

MARINE MONITOR DATA

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The geospatial data distributed here are in shapefile and KML (Keyhole Markup Language) format in decimal degrees and datum WGS84. They were collected via a Marine Monitor (M2) system and represent potential vessel activity in the nearshore coastal area within spatial range of the local system. Downloads are provided for the prior full day, prior full week, prior months, and current months up to the prior day.

Shapefiles and KML files are configured to be viewed in geospatial software. If interacting with or moving data into other platforms, be advised that typecasting may become unstable for some data fields.

*Note: This document is updated over time and packaged with data at the time of final data processing for the selected download time period. Therefore, older data may be packaged with previous versions of this document. Refer to recent data for the most up-to-date ReadMe file. Contact m2@protectedseas.net for questions or clarification on anything in this document.

Automatic Identification System (AIS) Data

These data are received by an AIS receiver (if installed at site). Data are provided by the vessels and their onboard instruments and transmitted to the M2 AIS receiver where the data are integrated into the M2 system processes.

Radar Data

These data are processed by the marine radar sensor. Targets are tracked using the Automatic Radar Plotting Aid (ARPA) which identifies unique targets and tracks them over time. Because radar may also track those vessels broadcasting AIS data, an algorithm is applied to search for the following similarities between radar and AIS data:

- target detections were within 100 meters in geolocation,
- target detections occurred less than 15 seconds apart,
- target detections had a difference in speed less than 1.5 knots, and
- target detections had less than a 10-degree difference in heading.

If these conditions are met for at least 20 target detection points, the corresponding radar target data are not presented under default conditions in the M2 Viewer, but note that all data are included in the data download package.

Radar Range

This polygon represents the spatial extent of reliable radar target detection. Most sites have the most reliable detection to 5 nautical miles, but this may be greater depending on conditions and vessel size and construction. This polygon is created by first considering the arc (range of degree values about the M2 site) of possible detection set via the proprietary radar system. Next, local topography is considered that may block the radar beam from reaching the water. This polygon is viewable as a map layer in the M2 Viewer.

Exclusion Zones

These polygons are zones where the M2 software does not collect radar tracking data. These zones are typically created around land and near-shore areas where there is a high likelihood of falsely detecting land and waves as targets. These zones are also used to block known structures on the water, such as oil platforms and buoys, so that they are not continuously detected as targets. *Note: These zones are editable within the M2 Viewer for some administrative users, so the boundaries may change slightly over time depending on changing conditions and need. Some sites may not have any associated exclusion zones.

CONSIDERATIONS

Because AIS data are transmitted via very high frequency (VHF) radio waves, the spatial range of AIS data received is likely different than the range of data collected via radar. The spatial range of radar data collection is dependent on local conditions and the radar antenna model specifications. See the M2 Viewer map for the most up-to-date radar ranges for each site.

Given the autonomous nature of vessel detection and tracking, false vessel tracks and missed vessels are possible. Since radar technology relies on electromagnetic pulse reflections off of solid objects, exclusion zones have been created around known buoys, land masses, etc. where the system may falsely identify these objects as vessels. When a vessel does pass nearby these objects and into the exclusion zone, the M2 system may drop the target and initiate a new one (depending on time spent in the zone) when the vessel leaves. The same result may occur if multiple vessels are in close proximity with one another as the radar cannot differentiate between multiple unique objects when they are within a certain distance (according to radar antenna model specifications). In certain conditions the M2 system can detect false targets such as standing waves, choppy waters, or rainfall which can also result in false target detection and tracking. Therefore, the total number of tracks observed can be an overestimate of total vessels observed.

The accuracy of radar target detection and tracking is dependent on the proprietary, built-in software belonging to the commercial off-the-shelf radar system. M2 applies a model developed using machine learning to assign target confidence scores (0-1) to each track detected by the system. These scores indicate the likelihood that a target is a true vessel track (scores closer to 1) and are meant to provide a tool for filtering out false targets. Tracks with low target confidence scores are hidden under default conditions in the M2 Viewer, but all tracks are accessible in the M2 Viewer and available in raw data format. While a target is live, the score is calculated every 5 minutes, so tracks with duration less than 5 minutes will not have an associated score. The model uses the following track attributes as potential inputs.

- Speed variation
- Minimum, maximum, average speed
- Curviness
- Distance traveled variation
- Circular mean and standard deviation of heading
- Mean and standard deviation of turning

Model accuracy was evaluated bi-monthly to start, but the frequency of evaluation was reduced to tri-annually beginning in 2022. Two days of recent data are selected from each site, the day with the highest average hourly wind speed and the day with the lowest (track count is used for those sites without available wind data). All observed tracks on these days are ground-truthed to determine if the model accurately predicted the track to be a true vessel or a false target. Model accuracy typically improves over time but can fluctuate with the incorporation of additional data from new sites and different site conditions. A new predictive model is typically trained and deployed at the time of evaluation.

Based on the local site configuration, power or internet outages may occur and lead to gaps in the data provided. In the event that the system loses internet connection only, the system will continue collecting data, and data will be available for download once connection is resumed. System updates and improvements will also occasionally occur that may impact data collection.

The polylines formed by connecting target detection points provided by the M2 system are estimates of the target path using the shortest distance between consecutive points.

DATA ACCURACY

AIS

Vessels equipped with AIS use global navigation satellite system (GNSS) receivers, e.g., GPS, to estimate their location in latitude/longitude format. Vessels using Class A AIS are required to use GNSS receivers with high positional accuracy, usually within 10 meters (IMO Resolution A.1106(29)). GNSS receivers must also report vessel speed over ground within 2% of a vessel's true speed, or 0.2 knots, whichever is greater. Modern satellite positioning systems use extensive model-based filtering to reduce positional and derivative errors.

Radar

Target positions detected by radar are subject to the reported accuracy of the radar systems in use at each location, as published in radar manufacturer specifications. The range accuracy (distance from the radar to the target) is 1% of the range scale in use. For example, if the radar range setting is 6 nautical miles, the range accuracy is 0.06 nautical miles (approximately 111 meters). The bearing accuracy (degrees from true north of the target position in relation to the radar) is ± 1 degree. See IMO Resolution MSC.192(79) for more information about radar system functionalities.

Positional Accuracy at Example Ranges

Range Scale (nautical miles)	Range Error (m)	Bearing Error* (m)
0.25	4.63	8.08
0.5	9.26	16.16
0.75	13.89	24.24
1.5	27.78	48.49
3	55.56	96.67
6	111.12	193.94
12	222.24	387.88
24	444.48	775.76

*Approximate bearing error distance expressed as the arc length of reported bearing error (± 1 degree) at given ranges

Target speed and course (reported as speed over ground and course over ground) are calculated by proprietary, manufacturer-specific algorithms. Radar manufacturer specifications do not typically report the accuracy of these variables. Empirical research using a large dataset of tracks estimated that radar systems have a speed accuracy of ± 1.8 knots and a course accuracy of ± 12.4 degrees (95% confidence). See <https://doi.org/10.3390/s25061676> for more information.

FILES PROVIDED

Target Detections (shapefile*, csv*)

These data show each individual detection point from both AIS and radar data. If applicable, filenames of photos captured are referenced. Contact m2@protectedseas.net for photo files.

*Due to file size, detection shapefiles and csv files are not included in monthly data packages, and KML files for detections are not included in any data packages. These files can be provided by request. Contact m2@protectedseas.net.

File name: track_detections_TIMERANGE (.shp or .csv)

Data type: Point

Attributes

-id_detect: Unique identification number for each detection

-id_track: Unique identification number for each track

-id_site: Unique M2 system identifier

-id_m2: Unique track identifier used on M2 Viewer

-source: Identifies if detected by AIS or radar

-speed: Observed speed over ground of target (knots)

-course: Observed course over ground of target (degrees clockwise from north)

-assoc_str: Association strength - numeric count of similar detection points with another track

-assoc_id: The id of the track (id_track) with the most associated detection points

-confidence: Target confidence score (0-1) reflecting the likelihood that a target is a true vessel and not a false target (all AIS tracks will automatically receive a score of 1)

-cdate: Local date when detection point was created in M2 system

-ctime: Local time when detection point was created in M2 system

-longitude: X coordinate (WGS 1984)

-latitude: Y coordinate (WGS 1984)

-photo_file: Filename of photo captured after detection point (if applicable)

-photo_diff: Time delay (seconds) of photo capture after detection point (time for camera to pan)

AIS Tracks (shapefile and KML)

These data are formed from connecting individual detection points from AIS data. Data received from Class A transceivers onboard vessels typically include both vessel and voyage information, but data from Class B transceivers typically only provide voyage information. Vessel-specific data may be missing from track records of those vessels using Class B.

Tracks with only a single detection point will have a record in this file but no drawn polyline geometry. These records are not assigned a unique M2 text identification number, do not populate in the M2 Viewer, and are not considered in reporting. These records can be identified in the raw data as they have NULL values in the 'id_m2' attribute.

KML files

These data are best viewed in the desktop application, Google Earth Pro. Large data sets (such as weekly and monthly) may exceed the file size allowed in the online application, Google Earth. Note that accessing the KML file may produce a warning if there are tracks that do not have at least two unique coordinate positions reported.

File name: tracks_ais_TIMERANGE (.shp or .kml)

Data type: Polyline

Attributes

- id_track*: Unique identification number for each track
- id_site*: Unique M2 system identifier
- id_m2*: Unique track identifier used on M2 Viewer
- source*: Identifies if track was detected by AIS or radar
- duration*: Duration of track time (seconds)
- alarm*: Track triggered local system alarm (0=no, 1=yes)
- min_speed*: Minimum observed speed over ground detected along track (knots)
- max_speed*: Maximum observed speed over ground detected along track (knots)
- avg_speed*: Average speed over ground of all detections along track (knots)
- curviness*: Total distance along track / distance between first and last detection
- duration_z*: Time spent in designated zone of interest (seconds)
- distance*: Total distance target traveled along track (kilometers)
- distance_o*: Maximum distance the target was from its origin (kilometers)
- assoc_str*: Association strength - numeric count of similar detection points with a radar track
- assoc_id*: The id of the radar track (id_track) with the most associated detection points
- tagged*: Whether user has tagged the track in some way on M2 Viewer (0=no, 1=yes)
- has_photos*: Track has associated photos (0=no, 1=yes)
- detections*: Total number of target detections along the track
- mmsi*: Vessel's unique Maritime Mobile Service Identity reported in AIS data
- imo*: Vessel's unique International Maritime Organization number reported in AIS data
- name*: Vessel name reported in AIS data
- type*: Vessel type code classification number reported in AIS data (see definitions below)
- dim_a*: Distance on vessel from AIS antenna fore reported in AIS data (meters)
- dim_b*: Distance on vessel from AIS antenna aft reported in AIS data (meters)
- dim_c*: Distance on vessel from AIS antenna to port reported in AIS data (meters)
- dim_d*: Distance on vessel from AIS antenna to starboard reported in AIS data (meters)
- draft*: Distance between water surface and lowest point on vessel reported in AIS data (meters)
- dest*: Vessel's destination reported in AIS data
- eta_month*: Estimated month of arrival at destination reported in AIS data
- eta_day*: Estimated day of arrival at destination reported in AIS data
- eta_hour*: Estimated hour of arrival at destination reported in AIS data
- eta_minute*: Estimated minute of arrival at destination reported in AIS data
- type_m2*: Internal classification of vessel type (see definitions below)
- sdate*: Local date of first detection along track
- stime*: Local time of first detection along track
- ldate*: Local date of last detection along track
- ltime*: Local time of last detection along track

AIS Vessel Type Definitions (see [MarineCadastre.gov](https://www.marinecadastre.gov) for details)

Type Code	AIS Vessel Type	M2 Vessel Type Class
0	-	other
1-19	Reserved	other
20-29	Wing in ground*	wing_in_ground_effect
30	Fishing	fishing_boat
31-32	Towing	towing_ship
33	Dredging or underwater operations	other
34	Diving operations	other
35	Military operations	military_ship
36	Sailing	sailboat
37	Pleasure craft	pleasure_craft
38-39	Reserved	other
40-49	High speed craft*	high_speed_craft
50	Pilot vessel	pilot_boat
51	Search and rescue vessel	search_and_rescue_boat
52	Tug	tug
53	Port tender	port_tender
54	Anti-pollution equipment	other
55	Law enforcement	law_enforcement_boat
56-57	Spare - local vessel	other
58	Medical transport	other
59	Noncombatant ship	other
60-69	Passenger*	passenger_ship
70-79	Cargo*	cargo_ship
80-89	Tanker*	tanker_ship
90-99	Other type	other

**	-	class_b
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*Type codes in range may further define subcategories

**Since Class B AIS data do not typically provide voyage information (including a vessel type code), these vessels cannot be classified with further detail.

Radar Tracks (shapefile and KML)

These data are formed from connecting individual detection points from all radar data. Tracks with only a single detection point will have a record in this file but no drawn polyline geometry. These records are not assigned a unique M2 text identification number, do not populate in the M2 Viewer, and are not considered in reporting. These records can be identified in the raw data as they have NULL values in the 'id_m2' attribute.

KML files

These data are best viewed in the desktop application, Google Earth Pro. Large data sets (such as weekly and monthly) may exceed the file size allowed in the online application, Google Earth. Note that accessing the KML file may produce a warning if there are tracks that do not have at least two unique coordinate positions reported.

File name: tracks_radar_TIMERANGE (.shp or .kml)

Data type: Polyline

-id_track: Unique identification number for each track

-id_site: Unique M2 system identifier

-id_m2: Unique track identifier used on M2 Viewer

-source: Identifies if track was detected by AIS or radar

-duration: Duration of track time (seconds)

-alarm: Track triggered local system alarm (0=no, 1=yes)

-min_speed: Minimum observed speed detected along track (knots)

-max_speed: Maximum observed speed detected along track (knots)

-avg_speed: Average speed of all detections along track (knots)

-curviness: Total distance along track / distance between first and last detection

-duration_z: Time spent in designated zone of interest (seconds)

-distance: Total distance target traveled along track (kilometers)

-distance_o: Maximum distance the target traveled from its origin (kilometers)

-assoc_str: Association strength - numeric count of similar detection points with an AIS track

-assoc_id: The id of the AIS track with the most associated detection points

-tagged: Whether user has tagged the track in some way on M2 Viewer (0=no, 1=yes)

-has_photos: Track has associated photos (0=no, 1=yes)

-confidence: Target confidence score (0-1) reflecting the likelihood that a target is a true vessel and not a false target

-detections: Total number of target detections along the track

- sdate*: Local date of first detection along track
- stime*: Local time of first detection along track
- ldate*: Local date of last detection along track
- ltime*: Local time of last detection along track

Tagged Radar Tracks (shapefile and KML)

These data are formed from connecting individual detection points from radar or AIS track data that have been tagged by a user in the M2 Viewer.

KML files

These data are best viewed in the desktop application, Google Earth Pro. Large data sets (such as weekly and monthly) may exceed the file size allowed in the online application, Google Earth. Note that accessing the KML file may produce a warning if there are tracks that do not have at least two unique coordinate positions reported.

File name: tracks_radar_tagged_TIMERANGE (.shp or .kml)

Data type: Polyline

Attributes

- id_track*: Unique identification number for each track
- id_site*: Unique M2 system identifier
- id_m2*: Unique track identifier used on M2 Viewer
- source*: Identifies if track was detected by AIS or radar
- duration*: Duration of track time (seconds)
- alarm*: Track triggered local system alarm (0=no, 1=yes)
- min_speed*: Minimum observed speed detected along track (knots)
- max_speed*: Maximum observed speed detected along track (knots)
- avg_speed*: Average speed of all detections along track (knots)
- curviness*: Total distance along track / distance between first and last detection
- duration_z*: Time spent in designated zone of interest (seconds)
- distance*: Total distance target traveled along track (kilometers)
- distance_o*: Maximum distance the target traveled from its origin (kilometers)
- assoc_str*: Association strength - numeric count of similar detection points with an AIS track
- assoc_id*: The id of the AIS track with the most associated detection points
- tagged*: Whether user has tagged the track in some way on M2 Viewer (0=no, 1=yes)
- has_photos*: Track has associated photos (0=no, 1=yes)
- confidence*: Target confidence score (0-1) reflecting the likelihood that a target is a true vessel and not a false target
- detections*: Total number of target detections along the track
- sdate*: Local date of first detection along track
- stime*: Local time of first detection along track
- ldate*: Local date of last detection along track

- ltime*: Local time of last detection along track
- user_id*: Last user to tag the track
- valid*: If track was successfully tracking a vessel (0=no, 1=yes (default))
- type*: Vessel type of the target the user has identified (default is "unknown")
- notes*: Text notes that the user may have included about the target
- transit*: User tagged track as a vessel engaged in transit (0=no (default), 1=yes)
- overnight*: User tagged track as a vessel loitering overnight (0=no (default), 1=yes)
- loiter*: User tagged track as a vessel loitering for sightseeing (0=no (default), 1=yes)
- cleanup*: User tagged track as a vessel engaged in cleanup (0=no (default), 1=yes)
- fishing_c*: User tagged track as a vessel engaged in commercial fishing (0=no (default), 1=yes)
- fishing_r*: User tagged track as a vessel engaged in recreational fishing (0=no (default), 1=yes)
- research*: User tagged track as a vessel engaged in science/research (0=no (default), 1=yes)
- diving*: User tagged track as a dive boat (0=no (default), 1=yes)
- repairs*: User tagged track as a vessel engaged in repairs (0=no (default), 1=yes)
- distress*: User tagged track as a vessel in distress (0=no (default), 1=yes)
- other*: User tagged track as a vessel engaged in an unlisted activity (0=no (default), 1=yes)
- miss_ai*: User tagged track as a radar track duplicating an AIS track (0=no (default), 1=yes)
- violation*: User tagged track as a vessel potentially violating regulations (0=no (default), 1=yes)
- le_contact*: User tagged track as vessel that was potentially violating regulations, and law enforcement was contacted (0=no (default), 1=yes)
- tdate*: Local date when most recent tag information was entered
- ttime*: Local time when most recent tag information was entered

Radar Range (shapefile and KML)

File name: range_SITEID#_wgs (.shp or .kml)

Data type: Polygon

Attributes

-*id_site*: Unique M2 system identifier

Exclusion Zones (shapefile)

File name: exzones_SITEID#_wgs.shp

Data type: Polygon

Attributes

-*id_site*: Unique M2 system identifier

-*id_zone*: Unique M2 zone identifier

-*name*: Zone name

System Uptime (csv and json)

These data provide the hourly status for M2 system components, including local weather conditions (if available), in .json and .csv format. If a system is inaccessible via internet

connection, these attributes will be most accurate after a connection is re-established. Note that weather data for some sites are provided by local weather stations outside of the M2 network, so M2 cannot confirm accuracy nor ensure proper sensor functioning at these sites.

File name: radar_uptime_TIMERANGE (.csv or .json)

Attributes

- id_site*: Unique M2 system identifier
- online*: If system was powered on (0=no, 1=yes)
- radar_status*: If radar data have recently been received (0=no, 1=yes)
- ais_status*: If AIS data have recently been received (0=no, 1=yes)
- camera_status*: If camera was operational (0=no, 1=yes)
- raw_status*: If raw radar return images were received (0=no, 1=yes)
- wind_speed*: Hourly average wind speed in knots at local weather station (if available)
- wind_direction*: Hourly average wind direction at local weather station (if available)
- wind_gust*: Hourly average wind gust in knots at local weather station (if available)
- radar_xmit*: If radar system was actively transmitting (0=no, 1=yes)
- radar_connected*: If radar had power and detected by M2 system (0=no, 1=yes)
- radar_sdk*: If radar data were successfully being integrated into M2 system (0=no, 1=yes)
- cdate*: Local date of system uptime evaluation
- ctime*: Local time of system uptime evaluation (hourly)

Radar and AIS Heat Maps

For sites with automated reports, the heat maps from the monthly reports are also available as separate files in the monthly data download packages. Note that these are GeoTIFF (.tif) files which are imagery files that have been geospatially referenced. Heat maps are generated using all tracks analyzed in the corresponding monthly reports. These track lines are rasterized using 500-meter x 500-meter grid cells and report the count of unique tracks that pass through each cell. Heat maps are limited to a range of 25 nautical miles from the site.

File name: heatmap_radar_1Month.tif

Attributes

- Value*: Count of unique track lines detected exclusively by radar

File name: heatmap_ais_1Month.tif

Attributes

- Value*: Count of unique track lines detected by AIS

TARGET CONFIDENCE SCORE ACCURACY

Prediction accuracy is evaluated using a target confidence score threshold ($p = 0.5$). Accuracy is reported using the true positive rate (TPR), which is the percentage of true vessel tracks classified correctly, and the true negative rate (TNR), which is the percentage of false targets

classified correctly. Contact M2@protectedseas.net for all site-specific historic evaluation results at sites for which you have access. Some sites may have been offline during certain evaluation periods or were decommissioned.

Document Updates

April 3, 2025 - Added section on AIS and radar accuracy

May 29, 2025 - Added section on monthly heat maps for sites with reports