Aalto University
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Polar Code

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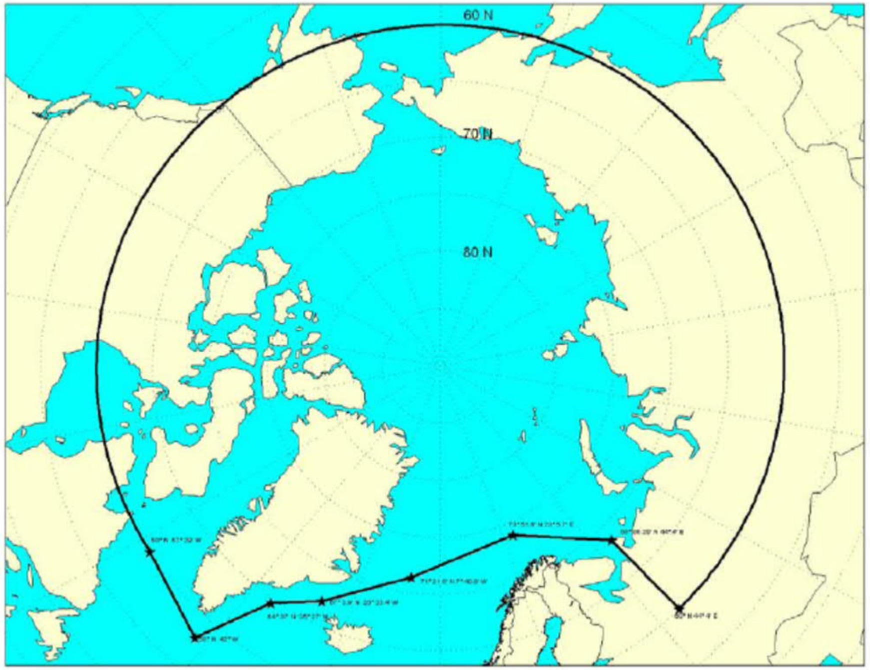
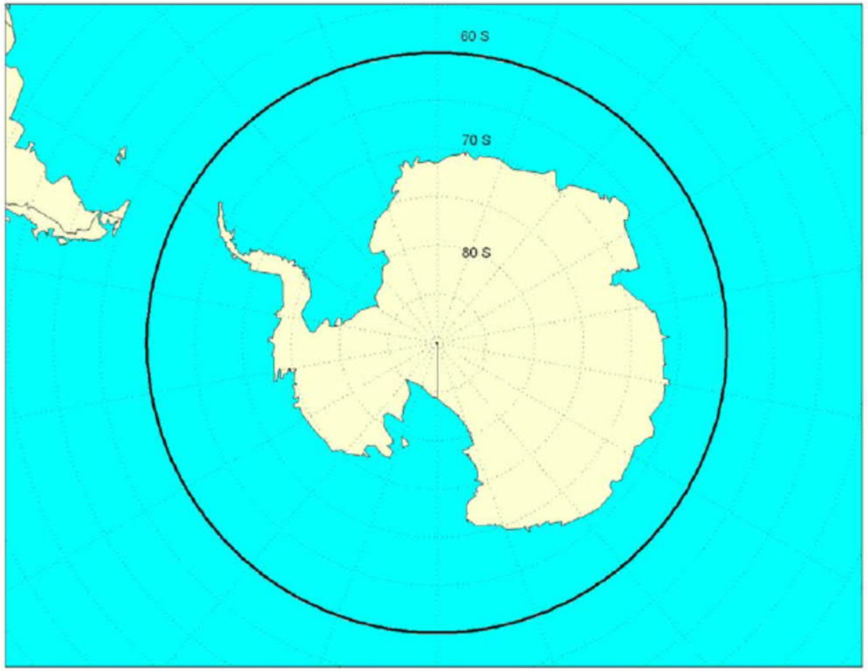
Contents

- Description of the new Polar Code
- Full scale measuring system onboard SA Agulhass II and MT Uikku
- Evaluation of the risk index values (RIV) based on the new POLARIS approach
- Comparison of the RIV values with the measured ice loads

IMPORTANT DEFINITIONS - THE ARCTIC AND ANTARCTICA POLAR AREA





CURRENT REGULATORY BASES FOR SHIPS SAILING IN POLAR WATERS

- International conventions apply to ships sailing in international waters in Polar areas:
  - SOLAS, MARPOL, STCW, AFS, Load Line, COLREG
- IMO has developed some guidelines for ships operating in Polar Waters:
  - Guidelines for ships operating in Polar waters (Res. A.1024(26)) adopted in 2009, recommended to be used from 1 January, 2011)
  - Guidelines on voyage planning for passenger ships operating in remote areas(Res.A.999(25))
  - Enhanced contingency planning guidance for passenger ships operating in areas remote from SAR facilities (MSC.1/Circ.1184)
- UN Convention on the Law of the Sea (UNCLOS)
  - Article 234 of UNCLOS allows coastal states to extend environmental control measures in ice-covered waters.

BACKGROUND OF THE POLAR CODE

STATUS OF DEVELOPMENT OF THE POLAR CODE

- The International Maritime Organization (IMO) has developed the mandatory International Code of Safety for Ships Operating in Polar Waters (Polar Code).
- The Polar Code has been developed to supplement the existing IMO instruments in order to improve the safety of shipping and to mitigate harmful effects of shipping on the environment in the remote, vulnerable and potentially harsh polar waters.
- The Code covers a full range of design, construction, equipment, operational, training, search and rescue and environmental protection matters relevant to ships operating in the inhospitable waters surrounding the two poles.
- The Polar Code would then come into force in the beginning of 2017.

IMPLEMENTATION OF THE POLAR CODE

- The two main conventions of the International Maritime Organization (IMO) related to safety and pollution prevention from ships are:
  - International Convention for the Safety of Life at Sea (SOLAS 1974); and
  - International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)
- The Polar Code will be adopted by adding a new Chapter XIV, Safety Measures for Ships Operating in Polar Waters, to the SOLAS Convention, and by adopting relevant amendments to the MARPOL Convention.

SOURCES OF HAZARDS LEADING TO ELEVATED LEVELS OF RISK IN POLAR AREAS

The Polar Code considers hazards which may lead to elevated levels of risk due to increased probability of occurrence, more severe consequences, or both:

1. ice
2. topside icing
3. low temperature
4. extended periods of darkness or daylight
5. high latitude
6. remoteness and possible lack of accurate and complete hydrographic data and information
7. potential lack of ship crew experience in polar operations
8. potential lack of suitable emergency response equipment
9. rapidly changing and severe weather conditions,
10. the environment with respect to sensitivity to harmful substances and other environmental impacts and its need for longer restoration.

CONTENTS OF THE POLAR CODE

- Preamble
- General regulations (application, definitions, certification)
- Part I contains safety regulations:
  - Part I-A: Mandatory provisions on safety measures in accordance with the relevant SOLAS chapter
  - Part I-B: Recommendations on safety
- Part II contains pollution prevention regulations:
  - Part II-A: Mandatory provisions on pollution prevention in accordance with relevant MARPOL Annexes
  - Part II-B: Recommendations on pollution prevention

POLAR CODE - STRUCTURE

Part I-A - Safety measures (mandatory)

- 12 chapters
- Largely goal-based

1. General
2. Polar water operational manual
3. Ship structure
4. Subdivision and stability
5. Watertight and weathertight integrity
6. Machinery installations
7. Fire safety/protection
8. Life-saving appliances and arrangements
9. Safety of navigation
10. Communication
11. Voyage planning
12. Manning and training

Part I-B – Pollution prevention measures (mandatory)

- 4 chapters
- Prescriptive

1. Prevention of pollution by oil
2. Control of pollution by noxious liquid substances in bulk
3. Prevention of pollution by harmful substances carried by sea in packaged form
4. Prevention of pollution by sewage form ships

IMPORTANT DEFINITIONS – SHIP CATEGORIES

- *Category A ship* means a ship designed for operation in polar waters in at least medium first-year ice, which may include old ice inclusions
  - Typically ships with IACS ice classes PC1 – PC5
- *Category B ship* means a ship not included in category A, designed for operation in polar waters in at least thin first-year ice, which may include old ice inclusions
  - Typically ships with IACS ice classes PC6 and PC7
- *Category C ship* means a ship designed to operate in open water or in ice conditions less severe than those included in categories A and B
  - Typically ships with a low ice class (e.g. IA), or no ice class

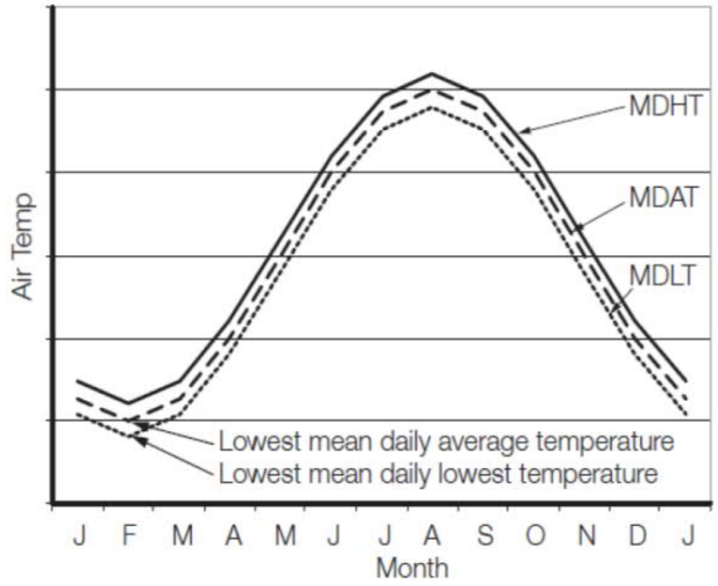
IACS: International Association of Classification Societies
PC: Polar Class

IMPORTANT DEFINITIONS - ICE CONDITIONS

- ***Ice free waters*** means no ice present.
- ***Open water*** mean a large area of freely navigable water in which sea ice is present in concentrations less than 1/10. No ice of land origin is present
- ***Sea ice*** means any form of ice found at sea which has originated from the freezing of sea water
- ***Ice of land origin*** means ice formed on land or in an ice shelf, found floating in water
- ***First-year ice*** means sea ice of not more than one winter growth developing from young ice with thickness from 0.3-2.0 m.
  - **Thin First Year ice**, the thickness is 30 to 70 cm.
  - ***Medium first-year ice*** means first-year ice of 70-120 cm thickness
- ***Old ice*** means sea ice which has survived at least one summer's melt; typical thickness up to 3 m or more. It is subdivided into residual first-year ice, second-year ice and multi-year ice

IMPORTANT DEFINITIONS
POLAR SERVICE TEMPERATURE

- ***Polar Service Temperature (PST)*** *means* a temperature specified for a ship which is intended to operate in low air temperature, which shall be set at least 10^{o}C below the lowest MDLT for the intended area and season of operation in polar waters.
- ***Mean Daily Low Temperature*** **(MDLT)** means the mean value of the daily low temperature over a minimum 10 year period.



Definitions used in the figure above

MDHT – Mean Daily High Temperature

MDAT – Mean Daily Average Temperature

MDLT – Mean Daily Low Temperature

CHAPTER 2 - POLAR WATER OPERATIONAL MANUAL

- Each ship sailing in Polar areas shall have a Polar Water Operational Manual (PWOM), which contains sufficient information regarding the ship’s operational capabilities and limitations, e.g. concerning ice-going capability of the ship, in order to support the decision-making process of the Master and the crew of the ship.
- The Manual shall include or refer to specific risk based procedures to be followed:

IMPORTANT DEFINITIONS - POLAR SHIP CERTIFICATE

The Polar Code requires that ships apply for a ***Polar Ship Certificate*** that determines among others:

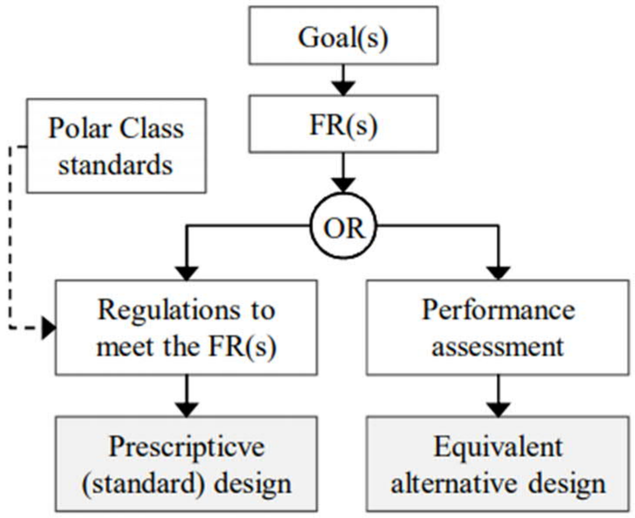
- Particulars of ship (name, IMO number, etc.)
- Ice class and ice strengthened draft range
- Ship type: tanker/passenger ship/other
- Ship restricted to operate in : ice free waters/open waters/other ice conditions
- Ship intended to operate in low air temperature: Yes/No
  - Polar Service Temperature: ……..°C/Not Applicable
- Maximum expected time of rescue …….days
- Operational limitations for operation in polar waters:
  - Ice conditions
  - Temperature
  - High latitudes

APPLICATION OF THE GOAL-BASED REGULATIONS OF THE POLAR CODE

STRUCTURE OF THE GOAL-BASED REGULATIONS OF THE POLAR CODE

Part I-A Safety measures

- Each chapter consists of the overall goal, functional requirements to fulfil the goal, and (prescriptive) regulations
- A safety goal is considered met
  - If a ship comply with all the regulations associated with the related functional requirements
    → Prescriptive (standard) design
  - *Or if the ship has been reviewed in accordance with IMO guidelines and found to meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety*
    → Equivalent alternative design



WHY GOAL/RISK-BASED DESING?

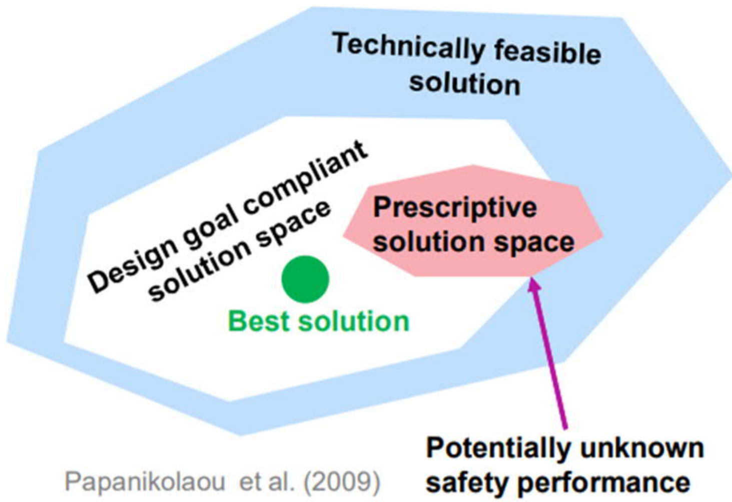
Traditional design

- Design following prescriptive (traditional) design regulations prescribing a specific solution
  - *Time and resource efficient application*
  - *The efficiency of the solution depends on the efficiency of the rules*
  - *Prescriptive rules might act as design constraints*

Goal-based design

- Design following goal-based regulations prescribing a specific function
  - *Goal-based rules → Expanded feasible design space*
  - *Holistic safety thinking (both active and passive safety measures considered)*
    - *Motivates safety thinking and active risk management*
  - *Time and resource consuming application*
  - *Risk of misleading safety assessments*

Various solution spaces



Papanikolaou et al. (2009)

APPLICATION OF GOAL-BASED REGULATIONS - EXAMPLE

Ch. 3 – Ship structure

Goal

- A ship structure that can deal with the anticipated global and local environmental (ice) loads

Functional Requirements

- Applied materials must be suitable for operation at the foreseen temperature
- The ship structure must be designed to resist both global and local structural loads anticipated under the foreseen ice conditions

Regulations

- In order to comply with the functional requirements, the ship shall either be designed in accordance with an suitable Polar Class standard, or another standard offering an equivalent level of safety

Polar Class	Ice description (based on WMO Sea Ice Nomenclature)
PC 1	Year-round operation in all polar waters
PC 2	Year-round operation in moderate multi-year ice conditions
PC 3	Year-round operation in second-year ice which may include multiyear ice inclusions
PC 4	Year-round operation in thick first-year ice which may include old ice inclusions
PC 5	Year-round operation in medium first-year ice which may include old ice inclusions
PC 6	Summer/autumn operation in medium first-year ice which may include old ice inclusions
PC 7	Summer/autumn operation in thin first-year ice which may include old ice inclusions

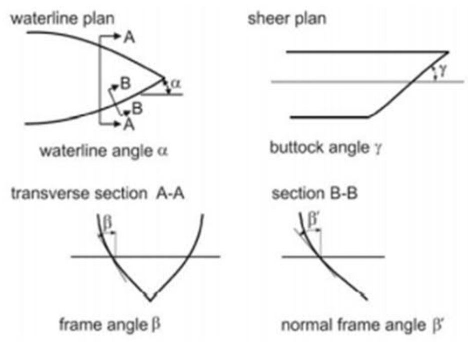
APPLICATION OF GOAL-BASED REGULATIONS - EXAMPLE

Ch. 3 – Ship structure

Alternative 1: Application of Polar Class rules

- General strengths
  - *Straightforward to apply and to verify compliance*
  - *Well-proven for 'conventional designs'*
- Weaknesses
  - *Prescriptive rules*
    - The rules might act as design constraints
  - *The efficiency of the solution depends on the efficiency of the rules*
    - The probabilistic nature of ice loading is not considered
    - Semi-empirically determined
    - No clear performance goal

Examples of prescriptive Polar Class rules:



(a) Shape coefficient, fa_i, is to be taken as

$$fa_i = \alpha_i / 30$$

(b) Force, F_i:

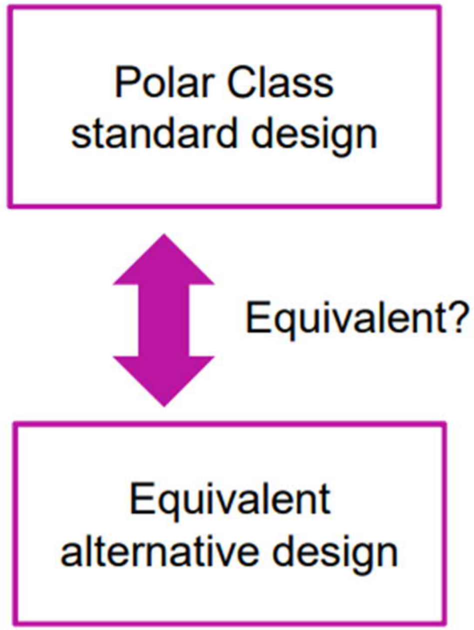
$$F_i = fa_i \cdot CF_{CV} \cdot D^{0.47} \text{ [MN]}$$

APPLICATION OF GOAL-BASED REGULATIONS - EXAMPLE

Ch. 3 – Ship structure

Alternative 2: Equivalent alternative design

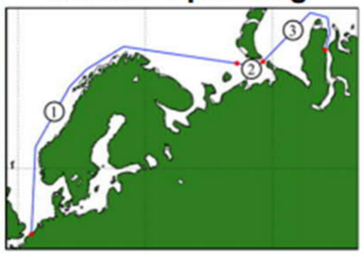
- Challenges
  - *The Polar Code does not determine any safety <u>performance metrics</u> for the ship structure*
    - Difficult to compare the ‘safety performance’ of an alternative design with that of a ‘Polar Class standard’ design
  - *There is no agreed on “testing standard”*
    - Lack of data as well as well-proven performance assessment methods



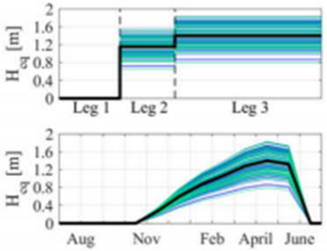
APPLICATION OF GOAL-BASED REGULATIONS - EXAMPLE

Design context

Route / Operating



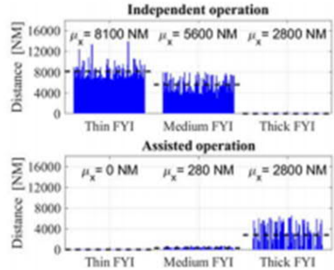
Stochastic data



Simulation

Simulated data

Ice exposure



Design tool(s)

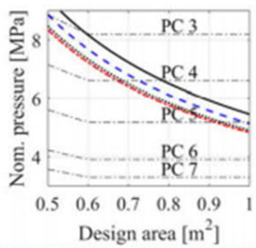
Probabilistic ice pressure assessment

$$z \stackrel{*}{=} [4.6 + \ln(xf)]CA^D$$

*Method by (Jordaan et al., 1993)

Estimated design load

E.g. 30-year maximum ice load



Functional requirement

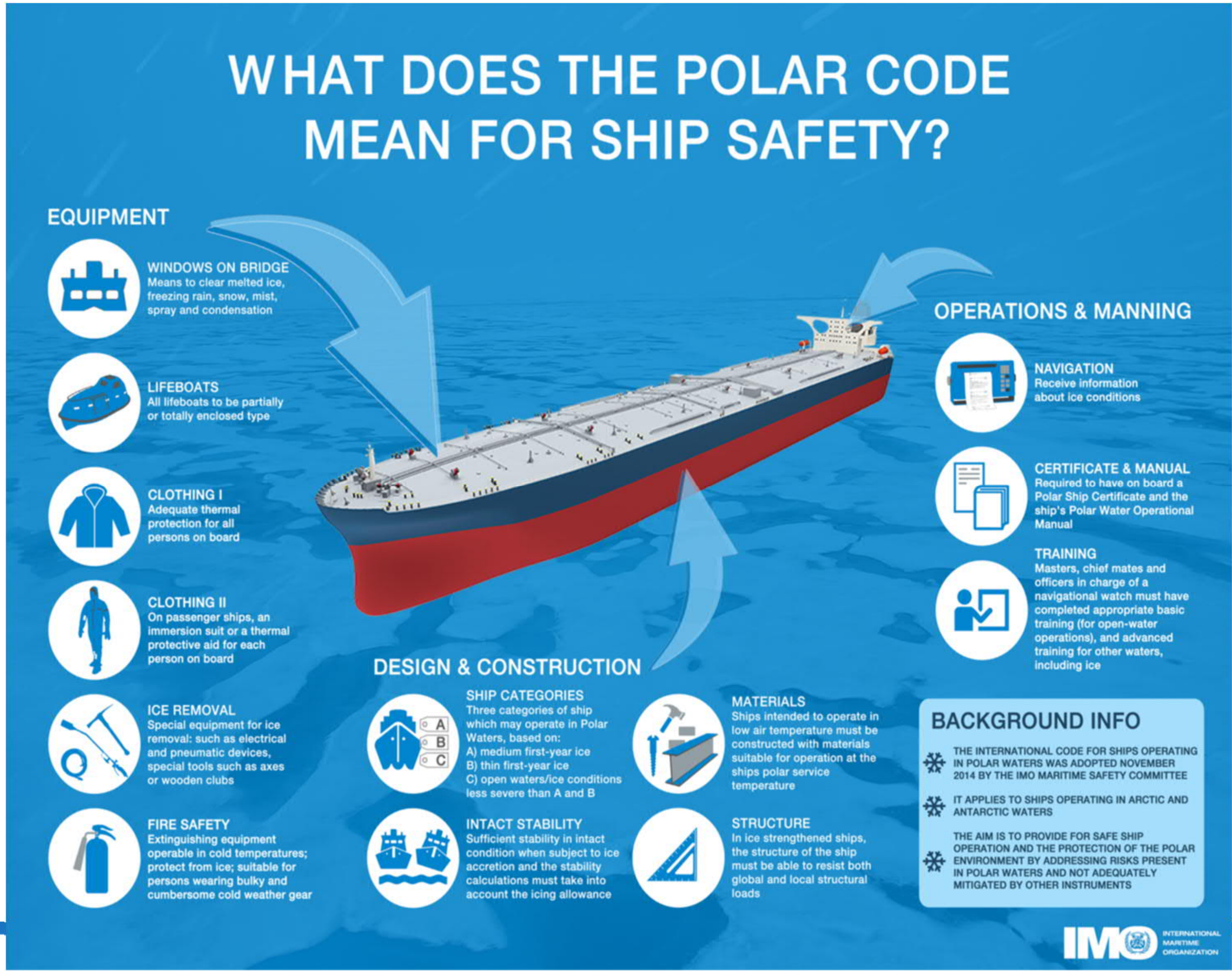
- E.g. minimum required strength margin

CHAPTER 12 – MANNING AND TRAINING

- The goal of this chapter is to ensure that ships operating in polar waters are appropriately manned by adequately qualified, trained and experienced personnel.
- Masters, chief mates and officers in charge of a navigational watch shall be qualified in accordance with chapter V of the STCW Convention and the STCW Code, as amended, as follows:

Ice conditions	Tankers	Passenger ships	Other
Ice Free	Not applicable	Not applicable	Not applicable
Open waters	Basic training for master, chief mate and officers in charge of a navigational watch.	Basic training for master, chief mate and officers in charge of a navigational watch.	Not applicable
Other waters	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch.	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch.	Advanced training for master and chief mate. Basic training for officers in charge of a navigational watch.

ADDITIONAL REQUIREMENTS TO SOLAS (see www.imo.org)



Polar Operational Limit Assessment Risk Indexing System (POLARIS)

PART I-A POLARIS (1)

Polar Operational Limit Assessment Risk Indexing System (POLARIS)

- A standard approach for the determining limitations in operations in ice
- Can be used
  - for voyage planning purposes or in real-time to aid in the decision making
  - by Administrations as a means to set operational limitations for ships.

IMPORTANT DEFINITIONS RELATED TO ICE CONDITIONS

- *Ice free waters* means no ice present. If ice of any kind is present this term shall not be used
- *Open water* mean a large area of freely navigable water in which sea ice is present in concentrations less than 1/10. No ice of land origin is present
- *Sea ice* means any form of ice found at sea which has originated from the freezing of sea water
- *Ice of land origin* means Ice formed on land or in an ice shelf, found floating in water
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- *Old ice* means sea ice which has survived at least one summer's melt; typical thickness up to 3 m or more. It is subdivided into residual first-year ice, second-year ice and multi-year ice

POLARIS (2)

- Uses a **Risk Index Outcome (RIO)** value to assess limitations for operation in ice.
- The RIO is determined by a summation of the **Risk Index Values (RIVs)** for each ice type present in an ice regime multiplied by its concentration (expressed in tenths):

$$\mathbf{RIO = (C_1xRIV_1)+(C_2xRIV_2)+(C_3xRIV_3)+\ldots(C_nxRIV_n)}$$

Where $C_1 \ldots C_n$ are the concentrations (in tenths) of ice types within the ice regime

$RIV_1 \ldots RIV_n$ are the Risk Index values corresponding to the ship's ice class

Risk Index Values (RIV) for different ice types and ice classes

POLAR SHIP CATEGORY	ICE CLASS	ICE FREE	NEW ICE	GREY ICE	GREY WHITE ICE	THIN FIRST YEAR FIRST STAGE	THIN FIRST YEAR 2ND STAGE	MEDIUM FIRST YEAR	MEDIUM FIRST YEAR 2	THICK FIRST YEAR	SECOND YEAR	LIGHT MULTI YEAR	HEAVY MULTI YEAR
A	PC 1	3	3	3	3	2	2	2	2	2	2	1	1
	PC 2	3	3	3	3	2	2	2	2	2	1	1	0
	PC 3	3	3	3	3	2	2	2	2	2	1	0	-1
	PC 4	3	3	3	3	2	2	2	2	1	0	-1	-2
	PC 5	3	3	3	3	2	2	1	1	0	-1	-2	-2
B	PC 6	3	2	2	2	2	1	1	0	-1	-2	-3	-3
	PC 7	3	2	2	2	1	1	0	-1	-2	-3	-3	-3
C	IAS	3	2	2	2	2	1	0	-1	-2	-3	-4	-4
	1A	3	2	2	2	1	0	-1	-2	-3	-4	-4	-4
	1B	3	2	2	1	0	-1	-2	-2	-3	-4	-5	-5
	1C	3	2	1	0	-1	-2	-2	-3	-4	-4	-5	-6
	NO ICE CL	3	1	0	-1	-2	-2	-3	-3	-4	-5	-6	-6

POLARIS (3)

Figure 10 of MSC 94/INF.13. Typical Arctic ice regime:
4/10 thick FY ice, 1/10 SY ice, 1/10 MY ice

POLARIS (4)

Table 1.1: Risk Index Outcome criteria

RIO_{SHIP}	***Ice classes PC1-PC7***	***Ice classes below PC 7 and ships not assigned an ice class***
RIO ≥ 0	Normal operation	Normal operation
-10 ≤ RIO < 0	Elevated operational risk*	Operation subject to special consideration**
RIO < -10	Operation subject to special consideration**	Operation subject to special consideration**

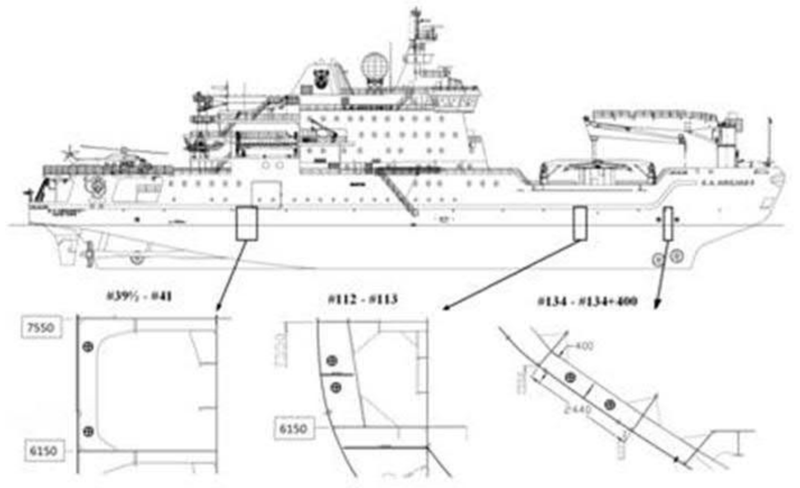
Table 1.2 Recommended speed limits for elevated risk operations

Ice Class	**Recommended Speed Limit**
PC1	11 knots
PC2	8 knots
PC3-PC5	5 knots
Below PC5	3 knots

Assessment of POLARIS

Measurements onboard SA Agulhas II

- Goal: A stochastic model linking ice loads with ice conditions
- Measurements onboard MS Agulhass II on the Baltic Sea (2012) and on the Antarctica (2012, 2013, 2014, 2015…)
- Co-operation with University of Oulu, University of Stellenboch (South Africa), Finnish Meteorological Institute
- Funding by Academy of Finland, TEKES, STX Finland, Aker Arctic, Rolls Royce, Wärtsilä

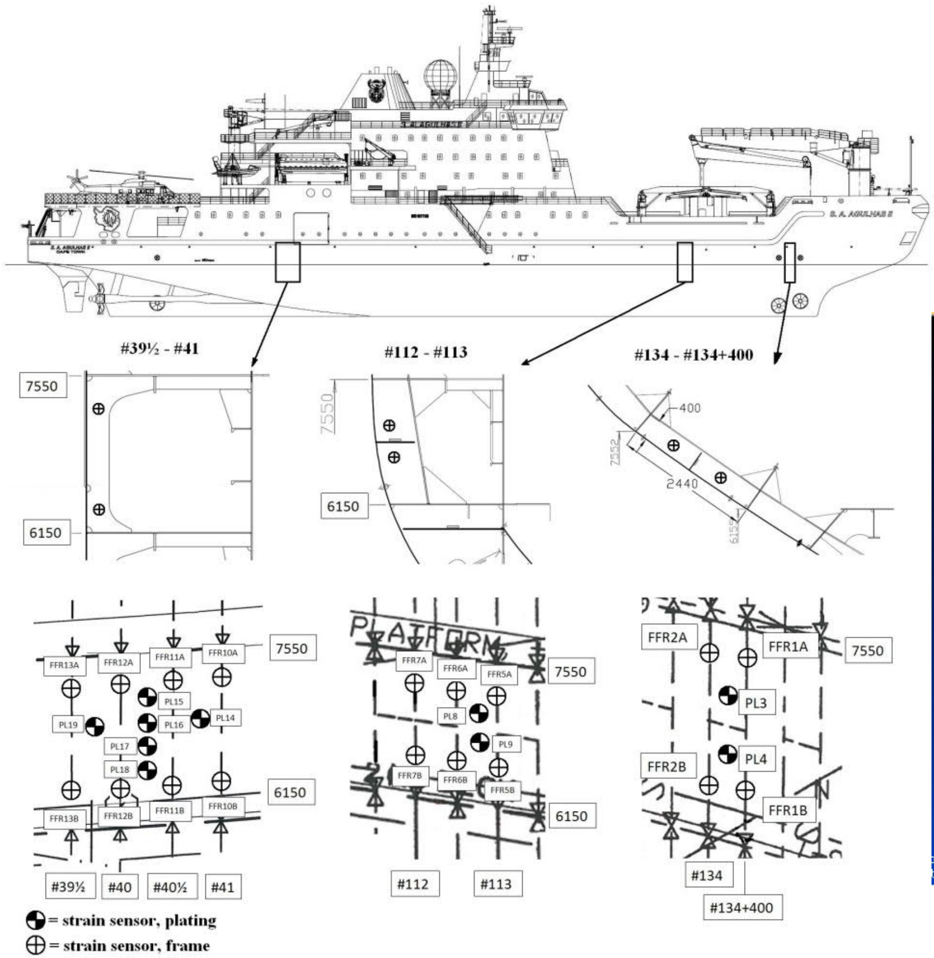


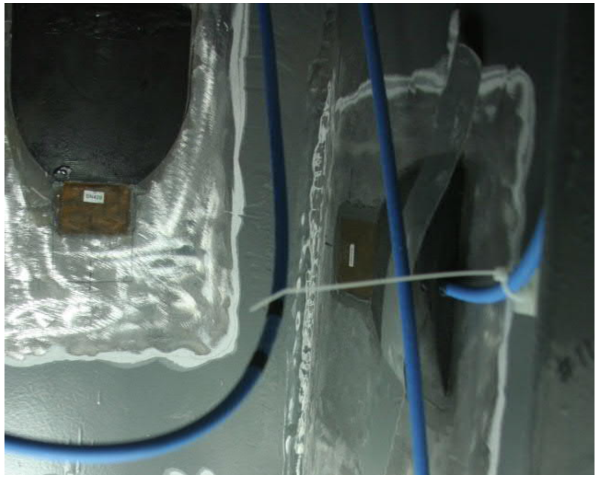
SA Agulhass II

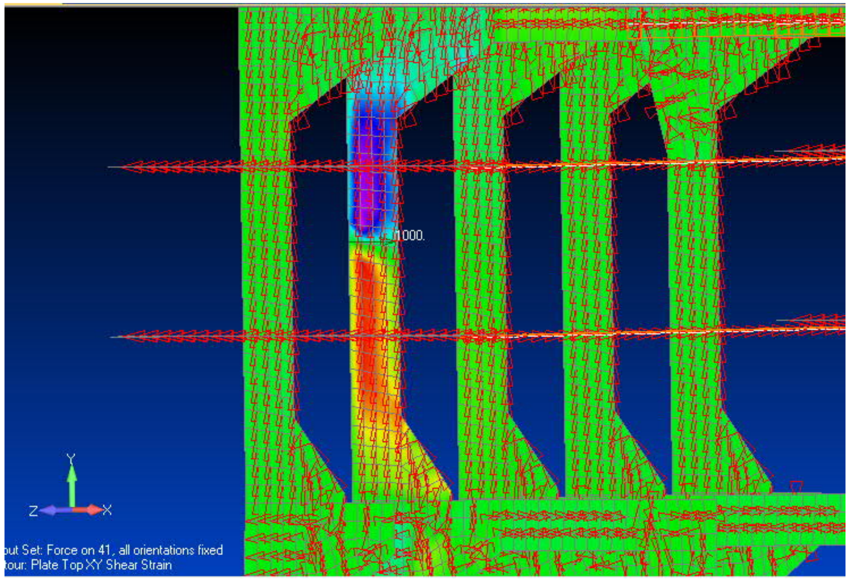
Table 1. Ship data (Wikipedia and Suominen *et al.*, 2015)

Ship type	Polar supply and research vessel
Tonnage	Gross tonnage 12,897 GT Net tonnage 3,840 NT
Length	134.2 m
Beam	21.7 m
Draught	7.65 m
Depth	10.55 m
Displacement	13,687 tons
Deadweight	4,780 DWT
Ice class	Polar Class 5 (DNV ICE 10 for the hull)
Installed power	4 × Wärtsilä 6L32 (4 × 3,000 kW)
Propulsion	Diesel-electric; two shafts (2 × 4,500 kW) Two controllable pitch propellers
Speed	16 knots (max) 5 knots in 1 m ice
Range	15,000 nautical miles at 14 knots.
Capacity	100 passengers in 46 cabins 4,000 m^3 cargo hold 500 m^3 of polar diesel
Crew	45

Ice loads measurements onboard SA Agulhas II

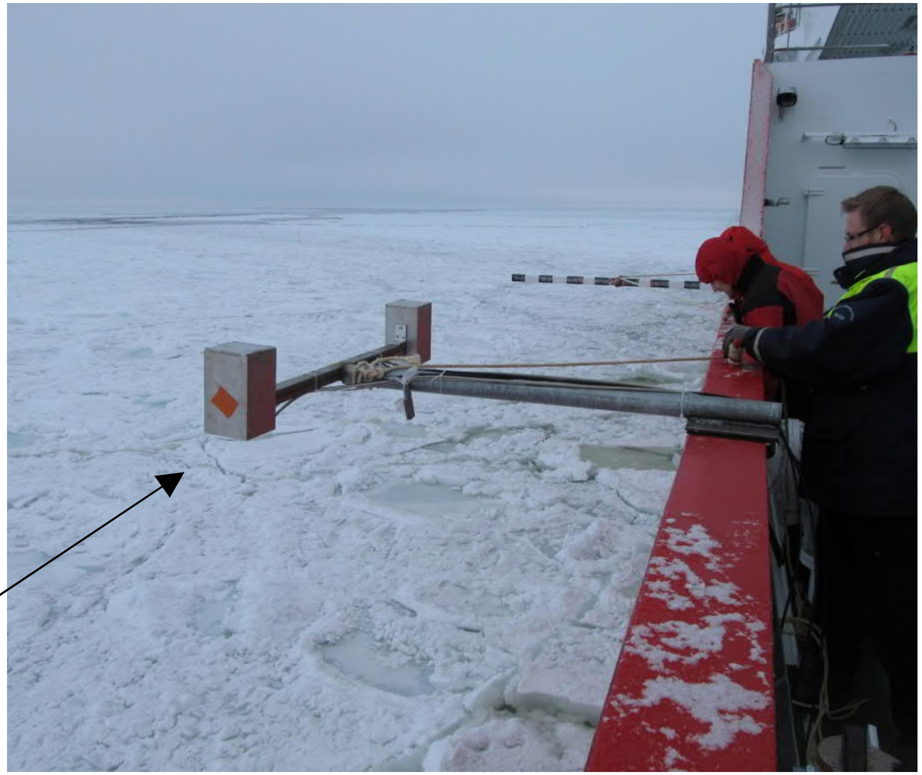






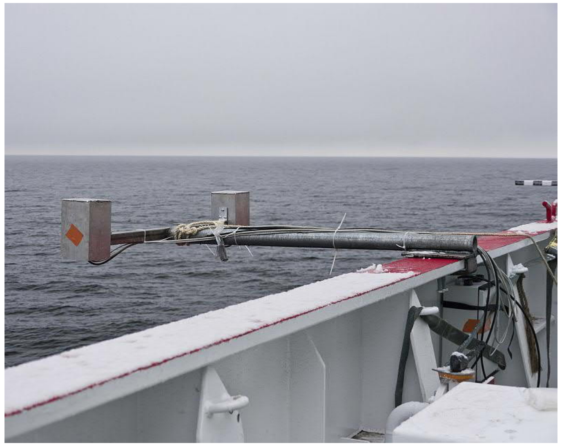
Ice thickness measurements

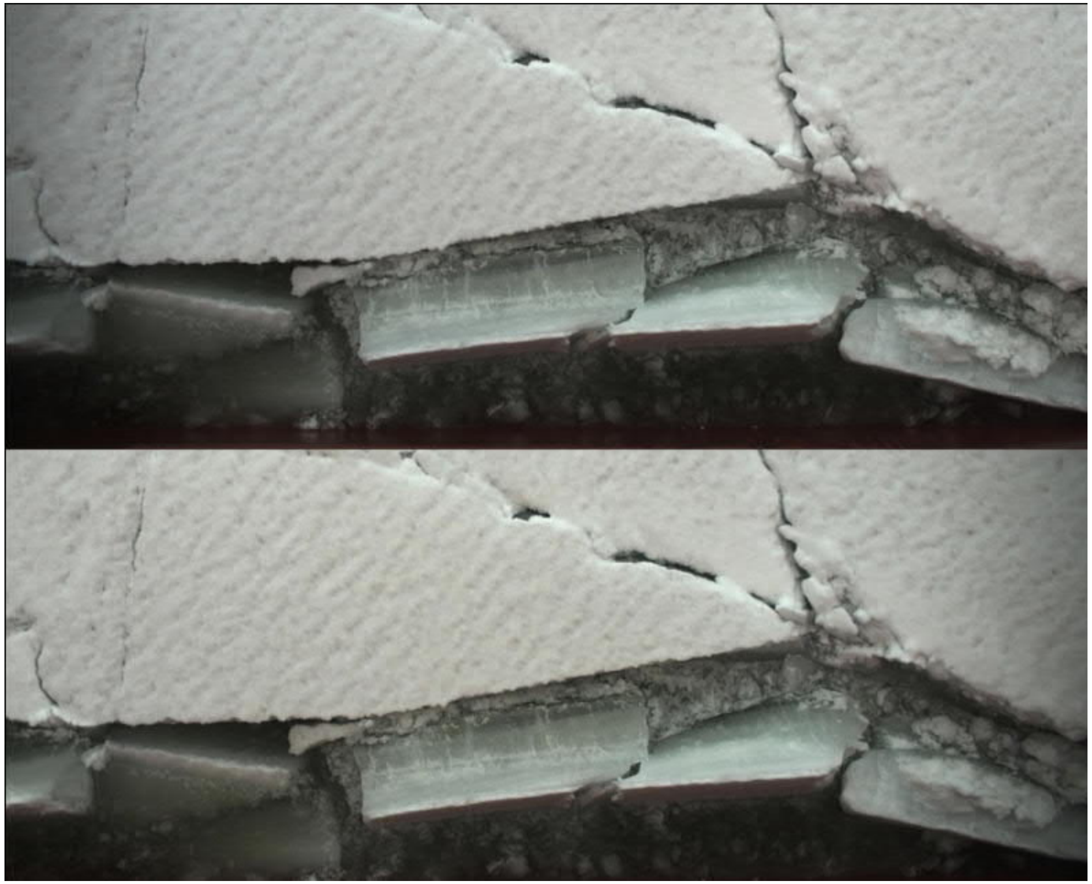
EM Device



Stereo camera

Stereo cameras to measure level ice thickness from the turning pieces





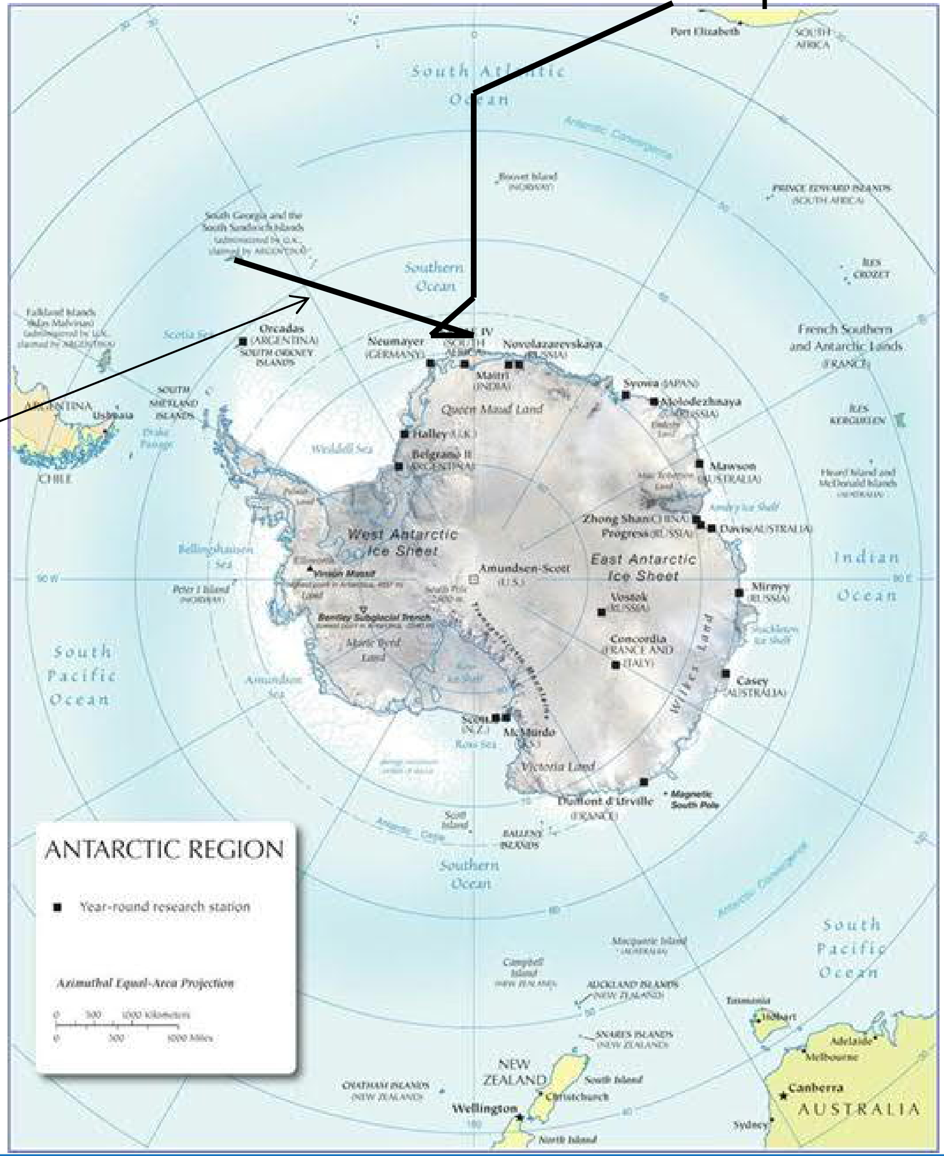
Antarctica voyage 2013-2014

Route of SA Agulhas II

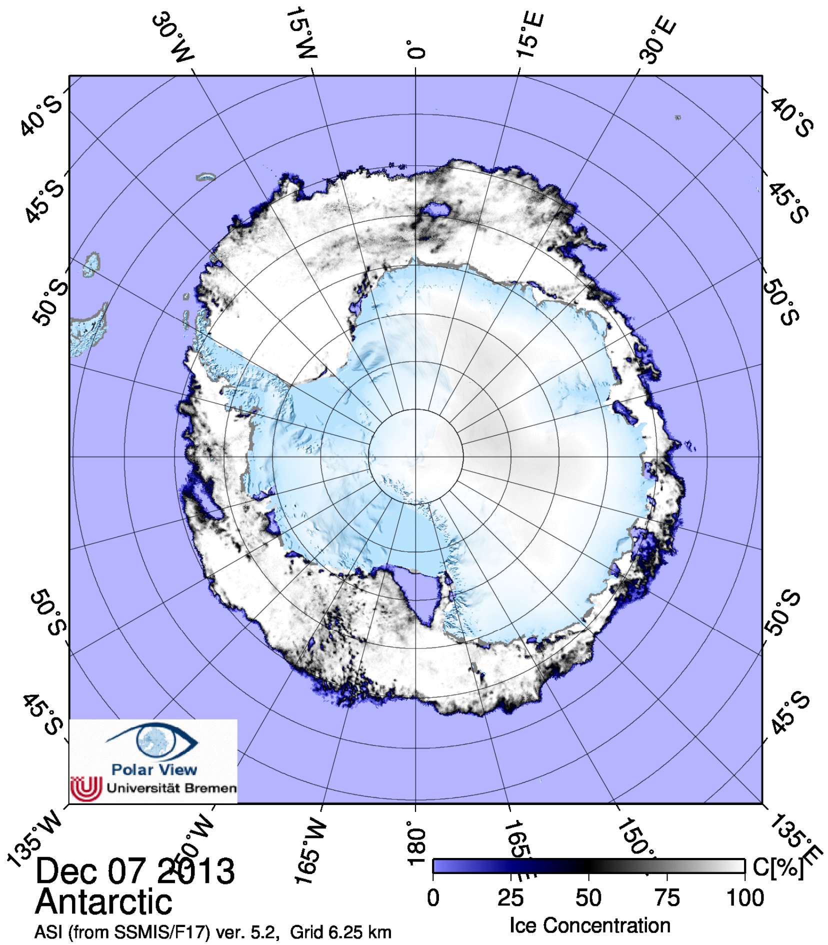
28.11.2013-

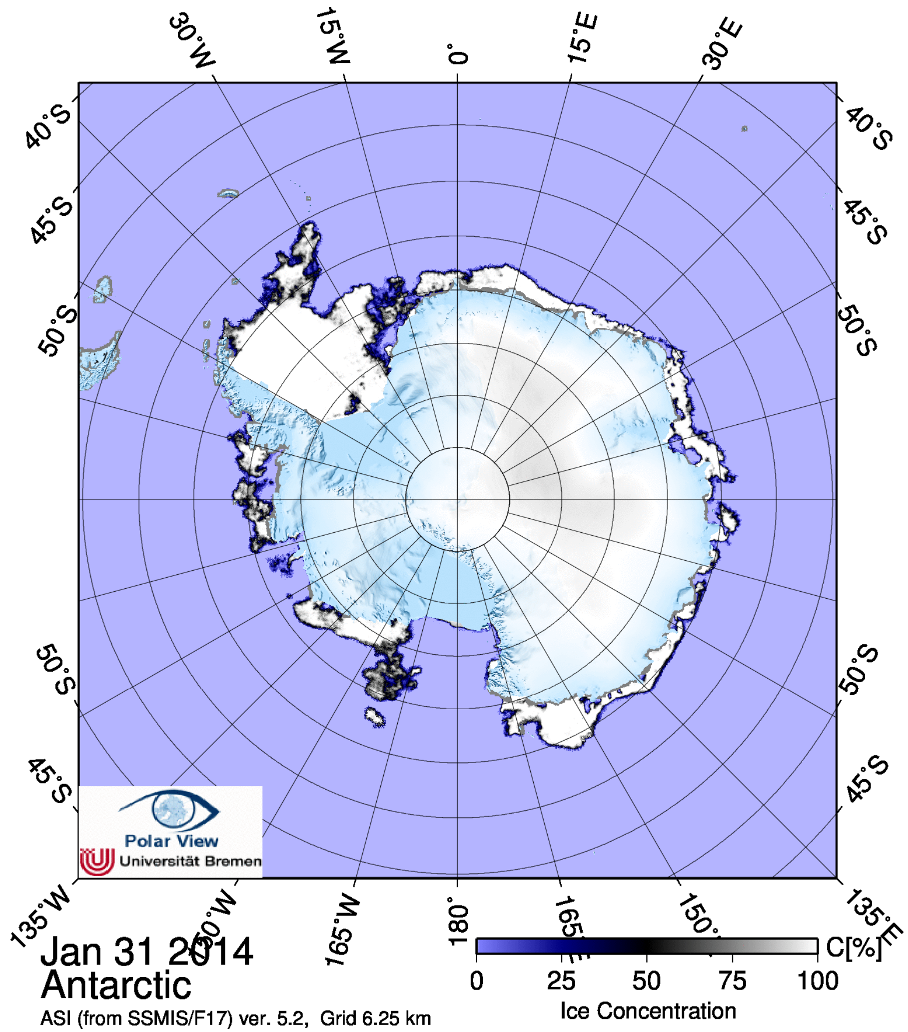
13.02.2014

Cape Town

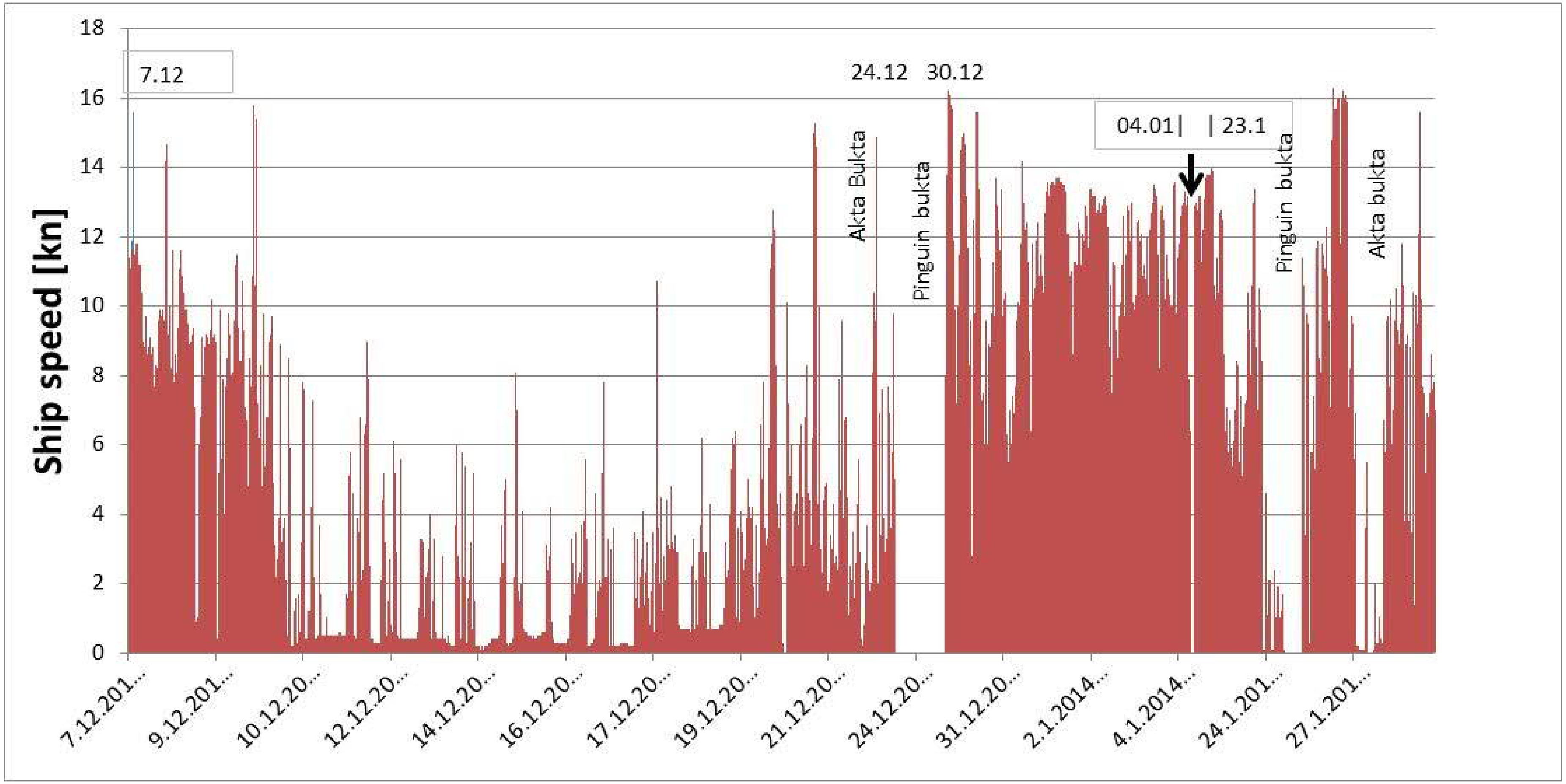


Ice conditions/Early December-Late January



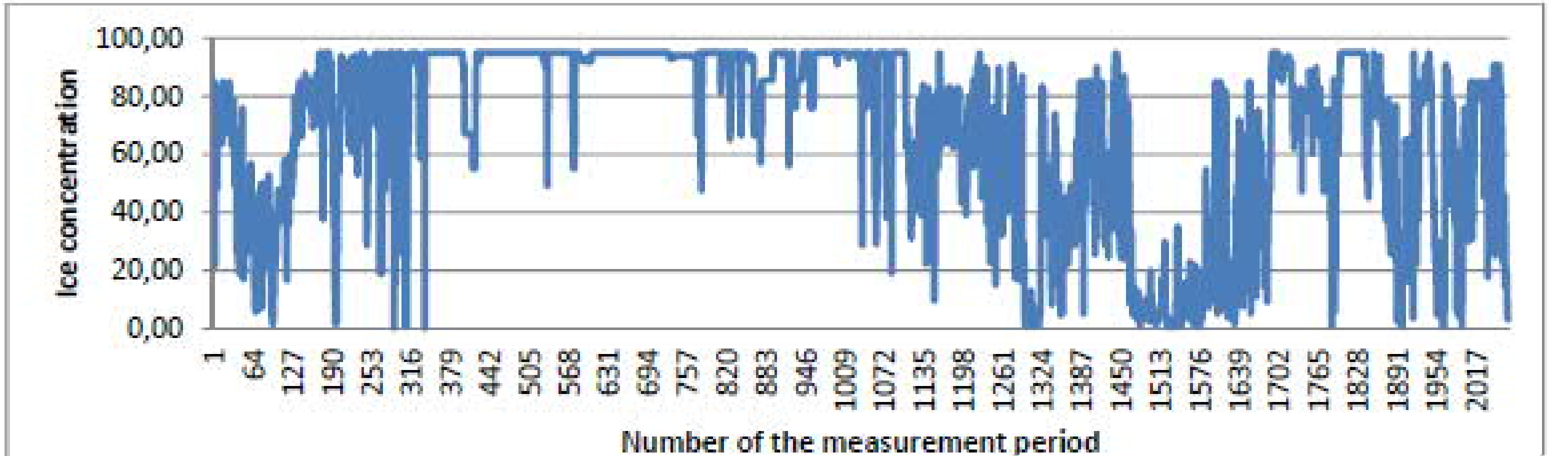


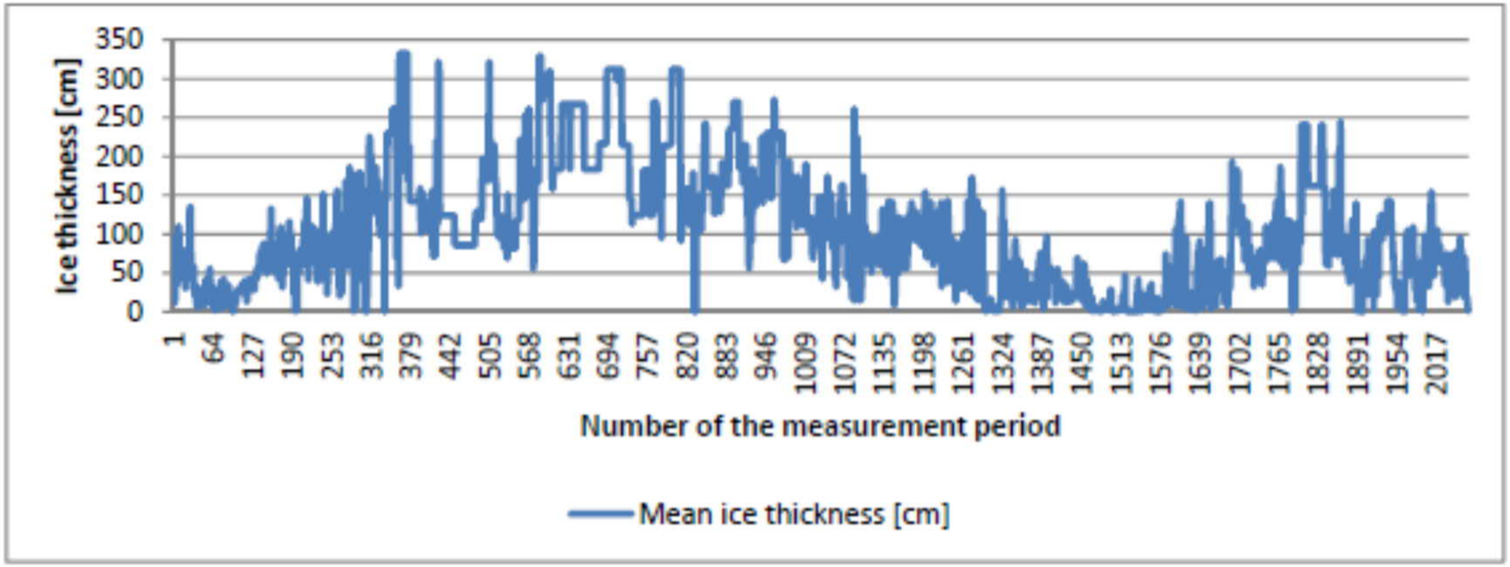
Ship's 10 min average speed



Comparison of the new Polar Code RIV values with the measured ice loads

Ice concentration /Thickness





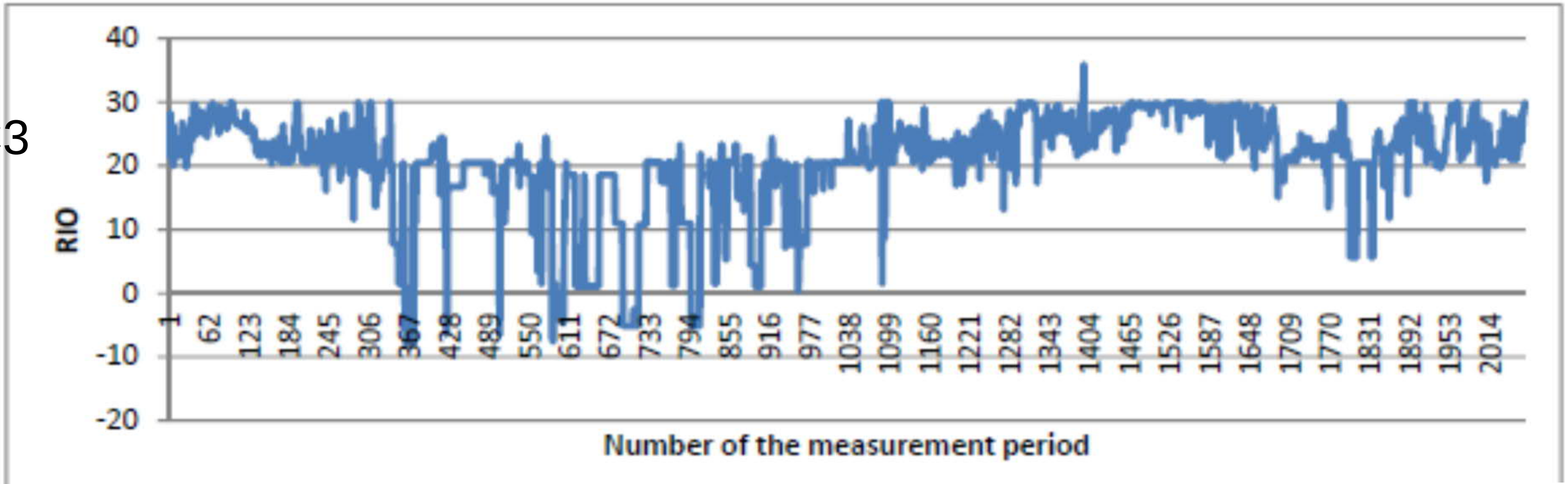
Risk Index Values for PC 3, PC 5 and IAS

Table 2. Risk Index Values (RIV) for ice classes PC3, PC5 and IAS for decayed ice conditions.

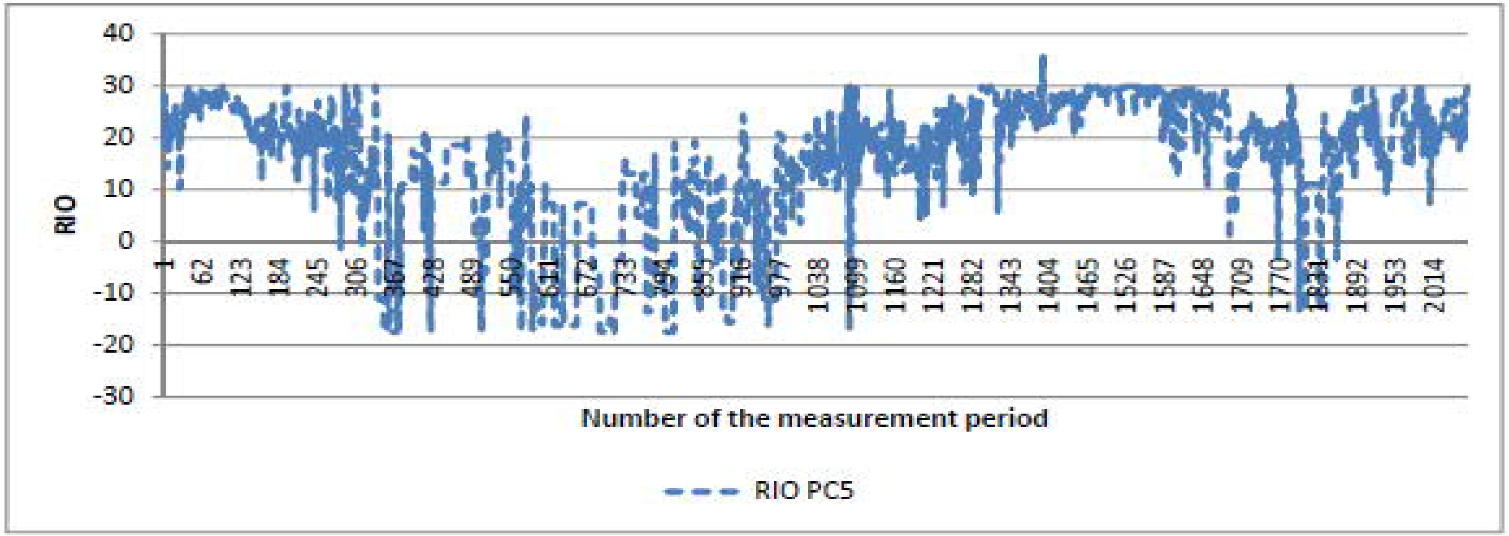
Stages of ice development defined by WMO	Open water to Grey-white ice (15 to 30 cm thick)		Thin FY ice, 1st stage (30 to 50 cm thick)	Thin FY ice, 2nd stage (50 to 70 cm thick)	Medium FY ice, 1st stage (70 to 95 cm thick)	Medium FY ice, 2nd stage (95 to 120 cm thick)	Thick FY ice (sea ice that is greater than 120 cm thick)				Second year ice	Light MY ice	Heavy MY ice
Range of ice thickness [cm]	0 - 20	20 - 40	40 - 60	60 - 80	80 - 100	100-120	120 - 140	140 - 160	160 - 180	180 - 200	200 - 250	250 - 300	300+
RIV for ice class PC3	3	3	2	2	2	2	2	2	2	2	1	0	-1
RIV for ice class PC5	3	2	2	2	2	2	1	1	1	1	-1	-2	-2
RIV for ice class IAS	3	2	2	1	1	0	-1	-1	-1	-1	-3	-4	-4

Risk Index Output (RIO) for PC3 and PC5

PC3



PC 5



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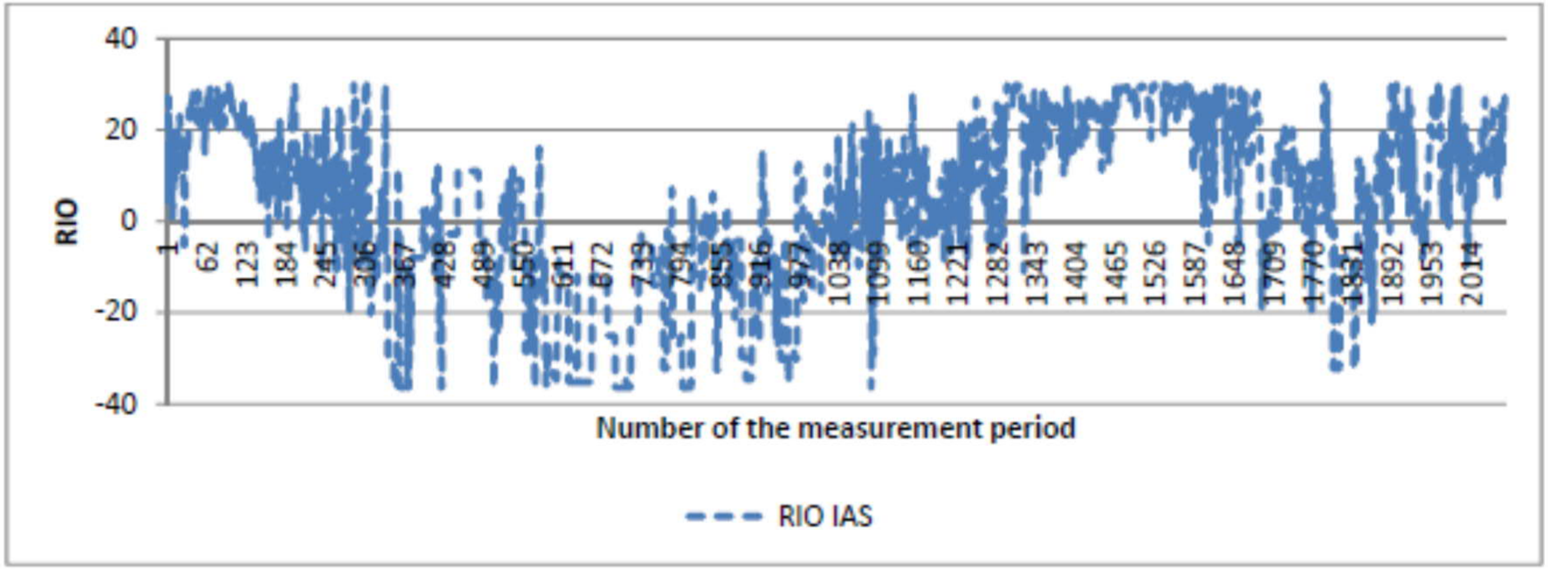
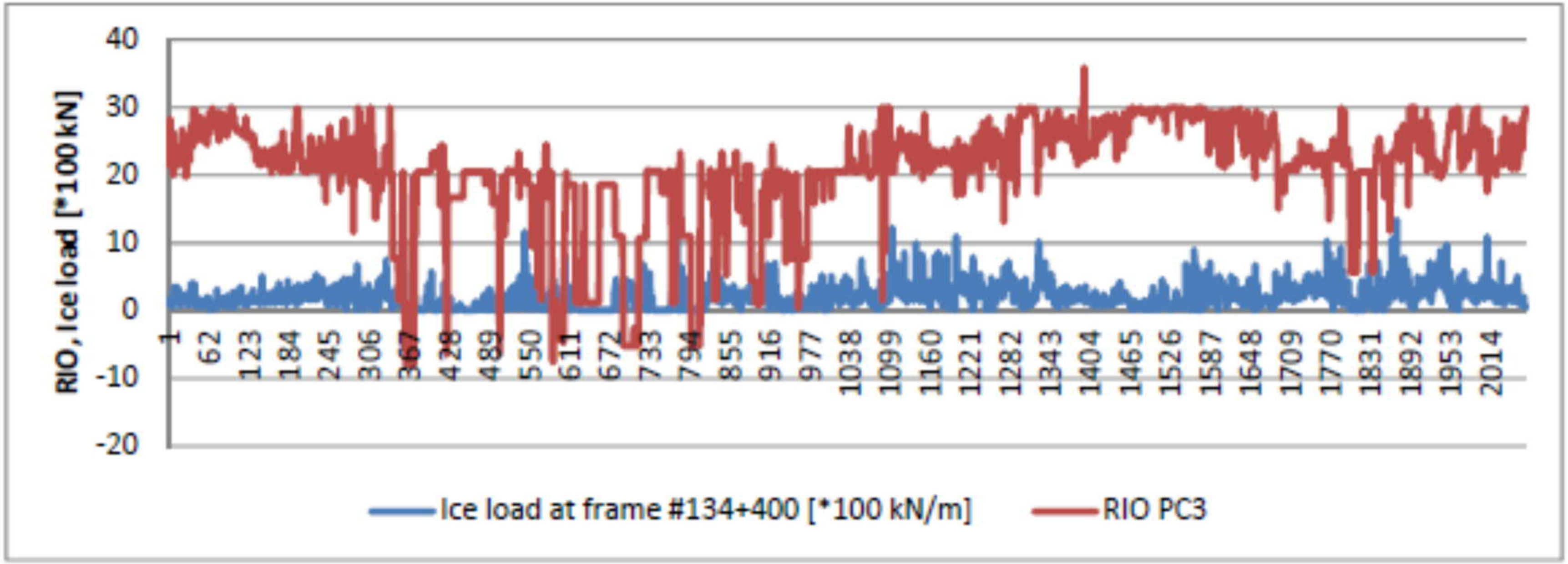
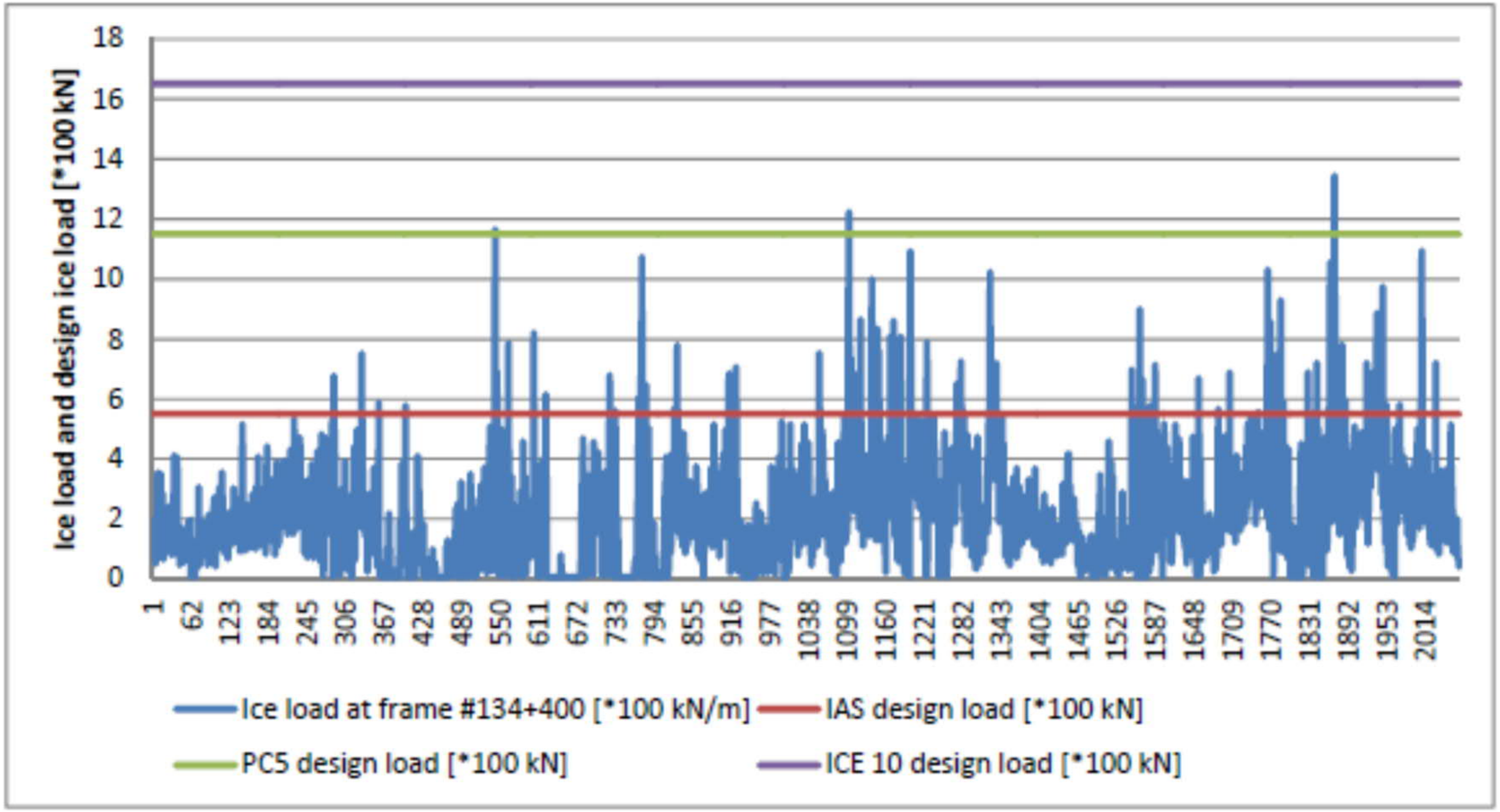
Risk Index Output (RIO) for IA Super



Comparison of the measured ice load and RIO for PC 3



Comparison of the measured ice load with the design load for PC 5, DNV ICE 10 and IA Super



ICE 10

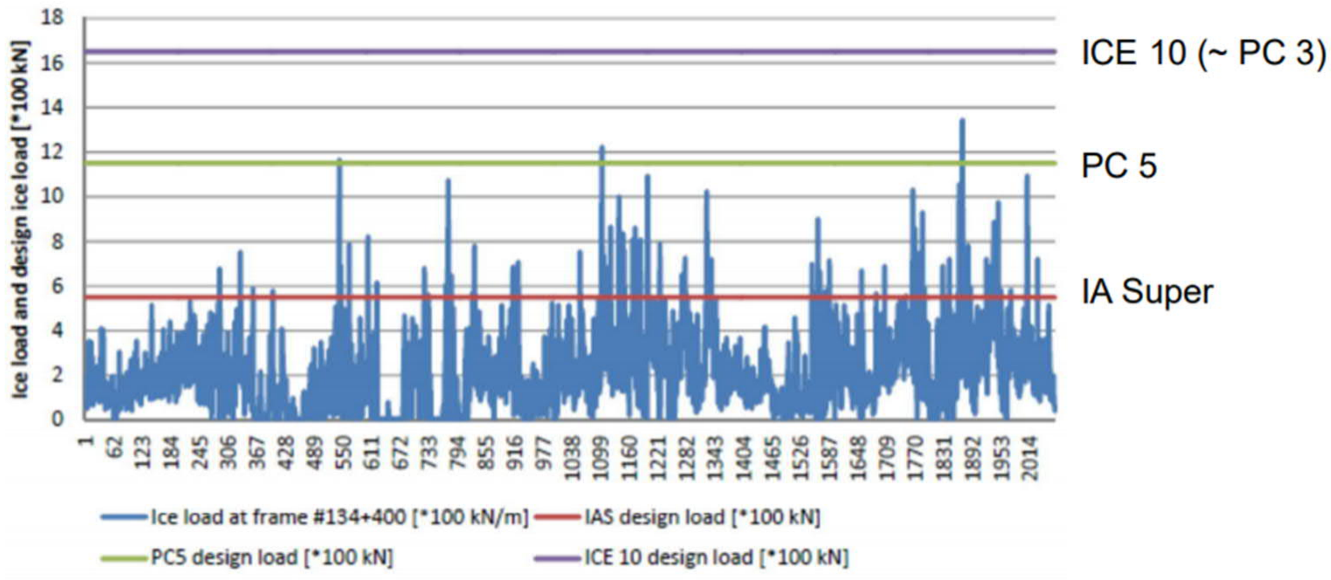
PC 5

IAS

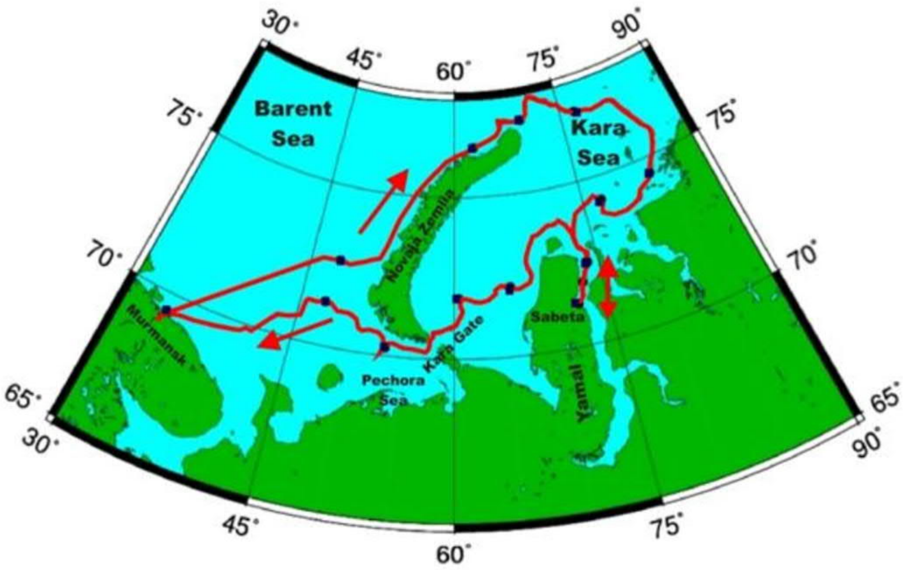
Assessment of POLARIS

- PC3: RIO is positive most of the time, but occasionally close to -10 → Elevated operational risk, limited speed operation permitted
- PC5 : RIO is positive most of the time, but occasionally close to -20 → Operation subject to special consideration
- IA Super: RIO is occasionally very low at around -40 → Operation not permitted

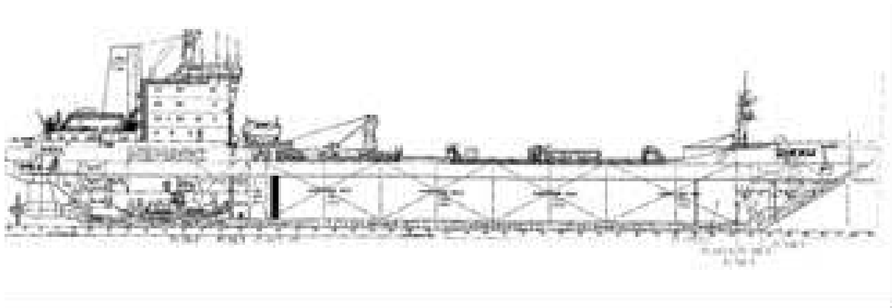
→ **This indicates that the POLARIS risk assessment is reasonable**



MT Uikku, 26.04.1998-13.05.1998

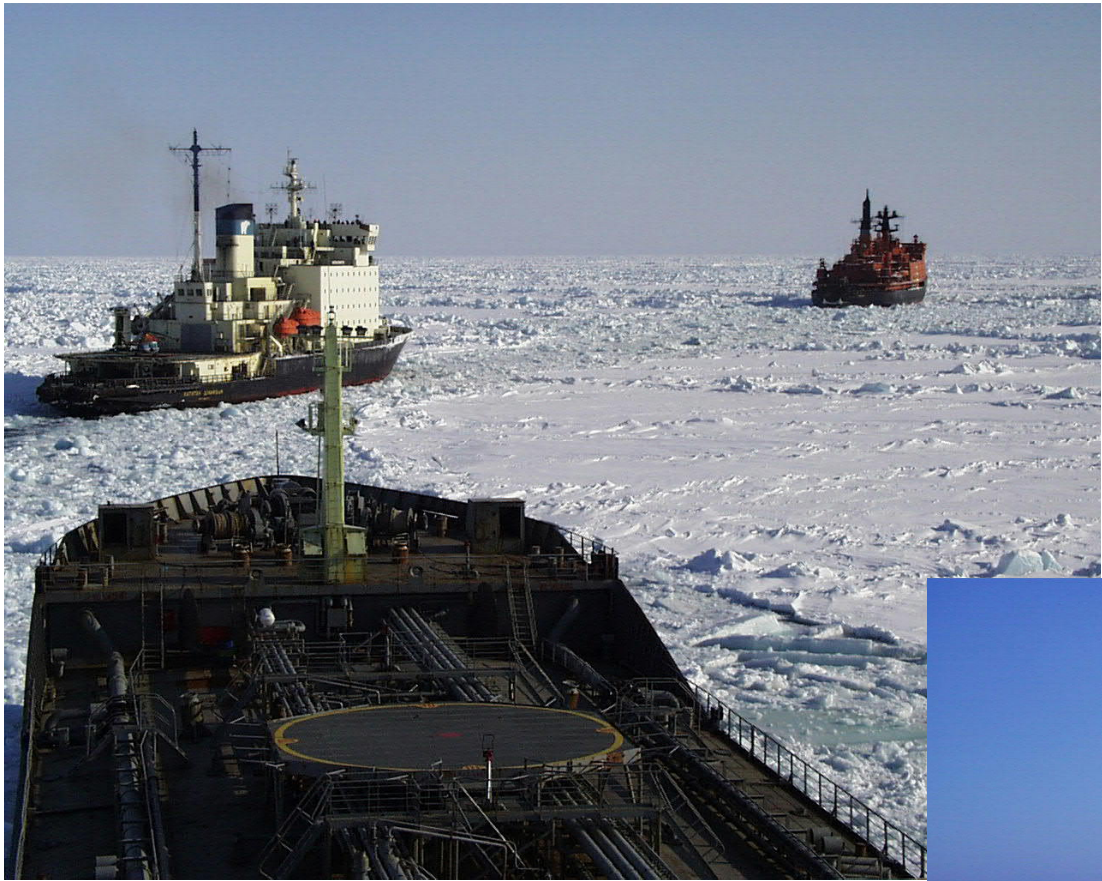


	SA Agulhas II	MT Uikku
Length, L_{pp} (m)	121,8	150
Breadth (m)	21,7	22,2
Draught (m)	7,65	9,5
Deadweight (t)	5000	15748
Displacement (t)	13632	22654
Speed (kn)	14	17
Propulsion power (MW)	9	11,4



30.04 North of Novaja Semlja

01.05
Kara Sea

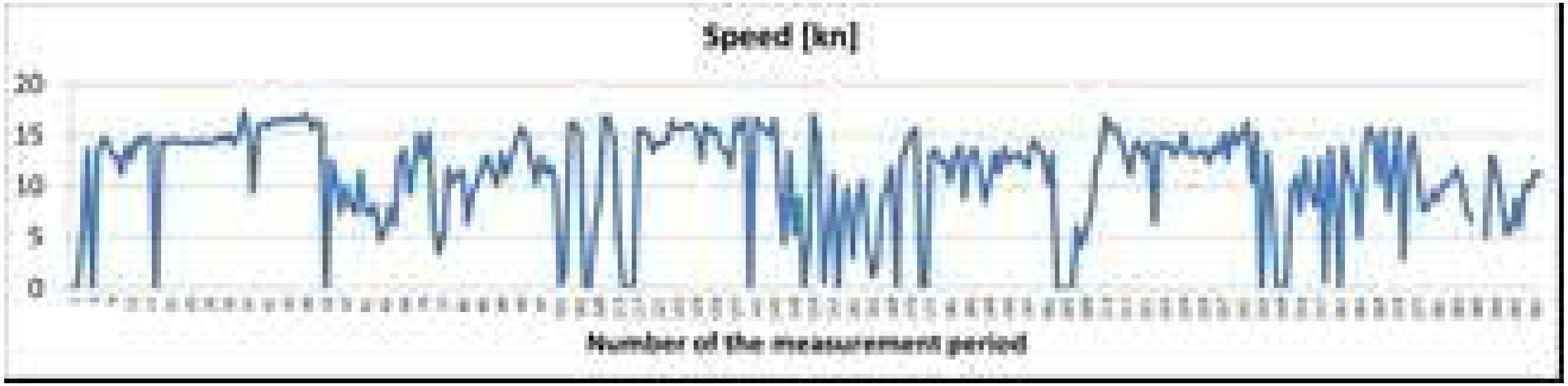


Assisted by IB Kapitan Dranitsyn
and Nuclear IB Rossiya

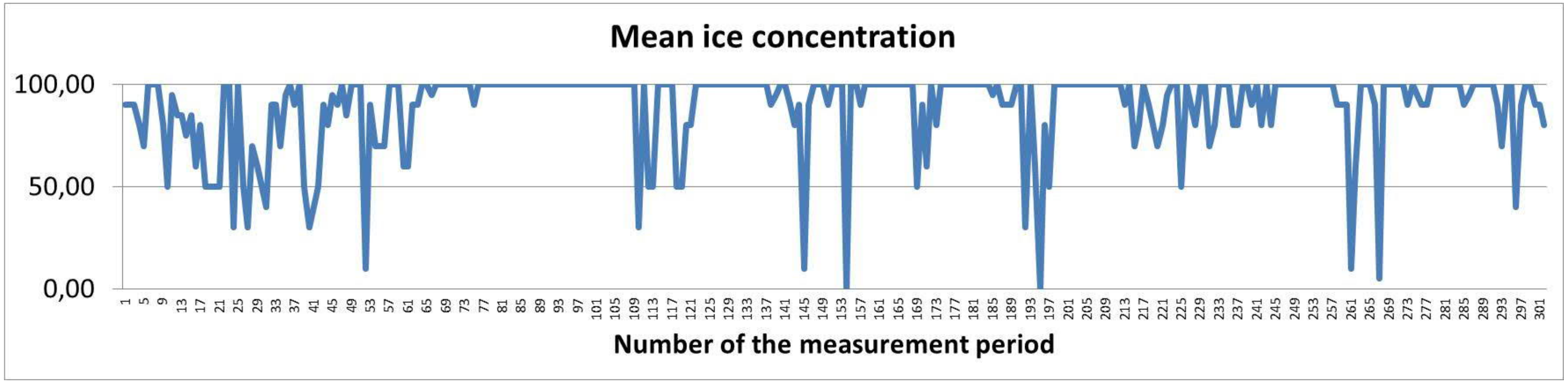
Aalto University
School of Engineering

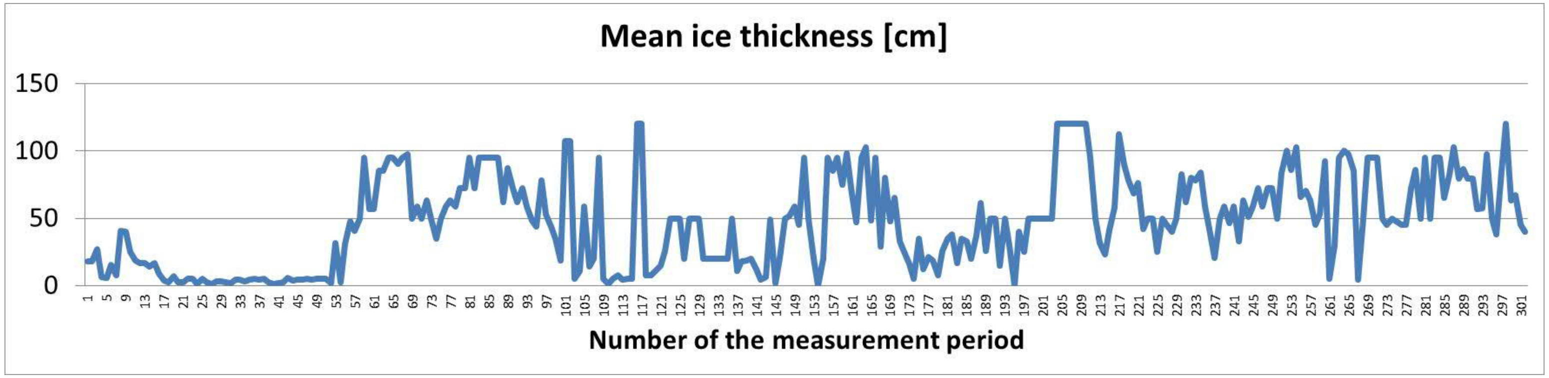
02.05
Getting close to Ob-Bay

Ship's 20 min average speed



Ice concentration /Thickness



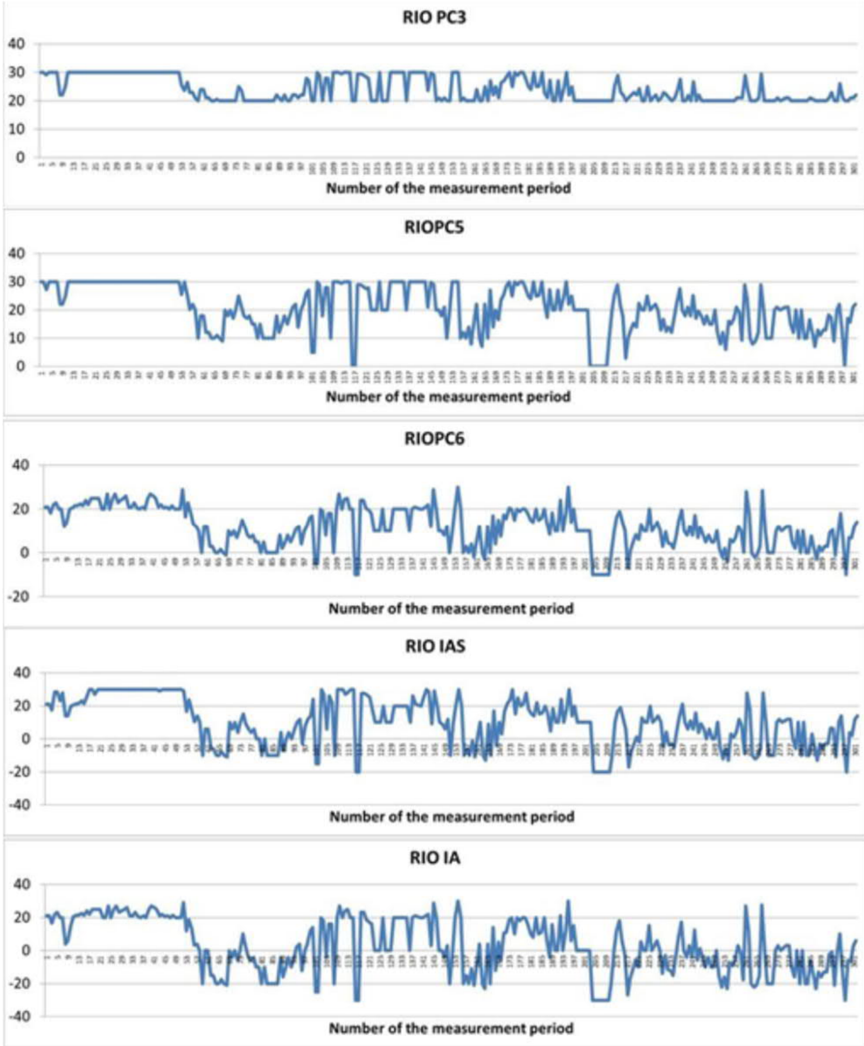


Risk Index Values for PC 3, PC 5 and IAS

Table 2. Risk Index Values (RIV) for ice classes PC3, PC5 and IAS for decayed ice conditions.

Stages of ice development defined by WMO	Open water to Grey-white ice (15 to 30 cm thick)		Thin FY ice, 1st stage (30 to 50 cm thick)	Thin FY ice, 2nd stage (50 to 70 cm thick)	Medium FY ice, 1st stage (70 to 95 cm thick)	Medium FY ice, 2nd stage (95 to 120 cm thick)	Thick FY ice (sea ice that is greater than 120 cm thick)				Second year ice	Light MY ice	Heavy MY ice
Range of ice thickness [cm]	0 - 20	20 - 40	40 - 60	60 - 80	80 - 100	100-120	120 - 140	140 - 160	160 - 180	180 - 200	200 - 250	250 - 300	300+
RIV for ice class PC3	3	3	2	2	2	2	2	2	2	2	1	0	-1
RIV for ice class PC5	3	2	2	2	2	2	1	1	1	1	-1	-2	-2
RIV for ice class IAS	3	2	2	1	1	0	-1	-1	-1	-1	-3	-4	-4

Risk Index Output (RIO) for PC3, PC5, PC6, IAS and IA



PC6 is the best ice class for a ship navigating behind an icebreaker on the Kara Sea during hard winter time ice conditions.

THANK YOU FOR YOUR ATTENTION !