Archives of Current Research International

Volume 25, Issue 5, Page 53-62, 2025; Article no.ACRI.134745
ISSN: 2454-7077

Comparing SeaDAS and ArcGIS Extracted Aqua MODIS Sea Surface Temperature DN Values at Bay of Bengal

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/acri/2025/v25i51187

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/134745

Original Research Article

Received: 21/02/2025
Accepted: 21/04/2025
Published: 25/04/2025

ABSTRACT

This study compares the Sea Surface Temperature (SST) DN values extracted from the Aqua MODIS data using SeaDAS and ArcGIS of Visakhapatnam coastal waters, Bay of Bengal (BOB), India. SST data from January to December 2024 were analyzed across buffer zones of 50 km ,75km,100km,125km,150km,200 km to assess their zonal statistics performance. Both tools showed high consistency, with absolute errors ranging from 0.000007°C to 0.000163°C and APE

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Cite as: *Sai, Jogiparthi Venkata, Kathavarayan Vasanth, Madhavan Narayanan, Thanabalan Palanisamy, Veepanagandla Gnanendra, and Anaparthi Praneeth. 2025. "Comparing SeaDAS and ArcGIS Extracted Aqua MODIS Sea Surface Temperature DN Values at Bay of Bengal". Archives of Current Research International 25 (5):53-62. https://doi.org/10.9734/acri/2025/v25i51187.*

values ranging from 0.000023 to 0.000563. Errors were negligible up to 150 km, but a one-pixel discrepancy was observed at 200 km buffer, which slightly increased the error percentage. Seasonal pixel fluctuations, notably a 15-20% drop in July due to monsoon cloud cover, were observed. Both tools proved reliable for zone delineation, with negligible errors well below the ecological thresholds. SeaDAS excelled in precise SST processing, whereas ArcGIS offered superior geospatial visualization.

Keywords: Sea surface temperature; buffer zone; zonal statistics; remote sensing.

1. INTRODUCTION

Remote sensing plays a crucial role in monitoring and analysing Sea Surface Temperature (SST), beacuse in-situ observations are often limited in frequency and spatial coverage. SST serves as a key indicator of climate system dynamics. Analysing SST distributions through remote sensing offers insights into ocean-atmosphere interactions and global climate patterns (Das, 2024). Remote sensing data facilitate the continuous monitoring of climate variables at regional and global scales, supporting assessments of climate change impacts and adaptation strategies (Gabriele et al., 2023). Remote sensing technologies, which integrate both active and passive sensors across the electromagnetic spectrum, are pivotal for the comprehensive observation of oceanic parameters, with particular emphasis on SST dynamics (Devi et al., 2015). Various satellite sensors are employed to measure SST, including the Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Very High-Resolution Radiometer (AVHRR), and Sea-viewing Wide Field-of-view Sensor (SeaWiFS). Such data are essential for detecting temperature fluctuations, assessing climate change, and informing marine resource management strategies (Dunstan et al., 2018). Among the various methodologies for spatial SST analysis, Region of Interest (ROI) extraction plays a pivotal role in delineating specific zones, analysing coastal influences, and evaluating the impact of spatio-temporal variations on marine biodiversity. Multiple approaches exist for retrieving remote sensing data from satellite imagery. Madhavan et al. (2015) used beam software to extract monthly mean values by importing polygons from ArcGIS for their study. Similarly, Al-Hajri et al. (2020) and Pandey and Liou (2022) extracted mean values using ArcGIS. Additionally, AlHossainy et al. (2025) and Ginanjar et al. (2025) employed SeaDAS to extract DN values for their research. Scholars or researchers who have no knowledge of coding for the extraction of SST values, the tools SeaDAS and ArcGIS will provide Zonal Statistics of study area. No such studies have compared the SEADAS and ArcGIS tools for zonal statistics. This article helps scholars and researchers choose the best tool to extract zonal statistics. SeaDAS is a free, open-source software designed for data processing, visualization and geospatial analysis, particularly for oceanographic applications. In contrast, ArcGIS is licensed software and is renowned for its mapping, multilayer analysis, and advanced geospatial analysis capabilities. A comparative evaluation of these tools will provide insights into their effectiveness in extracting zonal statistics and analyzing SST variations.

2. MATERIALS AND METHODS

2.1 Study Area

The study area includes the coastal waters of the Visakhapatnam district in northern Andhra Pradesh, which is located in the Bay of Bengal at approximately 17.695° N latitude and 83.3025° E longitude. This study established multiple buffer zones extending from the Visakhapatnam fishing harbour with radii of 50 km, 75 km, 100 km, 125 km, 150 km, and 200 km. The Bay of Bengal is the largest bay in the world and is a part of the Indian Ocean. It supports a diverse range of marine flora and fauna and is responsible for nearly 7% of the world's total fish catch (Transboundary Diagnostic Analysis, Vol. 2). Therefore, monitoring this region can be an effective strategy for delineating fishing zones and predicting fisheries yields (Fig. 1).

2.2 SeaDAS (Sea, Earth and Atmosphere Data Analysis System)

SeaDAS, which is developed by NASA, is a special tool for the processing ocean color data and thermal infrared satellite imagery. It offers advanced functions, such as atmospheric correction, radiometric calibration, spectral analysis, and time-series studies, making it a preferred choice for researchers dealing with

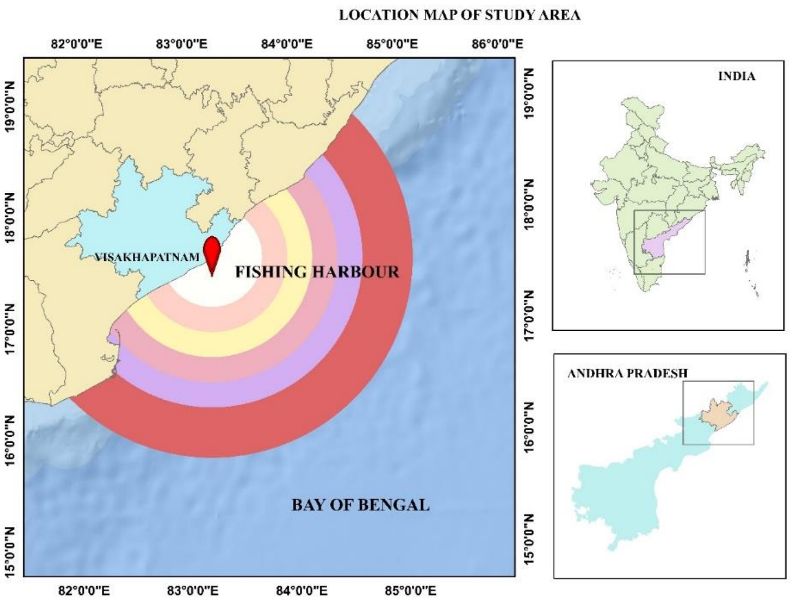

Fig. 1. Study area

satellite-derived ocean parameters, which are particularly suitable for marine and coastal studies (Ginanjar et al., 2025). SeaDAS ensures high accuracy in SST retrieval through a combination of remote sensing algorithms. Its open-source nature and user-friendly interface help in the exploration of complex datasets, supporting interdisciplinary studies on climate change and marine ecosystems (Ocean Biology Distributed Active Archive Center, 2017).

2.3 ArcGIS (Arc Geographic Information System)

ArcGIS, developed by Esri, is a software platform that helps users create, manage, analyse, and map data. ArcGIS is a widely used Geographic Information System (GIS) that provides advanced geospatial analysis tools, including buffer creation, spatial interpolation, data integration, mapping, and statistical modelling (Setiawan et al., 2021). ArcGIS excels in spatial visualization, making it an excellent choice for buffer zones, integrating multiple environmental datasets, and conducting geostatistical and zonal statistical analyses (Raja & Kumar, 2023). The advantage of ArcGIS is that it overlays different spatial layers and performs spatial queries, which enhances its applicability in marine studies, particularly in analysing SST gradients and their influence on coastal and offshore environments. GIS enabled the analysis of long-term climate data, including trends in temperature, sea level rise, and changes in ice cover and vegetation.

2.4 Satellite-Derived Sea Surface Temperature

Monitoring the SST is essential for understanding various scientific phenomena, including sea level rise, salinity, upwelling, Potential Fishing Zones (PFZ), eddies, and cyclones (Narayanan et al., 2013). One major advantage of satellite remote sensing for SST is its ability to collect data across vast areas in near real-time (Hosoda et al., 2007). Satellite sensors, such as MODIS, AVHRR and SeaWiFS can capture brightness values across different spectral bands. For this study, 12 monthly level 3 Aqua MODIS satellite images, each with a resolution of 4 × 4 km, were downloaded from the NASA Ocean Color website (https://oceandata.sci.gsfc.nasa.gov/l3/) for the period from January to December 2024.The Aqua MODIS SST retrieval algorithm is given below.

$$SST = aij_0 + aij_1 BT_{11\mu m} + aij_2 (BT_{11\mu m} - BT_{12\mu m}) T_{sfc} + aij_3 (\sec(\theta - 1)\ (BT_{11\mu m} - BT_{12\mu m})\ + aij_4(mirror) + aij_5(\theta *)\ + aij_6(\theta^2)$$

2.5 Methodology

The proposed methodology involves two types of DN value extraction to summarize statistics in a specific buffer zone or polygon from the downloaded image using SeaDAS and ArcGIS. Images downloaded from the NASA website are in the Net CDF format. Initially a buffer zone was created in ArcGIS in the form of shapefile for the

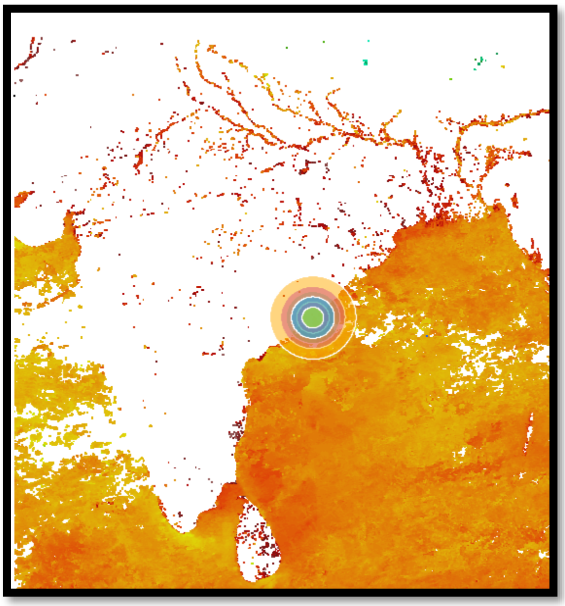

Fig. 2. SST image of SeaDAS with Vector File

Region of Interest (ROI). In this study, the shapefile was created with six different buffer radii with distance of 50km, 75km, 100km, 125km,150km, 200 km from the Visakhapatnam fishing harbor as our ROI.

2.5.1 Extraction of DN value from image using SeaDAS

As an initial step, it is necessary to load the downloaded NetCDF file into SeaDAS. Then, access the file manager and open the file. Within this, there are various folders, and we need to open the "bands" folder and select the "sst" band, which corresponds to the SST satellite image. The SST image will then be displayed. Now we need to add land mask, which is present in the tool bar. Next, add the ROI shapefile by following these steps: Go to the vector menu in the toolbar, click on "Import," then choose "ESRI shapefile," and select the Multi buffer shapefile. This action overlays the vector shapefile on the Net CDF SST image, which can be seen in the following image (Fig. 2). Now, navigate to the analysis section in the toolbar and click on "Statistics" to obtain the summary statistics. In the dialog box, we can observe various headings, including "bands," "ROImask," and "Flagmask." Click on the "band" option, then select "sst". For the ROI-Mask, click on the Multi buffer shapefile, at the bottom, select "Individual" on “Mask grouping" and finally click on "Run." The statistics will be displayed on the screen. This outlines the methodology for extracting statistics for an ROI in SeaDAS providing a straightforward approach for oceanographic data analysis (Alaudin et al., 2024). The entire process is depicted in flow chart as Fig. 3.

2.5.2 Extraction of DN value from image using ArcGIS

To extract SST data in ArcGIS, it is necessary to convert the image format from Net CDF to Geo TIFF, as Net CDF files are not supported in ArcGIS. For that in SeaDAS, load the SST Net CDF file, open the " sst" band, now apply the land mask present in the tool bar and proceed to the file menu in the toolbar, and export the file as a Geo TIFF file format. Next, open ArcGIS and load the TIFF file of SST into it. We then use various geoprocessing methods to remove negative values present in the data. Then to get the DN value of SST by opening the zonal statistics tool in the geoprocessing menu and select "Zonal Statistics as Table." For the input raster or feature zone data at the top, give input as ROI file. Next for the Zone Field, select the appropriate ID and for the Value Raster and give input as processed raster. It gives various statistical types such as mean, median, and standard deviation. In this study, the saved mean value from the ROI is used for comparison. This outlines the methodology used for extracting summary statistics is available in ArcGIS manual (Esri, 2025). The entire process is depicted in flowchart as Fig. 3.

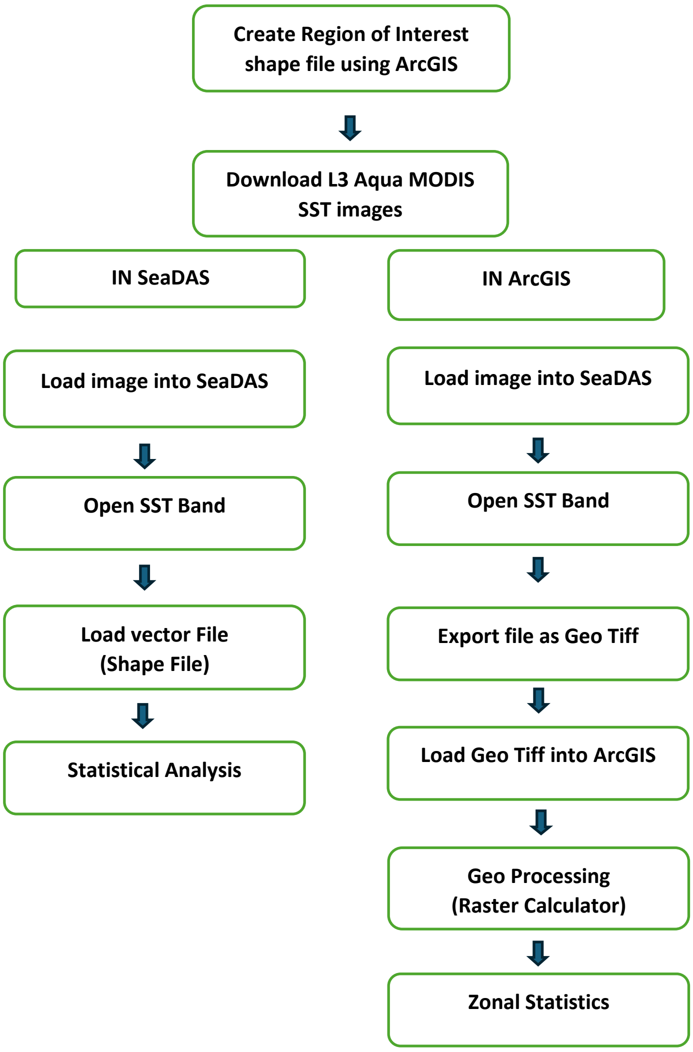

Fig. 3. Flow Chart of Methodology

2.6 Methods of Evaluation

The Absolute Percentage Error (APE) was utilized to quantify the difference between the mean values derived from SeaDAS and ArcGIS, enabling a comparative assessment of the two data extraction approaches (Khair et al., 2017).

$$APE = Abs\left(\frac{ArcGIS - SeaDAS}{ArcGIS}\right) \times 100$$

3. RESULTS AND DISCUSSION

The dataset examines the SST in the coastal waters of Visakhapatnam in the Bay of Bengal and compares the, ArcGIS and SeaDAS datasets across multiple buffer zones (50 km to 200 km). The analysis provides insights into seasonal variations, spatial patterns, and the accuracy of ArcGIS relative to SeaDAS. We also used metrics such as mean SST, error values, and APE. A detailed discussion of the results follows.

The evaluation of monthly buffer analyses presented in Table 1 and Table 2 reveal a consistent pattern across the year. For the 50 to 150 km buffers, the number of valid pixels remains identical between SeaDAS and ArcGIS, and the mean values are so closely matched that any error is negligible, typically appearing only at the sixth decimal place. This consistency demonstrates a high level of accuracy and agreement between the SeaDAS and ArcGIS within these buffer ranges.

However, a consistent discrepancy emerges in the 200 km buffer for each month, where SeaDAS reports one pixel fewer than ArcGIS. While the difference of a single pixel might seem insignificant, however it leads to a relatively

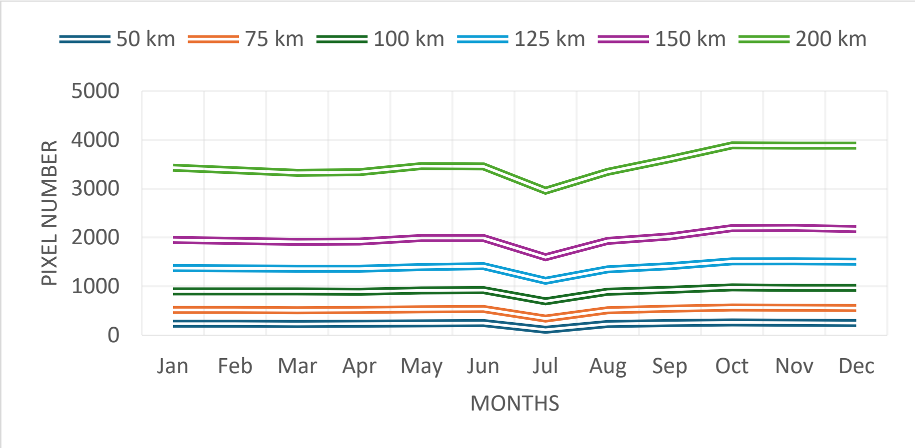

Fig. 4. Pixel Number of ArcGIS at different Buffer Zones

higher error in this buffer zone compared to the others. The associated error values and Absolute Percentage Errors (APE) for the 200 km buffers, although still quite low (ranging approximately from 0.000007 to 0.000163 for error values and from 0.000023 to 0.000563 for APE), are notably higher than those in the 50–150 km buffers. This suggests that while both tools are largely in agreement, the slight deviation in pixel count at the 200 km range introduces a minor yet consistent error, possibly due to differences in how each software handles buffer boundaries or pixel inclusion at outer edges.

It is evident that minimal absolute error between the values obtained from the two methods (Table 3). The error values are found within the range 0.000007 to 0.000163. We can see differrences in error values across the different months. The minimal error 0.000007 occurs in June and then in November at 0.000045. The highest error is observed in March at 0.000163, followed by August at 0.000137. The lowest APE is found in June at 0.000023, followed by November at 0.000157. The highest APE is recorded in March at 0.000563, followed by August at 0.000464.

The data indicate that the number of valid pixels fluctuates from month to month in SST readings (Fig. 4). The highest number of valid pixels is observed in October, November, and December. In contrast, there is a gradual decline in the number of valid pixels during the month of July across all buffers. Similar findings were reported by Redfern et al. (2023) in his study, who also noted missing pixels during July (2020). During the monsoon, there is a data gap of about 15-20%. Azmi et al. (2015) found that there is a 50-60% gap in data during the monsoon season at the Mumbai coast in the Arabian Sea.

4. CONCLUSION

This study assessed the performance of SeaDAS and ArcGIS in extracting zonal statistics for SST analysis in the coastal waters of Visakhapatnam, Bay of Bengal, using Aqua MODIS satellite imagery from January to December 2024 across buffer zones of 50 km, 75 km, 100 km, 125 km,150 km, 200 km. Both tools yielded highly consistent mean SST values, with absolute errors ranging from 0.000007 to 0.000163°C and absolute percentage errors (APE) ranging from 0.000023 to 0.000563. The errors remained negligible up to 150 km, but a consistent one-pixel discrepancy at 200 km slightly elevated errors, peaking in March (0.000163°C) and minimizing in June (0.000007°C). SeaDAS is an open-source free software, offers superior precision for processing satellite-derived Net CDF data, making it ideal for researchers prioritizing SST accuracy in oceanographic studies. ArcGIS, despite requiring format conversion, excels in geospatial visualization and multilayer integration, enhancing its utility for comprehensive marine and climate analyses. For fishery zone delineation in the Bay of Bengal, both tools are reliable because, errors below 0.0002°C fall well below typical SST thresholds for ecological impacts. The choice depends on user needs: SeaDAS for rapid, precise processing, and ArcGIS is suitable for advanced spatial presentation. Future research should address the monsoon-related data gaps, which reduce pixel counts by 15-20% in July, to improve SST retrieval accuracy in tropical regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

ACKNOWLEDGEMENT

The support and co-operation received from the Department of Fisheries Engineering, College of Fishery Science at every stage of the study is warmly acknowledged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Table 1. Monthly analysis From January to June

		ArcGIS		SeaDAS			
	Buffer in km	**Pixel**	**Mean**	**Pixel**	**Mean**	**Error**	**APE**
January	50	234	25.874762	234	25.874764	0.000002	0.000009
	75	519	26.001261	519	26.001261	0.000000	0.000001
	100	898	26.115992	898	26.115991	0.000001	0.000002
	125	1375	26.229845	1375	26.229847	0.000002	0.000007
	150	1951	26.351080	1951	26.351078	0.000002	0.000007
	200	**3427**	**26.546511**	**3426**	**26.546393**	**0.000118**	**0.000443**
Febuaruy	50	234	27.279337	234	27.279337	0.000000	0.000000
	75	516	27.358837	516	27.358837	0.000000	0.000000
	100	895	27.404587	895	27.404586	0.000001	0.000003
	125	1366	27.431904	1366	27.431903	0.000001	0.000003
	150	1929	27.486904	1929	27.486904	0.000000	0.000001
	200	**3376**	**27.627579**	**3375**	**27.627473**	**0.000106**	**0.000383**
March	50	232	28.711809	232	28.711810	0.000001	0.000003
	75	511	28.773289	511	28.773287	0.000002	0.000006
	100	895	28.885658	895	28.885659	0.000001	0.000003
	125	1364	28.938021	1364	28.938020	0.000001	0.000002
	150	1914	28.955896	1914	28.955895	0.000001	0.000005
	200	**3327**	**29.003969**	**3326**	**29.003806**	**0.000163**	**0.000563**
April	50	235	30.102489	235	30.102489	0.000000	0.000002
	75	514	30.138083	514	30.138083	0.000000	0.000002
	100	893	30.159155	893	30.159154	0.000001	0.000003
	125	1358	30.161255	1358	30.161255	0.000000	0.000000
	150	1916	30.203268	1916	30.203267	0.000001	0.000003
	200	**3340**	**30.305183**	**3339**	**30.305252**	**0.000069**	**0.000226**
May	50	244	30.826332	244	30.826331	0.000001	0.000004
	75	530	30.947727	530	30.947726	0.000001	0.000004
	100	916	30.984192	916	30.984191	0.000001	0.000003
	125	1394	31.015451	1394	31.015451	0.000000	0.000001
	150	1988	31.145554	1988	31.145555	0.000001	0.000005
	200	**3462**	**31.343615**	**3461**	**31.343521**	**0.000094**	**0.000299**
June	50	246	30.260061	246	30.260060	0.000001	0.000004
	75	535	30.269785	535	30.269784	0.000001	0.000003
	100	923	30.311268	923	30.311267	0.000001	0.000003
	125	1411	30.381163	1411	30.381165	0.000002	0.000008
	150	1987	30.410921	1987	30.410920	0.000001	0.000004
	200	**3456**	**30.579834**	**3455**	**30.579827**	**0.000007**	**0.000023**

Table 2. Monthly Analysis from July to December

		ArcGIS		SeaDAS			
	Buffer In Km	**Pixel**	**Mean**	**Pixel**	**Mean**	**Error**	**APE**
July	50	111	27.963554	111	27.963558	0.000004	0.000013
	75	340	28.130718	340	28.130720	0.000002	0.000006
	100	694	28.189150	694	28.189149	0.000001	0.000003
	125	1114	28.310106	1114	28.310107	0.000001	0.000003
	150	1596	28.364578	1596	28.364580	0.000002	0.000006
	200	**2958**	**28.510481**	**2957**	**28.510366**	**0.000115**	**0.000403**
August	50	232	29.496292	232	29.496292	0.000000	0.000000
	75	509	29.370001	509	29.369999	0.000002	0.000006
	100	893	29.340469	893	29.340470	0.000001	0.000002
	125	1346	29.391842	1346	29.391842	0.000000	0.000000
	150	1932	29.396414	1932	29.396412	0.000002	0.000006
	200	**3346**	**29.423143**	**3345**	**29.423280**	**0.000137**	**0.000464**
September	50	252	29.875872	252	29.875872	0.000000	0.000001
	75	540	29.866222	540	29.866222	0.000000	0.000001
	100	929	29.759581	929	29.759580	0.000001	0.000002

		ArcGIS		SeaDAS			
	Buffer In Km	Pixel	Mean	Pixel	Mean	Error	APE
	125	1415	29.709610	1415	29.709611	0.000001	0.000003
	150	2025	29.745995	2025	29.745994	0.000001	0.000002
	200	**3608**	**29.828123**	**3607**	**29.828210**	**0.000087**	**0.000291**
October	50	261	30.419653	261	30.419655	0.000002	0.000007
	75	567	30.447701	567	30.447698	0.000003	0.000008
	100	979	30.454050	979	30.454049	0.000001	0.000003
	125	1509	30.430580	1509	30.430579	0.000001	0.000004
	150	2194	30.451580	2194	30.451581	0.000001	0.000003
	200	**3886**	**30.522985**	**3885**	**30.523055**	**0.000070**	**0.000228**
November	50	256	28.731289	256	28.731288	0.000001	0.000003
	75	562	28.736244	562	28.736245	0.000001	0.000003
	100	971	28.711998	971	28.711997	0.000001	0.000003
	125	1513	28.706659	1513	28.706662	0.000003	0.000009
	150	2197	28.733824	2197	28.733823	0.000001	0.000003
	200	**3883**	**28.880903**	**3882**	**28.880858**	**0.000045**	**0.000157**
December	50	251	26.793924	251	26.793924	0.000000	0.000001
	75	557	26.988779	557	26.988779	0.000000	0.000000
	100	970	27.111784	970	27.111783	0.000001	0.000004
	125	1504	27.196808	1504	27.196808	0.000000	0.000001
	150	2174	27.301113	2174	27.301113	0.000000	0.000000
	200	**3882**	**27.481401**	**3881**	**27.481333**	**0.000068**	**0.000249**

Table 3. Annual 200Km Buffer Analysis

Month	ArcGIS Pixels	ArcGIS Mean	SeaDAS Pixel	SeaDAS Mean	Error	APE
January	3427	26.546511	3426	26.546393	0.000118	0.000443
February	3376	27.627579	3375	27.627473	0.000106	0.000383
March	3327	29.003969	3326	29.003806	0.000163	0.000563
April	3340	30.305183	3339	30.305252	0.000069	0.000226
May	3462	31.343615	3461	31.343521	0.000094	0.000299
June	3456	30.579834	3455	30.579827	0.000007	0.000023
July	2958	28.510481	2957	28.510366	0.000115	0.000403
August	3346	29.423143	3345	29.423280	0.000137	0.000464
September	3608	29.828123	3607	29.828210	0.000087	0.000291
October	3886	30.522985	3885	30.523055	0.000070	0.000228
November	3883	28.880903	3882	28.880858	0.000045	0.000157
December	3882	27.481401	3881	27.481333	0.000068	0.000249

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/134745