



BSI Standards Publication

Petroleum and natural gas industries – Arctic operations – Metocean, ice, and seabed data

National foreword

This British Standard is the UK implementation of EN ISO 35106:2019. It is identical to ISO 35106:2017. It supersedes BS ISO 35106:2017, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

**Petroleum and natural gas industries - Arctic operations -
Metocean, ice, and seabed data (ISO 35106:2017)**

Industries du pétrole et du gaz naturel - Opérations en
Arctique - Données océano-météorologiques et
données sur les glaces et les planchers océaniques (ISO
35106:2017)

Erdöl- und Erdgasindustrie - Arktisbetrieb - Metocean-,
Eis- und Meeresboden-Daten (ISO 35106:2017)

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European foreword

The text of ISO 35106:2017 has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 35106:2019 by Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" the secretariat of which is held by NEN.

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Endorsement notice

The text of ISO 35106:2017 has been approved by CEN as EN ISO 35106:2019 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 8, *Arctic operations*.

Introduction

The series of documents on arctic operations (currently ISO 35101 to ISO 35106) addresses operational requirements for use by the petroleum and natural gas industries in arctic and cold regions. Through their application, the intention is to ensure human life safety and to minimize environmental damage. At the same time, the series of documents is intended to provide wide latitude in the choice of operational and design solutions without hindering innovation. Sound engineering judgment is, therefore, necessary in the use of these documents.

This document is developed to provide a coherent and consistent definition of data requirements for operations and designs in arctic and cold regions. With application to offshore, coastal and onshore situations, the document focuses on meteorological, oceanographic, seabed and ice considerations. In addition to the requirements of this document, the requirements of ISO 19901-1 for metocean data, ISO 19906 for ice properties data and ISO 19901-4 and ISO 19901-8 for seabed data also apply.

For many geographical regions, physical environmental data are insufficient for rigorous statistical determination of appropriate extreme and abnormal environmental actions and are insufficiently detailed for the conduct of specialized operations. The determination of relevant operational and design parameters therefore relies on the interpretation of the available data by subject matter experts, together with an assessment of other meteorological, oceanographic, seabed and ice information. In particular, uncertainties can arise from analyses based on limited data sets.

[Annex A](#) provides background to and guidance on the use of this document and it is intended to be read in conjunction with the main body of this document. The clause numbering in [Annex A](#) is the same as in the normative text to facilitate cross-referencing.

Petroleum and natural gas industries — Arctic operations — Metocean, ice, and seabed data

1 Scope

This document specifies requirements and provides recommendations and guidance for the collection, analysis and presentation of relevant physical environmental data for activities of the petroleum and natural gas industries in arctic and cold regions. Activities include design and operations, which involve planning and actual execution.

Reference to arctic and cold regions in this document is deemed to include both the Arctic and other locations characterized by low ambient temperatures and the presence or possibility of sea ice, icebergs, shelf ice, glaciers, icing conditions, persistent snow cover, frozen surfaces of lakes and rivers, localized and rapidly changing weather systems and/or permafrost.

This document outlines requirements for a range of different operations that have been or are presently being undertaken and for existing design concepts. This document can also be used for other operations and new design concepts in arctic and cold regions as long as it is recognized that all data requirements are not necessarily addressed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12494, *Atmospheric icing of structures*

ISO 19900, *Petroleum and natural gas industries — General requirements for offshore structures*

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*

ISO 19901-4, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 4: Geotechnical and foundation design considerations*

ISO 19901-6, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 6: Marine operations*

ISO 19901-8, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 8: Marine soil investigations*

ISO 19906, *Petroleum and natural gas industries — Arctic offshore structures*

ISO 35101, *Petroleum and natural gas industries — Arctic operations — Working environment*

ISO 35103, *Petroleum and natural gas industries — Arctic Operations — Environmental monitoring for offshore exploration*

ISO 35104, *Petroleum and natural gas industries — Arctic operations — Ice management*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 35101, ISO 35103, ISO 35104, ISO 19900, ISO 19901-1, ISO 19901-6, ISO 19906 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

accretion

accumulation of snow, ice and other forms of frozen precipitation on surfaces

3.2

active layer

soil layer above the permafrost that is subjected to annual freeze-thaw cycles

3.3

arctic jet

low-level wind directed parallel to an ice edge or ice lead

3.4

areal density

number of ice features per unit area

Note 1 to entry: Usually averaged over a specific time interval.

3.5

bergy bit

floating glacial ice mass with waterline length between 5 m and 15 m

3.6

calibration

process by which physical parameter values are related to instrument readings

3.7

calving event

break-up of an iceberg or other glacial ice mass into two or more pieces

3.8

coastal region

offshore region adjacent to the coast where the physical environment is influenced by the coast

3.9

data analysis

data interpretation

expert assessment of physical environmental data to satisfy design or operational requirements

Note 1 to entry: Data analysis can include verification with other data sources or physical process models.

3.10

data storage

organization of physical environmental data into an accessible and documented database

3.11

data collection

data measurement

application of human systems or instruments for recording physical environmental data

3.12

data presentation

provision of physical environmental data in a format suitable to the design process or operational decision-making

3.13**downtime**

time interval for which an operation is suspended

Note 1 to entry: Downtime can be planned or unplanned.

3.14**expert**

individual who through training and experience is competent to provide advice specific to the subject in question

3.15**first-year ice****FY ice**

sea ice formed during the current or prior winter that has not survived one summer melt season

[SOURCE: ISO 19906:—¹], 3.16]

3.16**floe size**

waterline dimension of a sea ice floe

Note 1 to entry: Floe size can be defined as either the maximum waterline dimension or the diameter of a circular floe with the same plan area.

3.17**freezing degree days****FDD**

cumulative sum of average freezing daily air temperatures from the start of the winter season

Note 1 to entry: The reference point can be 0 °C or the freezing temperature of sea water.

Note 2 to entry: Usually initiated when the average daily temperature averaged over a specified period, for example, 30 days, falls below 0 °C or the freezing temperature.

3.18**growler**

floating piece of glacial ice with waterline length less than 5 m

3.19**ice action**

external load, displacement, deformation or acceleration applied to a structure as a consequence of an ice scenario

3.20**iceberg draft**

distance between the deepest point in the keel of an iceberg and the water surface

3.21**ice cover**

distribution of ice on the surface of a lake, river or ocean

3.22**ice edge**

line of demarcation between open water and floating *ice cover* ([3.21](#))

Note 1 to entry: Ice edge can be diffuse or compact, depending on the orientation of wind and current actions on the ice cover.

Note 2 to entry: Ice edge is sometimes based on a minimum concentration threshold over a specified averaging area in satellite imagery.

1) To be published. Stage at time of publication ISO/DIS 19906:2017.

Note 3 to entry: The concentration threshold can be dictated by the tolerance of the operation to *ice actions* ([3.19](#)).

3.23

ice encroachment

movement of sea ice onto the surface of a platform or man-made island

Note 1 to entry: Ice encroachment can result from ice ride-up, pile-up, and ride-down processes.

Note 2 to entry: Ice encroachment is typically associated with operational or design criteria.

[SOURCE: ISO 19906:—, 3.26]

3.24

ice feature

continuous mass of ice, floating or grounded, having a greater thickness than the surrounding *ice cover* ([3.21](#))

3.25

ice hazard

ice threat

ice feature ([3.24](#)) or conditions associated with operational criteria

Note 1 to entry: In this document, referred to without the “ice” qualifier.

3.26

ice length

accumulated distance travelled by the *ice cover* ([3.21](#)) past a point regardless of direction

3.27

ice management

processes and activities used to mitigate risks from ice

Note 1 to entry: Ice management can be used to alter icing, sea ice or iceberg environments or accumulations with the intent of reducing *downtime* ([3.13](#)) and reducing or avoiding ice action effects.

Note 2 to entry: Ice management can involve ice detection, forecasting, threat assessment, removal, alteration and destruction.

Note 3 to entry: Ice management is often conducted in the context of operating criteria such as alert procedures (see also ISO 19906 and ISO 35104).

3.28

ice ridge

linear feature formed of ice blocks created by the relative motion between ice sheets

Note 1 to entry: Ice pressure ridges are formed when ice sheets are pushed together and a shear ice ridge is formed when ice sheets slide along a common boundary.

[SOURCE: ISO 19906:—, 3.34]

3.29

ice season

period during the year when sea ice exceeds a specified concentration or when *ice features* ([3.24](#)) exceed a specified *areal density* ([3.4](#))

Note 1 to entry: Specified criteria can be different for the start and end of season.

3.30

ice shelf

floating ice sheet of considerable thickness attached to the shore

Note 1 to entry: Ice shelf can be determined based on freeboard in excess of 2 m.

3.31**ice scenario**

combination of circumstances involving the presence of ice, resulting in ice events

[SOURCE: ISO 19906:—, 3.35]

3.32**ice thickness**

vertical dimension of ice, measured from the bottom surface to the top surface

Note 1 to entry: Ice thickness can be determined as an average or maximum value over a specified horizontal scale or over the plan area of an *ice feature* (3.24).

3.33**ice type**

ice identified in WMO categorization according to the stage of development

3.34**icing**

ice accretion on the surface of a structure

Note 1 to entry: Icing can involve atmospheric or sea spray processes.

3.35**icing conditions**

combination of metocean, ice and operational conditions under which *icing* (3.34) can occur

3.36**katabatic wind**

gravity-driven flow of dense cold air from higher to lower elevations

Note 1 to entry: Katabatic winds are often associated with glaciers.

3.37**landfast ice****fast ice**

ice that remains attached to a shoreline, island or grounded *ice feature* (3.24)

[SOURCE: ISO 19906:—, 3.37]

3.38**level ice**

ice formed primarily as a result of thermal conduction and radiation processes and excluding mechanical processes

Note 1 to entry: Ice subjected to small amounts of rafting during the initial formation process is generally considered as level ice.

Note 2 to entry: Thicker level ice can vary by several centimetres over distances of several metres.

3.39**marginal ice zone**

sea ice region affected by waves and swell

3.40**multi-year ice****MY ice**

sea ice that has survived at least two summers' melt seasons

[SOURCE: ISO 19906:—, 3.44]

3.41

old ice

sea ice that has survived at least one summer's melt season

Note 1 to entry: Old ice includes both second-year ice and multi-year ice.

[SOURCE: ISO 19906:—, 3.45]

3.42

pack ice

sea ice consisting of discrete floes that is not landfast

[SOURCE: ISO 19906:—, 3.46]

3.43

pack ice pressure

horizontal pressure acting within pack ice

Note 1 to entry: Generally, pack ice pressure is the result of wind and current forcing, but can also result from larger scale mechanics of the *ice cover* (3.21).

Note 2 to entry: Pressure can be measured on an ordinal scale based on the closing rate of icebreaker tracks.

3.44

persistence

duration of a physical environmental parameter with respect to a specified threshold

3.45

rafted ice

ice feature (3.24) formed from the superposition of two or more ice sheet layers

[SOURCE: ISO 19906:—, 3.50]

3.46

region of interest

<design> geographical region around the facility selected to ensure data accuracy and representativeness

3.47

region of interest

<operation> geographical region over which an operation is undertaken and is influenced by ice and metocean processes

3.48

rolling event

distinct and sudden change in the vertical orientation of an iceberg or other floating glacial ice mass

3.49

second-year ice

SY ice

sea ice that has survived one summer's melt season

[SOURCE: ISO 19906:—, 3.62]

3.50

sea ice

thermally-grown ice formed on the surface of saline water bodies

3.51

season boundary

start or end of the *ice season* (3.29) according to specified criteria

3.52**shelf break**

seaward extent of the continental shelf characterized by a significant increase in slope of seafloor

Note 1 to entry: Shelf break can be used to determine the average seaward extent of sea ice.

Note 2 to entry: Shelf break can be used to determine the seaward limit of potential iceberg contact with the seabed.

3.53**snow cover**

areal distribution of snow on the ground or ice surface

3.54**stability**

state of hydrostatic or hydrodynamic equilibrium with respect to vertical orientation, usually with reference to icebergs

3.55**sub-gouge deformation**

displacement of seabed soil beneath a gouging *ice feature* ([3.24](#))

3.56**waterline length**

maximum dimension of an *ice feature* ([3.24](#)) in the plane of the water surface

3.57**waterline width**

maximum dimension of an *ice feature* ([3.24](#)) perpendicular to the *waterline length* ([3.56](#)) in the plane of the water surface

3.58**wind chill**

perceived temperature due to the combined effect of low ambient temperature and wind

4 Symbols and abbreviated terms

4.1 Symbols

d	distance from the ice edge
E	wave energy
E_0	wave energy in open water
h	ice thickness
M	ice sample mass
p_t	true precipitation
p_m	measured precipitation
S	salinity
T	air temperature
T_{wc}	wind chill temperature
U_{10}	wind speed at 10 m elevation

U	wind speed at the elevation parameter is to be estimated
V	ice sample volume
α	wave attenuation factor
ρ_i	ice density

4.2 Abbreviated terms

EER	escape, evacuation and rescue
FDD	freezing degree days
FEED	front-end engineering and design
FY	first-year, with reference to sea ice
HSE	health, safety and environment
IMO	International Maritime Organization
MY	multi-year, with reference to sea ice
SY	second-year, with reference to sea ice
WMO	World Meteorological Organization

5 General requirements

5.1 General

5.1.1 Physical environmental data requirements

An assessment of the physical environmental parameters affecting an operation or proposed offshore structure shall be made.

Information about the following physical environmental data should be determined.

- Distributions of parameters, which are required to determine actions and/or action effects associated with extreme and abnormal environmental events. These parameters are used to define design situation(s) and to perform design checks for structural limit states.
- Long-term distributions of parameters, in the form of cumulative conditional or marginal statistics. These parameters are used to define design situation(s) and to perform design checks for the fatigue limit state, and to make evaluations of downtime/workability/operability during a certain period of time, for the structure or for associated items of equipment.
- Normal environmental conditions, which are expected to occur frequently during the design service life of the structure, are required for carrying out checks for serviceability limit states, for developing actions and action effects to determine when particular operations can safely take place, and for planning construction activities, e.g. fabrication, transportation or installation, or field operations, e.g. drilling, production, offloading, underwater activities.
- Regional environmental oscillations, cycles and long-term trends associated with the parameters in a) through c).

5.1.2 Relationship with ISO 19901-1 and ISO 19906

General requirements, guidelines and information for metocean data are given in ISO 19901-1 for all regions. Mechanical properties of ice and derived physical parameters for arctic and cold regions are given in ISO 19906. This document deals with all other physical environmental and ice parameters for arctic and cold regions, including actions from snow and ice accretion.

5.1.3 Data sources

All data sources and methods used to generate physical environmental data shall be described and documented. The quality and validity of data shall be assessed by subject matter experts. Specific descriptions for relevant parameters are given in [Clauses 6 to 17](#).

All limitations with regard to data quality and/or validity shall be explicitly defined and taken into account in design and/or when planning operations.

If local data are not available and data from nearby areas are applied, the methods and models used in their application shall be documented, including all assumptions made. In addition, any uncertainties and how these have been dealt with should be included.

5.1.4 Selection of appropriate parameters

Sufficient data should be collected, analysed and interpreted to meet the requirements of the standards under which the design or operation is carried out. Sufficiency can involve, but is not limited to the location, spatial resolution, frequency, and accuracy of the data.

The selection of the appropriate physical environmental parameters depends on the location of interest, the type of structure or operation concerned, the design situation involved and the limit state considered. Different parameters can be required for different structure types, different designs or operational situations, and different limit states.

The seasonality and time periods associated with the operations should be taken into account according to [5.2.3](#) and [5.2.4.1](#).

Site-specific data on physical environmental parameters shall be collected, analysed and presented based on the requirements of [Clause 5](#) and the additional requirements for:

- oceanographic processes (waves, currents, water levels, temperatures, salinities) as included in [Clause 6](#), [Clause 8](#), [Clause 9](#), [Clause 10](#), [Clause 14](#) and [Clause 16](#);
- atmospheric processes and effects (wind, temperature, precipitation, visibility, drainage) as included in [Clause 7](#), [Clause 11](#), [Clause 14](#), [Clause 16](#) and [Clause 17](#);
- sea ice (thickness, extent, drift, origin, physical properties) as included in [Clause 12](#) and [Clause 16](#);
- icebergs and other discrete ice features (morphology, drift, physical properties) as included in [Clause 13](#) and [Clause 16](#); and
- seabed and subsurface processes (ice gouge, strudel scour, permafrost) as included in [Clause 15](#), [Clause 16](#) and [Clause 17](#).

5.1.5 Physical environmental data monitoring

All instrumentation and data collection devices should be designed for, or protected with respect to, icing, snow accumulation, ice encroachment, anticipated temperature range, moisture, frost, as well as anticipated combinations of ice and metocean conditions. Routine verification of data streams should be made to minimize gaps in data, particularly with respect to [5.2.2](#).

5.1.6 Data storage

All physical environmental data collected in the region of interest as part of offshore operations in arctic and cold regions should be archived.

5.2 Particular aspects

5.2.1 Region of interest

The region of interest for operations:

- a) shall be defined as the geographical region over which the operation or phase of the operation is undertaken, including the vessels supporting the operation;
- b) shall be defined as the geographical region over which ice and metocean features and processes affect the operation or phase of the operation;
- c) should include ice management, EER routes, mobilization and demobilization, local supply, overwintering sites for drilling and support vessels and personnel transfer. This region should be sufficiently large to ensure the accuracy of data within the regions defined in a) and b) and sufficiently constrained to ensure their representativeness within these regions.

For design, the region of interest shall be

- sufficiently large to ensure the accuracy of data at the location of the facility, and
- sufficiently constrained to ensure the representativeness of the data at the facility.

The size of the region of interest can vary depending on the particular parameter under consideration.

5.2.2 Criticality

The importance of the physical parameters should be understood in the context of operability, limit states for design and consequences involving life-safety, environmental damage and asset loss.

For critical operations, consideration should be given to the identification and use of maximum anticipated parameter values and combinations of parameter values with maximum consequences.

5.2.3 Variability

Different scales of variability can be distinguished for physical environmental parameters in arctic and cold regions.

- a) Short term variability is associated with events lasting less than an hour. Typical examples are ice concentrations or floe sizes and ice drift heading changes.
- b) Medium term variability is associated with events lasting from hours to days. Typical examples are ice drift rate, iceberg or sea ice feature proximity and wind and wave variability during polar lows.
- c) Seasonal variability is associated with natural seasonal cycles. Typical examples are seasonal sea ice and iceberg presence.
- d) Inter-annual variability is associated with longer cycles and climate change. Arctic ice thickness and extent vary on decadal time scales. Inter-annual variability is more pronounced between northern latitudes of 65° and 80°.

An analysis of parameter variability should be conducted for all important parameters in arctic and cold regions. Typically, the analysis should identify monthly or seasonal variability, including anticipated maximum and minimum values as well as physical limits on parameter values, where appropriate. Inter-annual variability should be accounted for, particularly when operating with data records for a limited number of years.

Variations in physical environmental parameters can be expressed in terms of

- the proportion of time for which the parameter values exceed or are less than a specified value, or
- the probability of exceeding or being less than a specified value within a given time period.

5.2.4 Statistical

5.2.4.1 General

Basic statistics, probability distributions, extreme values, abnormal values and relationships with associated parameters should be provided according to the design and operational requirements. Ranges, confidence intervals, biases and other measures of uncertainty should be documented for statistical data.

If redundant, independent measurements are made, they can be used to reduce the uncertainty through averaging techniques.

Site-specific ice and metocean data should be interpreted to identify monthly and seasonal variations and for application to operating time windows.

Datasets for ice parameters can be developed directly from site-specific measurements and from measurements at nearby locations or through the establishment of relationships between the desired parameters and other contributing factors. Due account shall be made for uncertainties, whether because of short time series or limitations of the models used.

Metocean datasets can either be established by site-specific measurements over a period of years or as an alternative, by numerical modelling (hindcasts) of historical events.

If hindcasts are used, the modelled results should be calibrated (or verified) against measurements from nearby locations for which measurements exist. If such measurements do not exist, hindcast models can be calibrated or verified against measurements from analogous sites with a similar climate.

If measurements or hindcasts exist for nearby locations, these datasets may be used, provided that conditions are similar in climate and that appropriate factors are applied.

5.2.4.2 Relationship between parameters

Data values should be tagged spatially, temporally and associated with specific features for the development of joint events. Emphasis should be placed on ensuring correct spatial, temporal and feature references.

Joint probability distributions shall be developed for important design and operational parameters that are correlated. In many cases, poorly sampled parameters can be related to parameters with more extensive measurements as long as uncertainties in these relationships are taken into account.

When developing parameter combinations in design formulae, joint probabilities shall be assessed to ascertain whether the combinations are stochastically dependent, stochastically independent or mutually exclusive.

5.2.4.3 Persistence

Persistence statistics should be developed for parameter values associated with human performance (see ISO 35101), for winterization, for marine operations and for aerial operations.

Reference should be made to [5.2.6](#) for persistence data for weather-restricted operations.

5.2.4.4 Record length

Where record lengths of local data are limited, relationships with measurements of other parameters for which longer periods of record are available should be considered.

Limited record lengths should be reflected in the uncertainty associated with parameter estimates. Seasonal, annual and regional biases shall be taken into account when estimating parameter uncertainties.

5.2.5 Forecasting

Forecasts of physical environmental conditions should be started as early as possible in the planning stage of operations to ensure timely collection of important parameters and to ensure that forecast accuracy can be quantified.

Forecasts should be verified with measured data, so that the accuracy can be reliably estimated and the forecasts can be improved over time.

Weather and physical environmental predictions required for operations should be monitored constantly and updated as necessary.

Regardless of accuracy, forecasts based on at least two independent models should be consulted and evaluated. The forecasts shall be based on up-to-date input data and shall be issued on a timely basis with respect to operational requirements.

The period over which a forecast is accurate shall be defined based on past forecasts and site-specific measurements. Forecasts may be used for executing marine operations carried out within the period of accuracy when contingency is sufficiently accounted for.

5.2.6 Weather windows

5.2.6.1 Criteria

Physical environmental data criteria for operations depend on the planned duration of the operation, including contingency.

For each specific phase of the operation, the design and operational physical environment criteria shall be defined as follows.

- The design criteria are the set of values of the physical environmental parameters for which design calculations are carried out and against which the structure and/or operation is checked.
- For weather-unrestricted operations, the operational physical environmental data criteria are the same as the design criteria.
- For weather-restricted operations, the operational physical environmental data criteria are set at values that cannot be exceeded at the start of the operation and for which forecasts are not exceeded for the duration of the operation.

Physical environmental data criteria can be set in the context of operational limits, systematic alert procedures and operational responses.

5.2.6.2 Weather-restricted operations

Weather-restricted operations shall be planned using accurate time history data that indicate not only the probability of not exceeding the limiting criteria but also the persistence of such conditions for the season in question. Reference to weather includes ice and other physical environmental criteria.

Consideration should be given to reducing the limiting criteria to account for uncertainties in the duration of the operation, in the data, and in forecast accuracy.

Weather windows should be developed based on thresholds of the key sensitive parameters of the operation. For example, the duration statistics for favourable conditions should be computed based on known limiting thresholds for physical environmental parameters.

5.2.6.3 Margins on weather

Planning for operational activities that are dependent upon specific physical environmental conditions shall take into consideration the quality and confidence level in the forecasts. The confidence level will vary depending upon the available data, the variability in the parameter being forecast and the experience of the forecaster. Forecasts for critical operations should indicate the probability that operational criteria associated with ice and other physical environmental parameters are met.

If the physical environmental criteria are based on statistical maxima, an appropriate margin should be added to account for inaccuracies in the calculation model and the probability of exceeding the maxima.

Margins should reflect the nature of the operation and whether suspension is possible once the operation is initiated. For operations requiring a continuous window, margins should be increased accordingly.

5.2.7 Climatic trends

Climatic trends should be assessed for key time-varying parameters, with specific consideration of air and water temperatures, as well as sea ice and iceberg presence.

Parameters used for design should take into account projected trends in climate, as justified by the most recent climate science, if the net effect leads to more severe conditions. Design criteria should not be reduced based on projected climatic trends.

The influence of climatic trends on data used for planning operations should be assessed when the operations are expected to take place over several years.

5.2.8 Expertise and experience

The collection, interpretation, analysis, storage and presentation of all physical environmental data and derived products within the scope of this document shall be performed or supervised by subject matter experts.

Operations personnel shall be trained in the collection and interpretation of physical environmental data pertinent to their responsibilities and have access to subject matter experts on a timely and reliable basis.

Interpretation of physical environmental data and forecasts associated with critical operational situations, as defined in [5.2.5](#), shall be conducted by subject matter experts.

6 Water depth, tides and storm surges

6.1 General

Water depth, tides and storm surge parameters shall be determined in accordance with ISO 19901-1.

Specific consideration should be given to tide and storm surge data during the months when icebergs and sea ice are present.

Particularly in shallow water environments, such as estuaries and river mouths, seasonal variations in water depth as a result of fresh water inflow and ice formation/melting processes should be characterized.

Deviations in the water surface elevation as a result of tides and storm surges shall take into account the presence of the sea ice cover.

Changes in water surface elevation should be characterized in a manner that allows for safe icebreaking operations, safe vessel transit and any other anticipated vessel and structure operations.

Ranges of water surface elevation should be determined to assist with the specification of operational and design values of ice loads on structures fixed to the seabed, on geotechnical structures and on natural and man-made shore facilities. Displacements, deformations, damage and abrasion of these facilities should also be considered in the specification of water level data.

6.2 Bathymetry

Accurate bathymetric data shall be consulted prior to the planning and conduct of operations and before designs are completed. Bathymetric data shall be collected where existing data do not meet the requirements of this document.

Changes to the local and regional bathymetry as a result of dredging, berms and structures shall be taken into account in the specification of parameters in this document.

The above-mentioned requirements regarding bathymetric data should cover the region of interest for operations and design (see [5.2.1](#)).

6.3 Tides

Tidal variations should be characterized from measurements, interpretations and forecasts at an accuracy and frequency consistent with requirements relating to:

- the formation of ice features;
- the grounding of ice features;
- drift and displacements of the ice cover and ice features;
- stresses transmitted to the ice cover;
- ice encroachment;
- EER systems;
- ice management and other vessel operations.

6.4 Storm surges

Water levels associated with storm surges shall be characterized from measurements, interpretations and forecasts with sufficient accuracy and frequency consistent with requirements relating to:

- the maximum and minimum elevations of ice actions;
- the maximum elevation to which floating ice features can be deposited on shore;
- the refloating of grounded ice features;
- displacements of the ice cover;
- ice encroachment on beaches, rockfill structures and other man-made structures;
- EER systems;
- ice management and other vessel operations.

7 Wind

7.1 General

Wind-related parameters shall be determined in accordance with ISO 19901-1.

Wind speed values shall be qualified by elevation, duration and averaging interval.

The joint distribution of wind speeds, air temperatures, and any other contributing parameters shall be interpreted for the determination of wind chill indices, sea spray icing, and other forms of snow and ice accretion to surfaces. Typically, data shall be interpreted in terms of normal values for operations planning and extreme values for design.

7.2 Polar lows

Information on polar low activity in the operating area should be collected in advance of operations and the likelihood of occurrence should be noted explicitly in the weather forecasts during operations.

If the effects of polar lows are not considered in wind hindcasts, their contribution to design values should be included through specific consideration of these events.

7.3 Katabatic wind

Information on Katabatic winds and contributing factors should be collected and interpreted if operations and structures are situated in areas that can be exposed to them.

7.4 Low level arctic jet

Where applicable, data should be collected and interpreted on the wind speeds associated with low-level jets as well as contributing parameters.

8 Waves

8.1 General

Information on waves and wave data shall be determined in accordance with ISO 19901-1.

The frequency of wave measurements during operations should be sufficient to capture relevant changes in key parameters.

For operations vulnerable to the combined effect of waves and ice, accurate measurement and timely dissemination of wave data should be prioritized.

Possible effects of long term reduction in ice extent and ice concentration on fetch should be considered in design and planning of operations.

8.2 Wave-induced ice motions

The basis for wave-induced motions of ice features should be the appropriate joint probability distribution between wave height and wave period at the relevant probability of exceedance.

Guidance on wave-induced ice motions of ice features can be found in ISO 19906.

8.3 Wave transmission through sea ice

In marginal ice zones, the potential for wave transmission through sea ice should be assessed.

Where operations are affected by interactions between sea ice and wave conditions, data should be collected to document and assist with the forecasting of changes to these conditions. Data for other contributing parameters, such as winds and currents, should be considered as well.

For design, the local wave regime and sea ice climate should reflect potential effects of wave transmission through sea ice.

9 Currents

9.1 General

Currents shall be determined in accordance with ISO 19901-1.

The local current regime shall be characterized for understanding ice drift patterns in the vicinity of the facility, the estimation ice interaction velocities with structures and for vessel operations, such as loading/unloading and ice management. Local anomalies in current fields should be identified, characterized and integrated into operational criteria. Particular attention should be given to currents in the vicinity of shelf breaks and in nearshore areas subjected to significant tidal effects or freshwater inflow. Conductivity and temperature measurements with depth can be used to supplement direct current measurements.

The regional current regime shall be characterized for understanding ice presence and deformation processes and for the development and implementation of drift forecasting algorithms.

Far-field current regimes can be used to understand ice formation processes and to assist with the sourcing of local ice features.

Vertical current profiles should be measured periodically where there is scour potential of berms, slope protection, piles, sheet-pile and other ice-resistant structural components.

9.2 Currents for sea ice and iceberg drift prediction

Ocean currents shall be assessed in terms of their influence on sea ice and iceberg drift. Consideration should be given to increased spatial, depth and temporal resolutions of data and models.

For sea ice drift forecasting, the surface current regime should be assessed by means of measurements, current models, inference from ice drift rates or some combination of these approaches.

For iceberg drift forecasting, the current regime through the water column to the depth of the deepest iceberg draft anticipated in the region should be assessed by means of measurements, current models, inference from iceberg drift data or some combination of these approaches.

9.3 Current records

Currents in arctic areas are generally poorly mapped.

In new areas, currents should be measured in accordance with ISO 19901-1 during the course of operations with durations of several weeks or longer.

Where activities are planned to take place over several years, simultaneous measurements of ice drift and local current measurements should be considered.

10 Temperature

10.1 General

Air and water temperatures shall be recorded according to the requirements of ISO 19901-1.

10.2 Sea water temperature

The freezing point of sea water shall be documented for the range of salinities present in the region.

Particular consideration should be given to sea water temperatures around the freezing point, potentially involving increased frequency, depth resolution and spatial resolution of measurements. Thermocline temperature profiles should be measured to forecast frazil ice formation and onset of new ice growth.

Where melting of ice features is a design or operational consideration, sea water temperatures should be measured to a depth at least equal to the draft of the largest ice features in the region.

10.3 Air temperature

Instruments used to measure air temperatures in arctic areas with temperatures lower than $-40\text{ }^{\circ}\text{C}$ shall be designed accordingly. This requirement exceeds the specifications outlined in ISO 19901-1.

The averaging interval and elevation associated with air temperature measurements shall be documented.

Wind chill shall be calculated for evaluating outdoor working conditions in cold climates. Wind and air temperature relationships should also be assessed in the context of ice growth, equipment performance and material properties.

11 Atmospheric parameters

11.1 General

Measurements of atmospheric parameters should be recorded in accordance with WMO standards and distributed to relevant national weather service providers. The requirements of this clause are incremental with respect to ISO 19901-1.

Atmospheric pressure shall be measured to assist with the interpretation of weather forecasts.

Consideration should be given to ultraviolet (UV) forecasts for operations involving outdoor personnel.

Geomagnetic storm forecasts should be consulted prior to commencement of operations.

11.2 Daylight considerations

Daylight conditions vary significantly throughout the year in the Arctic, stretching from complete darkness during winter to 24 h of daylight during summer. For planning operations, daylight conditions shall be taken into account.

11.3 Visibility and cloud ceiling

Atmospheric parameters should be measured to address optical visibility as well as the effectiveness of various imaging systems used for ice detection and characterization. Visibility measurements should be recorded in the horizontal and vertical directions.

Seasonal trends in fog conditions and their relationship with ice coverage should be assessed for operations planning. Inter-annual trends should be reviewed when increased incidence is anticipated in the future.

Visibility and cloud ceiling should be monitored and logged during operations.

11.4 Precipitation

Precipitation in the form of snow, rain, sleet and hail should be documented based on historical data prior to commencement of operations and should be monitored as part of operations.

Special requirements for the collection and interpretation of precipitation data in arctic and cold regions are given in [Clause 14](#).

12 Sea ice

12.1 General

Sea ice data shall be considered for all operations and for all phases of a structure's design service life in regions where sea ice has been present historically. Requirements for the consideration of sea ice actions are given in ISO 19906.

Sea ice information can be obtained from actual observations from the region of interest through the collection of new data or from representative historical data.

If ice data are unavailable for the region of interest, if local data records are less than 10 years in length or if local records do not accurately represent the expected ice conditions, information from nearby regions with similar ice environments and more significant archives can be used. If data from nearby regions are applied, any assumptions should be documented and uncertainties should be accounted for in the application of these data.

The region of interest for sea ice (see [5.2.1](#)) shall include the area of operations as well as the surrounding area. The surrounding area shall include an updrift distance based on a maximum drift rate, the full range of potential drift directions and a conservative estimate of the lead times associated with the proposed operations (see [5.2.1](#)).

Sea ice information collected during operations should be presented clearly and readily interpretable by all operational decision-makers.

Sea ice conditions can be influenced by the presence of engineered structures, abandoned berms or foundations and by dredging and icebreaking operations. Resulting changes to the ice cover, the presence of grounded features and sea ice mobility shall be documented and incorporated in design bases and operational protocols.

All sea ice data monitored during operations should be collected, verified and archived, if not otherwise dealt with by national and international ice services.

12.2 Sea ice season

12.2.1 Operations planning

Prior to the commencement of any offshore operations in regions where sea ice can occur, a historical study of sea ice season boundaries shall be conducted for the region of interest.

In areas where ice does not persist through the summer, the start of the ice season is when the first new ice growth takes place. Where ice can reach the region of interest at any point during the year, the start of the ice season is when the concentration of any ice type reaches a specified minimum value. The end of the ice season is when the total ice concentration falls below a specified value and remains so until the ice-free season begins.

In the absence of other information, a total of sea ice concentration of 1/10th in the region of interest can be used to define the end of the sea ice season unless the operation and equipment involved have zero tolerance to ice actions. Where new ice growth marks the start of the sea ice season, a total ice concentration in excess of 1/10th can be used as long as there is some ice tolerance to the operation and

equipment. Sea ice concentrations associated with season boundaries can vary with the nature of the operation and the vessels involved in its conduct.

The variability in the ice season start and end dates shall be assessed, with due account for uncertainties. Significant inter-annual variability in sea ice conditions is common in all arctic regions.

The frequency and duration of ice intrusions within the open water season shall be assessed.

12.2.2 During operations

Criteria defining the ice season boundaries shall be tracked prior to and throughout the operation.

Ice data defined in [12.3](#) through [12.6](#) shall be collected within the ice season boundaries defined in [12.2.1](#) and should be collected for a sufficient period prior to the start of operations to ensure data quality, to allow for training and to verify communications protocols.

Regardless of when an operation is undertaken, sea ice data shall be collected if ice is present or is forecast to be present in the region of interest.

12.2.3 Design

Ice season length should be assessed for the region of interest using the guidelines provided in [12.2.1](#). Season boundary definitions used for design situations should be developed specifically to accommodate parameters associated with these situations.

Where possible, the period of record for ice season length should be extended based on freezing degree day data for air temperatures.

12.3 Sea ice coverage

12.3.1 Operations planning

Sufficient ice cover data shall be collected and analysed to ensure that the important contributing factors to the formation, distribution and decay of sea ice are understood.

Local ice concentration shall be monitored under circumstances where ice coverage can impose operational constraints. Operational constraints can apply for EER, vessel access to a platform and weathervaning of moored vessels.

An assessment of historical frequency of sea ice incursions into the region of interest during the planned operating season should be made. Where relevant, a separate assessment of the frequency and variability of old ice incursions into the region of interest should be made.

Prior to the commencement of operations affected by sea ice, a historical study of sea ice concentrations and floe sizes by ice type in the region of interest shall be conducted.

A longer-term seasonal ice conditions forecast model for the region of interest should be applied if available and validated for the region of interest.

In marginal ice zones, historical data regarding seasonal and inter-annual variations in ice edge location shall be documented. The ice edge definition should be consistent with the requirements of the operations. Consideration should be given to the use of the national ice service definition as well, where different from the primary one used for operations.

12.3.2 During operations

Sea ice concentrations and floe sizes by ice type should be recorded at a frequency consistent with the requirements of the operation.

When physical ice management methods are used to reduce floe size (see ISO 35104 and ISO 19906), ambient and managed sea ice conditions, including floe size, shall be recorded.

Even if sea ice is not present within the region of interest, data on the concentrations of different sea ice types of the nearest sea ice should be monitored.

Ice edge (see [12.3.1](#)) positions shall be monitored prior to and for the full duration of the operation. Isolated areas of ice with total concentration in excess of the documented ice edge threshold shall be monitored.

Metocean conditions should be documented in accordance with ISO 19901-1 and archived together with the sea ice data as included in [Clauses 6](#) to [10](#). Forecast and measured data should be archived.

12.3.3 Design

Prior to the design of any offshore structure or vessel that services an offshore operation, a historical study of sea ice total concentrations and partial concentrations in the region of interest shall be conducted to document the frequency and attributes associated with the various ice types present.

Areal coverage of ridges, rubble fields, rafted ice and any other features distinguishable within the sea ice shall be assessed (see also [12.6](#)).

Data should be collected to document the length of sea ice passing by the site of interest over the course of one or more winter seasons. Ice length can be estimated by integrating the product of the ice concentration and the drift speed over the duration of the winter season.

Metocean conditions associated with sea ice occurrence should be identified and assessed as included in [Clauses 6](#) to [10](#). Fetch length characterization for wave-affected ice processes should also be considered.

12.4 Sea ice thickness

12.4.1 Operations planning

An assessment shall be made as to the sufficiency of ice thickness ranges provided in ice chart data. If not, the requirements of [12.4.3](#) for ice thickness estimation shall apply.

The thickness of all ice types interpreted from ice charts for the location(s) of the operation shall be considered.

12.4.2 During operations

Actual sea ice thickness should be recorded at locations and with a frequency that are consistent with the requirements of the operation. The measurements should also be consistent with the performance requirements of the vessels used in the operation.

Reference should be made to [12.6.3](#) for the thickness of specific ice features.

12.4.3 Design

Local measurements of ice thickness, where available, shall be used for design. Where local measurements are unavailable, data from nearby sites with similar temperatures, snow cover and sea ice regime may be used with proper justification.

Thermal growth models may be used to estimate ice thickness, if calibrated using data from local and regional sites with similar ice, wind, current and snow regimes. Due account shall be made for differences in these factors and in the potential for rafted ice contributions to the overall thickness.

Spatial differences in ice thickness shall be characterized on a scale consistent with design requirements.

With reference to [12.3.3](#), the annual average length of ice associated with different thickness and drift speed ranges should be estimated for use in local pressure and structural fatigue calculations (see ISO 19906).

Probability distributions of ice thickness and joint distributions with other parameters should be developed as required.

12.5 Sea ice drift and movement

12.5.1 Operations planning

All available records of regional sea ice drift within the region of interest should be collected for analysis and documented.

Prior to the commencement of operations, a historical study of sea ice drift speed variability and predominant directions in the region of interest shall be conducted.

Evidence of rapid changes in drift direction and contributing factors should be investigated.

An assessment of the respective influences of winds and currents on historical ice drift speeds, directions and pack ice pressure and dynamics shall be made prior to the commencement of offshore operations. Reference should be made to wind data ([Clause 7](#)) and current data ([Clause 9](#)) requirements.

Where relevant to the operations, evidence of tidally-induced movements of landfast ice shall be assessed.

12.5.2 During operations

Sea ice drift speeds and directions should be recorded at a frequency consistent with the requirements of the operation.

Drift speeds and directions for the nearest sea ice within the region of interest shall be monitored and estimates shall be made of travel time to the site of the facility or operation. Even if there is no sea ice present within the region of interest, the drift of the nearest sea ice should be monitored at a frequency consistent with potential time of entry into the region of interest.

Where relevant to the operation, sea ice drift and significant changes thereof should be forecast (see ISO 35104).

An assessment of the respective influences of winds and currents on ice drift speeds, directions and ice pack pressure shall be made throughout the duration of the operation. Consideration should be given to the drift of different ice types, e.g. first-year ice, old ice, new ice, as classified by the ice observation standard in the country where operations take place.

Landfast ice displacements should be documented and assessed where these have a material effect on operations.

12.5.3 Design

A historical study of sea ice drift speeds and directions in the region of interest shall be conducted.

The joint probability distribution of drift speed and direction shall be calculated. Site-specific data shall be collected, where necessary, to define the distribution. Effects of ice thickness, ice type, floe size and particular ice features on the distribution should be assessed.

Drift direction changes can be characterized in terms of drift track curvature and its relationship with drift speed.

In marginal ice zones, the influence of waves on the speed of ice features should be characterized and included, where appropriate, in probability distributions to be used for impact calculations.

In regions of landfast ice subjected to tidal actions, rates of ice movement away from shore should be characterized. Where historical data are not available, data should be collected. The effects of air temperature, tidal range and other relevant parameters on ice displacement rate should be assessed.

12.6 Sea ice features and conditions

12.6.1 General

Many sea ice scenarios can be defined in terms of readily identifiable ice features or conditions that are not dealt with specifically in [12.1](#) to [12.5](#).

Sea ice features of potential interest include extensive areas of rafted ice, ridges and rubble fields, stamukhi or grounded rubble piles, features formed or consolidated in the tidal zone and second-year or multi-year floes (old ice). Particular consideration should be given to features that are

- of large areal extent and consolidated to thicknesses in excess of the thermally-grown level ice thickness for a single winter, or
- of any size that are consolidated to thicknesses well in excess of the thermally-grown level ice thickness for a single winter.

Sea ice scenarios of potential interest can involve pressure, brash ice build-up, break-up, break-out, encroachment and other incursions.

12.6.2 Operations planning

Historical evidence of the areal density or frequency, magnitude and contributing factors relating to identifiable ice features and conditions shall be documented. Focus should be on expected parameter ranges as well as their seasonal and inter-annual variations.

Data shall be interpreted to allow the specification of robust operational criteria, in the form of unambiguous assessments of ice feature dimensions, ice conditions and metocean conditions.

Site-specific data shall be collected if available historical data are insufficient or if ice features and conditions cannot be inferred from existing local and regional data.

Consideration should be given to the clustering of ice features if this can have a material effect on the operation, such as for assessing ice management requirements.

12.6.3 During operations

The region of interest for data collection and observation shall be consistent with the requirements of the operation and for vessels involved in the operation.

Ice features and ice conditions should be monitored by dedicated and properly trained ice observers within the region of interest.

The locations, drift rates, significant attributes and dimensions of all identifiable ice features, as well as ice conditions in the region of interest, shall be recorded at a frequency commensurate with the safety requirements of the operation. Attributes, such as degree of consolidation for ridges, rubble fields and stamukhi that are measured or inferred based on resistance to icebreaking, should be recorded.

Data on previously observed features should be verified and updated as new observations are obtained. All measured data shall be saved for easy retrieval and interpreted data summaries shall be made available to operations personnel. Data shall also be placed in the context of thresholds associated with the ice operations criteria.

All operational data relating to ice features and conditions shall be archived and summarized for presentation following the completion of the operation or annually for ongoing operations.

12.6.4 Design

Measurement programs and interpretation procedures should provide unbiased estimates of the areal density (number of features per unit area) for ice features defined in [12.6.1](#). Typical values of interest for design include average values and ranges of values.

Measurement programs and interpretation procedures should also focus on obtaining unbiased probability distributions for the ice feature dimensions, e.g. waterline dimensions, thickness, mass, to be used for estimation of extreme values and other values used in design. Consideration should be given to the joint distribution of feature dimensions with other ice conditions, e.g. pack ice pressure, drift speed, and surrounding ice thicknesses and concentrations and physical environmental parameters, e.g. wind, waves, currents.

Due account should be taken for uncertainties resulting from limited record length (see [5.2.4.4](#)) and other factors related to the relevance and accuracy of the data (see [5.1.3](#), [5.1.4](#) and [5.2.4.1](#)).

The frequency of ice scenarios, such as encroachment, should be estimated by means of direct measurements or inference from contributing ice and metocean conditions. If inference is used to estimate frequency, the relationships used should be verified by means of field data.

12.7 Physical properties

The physical properties of ice include:

- ice temperature;
- ice density;
- sea ice salinity; and
- ice rubble porosity.

Physical properties of ice should be measured within the region of interest. If physical properties have not been measured within this region, data from regions with similar properties can be used with suitable justification. Justification should also be provided when ancillary data are used to correct parameter values measured in other regions.

The number of measurements and the accuracy of measurements should be consistent with their contribution to the design or operational situation.

Preference should be given to measurements made *in situ*. If ice property measurements are not made *in situ*, transportation and storage methods should ensure minimal changes to the state of the ice prior to testing.

Requirements relating to derived physical properties and mechanical properties of ice are included in ISO 19906.

13 Icebergs

13.1 General

13.1.1 General data requirements

Iceberg data shall be collected and assessed for structural design and to provide safe marine operations and EER for offshore facilities. Requirements for the consideration of iceberg actions are given in ISO 19906.

Iceberg data requirements should take into account the type of facility, the range of operations to be undertaken and the potential presence of vessels and equipment.

Unless stated specifically, the term “iceberg” is taken to encompass a range of glacial and similar ice features, including icebergs, bergy bits, growlers, ice islands and ice shelf fragments.

More specific information on regional iceberg climatology is included in ISO 19906.

13.1.2 Data collection

Requirements for the collection of iceberg frequency, size, shape and drift data, as well as associated sea ice and metocean data, are specified in [13.2](#) to [13.5](#). Requirements for the collection of physical iceberg properties are outlined in [13.6](#).

Sufficient redundancy in measurements and verification processes should be in place to ensure data correctness and accuracy.

13.1.3 Data analysis and presentation

13.1.3.1 Operations and design

Analysis and presentation requirements common to the various iceberg and associated parameters are provided in [13.1.3.2](#) to [13.1.3.4](#). Further requirements for specific data types are provided in [13.2](#) to [13.6](#).

13.1.3.2 Operations planning

Historical data for the area of interest should be summarized and presented in a summary report highlighting important features of the data and potentially their context in terms of operational criteria.

Iceberg drift forecast models should be verified in the region of interest with measured drift tracks and forecast accuracy should be documented. The spatial and temporal resolution of the models should be consistent with the needs of the operations.

Measurement equipment recommendations should be made to ensure that operational data are collected efficiently and accurately.

13.1.3.3 During operations

Iceberg data shall be interpreted to ensure accuracy in the re-identification and tracking of individual features.

Interpretation should be consistent with requirements for forecasting and deployment of ice management resources.

Sufficient data should be collected and recorded to allow the assessment of success for iceberg management operations.

All iceberg and associated physical environmental data relevant to the operations should be summarized in a daily report. Trends and changes in the data should be highlighted in each daily report.

All iceberg data collected during operations shall be archived. Incorrect data shall be corrected or flagged in the archive. Emphasis should be placed on the clear definition of parameters and on format for ease of retrieval.

Data should be summarized in a report following time-limited operations and annually for ongoing operations. The reports shall contain observational strategies and details of the measurements. Clear distinction should be made between actual observations and inference.

The performance of tactical and seasonal forecast models should be evaluated after completion of the operation.

13.1.3.4 Design

Iceberg data shall be analysed to provide the following information:

- probability distributions of parameters;
- estimates of uncertainty due to limitations of the instruments, number of data points, frequency of measurements and spatial resolution in the data;
- relevant correlations and relationships between parameters.

Reference should be made to ISO 19906 for a description of design situations.

Focus should be placed on removing biases in key parameters, including iceberg areal density and size.

13.2 Iceberg location and areal density

13.2.1 Operations planning

Prior to the commencement of any offshore operations in iceberg-prone regions, a historical study of iceberg frequency shall be conducted. Iceberg frequency shall be represented in terms of areal density (average number per unit area) for features in excess of a specified size. Iceberg size can be represented in terms of maximum waterline length, mass and other measures appropriate for the operation being undertaken. Iceberg frequency can also be represented in terms of the number of features crossing a particular latitude or into a geographical area over a specified period of time.

A region of interest shall be defined to include the actual area of operations. An extended region of interest, including an area updrift over which icebergs will be monitored, shall also be defined. The distance updrift will depend upon the rate of iceberg drift and the lead times associated with the operations and the procurement or allocation of resources.

All historical records of iceberg locations (generally expressed in terms of latitude and longitude) shall be assessed for the region of interest. Historical records shall be interpreted to minimize bias as a result of different iceberg detection methods. Projected future trends in iceberg frequency for the region of interest should be considered in operations planning and particular consideration should be given to circumstances that involve increased iceberg frequency.

Inter-annual variations, as well as seasonal and monthly variations in areal density, should be estimated to assess potential ice management and other operational requirements.

Where relevant for the operations, historical records of ice island, growler and bergy bit frequencies should be collected for the region of interest. A comparison with the frequency of accompanying icebergs should also be made.

13.2.2 During operations

Icebergs in the region of interest shall be tracked over time. Where possible, unique identifiers should be assigned to each iceberg. The iceberg status as freely-floating, grounded, gouging, under tow or influenced by another ice management technique shall be documented. Details of physical iceberg management operations shall be documented.

Iceberg positions shall be recorded in terms of latitude and longitude and consideration should be given to the provision of positions in terms of range and bearing from offshore facilities and service vessels.

The observation method or methods used to identify and track each iceberg target shall be documented.

Focus should be placed on the accuracy of iceberg positions, the frequency of iceberg observations and the re-identification of individual features. Typically, hourly positions should be recorded for all icebergs, day and night, within the region of interest.

The position of growlers and bergy bits observed in the region of interest should be recorded, if relevant for the operation. Growlers and bergy bits produced as the result of calving events should be tracked relative to the originating iceberg.

Consideration should be given to the forecasting of monthly and seasonal iceberg conditions for the region of interest and an extended region of interest.

13.2.3 Design

For offshore structure design purposes, historical records of iceberg positions, in terms of latitude and longitude, shall be collected for the region of interest (see [13.2.1](#)). Each iceberg position measurement should be tagged according to the detection system used for the measurement and the resolution of each measurement system should be documented.

Iceberg areal density, expressed in terms of the number of icebergs per unit area averaged over the course of the year, shall be estimated at the site of the facility. Seasonal (or monthly) and inter-annual variations in the iceberg areal density should be determined. Projected future trends in iceberg frequency should be considered and particular consideration should be given to circumstances involving increased iceberg frequency.

When counting icebergs, the smallest iceberg size (usually expressed in terms of waterline length) should be recorded to minimize bias in areal density estimates.

Iceberg data for preliminary design shall include, but not be limited to, areal density over a specified size threshold and an estimate of the proportion below this threshold.

Detailed design shall include but not be limited to annual and seasonal breakdowns of iceberg areal density and the location and duration of grounding events.

Where applicable for the design of offshore structures, growler and bergy bit areal densities shall be estimated.

13.3 Size, shape and stability

13.3.1 Operations planning

Historical records of iceberg sizes and shapes from the region of interest shall be collected. Seasonal and inter-annual variability of iceberg dimensions and shapes shall be assessed.

Where distinct iceberg populations are present, such as icebergs and ice islands, the relative proportions of these different populations should be estimated.

Available historical records of icebergs that have been observed to calve or roll in the region of interest should be collected and an assessment of the frequency with which icebergs were observed to calve or roll should be made.

Historical measurements of iceberg dimensions, profile information and metocean parameters should be assessed in terms of their influence on the frequency of observed rolling and calving events.

13.3.2 During operations

During operations, the dimensions and shapes of all icebergs observed in the region of interest shall be recorded. An assessment of the relative proportions of iceberg shapes and sizes shall be made throughout the operation.

The draft of all icebergs shall be measured or estimated based on above-water dimensions. Iceberg mass can be estimated based on above-water dimensions and profiles.

Underwater profile information should be collected when it is relevant for the operation.

Observed changes to iceberg dimensions as a result of melting, calving or rolling should be documented. Any observed iceberg calving and rolling events should be documented.

The frequency with which icebergs of different shapes and sizes are observed to roll or overturn should be documented.

Iceberg profile information should be collected as an indicator of instability. Long-period roll motions, symptomatic of unstable icebergs, should be noted and recorded.

13.3.3 Design

All historical records of iceberg dimensions and shapes from the region of interest around the facility shall be collected.

Iceberg data for preliminary design shall include, but not be limited to, probability distributions for waterline length and relationships between iceberg mass and waterline length.

Data for detailed design shall include, but not be limited to, further data on index dimensions, such as width, height, and draft, and relevant local and global shape data, preferably linked to the index dimensions.

Distinction shall be made between tabular and non-tabular icebergs and any other significant shape categorizations.

The relative proportions of icebergs with differing significant shapes and geographical origins, as well as their inter-annual variability, should be estimated.

Data shall be collected to define the size distribution of icebergs from all relevant shape categorizations.

Iceberg profiling should be conducted or interpreted to define global shape (for stability on impact, contact frequency and mass estimation) and local shape (for impact load estimation). Sufficient data should be analysed to ensure robust relationships between index iceberg dimensions and shape parameters used in the design.

Local iceberg shape data for icebergs in the area of interest shall be interpreted to minimize size bias. Where data for the region of interest are lacking, data from other areas where iceberg sizes and the degree of iceberg deterioration are similar can potentially be used.

If icebergs are present from different sources with distinct sizes and shape attributes, the above shape characterization shall be defined for each separate population.

Site-relevant iceberg profiling should be conducted to relate iceberg dimensions to potential hydrodynamic instabilities on impact with facilities.

Probability distributions of growler and bergy bit dimensions shall be developed for the design of structures with potential for damage from these features.

13.4 Iceberg drift

13.4.1 Operations planning

All available historical records of iceberg trajectories within the region of interest shall be collected for analysis and documented.

An assessment shall be made regarding the variability in drift directions and any predominant directions, considering the uncertainties of the records and their representation of local and regional conditions.

An assessment shall be made regarding the variability in iceberg drift speed, size effects, regional and water depth considerations, the mean and median speeds and extreme values of drift speeds.

A comparison between observed and modelled (hindcast or simulated forecast) iceberg trajectories should be performed to evaluate forecast accuracy for use in operations.

13.4.2 During operations

During operations, the drift speeds and directions of all icebergs observed within the region of interest shall be recorded at a frequency commensurate with the operational safety and decision-making requirements of the operation.

Drift velocity time series shall be plotted and analysed to identify anomalies and errors in positional information.

Drift velocity records shall be tagged to identify whether the iceberg was freely-floating, under tow or grounded.

Iceberg drift should be forecast using models verified with observed drift tracks in the region of interest. Uncertainty in drift forecasts should be based on past model performance and can be expressed in terms of 50 %, 90 % and 99 % iso-probability curves. Forecast models should be updated to reflect the latest available positional information and consideration should be given to correction of forecasts based on measured drift data. Additional iceberg drift forecasting requirements are given in ISO 35104.

Where applicable, an assessment of the drift of growlers and bergy bits relative to that of larger icebergs nearby should be made.

13.4.3 Design

All available historical records of iceberg drift speeds and directions in the region of interest shall be assessed. Focus should be on instantaneous speeds when considering ice impact scenarios.

The probability distribution of iceberg drift speed should be developed and any relationships or correlations with iceberg size, water depth and contributing metocean parameters should also be documented.

When ice scenarios involve bergy bits and growlers, probability distributions of drift speeds for these features shall also be developed. For bergy bits, growlers and larger icebergs under some circumstances, wave-induced velocities should be combined with the drift velocities to provide probability distributions for impact velocities against ships and structures.

The joint probability distribution between drift speed and direction (or velocity components) should also be developed when relevant to the design situation.

13.5 Metocean and sea ice context

13.5.1 Operations planning

Measured or hindcast wind, wave and current data shall be collected for the region of interest for periods in which iceberg drift and areal density data are available (see [13.2](#) and [13.4](#)). Sea ice cover data shall also be collected for the same periods.

An assessment of the respective influences of winds, waves, currents and sea ice on historical iceberg areal density and drift velocities shall be undertaken.

13.5.2 During operations

An assessment of the respective influences of winds, waves, currents and sea ice on observed iceberg drift velocities shall be undertaken during offshore operations. The effects of iceberg size and shape should be considered in the assessment.

Particular consideration shall be given to the detection of icebergs, bergy bits and growlers in waves and sea ice. Iceberg observations shall be tagged with information relating to sea state and sea ice concentrations, types and thickness in their vicinity.

Scenarios involving icebergs, sea ice presence and higher sea states should be forecasted.

13.5.3 Design

Measured or hindcast wind, wave and current data shall be collected for the region of interest for periods in which iceberg drift and areal density data are available (see [13.2](#) and [13.4](#)). When only hindcast data are available, these should be verified with actual measurements. Sea ice cover data shall also be collected for the same periods.

Relationships between wave conditions and orbital velocities of bergy bits and growlers shall be developed.

Available historical records of icebergs observed in the presence of sea ice in the region of interest shall be collected and assessed, including information relating to the extent, concentration, type and thickness of the sea ice.

Changes in sea state as a result of sea ice presence should be assessed and correlated with iceberg presence.

13.6 Physical properties

Where relevant to the operation or design, the ranges in density of the ice and surface temperatures should be established. These can be based on local data or inferred from data collected in other regions.

Data requirements on the mechanical properties of ice are given in ISO 19906.

14 Snow and ice accretion

14.1 General

14.1.1 Consideration of accretion

The effects of snow and ice accretion shall be assessed for operations and structures in regions where these forms of accretion occur. For time limited operations, it is sufficient to consider only the part of the year when operations are carried out.

Effects and associated risks that can influence the integrity, performance, operation, HSE and EER characteristics of a facility shall be assessed when determining the data needs. Requirements for snow and ice accretion data should account for the particular characteristics of each structure and operation.

14.1.2 Accretion data collection

Snow and ice accretion data shall be collected on all permanent structures in arctic and cold regions and should be collected on all vessels and rigs.

The snow and ice accretion data should include:

- a general description of the facility or operation;
- a general description of the accretion event;
- details of the accretion measurements, including the thickness of the accretion on affected surfaces;