ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR-
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User Guide

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AWI ICETrack

Antarctic and Arctic Sea Ice Monitoring and Tracking Tool

HELMHOLTZ
ASSOCIATION

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Important Note

The ICETrack application does not intent to be an operational fully tested data service. Updates will happen irregularly or upon request. Furthermore applied data products may change. We stress the fact that for the interpretation of ICETrack output, spatial and temporal resolution and uncertainties of the applied products should be taken into account.

We encourage users to give feedback (tkrumpen@awi.de) for further improvements.

Introduction

Purpose of this Document

Purpose of this document is the documentation of the **ICETrack** application developed at the Alfred Wegener Institute for Polar and Marine Research. This document will give a short description of the routines and methods applied to monitor key areas and calculate sea ice trajectories using sea ice motion and concentration data from satellites and additional parameters extracted along pathways of sea ice. Some of the results of the **ICETrack** application are publically available for download and a technical description of the data format is given here.

This document is aimed to the scientific community, therefore only a brief method description is given.

Scope of the AWI ICETrack application

The development of the **ICETrack** application was started at the Alfred Wegener Institute (AWI) with the goal of estimating pathways and source areas of sea ice using up-to-date sea ice motion and concentration information from satellites in the Arctic and Antarctic. Over the course of the years, new data products were added to provide additional information about atmospheric and oceanic processes acting on the sea ice along pathways. A validation of the application was performed using position data from buoys deployed in the Arctic and Antarctic.

Running ICETrack application

Prior running ICETrack following specifications need to be made:

- Input type (list of positions to track or EMEI number of buoy)
- Directional setup (forward/backward/stationary)
- Number of days to track individual parcels
- List of parameters to extract
- Ice concentration threshold when tracking is stopped.
- Output type (ASCII file, plot type)

AWI ICETrack Processing Scheme

The AWI **ICETrack** application follows the pathways of sea ice parcels based on sea ice concentration and motion data. Along pathways various other parameters (e.g. temperature, water depth) are extracted. The lagrangian model can be performed in a backward and forward direction, as well as for static positions (not moving mode: e.g. for the monitoring of sea ice conditions at static sites like HAUSGARTEN). The time range can be specified by the user. As an input a) a simple file list with geographic locations is required, b) a defined area of interest on an EASE grid or c) an IMEI Number of a buoy available on the IABP (international Arctic Buoy Program) website. The application will provide the users with an ASCII file for every input location that provides information about sea ice and atmosphere on a daily basis as well as various plots. The temporal resolution of the application is “daily”.

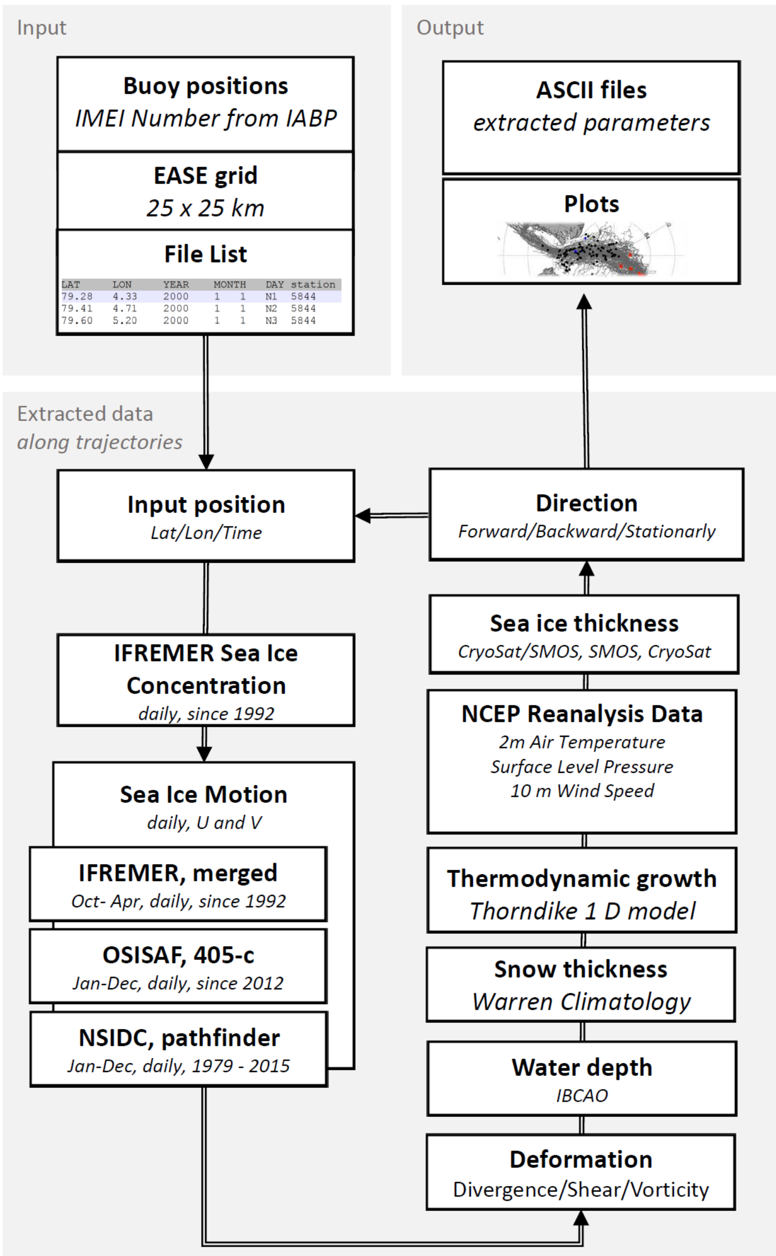


Fig: Schematic drawing of the **ICETrack** application

Input Requirements

File list of geographic coordinates

Monitoring and tracking can be done using a list of coordinates provided as an ASCII file (*.txt). The list shall include for every position the latitude and longitude information (in decimal degree), year, month and day to start with, a station name (string format) and duration (tracking time in days). An example is provided below.

LAT	LON	YEAR	MONTH	DAY	station	Duration
79.28	4.33	2000	1	1	N1	5844
79.41	4.71	2000	1	1	N2	5844
79.60	5.20	2000	1	1	N3	5844
79.73	4.47	2000	1	1	N4	5844
79.94	3.12	2000	1	1	N5	5844
78.92	5.00	2000	1	1	S1	5844
78.78	5.32	2000	1	1	S2	5844
78.61	5.06	2000	1	1	S3	5844
78.98	-5.37	2000	1	1	EG-I	5844
78.93	-4.65	2000	1	1	EG-II	5844
78.83	-3.92	2000	1	1	EG-III	5844
78.73	-2.75	2000	1	1	EG-IV	5844
79.02	10.85	2000	1	1	SV-I	5844
78.98	9.49	2000	1	1	SV-II	5844
79.02	6.98	2000	1	1	SV-IV	5844

Tab: Input file for ICETrack. In this case there are 16 positions to track. Tracking of the first position (79.28 N, 4.33 E, Station name "N1") will start on Jan 1st, 2000 and last for maximum 5844 days (Dec 31st, 2016).

EASE grid

Alternatively, the application can poll positions that fall within an area of interest defined by upper left and lower right coordinates on a 25 x 25 km EASE grid. The Equal-Area Scalable Earth Grid (EASE-Grid) is intended to be a versatile format for global-scale gridded data, specifically remotely sensed data, although it has gained popularity as a common gridding scheme for other data as well. Data from various sources can be expressed as digital arrays of varying grid resolutions, which are defined in relation to one of three possible projections: Northern and Southern Hemisphere (Lambert's equal-area, azimuthal) and full global (cylindrical, equal-area); see Figure 1. With EASE-Grid, visualization and intercomparison operations are greatly simplified, making analysis and intercomparison more convenient (source NSIDC).

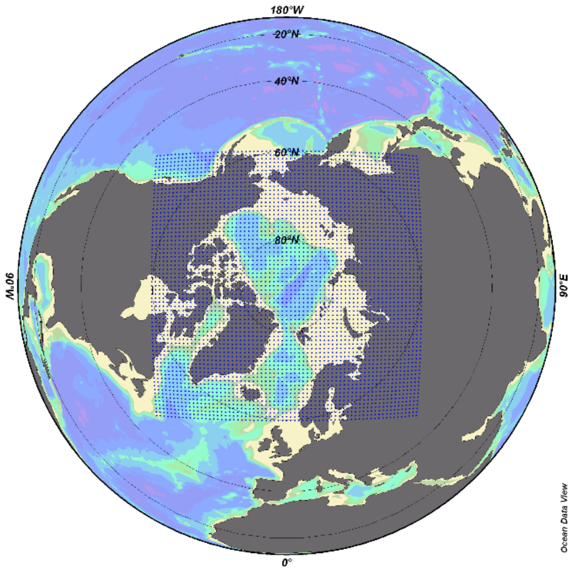


Fig: 25 x 25 km EASE grid, image source NSIDC

IMEI number from IABP buoys

The system is capable of following real buoys forward and backward in time. This option is used to validate the **ICETrack** application (backward mode) or to forecast pathways of buoys using ice drift data from the past (e.g. for the planning of recovery).

A list of available active buoys is provided via the IABP webpage: http://iabp.apl.washington.edu/

The program requires the IMEI numbers as an input for **ICETrack**.

Directional Settings

Forward

If set to “forward”, the application will calculate drift trajectories of provided input positions forward in time over a predefined period. Tracking is stopped if

a) Sea ice concentration at a specific location reaches the predefined threshold value and ice parcels are considered lost,
b) Tracking time exceeds the pre-defined tracking time

Backward

If set to “backward”, the application will calculate drift trajectories of provided input positions backward in time over a predefined period. A specific ice parcel is tracked backwards until:

a) Ice reaches a fast ice edge (simple parameterization based on water depth) or land
b) Sea ice concentration at a specific location reaches the predefined threshold value

Stationary

If set to “stationary”, the position stays at place. Note that this mode is used to monitor ice and atmospheric conditions at static sites like HAUSGARTEN. A specific location is monitored until:

a) the run time exceeds the pre-defined time range

Extracted Data

At every time step and position ice concentration and motion information are extracted. The applied dataset are listed below.

Parameter	Provider/Details
Sea-Ice concentration	IFREMER (User Guide) Daily sea ice concentration from SSMI based on the ASI algorithm provided on a 12.5 x 12.5 km grid Data is available since 1991 until present (Jan - Dec)
Sea Ice Motion	OSI-SAF 405-c (User Guide Validation Report) Daily sea ice motion from SSMIS, ASCAT and AMSR provided on a 62.5 x 62.5 km grid based on a cross-correlation method (U/V drift component) Data is available since 2012 until present (Jan – Dec)
Sea Ice Motion	IFREMER (User Guide) Daily sea ice motion from SSMI and QuikSCAT provided on a 62.5 x 62.5 km grid (U/V drift component) Data is available since 1991 until present (Oct – Apr)
Sea Ice Motion	NSIDC Polar Pathfinder (User Guide) Daily sea ice motion data from AMSR-E, AVHRR, IABP Buoys, ASSR, SSM/I, SSMIS, NCEP/NCAR provided on a 25 x 25 km grid Data is available since 1979 until 2015 (Jan – Dec)

The extraction of sea ice motion for individual positions follows a weighted approach. The application first checks the availability of IFREMER sea ice motion data within a predefined search range. Since IFREMER data only provides motion estimates for winter month (Oct. – Apr), during summer month motion estimates are based on the OSI-SAF 405-c (2012 to present) or the NSIDC Polar Pathfinder drift product (1979 – 2015). If no valid data is available within the predefined search range, the position stays unchanged.

Additional Data

At every time step and position additional atmospheric parameters, sea ice thickness and water depth are extracted. In addition, sea ice deformation along tracks is computed. Moreover a simple 1D thermodynamic model applied. Below, a list of extracted parameters is given:

Parameter	Provider/Details
CryoSat-2/SMOS ice thickness	AWI (User Guide) Weekly sea ice thickness information provided on a 25 x 25 km grid Data is available since 2010 until present (Oct – Apr)
Surface Level Pressure	NCEP/NCAR (User Guide) Daily mean surface level pressure (hPa) at 2 m from reanalysis dataset provided on a 2.5 x 2.5 degree grid (global). Data is available since 1948 until present
Air Temperature, 2m	NCEP/NCAR (User Guide) Daily mean air temperature (°C) at 2 m from reanalysis dataset provided on a 2.5 x 2.5 degree grid (global). Data is available since 1948 until present
Wind velocity, 10 m	NCEP/NCAR (User Guide) Daily mean wind velocities (U and V component) at 10 m from reanalysis dataset provided on a 2.5 x 2.5 degree grid (global). Data is available since 1948 until present
Bathymetry	IBCAO vers. 3.0, 2012 (User Guide Source Data) Water depth information provided on a 2 x 2 km grid
Snow depth	Warren Climatology (Warren et al., 1998)
Thermodynamic model	Sea ice thickness and growth (Thorndike 1992) Simple 1D model following Thorndike 1992
Deformation	Sea ice divergence, shear and vorticity

Output Data

ASCII file (.txt)*

For each timestep, the position, time, sea ice motion and concentration data is written to an ASCII file together with various other parameters extracted. An example output is given below.

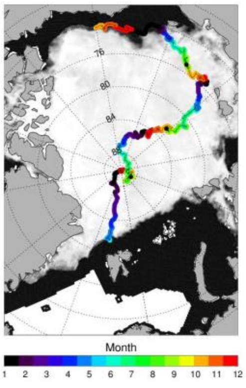
```
N_DAY YEAR MONTH DAY DIST LAT LON SOURCE U V ICEC TH ICE_DIV ICE_VORT ICE_SHEAR AIRT PRESSURE U_WND V_WND DEPTH
0000 2000 01 01 0.00 79.14000 2.84000 NAN NaN NaN 28 0.00 NaN NaN NaN NaN NaN NaN NaN -5424.08
0001 2000 01 02 0.00 79.14000 2.84000 CERSAT -6000.0 -6000.0 0 NaN NaN NaN NaN -1.38 972.90 1.82 -10.31 -5424.08
....
4780 2013 02 01 0.00 79.14000 2.84000 CERSAT -3000.0 3000.0 18 0.02 NaN NaN NaN -7.37 988.10 -1.80 -2.78 -5424.08
4781 2013 02 02 0.00 79.14000 2.84000 CERSAT 3000.0 3000.0 28 0.02 NaN NaN NaN -8.28 986.00 4.90 -0.75 -5424.08
4782 2013 02 03 0.00 79.14000 2.84000 OSISAF 2748.5 -482.7 57 0.02 NaN NaN NaN -7.07 983.50 6.07 1.02 -5424.08
4783 2013 02 04 0.00 79.14000 2.84000 OSISAF -485.1 -8199.7 80 0.02 NaN NaN NaN -4.55 986.40 0.75 -2.53 -5424.08
```

Following parameters are listed (if available)

- N_DAY — Runtime of program given in days. If direction is set to "forward/backward", N_DAYS is equivalent to sea ice age in days.
- YEAR/MONTH/DAY — Date
- DIST — Tracked distance (given im meters)
- LAT/LON — Position of ice parcel
- SOURCE — Applied motion dataset
- U/V — Ice velocity at LAT/LON position
- ICEC — Ice concentration. "128" is invalid data, "999" is land
- ICE_DIV — Ice divergence (not fully tested)
- ICE_VORT — Ice vorticity (not fully tested)
- ICE_SHEAR — Ice shear (not fully tested)
- AIRT — Air temperature at 2 m (°C)
- PRESSURE — Surface level pressure (hPa)
- U/V_WIND — U and V component of wind velocity at 10 m
- DEPTH — Water depth (m)
- TH — Sea ice thickness from satellite (m)
- TH_Model — Thermodynamic growth (m)
- TH_snow — Snow thickness (m)

Note that missing values or invalid data are indicated as NaN

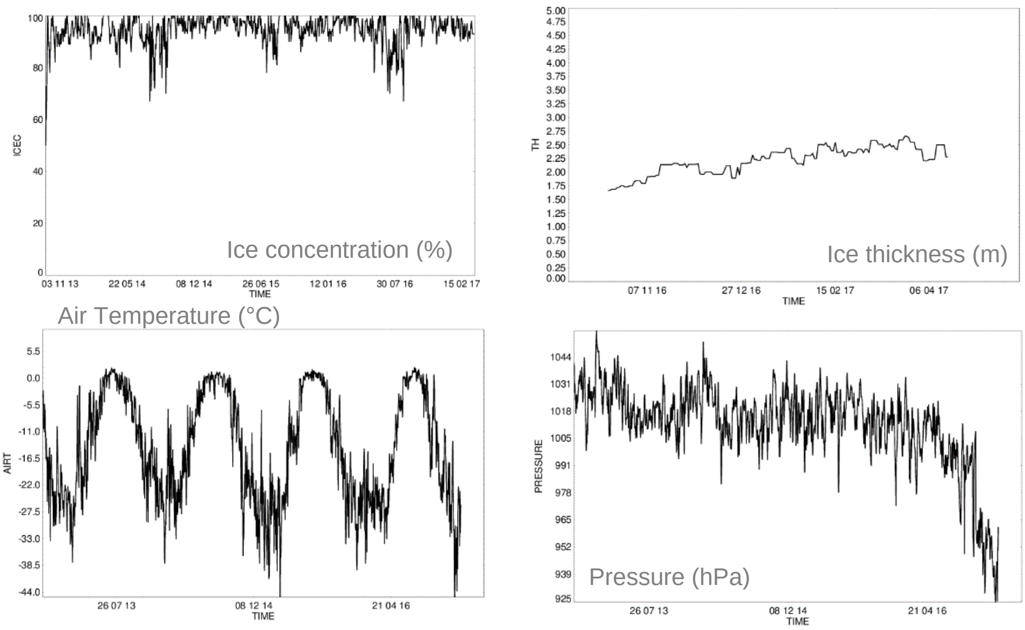
Standard Plots (.eps)*



The program returns for every input position a plot with the estimated pathway (see example). The sea ice concentration plotted in the background is the sea ice concentration at the time when application was stopped (end of tracking).

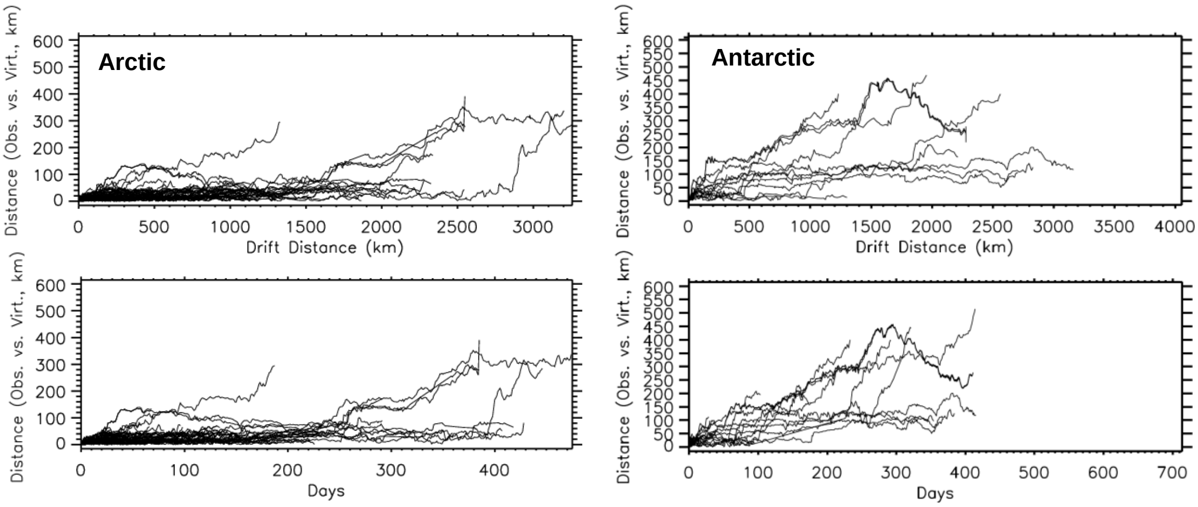
Time Series Plots (.eps)*

The application returns time series of additional data extracted along pathways such as ice concentration, ice thickness, pressure or temperature (see example below).


Ice concentration (%)
ICEC
TIME
Ice thickness (m)
TH
TIME
Air Temperature (°C)
AIRT
TIME
Pressure (hPa)
PRESSURE
TIME

Validation

To number uncertainties of provided sea ice trajectories, we reconstructed pathways of real buoys available via Meereisportal.de. In total, pathways of 56 Arctic buoys and 42 Antarctic buoys were reconstructed from their position of deployment until position of last valid data transmission. The figure below shows the distance between real buoys and virtual buoys over drift distance (upper panel) and time (lower panel) in the Arctic (left) and Antarctic (right). On average, the displacement between real and virtual buoys in the Arctic during the first 150 days (around 1000 km of ic e drift) is around 35 km. After one year (ice drift of more than 2000 km), the mismatch between virtual and real buoys is around 150 km. In the Antarctic, displacements are higher, likely associated to the larger uncertainties of applied motion products. Here, the average displacement of virtual buoys during the first 150 days is around 108 km. After one year, the average mismatch between virtual and real buoys is around 240 km.



Selected list of publications with an ICETrack application

Bergmann, M. , Peeken, I. , Beyer, B. , Krumpen, T. , Primpke, S. , Tekman, M. B. and Gerdts, G. (2017), Vast Quantities of Microplastics in Arctic Sea Ice—A Prime Temporary Sink for Plastic Litter and a Medium of transport / Baztan, J. , Jorgensen, B. , Pahl, S. , Thompson, R. and Vanderlinden, J. P. (editors), In: Fate and Impact of Microplastics in Marine Ecosystems, MICRO 2016, Amsterdam, Elsevier, 2 p., doi:10.1016/B978-0-12-812271-6.00073-9

Fernández-Méndez, M. , Turk-Kubo, K. A. , Rapp, J. Z. , Buttigieg, P. L. , Krumpen, T. , Zehr, J. P. and Boetius, A. (2016), Diazotroph diversity in the sea ice, melt ponds and surface waters of the Eurasian Basin of the Central Arctic Ocean, Frontiers in Microbiology, 7 , p. 1884, doi:10.3389/fmicb.2016.01884

David, C. , Lange, B. , Krumpen, T. , Schaafsma, F. , van Franeker, J. A. and Flores, H. (2015), Under-ice distribution of polar cod Boreogadus saida in the central Arctic Ocean and their association with sea-ice habitat properties, Polar Biology, special issu , pp. 1-14, doi:10.1007/s00300-015-1774-0

Hardge, K. , Peeken, I. , Neuhaus, S. , Krumpen, T. , Stoeck, T. and Metfies, K. (2017) , Sea ice origin and sea ice retreat as possible drivers of variability in Arctic marine protist composition, MARINE ECOLOGY PROGRESS SERIES, 571 , pp. 43-57, doi:10.3354/meps12134

Krumpen, T. , Gerdes, R. , Haas, C. , Hendricks, S. , Herber, A. , Selyuzhenok, L. , Smedsrud, L. H. and Spreen, G. (2016), Recent summer sea ice thickness surveys in Fram Strait and associated ice volume fluxes, The Cryosphere, 10 , pp. 523-534, doi:10.5194/tc-10-523-2016

Taylor, J. , Krumpen, T. , Soltwedel, T. , Gutt, J. and Bergmann, M. (2017), Dynamic benthic communities: assessing temporal variations in benthic community structure, megafaunal composition and diversity at the Arctic deep-sea observatory HAUSGARTEN between 2004 and 2015, Deep-Sea Research Part I-Oceanographic Research Papers, 122 , pp. 81-94, doi:10.1016/j.dsr.2017.02.008

Tekman, M. B. , Krumpen, T. and Bergmann, M. (2016), Marine litter on deep Arctic seafloor continues to increase and spreads to the North at the HAUSGARTEN observatory, Deep Sea Research Part I: Oceanographic Research Papers, doi:10.1016/j.dsr.2016.12.011