INCOIS Technical Report No: ESSO-INCOIS-OMARS-TR-02(2024)

Search and Rescue Aid Tool (SARAT) Version 2

By

Vijay Pottapinjara, Venkata Sai Gulakaram, Karthik TNC, Sudheer Joseph, and Balakrishnan Nair TM

Indian National Centre for Ocean Information Services (INCOIS)

Earth System Science Organization (ESSO)

Ministry of Earth Sciences

Hyderabad, India

March 2024

DOCUMENT CONTROL SHEET

Earth System Science Organization (ESSO)
Ministry of Earth Sciences (MoES)
Indian National Centre for Ocean Information Services (INCOIS)

ESSO Document Number: ESSO-INCOIS-OMARS-TR-02(2024)

Title of the report: Search and Rescue Aid Tool (SARAT) Version 2

Author(s): Vijay Pottapinjara, Venkata Sai Gulakaram, Karthik TNC, Sudheer Joseph, and Balakrishnan Nair TM

Originating unit: Applied Research & Research to Operations, INCOIS.

Type of Document: Technical Report (TR)

Number of pages and figures: 20, 09

Number of references: 03

Keywords: Search and Rescue, Leeway model, Monte-Carlo methods, Applied Research, Indian Ocean

Security classification: Open

Distribution: Open

Date of publication: March 2024

Abstract:

The Indian National Centre for Ocean Information Services (INCOIS) developed Search and Rescue Aid Tool (SARAT) to aid the Indian Search and Rescue (SAR) agencies in their operations at sea. The SARAT application can simulate the probable search area of a range of objects lost at sea, when provided with the last known time and location of the lost object. This document discusses the recent improvements to the existing SARAT application, paving the way for SARAT version 2. Most importantly, the position from which the search area expands has now been corrected to be the last known position of the object. In the earlier version, it was taken as the convex hull vertex with the minimum longitude, which was not collocated with the origin of the simulated particle tracks. The improved probable search area now corresponds well with the density of the simulated particle tracks. Other improvements in SARAT version 2.0 include the provision of simulated particle tracks, their mean trajectory in addition to the probable search area, better visualization in terms of distinct color-coded search regions, a marker for easier identification of the last known position of the object, among others. This report also discusses several improvements to Search and Rescue Aid Tool - Integrated (SARAT-I) such as running the SARAT simulations in all the high-probability cells and providing the results of each cell in the advisory. With all the above improvements, SARAT version 2 is expected to contribute to SAR operations in the Indian Ocean.

Search and Rescue Aid Tool (SARAT) Version 2

By

Vijay Pottapinjara, Venkata Sai Gulakaram, Karthik TNC, Sudheer Joseph, and Balakrishnan Nair TM

Indian National Centre for Ocean Information Services (INCOIS)

Earth System Science Organization (ESSO)

Ministry of Earth Sciences

Hyderabad, India

March 2024

Acknowledgements

Authors thank Dr. T. Srinivasa Kumar, Director, INCOIS for his support and encouragement. Authors acknowledge constant feedback from the Indian Coast Guard in improving SARAT.

Author Contributions

VP designed the study. VP and VSG conducted the experiments and prepared the manuscript. KTNC provided the necessary technical support. SJ and TMB provided support and guidance.

Table of contents

1. Introduction

To cater to the needs of concerned Search and Rescue (SAR) agencies in the Indian Ocean region, Indian National Center for Ocean Information Services (INCOIS) developed and operationalized the Search and Rescue Aid Tool (SARAT) in 2016 (Aswathi, 2016) based on the LEEWAY model (Brevik et al., 2013). This application is widely used, especially by the Indian Coast Guard, the nodal agency for the SAR operations in the northern Indian Ocean. It is currently available at https://sarat.incois.gov.in/sarat/home.jsp.

When a person or an object goes missing at sea, due to the ever-dynamic nature of the sea, the object, or the person drifts away from where it was lost. The main factors that influence the leeway or the drift of the object are surface winds, currents, and waves. Each object interacts differently with a given set of forcings, due to differences in the size, dimensions, buoyancy, among others. Such interactions of the object with forcing fields are encapsulated in the leeway coefficients of the object. Given the Last Known Position (LKP) and Last Known Time (LKT) of the missing object, type of the object and the time when the object would be searched, SARAT gives the probable regions where the object may be found, under the action of surface winds and currents. SARAT can estimate the marine drift of more than 70 objects stored in SARAT. The output can be used to plan marine SAR operations by the concerned authorities.

In the SARAT output, the space around LKP of the object is divided into regions of different probabilities of finding the missing object. In a recent exercise of a thorough validation of SARAT, it was discovered that the location from where the probability regions extend does not match with the LKP of the object, contrary to our expectations.

In such a case, the probable search areas differ from the actual, misguiding SAR operations. Therefore, it is important to resolve this problem for better accuracy and utility of SARAT outputs. In this report, we discuss the methodology of how this problem is resolved. It directly improves the Search and Rescue Aid Tool – Integrated (SARAT-I) as well. In addition, various improvements to the web interfaces of SARAT and SARAT-I have also been discussed. With all these improvements, the newer version is named SARAT version 2 and is available at https://sarat.incois.gov.in/saratV2/home.jsp. The updated SARAT-I version is available at https://sarati.incois.gov.in/.

2. Correcting the origin of search area expansion

We used a standalone SARAT system to conduct the experiments so that the existing operational system is not disturbed. The standalone setup uses the same SARAT numerical code and is forced by the 10 m winds from ECMWF and surface currents from ROMS 1st-day forecasts.

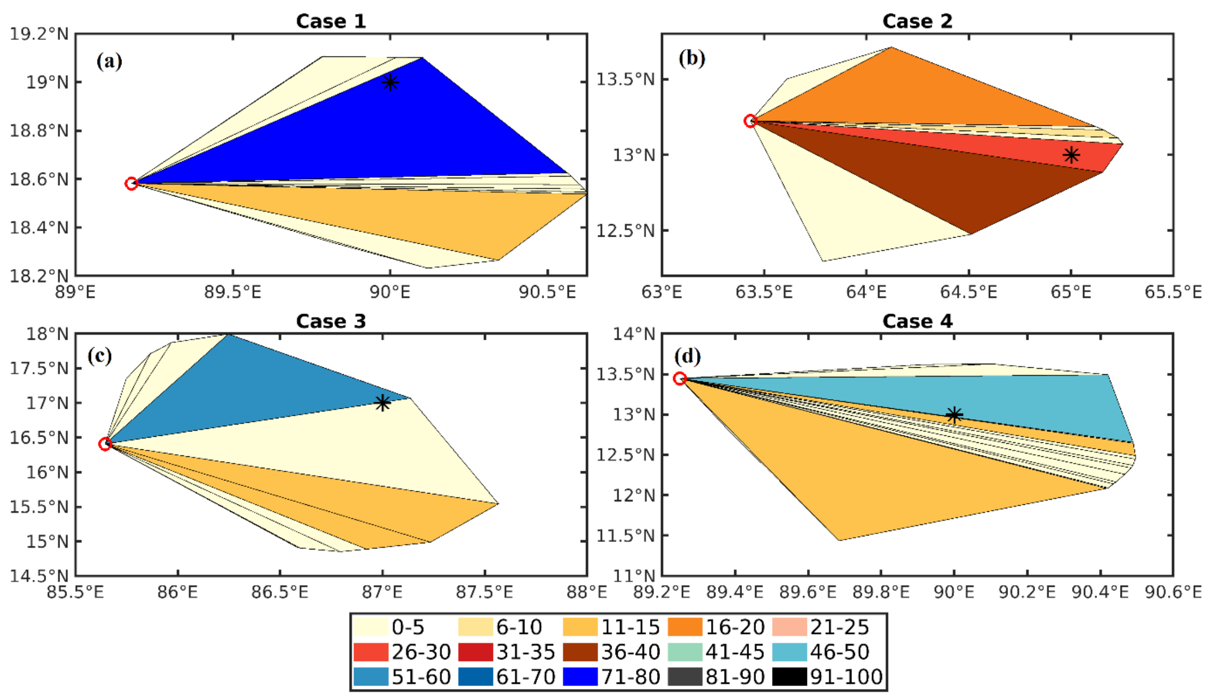

Figure 1: SARAT version 1 simulations of the probable search regions for different LKP and LKT showing the expansion of search regions from the location marked by a circle in red. The LKP is marked by * in black. The object class used in the simulations is Person-in-Water-Deceased (PIWD). The period of simulation and LKP are, a) Case 1 (during 15-01-2016 05:30 – 19-01-2016 05:30 at 19°N and 90°E), b) Case 2 (during 15-01-

2016 05:30 – 19-01-2016 05:30 at 13°N and 65°E), c) Case 3 (21/02/2016 00:00 – 25/02/2016 21:00 at 17°N and 87°E), and d) Case 4 (15/01/2016 06:00 – 19/01/2016 06:00 at 13°N and 90°E). Note that the search area expands from a location other than the LKP.

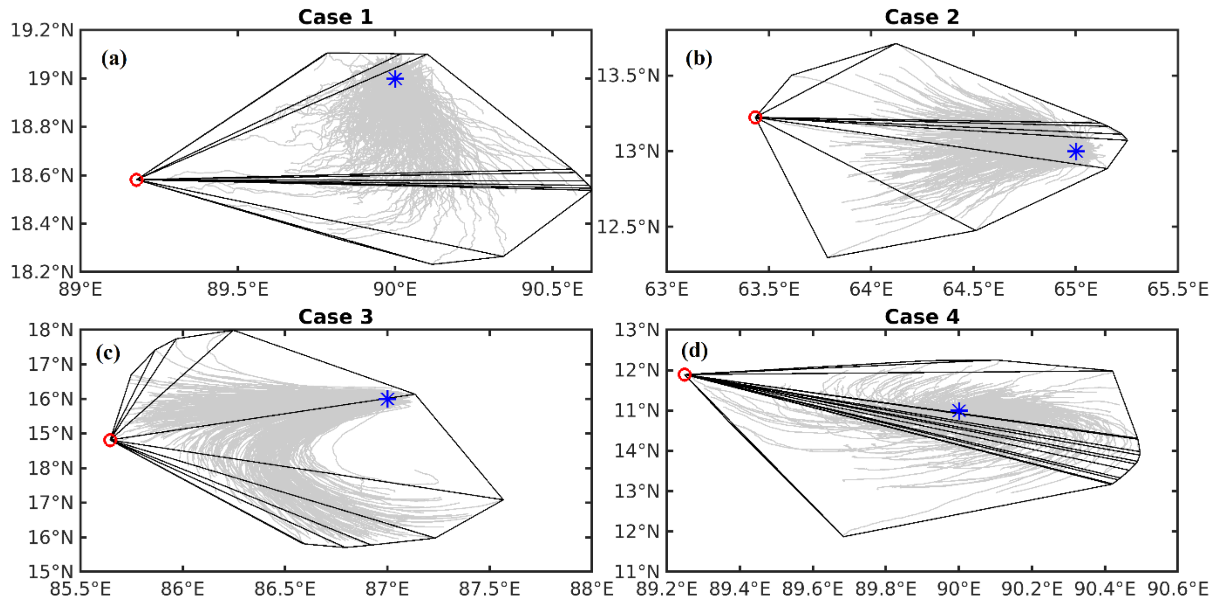

Figure 2. The corresponding particle tracks for the simulations shown in Figure 1. The LKP is marked as * in blue, and the location where the search area expands is marked by circle in red. Note that the particle tracks diverge from the convex hull vertex with the westernmost longitude, a location other than the LKP.

Simulations with different LKT and LKP have been conducted to diagnose the problem in the representation of probable regions using the existing version of SARAT (Fig. 1). In each case, irrespective of LKP and LKT, the search area expands from a location different from the respective LKP, more specifically, from the vertex of the convex hull with the westernmost longitude. This is contrary to our expectation, because, ideally, the search area should expand from the respective LKP. To further ascertain this observation, the corresponding simulated particle trajectories are shown in Fig. 2 wherein the particles drift away from the LKP as they should, confirming our observation about the search area expansion. Moreover, the search areas (triangular regions) are completely different between Fig. 1 and Fig. 3.

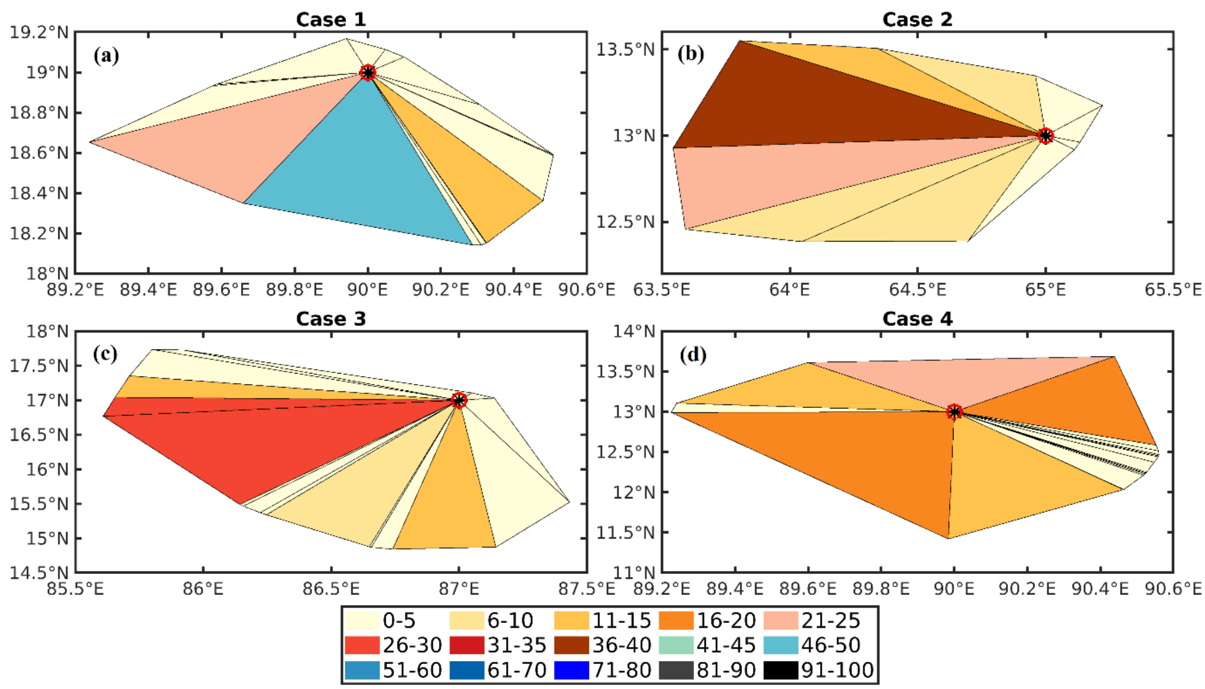

Figure 3. SARAT version 2 simulations for the same LKP and LKT as shown in Figure 1 but after modifications to the numerical model. The LKP is marked by * in black and the location where the search area expands is marked by a circle in red. Note that after modifications, the search expands from LKP as it should.

It is important to understand how the probabilities are computed in each search area to appreciate the role of origin of search area expansion. The farthest points of all simulated particle trajectories or vertices are identified and joined with the origin. The vertices are all joined to form a convex hull. Each triangular region forms a search area and the probability of finding the missing object is computed as the ratio of number of particle trajectories ending up in the search area to the total number of particles released (500, in general). If the origin is moved, the triangular search areas will be different, and the corresponding probabilities will change.

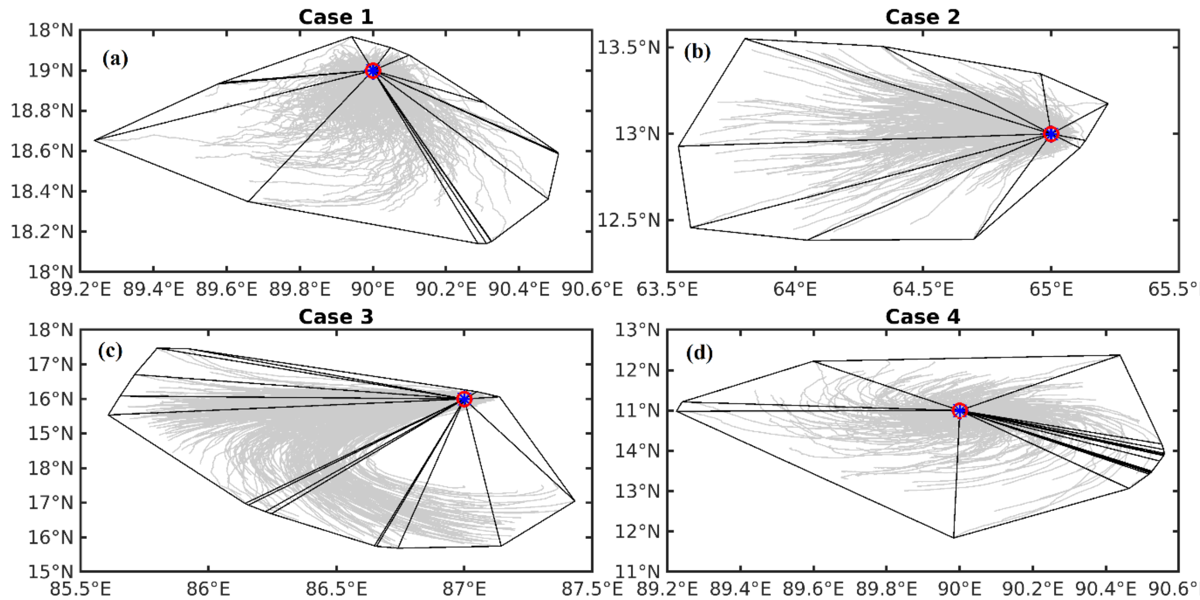

Figure 4. Particle tracks for the simulations shown in Figure 1 but after modifications to the numerical code (SARAT version 2). These particle tracks correspond to search areas shown in Figure 3. The LKP is marked by * in blue, and the location where the search area expands is marked by a circle in red. Note that after modifications, the particle tracks diverge from LKP as they should.

The search area expansion from an incorrect location other than the LKP in the earlier version can mislead the SAR operations. Generally, the SAR authorities search for the missing object in the highest probability region first. If they cannot trace the object in the highest probability region, they are advised to search for the object in the next highest probability region. As we know, 'time' is the most important limiting factor in the SAR operations. Therefore, the SAR operations need to be conducted in more appropriate search regions to ensure a faster response and higher chances of rescue.

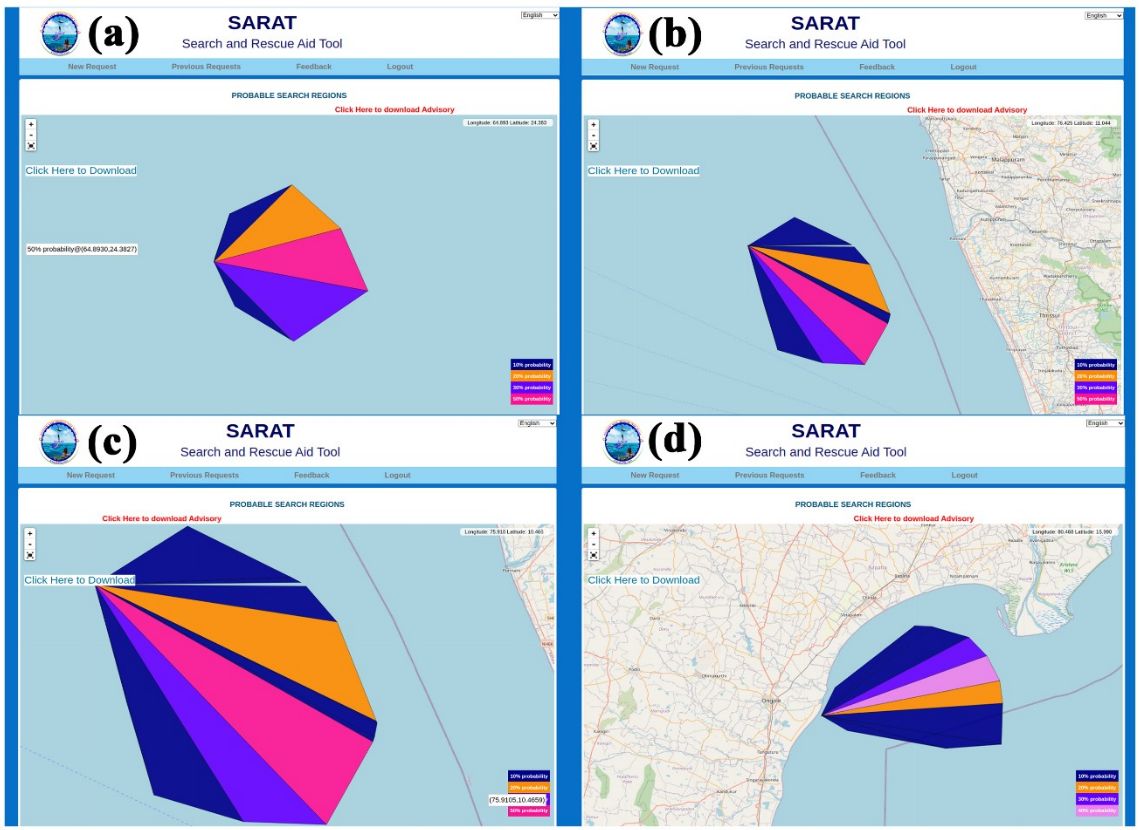

Figure 5: The SARAT (version 1) outputs for different cases in the web application. The search area expansion occurs from the convex hull with the westernmost longitude as in Fig. 1.

The incorrect search area expansion is corrected in SARAT version 2 by changing the numerical code of SARAT. The simulations for the same cases in Fig. 1 are conducted using SARAT version 2 again (Fig. 3), and the corresponding particle trajectories are shown in Fig. 4. The search areas now expand from the LKP (Fig. 3) as they should, further ascertained by the corresponding particle trajectories (Fig. 4). As noted earlier, all these simulations have been conducted using a standalone SARAT model. The SARAT numerical code is modified suitably to correct the search area expansion in the standalone version and the same is used in version 2 of operational SARAT in the web application. Example web outputs of SARAT version 1 and version 2 are shown in Fig. 5 and Fig. 6, respectively.

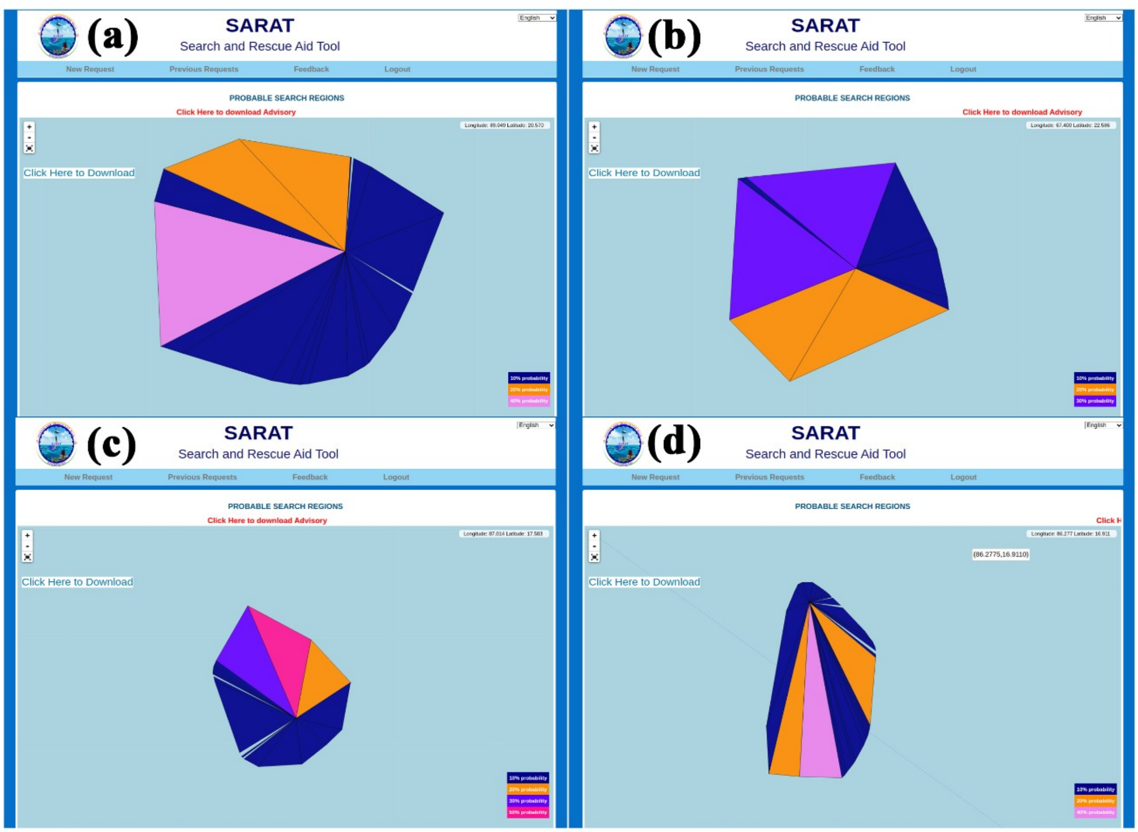

Figure 6: The SARAT (version 2; during modifications) outputs for different cases in the web application. The search area expansion occurs from the LKP as in Fig. 3.

3. Improved visualization in SARAT version 2

Various changes to the SARAT numerical code and the corresponding probable search regions are shown in Fig. 6. In Fig. 6a – 6c, although the probable search area expands from the LKP, some of the vertices of the convex hull are not joined. With suitable modifications in the numerical code, those problems are solved in Fig. 6d. The eventually successful changes to the numerical code are implemented in SARAT version 2. Further, the gaudy color coding of probable search areas in the earlier version of SARAT are now modified with soothing color coding with 5% interval below 50% and 10% interval from 50% to 100% in version 2 as shown in Fig. 7. The simulated particle trajectories are shown overlaid on the probable search regions along with a mean trajectory (Fig. 7b). The simulated particle trajectories and the mean trajectory can be shown as per the user's choice. Furthermore, the outputs, i.e., probable search area regions and the particle trajectories are provided in the downloadable output file as well (Fig. 8). The LKP is marked for easier identification. The mean trajectory is the average of all the particle trajectories. The mean trajectory gives us the general direction of drift of general from the LKP. However, in the case of an eddy or a cyclone, surface currents tend to move the simulated particles in all directions, making the mean trajectory a less useful piece of information.

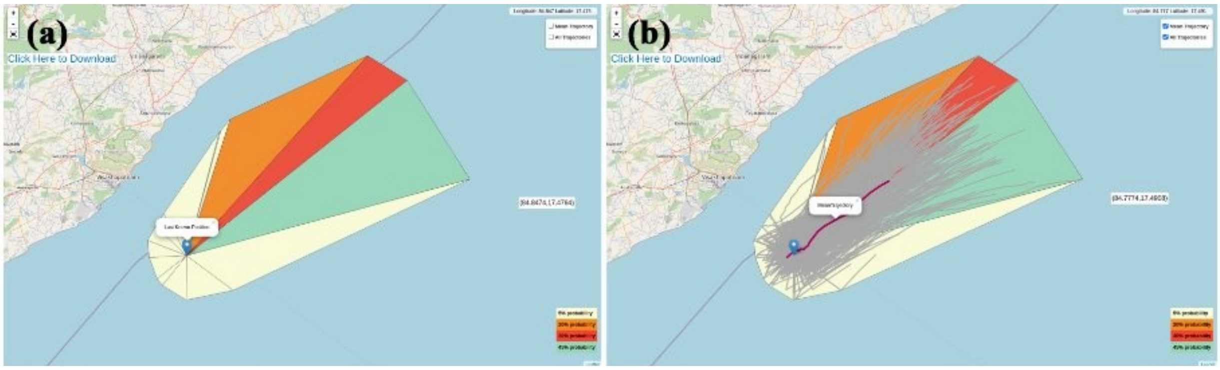

Figure 7. Web interface of probability regions of the missing object from the SARAT application without (a) and with (b) simulated particle trajectories along with the mean trajectory.

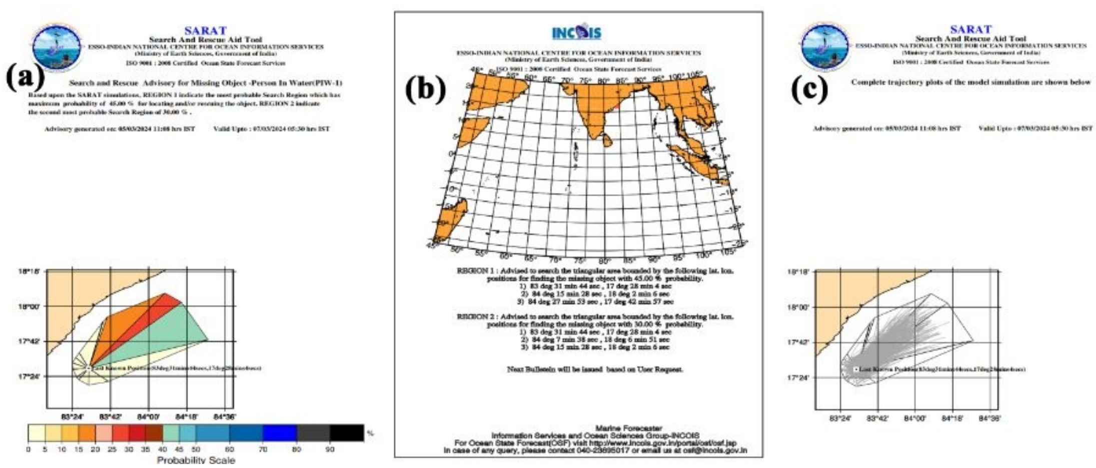

Figure 8. Downloadable pdf output of search and rescue advisory for the missing object or person from the SARAT application.

4. Implied improvements to SARAT-I

INCOIS developed the Search and Rescue Aid Tool – Integrated (SARAT-I) as described in Banoth et al. (2022). It aids the SAR agencies in tracing the wreckage or debris of an aeroplane that crashed while flying over the sea. The probable marine drift of the airplane is simulated using SARAT. The latest SARAT version 2 is now integrated into SARAT-I and the subsequent improvements to SARAT-I are discussed in the following.

As discussed in Banoth et al. (2022), the probable area of finding the wreckage or debris of crashed aircraft can be simulated using a series of SARAT simulations starting from the cell centers of the highest probability (of the plane landing/crashing into the sea) along the planned flight path. The improvement in the marine drift (SARAT) search area expansion can be observed between Fig. 7 and Fig. 8. Whereas in Fig. 7, the search area expands from a location other than the cell center, which was taken as LKP for the SARAT simulation, it expands from the high probability cell centers in Fig. 8. In addition to the integrated view of the probable search regions, the downloadable output of SARAT-I now contains the ten individual SARAT simulations for each high probability cell along the planned flight path. In the SARAT-I web application, individual SARAT simulations for each high probability cell can be selected as shown in Fig. 9.

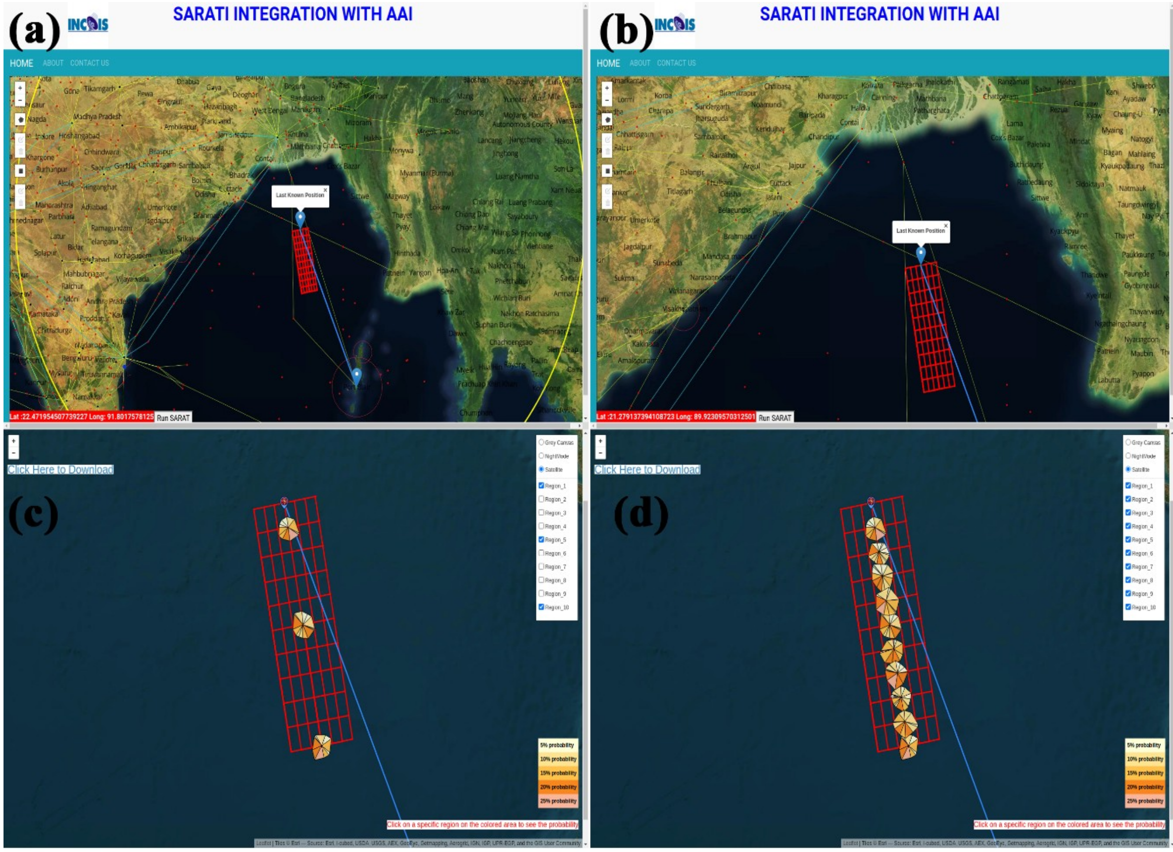

Figure 9: Web interface of SARAT-I application showing the grid cells of probable crashing area of the aeroplane (a, b), probability regions at different cell centers obtained from SARAT (c, d).

5. Conclusion

SARAT version 2 is a major improvement over the earlier version. Most importantly, the origin of search area expansion and corresponding search regions have been corrected in SARAT version 2. This implies the search regions are more accurate than before. Several important changes to the visualizations have also been made such as the provision of particle trajectories for a better judgement of probable area of finding the missed object, color coding of search regions and identification of the LKP in the SARAT outputs. These improvements in SARAT version 2 are also reflected in the SARAT-I. With all the above improvements, SARAT version 2 and SARAT-I instill more confidence in India's SAR capabilities.

References

1. Aswathi, D. M. T. (2016). *Efforts of Setting Up Search and Rescue Operations in Indian Ocean.* Dissertation thesis. Cochin University of Science and Technology, Kerala, India.
2. Banoth, T., Pottapinjara, V., Modi, A., Joseph, S., Nair, T. M. B., Rohilla, Y., Singh, A., Kumar, T.S. (2022). Development of Search and Rescue Aid Tool-Integrated (SARAT-I) to simulate the probable drift area of a missing aircraft at sea. *Tech. Rep.* Indian National Centre for Ocean Information Services. (ESSO-INCOIS-OMARS-TR-04).
3. Breivik, Ø., Allen, A. A., Maisondieu, C., & Olagnon, M. (2013). Advances in search and rescue at sea. *Ocean Dynamics*, 63, 83-88.