Comparison of Intermap 5 m DTM with SRTM 1 second DEM

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Cover Image:
Description: A subset of the Intermap 5 m digital terrain model, showing irrigation bays constructed in Lake Tandou, NSW, near the South Australia border.
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ACKNOWLEDGMENTS

The Intermap IFSAR data used in this report were provided by the Murray Darling Basin Authority for the purpose of this assessment.
1. INTRODUCTION

This report describes a brief comparison of the Intermap 5 m resolution elevation data with the national 1 second resolution elevation data derived from the Shuttle Radar Topographic Mission (SRTM). The comparison examines:

- Differences between the SRTM-derived and Intermap elevations and slopes
- Differences in vegetation removal in SRTM-derived and Intermap data
- Differences in stream networks and catchments derived from the drainage-enforced SRTM product and the Intermap data

The comparison is not exhaustive and is intended as a quick overview of the similarities and differences of the two products, and to determine whether the Intermap product can be used for hydrological purposes without hydrological enforcement.

Both the SRTM and Intermap data are derived from radar instruments, with SRTM acquired from NASA’s Space Shuttle in 2000 and the Intermap data from an aircraft in 2009. Neither instrument can penetrate trees so both data sets require additional processing to produce a bare-earth elevation model.

The comparison is based on Block 3 of the Intermap data covering the area around the confluence of the Murray and Darling rivers (inset, Figure 1) and includes ephemeral lakes, agricultural land, dunes, uncleared scrub and riparian forests. This is a flat area that is useful for evaluating whether the Intermap product can detect subtle drainage features in low relief landscapes.

Both SRTM-derived and Intermap data sets comprise multiple products. The original SRTM product is a digital surface model (DSM) that includes the effects of vegetation. A vegetation offset removal (VOR) process produced a bare-earth digital elevation model (DEM) which was then smoothed to reduce noise resulting in a smoothed DEM named DEM-S. Drainage enforcement with 1:250,000 scale stream lines produced a hydrological DEM named DEM-H.

The Intermap interferometric synthetic aperture radar (IFSAR) data also produce a digital surface model (DSM) that includes the effects of vegetation, and a bare-earth digital terrain model (DTM) was derived using a vegetation offset removal (VOR) process. The DTM has not had drainage enforcement applied except in a few areas where trees obscure channels.

Table 1 summarises the different products and their uses in this comparison. The Intermap DTM was used in each comparison. The SRTM-derived DEM-S is the closest equivalent to the Intermap DTM for the purpose of comparing elevations and slopes, while the SRTM-derived DEM-H is used for catchment comparison.

Table 1. Input datasets

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Surface</th>
<th>Use in this report</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM</td>
<td>Digital Surface Model (DSM)</td>
<td></td>
</tr>
<tr>
<td>Height datum</td>
<td>Digital Elevation Model – Smoothed (DEM-S)</td>
<td>Elevation and slope comparisons</td>
</tr>
<tr>
<td>EGM96 Resolution 1 second</td>
<td>Digital Elevation Model – Hydrologically Enforced (DEM-H)</td>
<td>Catchment comparison</td>
</tr>
<tr>
<td></td>
<td>Vegetation Offset Removal (VOR)</td>
<td>Vegetation removal comparison</td>
</tr>
<tr>
<td>Intermap IFSAR</td>
<td>Digital Surface Model (DSM)</td>
<td>Vegetation removal comparison</td>
</tr>
<tr>
<td>Height datum</td>
<td>Digital Terrain Model (DTM)</td>
<td>Elevation and slope comparisons; Vegetation removal comparison; Catchment comparison</td>
</tr>
<tr>
<td>AHD Resolution 5 metres</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The SRTM data have a horizontal resolution of 1 second (about 25 m in this area) while the Intermap IFSAR data have a resolution of 5 m. As well as a much finer resolution, the IFSAR
data have much lower noise levels than SRTM, so are expected to produce a substantially better representation of the terrain surface.

The SRTM elevation values are based on the global EGM96 datum whereas the IFSAR DEM uses the Australian Height Datum (AHD) as its reference. EGM96 was used for SRTM because of the need for a global datum for a global dataset. EGM96 and AHD have been compared by Geoscience Australia but the relationship has not been satisfactorily quantified. Currently there is no accepted way of correcting EGM96 to match AHD, however the difference is less than 1 m (1 Second SRTM Derived DSM and DEM User Guide, 2010).

2. DATA PROCESSING

The SRTM and IFSAR DEMs are at different resolutions, have different projections and different tiling structures, so both data sets required pre-processing before the comparisons could be completed.

To achieve a consistent cell size the finer resolution IFSAR data were aggregated by averaging to match the coarser SRTM resolution. This approach is considered to be more defensible than the alternative of resampling the SRTM to the finer IFSAR resolution.

2.1. SRTM Processing

The eight SRTM DEM-S tiles that overlapped with the Block 3 IFSAR data were mosaicked and then reprojected to 25 m resolution, chosen to approximately match the SRTM resolution and be a multiple of the IFSAR resolution (5m). Slope in degrees was calculated from the reprojected DEM-S grid.

The eight SRTM VOR tiles were similarly mosaicked and reprojected to 25 m resolution for the vegetation removal comparisons.

2.2. IFSAR Processing

The 5 metre resolution and large size of the IFSAR data limited the number of tiles that could be processed together. Consequently the IFSAR DSM and DTM tiles for Block3 were initially merged into nine grids. Slope in degrees was calculated from the merged DTM grids.

The nine merged DTM and slope grids were then aggregated to match the reprojected SRTM cell size, with the mean elevation and slope values calculated for each cell. The nine aggregated elevation grids were then merged into one, and the same was done for the slope grids.

Vegetation offset removal was calculated by subtracting the nine merged DTM grids from the merged DSM grids, aggregating the nine outputs to match the reprojected SRTM cell size (taking the mean as the value) and then merging the nine aggregated-difference grids to create a single vegetation offset removal grid equivalent to the SRTM VOR grid.

2.3. VOR Processing

A threshold of +0.4m difference in the IFSAR VOR grid was used to define where the IFSAR DSM had vegetation removed. This was done because there are differences between the DSM and DTM datasets due to smoothing, not just removal of vegetation offsets.

The SRTM and IFSAR VOR grids were combined to create a VOR mask grid with four classes: no VOR for either dataset, VOR for SRTM only, VOR for IFSAR only, and VOR for both datasets. These were numbered 1 to 4 respectively.

Using the VOR mask grid, four new grids were created for elevation and slope, representing the differences between IFSAR and SRTM within each of the four VOR mask classes.
2.4. Catchment Processing

For both the hydrologically-enforced SRTM (DEM-H) and IFSAR DTM tiles, catchments were derived using the following steps:

1. Flow direction and flow accumulation calculated in GRASS. The GRASS r.watershed algorithm was used because it can derive flow directions through depressions without having to fill them first.

2. Watersheds delineated in ArcInfo, using a threshold of 50,000 cells for SRTM and 1,250,000 cells for IFSAR (reflecting their resolutions of ~25m and 5m respectively) for stream creation.

3. SRTM watershed tiles (each with 0.5 tile overlap) reprojected to 25 m for comparison with IFSAR

The SRTM data used in the catchment processing were reprojected after the watershed delineation because projection destroys drainage connectivity in a hydrologically-enforced DEM.

Due to the high resolution of the IFSAR data and the memory constraints of the virtual machine used for the GRASS processing, the area for each IFSAR tile processed was smaller than the equivalent SRTM, and the IFSAR tiles did not include overlapping data.

Note that there has been no hydrological enforcement applied to the IFSAR DTM data except along some important drainage lines where vegetation obscured the channel, while the SRTM DEM-H has been hydrologically enforced.

3. RESULTS

3.1. Elevation and Slope Differences

Table 1 reports the statistics of differences between the two DEMs. Overall, the SRTM DEM-S is higher than IFSAR DTM by about 3.6 m, and the standard deviation of differences is about 1.6 m. The reason for the 3.6 m mean difference is not known. The SRTM DEM is based on the EGM96 geoid while the IFSAR DEM is based on AHD, but information from Geoscience Australia suggests differences between the two datums should be less than 1 m. The IFSAR campaign was supported by ground survey to verify the elevations, while the global SRTM data has much less ground control so it seems likely that any errors are mostly in the SRTM DEM.

The mean height difference is reduced where vegetation offsets have been removed only in the SRTM DEM, and increased where they have been removed only in the IFSAR DTM, as would be expected given the SRTM DEM-S is higher on average. The standard deviation of differences is smaller where vegetation offsets have been removed only in the IFSAR DTM, larger where they have been removed only in the SRTM DEM-S and larger again where they have been removed in both. This suggests that the vegetation removal processes for both datasets are unreliable, more so in the SRTM than the IFSAR.

Table 2. Elevation and slope differences between the aggregated-IFSAR DTM and reprojected-SRTM DEM datasets over the Block 3 area

<table>
<thead>
<tr>
<th>VOR Mask</th>
<th>Elevation Difference (m)</th>
<th>Slope Difference (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>No VOR</td>
<td>-3.466</td>
<td>1.304</td>
</tr>
<tr>
<td>SRTM VOR only</td>
<td>-2.933</td>
<td>2.204</td>
</tr>
<tr>
<td>IFSAR VOR only</td>
<td>-4.347</td>
<td>1.414</td>
</tr>
<tr>
<td>Both VOR</td>
<td>-3.190</td>
<td>2.514</td>
</tr>
<tr>
<td>All cells</td>
<td>-3.630</td>
<td>1.597</td>
</tr>
</tbody>
</table>

The slopes calculated from the IFSAR DTM are on average slightly higher than those from the SRTM DEM-S. This is consistent with the expected greater detail in the IFSAR DTM, due
both to the finer horizontal resolution and better vertical precision. Higher slopes can also be due to higher noise levels and inclusion of constructed features such as irrigation bays in a lake bed (e.g. Lake Tandou, cover image).

Figure 1 shows differences in elevation between the aggregated-IFSAR DTM and the reprojected-SRTM DEM-S. Note that the colour scale has been selected so that the neutral central colour is -3.5 m, close to the mean difference. The diagonal patterns – both large blocks and fine striping – are consistent with the orbital patterns in the SRTM data suggesting they are due to errors in the SRTM DEM-S. The blue colours show where the SRTM DEM-S is higher than the IFSAR DTM, and the watercourses in those colours show that the IFSAR DTM is capturing the lower elevations along the watercourses better than the SRTM DEM-S. Some of the differences are due to different patterns of vegetation offset removal.

The differences in lake elevations are mostly due to different conditions at the acquisition times of the two data sets. Lake levels change over time in the ephemeral lakes so differences in DEM elevations in those areas are expected.

Figure 2 shows differences in slope between the aggregated-IFSAR DTM and the reprojected-SRTM DEM-S. The patterns of slope differences show larger slopes from the IFSAR DTM in higher relief areas across the north of the study area and around drainage lines, suggesting that the difference in average slope is probably due to better capture of fine scale topographic structure in the higher resolution IFSAR DTM, rather than higher noise overall.

Figures 3 and 4 provide a closer view of the elevation and slope differences. The residual SRTM striping is more clearly visible in these figures, as are some square block shapes that may be due to the way vegetation offsets were removed or left untouched in the SRTM DEM. The slope differences in Figure 4 show a subtle north-south striping that is suspected to arise from the IFSAR DTM, possibly due to near-far range errors: instrument errors translate to errors in height in a manner that depends on angle from the antenna and hence distance across the acquisition swathe.
Figure 1. Elevation difference between the aggregated-IFSAR DTM and reprojected-SRTM DEM. The black outline shows the location of Figure 3 within Block 3.
Figure 2. Slope difference between the aggregated-IFSAR DTM and reprojected-SRTM DEM. The black outline shows the location of Figure 4 within Block 3.
Figure 3. Elevation difference image showing NW-SE and NE-SW striping, as well as N-S and E-W striping
3.2. Vegetation Offset Removal

Figure 5 shows the VOR mask grid, while Figures 6-8 show various areas of IFSAR-only and SRTM-only VOR. There are large areas where vegetation offsets have been removed from the IFSAR DSM but not from SRTM DSM (orange). These areas are sparsely vegetated and the difference is likely due to the difference in horizontal resolution and vertical precision of the two instruments: sparse tree cover often produces little or no visible vegetation offset in the SRTM DSM, while individual trees and shrubs produce visible offsets in the IFSAR DSM. There are also some areas in the south of Block 3 where vegetation offsets have been removed from the SRTM DSM but not the IFSAR DSM (Figure 8). These appear to be oversights in the IFSAR vegetation removal process – vegetation cover is essentially continuous in the south-western corner of the area so should have been treated uniformly.

The two close ups of IFSAR-only VOR areas show sparse to medium tree density in the associated IFSAR imagery (Figure 6) and small high density tree patches (Figure 7). In these cases the IFSAR VOR is supported by Google Earth imagery.
Figure 5. VOR mask classes showing where a vegetation height offset was removed from the datasets. Figure 6 location outlined in black, Figure 7 location outlined in purple, and Figure 8 location outlined in red.
Figure 6. Area showing predominantly IFSAR-only VOR and the associated IFSAR image which indicates sparse to medium density tree cover.
Figure 7. Area showing IFSAR-only VOR and the associated IFSAR image with some dense patches of vegetation not removed by the SRTM classification.
Figure 8. A location showing a distinct boundary between dense vegetation and cleared land (lower image - N6180E550_Z54ori.tif). The lack of green in the VOR mask (upper) indicates the IFSAR classification did not consistently recognise the vegetation.
3.3. Catchments

Catchments derived from the IFSAR and SRTM tiles are shown in Figure 9. This low relief landscape has poorly defined drainage network so different DEMs produce different catchment boundaries. Due to the high resolution of the IFSAR data and the memory constraints of the virtual machine used for the GRASS processing, the area for each IFSAR tile processed was smaller than the equivalent SRTM, and the IFSAR tiles did not include overlapping data. The non-overlapping tiles means there are edge effects influencing the IFSAR catchments, but the patterns within the IFSAR tiles are still a valid basis for comparison. These limitations resulted in straight lines in catchments around the IFSAR tile edges and gaps between the catchments in different tiles. Nevertheless, the pattern of catchment boundaries and drainage lines away from those edges provides a reasonable impression of the performance of the two DEMs.

In some areas there is quite good correspondence between IFSAR and SRTM catchment boundaries and drainage lines: Figure 10 shows an area of mostly good agreement. Given that the SRTM DEM-H has been hydrologically enforced, the location and pattern of drainage lines are considered to be fairly reliable. The IFSAR DTM, which has not been hydrologically enforced, has defined drainage lines and catchment boundaries quite well in some parts of Figure 10, with some areas of clear difference.

Figure 11 shows an area of poorer correspondence, where many of the drainage lines derived from the IFSAR data do not match those in the SRTM DEM-H. The smooth drainage line on the right of Figure 11 where IFSAR and SRTM lines match exactly is probably an instance of where the 1:250,000 stream line data was used to correct the IFSAR DTM.
Figure 9. SRTM DEM-H catchment boundaries (black outlines) over IFSAR DTM catchments (grey outlines) for Block 3. Gaps in the IFSAR are caused by non-overlapping tiles.
Figure 10. Good correspondence between IFSAR DTM catchments (grey outlines) and SRTM DEM-H catchments (black outlines).
Figure 11. Relatively poor correspondence between IFSAR DTM catchments (grey outlines) and SRTM DEM-H catchments (black outlines)
4. CONCLUSIONS

There was a substantial mean height difference of 3.6 m between the SRTM and IFSAR DEMs that was tentatively ascribed to systematic height errors in the SRTM DEM. The IFSAR DEM produces a higher average slope than the SRTM, which is consistent with increased detail in the IFSAR data.

The vegetation offset removal was performed differently between the two DEMs and the comparison showed limitations in both DEMs. Overall the IFSAR VOR appeared to be more accurate, however there are some omissions. The standard deviation of elevation differences between the SRTM and IFSAR DEMs was larger in areas where vegetation offset was removed than in areas without vegetation processing, particularly for the SRTM vegetation removal. This increased variability in elevation difference probably reflects increased uncertainty in elevations due to vegetation removal.

The comparison of derived drainage lines and catchment boundaries showed reasonable agreement in some areas and significant disagreements in other areas. This is to be expected in such a low relief landscape where drainage features are hard to detect. Since the SRTM DEM-H is hydrologically enforced to capture drainage patterns in the 1:250,000 stream line map it was considered to be a reasonably reliable representation of drainage structure, and differences were primarily due to the inability of the IFSAR DTM to capture drainage lines reliably. Riparian forests along stream lines play a significant role in preventing clear representation of drainage lines in both the IFSAR and SRTM DEMs. It appeared that the IFSAR DTM would require hydrological enforcement using suitable stream line data to produce a hydrologically reliable DEM in the low relief typical of much of inland Australia. Given the resolution of the IFSAR, 1:10,000 or 1:25,000 scale stream lines would be needed to enforce the DTM. This could be incorporated into the production of the IFSAR DTM, with optical imagery used as a supplementary dataset to define channel locations where no existing fine scale stream line data were available.

A set of predefined nodes would be a better basis for catchment comparison, and these could be provided by the contracted nodes currently being prepared by the Bureau of Meteorology.
REFERENCES

1 Second SRTM Derived DSM and DEM User Guide, version 1.0.1, 2010. (Distributed by Geoscience Australia with the 1 second DEM products).