IfSAR Data: Notes and Considerations

Introduction

The National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center partners with private-sector companies to provide geospatial data to the coastal resource management community. With a demonstrated need for updated digital elevation models (DEM) by the community, the Center has acquired Interferometric Synthetic Aperture Radar (IfSAR) data. IfSAR data can provide an accurate and detailed synoptic elevation model at a reasonable cost.

As with any data set, the user needs to be aware of its limitations. IfSAR's performance is best in sparsely vegetated areas with relatively low slopes and away from dense urban areas. Also, analysis using an IfSAR elevation model is more appropriate for a watershed-scale analysis and is probably not appropriate for a detailed analysis of a small region (e.g., determining the height of a specific tree). If available, ancillary information, such as land cover maps or the IfSAR correlation mask[1], can be very helpful in indicating areas where the elevation model is likely to be less accurate. As with any project, the data limitations need to be considered within the context of the application.

This document provides initial guidance on the use of Intermap's NEXTMap USA IfSAR product; however, most of the cautions apply to any IfSAR data set. The intent is to provide potential users with information on the limitations of the technology and avoid inappropriate application of the data. While most of the cautions expressed in this document can also be found in Intermap's *Product Handbook and Quick Start Guide*[2] (version 3.3, hereafter referred to as *handbook*), some considerations were only discovered during further discussions with Intermap. In these notes, we, the NOAA Coastal Services Center and its staff, have selected the issues we consider most relevant to our partners. The primary focus is on the identification of areas that may not meet the fundamental accuracy[3] specification. It should be noted that the products from the IfSAR vendors we have worked with do meet their specifications for accuracy, but their specifications need to be clearly understood. Additional information on applications and editing rules can be found in the product *handbook*.

I. Ground Truth and Accuracy Verification

IfSAR data have a reported fundamental accuracy that is based on comparisons with surveyed ground checkpoints. The reported accuracy is only valid for the areas suitable for these checkpoints and cannot be considered to represent the entire data set. For instance, data in forested areas cannot be considered to have the same accuracy as data in open terrain areas,

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[1] A correlation mask can show where the IfSAR system was unable to determine the elevation with sufficient confidence and, thus, where interpolation was required.

[2] *www.intermap.com/products/ProductHandbookVer3.3.pdf*

[3] Fundamental accuracy is determined from checkpoints located only in open terrain. See the National Digital Elevation Program's *Guidelines for Digital Elevation Data* for more information (*www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf*)

unless it was also tested and validated. Note that different technologies will have different vertical checkpoint criteria (e.g., a LiDAR, or light detection and ranging, checkpoint can be closer to the trees than an IfSAR checkpoint). Several references in this document and in the *handbook* refer to appropriate locations for vertical checkpoints to test the accuracy of the data. Again, only areas suitable for checkpoints are used in the calculation of fundamental accuracy. If a location is not suitable for a checkpoint, the fundamental accuracy statement does not represent that area and the data in that location may have an unknown accuracy. These data may be accurate, but without verification of representative areas (e.g., checkpoints near steep slopes or near obstructions), there is no way for the user to know. This is an important issue because users of other digital elevation model (DEM) data sources would likely assume these areas of unknown accuracy in IfSAR were covered by the fundamental accuracy because they were suitable checkpoint locations for other technologies.

Obstructions

The least restrictive guidance given for an area suitable for a checkpoint is an area clear of objects for at least 5 meters in all directions. Within this area the surface should be flat or uniform with a slope less than 10 degrees. The following bullets illustrate additional restrictions that accompany the 5-meter rule.

- Areas with obstructions at about 30 degrees elevation or higher can cause problems in the radar observation of an area. While a single tree may not cause a problem, it could shadow any given point within a distance of approximately two times the tree's height and result in an erroneous return; therefore, checkpoints need to be placed at a distance from trees at least twice their height. Thus, areas with trees, even sparse trees, have the potential for error beyond specifications. Lamp posts, telephone poles, etc., can also cause problems in the same way. Thus, a typical residential area is very likely to have some problem areas even though much of the data are good.
    - Note that the 30 degree elevation is derived from the *handbook* recommendation for ground checkpoints to create "a buffer of width about twice the height of the building/woods (version 3.3, page 39)." However, Intermap's International Standards Organization (ISO) documentation[4] indicates that vertical checkpoints should have:
        - An unobscured view of the sky in all directions above 10 degrees elevation (this would be a buffer of width almost six times the height of a potentially shadowing object).
        - No Multi-path sources nearby (e.g., building, trees, etc.).
        - No interference sources nearby (e.g., cell, microwave, and radio towers).
- Terrain and the viewing angle of radar and the radar "look direction" are considerations when using any radar data. The viewing angle of radar is from 30 to 60 degrees. For example, the look direction for the Hawaiian Islands is approximately west. Therefore, vertical features will cause radar shadows on the west side of the feature. Very steep terrain facing east can result in areas of layover or saturated areas, preventing the estimation of elevation. While the look direction may not be known to the user in advance, it can generally be determined from the DEM and the radar imagery.
- In addition to objects that present an intuitive shadow, such as trees, objects such as overhead phone and power lines also must be considered obstructions. Power lines that

[4] This information regarding the contents of Intermap's ISO documents was provided by Intermap. The NOAA Coastal Services Center has not seen or reviewed the actual ISO documents.

are perpendicular to the look direction of the radar sensor can cause errors beyond specification. This same situation may be true for wire fences. Since the user may not be aware of the look direction, these features should be viewed with caution in all cases.

Bright Objects and Low Correlation

- Objects that are bright (i.e., high signal return) in the radar can cause errors in the elevations near the objects, especially if the other areas are dark in the radar image. For example, a guardrail on a road will cause a problem retrieving the road elevation because the guardrail is very bright and the road is typically dark. Street signs with the right orientation relative to the radar look direction can also return a very bright signal and cause errors in nearby elevations.
- There are areas where the radar signal is not able to sufficiently retrieve a height (areas with low correlation). These areas are generally in high slope areas or areas with low radar return, such as pavement, and have been interpolated based upon surrounding areas. Interpolations in rapidly varying terrain can have very large errors. For example, vertical errors greater than 10 meters were found in interpolated areas in the Hawaiian Islands. A mask of low correlation areas can be provided to identify these areas.

Slopes

- Slopes greater than 10 degrees can often result in a higher error. Note that it is not only the local slope within a few pixels that matters, but also the general slope of the area for several tens or hundreds of meters around. A flat area near a steep slope may be good, but it may also have added error because of the generalized slope.

II. General Data Applicability

Analysis Scale

- The data are best suited for regional-scale analysis, although smaller scale analysis have been done. Using the data on a local scale may result in erroneous conclusions. For instance, the data are not suitable for determining water flow in a neighborhood, but they should be adequate for generalized flow for a whole watershed. As an example, stream edit rules used by Intermap are detailed in the *handbook* for both double line drainages (at least 20 meters wide for more than 400 meters) and single line drainages (less than 20 meters wide and longer than a kilometer). While the water should flow correctly within these drainage features, if you need water to flow correctly over the general landscape (e.g., through the forest, not around it), serious errors could arise where first-surface features, such as large tree stands, could not be removed. Even where first-surface features have been removed, it should be remembered that an interpolation has been done.

NEXTMap Data Editing

The following edit rules from the *handbook* are used by Intermap when it creates its NextMap USA product and so are relevant to coastal resource managers. Other IfSAR providers will have their own edit rules that may have similar implications.

- Bridge features and raised roads remain in both the digital surface model (DSM) and digital terrain model (DTM) products. This may have water flow implications by

creating a "dam" feature where one does not exist; however, it does allow for more accurate terrestrial transportation networks.

- Roads edits (smoothing of road surface): Only roads that have a TIGER line classification of A1, A2, or A3 have been smoothed. All other roads may display sharp undulating elevations or inconsistencies.
- Stream and river edits (Hydro enforcing): double line drainages (at least 20 meters wide for more than 400 meters) and single line drainages (less than 20 meters wide and longer than a kilometer) are smoothed in a stepped fashion to enforce monotonic flow.
- Road networks and rivers sometimes must be edited in interpolated areas by the image editor. In these cases, ancillary data are used to determine where the roads or rivers should be placed and can result in "cutting" through interpolated elevations, sometimes resulting in unrealistic canyons. There can be error in the placement of the river or road feature or in the interpolated terrain.

Digital Terrain Model (DTM)

- The removal of first-surface features, such as trees and buildings, in the DTM product is contingent upon a couple of factors. First, according to the *handbook*, regions of trees greater than 50 meters in radius will not be removed. Additionally, a sufficient area of unobstructed regions surrounding the first-surface features is required for accurate interpolation. Consequently, regions in the DTM bordering the coastline are not considered dependable because of the lack of unobstructed land on one side for interpolation due to the ocean presence. Similar observations are also found in dense urban regions.

Additional Resources

American Society for Photogrammetry and Remote Sensing. 2001. *Digital Elevation Model Technologies and Applications: The DEM Users Manual*. 539 pages.

Federal Geographic Data Committee (FGDC). 1998. *Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy*. Federal Geographic Data Committee. This document is available on-line at *www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3*.

Intermap Product Handbook and Quick Start Guide. 2004. Version 3.3. This document is available on-line at *www.intermap.com/products/ProductHandbookVer3.3.pdf*.

National Digital Elevation Program. 2004. *Guidelines for Digital Elevation Data*. This document is available on-line at *www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf*.

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