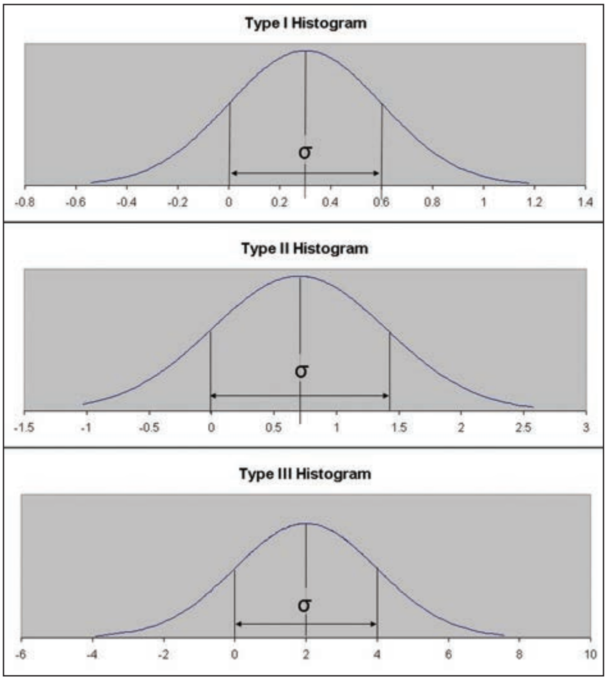

Figure 7.7: Typical DSM difference histograms.

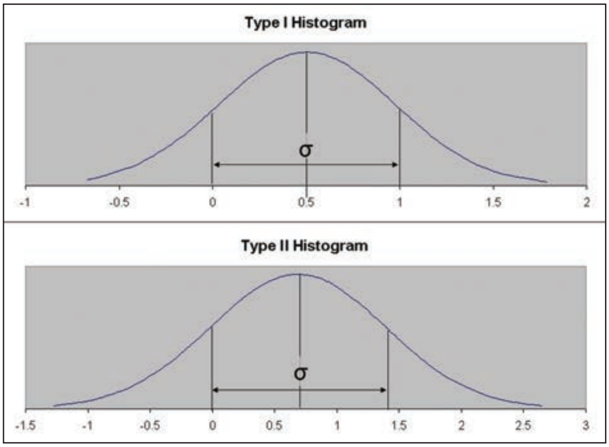

Figure 7.8: Typical DTM difference histograms.

Based on these assumptions, the relative noise level can be simplified to plus or minus the standard deviation (σ). In Figure 7.9 and Figure 7.10, the uncertainty bars represent the elevation range such that any change in height will be distinguishable outside this range.

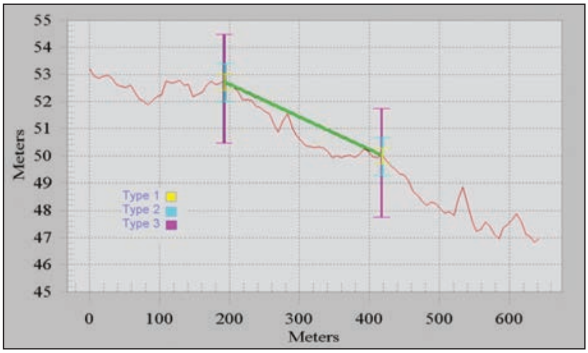

Figure 7.9: DSM relative noise.

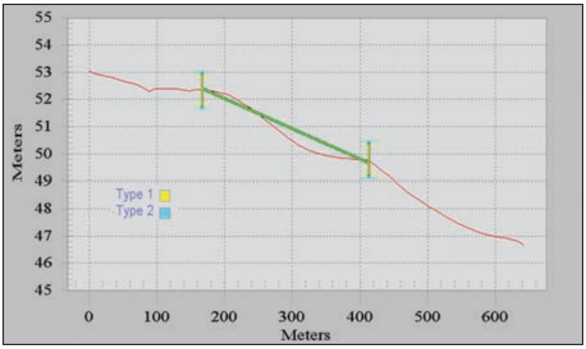

Figure 7.10: DTM relative noise.

Therefore, it can be seen that it is possible to distinguish differences in elevation that are in excess of the uncertainty bars shown in the graphs. For example, a Type I DSM (0.5 m RMSE) has a vertical accuracy of ½ meter. However, it is possible to detect changes in elevation of 0.3 m or greater – because it has a relative noise level of only +/– 0.3m (See Figure 7.7, Type I Histogram). So the height difference in the DSM figure (Figure 7.9) would be detectable with a Type I DSM. Similarly, in a Type II DSM (1.0 m RMSE), it is possible to detect changes in elevation of 0.7 m or greater – because it has a relative noise level of only +/– 0.7 m (See Figure 7.7, Type II Histogram). However, the same height difference would not be detectable with a Type III product, because the relative noise exceeds the change in elevation (see Figure 7.9; the purple uncertainty bars overlap each other).

It should be further noted that subtle elevation features that that are persistent over extended areas (trenches, for example) may be detected in shaded relief or other visualizations owing to the integration effect of the observation.

Product Validation 8.0

To ensure Intermap meets its customers' demands for highly accurate elevation data, Intermap employs a separate validation team that, in addition to the extensive verification procedures that are built into the production processes, reviews all products. The team conducts analyses at key points in the production workflow process, accuracy assessment of all final products, and random inspections of edit work. These analyses are conducted independently of the workflow process and do not interfere with or delay production in any way. To ensure the success of this validation the team is technically, managerially, and operationally independent from the production team so that its analyses can be conducted from an objective and unbiased point of view.

Conducting analysis under this philosophy allows Intermap to examine the quality of the data through alternative methods – which often leads to new findings about the data – as well as identify areas of improvement in the current production process. Ultimately, the validation team's goal is to provide internal departments, such as production, sales, and management, with information about the overall quality of Intermap data as production is completed.

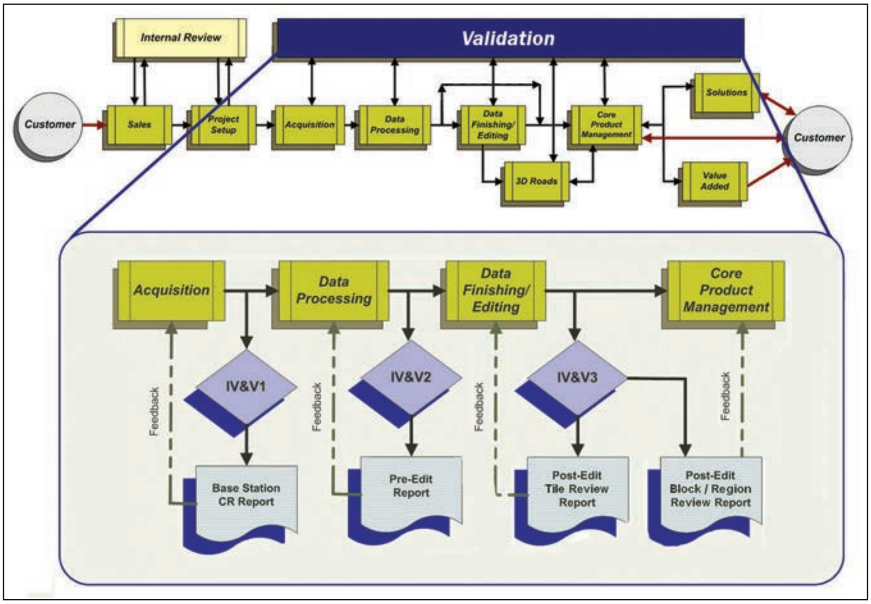

Figure 8.1: Enterprise workflow and validation workflow.

INTERMAP

Product Validation

The team fully supports Intermap's NEXTMap® countrywide mapping programs. These ongoing initiatives help to ensure the delivery of high-quality data products across entire countries. For these programs, the validation team performs independent inspections during the data collection and production stages and provides the following:

- Acquisition feedback (Pre-edit Reports)
- Data processing pre-edit feedback (Pre-edit Reports)
- Data processing post-edit adherence to edit rules feedback (Tile Review Reports)
- Core product management post-edit block / region summary (Final Block / Region Reports)

At no point in the production process for any project ever delayed awaiting feedback from the validation team.

Pre-Edit Reports

Before the IFSAR data is sent to Production for interactive editing, IV&V provides a Pre-edit Report. The report is divided into three parts: Reflector Checks, VCP Checks, and DSM Mapsheet Checks. The Reflector Checks verify the precise location of the corner reflectors. Since all DEM data is processed with respect to the reflector coordinates, the accuracy of these coordinates must fall within the defined specification. The VCP Checks describe the vertical accuracy assessment of the IFSAR data prior to the interactive editing stage of production. This pre-edit assessment is performed with the use of third-party ground survey points (referred to as Vertical Check Points, or VCPs) which are used as the basis of truth. The process is designed to provide feedback on the general quality of the unedited IFSAR data as early as possible in the production process, and to identify any major errors in the data that may indicate the need for reprocessing or re-acquisition of data. The DSM Mapsheet Checks consist of several visual checks for artifacts or other issues that may have occurred during acquisition, processing, or mosaicing. These may include motion or CORVEC ripples, seam lines, and cycle shifts. It is important to report possible issues prior to the editing process in order to avoid additional work at a later stage.

Tile Review Reports

The Tile Review Report is designed to provide early feedback concerning adherence to established edit rules within selected tiles throughout the block. The reviewed tiles are carefully selected in order to provide a good spatial distribution, while also covering areas in which the editing process requires varying levels of effort. A Tile Review Report will provide a review on 5-10% of the tiles in every NEXTMap block. This report includes the results of analysis and interactive reviews performed on the DSM, DTM, and ORI to ensure adherence to the Core Product Edit Rules.

Product Validation

Final Block / Region Reports

Final Reports are intended to provide feedback regarding all aspects of finalized NEXTMap blocks. This includes ORI masking checks for all tiles, minimum-elevation checks for all tiles, NEXTMap block edge checks, post-edit VCP analysis, and a comparison of data quality to other publicly available data.

As large geographic regions are completed (countries or states, for example), a summary report of information contained in the associated Final Reports is compiled to provide general information on the quality of Intermap data within those regions.

The two key results from the validation analysis are reporting the findings about data quality and informing management of potential refinements that could be made to improve how we produce our data. Intermap continues to explore new methods of data verification and refine its procedures to ensure that our products meet the ever-increasing demands of customers who use highly accurate digital elevation data.

Introduction to Applications 9.0

The host of elevation and image products that are available from Intermap Technologies® provide a foundational basemap for many geospatial applications. Our core products can be used directly, without further processing, in many of these applications. Specific client requests that go beyond our core products are available as value-added products or services.

This section discusses applications in which both core products and added products have been used successfully. When assessing your particular application needs, specifically with respect to the use of our DTM data, please refer to Section 6.2, *Product Characteristics*, and speak with an Intermap sales representative to identify the DTM version that best suits your needs. It is important to note that the scale of your particular application, as well as the tools and processes you are using, can directly impact the suitability of our data.

9.1 Core Product Applications

Flood Modeling / Watershed Analysis: As a primary application of Intermap's DTM product, great care is given to the representation and editing of hydrology and flood defense features. Our value-added service offering supports requests regarding the editing and modeling of individual features to support specific hydrology applications. The image below depicts an ORI of eastern Shrewsbury, England, that was produced specifically to support the production of flood insurance maps for Norwich Union.

Figure 9.1: Flood hazard example.

Overlaying ORI data onto our DTM within that area generated the shaded area of a flood plain in eastern Shrewsbury, England.

Introduction to Applications

Topographic Mapping / Contours: A natural extension of the DTM elevation data is the production of contour maps. Elevation data can be used to generate contours at any interval; however, careful consideration should be given to the accuracy expectations of these contours. A generally accepted specification is that contours will meet expected accuracies when the contour interval is limited to 3.25 times the vertical accuracy (RMSE) of the elevation data. For example, Intermap's published vertical accuracy for NEXTMap USA data of 1 meter RMSE in unobstructed areas with slopes less than 10 degrees would yield contours at 3.25 meters and thereby meeting accepted accuracy standards.

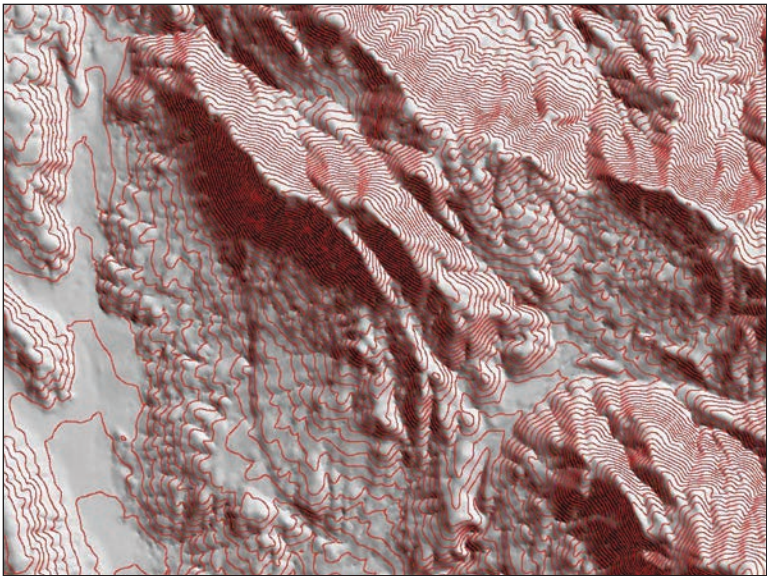

Figure 9.2: Contour map example.

Introduction to Applications

3D Visualization: Traditional 3D visualization applications, involving the draping of imagery and thematic or place-specific data over 3D landscapes, is useful in activities such as land use planning (to provide visual impact of new development), in-office viewing of real estate properties, virtual tourism, and many others. Once registered to the ORI, the imagery can be draped over the DSM to provide added meaning and context to your imagery through 3D visualization. The ESI product also has direct application in this area.

In Figure 9.3, a 1m, pan-sharpened IKONOS satellite view from GeoEye® is draped over an Intermap DSM to create this 3D perspective of Morrison, CO.

Figure 9.3: 3D visualization.

Image Rectification: Satellite and aerial imagery is often delivered without being registered to any type of real-world data. The ORI product is well-suited to rectifying both types of imagery.

Figure 9.4, an image of Castle Rock, Colorado, features a DigitalGlobe® QuickBird 0.7-meter satellite image that is suitable for rectification with Intermap's ORI product.

Figure 9.4: QuickBird image from DigitalGlobe, suitable for rectification with Intermap's ORI.

Base Mapping: Because of the underlying geospatial accuracy, the ORI product provides an economical alternative in areas where aerial photography or cloud-free satellite imagery is not readily available. In addition, ground-control coordinates of identifiable features such as roads and waterways can be extracted from the ORI to assist with the georeferencing of complementary data layers.

Vehicle Navigation / Intelligent Vehicle Systems: Numerous programs within the automobile industry benefit from a high-resolution 3D road network, which is supported by Intermap's elevation and image products. Some examples are vision-enhancement products like Predictive Adaptive Lighting (PAL) that anticipate road curves and slopes, and Advanced Driver Assistance Systems (ADAS), such as adaptive cruise control systems and lane-keeping systems that anticipate threatening situations and warn the driver or even brake accordingly.

GPS / Consumer Electronics Devices: Various hand-held GPS and broadband wireless communications devices can be embedded with a range of 3D rendering and position-tracking capabilities. For many applications, a 3D interface and supporting 3D data enhance both the understanding and usability of the data. This type of next-generation interface requires 3D terrain at resolutions supported by Intermap's DSM and DTM products.

Precision Farming / Forestry: Slope and aspect derived from Intermap's DSM and DTM products support various agricultural and forestry applications such as:

- Farm boundary delineation within major domestic crop-producing areas
- Conservation planning / wetland delineation
- Monitoring subsidy programs associated with slope or challenged terrain
- Inventory assessment
- Watershed management programs
- Erosion runoff and nutrient management plans, such as concentrated animal feeding operations (CAFOs), variable-rate planting, and fertilizer application plans

Flight Simulation / In-cockpit Situational Awareness: The aviation industry uses Intermap's products in applications such as interactive 3D approach charts and flight planning tools and in-cockpit synthetic vision, situational awareness, and Terrain Avoidance Warning Systems (TAWS). Computer software companies also use Intermap's DSM data to enhance the quality of their flight simulation applications.

9.2 Value-Added Products

Intermap is happy to provide value-added products and services to optimize the fit of our data to your particular application. For example, we can help you develop specific tools to match your processing needs. We can also discuss changes to our data-finishing processes to emphasize a specific need you may have as we make final edits to our core products.

Introduction to Applications

Pricing is negotiated on a per-project basis, using off-the-shelf data and readily available technology to the fullest extent possible.

We are always ready to work on new and challenging projects, but here are some examples of how we are frequently called upon to provide value-added assistance:

Surface Analysis Applications: Our core products are well suited to the following surface analysis and viewshed applications:

- Creation of profiles and cross sections (Figure 9.7)
- Determination of spot heights
- Line-of-sight calculations
- Viewshed analysis
- Creation of a hydrology layer
- Creation of slope and aspect maps
- Area and volume calculations
- Distance measurements

We can provide these services to you or provide the tools to enable you to make full use of the data.

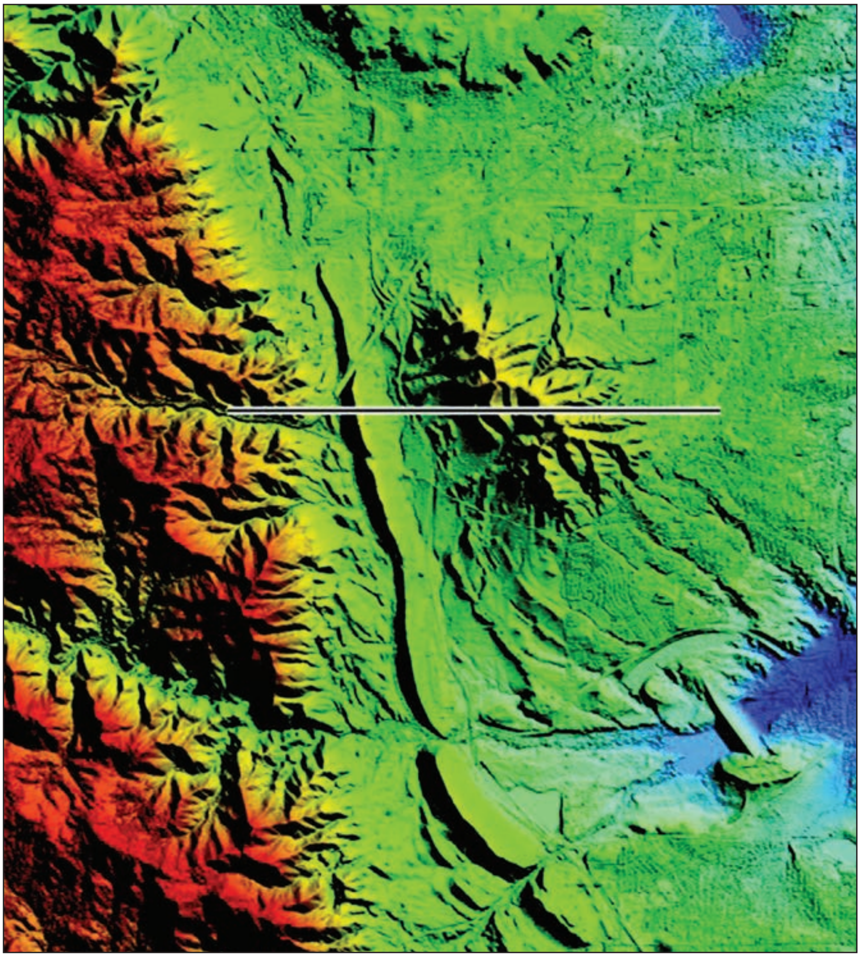

Figure 9.5: Colorized shaded relief of a DSM for Morrison, Colorado.

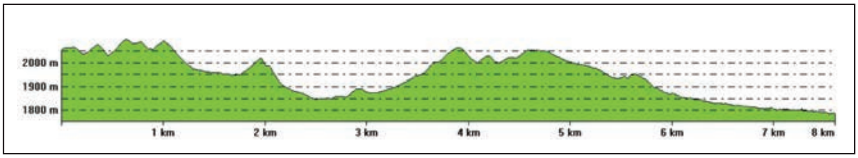

Figure 9.6: Profile view created from the line drawn across the image in Figure 9.5.

Introduction to Applications

Using Intermap elevation data, line-of-sight calculations can be conducted in order to assess the viewable terrain from a given position in a DEM.

Figure 9.5 is a line-of-sight calculation for a transmitter and receiver located 10 meters above the ground in the shaded relief image of Morrison, Colorado, above. In this example, the transmitter and the receiver are at the same elevation. However, from the point of view of someone standing next to the transmitter, the receiver appears to be lower because it is further away (indicated by the lower red dot). This is a perspective effect, best known by artists in the classic example of a row of telephone poles that appear to diminish in size as they recede from the observer and approach a vanishing point – an imaginary location on the horizon that approximates infinity.

In this figure, it is apparent that all of the green area above the yellow line represents terrain that intervenes to block the line of sight between the receiver and the transmitter. This demonstrates how it is possible for a lower peak to block the view between two higher peaks, if the lower one is close enough to the observer.

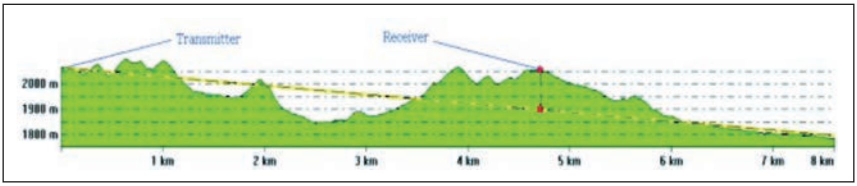

Figure 9.7: Line-of-sight calculation.

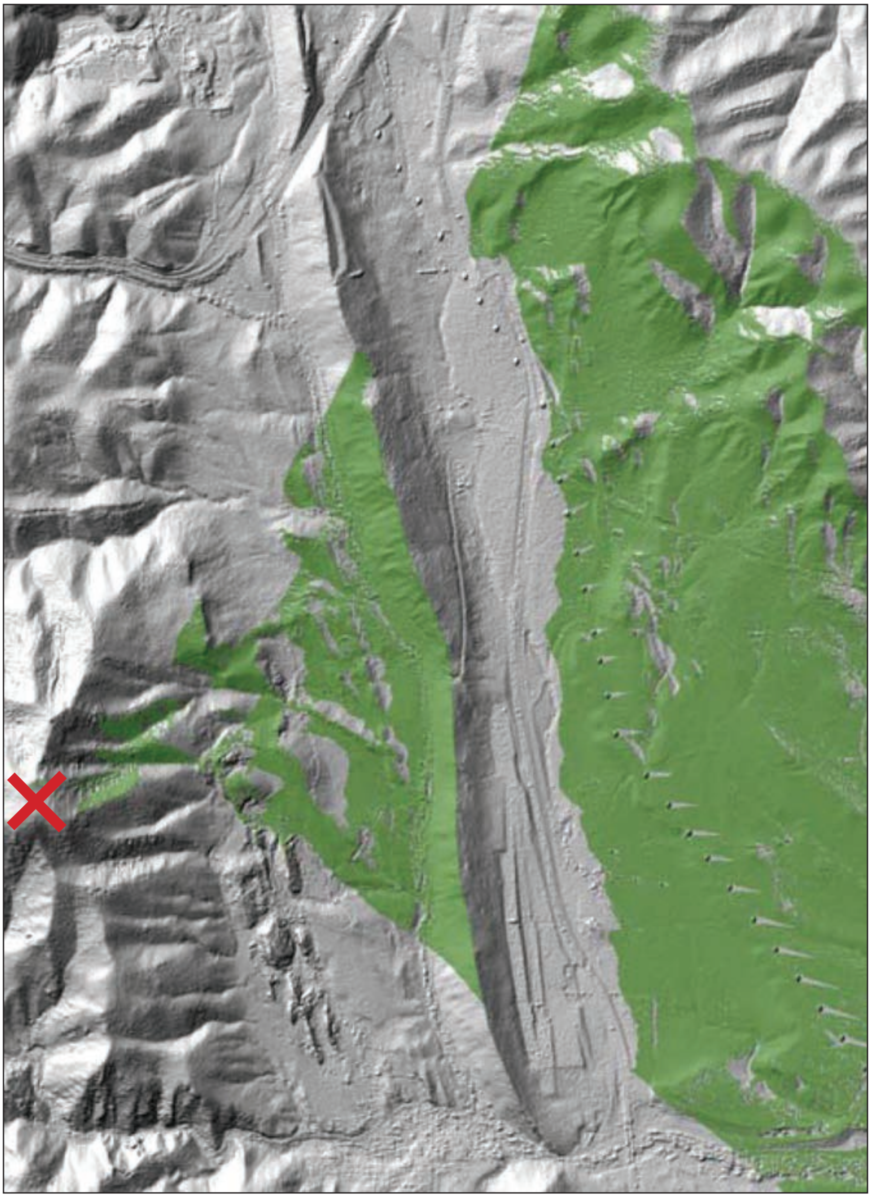

Figure 9.8: Viewshed analysis using the DSM of Morrison, Colorado.

Figure 9.8 is the resulting output of a viewshed analysis using Intermap DEM data. The red "X" represents the observation point selected for this analysis. The green areas depict the terrain that is visible to an observer standing at that observation point.

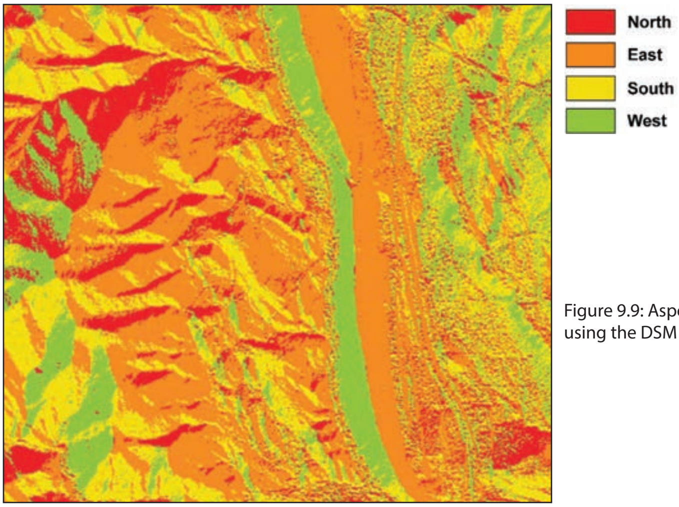

Figure 9.9: Aspect analysis using the DSM of Morrison, Colorado.

Figure 9.9 is the resulting large-scale output from an aspect calculation using Intermap's DSM product. Each color represents a range of aspect (azimuth) according to the topography of the area. In other words, the direction of each particular slope can be determined by referring to the legend.

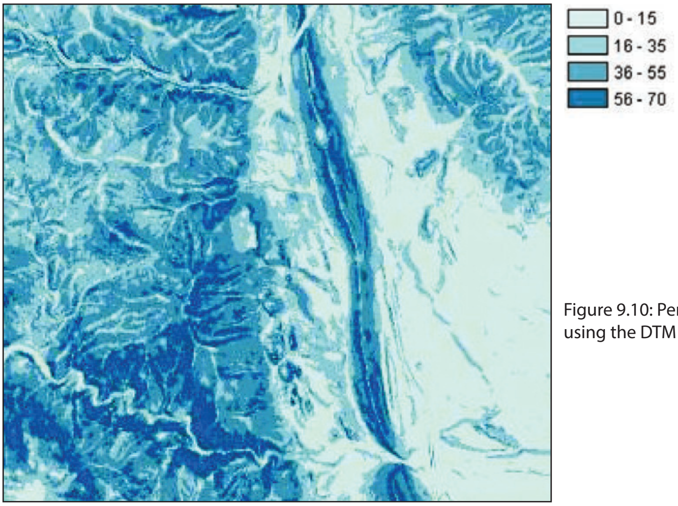

Figure 9.10: Percent slope analysis using the DTM of Morrison, Colorado.

Figure 9.10 is the resulting large-scale output from a slope calculation using Intermap's DTM product. Each color represents a range of slope by percent according to the topography of the area.

Shaded Relief: As the name suggests, a shaded relief product draws out terrain features by controlling their appearance with the use of digitally created sunlight. The effect is created by specifying an angle and direction for the sun and then calculating the length of the shadows these terrain features would cast, given the elevation information contained in the DSM or DTM. However, a shaded relief is more intuitive to use than either the DSM or DTM on which it is based. This is because it does not rely on pixel brightness to connote elevation, as in the corresponding ORI. Similarly, because it has a monochromatic character, subtle features in a shaded relief, such as drainage features are more readily apparent than in the ORI, where the same information can be overwhelmed by textural information.

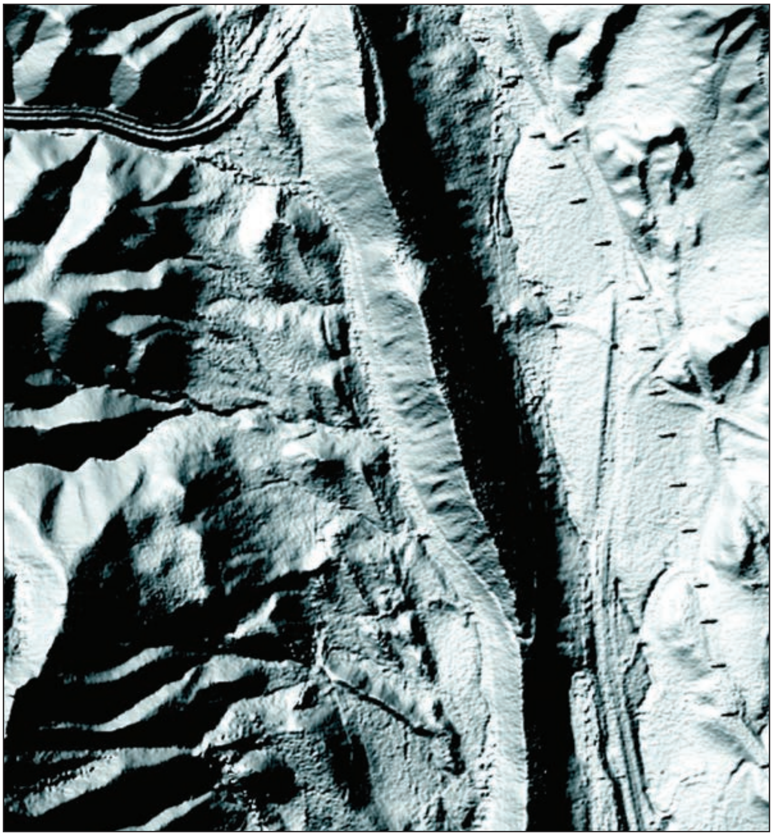

Figure 9.11: Shaded relief generated from the DSM of Morrison, Colorado.

In Figure 9.11, the shaded relief clearly shows the topographic features of the area to a level of detail where even power lines can be discerned as small dots on the right side of the image.

Introduction to Applications

Elevation Shaded Image: Intermap's ESI combines the characteristics of both optical images and relief maps: an aerial or satellite image provides the representation of ground features, while the NEXTMap DTM provides the highly accurate elevation information to supply a visualization that offers a high degree of information about the surrounding topography. The ESI possesses all of the benefits of a shaded relief product, such as representing geomorphic and elevation changes in a natural fashion – allowing the viewer to perceive the visualization in a realistic manner. Because of the optical images used as a component of the ESI, the product continues to display the features of the terrain.

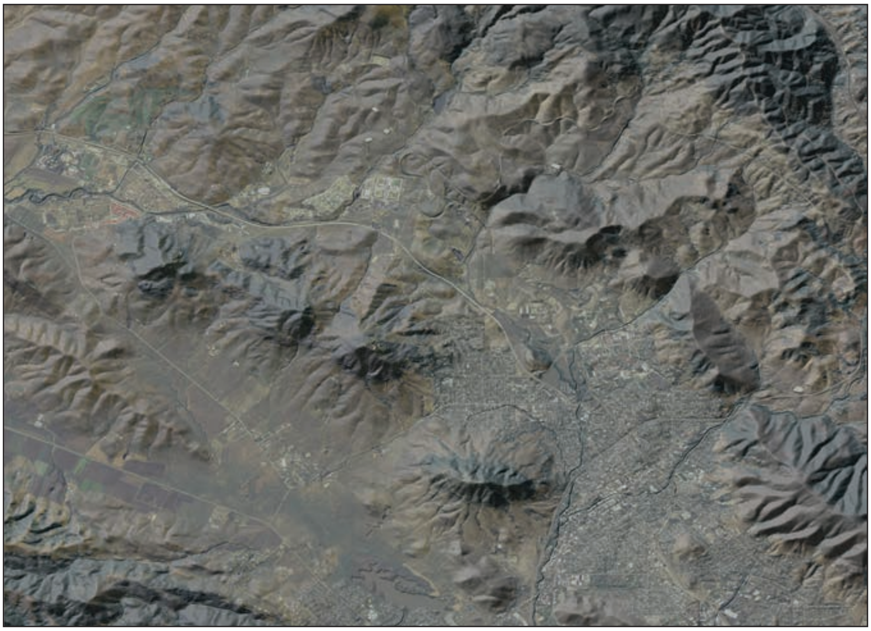

Figure 9.12: Elevation shaded image of San Luis Obispo County, California.

9.3 Other Optional Products and Services

Difference Layer: A difference layer file contains only the change in elevation "difference" between the DSM and DTM, making it valuable for applications such as forest inventory.

Decimated Datasets: Intermap can provide the DSM and DTM core products at reduced resolutions (e.g., at 10m or 25m postings) to support applications where a high detail of elevation data is not required.

Alternative Geodetic Reference Systems: We can include data transformations to support the realization of various datums, map projections, or units.

Customized Delivery: Alternative file formats, tile size, file-naming conventions, overlap between adjacent tiles, pixel origin, etc. can be provided to comply with industry-specific software programs or specific client requests.

Introduction to Applications

Customized Feature Characteristics: Intermap can perform custom editing of DSM or DTM features to meet your specific needs. For example, your application might require setting the pixel value to 1 for all bodies of water within the ORI product. You may also want to have all bridges added to your DTM product, or have other specific radar features removed from the DSM. Specific feature information for our DSM and DTM products can be found in Section 6.6.2, *DSM and DTM Feature Content*.

Correlation File: An optional product associated with the DSM or DTM is the radar correlation data file. The data is co-registered with the elevation products and provides insight regarding the relative agreement of the received signal strength at each antenna for each measurement.

Substitution of Other DEM Sources: We can substitute localized areas within our DSM or DTM products with alternate DEM sources that you may already have if you have higher accuracy or density needs.

Quick Start Guide 10.0

THIS SECTION EXPLAINS HOW TO LOAD PRODUCTS from Intermap Technologies® into eight popular software packages. While we have made every effort to ensure this information is complete, you may want to check with your software vendor regarding the specific file formats they support.

This guide includes information for the following software providers:

10.1 ESRI
10.2 ERDAS
10.3 MapInfo
10.4 ER Mapper
10.5 ENVI
10.6 PCI Geomatics
10.7 Autodesk
10.8 Global Mapper

Please note that references to a DEM refer to either a DSM or DTM. Also, note that all Intermap DEM products in .bil format are delivered with an ESRI-formatted .hdr header file.

10.1 ESRI Software

10.1.1 Loading a DEM into ESRI Workstation ArcInfo

1. Start Workstation ArcInfo and run the Floatgrid command, which will convert a file of binary floating point numbers to a grid. An example of the Floatgrid command is shown below:

   Arc> floatgrid sample.bil output_name.

2. In Workstation ArcInfo, open a display, set the map extent, select the image, and draw it, as shown in the following sample command lines:

   Arc> arcplot
   Arcplot> display 9999
   Arcplot> mapextent output_name
   Arcplot> image output_name.

10.1.2 Loading an ORI into ESRI Workstation ArcInfo

To load a GeoTiff ORI file into Workstation ArcInfo, follow these seven steps:

1. Start Workstation ArcInfo.
2. Set the mapextent, select the image, and draw the image, as shown in the following sample command lines:

    Arc> arcplot
    Arcplot> display 9999
    Arcplot> mapextent sample.tif
    Arcplot> image sample.tif.

10.1.3 Loading a DEM into ESRI ArcMap 8.x

1. Launch Arc Toolbox. Under Conversion Tools, select Import to Raster, then select Floating Point Data to Grid.

Figure 10.1: Arc Toolbox.

2. In the popup dialog box, click the folder icon to the right of Input Float File. Navigate to the directory where your DEM (*.bil) file is saved.

3. For the Output grid, provide a name and directory for each of the new grid datasets created. Grid dataset names must be 13 characters or less and cannot contain a period or space. Make sure the path name where the dataset is to be saved contains no spaces. Click OK. In order to import several .bil files at one time (batch process), click Batch on the lower right corner of the import dialog box. This will expand the dialog box and enable you to build a table of input / output paths for multiple files. Make sure that the output path does not contain spaces.

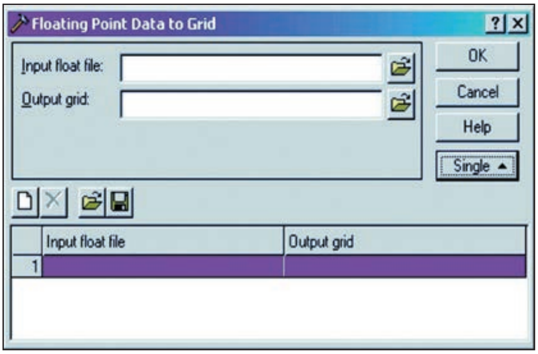

Figure 10.2: Floating Point Data to Grid dialog box.

4. After the raster files have been imported to grid datasets, remain in Arc Toolbox. Under Data Management Tools, select Projections, then Define Projection Wizard (coverages, grids, TINs).
5. In the dialog box that follows, select Define Coordinate System Interactively and click Next. In the dataset selection screen that follows, navigate to the grid file exported in Step 3. Click Next.
6. In the screens that follow, the wizard will ask a series of questions regarding the specifics of the projection of the dataset that you are working with, such as projection type, parameters, datum, spheroid, etc. Refer to the metadata associated with your DEM file to answer these questions, and click Finish.
7. Launch ArcMap. To load the DEM into to a map file, select Add Data under the File menu, and navigate to your new grid file location.

10.1.4 Loading an ORI into ESRI ArcMap 8.x

1. Open ArcMap.
2. Click A New Empty Map and then click OK.
3. Click Add Data (look for the black cross in the yellow diamond) and navigate to the file.
4. Click OK, and the image will appear.

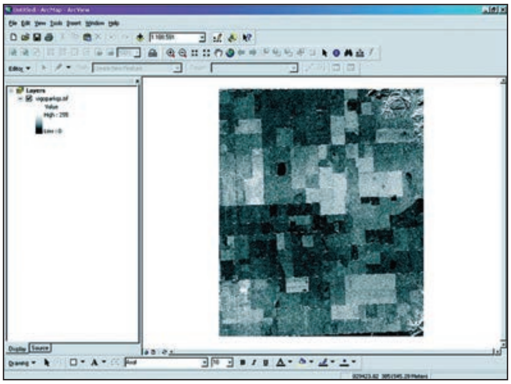

Figure 10.3: Intermap ORI in ArcMap.

10.1.5 Loading a DEM into ESRI ArcMap 9.x

Before loading Intermap DEM files into ArcMap 9.x, you must first change the .bil extension in the file name to .flt.

In Windows Explorer, navigate to the location of the Intermap DEM files.

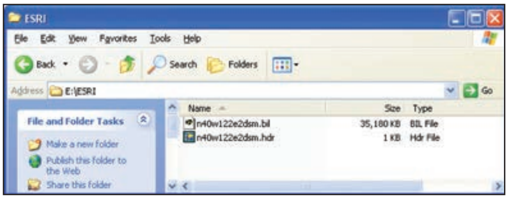

Figure 10.4: MS Windows Explorer window.

If the file extensions are not visible, make them visible by unchecking the Hide Extensions for Known File Types checkbox in the Folder Options dialog box.

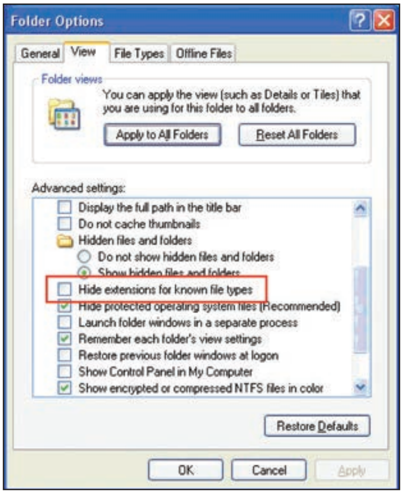

Figure 10.5: Folder Options dialog box.

Click the Tools menu in the Windows Explorer window and select Folder Options. Within the Folder Options window, select the View tab, scroll to Hide Extensions for Known File Types, uncheck the corresponding box, and click OK.

Change the extension by right-clicking on the file name and selecting Rename from the popup dialog box. Replace ".bil" with ".flt" and press Enter.

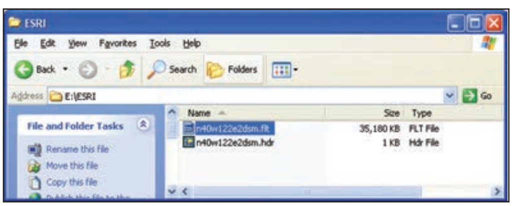

Figure 10.6: MS Windows Explorer window with the .bil file renamed as .fit.

1. Launch Arc Toolbox. (Arc Toolbox can be accessed in both ArcMap and ArcCatalog).Under Conversion Tools, select “To Raster”. Under “To Raster”, double-click “Float to Raster”.

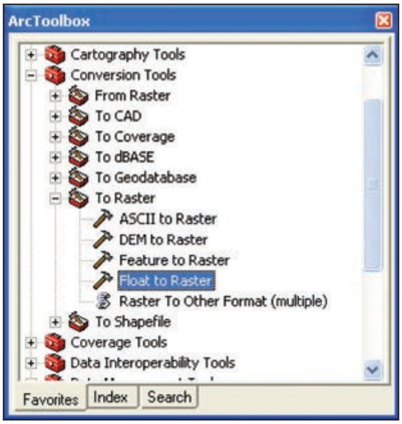

Figure 10.7: Arc Toolbox.

2. In the popup dialog box that follows, click the folder icon to the right of Input Floating Point Raster File. Navigate to the directory where the DEM (*.flt) file is saved.
3. For the Output raster, provide a name and directory where you want to place the new grid datasets. Grid dataset names must be 13 characters or less and cannot contain a period or space. Make sure that the path name where the dataset is to be saved contains no spaces. Click OK.

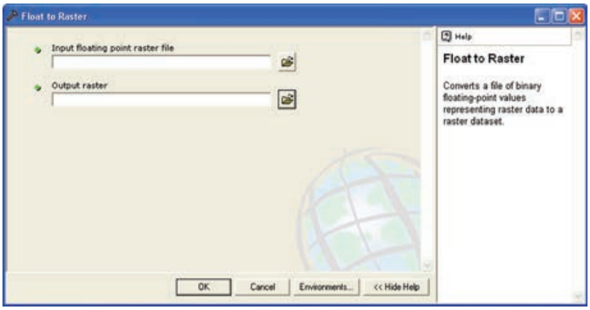

Figure 10.8: Float to Raster dialog box.

4. After the raster files have been imported to grid datasets, remain in Arc Toolbox. Within Data Management Tools, open Projections and Transformations, then double-click Define Projection.

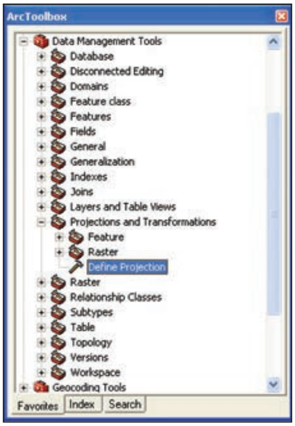

Figure 10.9: Arc Toolbox.

In the Define Projection dialog box that follows, click on the button to the right of the Input Dataset text box, then navigate to your DEM file.

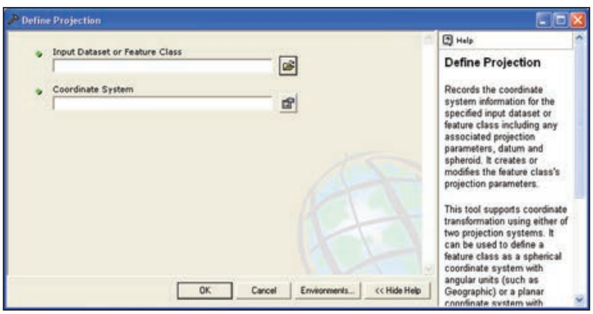

Figure 10.10: Define Projection dialog box.

Click on the button to the right of the Coordinate System text box to bring up the Spatial Reference Properties dialog box.

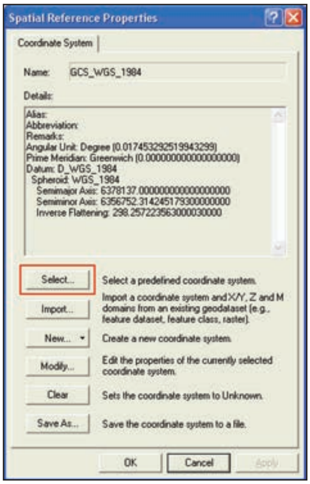

Figure 10.11: Spatial References Properties dialog box with the corresponding Browse for Coordinate System popup box.

Click on Select. Using the information in the header file, choose the appropriate coordinate system. Click Add in the Browse for Coordinate System window.

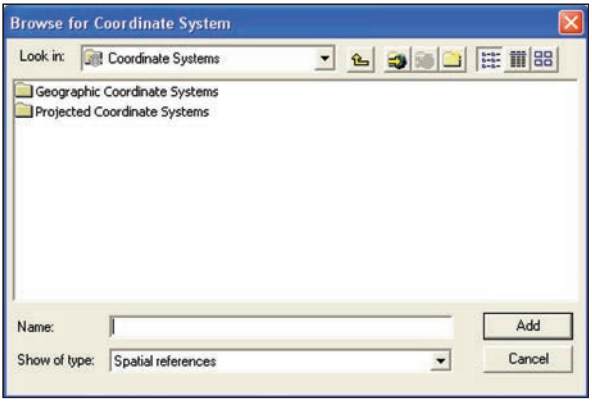

Figure 10.12: Browse for Coordinate System window.

Click OK on the Spatial Reference Properties dialog box (see Figure 10.11).

10.1.6 Loading an ORI into ESRI ArcMap 9.x

See instructions in Section 10.1.4.

10.2 ERDAS Software

10.2.1 Loading a DEM into ERDAS IMAGINE

1. Start IMAGINE.
2. Click Import to convert the Intermap DEM .bil file into an ERDAS .img file.

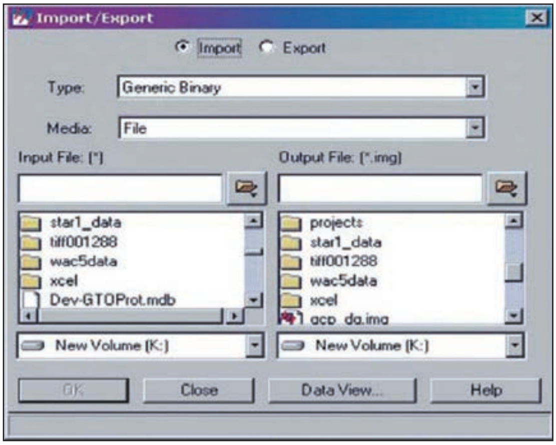

Figure 10.13: IMAGINE Import / Export dialog box, set to Import.

3. In the new dialog box, click on the Import radio button and set the type to Generic Binary. Then set the Media to either CD-ROM or File, depending on the location of the .bil file. Select Input and Output directories.

4. After clicking OK, the dialog box shown in Figure 10.14 will open.

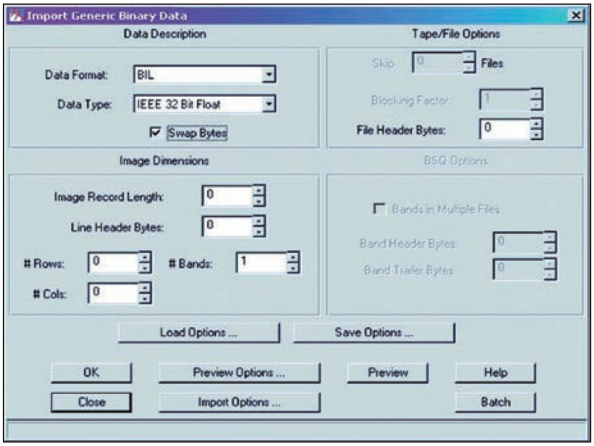

Figure 10.14: Import Generic Binary Data dialog box.

5. Set Data Format to BIL, Data Type to IEEE 32-Bit Float, and set the number of rows and columns. Values for these can be obtained from the associated header file. (See NCOLS and NROWS in the .hdr file.) Click Swap Bytes in the UNIX version of IMAGINE. Click OK to import.
6. Open a new viewer in IMAGINE by clicking the Viewer button on the main IMAGINE toolbar. From the viewer menu bar, select File. Select Open, then Raster Layer, and specify the new .img file.
7. The image is now viewable, but not properly referenced to geographic coordinates. To begin referencing, select Utility, then Layer Info.

8. In the new dialog box, select Edit, then Change Map Model. The information to enter here can be found in the associated metadata file. Excerpts from the .txt version are listed below.

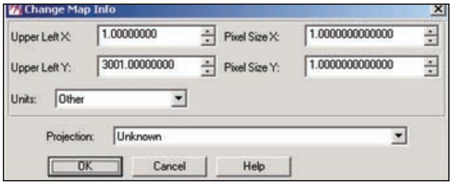

Figure 10.15: Change Map Info dialog box.

Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -118.375021 → **Upper Left X**
East_Bounding_Coordinate: -118.249979
North_Bounding_Coordinate: 36.375021 → **Upper Left Y**
South_Bounding_Coordinate: 36.249979

Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition: Geographic → **Projection**
Latitude_Resolution: 0.0000416667→ **Pixel Size Y**
Longitude_Resolution: 0.0000416667 → **Pixel Size X**
Geographic_Coordinate_Units: Decimal degrees → **Units**

9. Select Edit, then Add / Change Projection. In the dialog box, click on the Custom tab. The information to be entered can be found in the associated metadata file. Excerpts from the .txt version are provided below.

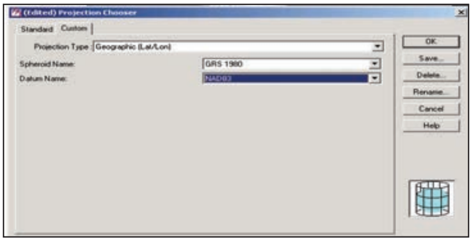

Figure 10.16: Projection Chooser dialog box.

Geodetic_Model:
Horizontal_Datum_Name: NAD83 → **Datum Name**
Ellipsoid_Name: GRS80 → **Spheroid Name**

10. The Layer Info menu is now complete and the .img file is ready for IMAGINE.

10.2.2 Loading an ORI into ERDAS IMAGINE

1. Start IMAGINE and open a viewer.
2. Select File, then Open Raster Layer.
3. In the Files of Type dropdown menu, select TIFF.

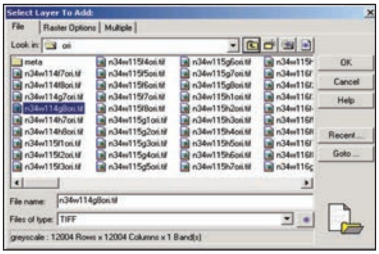

Figure 10.17: Add layer dialog box.

10.3 MapInfo Software

10.3.1 Loading a DEM into MapInfo

1. Convert the DEM (*.bil) file into an ASCII "XYZ"-format text file (e.g., easting, northing, elevation) using third-party software such as PCI EASI / PACE or Arc Toolbox.
2. From the File menu in MapInfo, select Open Table and set Files of Type to Delimited ASCII.
3. Select the desired text file and click Open.
4. Select the appropriate delimiter (e.g., tab or space).
5. In most cases, the default File Character Set can be used.
6. If the text file has column headings (e.g., easting, northing, elevation), click the Use First Line for Column Titles checkbox. Otherwise, leave it unchecked.
7. Click OK to load the text file into MapInfo. Note that for large text files, this step may take several minutes.
8. To create a Vertical Mapper Grid file, select Vertical Mapper from the menu bar. Then select Create Grid and Interpolation.
9. Select Rectangular (Bilinear) Interpolation and click Next.
10. Under Select Table to Grid, choose the table that was created in Step 7.
11. Under Select Column, select the column containing the elevation information.
12. Under X Column, select the column containing the x (easting) coordinate information.
13. Under Y Column, select the column containing the y (northing) coordinate information.
14. Click on Projection.

15. Under Category, select Universal Transverse Mercator (WGS84).
16. Under Category Members, select the desired UTM Zone for the dataset and click OK.
17. Type in a Data Description (e.g., elevation).
18. Select the correct unit (e.g., meters) from the Unit Type dropdown menu and click Next.
19. Set Cell Size to five meters and leave the Search Radius as the default value.
20. Use the Browse button to select a file name and location for the new grid file. Click Finish to generate the grid file.

10.3.2 Loading an ORI into MapInfo

1. Obtain coordinate information for three pixels within the image (usually the upper-left, lower-left, and lower-right corner pixels). The coordinates must refer to the upper-left corner of each pixel and not to the center of the pixel.

   For example, let's assume that an ORI that is 1,000 pixels wide and 2,000 lines long with a pixel size of 2.5 meters is to be registered. The upper-left coordinate is given in UTM (WGS 84) coordinates (referenced to the center of the pixel) and is (450500 E, 5400850 N).

   The coordinates required to register the image would be as follows:

   Point 1 (upper-left): (450498.75 E, 5400851.25 N)
   Point 2 (lower-left): (450498.75 E, 5395853.75 N)
   Point 3 (lower-right): (452996.25 E, 5395853.75 N)

   In a general case, given the upper-left center of pixel coordinate for the image, the pixel size, and the number of pixels and lines that make up the image, the following applies:

Map X	Map Y	Image X	Image Y
Given Upper-Left Easting – half the Pixel Size	Given Upper-Left Northing + half the Pixel Size	0	0
Point 1 Easting	Point 1 Northing – {(Number of Lines – 1) x Pixel Size}	0	Number of Lines – 1
Point 1 Easting + {(Number of Lines – 1) x Pixel Size}	Point 2 Northing	Number of Pixels – 1	Number of Lines – 1

2. From the menu bar in MapInfo, select File, then Open Table. Set Files of Type to Raster Image.
3. Select the desired raster file and click Open.
4. Click the Register button.

5. Click the Projection button.
6. Under Category, select Universal Transverse Mercator (WGS84).
7. Under Category Members, select the desired UTM zone for the ORI and click OK.
8. Click the Units button.
9. Select Meters from the dropdown menu and click OK.
10. Click anywhere within the image to select Point 1.
11. Set Map X to the calculated easting coordinate and set Map Y to the calculated northing coordinate. Set Image X to 0 and set Image Y to 0 (for Upper-Left pixel). Click OK.
12. Repeat steps 10 and 11 for Point 2 and Point 3. For Point 2, Image X and Image Y would be 0 and the Number of Lines minus 1, respectively. For Point 3, Image X and Image Y would be the Number of Pixels minus 1 and the Number of Lines minus 1, respectively.
13. Click OK.

10.4 ER Mapper Software

10.4.1 Loading a DEM or ORI into ER Mapper

Both the 32-bit Binary DEM and GeoTIFF image can be viewed in ER Mapper or ER Viewer in their present formats simply by selecting File, then Open. However, the DEM file requires a standard ArcInfo header file. An example is given below. The coordinates in the ArcInfo header file are referenced to the center of the upper-left DEM pixel, whereas ER Mapper references the upper left of the upper-left pixel and does not make a correction when reading the header file. In order to correct this discrepancy, the “ulxmap” and “ulymap” coordinates must have a half pixel subtracted and added, respectively, when creating the header file. The DEM row, column, pixel size, and georeferencing information for the header file can be extracted from the metadata file supplied with the data. Both programs can display the two-dimensional UTM georeferencing of the DEM and GeoTIFF, but ER Mapper requires the DEM to be imported and registered before any three-dimensional georeferencing can be displayed.

Sample ArcInfo Header File:

ncols	2811
nrows	2811
nbands	1
nbits	32
byteorder	M
layout	BIL
ulxmap	555557.50
ulymap	9958662.50
xdim	5.0
ydim	5.0

1. Once the header file has been created, the DEM can be imported through the Utilities menu.

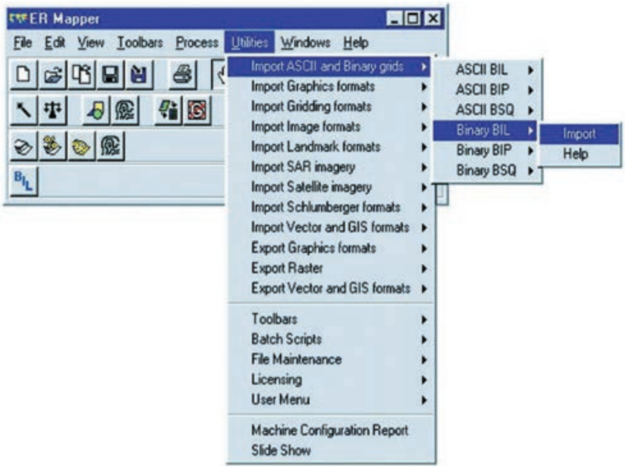

Figure 10.18: Popup menus for importing a DEM.

2. In the Import Binary_BIL dialog box, enter the DEM (*bil) file in the Import File / Device Name field and an output name in the Output Dataset Name. Geodetic Datum and Map Projection information can be obtained from the metadata file supplied with the DEM. All other fields are optional. Once the information is entered, click Setup.

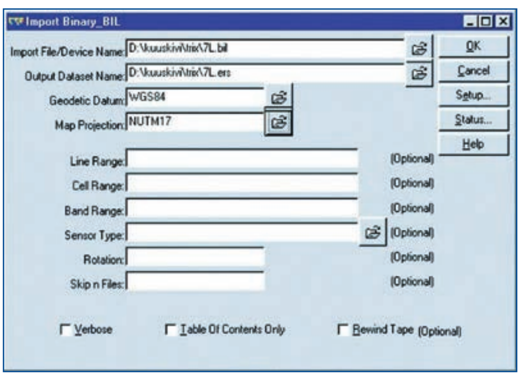

Figure 10.19: Import Binary_BIL dialog box.

3. In the Import Setup dialog box, set Input Data Type to IEEE 4-Byte Real, Byte Order to Motorola, and Number of Bands to 1. Obtain the number of lines (rows) and number of cells (columns) values from the metadata file and click OK. Click OK again in the Import Binary_BIL dialog box.

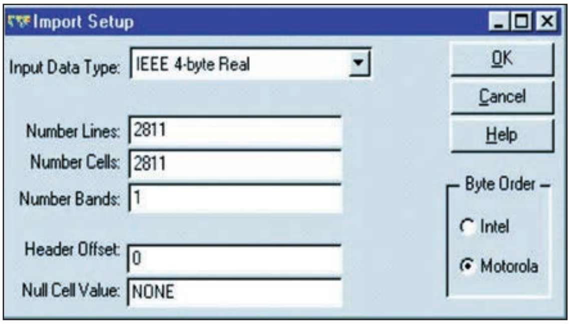

Figure 10.20: Import Setup dialog box.

4. Once imported, the elevation values for the DEM can be viewed, but to obtain easting and northing coordinates, the file must be georeferenced. Click on Process, then Geocoding Wizard.

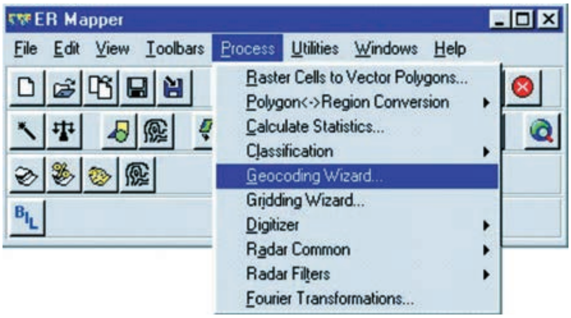

Figure 10.21: Geocoding Wizard pop-ups.

5. In the Start window, enter the name of the imported DEM (*.ers) file in the Input File field and select the Known Point Registration option.

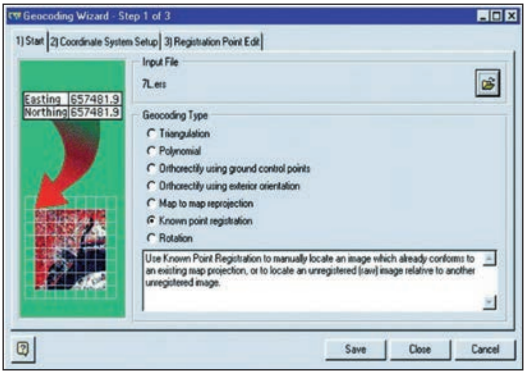

Figure 10.22: Geocoding Wizard dialog box.

6. In the Coordinate System Setup dialog box, change Units to the appropriate unit of measure.

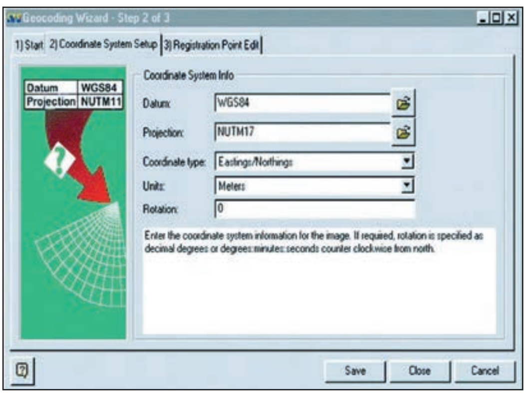

Figure 10.23: Geocoding Wizard second dialog box.

7. In the Registration Point Edit dialog box, change Cell Size X and Cell Size Y to the values from the metadata file and the PCI EASI eastings and northings to the values from the ArcInfo header file. Click Save and Close. The ER Mapper file will now be fully georeferenced.

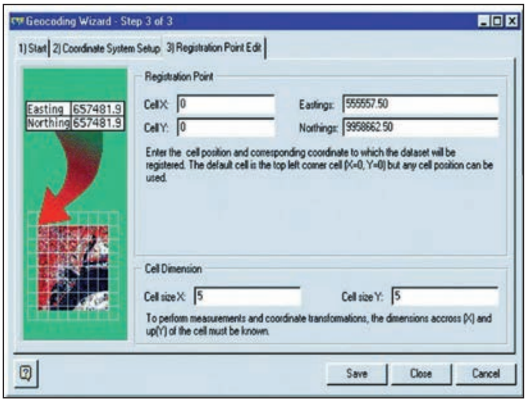

Figure 10.24: Geocoding Wizard third dialog box.

10.5 ENVI Software

10.5.1 Loading a DEM into ENVI 4.3

1. From the main ENVI menu, select File, then Open Image File.
2. In the Enter Data Filenames dialog box, navigate to the directory where the DEM (*.bil) file is stored, and open the file.

3. In the Header Info dialog box, you will need the associated metadata file for the DEM file you are importing. Enter the data as follows:

   Samples → Number of columns from metadata (This can be found in both the .html and .hdr files associated with the .bil file.)
   Lines → Number of rows from metadata
   Bands → 1
   Offset → 0
   xstart → 1
   ystart → 1
   Data Type → Floating Point
   Byte order → Host (Intel)
   File Type → ENVI Standard
   Interleave → BIL

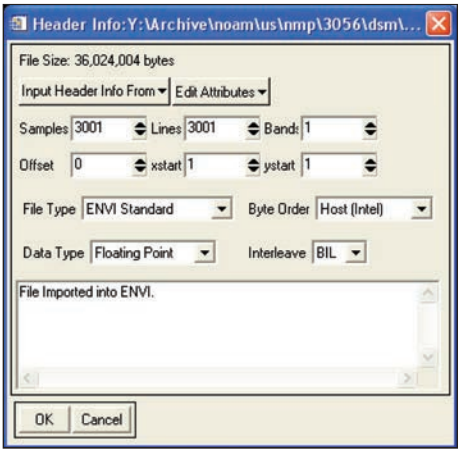

Figure 10.25: Header info dialog box.

4. Click on the Edit Attributes button near the top of the Header Info dialog box. Choose MapInfo and then enter:

   Image X → 1
   Image Y→ 1
   For E and N, enter the upper left x and y values from the metadata file – typically UTM Easting Min., and UTM Northing Max., respectively.
   X Pixel Size→ from metadata
   Y Pixel Size→ from metadata
   Map Rotation → 0.00

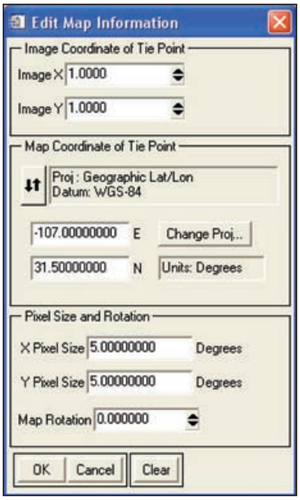

Figure 10.26: Map Information dialog box.

Click on the Change Projection button. In the following screen, enter values for Projection, Datum, Units, and Zone based on the associated metadata file.

Figure 10.27: Project Selection dialog box.

Select OK in the Map Information dialog box and the Header Information dialog box. This will bring up the Available Bands List dialog box.

5. Select Load Band in the Available Bands List dialog box.

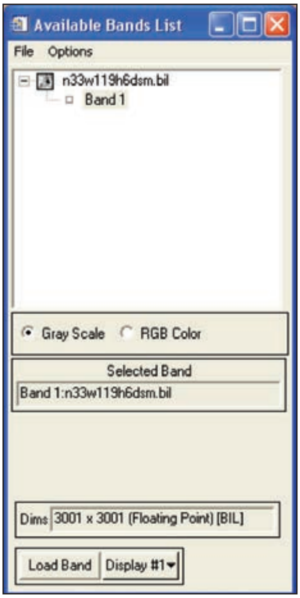

Figure 10.28: Available Bands List dialog box.

10.5.2 Loading an ORI into ENVI 4.3

1. Open ENVI.
2. Click File, then Open External File.
3. Select either LANDSAT or IKONOS GeoTIFF, then navigate to the desired file (*.tif).
4. Double-click on the file name in the popup box viewer.

10.6 PCI Geomatics Software

10.6.1 Loading a DEM into PCI Geomatica Focus 10

1. Ensure that the .hdr file is not in the same folder as the .bil file.
2. Open Geomatica Focus. Within the File menu, select Utility, then Import to PCIDSK.

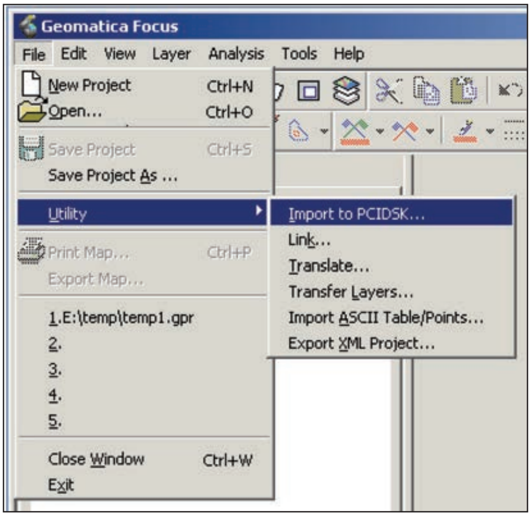

Figure 10.29: Import to PCIDSK popup menu.

3. In the following dialog box, click the Browse button and navigate to the .bil file.

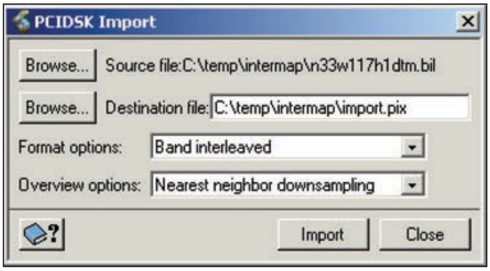

Figure 10.30: PCIDSK Import dialog box.

4. A dialog box prompt will ask if you would like to define the file as a raw image. Choose Yes and the Raw Imagery File Definition Information dialog box will appear. Choose Line for Data Interleaving, 32-Bit Real for Data Type, and LSB: Intel / VAX for Byte Order. Enter 0 for the Header Bytes. Click Accept, and a prompt will ask you to save the information just entered to an .aux file. Choose Yes and the Import to PCIDSK dialog box will reappear.

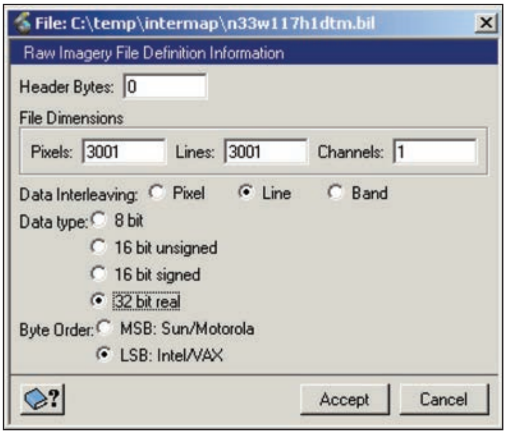

Figure 10.31: Image parameter dialog box.

5. With the Import File dialog box displayed, make sure that the Format Options is set to Band Interleaved and the Pyramid Options is set to Nearest Neighbor Downsampling. Click Import.

6. In order to convert the .bil file into a PCI-formatted file, select the Add File command from the File menu.

7. Once the .bil file has been added to the layer list, right-click File in the table of contents to export the file to a PCI format. The dialog box in Figure 10.32 will appear.

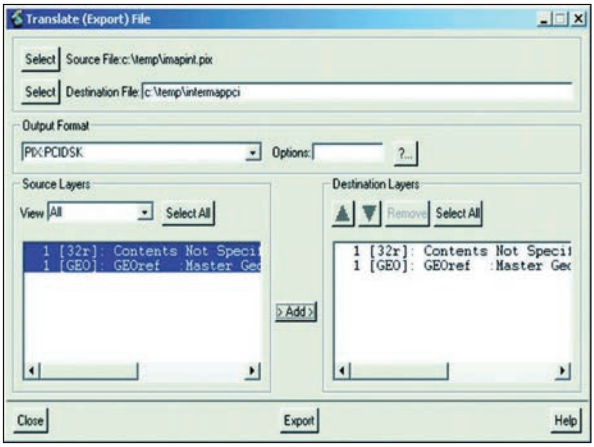

Figure 10.32: Translate (Export) File dialog box.

8. Provide a destination file path with a .pix file extension, select PIX-PCIDSK from the Output Format dropdown menu, click Select All, click Add to define the destination layers, and then click Export.
9. Once the software has finished converting the .bil file, click Open File in the viewer, navigate to the location of the file you just created, and add it to Focus.

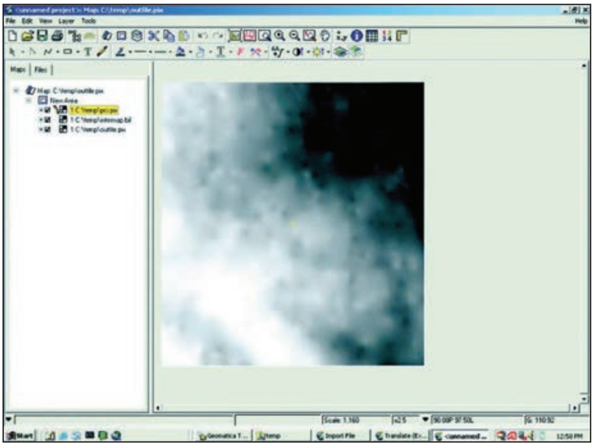

Figure 10.33: Maps tab in main workspace.

10.7 Autodesk Software

10.7.1 Loading DEM data into AutoCAD Map 3D

1. Open AutoCAD Map 3D 2009. If the Workspace screen is displayed (see Figure 10.34), select "Map 3D for Geospatial" and click OK.

Figure 10.34: Select Workspace type.

This will open the map2d.dwt drawing template which will display data in two dimensions by default. (See Figure 10.35.)

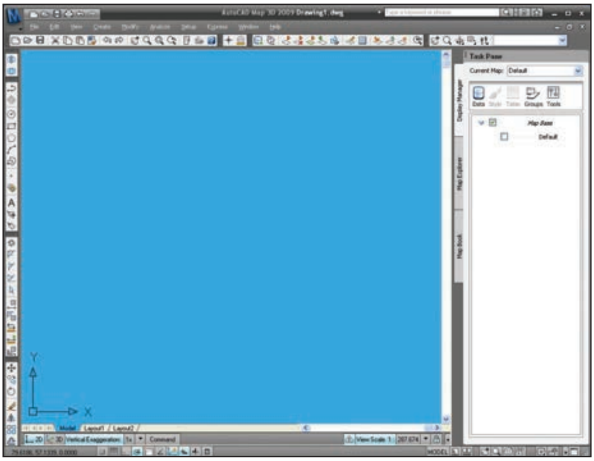

Figure 10.35: Home screen.

If you already have Map 3D running, you can open a new template for drawing Intermap's DTM and DSM data by going to the File menu and selecting New. In the template popup, select either map2d.dwt or map3d.dwt and click Open. (See Figure 10.36.)

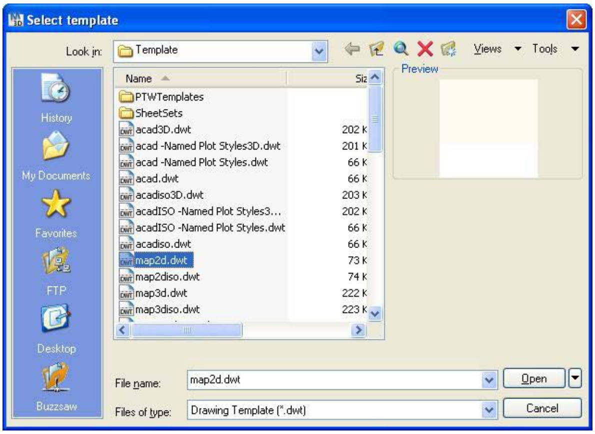

Figure 10.36: New template popup.

You can open Intermap data when using other templates, but if the drawing already contains other types of data with different spatial orientation, you may not end up with the desired results.

2. Selecting Intermap data. If the Task Pane is not visible, click the View menu and check Task Pane. Within the Task Pane, click the Data icon in the Display Manager Tab to load data. Select "Connect to Data." (See Figure 10.37.)

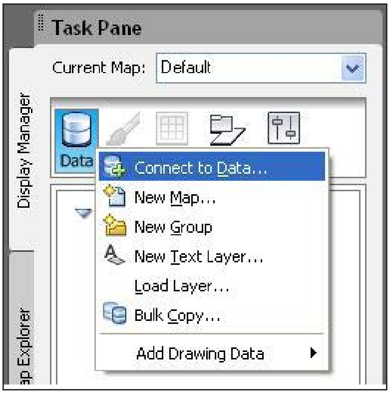

Figure 10.37: Select Data icon.

Within the Data Connections by Provider list, select "Add Raster Image or Surface Connection." To navigate and find your Intermap data most easily, click the Open File button circled in Figure 10.38.

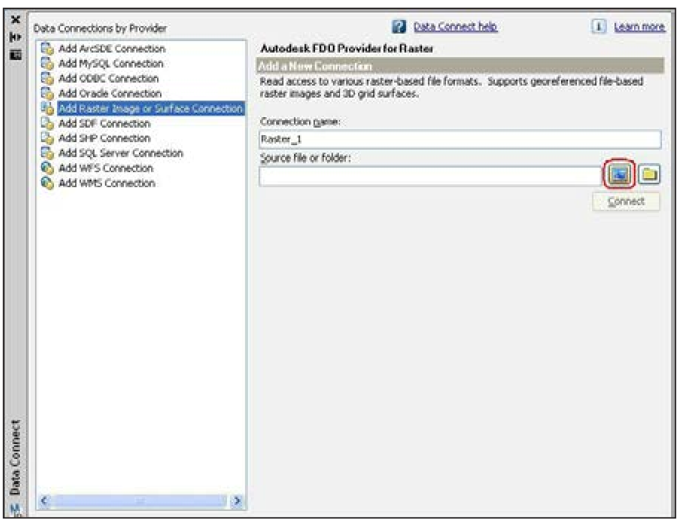

Figure 10.38: Data connect window.

Navigate to the location of the desired file, making sure that the File type drop down box specifies the appropriate file type. (See Figure 10.39.) The optimal file formats for DEM data provided by Intermap are:

- TIFF files
  - 32-bit GeoTiff .tif files
- ESRI ASCII and Binary Grid files
  - ESRI ASCII .asc files
  - ESRI ArcGrid w001001.adf files

(Note: While the .dem file format is supported by Map 3D, the format does not provide optimal precision, which is evident when looking at contour data generated from .dem data.)

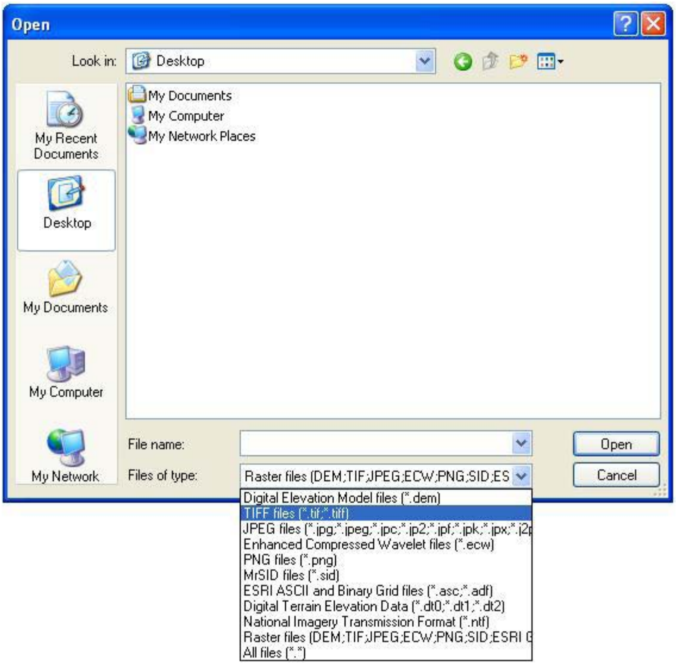

Figure 10.39: File Selection popup.

After selecting the file, click Open. With the desired file selected, click Connect. (See Figure 10.38.)

If the Data Connect window does not display after clicking Open in the File Selection popup, the Auto-hide function may be set. Either click the Auto-hide button to display the window or click Connect to Data in the Task Pane. (See Figure 10.37.)

3. Loading Intermap DEM data. With the data file specified, click the checkbox next to the Schema entry for that file. (See Figure 10.40.)

   Check the box next to the data you want and the Add to Map button becomes active. Clicking the Add to Map button adds the data to the drawing and displays it with the default style for that data type.

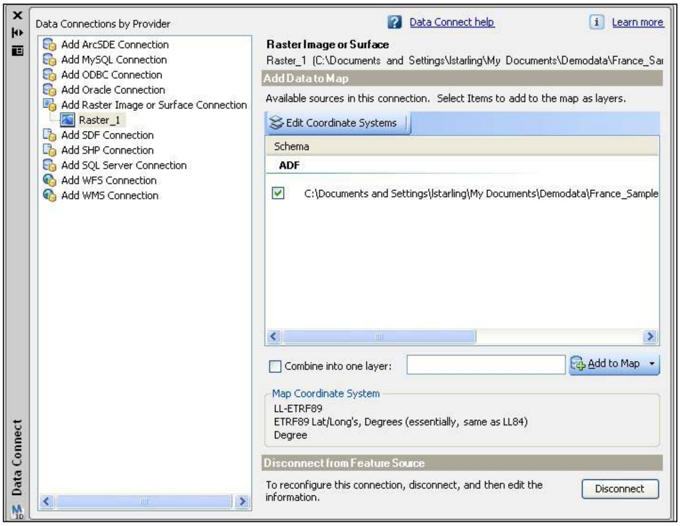

Figure 10.40: Schema view after selecting data.

Depending on the drawing template used, the data will display in either 2D (with the map2d.dwt template) or 3D (with the map3d.dwt template). Figure 10.41 shows DTM data displayed in 2D.

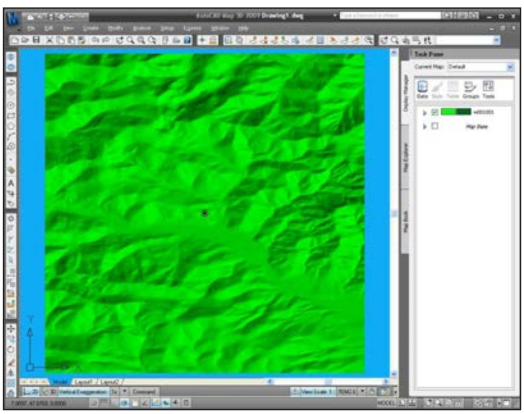

Figure 10.41: Intermap DTM data loaded in 2D.

4. Displaying data in 3D. To toggle between 2D and 3D, click the corresponding buttons in the lower left of the drawing window. (See Figure 10.42.)

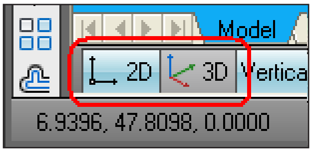

Figure 10.42: 2D and 3D buttons.

Figure 10.43 shows the Intermap DTM data depicted in Figure 10.41, but displayed in 3D with the Style Theme set to Contour Palette.

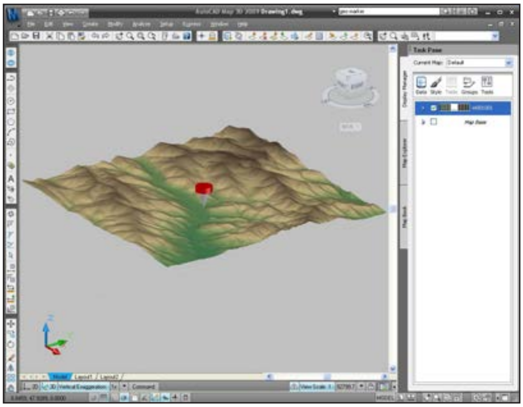

Figure 10.43: Intermap DTM data loaded in 3D.

10.7.2 Loading ORIs into AutoCAD Map 3D

1. Open AutoCAD Map 3D 2009. If the Workspace screen is displayed (see Figure 10.44), select "Map 3D for Geospatial" and click OK.

Figure 10.44: Select Workspace Type.

This will open the map2d.dwt drawing template which will display data in two dimensions by default. (See Figure 10.45.)

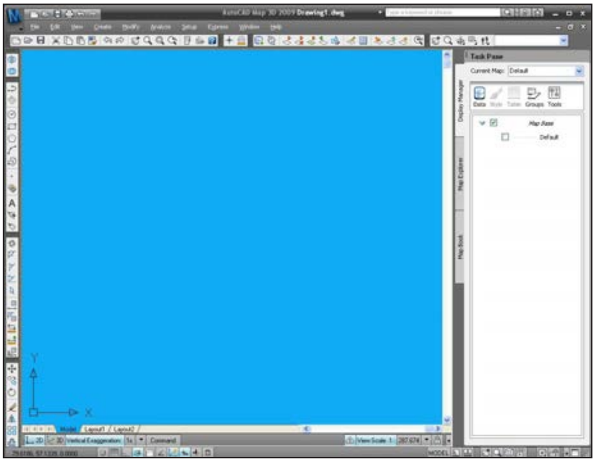

Figure 10.45: Home screen.

If you already have Map 3D running, you can open a new template for drawing Intermap's DTM and DSM data by going to the File menu and selecting New. In the template popup, select map2d.dwt and click Open. (See Figure 10.46.)

(Note: you can open Intermap data when using other templates, but if the drawing already contains other types of data with different spatial orientation, you may not end up with the desired results.)

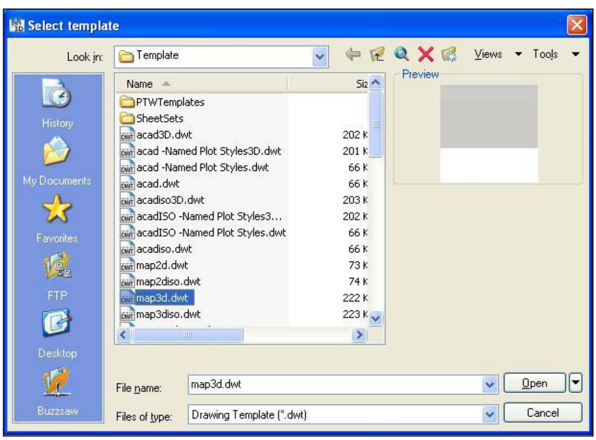

Figure 10.46: New template popup.

2. Selecting Intermap data. If the Task Pane is not visible, click the View menu and check Task Pane. Within the Task Pane, click the Data icon in the Display Manager Tab to load data. Select "Connect to Data." (See Figure 10.47.)

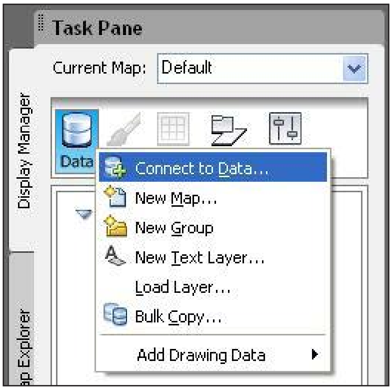

Figure 10.47: Select Data icon.

Within the Data Connections by Provider list, select "Add Raster Image or Surface Connection." To navigate and find your Intermap data most easily, click the Open File button circled in Figure 10.48.

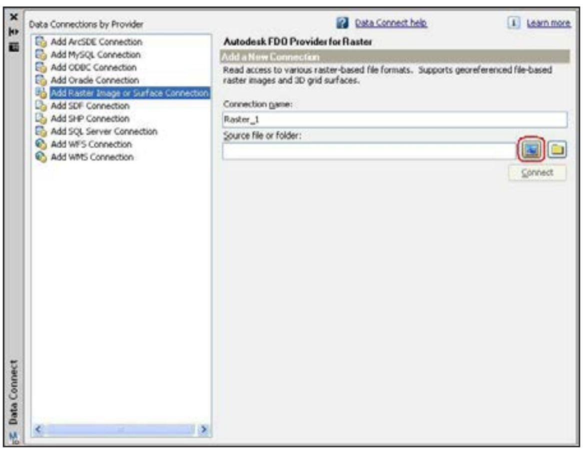

Figure 10.48: Data Connect window.

Navigate to the location of the desired file, making sure that the File type drop down box specifies the appropriate file type. (See Figure 10.49.) The optimal file format for data provided by Intermap is an 8-bit GeoTiff .tif files for the ORI.

After selecting the file, click Open.

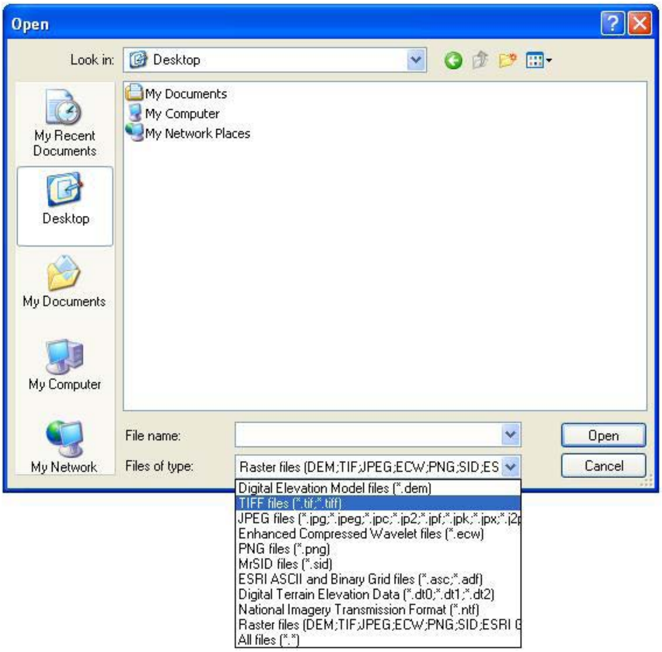

Figure 10.49: File Selection popup.

With the desired file selected, click Connect. (See Figure 10.48)

If the Data Connect window does not display after clicking Open in the File Selection popup, the Auto-hide function may be set. Either click the Auto-hide button to display the window or click Connect to Data in the Task Pane. (See Figure 10.47.)

3. Loading Intermap imagery data. With the desired file selected, click Connect. (See Figure 10.48.) With the data file specified, click the checkbox, next to the Schema entry for that file. (See Figure 10.50.)

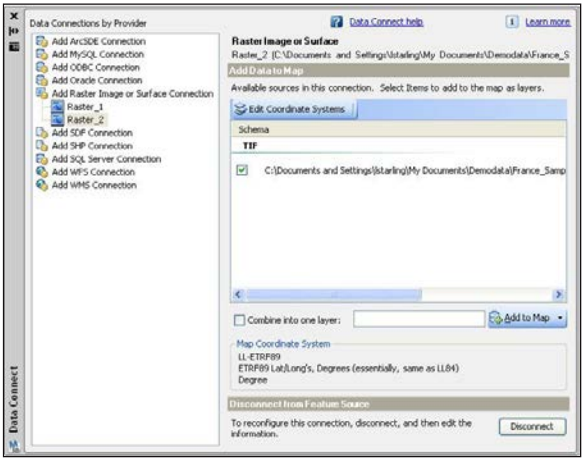

Figure 10.50: Schema view after selecting imagery.

Check the box next to the imagery you want and the Add to Map button becomes active. Clicking the Add to Map button adds the imagery to the drawing and displays it with the default style for that data type.

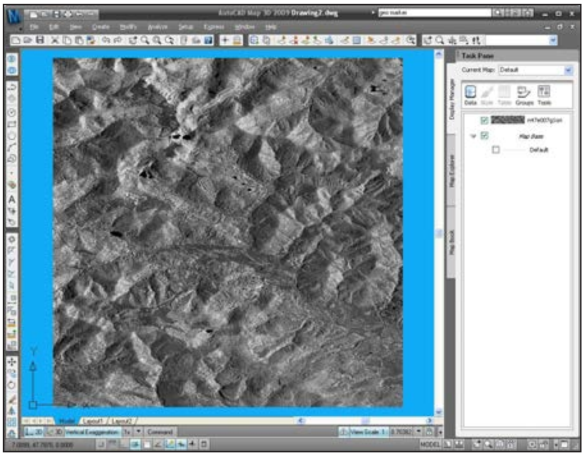

Figure 10.51: Intermap ORI data loaded in 2D.

4. Displaying imagery in 3D. To toggle between 2D and 3D, click the corresponding buttons in the lower left of the drawing window. (See Figure 10.52.)

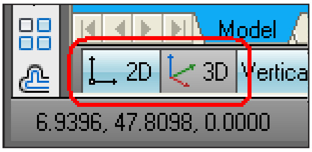

Figure 10.52: 2D and 3D buttons.

If you are adding the imagery to a 3D drawing that is displaying DEM data, and if the coordinates of the imagery match the coordinates of the DEM data, the imagery will overlay on top of the DEM data. Figure 10.53 shows the Intermap ORI imagery depicted in Figure 10.51, but displayed in 3D overlaid on DEM data of the same area.

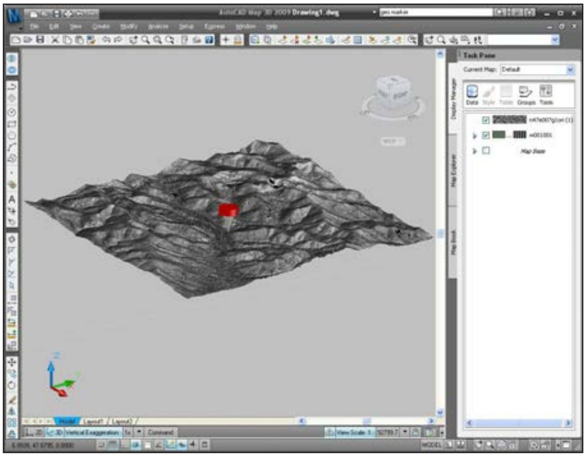

Figure 10.53: Intermap ORI image overlaid on a DTM and displayed in 3D.

10.8 Global Mapper

10.8.1 Loading a DEM into Global Mapper 10

Global Mapper software is available to download, for a 30-day trial period, on Intermap's Web site.

1. Open Global Mapper

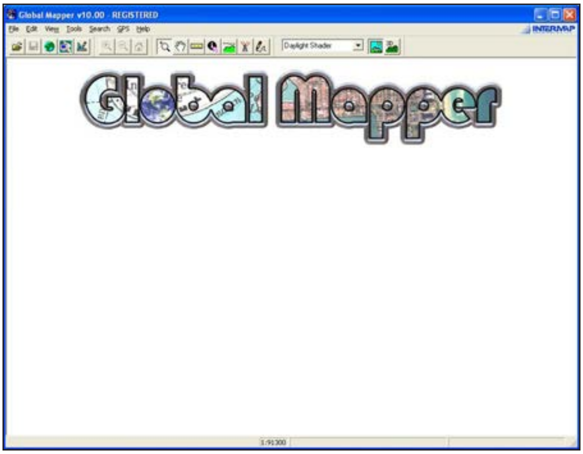

Figure 10.54: Global Mapper interface.

Click on Open Data Files to navigate to your data.

Figure 10.55: Open Data Files icon.

2. Locate your data. Under File of Type, choose Supported Commonly Used Types or the specific DEM file type you want, then navigate to your data. Select the file and click Open.

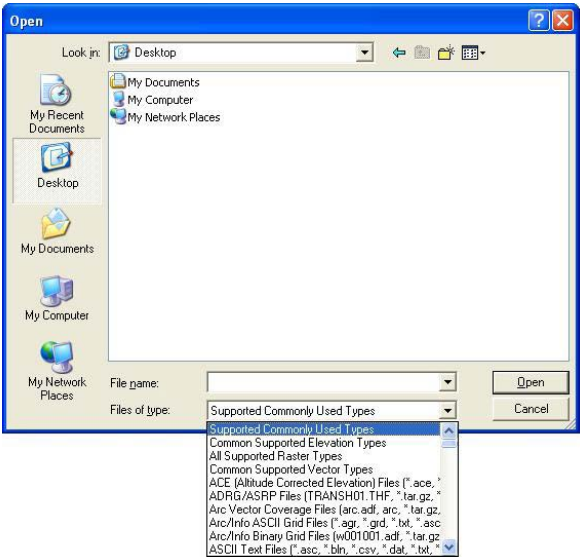

Figure 10.56: Opening file dialog box.

If the projection information of your data is not known, a dialog box opens allowing you to specify the projection information for your data. If metadata was provided with your data, it will contain this information.

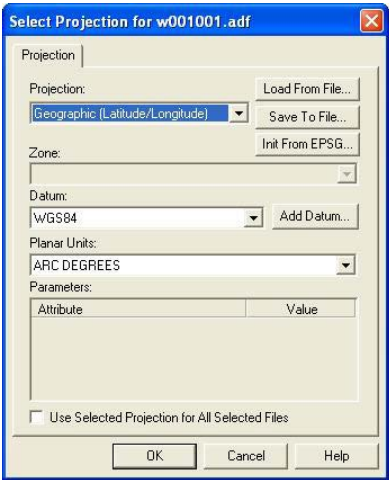

Figure 10.57: Select Projection dialog box.

After the projection information is specified, click OK and the viewer window will display the data in 2D using the default shader. The Daylight Shader is depicted in Figure 10.58.

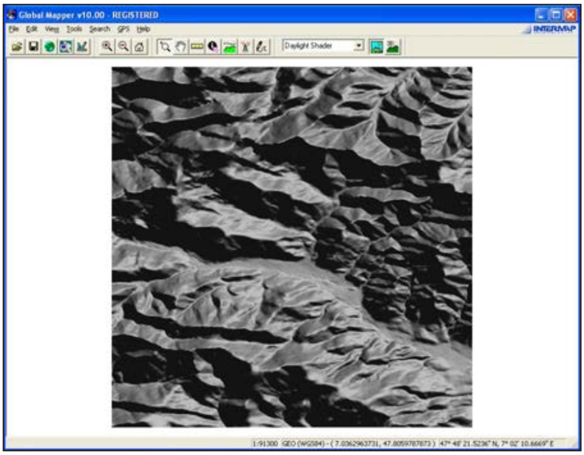

Figure 10.58: Intermap DEM in 2D.

3. Displaying data in 3D. To display data in 3D, click the 3D button at the right of the tool bars. (See Figure 10.59.)

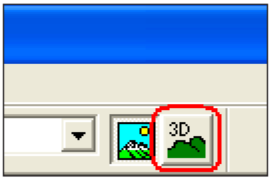

Figure 10.59: 3D button in Global Mapper.

Figure 10.60: Intermap DEM in 3D.

A new window will open displaying the content of the main window, but in 3D. (See Figure 10.60.)

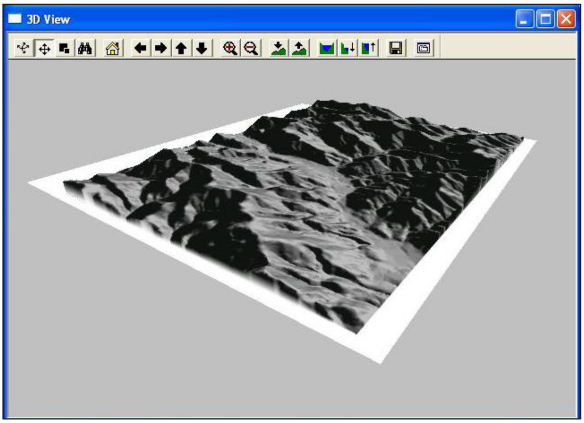

Figure 10.60: Intermap DEM in 3D.

10.8.2 Loading an ORI into Global Mapper 10

Global Mapper software is available to download, for a 30-day trial period, on Intermap's web site.

1. Open Global Mapper.

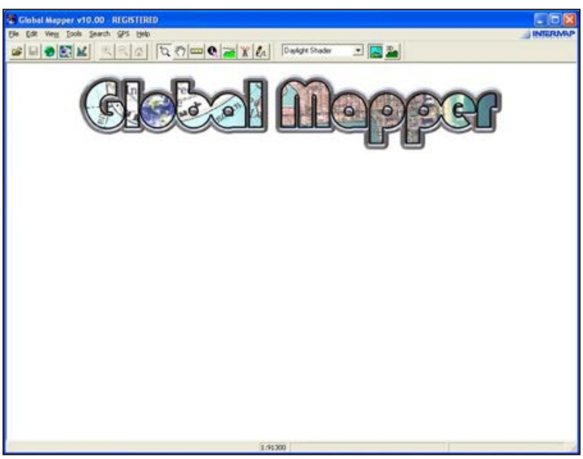

Figure 10.61: Global Mapper interface.

Click on Open Data Files to navigate to your data.

Figure 10.62: Open Data Files icon.

2. Locate your data. Under File of Type, choose Supported Commonly Used Types or the specific imagery file type you want, then navigate to your data. Select the file and click Open.

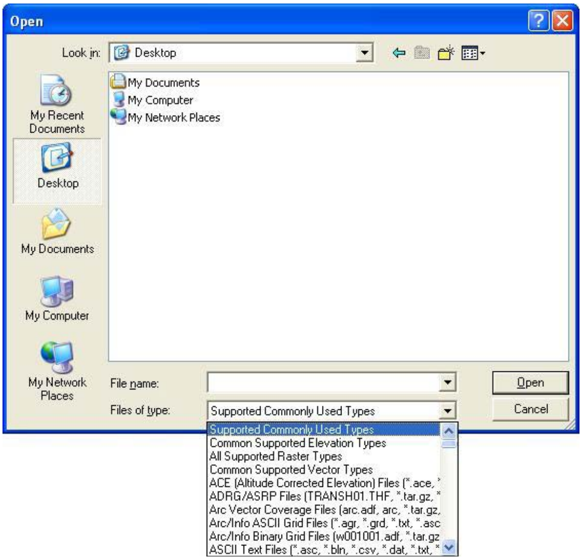

Figure 10.63: Open dialog box.

The viewer window will display the imagery specified.

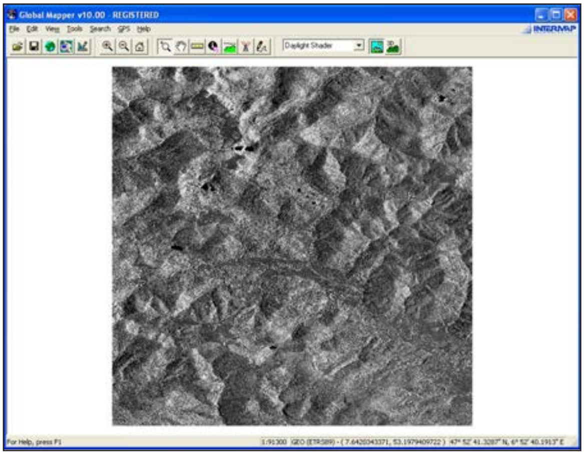

Figure 10.64: Intermap ORI image.

10.8.3 Exporting a DEM to a 32-bit GeoTiff file

1. Open Global Mapper and follow steps 1 and 2 in Section 10.8.1 to load a DEM.
2. Export to GeoTiff. Go to File menu, select Export Raster and Elevation Data, and choose Export GeoTiff.

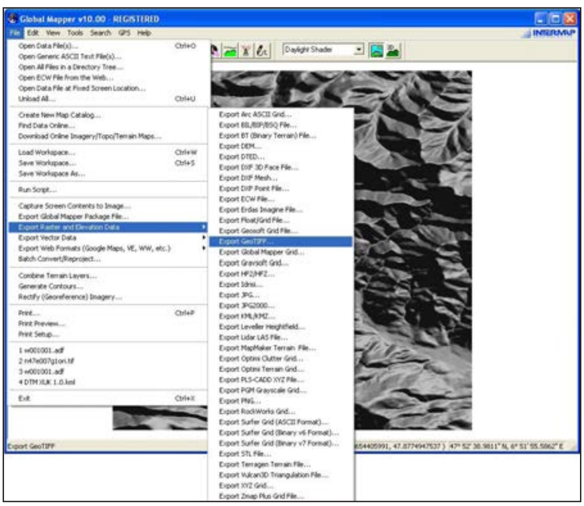

Figure 10.65: Exporting a DEM.

In the GeoTIFF Export Options dialog box, specify the following parameters (See Figure 10.66):

- Elevation (32-bit floating point samples)
- Vertical Units: Meters
- Always Generate Square Pixels: checked
- Generate TFW file: checked

After the parameters are specified, Click OK.

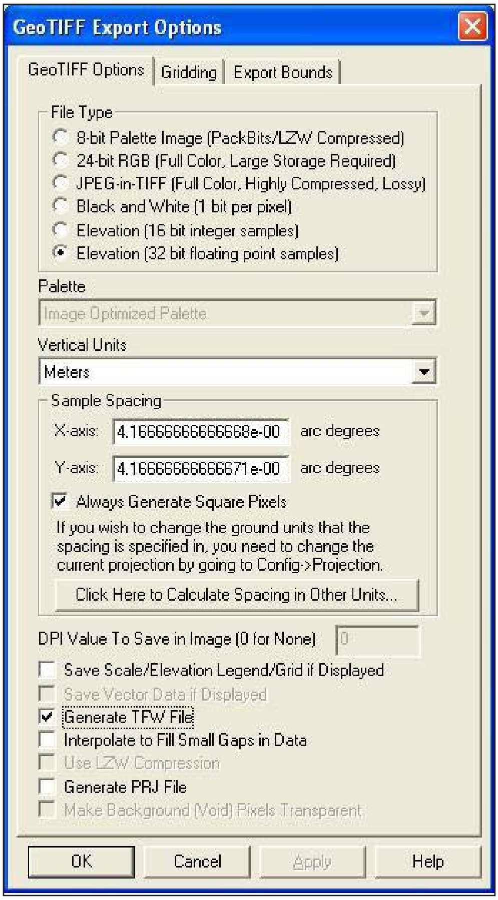

Figure 10.66: GeoTIFF Export Options dialog box.

Navigate to the location to save the file, enter the name of the file to be saved, and click Save (See Figure 10.67).

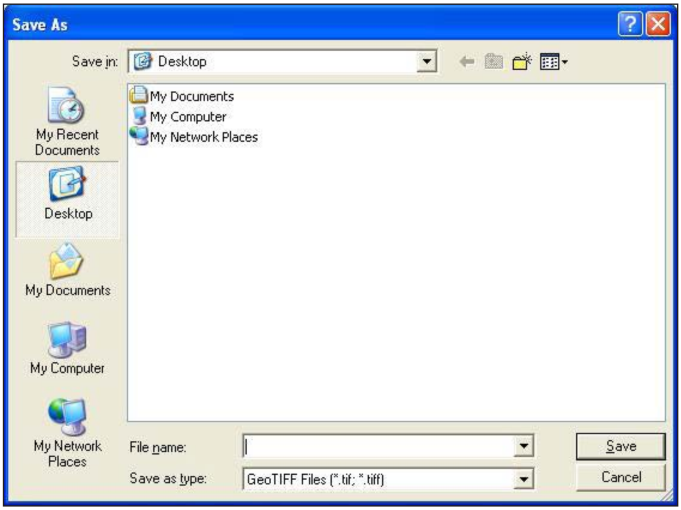

Figure 10.67: Save dialog box.

The Exporting GeoTIFF status popup displays indicating the progress of the export.

Figure 10.68: Export status popup.

When the export is complete, two files will be created: the .tif file itself and a .tfw world file. The world file may be needed by some applications for geographically referencing the GeoTIFF image.

10.8.4 Reprojecting a DEM

1. Open Global Mapper and follow steps 1 and 2 in Section 10.8.1 to load a DEM.
2. Specify file formats. Go to File menu, select Batch Convert/Reproject (See Figure 10.69).

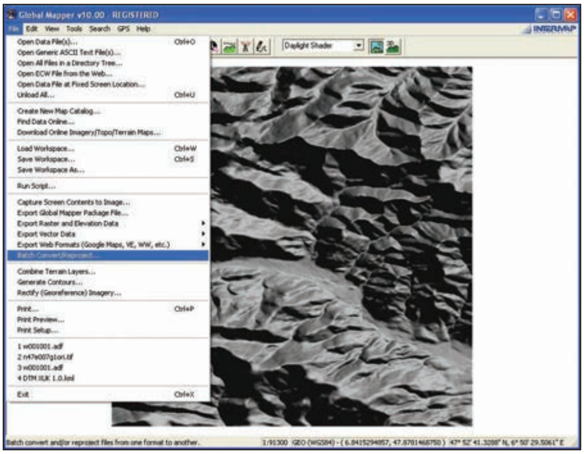

Figure 10.69: Reprojecting a DEM.

Select the type of file you want to convert from (See Figure 10.70). If you don't find the file that you have listed, you can first export to a supported file format. See Section 10.8.3 for instructions on how to export to a different file format.

Figure 10.70: Convert From dialog box.

Select the type of file you want to convert to (See Figure 10.71). For best results, select a format that has a 32-bit entry.

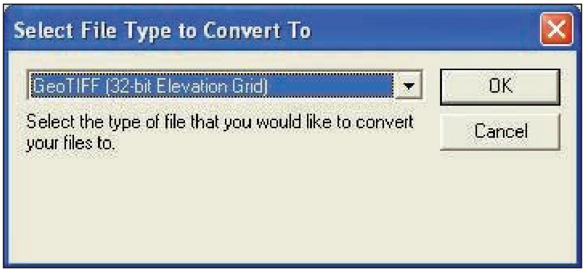

Figure 10.71: Convert To dialog box.

3. Specify files. With these file formats specified, the Batch Convert dialog box opens (See Figure 10.72).

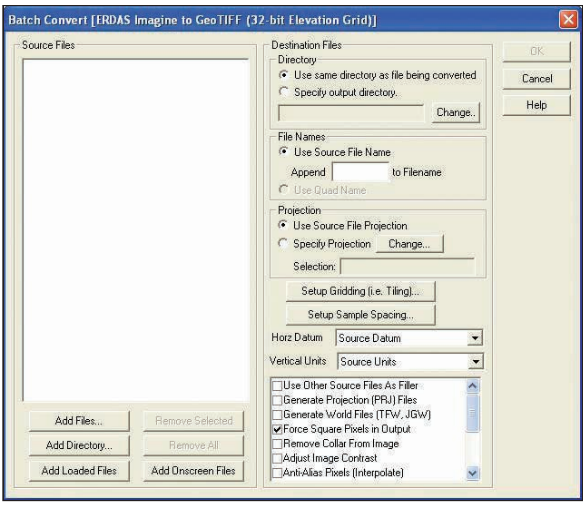

Figure 10.72: Batch Convert dialog box.

Locate the file to be projected using one of the Add buttons in the lower-left of the dialog box. In this example, where we've already added the file to our viewer, we can click the Add Onscreen Files button.

Next, specify the destination location for the new file and the new file name, in the upper-right of the dialog box.

4. Specify Projection parameters. In the Projection section in the middle-right of the dialog box, click the radio button for Specify Projection. The projection dialog box will display (See Figure 10.73).

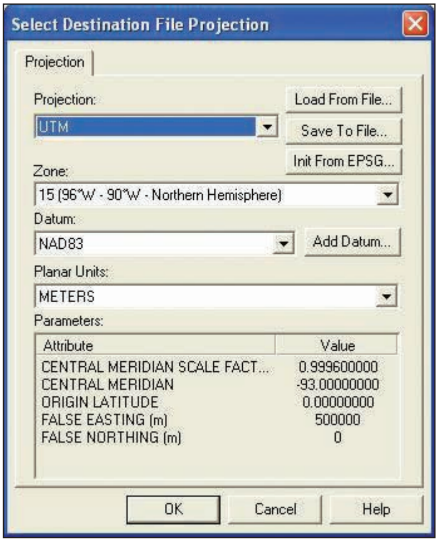

Figure 10.73: Projection dialog box.

If you have a .prj projection file that you want to use or if you want to specify an EPSG projection code that you want to use, use the buttons to the right. Otherwise, specify the desired Zone, Datum, and Planar (horizontal) Units parameters that apply to the Projection you have specified. Click OK to accept the specified parameters.

Next, specify the Vertical Units and Horizontal Datum as appropriate within the Batch Convert dialog box (See Figure 10.72).

Lastly, check off any other optional parameters that you want to utilize from the scrolling list to the lower-right of the Batch Convert dialog box (See Figure 10.72).

5. Initiate Projection. Click OK to begin the batch process of reprojecting your data. The Exporting status popup displays indicating the progress of the reprojection (See Figure 10.74).

Figure 10.74: Export status dialog box.

The new DEM file will be created in the location specified, but it will not be added to your viewer. To see the new file in its new projection, start a new Global Mapper session and follow steps 1 and 2 in Section 10.8.1 to load a DEM. If you attempt to add the new file to the current session, Global Mapper will attempt to dynamically reproject the new file to the projection of the current session.

10.8.5 Resampling a DEM

Global Mapper has the capability of resampling a DEM. This refers to generalizing or decimating the posting or cell size of the source DEM data. If you have a 5m posted DEM, a DEM with a cell size of 5 m, and you want to generalize it to be a 10m posted DEM, Global Mapper provides you with that capability.

(Note: 10m resampled data will take up one-quarter the disk space as the 5m posted data because a 10m cell covers the area of four 5m cells, so there is one quarter the amount of data being stored. Similarly, 10m posted data will be processed four times as fast as 5m posted data.)

1. Open Global Mapper and follow steps 1 and 2 in Section 10.8.1 to load a DEM.
2. Specify Batch Convert parameters. Follow steps 2 and 3 in Section 10.8.4 above.
3. Specify Projection and Sample spacing parameters. Since resampling does not in itself involve reprojecting the data, set the Projection radio button to User Source File Projection (See Figure 10.75).

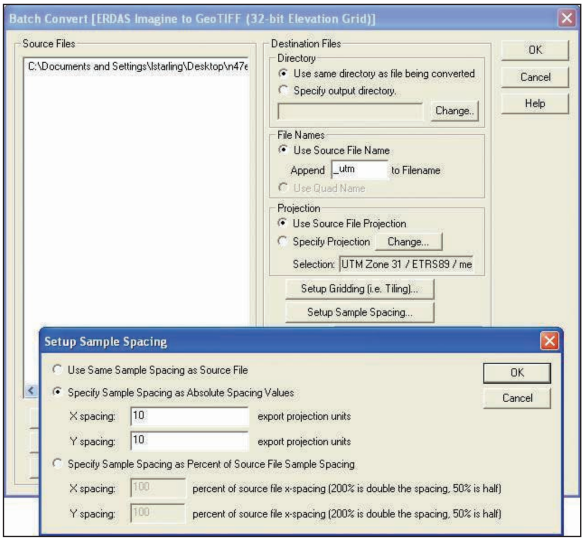

Figure 10.75: Batch Convert with Setup Sample Spacing dialog box open.

Click the Setup Sample Spacing button to open the dialog box for specifying the new spacing parameters (See Figure 10.75). After setting the new spacing parameters, click OK to apply the change.

4. Initiate Resampling. Click OK in the Batch Convert window to begin the batch process of resampling your data. The Exporting status popup displays indicating the progress of the resampling (See Figure 10.76).

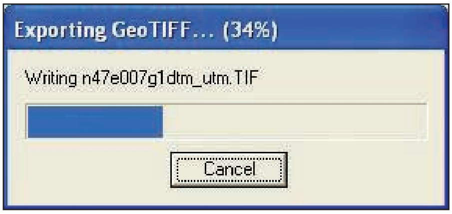

Figure 10.76: Export status popup.

The new DEM file will be created in the location specified, but it will not be added to your viewer.

5. Add resampled data to viewer. To add the new resampled file to the viewer with your existing file, click on Open Data Files to navigate to your data (button in red in Figure 10.77).

Figure 10.77: Open Data Files icon.

After selecting the new data in the Open dialog box, your new data will be displayed on top of your original data. Open the Overlay Control Center (button in green in Figure 10.77) to turn the files on or off and see the difference between the two. (See Figure 10.78).

Figure 10.78: Overlay Control Center.

Product Licensing A

Intermap Technologies® has developed a generic end-user license agreement to address the needs of our customers and the uses of Intermap® data products. A copy of the agreement (current at the time of this handbook's production) is contained in this appendix. Please visit www.intermap.com for the most recent version.

Various addendums may also be required, depending on the purpose and use of the data acquired from Intermap.

INTERMAP TECHNOLOGIES INC.
END USER LICENSE AGREEMENT FOR DATA

http://www.intermap.com/legal

Core Product DEM Edit Rules

B

One of the factors that makes Intermap's DSM and DTM products unique in the marketplace is our rigorous editing process and the edit rules used in that process. These edit rules are in place to make it easier and quicker for members of the 3D Edit Group to generate a uniform product by reducing ambiguity during the editing process – from tile to tile, from project to project, across entire continents.

The content of this section is intended only for use by existing customers and existing partners, and as reference material only.

B.1. Scope

This section discusses how particular features are edited in the DSM or DTM, but it does not describe how or when to use a specific edit tool. The Edit Rules are updated from time to time to improve the means by which Intermap's DSM and DTM products are edited. The DTM edit rules listed below apply to the DTM v1.5 data described in Section 6.2, *DTM Product Characteristics*. The DTM v1.0 data referenced in Section 6.2 was edited with an earlier version of the edit rules. Contact your Intermap sales representative for more details.

B.2. Definitions

As mentioned in Section 6.4, *Product Accuracy*, there are a number of factors that affect product quality. These include slope, obstructed areas, and artifacts. How they are handled during the editing process depends on the size of area they cover and their severity. To aid in the editing process, the following definitions are provided.

B.2.1. Ancillary data

Ancillary data is any cartographic information that covers the same area as the data being edited, but was collected independently. Ancillary data can include topographic maps, air photos, previously collected radar information, or DEM data from other sources.

Ancillary data will be provided as part of the process for any edit when it is available, and will be used for guidance only. This ancillary data will be used where assistance is required in interpreting features found within the radar data.

Ancillary data is not to overrule the data that has been collected by the IFSAR sensor. For example, if a stream in a DRG does not coincide with what is seen in our imagery, then our imagery should be relied upon.

Ancillary DEM data is used to approximate the terrain in obstructed areas using the Fully Integrated Terrain Solution (FITS) software. The ancillary DEM is fit or indexed to the radar data in unobstructed areas to improve data quality and accuracy in obstructed terrain.

B.2.2. Obstruction

An obstruction is any target that is not open ground or water. This includes:

- Vegetation
- Cultural features that project above the ground (such as buildings, towers, or bridges)
- Effects of obstructed areas greater than the footprint of the obstruction (for example, the radar shadow of a 30 m obstruction at center swath obstructs an area of 42 m on the ground)

The effects of obstructions include the following:

- Creation of radar shadows or areas of missing information that are represented as interpolated voids within the DEM data
- Hiding the underlying ground or water surface without causing a void (for example, trees hide the underlying ground but are not associated with a void – except, perhaps, at a forest edge)
- Misrepresentation of features caused by layover, which is the tendency for an object to look much shorter than it really is (as a result of the side-looking nature of radar with respect to the ground it is imaging)

Obstructions, or the effects they cause, need to be edited according to Section B.3, *Priority of Edits by Classification*, below.

B.2.3. Seamlines / Edges

A seamline or edge is the shared boundary between two tiles. All digital values in every data layer within a tile edge will be equal to the values in the corresponding edge of adjacent tiles. Edges may not match when there are temporal changes between missions and changes in editing specifications. Differences between adjacent missions may also be apparent based on variable acquisition factors, such as radar look direction or relative incidence angle.

B.3. Priority of Edits by Classification

This section describes how to edit features that may be considered as intersecting each other. Features need to be recognized as having differing orders of precedence, or rank, in the final data. This precedence may or may not exist in the un-edited DTM (the DSM), and this section describes how this precedence is to be imposed during the course of the edit.

Features are ranked, highest to lowest, according to the list that is shown below.

- Cultural features are edited as follows:
  - Cultural features cover features from any other classification with which they intersect (“culture always wins”).
  - The specific cultural features identified in this document take priority over other cultural features that are not specifically mentioned.

- Vegetation is removed such that both hydrology and cultural features take precedence.

Consider the following examples:

- If void fill occurs in a river, then the fill region would be replaced by a stepped river.
- If a river or stream was obstructed by vegetation, then the appropriate edits would be made to the vegetation to ensure that proper drainage was re-established.
- Drainage is only interrupted by cultural features, such as a culvert, and never by vegetation or processing anomalies.

B.4. Edit Exceptions

B.4.1. NEXTMap® Edit Exceptions

The NEXTMap® program will utilize the Core Product DEM Edit Rules along with some more specific guidelines to ensure consistency and efficiency for all deliverables. It should be noted that different ancillary data will be used for the various NEXTMap programs; therefore, exceptions can occur.

Core Product DEM Edit Rules

B.5. Edit Rules

The following tables describe the specific rules to be followed per feature category. If a feature category rule is not found, it can be assumed that no special edit will be undertaken for that category. While every effort is made to address all occurrences of a particular feature, the editing is expected to be met at a 95 percent confidence level.

B.5.1. DEM Feature Edits – Cultural

Feature:	Bridge
Definition:	Bridges and overpasses over water features (lake, ocean, single line drain – SLD, and double line drain – DLD), and land features (roads, railways). Aqueducts built above grade will be considered to be bridges.
DTM Edit Rule:	Bridges will be removed in the DTM over open water. Bridges over roads and railways that can be identified in the ORI or available ancillary data will be removed from the DTM. Culverts and footbridges will not be removed from the DTM. Tunnels will not be represented in the DTM. Primary features, such as airport runways or railroad stations built on top of roads or railroads, will be preserved in the DTM.
DSM Edit Rule:	Bridges over edited oceans, lakes, and rivers (DLDs) are flattened as water.
Obstruction Rule:	Obstructed bridges shall be removed in the DTM, but only if supported by ancillary data.
Ancillary Data Usage:	Ancillary data will be used to aid in the identification of bridges.

Feature:	Airport
Definition:	An active terminus of operation for air traffic.
DTM Edit Rule:	Runways, aprons, and taxiways that are equal to or greater than 10m in width will be edited and flattened. Runways will follow the lay of the land. Only paved airports will be edited.
DSM Edit Rule:	Extents and elevations of airport runways, aprons, and taxiways will be the same as those in DTM.
Obstruction Rule:	Areas of obstructions shall be approximated by taking into account surrounding relief and information in the ORI.
Ancillary Data Usage:	Ancillary data will be used to aid identification of runways and whether they are currently in active use.

Core Product DEM Edit Rules

Feature:	Manmade features built above grade
Definition:	Includes dams, embankments, piers, commercial docks, breakwalls, levees, causeways, canal locks, berms, weirs, and spillways.
DTM Edit Rule:	These features will not be removed from the DTM. A variance in the elevations may exist between the DSM and the DTM. The cultural features identified here will be added back to the DTM product when obstructed by other cultural features or vegetation and have been removed as part of the bald earth process. The allowable difference between the DSM and DTM in these areas is 1 m.
DSM Edit Rule:	These features will remain in the DSM as sensed by the radar.
Obstruction Rule:	See Edit Rules above.
Ancillary Data Usage:	Water management constructs shall be checked against ancillary data, where available, to ensure they are properly captured.

Feature:	Cultural construct
Definition:	Cultural features that project above grade. These include villages, towns, and cities – but exclude dams, berms, and road or railway beds, for example.
DTM Edit Rule:	All cultural constructs shall be removed from the DTM (see Exceptions, above). The fully obstructed areas will be fitted from surrounding unobstructed terrain (including edited DSM features such as roads, etc). Where there are insufficient unobstructed areas or DSM features to use for interpolation, these areas will be improved with ancillary data. Where no ancillary data is available to replace dense areas of Cultural Obstruction, a manual solution will be applied.
DSM Edit Rule:	Cultural features will exist in the DSM as sensed by radar. However, due to the nature of IFSAR, features such as buildings (heights and edges) may not be well defined.
Obstruction Rule:	See Edit Rules above.
Ancillary Data Usage:	See Edit Rules above.

Feature:	Isolated cultural features
Definition:	Isolated cultural features such as buildings, water towers, pylons, poles, and other manmade structures.
DTM Edit Rule:	Isolated cultural features will be removed from the DTM. They will be interpolated from surrounding terrain, and / or a manual solution will be applied.
DSM Edit Rule:	Cultural features will exist in the DSM as sensed by radar. However, due to the nature of IFSAR, features such as buildings (heights and edges) may not be well defined
Obstruction Rule:	N/A
Ancillary Data Usage:	N/A

B.5.2. DEM Feature Edits – Natural

Feature:	Lake
Definition:	All lakes over 400 square meters will be flattened to a single elevation.
DTM Edit Rule:	Lakes will be leveled to a single elevation (expressed to the nearest 0.1 m) based on the water elevations and the surrounding shoreline. All shoreline posts immediately adjacent to the water shall be adjusted, to ensure an elevation greater than the lake level. Un-natural depressions adjacent to lakes will be elevated to concur with the surrounding land. Edge match at tile boundaries of a lake shoreline must be preserved.
DSM Edit Rule:	Extents and elevations of lakes will be the same as those in DTM.
Obstruction Rule:	Obstructed shorelines shall be completed to maintain hydrological consistency based on surrounding topography and available ancillary data, and occurring in a bare region of at least 100 m radius.
Ancillary Data Usage:	Primary identification of lake shorelines is from the radar data. Ancillary data, if available, will be used to complete obstructed areas.

Core Product DEM Edit Rules

Feature:	Double line drain (DLD)
Definition:	Flowing water that is at least 20 m wide for more than 400 m in length.
DTM Edit Rule:	Drains must be edited unless completely obscured for a length greater than 2 km. Any visible portion of drain resets the obscured length. In obscured areas, the positioning of the drain is the editor's best estimate, horizontally and vertically. Rivers will be flattened to the nearest decimeter with monotonic flow based on the water elevations and the surrounding shoreline. Water elevation stepping should not exceed 50 cm*. Where DLDs are obstructed for any reason, the operator will use the following, listed in order of priority: Ancillary data to determine the existence of the feature Radar data to position the feature. Best judgment in placing the feature as accurately as possible in the horizontal and vertical. * Water stepping will exceed 50 cm in cases of waterfalls, rapids, locks, or other features where large-magnitude elevation changes are visible in the ORI or ancillary source and are supported by the elevation data. All DLD shoreline posts immediately adjacent to the water shall be adjusted, if necessary, to ensure an elevation greater than the DLD level. Unnatural depressions adjacent to DLD will be elevated to concur with the surrounding land. Valid negative DLDs will not be adjusted to zero elevation at the ocean/river interface. Where a DLD with valid negative elevation connects with an ocean (having an elevation of zero), the elevation will step up from the DLD elevation to the zero ocean elevation at the ocean/river interface. Ancillary data may be used to assist in determining the location of this interface. Monotonic flow within the DLD will be maintained until it reaches the ocean/river interface. *(Table continues, next page)*

Core Product DEM Edit Rules

DTM Edit Rule (continued):	When the DLD reduces to a width less than 20 m for a distance of 2 km or greater, where obstructed extensions are not supported by ancillary data, the editor will terminate the edit at a logical point within this 2 km measurement. The editor will continue the drainage feature using the SLD rule. The delineation of the DLD shoreline must match between tiles. Changes in river elevation at tile boundaries must be edited to maintain correct directional flow of river. IQC and IV&V will not question any reasonable positioning Editor will use best judgment at start of drain Editor will use best judgment for the X, Y and Z placement of the drain Editor should trust the ORI; however, ancillary data should be consulted when in doubt Sausage drainage (DLD-SLD-DLD) should be avoided if at all possible. Care must be taken to ensure consistency and correct flow between tiles.
DSM Edit Rule:	Extents and elevations of rivers will be the same as those in DTM.
Obstruction Rule:	The radar data has precedence in river identification. Ancillary data will be used in obstructed areas to improve interpretation.
Ancillary Data Usage:	Every effort will be made to ensure that rivers present in ancillary data are present in the DEM. The ORI takes precedence over any ancillary data.

Feature:	Single line drain (SLD)
Definition:	Any drainage feature that is less than 20 m in width and greater than 1 km in length which is visible in the ancillary source and can be accurately identified in the radar data. In the absence of ancillary data, the drain will be edited as long as it can be accurately identified in the radar data. *(Table continues, next page)*

Core Product DEM Edit Rules

DTM Edit Rule:	Water does NOT have to be visible: Ancillary vector data is used to guide which SLDs may require monotonic correction. Where no ancillary vector data is available to guide which SLDs may require monotonic correction, SLDs longer than 1 km will be corrected for monotonicity. The radar data is the primary identifier for single line drainage. Ancillary data, including ancillary DEM, vector lines, or raster images, will be used to assist in the identification of single line drains. A hydrological process algorithm specifically developed for IES is used to determine the locations where the theoretical flow of water in the DTM is interrupted by elevations greater than 1 m (saddle). Where there is no valid feature in the DTM to physically block the flow (i.e. dam, road, embankment, etc.) the saddle is removed by lowering elevations along the visible channel of the SLDs that are identified as requiring monotonic correction. IQC and IV&V will not question any reasonable positioning. Editor will use best judgment for the X, Y, and Z placement of the drain. Editor will use best judgment when determining how to capture SLDs that stop and start, or which contain islands. The intention is to only portray surface drainage; drainage that is below the surface in culverts will not be shown. SLDs are not depicted with vectors and hydrologic modeling software may not automatically delineate SLDs to be coincident with the SLD as seen in the ORI or ancillary data. Valid negative SLDs will not be adjusted to zero elevation at the ocean/river interface. Where an SLD with valid negative elevation connects with an ocean (having an elevation of zero), the elevation will step up from the SLD elevation to the zero ocean elevation at the ocean/river interface. Ancillary data may be used to assist in determining this location. Monotonic flow of the SLD will be maintained until it reaches the ocean/river interface. *(Table continues, next page)*

Core Product DEM Edit Rules

DSM Edit Rule:	Single line drains are not edited in the DSM.
Obstruction Rule:	Cultural features will interrupt monotonic flow as specified in the Priority of Edits by Classification section, above. All other obstructions creating saddles in an identified stream will be cleared to maintain hydrological continuity along the direction of flow.
Ancillary Data Usage:	Radar data is the primary identifier for single line drainage. Ancillary data will be used to identify streams. Streams present in ancillary data and reasonably supported by the radar data will be edited as streams.

Feature:	Ocean
Definition:	Tidal water body into which continental hydrological systems drain.
DTM Edit Rule:	Ocean elevations shall be set to 0 m. Shorelines shall be delineated at the water/land interface as visible within the ORI. All shorelines less than or equal to 0 m will be set to 0.1 m. Where SLDs and DLDs meet with ocean, the ocean elevation will remain 0 m. All inland invalid negative elevations shall be removed.
DSM Edit Rule:	Extents and elevations of oceans will be the same as those in DTM.
Obstruction Rule:	Obstructed ocean shorelines shall be completed to maintain hydrological consistency based on surrounding topography and available ancillary data. Editor will make the best effort to blend shorelines when tidal changes are involved.
Ancillary Data Usage:	Primary identification of shorelines is from the radar data. If ancillary data is available it will be used to complete obstructed areas.

Core Product DEM Edit Rules

Feature:	Island
Definition:	Land mass visible in the ORI/DSM and supported by ancillary data, having an area of 100 square meters or greater, completely surrounded by water.
DTM Edit Rule:	All Islands greater than 400 square meters and visible in the ORI will be included in the DTM. Islands less than 400 square meters, but greater than 100 square meters, will be included in the DTM if supported by both the ORI and the DSM and visible in the ancillary data. Islands less than 100 square meters will be flattened as water, unless supported by ancillary data whereby the elevation will be set to 1 m above the water level. Elevations will be derived from the DSM with first surface feature elevations removed.
DSM Edit Rule:	Elevations will remain as sensed by the radar.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used to improve interpretation. Every effort will be made to ensure islands present in ancillary data are present in the DSM. The ORI takes precedence over any ancillary data.

Feature:	Bare ground
Definition:	Unobstructed terrain.
DTM Edit Rule:	The elevations of unobstructed terrain will be smoothed to remove radar noise. A conservative smoothing algorithm balances the need to preserve terrain features in the DTM while reducing the amount of noise in the data. The smoothing process both lowers and raises individual posts.
DSM Edit Rule:	Elevations will remain as sensed by the radar.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used to improve interpretation.

Feature:	Crops
Definition:	Agricultural crops.
DTM Edit Rule:	Crops that can be detected above bare ground will be removed from the DTM. Crops will be filled with the best available ancillary data or a manual solution will be applied based on the editor's best judgment.
DSM Edit Rule:	Elevations will remain as sensed by the radar.
Obstruction Rule:	N/A
Ancillary Data Usage:	When possible, ancillary data (e.g., DRG) will be used as a guide to improve interpretation and determine underlying elevations.

Core Product DEM Edit Rules

Feature:	Single trees and scattered trees
Definition:	Single trees and scattered trees, hedgerows, and small clumps of trees less than 100 m across.
DTM Edit Rule:	Single and scattered trees will be removed from the DTM. They will be interpolated from surrounding terrain and / or a manual solution will be applied. Clumps of trees (less than 100 m across) will be removed from the DTM. They will be either interpolated, filled with the best available ancillary data, or a manual solution will be applied.
DSM Edit Rule:	Vegetation elevations will remain in the DSM as sensed by radar.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used in to improve interpretation.

Feature:	Forest
Definition:	Closed canopy wooded areas exceeding 100 m in all directions.
DTM Edit Rule:	Forest areas will be removed in the DTM. They will be filled with the best available ancillary data. Where no ancillary data is available to replace large forest areas, a manual solution will be applied.
DSM Edit Rule:	Forest elevations will be in the DSM as sensed by radar.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used in to improve interpretation.

Feature:	Scrub brush
Definition:	Scrub brush is defined as scattered or clumped vegetation between 1 and 3 meters in height.
DTM Edit Rule:	Scrub brush will be treated as bare ground. The elevations of scrub brush will be smoothed to remove radar noise. A conservative smoothing algorithm balances the need to preserve terrain features in the DTM while reducing the amount of noise in the data. The smoothing process both lowers and raises individual posts.
Obstruction Rule:	Although this area is being treated as bare ground, it is an obstructed area that cannot be used for RMSE verification.
Ancillary Data Usage:	Ancillary data will be used to aid identification of scrub brush.

Core Product DEM Edit Rules

B.5.3. DEM Data and Processing Edits

Feature:	Blunder
Definition:	Blunders are artificial elevation changes, either positive (elevation too high) or negative (elevation too low), where there is a large elevation difference from surrounding ground elevations and where such a difference is not supported by the interpretation of the ORI or ancillary data. In unobstructed areas and low slope areas, a large elevation difference is defined as 10 m from surrounding ground elevations. In obstructed areas or high slope areas, a large elevation difference is defined as 20 m from surrounding ground elevations.
DTM Edit Rule:	Blunders should not appear in the DTM. The editor should return to the DSM to determine the appropriate edit to make.
DSM Edit Rule:	Blunders shall be identified through visual inspection of the radar data. They shall be removed either by directly editing the blunder, by voiding the blunder posts and replacing them using an interpolation based on the surrounding good points, or by filling with the best available ancillary data.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used to aid the identification of blunders.

Feature:	Depression
Definition:	Depressions are regions, which appear as trenches or large holes between 4 m and 10 m deep, not supported by the interpretation of the ORI or ancillary data, where the distance from the center of the depression to surrounding obstructions is greater than 50 m.
DTM Edit Rule:	Depressions should not appear in the DTM. The editor should return to the DSM to determine how depressions effecting DTM elevations shall be corrected.
DSM Edit Rule:	Depressions shall be removed and replaced using interpolation based on the surrounding good points or they will be filled using the best available ancillary data.
Obstruction Rule:	If a depression touches a waterway, it shall be removed, regardless of its proximity to obstructions.
Ancillary Data Usage:	Ancillary data will be used to aid identification of depressions.

Core Product DEM Edit Rules

Feature:	Void (null) data
Definition:	Any area that is void (null)
DTM Edit Rule:	All void areas in the DTM will be filled in with the best available ancillary data. In areas where the ancillary data is incorrect, the editor will use best judgment to manually rebuild the void area.
DSM Edit Rule:	All void areas in the DSM will be filled in with the ancillary data used in the DTM edit rule above. In areas where the ancillary data is incorrect, the editor will use best judgment to fill the void area with DTM values or with a manual solution.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used as a guide to manually rebuild the void area.

Feature:	Cycle shift
Definition:	A cycle shift appears as an unnatural cliff or trench in the DSM which is not supported by the interpretation of the image or the DSM. The magnitude of a cycle shift is typically 20-50 m in the near range and 500-1000 m in the far range.
DTM Edit Rule:	Cycle shifts should not appear in the DTM. The editor should return to the DSM to determine the appropriate edit to make.
DSM Edit Rule:	Cycle shifts with a medial length less than 1000 m shall be removed (voided) in the DSM and filled (replaced) using an area interpolation based on the surrounding good points, or they will be filled using ancillary data. The area of the replacement shall be determined by the extents of the cycle shifts. Where possible, a bias shall be used by the editor to recover as much good data as possible from the cycle shift. Cycle shifts exceeding a medial length of 1000 m shall be grounds for rejecting the map sheet and requesting it to be reprocessed by DPC.
Obstruction Rule:	N/A
Ancillary Data Usage:	Ancillary data will be used to aid identification of cycle shifts.

Feature:	Negative elevation
Definition:	A negative elevation is less than 0 m.
DEM Edit Rule:	All invalid negative elevation regions shall be edited using surrounding data.
Obstruction Rule:	N/A
Ancillary Data Usage:	Radar data is the primary identifier of valid negative elevations. Ancillary data shall be used, where available, to determine the validity of the negative elevations.

Core Product DEM Edit Rules

Feature:	Seam line
Definition:	A seam line is a visible and measurable line of discontinuity in the DTM or DSM that results from merging adjacent datasets.
DEM Edit Rule:	If a seam line longer than 25 m exceeds one-half the vertical accuracy specified for the product, then the edge of the seam line shall be feathered to eliminate linear edges. If the seam line travels the entire length of the mapsheet, it shall be rejected and sent back to IP for investigation. If it is contained within the mapsheet, it shall be investigated by the team lead, who may elect to submit the data to IP for comment and possible investigation. Specification of the product: Type I: RMSE = 0.7 m (seam less than 0.35 m) Type II: RMSE = 1.0 m (seam less than 0.50 m)
Obstruction Rule:	See DEM Edit Rule, above.
Ancillary Data Usage:	N/A

Core Product DEM Edit Rules

Feature:	DTM is high (above the DSM)
Definition:	Expectations for the DTM are that the elevations will be lower than the DSM in obstructed areas and approximately equal to the DSM in unobstructed areas. In some cases, the DTM creation process will violate this condition, causing localized areas of DTM above DSM. This can be caused by several factors, including: DSM noise that is represented as a smoothed surface in the DTM Areas of natural rapid elevation change in the DSM, such as: pits, forest edges, cliff bottoms, embankment bottoms, unedited bridges bottoms, and cuttings through trees or ground, valleys, ridge bottoms, dam bottoms, weir bottoms, and forest clearings Areas of unnatural rapid elevation change in the DSM due to radar or processing artifacts, such as: parking lots or other unedited road features (due to low radar signal return), and depressed edges behind buildings, trees, or similar objects Depending on the amount the DTM is above the DSM and where this occurs, some of these deviations will be corrected and some will be retained. DTM high errors will be fixed according to automatic QC tool parameters and the DTM-above-DSM tool. This rule applies in areas in which the Forest edit rule is not utilized.
DTM Edit Rule:	Areas of DTM above DSM shall be edited if they meet the following criteria: Where there is an automatic QC Tool error on a 2000 square meters area of bare ground with valid DSM elevations Where the difference between the DTM and DSM is greater than 4m over an area of 2000 square meters Where there is an automatic QC Tool error on any SLD, provided the DSM elevations are valid Edits will be performed until these criteria (elevation difference and/or size) are no longer met. Areas of DTM above DSM may remain after editing.
Obstruction Rule:	See Definition above.
Ancillary Data Usage:	N/A

Core Product DEM Edit Rules

Feature:	DTM is low (below a bare-earth DSM)
Definition:	Expectations for the DTM are that the elevations will be lower than the DSM in obstructed areas. It is expected that the DTM will not be lower than the DSM by more than the height of the obstruction. In some cases, the DTM creation process will violate this condition.
DTM Edit Rule:	In areas of bare ground of at least 2000 square meters, the DTM is expected to be within 1 m of the actual ground elevation. In areas of full obstruction (where the ground is not visible) the DTM is expected to be lower than the DSM by approximately the height of the obstruction. In areas of partial obstruction (where the ground is visible in some areas but not larger than 2000 square meters) the DTM is expected to be no more than 4 m lower than the interpreted ground elevation. In partially obstructed areas with cultural constructs affecting water and river banks the DTM must be within 1 m of the interpreted ground elevation.
Obstruction Rule:	See Definition and DTM Edit Rule above.
Ancillary Data Usage:	N/A

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