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MARITIME FUTURES 2035: THE ARCTIC REGION

WORKSHOP REPORT & TECHNICAL DOCUMENTATION

Scenario Workshop | November 13, 2018 | Danish Meteorological Institute Copenhagen, Denmark

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These are the participants who graciously gave their time, energy, and ideas to shaping scenarios for creating safe and sustainable Arctic maritime activities by 2035. The affiliations listed are those given at the workshop. We thank them, again, for their work with us.

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Acknowledgements

First and foremost we would like to thank the incredible group of experts who gathered at our workshop to volunteer their time and expertise to brainstorming about safe and sustainable Arctic maritime futures; and without whom this workshop would not have been possible.

We would also like to acknowledge the generous funding support for the SALIENSEAS Project from ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462). Additional support for this workshop was contributed by our host institute, the Danish Meteorological Institute who offered their facilities and logistical resources necessary.

To provide a forum for people to discuss the future in a workshop is important, but the process only comes alive throughout the project if those discussions are captured. For this, we would like to thank Doug Cost (University of Alaska Fairbanks) for his skilled facilitation and insights provided during the workshop.

In addition to our group of dedicated participants, we are also grateful for the support provided by the following organizations:

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Study of Environmental Arctic Change (SEARCH): support provided in the form of presentation templates for workshop activities. https://www.searcharcticscience.org/

Polar Research and Policy Initiative: support provided by a network of experts at the workshop as well as in public outreach immediately following the workshop about preliminary results. http://www.polarconnection.org

Executive Summary

What kind of forecast information is needed for safe and sustainable Arctic maritime activities now and through 2035? Building on the SALIENSEAS project's platform for coproduction of climate services for maritime sectors active in European Arctic waters, a group of experts were brought together to develop scenarios for safe and sustainable maritime operations by the year 2035. Starting with the focal question "What information is needed to successfully respond to changes impacting Arctic maritime activities now and through 2035?" participants deliberated the most influential drivers of change that will impact the need for metocean and sea ice services to reduce uncertainties in maritime operational and tactical planning.

The workshop was envisioned as a participatory environment in which certain aspects of different likely futures could be explored, with the series of scenarios feeding into, and informing subsequent SALIENSEAS products. The workshop produced three scenario outcomes based on participants' expertise, each with a unique emphasis on either consistency or plausibility, or a combination of both: robustness. While it is not possible to predict the future, scenario analysis can aid communities and organizations to better prepare for the future considering "what if" questions and considering multiple plausible outcomes. For example, carrying the scenario results from the workshop forward into other SALIENSEAS project outputs (especially ones relying on serious games and participatory modeling), products may have increased relevance and longevity for future strategizing on how to best meet certain challenges.

To produce the scenarios presented herein, participants deliberated definitions of safe and sustainable Arctic maritime activities, refined a core group of 12 Key Factors that are likely to have major influence on operations in the future, and improvements in forecast services that will be needed in support. These Key Factors span political, scientific and socio-economic themes and notably include the uncertainties surrounding an influential outside player, China's activities. The Key Factors are: 1) Geopolitical stability, 2) Accessibility of Arctic sea routes, 3) User-centric information infrastructures and data, 4) Global economic trends, 5) Demand for Arctic resources, 6) Regulations and policy affecting Arctic operations, 7) Major incidents and critical events, 8) Predictability of sea ice variability, 9) Fluctuating energy prices, 10) China's strategic plan, 11) Sustainable and resilient local communities, 12) The trajectory of technological development in marine technologies. For each Key Factor, participants also produced a series of future projections (or possible future states) describing the range of possible trends for each. For example, for geopolitical stability, the three future projections identified by the participants range from total harmony and cooperation, to sporadic flexing of muscles via cyber attacks but without military action, to Cold War 2 over resources and regional dominance.

The post-workshop robustness analysis then explored the most plausible, consistent and robust bundles or combinations of future projections under each Key Factor. This produced three scenarios, for each the twelve Key Factors contributed one future projection -depending on whether the criteria for analysis is plausibility, consistency or robustness. This revealed the most plausible one to be a "Growing Pains" scenario, the most consistent to resemble a "The Winner Takes it All" scenario, and the most robust titled "All Aboard the Arctic Express"; a scenario series that demonstrates complex social, political and biophysical conditions dictating cross-sectoral stakeholder needs for research, observation and policy focus (see **Results)**.

Climate change and increased access in Arctic waters are creating a suite of questions for development planning policies: will increased access enable increased development? What are the strategic and security dimensions of upcoming changes? Maritime sectors, agencies, and communities have been trying to tackle what information they need to adapt to changes and to benefit from upcoming opportunities. By revealing the core drivers of change that maritime stakeholders and policy experts find significant to support safe and sustainable Arctic operations, these scenarios can help guide scientific engagement and development planning policy by taking the long view.

Geopolitical stability	Accessibility of Arctic sea routes	User-centric information infrastructures and data	Global economic trends	Demand for Arctic resources	Regulations and policies affecting Arctic operations	Major incidents and critical events	Predictability of sea ice variability	Fluctuating energy prices	China's strategic plans	Sustainable and resilient local communities	Trajectory of development in marine technologies
Cake for everyone	Easy access	Global harmonization	Arctic rush	Seafood first	Arctic 5 harmony	Ship crash	Breakthrough	Northern push	Mad Max	Expat haven	Techno-utopia for some, stormy seas for others
Status quo (occasional bullying)	Difficult access	Few specialized, big actors	High-cost closing off	Tourism first	Economic and commercial uses dominate	Status quo	Gradual improvement of predictive models	Northern blockade	Chinese finger cuffs	Education boost	Slow innovation and adoption
Cold War 2	No access	No development toward harmonization		Fossil futures	Environmentally driven regulation and policy		Unforeseen changes			Tax haven	
					Fragmented, soft regulatory regime						

Fig 1. The most robust scenario bundle. Key factors (column headers) and their future projections in the cells below, as developed by participants. The red line transecting future projections represents the most robust (plausible and consistent) scenario bundle. The future projections' hue of blue represents most plausible (darkest) to least plausible (lightest). As shown, the most robust scenario does not necessarily select all the most plausible future projections, because the pairwise consistency of each future projection is also taken into account. The detailed write up of Key Factors and Future Projections can be found in Appendix A1.

The following pages depict the graphic illustrations of the most robust scenario bundle "All Aboard the Arctic Express." The Future Projection that emerged from each Key Factor is depicted in a whimsical visual narrative. These illustrations will be used as visual assets in the computerized gaming platform, currently in development, that will explore uncertainties in maritime planners' decision environments during itinerary planning and possible interventions by demonstration services developed by project partners.

Graphic illustrations of the most robust future projection bundle: "All Aboard the Arctic Express"

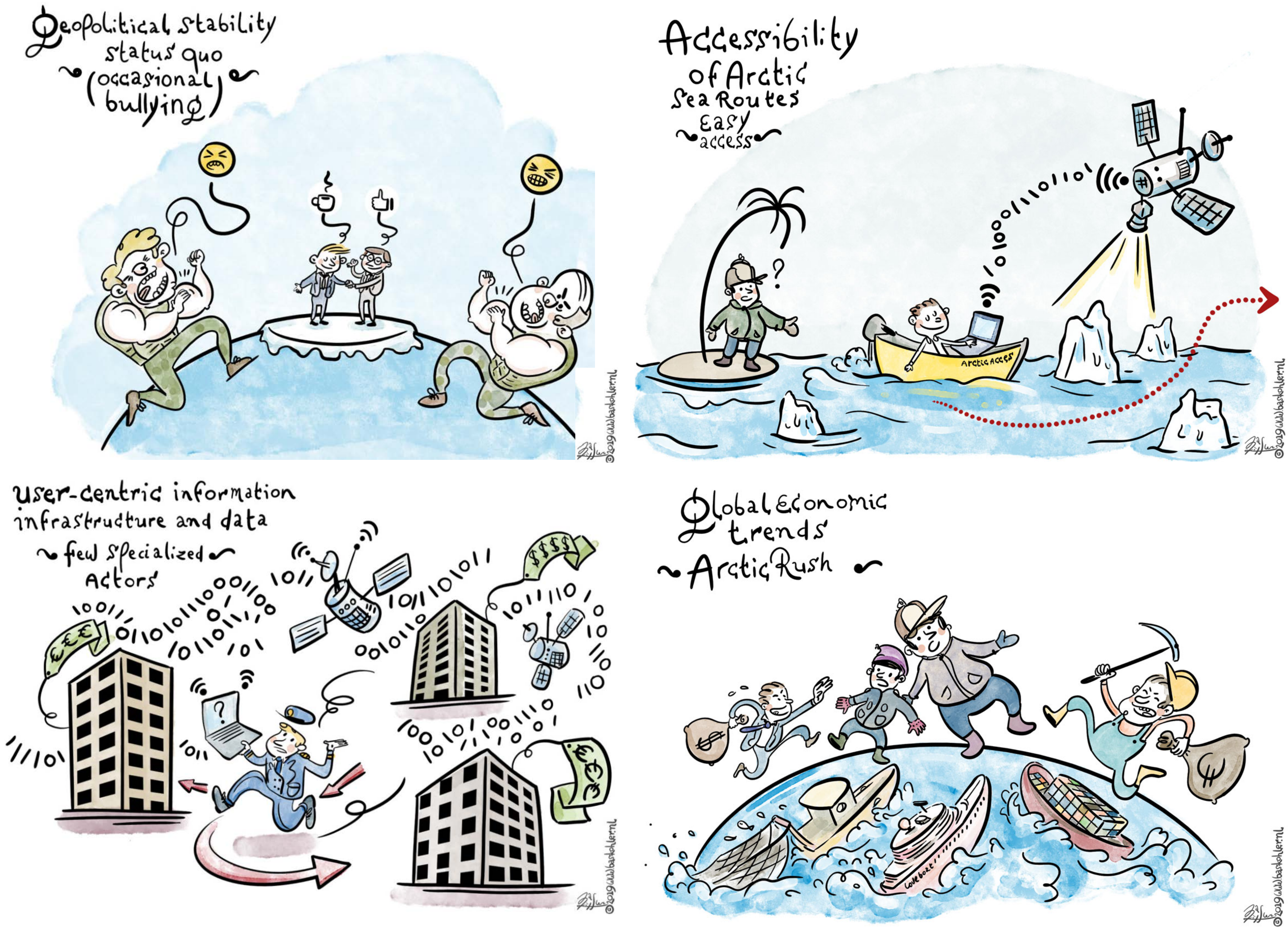


Fig 2a. Graphic narrative for the Future Projections in the most robust scenario bundle from Key Factors Geopolitical stability, Accessibility of Arctic sea routes, User-centric information infrastructures and data and Global economic trends. Descriptions can be found in Appendix A1. Illustrations by Bas Köhler (www.baskohler.nl).

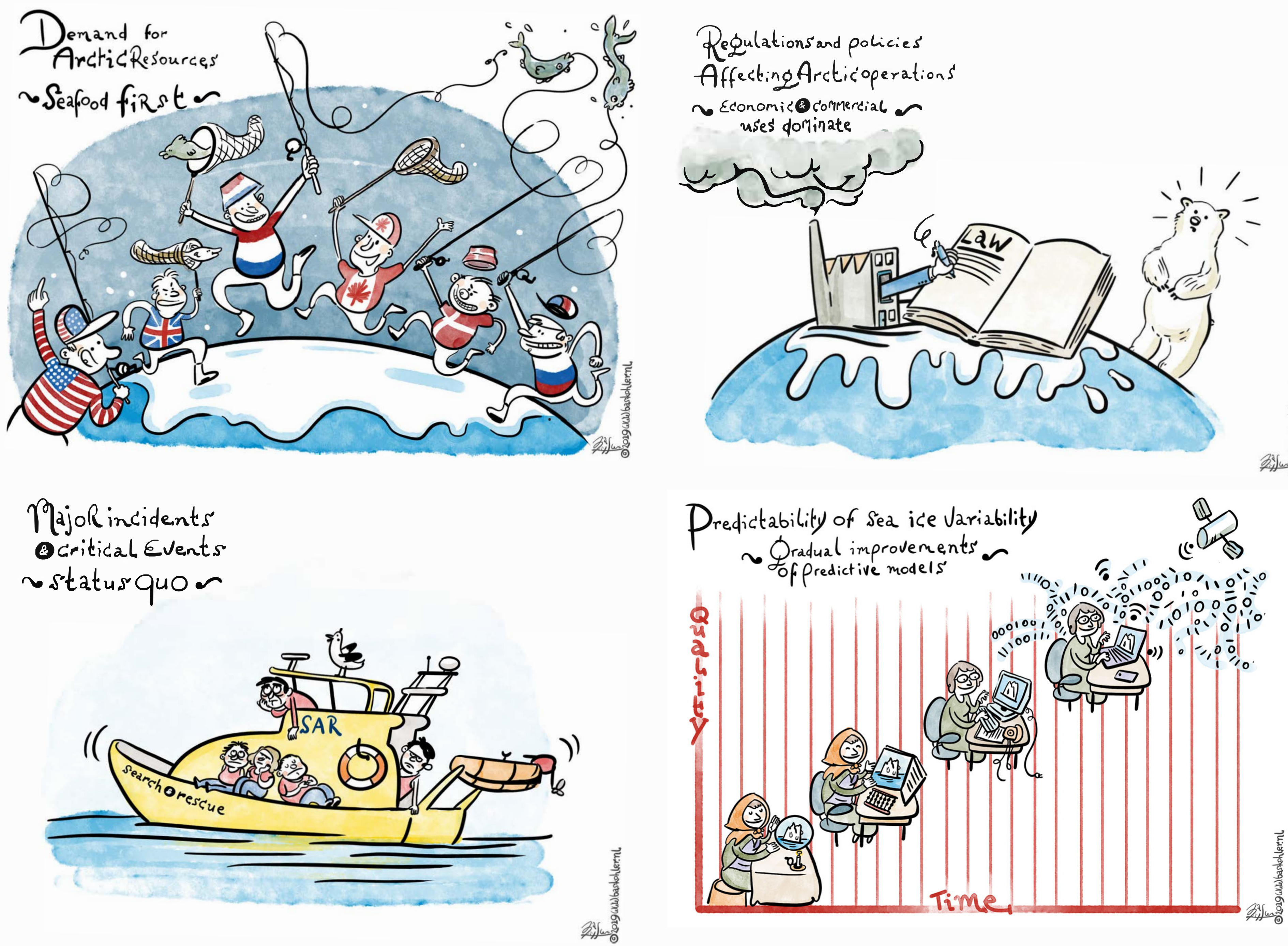


Fig 2b. Graphic narrative for the Future Projections in the most robust scenario bundle from Key Factors Demand for Arctic resources, Regulations and policies affecting Arctic operations, Major incidents and critical events and Predictability of sea ice variability. Descriptions can be found in Appendix A1. Illustrations by Bas Köhler (www.baskohler.nl).

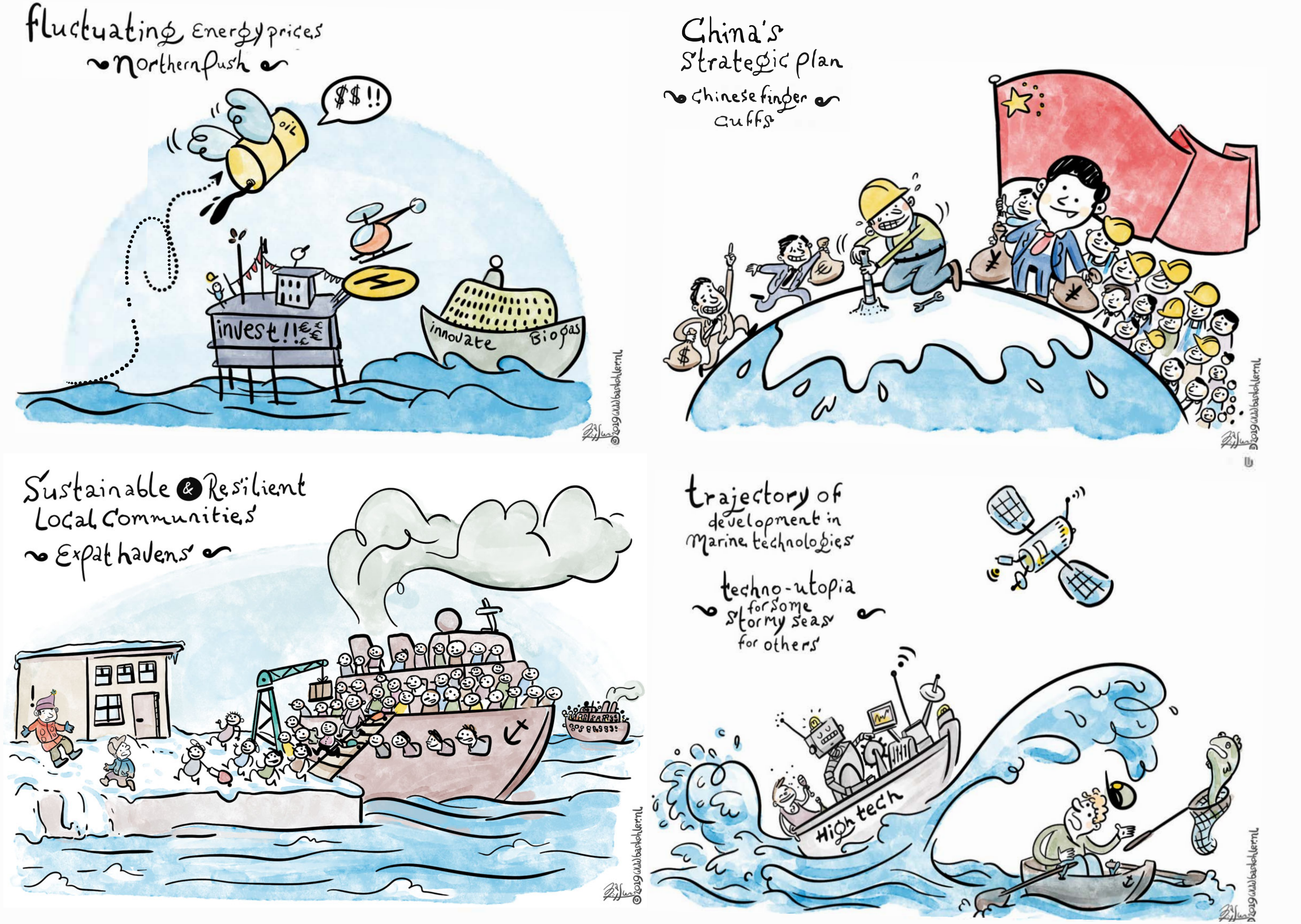


Fig 2c. Graphic narrative for the Future Projections in the most robust scenario bundle from Key Factors Fluctuating energy prices, China's strategic plan, Sustainable and resilient local communities and Trajectory of development in marine technologies. Descriptions can be found in Appendix A1. Illustrations by Bas Köhler (www.baskohler.nl).

What is the SALIENSEAS Project?

Introduction

Current and expected climatic changes in the Arctic are propelling growth in marine mobile activities, such as shipping, tourism and fisheries. This triggers a demand for more accurate and salient Arctic weather and climate predictions, which puts great expectations on our current global and regional forecasting systems. Improving access to, and quality of, climate relevant information is particularly pertinent to those operating in remote and dynamic polar marine environments. There is a need for research that considers the situated context of Arctic marine activities, in which various climate services are used. Particularly, given the different interests, challenges, abilities, routines and decision-making contexts of end-users across different spatial and temporal scales, a better understanding is needed of what this means for the saliency of the variety of available –and to be developed– weather and climate services.

While large public and private sector investments are currently made in the development of observations, modelling, forecasting and integrating weather and climate information in, and for, the Arctic region, the potential of these efforts for enhancing services for Arctic marine end-users is currently not yet fully realized. The Norwegian and Danish meteorological institutes are both represented as partners in the SALIENSEAS project. Each hold national and international responsibilities for large parts of the Arctic to provide weather, ocean, and sea-ice services on time scales from days to seasons. The mandate of these institutions are based on developing services for the interest of the end users, thus they have large experience in communication with their users.

Aims

SALIENSEAS brings together a team of social and natural scientists, metocean service personnel, and end-users, with the aim to

1. Better understand the mobility patterns, constraints, challenges, decision making contexts and information needs of end-users in different European Arctic marine sectors;
2. Develop and apply participatory tools for co-producing salient weather and sea ice services with Arctic marine end-users, and
3. Co-develop user-relevant and sector specific weather and sea ice services and dissemination systems dedicated to Arctic marine end-users tailored to key social, environmental and economic needs.

Approach

SALIENSEAS is organized in three work packages.

- Work package 1, led by Prof. D. Muller (Umeå University, Sweden), studies mobility patterns and constraints of different Arctic marine sectors.
- Work package 2, led by Dr. M. Lamers (Wageningen University, the Netherlands) formulates design principles, simulates the use of tailor-made services and develops a support-tool for co-producing and testing climate services.
- Work package 3, led by Dr. M. Muller (MET Norway, Norway) develops new services tailored to meet the requirements of the end-users.

The Scenario Workshop

The workshop took place in Copenhagen at the Danish Meteorological Institute on November 13, 2018.

Format and content

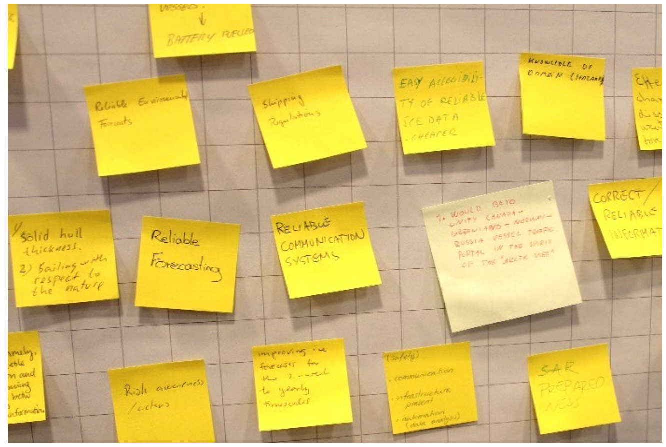
Participants were provided with read-ahead materials in advance, relevant to the specific workshop process to be used. At the workshop a Participant Booklet with the agenda, detailed description of activities and other pertinent information was handed out. At each table a number of thematic maps of the Arctic region were provided to aid and stimulate discussions. All workshop planning materials (briefing materials, Participant Booklet including a detailed agenda and description of activities) are available in Appendices B and C.

Participants listen during the opening presentation of the workshop. Photo by Jelmer Jeuring

The day followed a highly participatory structure. While some presentations were necessary to introduce the workshop process and specific activities, these were kept to a minimum in order to maximize plenary discussion time, as well as ample time for small breakout-group activities.

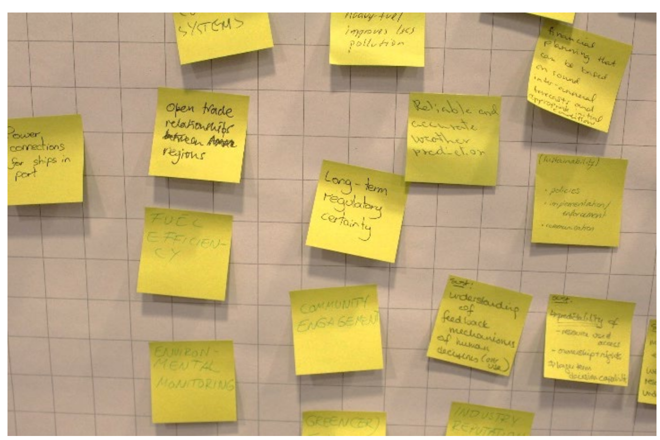
Activities

The workshop began with a brief process introduction and the focal question "*What information is needed for optimal decisions toward safe and sustainable maritime activities now and through 2035?"* The plenary discussion that followed asked participants to brainstorm about the focal question itself, and think about issues that may arise in discussing the topic throughout the workshop. Feedback at this point centered around the predictability of future needs due to complex and rapidly changing climatic trends, the difficulty around predicting extremes, and the challenge of analyzing and operationalizing vast amounts of information that is already available.



Participant feedback on maritime safety

On the meaning of safety and sustainability, participants were asked to complete the following sentences on sticky notes "*The things that enhance safety in maritime activities include..*," and "*The things that promote sustainability in maritime activities include..*" The sticky notes were then displayed on the wall on large paper sheets and left on display throughout the day for reference and further discussion. The results of this activity showed that enhanced safety demands easily accessible and reliable (timely and accurate) forecast information, in support of risk awareness of all actors; but training and experience are vital as well as search and rescue coordination in the region. Fuel efficiency, the proliferation of green ship technologies, a stable regulatory environment, and reliable (inter-annual) forecasts in support of long-term financial planning dominated feedback on sustainability (Appendix A7).



Participant feedback on maritime sustainability

Next, participants were introduced to the concept of "Key Factors" or drivers of change that will impact maritime futures in the Arctic region. Relying on the question "*What factors will strongly influence the development of Arctic Maritime Futures by 2035?* four breakout groups were tasked to brainstorm and come up with a minimum of four Key Factors each, in answer to the question. The breakout groups were created to include a diversity of expertise, skills and experiences in each. In a subsequent plenary session the groups shared their results, identified Key Factors that could be collated into one, eliminated duplicate Key Factors and arrived at a final list of 17 Key Factors.

A participant shares in plenary discussion results from the breakout group. Photo by Jelmer Jeuring

Due to the number of participants and workshop time constraint it was decided in advance of the workshop that the list had to be prioritized into a final list of no more than 12 Key Factors. This was achieved in in an activity where each participant voted on each Key Factor's *importance* and *uncertainty*. The prompt "Which of the drivers most influence metocean / sea ice forecast needs in the region and / or which drivers have the most influence over future change?" to ask for input on importance, and "Which drivers represent characteristics of systems that may be relevant to the focal question, but about which limited knowledge is available and/or over which there is disagreement about their current or future state?" to ask about uncertainty, were used. The Key Factors were posted on the walls on large sheets of paper, and each participant allocated 10 green sticker dots for importance, and 10 red dots for uncertainty according to how they ranked each. The importance and uncertainty scores were added and the Key Factors ranked high to low based on these compound scores (Table 1).

Participants vote on each Key Factor's importance and uncertainty. Photo by Jelmer Jeuring.

Subsequent activities took place in breakout groups once again, but unlike earlier in the day, the four breakout groups were created to place participants with similar expertise and shared skills together. Each group was assigned Key Factors to match their expertise, and tasked with developing 2-4 distinct future projections for each Key Factor (its possible future states in 2035). Participants were encouraged to make a bullet list of what each Key Factor would look like under each future projection especially with regards to any impacts on the type of metservices needed by users and policy makers. To finish the activity, each participant completed a plausibility scoring sheet for the future projections in their group. Taking 1.0 as the total sum plausibility score, each future projection received a plausibility score relative to one another (e.g. for a Key Factor with 3 future projections, it may be 0.8, 0.1, and 0.1 indicating that one is much more plausible than either of the other two (Appendix A2).

The workshop concluded with a plenary session in which a representative of each breakout group shared the results of their work, with feedback in the form of comments and questions from the whole group.

Output

All workshop output was photographed on site. In the weeks that followed, these materials and written notes were used to process the Key Factors and Future Projections for analyses that ultimately fed into the raw scenario bundles in Results.

The Scenario Process and Results

This section describes the data analysis that followed the workshop, starting with an introduction to the specific scenario method used and ending with the presentation of final results.

Introduction

Almost all scenarios projects formally begin with a workshop in which the future of a particular topic area is discussed and explored in more or less formal exercises. Quite a number of these projects also end shortly after this workshop with a quick set of narrative scenarios. An informal collection of impressions from such scenario projects was the impetus of developing a methodology that allows for engagement for a longer period of time and deeper delving into the subject matter.

This section provides the technical summary for the execution of a scenarios process using the Robustness Analysis Method. Specifically, we are outlining the *Maritime Futures 2035: The Arctic Region* scenarios workshop initiated by the SALIENSEAS Project.

We introduce and discuss some Practical and Technical Aspects of the scenarios workshop and the post-workshop interaction among project team members and workshop participants. The detailed outlines of several key documents are provided in Appendices for replication and improvement.

The Robustness Analysis Method is outlined with its key concepts here, and put into the context of the project at hand. This also provides insight regarding how the data collected in the workshop and post-workshop interactions is further refined and distilled into a final scenarios product.

The core of this document is the description of the Results of the project, with the most plausible, consistent and robust raw scenario bundles. A couple of additional interesting counterpoint scenario bundles are also introduced.

Practical and Technical Aspects

A quantitative scenario project with strong stakeholder engagement requires significant efforts regarding coordination, workshop organization, and pre- and post-workshop engagement. The following sections serve as a high-level illustration of the approach taken in the various stages of this project with detailed materials being provided in the appendices.

Workshop Planning and Implementation

A scenario workshop serves two main functions. It creates buy-in from stakeholders that are invited to participate and it serves as a vehicle for data collection and information exchange that informs the further scenario process. Ideally, during the workshop, some time is also spent on the introduction of the concept of strategic scenarios in general, and the specific methodology utilized in the project. However, it is not recommended to go into more technical detail than is absolutely necessary.

For the SALIENSEAS *Maritime Futures 2035: The Arctic Region* scenarios workshop a group of 23 stakeholders were invited. The invitees were deliberately selected to provide a good representation of climate services providers, experts active in Arctic maritime sectors or familiar with related policy areas. We placed particular emphasis on representation of Arctic Indigenous Hunters and Fishers, maritime planners and pilots, as well as members from the scientific community with particular focus on specialty areas for Arctic issues relevant to marine sectors from policy to climate.

Since the workshop was intended to be interactive and collaborative, much time was spent in breakout groups. In order to effectively capture the discussions in these groups several note takers were employed throughout. Their notes, and additional photos of workshop materials were the basis for the further steps of Key Factor and Future Projection development.

Prior to the workshop a full script and associated presentations, a bill of materials, a staff presentation and a note takers' handbook were developed. A selection of these materials is available in Appendix B. Materials distributed to workshop participants prior to and during the workshop are provided in Appendix C.

The workshop was held over the course of one full day.

Post-Workshop Interaction

After the workshop, the workshop notes and photos of workshop materials were used as a basis for Key Factor descriptions and definitions. Workshop lead B. Blair relied on these workshop materials and further research to transcribe the definition of each Key Factor and the Future Projections created by workshop participants. The final version of each Key Factor and associated Future Projections is given in Appendix A1. Finally, Consistency Scores were developed. For this task, the core scenarios team comprised of B. Blair, M. Lamers and J. Jelmer using the scenario management software ScenLab.

Technical Systems

For the Consistency Scoring, as well as for the Raw Scenario development the ScenLab scenario management software version 1.8.1 was used.

Lessons Learned

Though this did not come as a surprise, the importance of a sufficient number of dedicated note takers became quickly obvious in the process and cannot be overstated. The workshop team only included one dedicated note taker due to logistical hurdles, and this posed challenges during breakout groups. While each breakout group had a dedicated project member present as moderator, who also took on the dual role of note taker, this assignment was far from ideal. The breakout discussions demand a fair amount of guidance and moderation, which makes note taking very difficult. In the future, recruiting the same number of note takers as the planned number of breakout groups is crucial.

Furthermore, it is also ideal to obtain buy-in from stakeholders to participate in consistency scoring. While project members familiar with the field and present at the workshop can fill this role, it is recommended that final scores are verified relying on a small group of dedicated respondents. Since SALIENSEAS is a multi-work package, multi-year project, in which the scenario workshop was just one small milestone, and our stakeholders are asked to volunteer their time and expertise on numerous tasks and products, we decided to refrain from adding further burden to their work load. Consistency scoring demands numerous hours of dedicated analysis, often equaling several work days of full time engagement, and this was a level of involvement this project could not ask of its participants. In some cases however, a core group of participants in an advisory role, especially if financial compensation is possible, might take on such task. Otherwise projects, similar to our case, can rely on experience from workshop discussions and knowledge of literature to complete this exercise.

Robustness Analysis Method

Robustness Analysis is a quantitative scenario method that was developed by evolve:IT LLP (Drs. Erik Gauger and Marc Müller-Stoffels) in collaboration with Z_punkt GmbH. It is based on Consistency Analysis (extensively described in Gausemeier, et al. 1996). Where the Consistency Analysis treats Plausibility and Consistency scores strictly separately, the Robustness Analysis recognized that a good (or robust) scenario is required to be plausible and self-consistent at the same time, and takes this under consideration in the calculation of viable raw scenarios.

Any scenario project using Robustness Analysis has the following flow:

1. Define the focal question and time frame. This generally is a premise for the entire process and should be settled prior to any workshop as otherwise workshop preparation becomes difficult. A focal question should constrain the area of investigation to a manageable size, and the time frame should be generally further out than just a few years.
2. Key Factor and Future Projection development. The initial steps for this are generally performed during a workshop. However, for expediency, but at the cost of inclusiveness, some Key Factors could be pre-determined prior to a workshop. Further definition and fleshing out of Key Factors and Future Projections is usually done by a core team and reviewed by the stakeholder group.
3. To calculate the most robust scenarios a Plausibility and Consistency scoring is performed. This can be done by the core team, or by a larger stakeholder group.
4. The scoring in the previous step is the basis for calculating the viable Raw Scenario Bundles out of what usually is billions of possible raw scenario bundles.
5. Raw scenario bundles can then be used as the framework for narrative scenarios, and other developments, e.g., scenario games.

Key Factor and Future Projection Development

At the core of a scenario project are the Key Factors and Future Projections. Key Factors are those factors that are most influential in the development of the area selected in the focal question. A scenario project usually has between 10 and 20 Key Factors.

Future Projections describe potential developments of each Key Factor by the selected time frame. They do not all have to be equally plausible. However, any given Future Projection should lie within the realm of the plausible. That is, if no reasonably conceivable pathway without major disruptive events from the current state of the Key Factor to a specific Future Projection can be described, that Future Projection should be considered a Wild Card. Wild Cards are events of very low likelihood to occur. Yet, if they occur they are very disruptive and affect significant change.

Usually, Key Factor titles and some initial input on possible Future Projections are collected via a workshop setting through various exercises such as development of mini-scenarios. Post workshop Key Factor titles need to be turned into fully described Key Factors, which requires literature research to understand good delineations, develop a good understanding of underlying concepts, and ensure that workshop participant intent of the Key Factor is honored.

Once Key Factors are defined, Future Projections are assigned. It is recommended to have between three and five Future Projections for each Key Factor, but no less than two. These Future Projections should cover the range from (perceived) worst-case to best-case developments. Future Projections must also be defined, where possible, by citing trends described in the literature specific to a Key Factor or some parallel area. However, some speculation and outside-the-box thinking is wanted during Future Projection development, within the confines of plausible developments.

It is important that definitions are sufficiently clear, yet sufficiently brief, so that they can provide a good basis for the scoring exercises that are to follow.

Plausibility Scoring

Plausibility scores provide a relative ranking of Future Projections of a particular Key Factor. The objective is to provide a weight towards those Future Projections that appear, to the scoring individual, more plausible to become the actual future of a given Key Factor. For this, *Individual Plausibility Scores* are assigned to each Future Projection.

For internal consistency, the scoring is governed by the following constraints:

1. Any Individual Plausibility Score can be an integer between 0 and 1,
2. The sum of the Individual Plausibility Scores distributed to the Future Projections of a particular Key Factor has to be 1.
3. Future Projections that receive an Individual Plausibility Score of 0 are considered Wild Cards that are removed from the core pool of Future Projections.

Collection of Plausibility Scores:

A total of 32 Individual Plausibility Scores had to be assigned and calculated across the 12 Key Factors that were successfully developed during the workshop. These plausibility scored were collected at the workshop. A total of 23 participants gave input on pre-printed forms during this exercise. Two participants gave incomplete, unusable forms which were excluded from calculations. Instead of assigning all future projections to all participants, due to time constraints, each of the 4 breakout groups was asked to score the plausibility of the future projections they developed for their own Key Factors. In this way, each future projection was assigned scores from 0 to 1 (in integer steps), on pre-printed forms, by 5-7 individuals depending on group size. There was some group discussion in some of the groups about the plausibility of the future projections (not a lot due to time constraints) but ultimately scores were individually assigned.

Plausibility Score Analysis and Collation:

The Individual Plausibility Scores collected at the workshop were imported into a spreadsheet for further analysis. Data was checked for integrity by running checksums for each set of Individual Plausibility Scores.

To arrive at a final Individual Plausibility Score for each Future Projection, the mean of the responses was calculated. Standard deviation from the mean of individual scores was generally less than 0.14, with a range from 0 to 0.2. That is, statistical variability of scores for this size sample, was within acceptable bounds. The final Individual Plausibility Scores can be found in Appendix A2.

Consistency Scoring

Consistency scores are designed to provide a metric to determine if two Future Projections from two *different* Key Factors are consistent to appear in the same scenario. For this each possible pair of Future Projections that are not of the same Key Factor is assigned a *Pairwise Consistency Score*. The objective of the Pairwise Consistency Score is to ensure that those combinations of Future Projections receiving a high Pairwise Consistency Score rank higher in the search for final scenarios, and that those combinations that receive very low Pairwise Consistency Score, i.e. they are totally inconsistent to appear in the same scenario, are excluded from the final ranking altogether.

The following points govern Pairwise Consistency Scores and their allocation:

1. Pairwise Consistency Scores range from -2 to 2 with decimal numbers in this range being allowable scores.
2. Pairwise Consistency Scores lesser or equal to -1.55 denote *total inconsistencies*, and scenarios exhibiting one of these Pairwise Consistency Scores will be excluded from the final list of scenarios.
3. Pairwise Consistency Scores lesser or equal to -1, but greater than -1.55 are denoted *partial inconsistencies* and scenarios exhibiting such scores will be penalized in the final ranking for each occurrence.
4. Pairwise Consistency Scores greater than -1 do not carry a special designation or handling, but the higher a Pairwise Consistency Score the likelier a scenario exhibiting this pair of Future Projections to rank high [barring other contributing factors, see Raw Scenario Development]
5. Typically Pairwise Consistency Scores lay between -0.5 and 0.5, i.e., most combinations of Future Projections are neither very consistent, nor very inconsistent. Extreme scores should only be distributed where this can be well justified.

Collection of Consistency Scores:

Since for this project, there were 870 Pairwise Consistency Scores to be evaluated, creating a massive work load requiring many dedicated hours of work, it was decided that the entire consistency matrix would be scored by the core members of the scenarios team (Blair, Lamers and Jeuring). The core team has extensive experience with the Arctic maritime policy and climate services issues embodied by the Key Factor, and this experience combined with previous stakeholder interviews and workshop discussions supported the decisions that went into the scoring process.

Consistency Score Analysis and Collation:

Each matrix was checked for issues with scoring individually to ensure that the scores provided could yield any raw scenario bundles. This is necessary because a condition can occur where all combinations of Future Projections of two Key Factors are scored totally inconsistent. At that point, all possible raw scenario bundles would be invalid. None of the consistency matrices at hand exhibited any technical issues. The available scored consistency matrices were collated by calculating the average of each individual Pairwise Consistency Score for the final consistency matrix. The final matrix is shown in Appendix A3. For this matrix, the average Pairwise Consistency Score was calculated. This serves as a check regarding a general bias toward positive or negative scores. In balanced scoring the average Pairwise

Consistency Score should be close to zero. The average Pairwise Consistency Score for this project was 0.2.

Raw Scenario Bundle Development

A *Raw Scenario Bundle* is a collection of Future Projections, one from each Key Factor. In this particular project, that technically means that over 93,312 possible combinations need to be evaluated based on their Individual Plausibility Scores and Pairwise Consistency Scores. However, the computations for this would be extremely time-consuming; therefore, a genetic algorithm[4] is deployed to search for the highest scoring Raw Scenario Bundles without evaluating absolutely all possible Raw Scenario Bundles.

Each Raw Scenario Bundle can be assigned several distinct scores:

1. A *Bundle Plausibility Score,* which is the product of the Individual Plausibility Scores for the Future Projections present in the bundle
2. An *Average Bundle Consistency Score,* which is the sum of the Pairwise Consistency Scores between the Future Projections present in the bundle, normalized by the maximum theoretical consistency achievable in the project
3. A *Number of Partial Inconsistencies* which is a count of Pairwise Consistency Scores between -1 and -1.55 between the Future Projections present in the bundle
4. A Robustness Value which is defined to be $R = \left(\frac{log(BPS) \cdot aBCS}{1 + NPI}\right)^{1/2}$
5. A *Number of Total Inconsistencies* which is defined as a count of Pairwise Consistency Scores lesser or equal to -1.55. Any bundle having Number of Total Inconsistencies > 0 is discarded.

Even with the use of a genetic algorithm-based search and the constraint that any Raw Scenario Bundle exhibiting a total inconsistency is discarded, the final result list typically is quite long and difficult to manage. In order to mitigate this issue, secondary algorithms are used to find similar Raw Scenario Bundles and discard some of them to reduce list length. For this several list reduction approaches are available:

Trivial Reduction: This method simply truncates the list of Raw Scenario Bundles at the desired list length, i.e., it sorts the list in descending order by Robustness Value [or Average Bundle Consistency Score, or Bundle Plausibility Score] and discards all items ranking lower than the desired list length.

Complete Projection Scanning: This method searches the list of Raw Scenario Bundles for the *n* Raw Scenario Bundles containing Future Projection 1 of Key Factor A with the highest Robustness Value [or Average Bundle Consistency Score, or Bundle Plausibility Score], where *n* is a user

[4] Genetic algorithms are random directed search algorithms that use principles of natural selection from evolutionary theory to effectively solve optimization and search problems. They are particularly deployed in situations where solving the problem analytically requires too much computational resources. For example, see Z. Michalewicz, *Genetic Algorithms + Data Structure = Evolutionary Programs*, Springer, New York, 1996.

adjustable value. It then proceeds searching the high value bundles containing Future Projection 2 of Key Factor A, then with Future Projection 1 of Key Factor B and so forth.

Example: *Assume a project with four Key Factors A, B, C, D with two Future Projections each. The following table shows all possible projection bundles with their overall Robustness Values (rVal below for brevity).*

Bundle No.	*Raw Scenario Bundle*	*rVal*	*Bundle No.*	*Raw Scenario Bundle*	*rVal*
1	*A1B2C1D2*	*0.45*	*9*	*A1B1C1D1*	*0.29*
2	*A2B1C2D2*	*0.44*	*10*	*A2B2C1D1*	*0.26*
3	*A1B1C2D2*	*0.41*	*11*	*A1B2C2D2*	*0.24*
4	*A1B1C1D2*	*0.41*	*12*	*A2B2C2D2*	*0.14*
5	*A2B2C1D2*	*0.39*	*13*	*A1B2C1D1*	*0.14*
6	*A2B1C2D1*	*0.37*	*14*	*A1B2C2D1*	*0.11*
7	*A2B1C1D2*	*0.37*	*15*	*A2B1C1D1*	*0.09*
8	*A1B1C2D1*	*0.33*	*16*	*A2B1C1D1*	*0.07*

If a Complete Projection Scanning is run on the above list with n = 3, then the three bundles with the highest Robustness Value for each Future Projection will result in the following reduced list.

Bundle No.	*rVal*	*No. of Picks*
1	*0.45*	*4*
2	*0.44*	*4*
3	*0.41*	*4*
4	*0.41*	*3*
5	*0.39*	*3*
6	*0.37*	*3*
8	*0.33*	*1*
10	*0.26*	*1*
11	*0.24*	*1*

The result is, that bundles 8, 10, and 11 will be in the list even though are a considerably smaller Robustness Value. They are unlikely to have been in a list that would have been simply truncated at one-third of its size.

So even in this small example project the different reduction method affects significant changes to the outcome of the reduction.

Another important point that can be seen in the example is that reduction by complete projection scanning ensures that the projection bundles with the highest Robustness Values will remain in the list. In fact they usually represent more than one Future Projection and are therefore picked more than once.

In a small project like this it might be significant if even one of the Future Projections in a Raw Scenario Bundle is different. But in bigger projects, where the use of a reduction method is necessary to keep the amount of results manageable, this is not the case. If two projection bundles differ only in one or two future projections they are still very similar and it might therefore be sufficient to keep just one of them.

Complete Combination Scanning: This method works similar to the Complete Projection Scanning except that the scanning is done on combinations of Future Projections. In the example above one would look for all Raw Scenario Bundles that contain the pair A1B1, then A1B2, …, C2D1, and C2D2.

Which list truncation method to use requires some experimentation and depends on the objective - Trivial Reduction only yields high scoring Raw Scenario Bundles without regard for diversity, Complete Combination Scanning provides are more diverse results list that generally is longer, and includes lower scoring Raw Scenario Bundles.

For the final list, clustering and multi-dimensional scaling algorithms are available to visually compartmentalize results further.

The final objective is to choose three to five Raw Scenario Bundles of sufficiently high Robustness (or Bundle Plausibility Score, or Average Bundle Consistency Score) that span a range of futures from a perceived best- to worst-case with one of two scenarios being more middle of the road. These final Raw Scenario Bundles can then be further developed into a brief narrative, a long story, or any other scenario product, e.g., as the basis for a game, animated movie, visioning exercise, etc.

Results

The findings of this project can be broken out into several discrete intermediate steps which are defined by specific participant input, and core scenarios team activities. The first such step is the development of Key Factors and Future Projections through collection of input via a workshop, consolidation based on categories and scoring from the workshop, and research of individual items by the core scenarios team. The second step revolved around the scoring of individual plausibilities for each Future Projection by the project participants and the analysis of these scores by the core scenarios team. The third step was the scoring of the consistency of each pair of Future Projections by the core scenarios team, the review and editing of these scores by project participants, and the final collation and analysis to the project consistency matrix. Last, the combined scores were used by the core scenarios team to calculate the Raw Scenario bundles.

Key Factors and Future Projections

Development of the final list of 12 Key Factors began with an exercise during the scenarios workshop, which provided 17 distinct Key Factors as input from workshop participants. It was decided in advance of the workshop that the workshop output would be limited to 12 Key Factors, based on the time constraints given the number of participants and ultimately the number of breakout groups (four), allocating three Key Factors per group for breakout discussions and further analysis. This workload proved doable, but quite sizeable still.

These initial Key Factors were scored by workshop participants for their importance and uncertainty. The following table shows the entire set of Key Factors with the top 12 highlighted in blue (in reality 13 as two Key Factors tied with a score of 24, though one was later eliminated due to insufficient data).

Table 1 Key Factors based on breakout group work and finalized in subsequent plenary discussion.

Key Factor	Importance	Uncertainty	Importance + uncertainty
Geopolitical stability	13	31	**44**
Accessibility of Arctic sea routes	16	19	**35**
User-centric information infrastructures and data	26	6	**32**
Global economic trends	12	20	**32**
Demand for Arctic resources	20	12	**32**
Regulations and policy affecting Arctic operations	21	10	**31**
Major incidents and critical events	16	11	**27**
Predictability of sea ice variability	16	8	**24**
*Dynamic effects of a changing Arctic on Arctic social and ecological systems	9	15	**24**
Fluctuating energy prices	4	19	**23**
China’s strategic plan	8	15	**23**
Sustainable and resilient local communities	9	11	**20**
The trajectory of technological development in marine technologies	11	9	**20**
Public opinion about industry	7	10	17
Enhanced collaboration and information sharing (science-policy, idustry, military)	9	7	16
Improved situational awareness of all stakeholders	14	1	15
Information needs across supply chain	9	6	15

*this Key Factor was eliminated from raw bundle scenario calculations during post-workshop analysis, because it was not developed adequately during the workshop to be a functional component. Its description was fuzzy and its future projections were not mutually exclusive with quite a bit of overlap, not allowing clear distinction between it and some of the other Key Factors, between its own Future Projections and preventing consistency analysis with other Future Projections.

The final list of Key Factor titles, together with bullet point descriptions by the participants, extensive notes taken during the workshop, as well as research by workshop lead B. Blair were used to develop definitions for each Key Factor (1-2 paragraphs per Key Factor).

At the same time, two to four Future Projections were developed for each Key Factor, each with a brief bullet point definition, using the same workshop data sources and process as described above for the Key Factors. All final Key Factors and their associated Future Projections are given in Appendix A1.

Plausibility Scores

Individual Plausibility Scores were collected as described above. The collected scores were tested for their integrity and self-consistency by considering the observed deviations from the mean, the range between minimum and maximum for a given Individual Plausibility Score, and the occurrence of zeros. For a detailed view of all scores please see Appendix A2.

There are two major indicators regarding the integrity of the scoring. For one, it can be expected that a group of people will score the Future Projections closest to a status quo development the most plausible. This is the case across the board in this project, particularly, where the status quo distinctly is given as a Future Projection. Secondly, it appears a hallmark of our times that Future Projections describing collaborative developments were given relatively low Individual Plausibility Scores by the group.

Consistency Scores

Pairwise consistency scores were collected as described above. The individual consistency matrices were checked for methodological issues; particularly, for excessive use of total inconsistencies, as this can create a situation where no scenarios are viable. Then all consistency matrices were collated into a master matrix by averaging each Pairwise Consistency Score. The final matrix was checked again for methodological issues. The expectations for a consistency matrix are that the mean across all Pairwise Consistency Score values falls around zero. In this case, with a Pairwise Consistency Score average was 0.2. In addition, the number of total inconsistencies, i.e., Pairwise Consistency Scores that are less than or equal to -1.55, should be low, as in this consistency matrix with only 16 total inconsistencies (1.84 % of all Pairwise Consistency Scores). The final consistency matrix is provided in Appendix A3.

Raw Scenarios

Raw Scenario Bundles were developed using the ScenLab Scenario Software and following the definitions given above.

The following approach was taken in searching for Raw Scenario Bundles. The ScenLab algorithm was instructed to search for the most robust, most plausible and most consistent Raw Scenario Bundle in individual algorithm runs. In addition, algorithm runs were dispatched to search for variations in prevalent features in the most robust and most consistent Raw Scenario Bundles. This was done in order to check if the most consistent and most robust scenario are volatile or stable under small variations.

Note that larger versions of the images shown in this section are provided in Appendices A4, A5 and A6.

Most Plausible Scenario: Growing Pains

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.284	0.591	**7.044×10^{-4}**	7

The selected Future Projections in this Raw Scenario Bundle follow the highest Individual Plausibility Scores, which is what should happen as long as two plausible developments are not inconsistent with each other.

The Bundle Plausibility Score for this Raw Scenario Bundle is 7.044×10^{-4}, but the robustness is quite low at 0.284 with 7 partial inconsistencies, meaning that while this scenario strand is highly plausible, the robustness of this development is poor.

This scenario describes a development based on a rush for resource exploitation but without the necessary harmonization and investments in climate services and underlying infrastructure, resulting in increased marine traffic incidents and demographic stresses on Arctic communities from an influx of new residents and seasonal workers. Tourism is a winner in terms of being a major maritime economic engine, but development speeds up across all sectors.

The figure shows the most plausible Raw Scenario bundle. For each Key Factor, the most plausible Future Projection (darkest hue in each column) is selected:

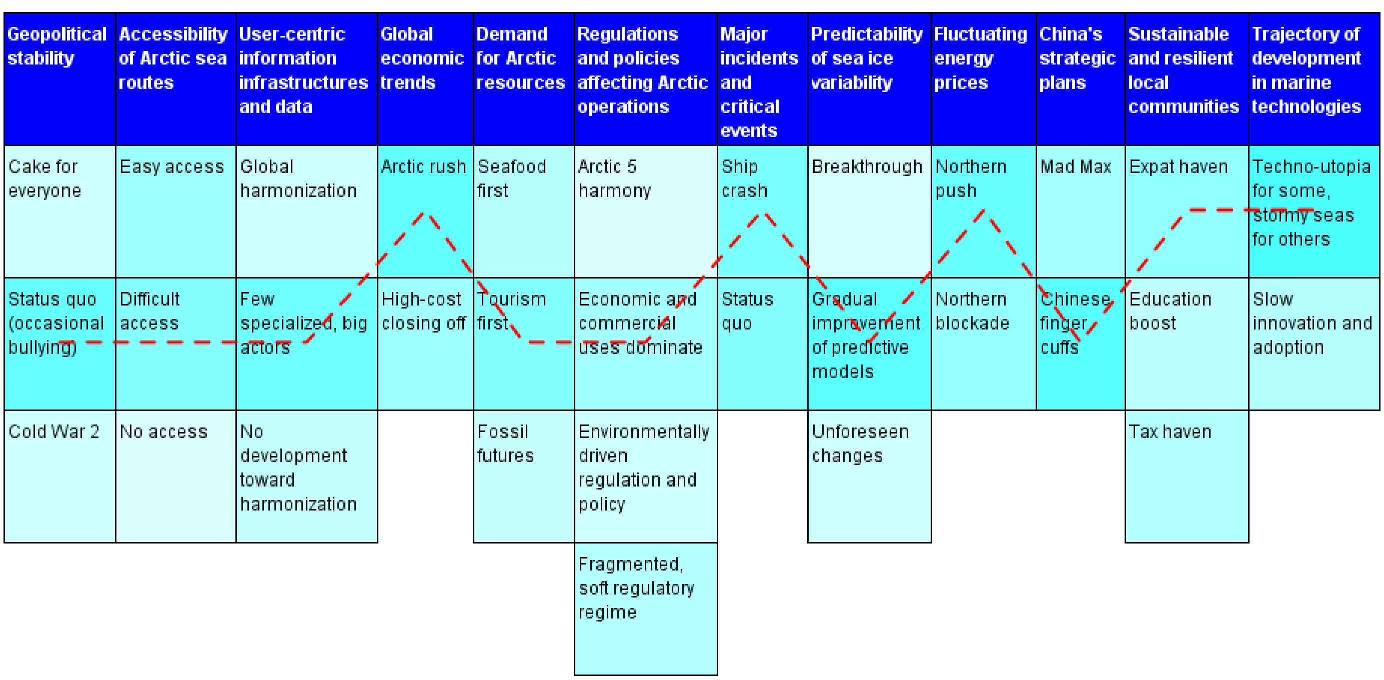


Figure 3: The most plausible Raw Scenario Bundle.

Most Consistent Scenario – The Winner Takes It All

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.687	**0.938**	2.975×10^{-5}	0

The most consistent Raw Scenario Bundle describes a rather intense picture of development into the future. Framed by geopolitical status quo and Pan-Arctic regulatory focus on economic development, resource extraction (though maximized) is conducted without any major maritime incidents, and supported by technological investments and breakthroughs. Outside actors, namely China are key in driving and executing development.

This Raw Scenario Bundle scores quite high on consistency with a Bundle Consistency Score of 61.95. Its Robustness is fair at 0.545 but the Bundle Plausibility Score is one order of magnitude lower than that for the most plausible Raw Scenario Bundle. This is not an extremely low plausibility, but still it still impacts the Robustness value.

The figure shows the most consistent Raw Scenario Bundle found.

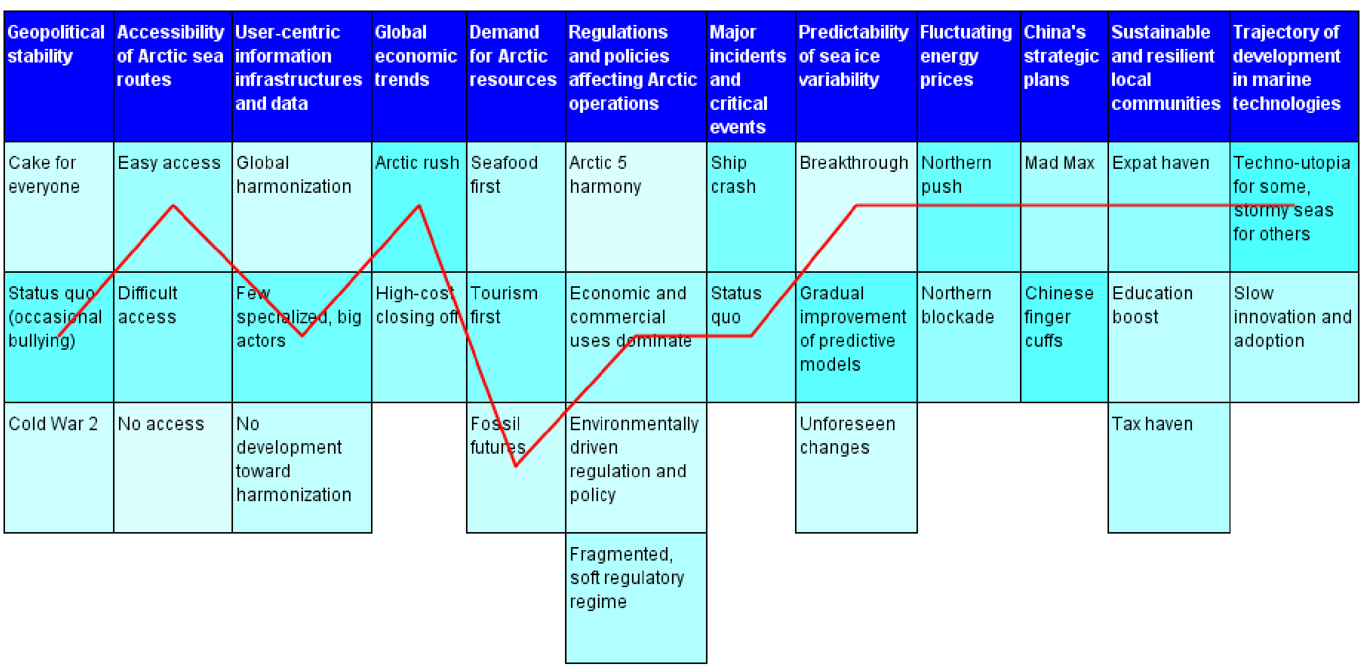


Figure 4: The most consistent Raw Scenario Bundle.

Most Robust –All Aboard the Arctic Express

Robustness	Average Bundle Consistency Score	Bundle Plausibility Score	Number of Partial Inconsistencies
0.799	0.825	**3.047×10^{-4}**	0

The most robust Raw Scenario Bundle provides a somewhat middle of the road outcome between the most consistent and most plausible bundles. It shows status quo development in those Key Factors (*Geopolitical stability; Major incidents and critical events*) where a 'status quo' Future Projection was given, and also includes several Future Projections that reference status quo conditions without being named as such (e.g. *Few, specialized, big actors, Arctic rush, Economic and commercial uses dominate*). It describes continued interest from outside actors, increasing developments and investments in resource exploitation, but all this is done rather pre-emptively where China's strategic investment plans are scrutinized and rejected to thwart outside geopolitical leverage. The selected Future Projections in this Raw Scenario Bundle follow the highest Individual Plausibility Scores, except where two plausible developments are not inconsistent with each other.

Of note is that this Raw Scenario Bundle does not exhibit any partial inconsistencies, and that its Robustness is significantly higher than that of the most consistent and most plausible while still maintaining fairly high Bundle Consistency Score and Bundle Plausibility Score.

The figure shows the most robust Raw Scenario Bundle:

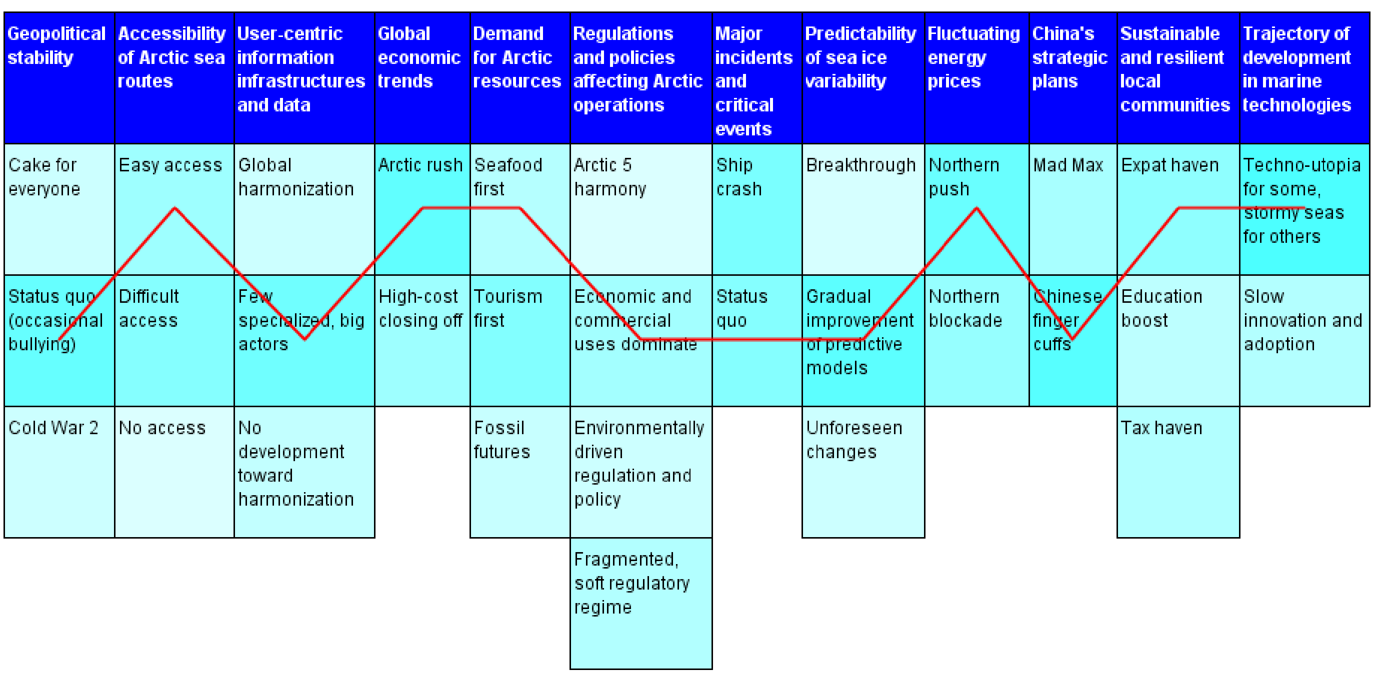


Figure 5: The most robust Raw Scenario Bundle.

Appendix A: Scenario Development Results

Appendix A1: Key Factors and Future Projections

KEY FACTORS

As identified and outlined by the participants of the SALIENSEAS Project during the scenario workshop in Copenhagen, November 13, 2018.

Please feel free to contact the author of this document directly if you have questions, suggestions, note errors, or have other comments:

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Thank you.

Focal question:

"What information is needed to successfully respond to changes impacting Arctic maritime activities now and through 2035?"

Below is the ranked table of the top 12 key factors that strongly influence the development of Arctic maritime activities now and through 2035, based on importance and uncertainty, as identified by participants. The following prompts were used in the workshop to elicit these results:

Importance: Which of the drivers most influence metocean / sea ice forecast needs in the region? Which drivers have the most influence over future change?
Uncertainty: Which drivers may be relevant to the focal question, but about which limited knowledge is available and/or over which there is disagreement about their current or future state?

Key factor	Importance + Uncertainty score
Geopolitical stability	44
Accessibility of Arctic sea routes	35
User-centric information infrastructures and data	32
Global economic trends	32
Demand for Arctic resources	32
Regulations and policy affecting Arctic operations	31
Major incidents and critical events	27
Predictability of sea ice variability	24
Fluctuating energy prices	23
China's strategic plan	23
Sustainable and resilient local communities	20
The trajectory of development in marine technologies	20

Key Factor: Geopolitical stability

Definition

Geopolitical security describes the extent to which international relations (Pan-Arctic as well as on the global scale) are collaborative or contentious; and the level to which political tensions may impact demands for and access to Arctic resources, militarization efforts, and ultimately, marine operations. Instability of certain regions impact fuel prices and have a direct effect on maritime logistics and planning. In addition, control over sea routes (i.e. protection of shipping routes globally, a costly endeavor) impacts marine traffic in the Arctic region as well.

Future Projections

1. **Cake for everyone:**
    - Increased collaboration
    - No resource competitions
    - Expanded scope and extent of collaborative institutions (e.g. Arctic Council)
    - Common definitions of sustainability

mean plausibility score: 0.20

2. **Status quo (occasional bullying):**
    - Current trends continue
    - Showmanship: showing off military might
    - Trying to out-muscle without using muscle
    - Mainly verbal threats with occasional cyber and electronic attacks

mean plausibility score: 0.60

3. **Cold War 2:**
    - Russia's interference re-divides alliances into a new organization of allied countries
    - Arctic War over resources
    - Militarization on the rise
    - Information sharing is limited
    - Much of the data produced is customized for military strategic needs
    - Transiting Arctic routes becomes difficult (political and informational hurdles)
    - Accidents are on the rise
    - There is an escalation in cyber and electronic warfare
    - Shipping sector negatively impacted by shrinking theater of globalization
    - The types of resources that are highly sought-after shift (bulk fresh-water, oil, minerals)

mean plausibility score: 0.20

Key Factor: Accessibility of Arctic sea routes

Definition
Accessibility of Arctic sea routes refers to uncertainties surrounding both physical and regulatory access: In other words, the unpredictability of access that impacts maritime planning and logistics can be due to uncertainties in forecast and climatology models, and / or regulatory uncertainties. This key factor draws on the regulatory setting of Northern sea routes (west and east), any possible political tensions between Russia and the West, the predictability of sea ice seasonal variability, and search and rescue capacities or Arctic nations.

Future Projections

1. **Easy access:**
    - Less sea ice
    - Reliable predictive models
    - Increasing global agreement, collaboration due to collaborative leadership as well as efficient coordination
    - New icebreakers
    - Strengthened Search and Rescue operational networks and infrastructure

mean plausibility score: 0.38

2. **Difficult access:**
    - Persistent sea ice
    - Unreliable predictive models
    - More regulatory barriers
    - No new resource developments

mean plausibility score: 0.48

3. **No access:**
    - More sea ice or sea ice variability
    - Ban on routes
    - Restricted use of ice breakers

mean plausibility score: 0.14

Key Factor: User-centric information infrastructures and data

Definition

User-centric information infrastructures and data describes the extent to which there is a concerted effort amongst Arctic nations, forecast service providers toward harmonization of information, resources and models. This key factor centers around easily accessed and interpreted data, and a push toward user-centric practices in data provision, and publicly available service points.

Future Projections

1. **Global harmonization:**
   - Single-point source (e.g. 'Copernicus')
   - Investments in new systems and means of communication
   - Uncertainties decrease in planning maritime activities
   - Portal contents reflect the level of knowledge of users
   - User-friendly data formats
   - Increased co-design and production with users

mean plausibility score: 0.20

2. **Few specialized, big actors (data and service providers):**
   - Portfolio of regular, public services remains similar to now
   - Increase in specialized, commercial, subscription-based services

mean plausibility score: 0.56

3. **No development toward harmonization:**
   - Lack of centralized portals
   - Scattered data
   - Fragmented infrastructure

mean plausibility score: 0.24

Key Factor: Global economic trends

Definition
This key factor describes economic drivers exerting pressures on Pan-Arctic economies and regulatory landscapes from outside of the Arctic region, and describes an overall trend towards increased or decreased investments in Arctic development.

Future Projections

1. **Arctic rush:**
    - Rising global commodity prices provide incentives for natural development resources and destination shipping, fishing, and marine tourism
    - Influx of people increases need for shipping supplies to remote Arctic communities
    - More mineral exploration & cruise tourism leading to increased infrastructure needs, overwhelming local users / communities
    - More tourism results in more development, increasing the complexity of port logistics
    - Increased traffic leads to moving traffic into shoulder season, thereby increasing high risk operations

mean plausibility score: 0.62

2. **High-cost closing off:**
    - Regulatory pressures leading to increased rules
    - High taxes, high field costs
    - Lack of markets, potential for disruptive technology
    - Trade war

mean plausibility score: 0.38

Key Factor: Demand for Arctic resources

Definition

Demand for Arctic resources is a key factor about economic drivers of change based on global demand for Arctic living, renewable and fossil fuel resources. This key factor is closely linked with trade routes as well as status quo attitudes within the Arctic region itself toward resource development, and the politics of outside interests. The key factor describes the potential to intensify development in one sector over another, thereby increasing not only investments but available funding for metocean information and research as well.

Future Projections

1. **Seafood first:**
    - More processing and transport of seafood products (increased fishing traffic)
    - Global food demand grows
    - Global demand for eco-friendly protein grows
    - Seafood is an increasingly valuable export commodity from Arctic region

mean plausibility score: 0.29

2. **Tourism first:**
    - People with disposable income eager to spend on exotic experiences
    - Accessibility of Arctic destinations increases as does the portfolio of metocean services needed
    - Adventure tourism grows
    - Straining resources and cultural values of communities

mean plausibility score: 0.49

3. **Fossil futures:**
    - Conflict in the Middle East increases
    - Alternatives to fossil fuel are not viable
    - Rising oil prices
    - Oil crisis creates higher demand for Arctic fossil fuel

mean plausibility score: 0.22

Key Factor: Regulations and policies affecting Arctic operations

Definition

This key factor is determined by the level to which environmental vs. economic considerations drive regulations directly impacting Arctic operations, and the extent to which international cooperation stabilizes the political landscape to reduce uncertainty in business decisions. The tension between safety and environmental protection versus exploitation of the Arctic impacts risk tolerance and relevant legal frameworks and collaborations; while changing rules and shifting stakeholder interests raise questions regarding the extent to which rules are enforced where they should be.

Future Projections

1. **Arctic 5 harmony:**
    - Harmonized, strict, enforced regulations and policies
    - Increased investments and close links with investors strengthen essential networks for shipping sector
    - Investments and steady regulatory landscapes create certainty for planning and operations
    - Traffic levels in Arctic routes may or may not increase due to the certainties provided by investments and policies as traffic depends on other globally determined processes as well

mean plausibility score: 0.14

2. **Economic and commercial uses dominate:**
    - Regulations determined by industry (industry writes code)
    - Environmental requirements take a backseat to economic efficiency
    - Ice class and search and rescue requirements may ease
    - Traffic may increase if cost of operations decreases sufficiently

mean plausibility score: 0.36

3. **Environmentally driven regulation and policy:**
    - Environmental basis for regulation and policy development
    - Communities and human rights organizations help give access to Indigenous voices
    - Ice class requirements may stiffen
    - Ban on heavy fuels and incentives for alternate fuels

mean plausibility score: 0.20

4. **Fragmented, soft regulatory regime (status quo):**
    - Lack of uniformity in rules and enforcement, rapid changes
    - Difficulties arise for maritime traffic from fragmented policies
    - Traffic may increase if cost of operations decreases sufficiently and there is a sense of stability in the regulatory landscape

mean plausibility score: 0.30

Key Factor: Major incidents and critical events

Definition

This key factor is determined by the cumulative learning and regulatory changes that occur in response to major incidents that help us face unpredictability. The type of incidents and critical events that are likely are driven by their locality: in Greenlandic waters it may be cargo ship stuck in ice, in Norway it may be cruise ship related or oil blowout while Iceland may see accidents leading to regulatory actions. Some sectors are more vulnerable to a political and economic fallout from incidents; for example cruise tourism doesn't need multiple incidents to experience a devastating impact on the business.

Future Projections

1. **Ship Crash (medium-to-large event):**
    - More Arctic ship traffic increases chances for major incidents
    - Incidents are on the rise
    - Major incident occurs slowing down shipping
    - A lack of search and rescue response capacity combined with regulations designed to facilitate merchant necessities and not the luxury cruise industry leaves major marks on the cruise sector

mean plausibility score: 0.52

2. **Status Quo:**
    - Good record of marine operations
    - Industry reputation is good, slightly blemished at times of minor incidents
    - Traffic expands in linear relation with local trade

mean plausibility score: 0.48

Key Factor: Predictability of sea ice variability

Definition

This key factor describes the challenges faced by meteorological institutions in their capacity to keep up with rapid developments around new data needs due to fast-changing environmental conditions. Large seasonal variability such as East Greenland's high variability makes prediction difficult. There is a concern over a mismatch between rapid changes (and resulting need for accurate, salient information) and predictive skill, testing the limits of researchers and funders.

Future Projections

1. **Breakthrough:**
    - Breakthrough in sea ice prediction beyond weeks, observational models

mean plausibility score: 0.16

2. **Gradual improvement of predictive models:**
    - Sea ice prediction improves gradually over time

mean plausibility score: 0.64

3. **Unforeseen changes:**
    - Unforeseen changes in climatic trends make current methods degrade
    - Missing observations to initialize models
    - Software development cannot keep up with hardware development

mean plausibility score: 0.20

Key Factor: Fluctuating energy prices

Definition

This key factor encompasses the complex role energy prices have in driving the profitability of Arctic maritime operations. On the one hand, all marine industries are greatly impacted by high fuel prices and resultant increases in operational costs. On the other hand, the sectors involved in fossil fuel extraction are incentivized by increased profitability as oil price per barrel goes up. While high bunker fuel price incentivizes the use of trans-Arctic routes, the extent to which Arctic routes are used in practice depends on certain tradeoffs in transit time: the need for slower speed in ice infested areas can tip the scale in favor of alternate, traditional shipping routes. While this key factor is linked with the key factor 'Global economic trends,' it specifically highlights the importance played by trends in energy prices in creating economic incentives for increased or decreased activities in the Arctic region.

Future Projections

1. Northern push:

- Increased bunker fuel prices
- Increased replacement of inefficient ships, and building of fuel-efficient ships
- High fuel costs results in preference toward shorter Arctic route
- Some sectors hard-hit by large fuel price fluctuations (e.g. cruise industry when price is high, extractive industries when prices are low)
- Industry-friendly regulations are likely in areas that profit from the fossil industry
- Profitable Arctic operations in extractive industries, increased revenue for fossil industry (potential for benefit sharing with communities)
- Supply chain decision making possible due to predictability or operations and contingency planning
- Increase in Arctic exports
- Insurance availability widens, cost decreases

mean plausibility score: 0.59

2. **Northern blockade:**

- Decrease in bunker fuel prices
- Decreased incentive for shipping industry to use trans-Arctic routes instead of traditional routes (Suez and Panama Canals)
- Decreased incentive in fossil fuel industries for Arctic operations
- Arctic shipping companies such as Royal Arctic Line (Greenland) who supply remote communities benefit from lower fuel prices
- Remote communities benefit from lower energy prices
- Likely increasing resource (energy) pressures globally, but decreasing production of resources in Arctic region
- Decrease in Arctic exports

mean plausibility score: 0.41

Key Factor: China’s strategic plan

Definition
This key factor describes the interactions between China’s inclusion in Arctic regional body politic, and the impacts on Pan-Arctic and domestic, national regulations. This key factor is about the extent of acceptance of China as an influential player in Arctic political economy, as well as the extent to which big ideas for development spread in response to China’s strategic plans. The questions that drove the development of this key factor include: Will Arctic nations accept Chinese investments and influence, by passing favorable national legislation? Or will there be a pushback and a speeding up of domestic and Pan-Arctic cooperative development projects to preempt China’s plans?

Future Projections
1. Mad Max:

- Heavy critical infrastructure investments
- Shipping shares shift toward state-owned companies
- Mining and fishing rights shift toward Chinese ownership
- China follows their own strategic plans for Arctic development
- Increased demands on local resources and communities
- Increase in shared liabilities and responsibilities of information provision
- Potential for growth in joint information hubs and cooperative solutions (price of information may decrease)

mean plausibility score: 0.34

2. Chinese finger cuffs:

- China’s strategic plans provoke preemptive developments and increase in investments by Arctic nations (control remains within the Arctic)
- China’s and Koreas’ strategic plans are controlled via pro-active action by Arctic states
- China's strategic investment plans are scrutinized and rejected to thwart outside geopolitical leverage

mean plausibility score: 0.66

Key Factor: Sustainable and resilient local communities

Definition

This key factor draws on the importance of Arctic community resilience in the wake of rapid biophysical, demographic and infrastructural changes, and the importance of self-determination as a vital resource in community sustainability. Sustainable local communities are vital constituents in safe, sustainable Arctic maritime sectors as active partners in the tourism industry, as consumers of shipping services and as influential stakeholders in extractive industries.

Future Projections

1. Expat haven:

- Increased influx of people from outside the Arctic region
- Increase in labor force
- Increasingly mixed cultural identity

mean plausibility score: 0.44

2. Education boost:

- Investments in increased Indigenous Knowledge inclusion and Indigenous teachers teaching in Arctic Indigenous community schools
- Incentives for youth to remain in community
- Increasing elder-youth contact
- Strengthening local identity
- Building resilience via increased fate control

mean plausibility score: 0.26

3. Tax haven:

- Fossil fuel industry making profit without being part of the local communities
- Arctic exports are on the rise but benefit sharing agreements are not representative of this boom

mean plausibility score: 0.30

Key Factor: Trajectory of development in marine technologies[1]

Definition

This key factor recognizes the role played by the direction of technological developments toward disruptive vs. green development, as well as the speed of advancements made in Arctic marine navigation, automation, fuel innovation and route accessibility. The significance of marine technological developments ultimately lies in the safety and efficiency of operations, impacting greatly the economic viability of Trans-Arctic routes. The future projections and their descriptions below have been developed based on the Global Marine Technology Trends 2030 report.[2]

Future Projections

1. **Techno-utopia for some, stormy seas for others:**
    - Favorable regulatory frameworks and intense competition for smart marine technologies speed up worldwide technical standardization and cooperation
    - Portfolio of technologies supporting electromagnetic stealth and resilience to electromagnetic attacks increases
    - Private sector is confident to invest
    - Big-data analytics advance coupled models ground-truthing forecast information with in-situ data
    - Robotics, advanced materials and new communication technologies increasingly saturate marine operations
    - These new, expensive technologies will require changes in supply chain management and likely adopted quicker by larger corporates
    - The speed of green development picks up due to policies incentivizing cleaner, more efficient vessels
    - New build orders based on clean, efficient propulsion and powering increase
    - Onboard energy management increases in efficiency, marine fuels focus on novel technologies
    - Environmental regulations play catch-up with intensifying activities and new places of exploration, increased focus phasing our heavy fuels and search-and-rescue capacities
    - Increasing complexity of technologies and speed of development requires new skills and training from people operating systems and equipment
    - Growing demand for highly-qualified sea-going staff
    - Unprecedented amount of data available to users aids those with access to big data analytics, while those without struggle to translate complex data sets for use
    - Demand for increased portfolio of metocean services continues to rise rapidly: increasing demand for data transfer services

[1] This key factor was recognized by participants as an important driver of change, however participants felt they lacked the necessary expertise to develop it further. Workshop Lead B. Blair used notes from the workshop on the discussion surrounding this topic and literature to develop future projections.
[2] Lloyd's Register, QinetiQ and University of South Hampton. (2015) *Global Marine Technology Trends 2030*. Available online: https://www.lr.org/en/insights/global-marine-trends-2030/global-marine-technology-trends-2030/

- Public services struggle to keep up to finance growing service demands, private subscription-based providers grows
- Increasing deployment of sensors in remote locations to support users and decision makers in decision making, and a better understanding of environmental preservation needs

mean plausibility score: 0.70

2. **Slow innovation and adoption**
    - Rate of transition from emergent technologies to mature technologies slows down
    - Accessibility and viability of Trans-Arctic routes remains about the same as today
    - Private sector lacks the confidence to invest in marine technologies and infrastructure to prop up viability of Arctic ports and routes
    - Demand for information continues to grow from some sectors in destination shipping while others in transit shipping continue to prefer alternate routes
    - Intelligent port management technologies lag behind the complexity of increased traffic density due to expected growth in destination shipping
    - Marine fuel sources focus on proven technology, with start of adoption of LNG

mean plausibility score: 0.30

Appendix A2: Plausibility Scores (individual scores)

China's strategic plans	**FP1 Mad Max**	**FP2 Chinese Fingercuffs**		
	0.3	0.7		
	0.35	0.65		
	0.3	0.7		
	0.4	0.6		
SD	0.047871355	0.047871355		
Global economic trends	**FP1 Arctic Rush**	**FP2 High-cost closing off**		
	0.9	0.1		
	0.5	0.5		
	0.6	0.4		
	0.5	0.5		
SD	0.189296945	0.189296945		
Energy prices	**FP1 Northern Rush**	**FP2 Northern Blockade**		
	0.5	0.5		
	0.65	0.35		
	0.7	0.3		
	0.5	0.5		
SD	0.103077641	0.103077641		
Geopolitical stability	**FP1 Cake for everyone**	**FP2 Occasionnal bullying (status Quo)**	**FP3 Cold War 2**	
	0.3	0.6	0.1	
	0.01	0.89	0.1	
	0.1	0.6	0.3	
	0.3	0.6	0.1	
	0.3	0.3	0.4	
SD	0.137913016	0.208614477	0.141421356	
Major incidents	**FP1 Ship Crash**	**FP2 Status Quo**		
	0.4	0.6		
	0.8	0.2		
	0.6	0.4		
	0.4	0.6		
	0.4	0.6		
SD	0.178885438	0.178885438		
Regulations and policies affecting Arctic operations	**FP1 Arctic 5 Harmony**	**FP2 Commercial use encouraged by regulations**	**FP3 Environmentally driven regulation**	**FP4 Fragmented, soft policy**
	0.2	0.3	0.2	0.3
	0.1	0.5	0.2	0.2
	0.1	0.4	0.2	0.3
	0.2	0.3	0.2	0.3

	0.1	0.3	0.2	0.4
SD	0.054772256	0.089442719	0	0.070710678
Demand for Arctic resources	**FP1 Seafood first**	**FP2 Tourism first**	**FP3 Fossil future**	
	0.333333333	0.333333333	0.333333333	
	0.2	0.6	0.2	
	0.4	0.4	0.2	
	0.3	0.5	0.2	
	0.2	0.6	0.2	
SD	0.086922699	0.119256959	0.059628479	
Sustainable & resilient local communities	**FP1 Expat Haven**	**FP2 Education boost**	**FP3 Tax Haven**	
	0.6	0.1	0.3	
	0.5	0.4	0.1	
	0.4	0.4	0.2	
	0.5	0.3	0.2	
	0.2	0.1	0.7	
SD	0.151657509	0.151657509	0.234520788	
User-centric information infrastructures and data	**FP1 Global harmonization (single-point access)**	**FP2 Few, specialized, big actors**	**FP3 No development toward harmonization**	
	0.2	0.4	0.4	
	0.1	0.7	0.2	
	0.5	0.4	0.1	
	0.2	0.6	0.2	
	0.2	0.5	0.3	
	0.1	0.8	0.1	
	0.1	0.5	0.4	
SD	0.141421356	0.151185789	0.127241802	
Access to Arctic sea routes	**FP1 Easy access**	**FP2 Difficult access**	**FP3 No access**	
	0.2	0.7	0.1	
	0.65	0.25	0.1	
	0.3	0.7	0	
	0.3	0.4	0.3	
	0.4	0.5	0.1	
	0.5	0.3	0.2	
	0.3	0.5	0.2	
SD	0.15236235	0.177616494	0.097590007	
Predictability of sea ice variability	**FP1 Breakthrough**	**FP2 Gradual improvement of predictive models**	**FP3 Unforeseen changes**	

	0.1	0.8	0.1	
	0.1	0.6	0.3	
	0.3	0.5	0.2	
	0.1	0.8	0.1	
	0.3	0.6	0.1	
	0.1	0.7	0.2	
	0.1	0.5	0.4	
SD	0.097590007	0.127241802	0.115470054	

Appendix A3: Consistency Matrix

	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	E1	E2	E3	F1	F2	F3	F4	G1	G2	H1	H2	H3	I1	I2	J1	J2	K1	K2	K3	L1	L2
A1																																
A2																																
A3																																
B1	0.5	0.5	-1.0																													
B2	0.5	0.5	1.0																													
B3	-1.0	-0.5	1.0																													
C1	0.6	0.6	-1.0	1.0	-1.0	-1.25																										
C2	0.6	0.6	0.5	1.0	1.1	-0.5																										
C3	-1.0	-0.6	1.0	-1.25	0.5	1.0																										
D1	1.0	1.0	-1.25	1.5	-1.0	-2.0	1.0	1.25	-0.44																							
D2	-1.0	0.5	1.1	-1.25	1.0	1.75	-1.0	0.75	1.5																							
E1	1.0	0.75	-0.85	1.25	0.0	-1.0	1.0	0.5	-0.5	1.5	-0.75																					
E2	1.25	0.85	-1.25	1.25	-0.75	-1.5	1.0	0.5	-0.5	1.0	-0.75																					
E3	0.75	0.9	0.9	0.75	-1.0	-1.5	0.5	1.0	0.0	1.5	-1.5																					
F1	2.0	-1.0	-2.0	1.0	0.25	-1.25	1.75	0.0	-1.5	0.75	-0.25	1.1	1.25	0.75																		
F2	-0.75	1.1	0.0	0.0	-0.5	-1.5	1.0	1.25	0.0	1.75	-1.5	0.75	1.0	1.25																		
F3	1.0	0.09	-1.5	-0.25	0.5	1.0	0.9	0.75	-0.5	-1.25	0.0	0.0	0.75	-1.5																		
F4	-1.5	1.5	0.25	-1.25	0.0	0.75	-0.5	0.75	1.15	0.0	0.0	0.5	0.75	0.4																		
G1	0.5	1.0	1.25	-1.0	0.75	1.25	-1.25	-0.25	1.25	1.25	-1.25	0.85	0.85	1.1	-1.0	1.25	-1.0	1.0														
G2	1.0	1.25	-0.5	1.0	-0.75	-1.25	1.0	1.0	-0.5	0.0	0.0	0.75	0.75	0.25	1.0	0.75	-0.25	1.0														
H1	1.0	0.5	1.0	1.25	-0.75	-1.5	0.75	0.5	-1.25	1.0	-0.5	0.85	0.85	0.4	1.0	0.5	0.0	-0.75	-1.25	0.75												
H2	1.0	1.5	-0.25	1.5	0.75	-0.35	1.5	1.0	-1.25	0.65	0.25	0.35	0.35	0.3	1.0	0.25	0.0	0.25	-0.25	1.0												
H3	0.0	0.75	0.5	-1.25	0.75	1.25	-1.25	0.5	1.25	0.0	-0.5	-0.6	-0.5	-0.75	-0.5	-0.25	0.5	0.5	1.25	-0.25												
I1	0.5	1.25	-0.75	1.0	-1.0	-1.75	1.15	1.25	-1.0	2.0	-1.75	0.75	-1.0	1.6	0.5	0.75	0.0	-0.5	0.75	0.75	1.0	0.25	-1.0									
I2	-0.5	0.25	-0.5	-1.0	1.0	1.5	-0.65	0.0	1.0	-1.75	0.75	0.5	0.0	-1.25	0.0	0.0	0.75	0.5	-0.75	0.25	-0.5	0.0	0.75									
J1	-1.0	0.5	0.0	1.15	-1.0	-1.25	0.5	0.9	0.0	1.25	-1.5	0.0	0.0	0.6	-0.75	1.25	-1.0	0.5	0.5	0.0	1.25	0.65	0.5	1.25	-1.25							
J2	1.0	0.25	-1.25	1.1	1.0	-0.5	0.5	0.65	-0.75	0.75	0.25	0.25	0.75	0.5	1.0	0.75	-0.5	0.5	0.0	0.25	0.75	0.65	0.0	0.5	0.5							
K1	1.15	0.5	-0.25	1.25	0.0	-1.25	0.25	0.35	0.0	1.25	-1.25	1.0	1.0	1.25	0.75	0.75	-0.25	0.0	0.0	0.25	0.75	0.5	-0.5	1.0	-1.0	1.0	0.25					
K2	1.25	0.5	-1.75	0.9	0.75	0.65	0.25	0.35	0.0	0.0	0.75	1.0	1.0	-0.25	0.75	-1.0	0.25	-0.5	-0.5	0.75	0.25	0.25	-0.25	0.25	0.0	-0.5	0.25					
K3	-1.0	0.0	0.75	1.0	-1.0	-1.25	0.25	0.35	0.0	1.25	-1.5	0.0	-0.5	1.75	-1.25	1.25	-1.5	0.25	1.0	-0.5	0.5	0.25	0.25	0.75	-1.0	1.25	-0.5					
L1	1.25	0.0	-1.0	1.5	-0.75	-1.75	1.5	1.75	-1.75	1.5	-1.0	0.5	0.85	0.85	1.25	1.0	0.0	-1.25	-0.75	0.75	1.5	-0.25	-1.25	1.0	-0.75	1.0	0.25	0.5	0.25	-0.5		
L2	-0.75	1.0	0.0	-0.75	1.0	0.75	0.0	0.5	0.75	0.0	0.75	0.85	0.85	0.25	-0.75	-1.0	0.0	0.75	0.5	0.85	-1.25	1.5	0.75	-0.75	0.75	-0.75	0.75	0.25	-0.25	-0.5		

see alphabetical codes on next page

Appendix A3: Consistency Matrix (cont.)

Codes for Consistency Matrix

Code	Key Factor / Future Projection
A1	Geopolitical stability/Cake for everyone
A2	Geopolitical stability/Status quo (occasional bullying)
A3	Geopolitical stability/Cold War 2
B1	Accessibility of Arctic sea routes/Easy access
B2	Accessibility of Arctic sea routes/Difficult access
B3	Accessibility of Arctic sea routes/No access
C1	User-centric information infrastructures and data /Global harmonization
C2	User-centric information infrastructures and data /Few specialized, big actors
C3	User-centric information infrastructures and data /No development toward harmonization
D1	Global economic trends/Arctic rush
D2	Global economic trends/High-cost closing off
E1	Demand for Arctic resources/Seafood first
E2	Demand for Arctic resources/Tourism first
E3	Demand for Arctic resources/Fossil futures
F1	Regulations and policies affecting Arctic operations/Arctic 5 harmony
F2	Regulations and policies affecting Arctic operations/Economic and commercial uses dominate
F3	Regulations and policies affecting Arctic operations/Environmentally driven regulation and policy
F4	Regulations and policies affecting Arctic operations/Fragmented, soft regulatory regime
G1	Major incidents and critical events/Ship crash
G2	Major incidents and critical events/Status quo
H1	Predictability of sea ice variability/Breakthrough
H2	Predictability of sea ice variability/Gradual improvement of predictive models
H3	Predictability of sea ice variability/Unforeseen changes
I1	Fluctuating energy prices/Northern push
I2	Fluctuating energy prices/Northern blockade
J1	China's strategic plans/Mad Max
J2	China's strategic plans/Chinese finger cuffs
K1	Sustainable and resilient local communities/Expat haven
K2	Sustainable and resilient local communities/Education boost
K3	Sustainable and resilient local communities/Tax haven
L1	Trajectory of development in marine technologies/Techno-utopia for some, stormy seas for others
L2	Trajectory of development in marine technologies/Slow innovation and adoption

Geopolitical stability	Accessibility of Arctic sea routes	User-centric information infrastructures and data	Global economic trends	Demand for Arctic resources	Regulations and policies affecting Arctic operations	Major incidents and critical events	Predictability of sea ice variability	Fluctuating energy prices	China's strategic plans	Sustainable and resilient local communities	Trajectory of development in marine technologies
Cake for everyone	Easy access	Global harmonization	Arctic rush	Seafood first	Arctic 5 harmony	Ship crash	Breakthrough	Northern push	Mad Max	Expat haven	Techno-utopia for some, stormy seas for others
Status quo (occasional bullying)	Difficult access	Few specialized, big actors	High-cost closing off	Tourism first	Economic and commercial uses dominate	Status quo	Gradual improvement of predictive models	Northern blockade	Chinese finger cuffs	Education boost	Slow innovation and adoption
Cold War 2	No access	No development toward harmonization		Fossil futures	Environmentally driven regulation and policy		Unforeseen changes			Tax haven	
					Fragmented, soft regulatory regime						

Appendix A4: Most plausible bundle

Appendix *A5: Most consistent bundle*

Geopolitical stability	Accessibility of Arctic sea routes	User-centric information infrastructures and data	Global economic trends	Demand for Arctic resources	Regulations and policies affecting Arctic operations	Major incidents and critical events	Predictability of sea ice variability	Fluctuating energy prices	China's strategic plans	Sustainable and resilient local communities	Trajectory of development in marine technologies
Cake for everyone	Easy access	Global harmonization	Arctic rush	Seafood first	Arctic 5 harmony	Ship crash	Breakthrough	Northern push	Mad Max	Expat haven	Techno-utopia for some, stormy seas for others
Status quo (occasional bullying)	Difficult access	Few specialized, big actors	High-cost closing off	Tourism first	Economic and commercial uses dominate	Status quo	Gradual improvement of predictive models	Northern blockade	Chinese finger cuffs	Education boost	Slow innovation and adoption
Cold War 2	No access	No development toward harmonization		Fossil futures	Environmentally driven regulation and policy		Unforeseen changes			Tax haven	
					Fragmented, soft regulatory regime						

Geopolitical stability	Accessibility of Arctic sea routes	User-centric information infrastructures and data	Global economic trends	Demand for Arctic resources	Regulations and policies affecting Arctic operations	Major incidents and critical events	Predictability of sea ice variability	Fluctuating energy prices	China's strategic plans	Sustainable and resilient local communities	Trajectory of development in marine technologies
Cake for everyone	Easy access	Global harmonization	Arctic rush	Seafood first	Arctic 5 harmony	Ship crash	Breakthrough	Northern push	Mad Max	Expat haven	Techno-utopia for some, stormy seas for others
Status quo (occasional bullying)	Difficult access	Few specialized, big actors	High-cost closing off	Tourism first	Economic and commercial uses dominate	Status quo	Gradual improvement of predictive models	Northern blockade	Chinese finger cuffs	Education boost	Slow innovation and adoption
Cold War 2	No access	No development toward harmonization		Fossil futures	Environmentally driven regulation and policy		Unforeseen changes			Tax haven	
					Fragmented, soft regulatory regime						

Appendix *A6: Most robust bundle*

Appendix A7: Definitions of safe and sustainable Arctic maritime operations

safety: "The things that enhance safety in maritime activities include..."	sustainability: "The things that promote sustainability in maritime activities include..."
information requirements regulations	correct / reliable information
remove people from the vessel: autonomous vessels	long-term model forecasts including extremes
remove oil (fuel oil) from vessels: battery fueled	"green" ships, batteries
near real-time, high-resolution information	reduce the need for transportation: production close to consumers
reliable environmental forecasts	reliable communication systems
shipping regulations	avoiding heavy fuels improves less pollution
easy accessibility of reliable ice data (cheaper)	open data: standardized formats and availability
knowledge of domain (hazards)	low-carbon fuels
effective channels to disseminate weather forecasts	ban hfo
Reliable forecasts for planning activities	effects on environment
solid hull thickness	power connections for ships in port
sailing with respect to the nature	open trade relationships between regions
reliable forecasting	reliable and accurate weather prediction
reliable communication systems	financial planning that can be based on sound inter-annual forecasts and appropriate initial conditions
would BETO unify Canada-Greenland-Norway-Russia vessel traffic portal in the pirit of the "Arctic web"	unify and stricten ship-borne pollution regulation CAN-GL-NOR-
correct/reliable information	political actors
geo-political information among Arctic littoral countrie	fuel efficiency
Strong & coordinated SAR capability	long-term regulatory certainty
available, timely, frequent, reliable information and forecasts for planning	policies / implementation / enforcement / communication
Collaboration betwen authorities: sharing the informat	timely signals: indicators and mechanisms for acting on signals
risk awareness / actors	shared, free information
improving ice forecasts for the 2-week to yearly timesc	collaboration
communication	awareness of implications of your activity
infrasctructure present	generating local benefits
automation of data analysis	environmental monitoring
SAR preparedness	community engagement
experienced operators	understanding of feedback mechanisms of human decisions (overuse)
regulation (ice class vessels)	predictability of resource use / access, ownership rights leading to longer term decision capabilities
knowledge of: wind speed, wave height & surrounding temepratures, depth of water, sea ice extent, sea ice probability, sea ice location	monitoring and enforcement of well-developed resource sharing under uncertainty
user knowledge of how to interpret weather forecasts	co-management of resources and risks
real-time access to satellite data	predictability of ice conditions
understanging the impacts of climatic changes on the v	cost-effectiveness
ship technology	vessel navigation with (?) support
knowledge sharing	use of alternative fuels to HFO
accurate data that is understandable by user	accident prevention
use of drone can / will increase safety	zero gas flaring
the willingness of companies to adapt their behaviour according to scientific data even if it is economically not optimal	green (er) fuel options
	industry reputation management
	access to historical data for analysis of environmental factors

Appendix B: Workshop Preparation Materials

Appendix B1: List of Materials

Item No.	Item	Comment	Completed [Y/N]	Product Example
M1	Workshop Briefing Booklet	Compilation of Workshop Materials/Read ahead materials, etc.		
M2	Timer	A digital `egg timer` would be great to have. Otherwise smartphone		
M3	Pens (50?)	Pens. Could we find a donation with branding? Wageningen U pens?		
M4	Adhesive notepads (Post its); (40)	Notepads for KF exercise. Do not need thick notepads, ~10 sheets/pad would do.		
M5	Poster boards/large adhesive easel pads (or similar) (6 with 25 pages each)	Place to collect sticky notes from KF execise		Post It Easel Pad
M6	Markers, multiple colors sets (12 sets)			Sharpie
M7	Sticky dots green (500), blue (500),	Colors are secondary as long as they are distinct.		Avery dots
M8	Sticky dots green (500) and red (100)	Colors are secondary as long as they are distinct,		Avery dots
M9	Scissors	For cutting up dot strips to hand to participants		
M10	digital camera	For pictures of the process but also to record all the materials produced		
M11	Easels to support the flip charts			
M12	Name Tags	Will be included in participant folders distributed at registration		
M13	Participant Folders	Labeled folders to include: pre-survey, participant booklet, photo release, informed consent form, nametags		
M14	Sign-In sheet	printed sign-in sheet		
M15	Presentation computer			
M16	Posters to hang			
M17	Large binder clips	For hanging posters		
M18	Double-sided sticky tape	For hanging posters		

Appendix B2: Pre-event briefing guide

Photo: MAERSK

Arctic Maritime Futures 2035

Copenhagen, 13th November 2018

Pre-event Briefing for Participants

SALIENSEAS

CO-PRODUCING CLIMATE SERVICES

1. Objectives
2. Approach
3. Our project
4. Workshop location
5. Workshop participants & facilitators
6. Agenda
7. Dinner event
8. Logistics: funding, reimbursement
9. Contact details
10. Acknowledgments

SALIENSEAS
CO-PRODUCING MARINE CLIMATE SERVICES

1. Objectives

Opportunities

- To support MET.no and DMI in strategic product development and stakeholder engagement
- To support maritime sectors active in European Arctic waters with strategic planning
- To inform the European Commission in support of integrated Arctic policy objectives
- To shape ongoing and future plans for safe, sustainable Arctic marine resource use

Goals

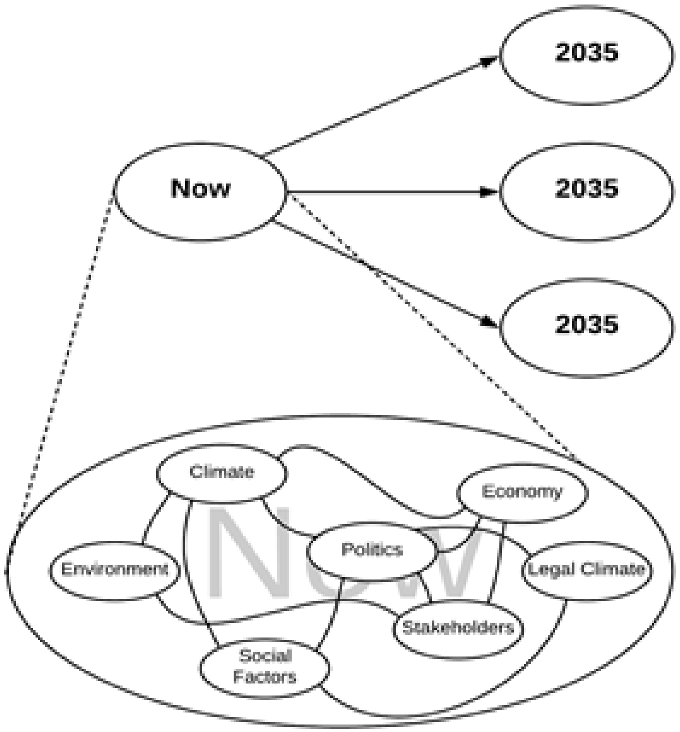
- Engage participants who are experts on different aspects of maritime activities in the Arctic
- Creatively approach new ideas and thinking about the present and also the coming decades
- Brainstorm then prioritize the key factors that are / will be most impactful in shaping the information needed most by mariners in European Arctic waters
- Envision the most plausible states for each key factor in the coming years

2. Approach & Significance

- The workshop starts by fine-tuning our focal question *"What is needed for optimal metocean / sea ice forecast services for maritime sectors in European Arctic waters now and until 2035?"*
- Participants determine the breadth of systemic variables that ultimately impact metocean / sea ice information needs
- Participants identify the most impactful key factors that drive information needs now and in the coming years, and prioritize them based on projected impact and uncertainty
- Participants determine a handful of most likely future states (future projections) for each driver, and their plausibility

How will workshop products be used?

- The raw scenarios and workshop report can be used by participants, operators & policy makers to inform strategic decisions
- The scenarios produced will be a vital component of a computerized simulation currently being developed by the SALIENSEAS project



The future is influenced by many different factors. Precise predictions are difficult. Hence it is more suitable to consider various scenarios.

SALIENSEAS CO-PRODUCING MARINE CLIMATE SERVICES

3. The Project

SALIENSEAS aims to:

- Understand the mobility patterns, constraints, challenges, decision-making contexts and information needs of end-users in different European Arctic marine sectors,
- Develop and apply participatory tools for producing salient weather and sea ice services with Arctic marine end-users,
- Develop weather and sea ice services and dissemination systems dedicated to Arctic marine end-users that are tailored to their key social, environmental and economic needs

SALIENSEAS is organized in three work packages (WP) with the following themes:

WP1 Mobility patterns, uncertainties and risks faced by Arctic marine sectors

WP2* Risks and decision-making, role of climate services in decision-making

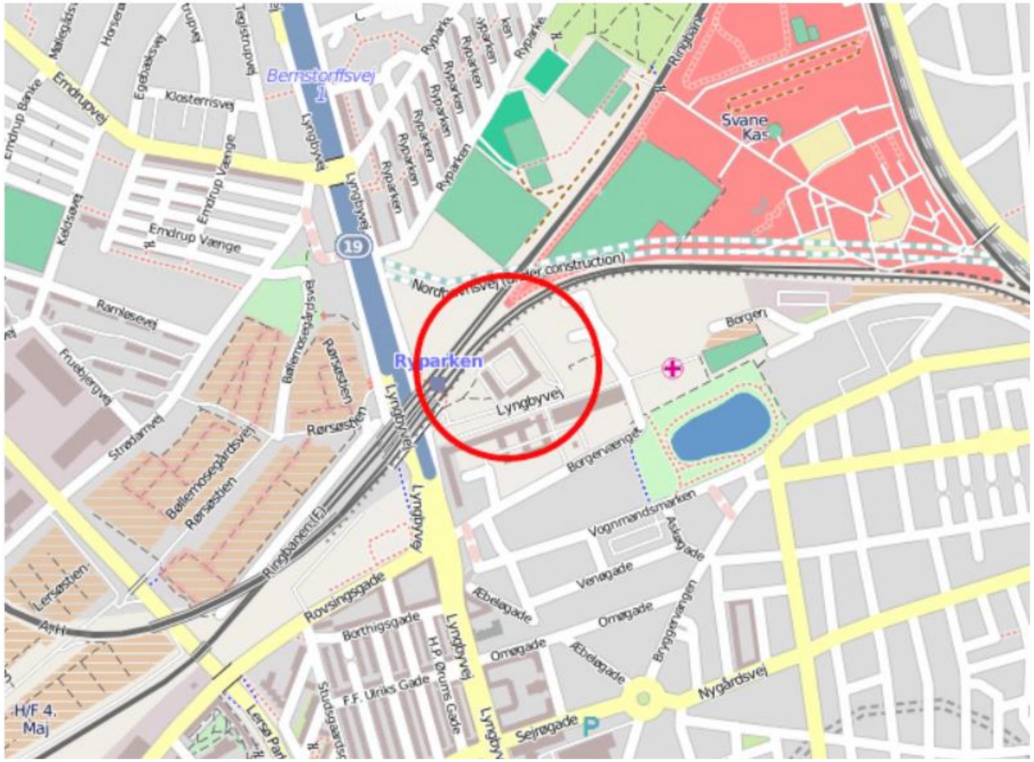
WP3 Multi-model climate forecasts, statistical downscaling, demonstration services

**this workshop facilitates the activities of work package 2*

SALIENSEAS
CO-PRODUCING MARINE CLIMATE SERVICES

4. Workshop Location

**Room number and location will be announced via a dedicated email in the days prior to the event



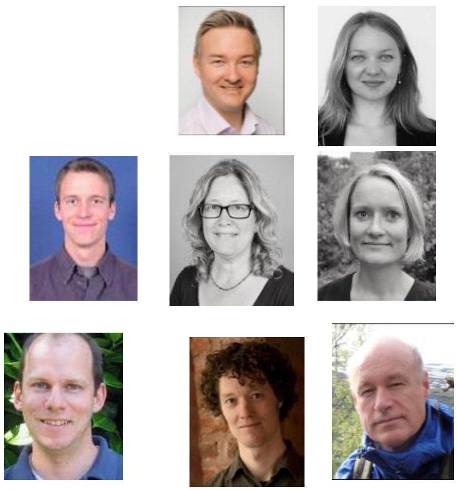
Directions:

Danish Meteorological Institute (DMI) is situated next to the S-train station Ryparken. Leave the station by the southern exit and use the stairs at your left leading directly to DMI. On bike or in car drive to Hans Knudsens Plads toward north. 100 meters along Lyngbyvej (parallel to the Helsingør Freeway) turn to the right just before passing under the railway tracks.

Danish Meteorological Institute
Lyngbyvej 100
DK-2100 Copenhagen E
Ph. +45 39 15 75 00
Fax +45 39 27 10 80

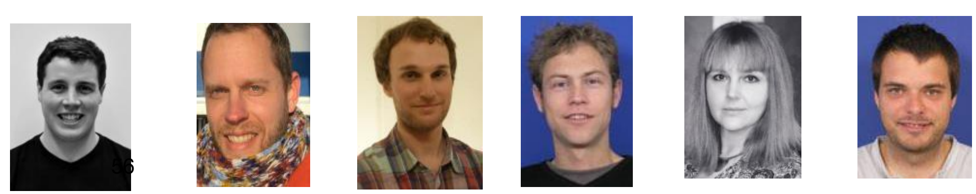
5. Participants & facilitators

- 20 participants representing a diversity of expertise in Arctic maritime sectors and policy
- 5 workshop facilitators to lead activities, track time and take notes



Participant affiliations:

Association of Arctic Expedition Cruise Operators (AECO)
Association of Fishers and Hunters in Greenland (KNAPK)
Maritimt Forum Nord
Greenland Pilot Service
Arctia
Harnvig Arctic & Maritime
RJB Consultancy Arctic & Energy
Visit Greenland
Polar Research and Policy Initiative
The University of Tromsø - The Arctic University of Norway
University of Copenhagen
Nordland Research Institute
University of Southern Denmark
Danish Meteorological Institute
Norwegian Meteorological Institute



6. Agenda draft

8:30 Registration and coffee

9:00 Host's welcome and introductions

9:30 Activity 1 | Process introduction and focal question

10:00 Activity 2 | Key Factors identification

10:45 Break

11:00 Activity 3 | Key Factors prioritization: Impacts and uncertainties

12:00 Lunch

13:00 Activity 4 | Future Projections: Identification and plausibility scores

14:45 Break

15:00 Activity 5 | Discussion: Indicators

-- scenarios activities conclude here--

16:00 Presentation and discussion led by DMI and MET.no about ongoing activities

17:00 Adjourn

18:30 Dinner event at Restaurant PUK

SALIENSEAS
CO-PRODUCING MARINE CLIMATE SERVICES

7. Dinner event

You are warmly invited to our post-workshop dinner event.

Restaurant PUK

HISTORIC DANISH DINING

Vandkunsten 8, 1467 Copenhagen
November 13 | 18:30

From the restaurant's site, an invitation:
"Since 1750, herring, pork and brandy have been served in our basement. Come down and listen to the walls whisper a little about the history."

Aperitifs: 18:30
Dinner: 19:00

Pre-registration with pre-selection of individual menu choices is requested by the restaurant.

Please RSVP via
THIS FORM
to indicate your attendance and menu selections.

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8. Logistics: funding, reimbursement

Name		
	Short description	Amount
Travel costs*		
Accommodation costs*		
Other costs*		
Name of account holder (if different)		
Address of account holder (street name, number, postal code, town and country)		
Bank name		
Bank address (street name, number, postal code, town and country)		
Account number		
IBAN number		
BIC number		

I certify that the above information is correct and the claimed costs are true.
Date:
Signature:

Name:

For reimbursement of travel and lodging costs related to the workshop, please send the information shown on the left either electronically to corry.rothuizen@wur.nl or by mail to:

Wageningen University, Environmental Policy, Bode 175, Hollandseweg 1, 6706 KN Wageningen, The Netherlands

You will also receive this reimbursement form via email for your convenience.

Please note, we need the (original) tickets and receipts to reimburse your costs (a scanned copy of the receipts is also ok).

9. Contact

Questions about the scenario workshop:

Berill Blair
berill.blair@wur.nl

Questions about the SALIENSEAS project:

Machiel Lamers
machiel.lamers@wur.nl

For urgent matters in Copenhagen, please contact Berill at +31 64 383 1413

For more information about our project and our partners:
www.salienseas.com

10. Acknowledgments

We wish to express our gratitude to our stakeholder advisory group whose support has been invaluable to our project efforts:

Edda Falk (AECO)
Tønnes Berthelsen (KNAPK)
Thomas Bøggild (Greenland Pilot Service)
Sampo Viheriälehto (Arctia)
Tor Husjord (Maritimt Forum Nord)
Klaus Harnvig Krane (Harnvig Arctic & Maritime)

This workshop is benefiting greatly from support by the Polar Research and Policy Institute (polarconnection.org) and its experts who have committed to participating and sharing their insights.

SALIENSEAS is part of the ERA-NET program initiated by JPI Climate. SALIENSEAS is funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462).


Photo: MAERSK

Appendix C: Workshop Implementation Materials

Appendix C1: Note taker's handbook

SALIENSEAS

Maritime Futures 2035: The Arctic Region

Scenario Workshop

Notetaker’s Handbook

This document serves as the basic instructions for taking and handling notes taken during the SALIENSEAS Maritime Futures: The Arctic Region Scenario Workshop, November 13, 2018 in Copenhagen Denmark.

Objective

The objective of taking notes at the scenario workshop is to document the discussions that will take place in plenary and group sessions. These notes will form part of the basis of future scenario development by the workshop facilitators. As such, a reviewed and redacted form of the notes will become public record, which should be kept in mind when creating them.

Workshop format

November 13: This will be a full day of workshop with an interplay of plenary and group sessions. Notetakers should be ‘on deck’ at 8:30 am for a briefing, final prep, etc. Coffee, tea, refreshments and lunch are provided.

What you need

Final notes are expected to be in electronic text format (MS Word). Thus, for simplicity, you will need a laptop computer or tablet that you can write on at sufficient speed. Please email a copy of your notes to Berill (berill.blair@wur.nl).
You may elect to take notes by hand, but are required to (a) provide scanned copies/photos immediately at the end of the day, and (b) transcribe them within one week after the workshop into one of the above electronic formats.

Note requirements and format

Notes are expected to be clear, yet concise. Where possible statements made should be attributed to the person that has made them. Discussions do not have to be recorded verbatim. However, the notes should reflect the core arguments, agreements and disagreements. In addition, the notes are meant to record how products during group exercises were developed (this is in addition to any written materials the workshop participants may develop during exercises).

Each specific activity has been given a control number which can be found in the agenda below. These control numbers should be used on each page that contains notes for a particular exercise. Do not use the same page for notes from more than one exercise. For notes from group exercises, at the top of the page, record which participants were part of the particular group you are taking notes for.

Schedule

Most group exercises will require one notetaker to each breakout group discussions during these exercises should be captured as completely as possible. During plenary sessions note taking will be done by Lena; only question and answer session/comments from the audience and replies need be recorded, presentations by facilitators will not need to be recorded. Below is a schedule showing the rotation of note takers.

Activity Reference (control code)	**Activity Title**	**Activity Time**	**Dedicated Notetakers**
	Introductions	9:05 to 9:30	Lena
A1	Process Intro & focal question	9:30 to 10:00	Lena
	Plenary presentation: Intro to A2	10:00 to 10:15	
A2	Key Factors: Breakout groups	10:15 to 11:15	G1: Lena, G2: Berill
			G3: Jelmer, G4: Machiel
A3	Key Factors Plenary	11:30 - 12:00	Lena
A4	Key Factors Voting	12:00 - 12:30	
	Plenary presentation: Intro to A5	13:30 to 13:45	
A5	Future projections: Breakout groups	13:45 to 15:15	*as assigned during lunch*
A6	Plenary reflections	115:30 - 16:00	Lena

Contacts

If there are any questions, please inform: Berill Blair
berill.blair@wur.nl
+31 643 831 413

Appendix C2: Read-ahead

Quantitative scenarios can help identify Arctic policy and research needs

Marc Müller-Stoffels, Amy L. Lovecraft

THE ISSUE. What the state of the Arctic in 2050 will be depends on the trajectories of multiple variables. Policy responses to rapid change must consider complex combinations of social, environmental, political, and economic factors that can determine possible outcomes. Quantitative scenarios offer a transparent and replicable method for determining plausible combinations of factors that produce different futures, letting us analyze the future today.

WHY IT MATTERS. People making decisions that affect our future need scientific evidence that can be used to address real-world problems. Developing relevant research in a rapidly changing world—of which the Arctic is the epitome—is important to the current and future well-being of society and ecosystems. However, forecasting is difficult, and best guesses are inadequate for planning. Quantitative scenarios use empirical evidence in combination with participant expertise to systematically develop robust, plausible, and consistent pictures of multiple possible futures. In addition, scenarios can be scaled directly to the level of concern – local, regional, or global. Scenario-informed research can demonstrate different potential outcomes and nimble policy strategies can be developed to account for more than one future state of the Arctic.

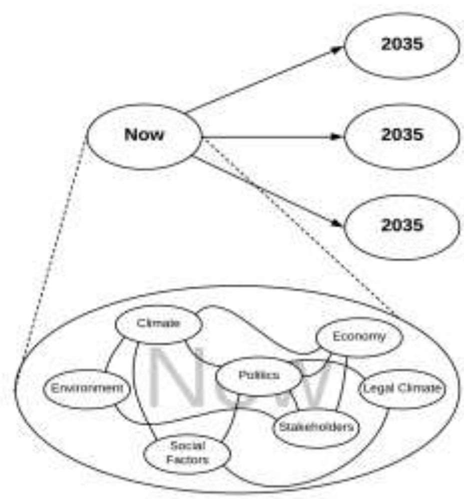

Figure 1: The future is influenced by many different factors. Precise predictions are difficult. Hence, it is more suitable to consider various scenarios.

STATE OF KNOWLEDGE. Scenarios are depictions of the future that form a framework for *what if–ing* that relies on the exchange of diverse perspectives about multiple views of the future, incorporates uncertainty, and engages participants in sharing knowledge about possible courses of action [1]. In contrast to forecasts—which narrow possibilities to the most likely—scenarios are designed to span the range of possibilities. In this way scenarios are not visions of what we would like to have happen, but guides to help us prepare to respond to multiple possible circumstances, desired or not, that may arise.

Scenario techniques are well established as part of the futurist's toolkit [e.g., 1, 2]. There are many different nuances of scenario techniques, but broadly, these can be differentiated as either qualitative or quantitative. Qualitative scenarios are generally based on the judgment, experiences, and creativity of one or more people. Quantitative scenarios offer a deeper analysis of underlying factors driving the future based on research, scoring, and calculation. When done well, quantitative scenarios can also ensure that biases and opinions of project participants are either completely removed or significantly buffered by designing scoring processes such that any participant or the futurist is unable to 'engineer' any most, or least, likely scenario. One quantitative scenario method is Robustness-Analysis [3], an elaboration of Consistency-Analysis [4]. The Robustness-Analysis method relies on an iterative process of collecting data through research and participant engagement (e.g. workshops) to determine the *Key Factors* influencing the future state of—in this case—the Arctic**.** Analyzing potential future states of the Key Factors (*Future Projections)* in different combinations lets a futurist and participants play with a range of possibilities thought to be driving change in coming decades. This process is open to diverse sources of expertise that allows a wider range of possible Key Factors, their Future Projections, and the detection of “wild cards”, or “black swans” – the unlikely but system-transforming events that may be missed by too narrow of a focus or lack of knowledge. A Key Factor should lead to two to five Future Projections. Quantitative scenarios result from first scoring the plausibility that any one Future Projection will occur relative to all Future Projections of a given Key Factor and secondly, scoring the pairwise consistency of Future Projections from different Key Factors (Fig. 2). Thus, each scenario for the future produced is a combination of possible future projections. This process can eliminate inconsistent possibilities and demonstrate possible linkages between Key Factor trajectories. As a simple example, if we consider the development of shipping in the High North, it is plausible that there will be some years of significant ice coverage and others without it. It is also plausible that more nations will seek to operate in the Arctic environment or that many nations will find it too expensive. These ranges demonstrate the possible Future Projections. But, when Future Projections are compared, year-round thick and widespread sea ice is not consistent with increased Arctic shipping. This process of quantitative pairwise comparison means a scenario can have many possible future states for each Key Factor rather than limiting the research to two vectors or simplifying future trajectories. Each scenario output thus has a plausibility score, a consistency score, and robustness score, which directly denote the scenarios’ quality. These scores are combinations of the expertise of participants in their development and evaluation of a set of Key Factors and Future Projections.

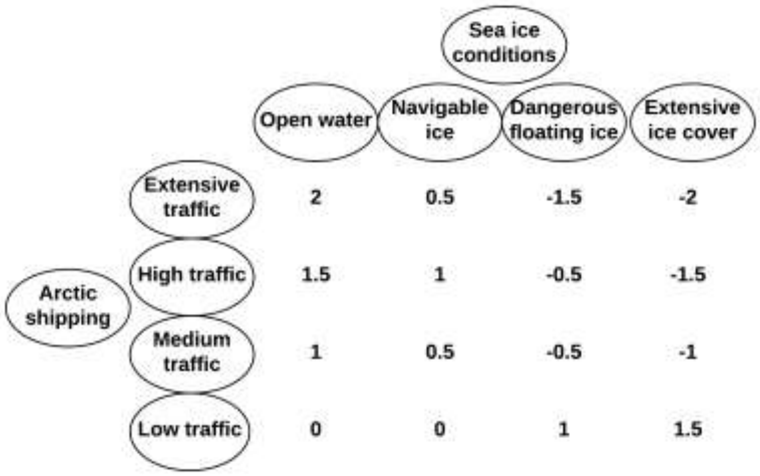

Figure 2: Two key factors (Arctic shipping and sea ice conditions) with their respective future projections and consistency scores shown. Scoring ranges from -2 to +2 with the former meaning entirely inconsistent future projections – these two futures cannot exist at the same time in the same place - and the latter indicating entirely consistent, in some cases dependent, relationships between the two future projections Numbers between these two endpoints indicate some possibility of consistency. For example, ‘Open Water’ and ‘Extensive traffic’ are highly consistent in the same future; whereas “Extensive ice cover” and “Extensive traffic” are inconsistent to one another.

Scores are combined in order to create possible future scenarios that can be evaluated and ranked relative to each other. All possible combinations of Future Projections for all Key Factors are assessed in terms of plausibility. Thus, a hypothetical “most plausible” overall future would include all Future Projections (one for each Key Factor) that received the highest plausibility scores, when viewed independently. However, this “most plausible” future is not necessarily internally consistent, given that Key Factors are not actually entirely independent of one another. Thus, the method also assesses consistency. Every possible combination of Future Projections has a pairwise consistency score assigned based on the project participants’ input and other pertinent research. The “most consistent” future would the one with the highest score based on all the pairwise consistency values described above. Finally, plausibility and consistency are combined into one score for “robustness”. “Robust” sets of the Key Factor’s Future Projections have scored relatively highly in both consistency and plausibility. In other words, the “most robust” model is a future that is both internally consistent and reasonably plausible in all its component parts. Another way to describe the robust scenario is that meaningful stories can be developed to explain them and it is possible for anyone to understand, if not favor, how we might get to any particular future. If you think of the Arctic in 2050 as a bundle of variables related to a range of social and environmental indicators, scenarios development lets us unpack and repack these bundles to imagine and plan now for different possible combinations in 2050.

Because scenarios span a range of possibilities, they then can shape agile research and inform policy strategies. Thus, decisions made in both domains are less fragile as narrow strategies based on rigid assumptions about the future. More flexible strategies open to a wider array of possible futures can help shape the distant outcomes toward desirable states. Identifying a range of plausible scenarios facilitates the monitoring of *early indicators* of undesirable trajectories.

WHERE THE SCIENCE IS HEADED. Scenarios have been used previously to assess developments in certain areas of the Arctic [e.g., 5, 6, 7]. Those projects yielded valuable insights for communities, industries, and policy-makers. Most recently, the Adaptation Actions for a Changing Arctic project of the Arctic Council's Arctic Monitoring and Assessment Program (AMAP) completed a three-region review of ongoing adaptation processes and scenarios in the Arctic. For the Bering Chukchi Beaufort region report, an extensive discussion of different types of scenarios was reviewed for different scales of decision-making [6].

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2. J.C. Glenn, and T.J. Gordon (2009). *Futures Research Methodology – Version 3.0.* The Millenium Project, Washington D.C., USA. ISBN 0-9818-9411-9.
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4. J. Gausemeier, A. Fink, and O. Schlake (1996). *Szenario-Management: Planen und Führen mit Szenarien (English: Scenario management: plan and lead with scenarios).* Carl Hanser Verlag, Munich, Germany. ISBN 3-446-18721-9
5. Mueller-Stoffels, Marc and Hajo Eicken (2011). *Futures of Arctic Marine Transport 2030: An Explorative Scenario Approach*. In: North by 2020: Perspectives on Alaska's Changing Social-Ecological Systems. Ed. by Hajo Eicken and Amy Lovecraft. University of Alaska Press, pp. 477–492.
6. Lovecraft, A.L. and B. Preston (Lead Authors) (2017). *Arctic Scenarios.* In Adaptation Actions for a Changing Arctic - Perspectives from the Bering/Chukchi/Beaufort Region, Chapter 8. Arctic Monitoring and Assessment Programme (AMAP), Arctic Council, Oslo, Norway.
7. L.W. Brigham (2007). *Thinking about the Arctic's Future: Scenarios for 2040.* The Futurist, World Future Society, Bethesda, MD, USA.

Appendix C3: Participant Booklet

SALIENSEAS

CO-PRODUCING MARINE CLIMATE SERVICES

Enhancing the Saliency of climate services for marine mobility Sectors in European Arctic Seas

Participant Booklet

Scenario Workshop

November 13, 2018
Danish Meteorological Institute
Copenhagen, Denmark

Table of Contents

We would like to acknowledge the generous funding support for the SALIENSEAS Project from ERA4CS, an ERA-NET initiated by JPI Climate, and funded by FORMAS (SE), DLR (DE), BMWFW (AT), IFD (DK), MINECO (ES), ANR (FR) with co-funding by the European Union (Grant 690462). Additional support for this workshop was contributed by our host institute, the Danish Meteorological Institute who is offering their facilities and logistical resources necessary. We are also grateful for the Center for Arctic Policy Studies (University of Alaska Fairbanks) for their valuable expertise provided in support of the workshop, and for the support provided by the Polar Research and Policy Initiative's network of experts.

November 13, 2018

Good Morning Participant,

On behalf of the SALIENSEAS Project, Wageningen University, University of Tromsø, Umeå University, and the Danish and Norwegian Meteorological Institutes we would like to welcome you to our scenarios workshop.

This will be a gathering of a diverse groups of experts to explore biophysical and socio-economic systemic factors that drive the need for climate forecasting services in Arctic waters. The core purpose of the workshop is to support MET.no and DMI in strategic product development and stakeholder engagement, to support maritime sectors active in European Arctic waters with strategic planning, to inform the European Commission in support of integrated Arctic policy objectives and to shape ongoing and future plans for safe, sustainable Arctic marine resource use. You have been invited because you have expertise in one or more issue areas concerning Arctic maritime activities, and your knowledge will be considered in the assessment of service needs. Each invited participant will bring a unique perspective to the workshop so that we may form a comprehensive view of the information needed to enhance safety and sustainability in Arctic maritime activites.

Again, welcome to the SALIENSEAS scenario workshop.

Sincerely,

The Project Team

Wageningen University and Research
University of Tromsø
Umeå University
Danish Meteorological Institute
Norwegian Meteorological Institute

Agenda

Location: Danish Meteorological Institute | room *Satellitten*

8:30 – 9:00	Welcome and Registration
9:00 – 9:05	Host's Welcome
9:05 – 9:30	Introductions
9:30 – 10:00	Activity 1 | Process Introduction and focal question
10:00 – 10:15	Presentation | Key factors
10:15 – 11:15	Activity 2 | Key factors
11:15 – 11:30	Break
11:30 – 12:00	Activity 3 | Key factor discussion
12:00 – 12:30	Activity 4 | Key factor votes
12:30 – 13:30	Lunch
13:30 – 13:45	Presentation | Future projections and plausibility
13:45 – 15:15	Activity 5 | Future projections
15:15 – 15:30	Break
15:30 – 16:00	Activity 6 | Plenary discussion

scenario process ends here

16:00 – 17:00	Presentation and discussion of current projects and next steps from service provider perspective: DMI and MET.no
17:00	Adjourn

Workshop Team

Facilitator	Affiliations	SALIENSEAS role
	**Douglas Cost** Assistant Professor University of Alaska Fairbanks USA	
Moderators		
	**Machiel Lamers** Assistant Professor Wageningen University The Netherlands	SALIENSEAS Principal Investigator
	**Berill Blair** Researcher Wageningen University, The Netherlands and Polar Research and Policy Initiative	SALIENSEAS Project Team
	**Jelmer Jeuring** Researcher Umeå University Sweden	SALIENSEAS Project Team
Scribe	**Lena Hermesdorf** University of Copenhagen Denmark	

Participants

Participant	Affiliation	SALIENSEAS role
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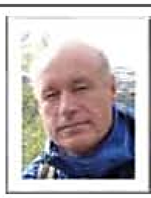
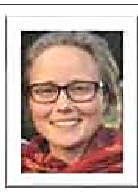
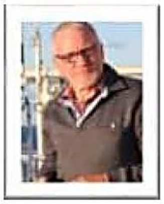
	**Brooks Kaiser** University of Southern Denmark and Polar Research and Policy Initiative baka@sam.sdu.dk	
	**Gunnar Noer** Norwegian Meteorological Institute gunnarn@met.no	
	**Thomas Boggild** Greenland Pilot Service tpb@gps.gl	SALIENSEAS Stakeholder Advisory Group Member
	**Dwayne Ryan Menezes** Polar Research and Policy Initiative d.menezes@polarconnection.org	
	**Siri Veland** Nordland Research Institute sve@nforsk.no	

	**Klaus Harnvig** Harnvig Arctic and Maritime Klaus.harnvig.krane@harnvig-ice.dk	SALIENSEAS Stakeholder Advisory Group Member
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	**Andrea Gierisch** Danish Meteorological Institute ang@dmi.dk	SALIENSEAS Project Team
	Alexandra Stocker The University of Tromsø alexandra.n.stocker@gmail.com	

Key Concepts

Scenario terms

Key Factors (Drivers of Change)
Also known as "driving forces", or "drivers", these are factors or conditions which collectively will influence the trajectory, magnitude and speed of changes that are relevant to the focal question.

Uncertainties
Characteristics of systems that may be relevant to the focal question, but about which limited knowledge is available or over which there is disagreement about their current or future state.

Scenario process
Identification and evaluation of plausible alternative futures for a region, in light of the identified driving forces and key uncertainties, in order to assess the implications of these alternative futures on the natural and socioeconomic resources of the region, and inform and prioritize long-term research and monitoring decisions for resource managers.

Trends
Directional changes that are relevant to the focal question (i.e., that may influence or be influenced by the outcomes to that question) and are sufficiently clear that they are to some extent predictable.

Future projection
The way a key factor/driver of change could develop in the future. Key factors usually have two to five future projections. Future projections are the core components building individual scenarios.

Plausible/Plausibility
In order to have logical storylines that make sense, developed from the scenarios process, future projections are required to be plausible. Note that plausibility of a future projection is not the same as its probability of occurring. Plausibility assessments are a key scoring component in the formal scenario building process that follows this workshop.

Consistency
Scenarios should be internally consistent, i.e., components of the scenario should not be in stark conflict to each other, or mutually exclusive of occurring. Consistency is another important scoring criteria during the scenario process following this workshop.

Robustness
A robust scenario is both plausible and consistent, but not necessary the most plausible or most consistent.

Definitions of meteorological forecasting ranges (from the WMO)

Nowcasting
A description of current weather parameters and 0 -2 hours description of forecasted weather parameters

Very short-range weather forecasting
Up to 12 hours description of weather parameters

Short-range weather forecasting
Beyond 12 hours and up to 72 hours description of weather parameters

Medium-range weather forecasting
Beyond 72 hours and up to 240 hours description of weather parameters

Extended-range weather forecasting
Beyond 10 days and up to 30 days description of weather parameters, usually averaged and expressed as a departure from climate values for that period.

Long-range forecasting
From 30 days up to two years

Monthly outlook
Description of averaged weather parameters expressed as a departure (deviation, variation, anomaly) from climate values for that month (not necessarily the coming month).

Three month or 90 day outlook
Description of averaged weather parameters expressed as a departure from climate values for that 90 day period (not necessarily the coming 90 day period).

Seasonal outlook
Description of averaged weather parameters expressed as a departure from climate values for that season.

> Notes:
> (1) In some countries, long-range forecasts are considered to be climate products
> (2) Season has been loosely defined as Dec/Jan/Feb = Winter; Mar/Apr/May = Spring; etc...in the northern hemisphere. In the tropical areas seasons may have different durations. Outlooks spanning several months such as multi-seasonal outlooks or tropical rainy season outlooks may be provided.

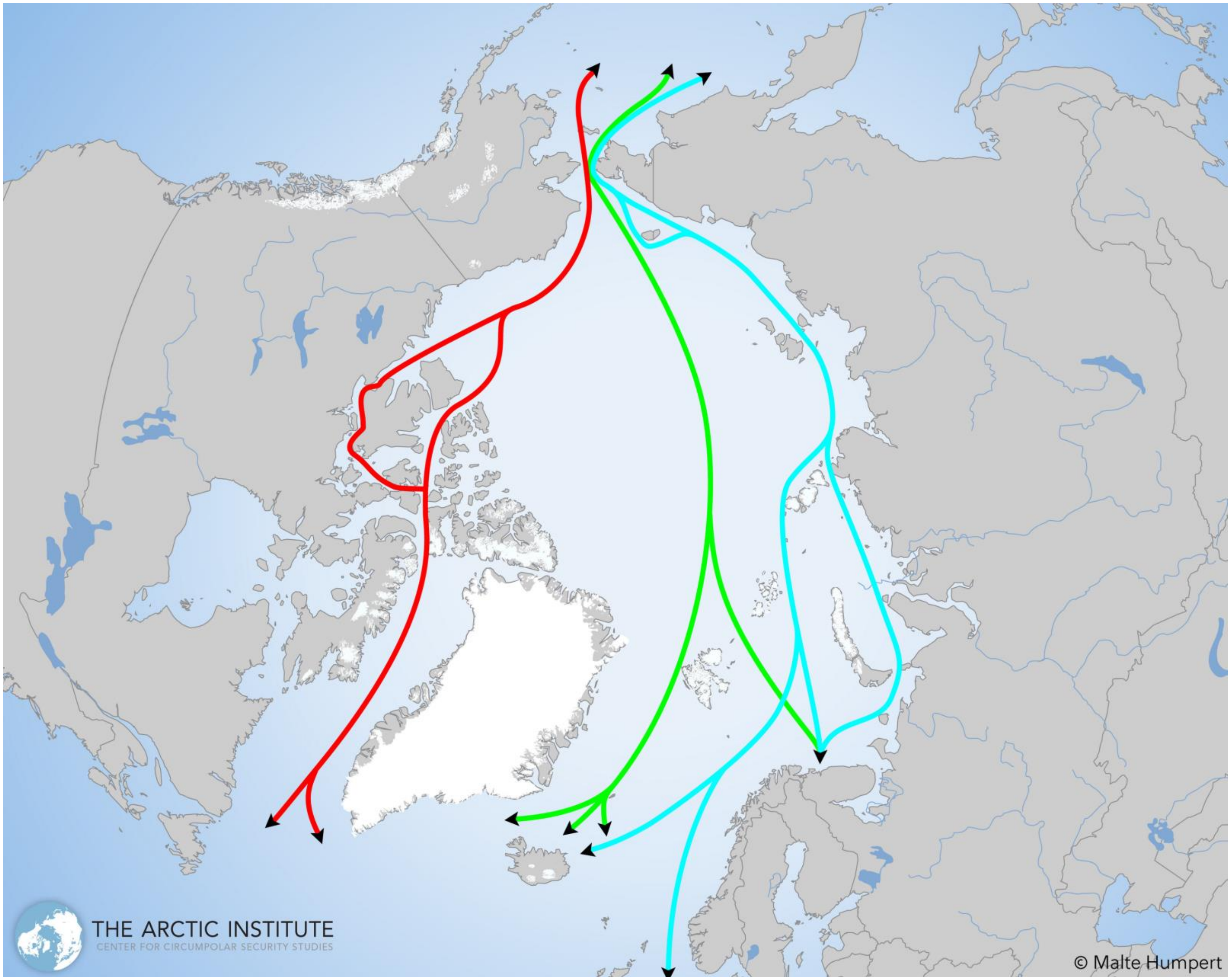
Climate forecasting
Beyond two years

Climate variability prediction
Description of the expected climate parameters associated with the variation of inter-annual, decadal and multi-decadal climate anomalies.

Climate prediction
Description of expected future climate including the effects of both natural and human influences.

Subseasonal prediction
Time scale of two weeks to two months.

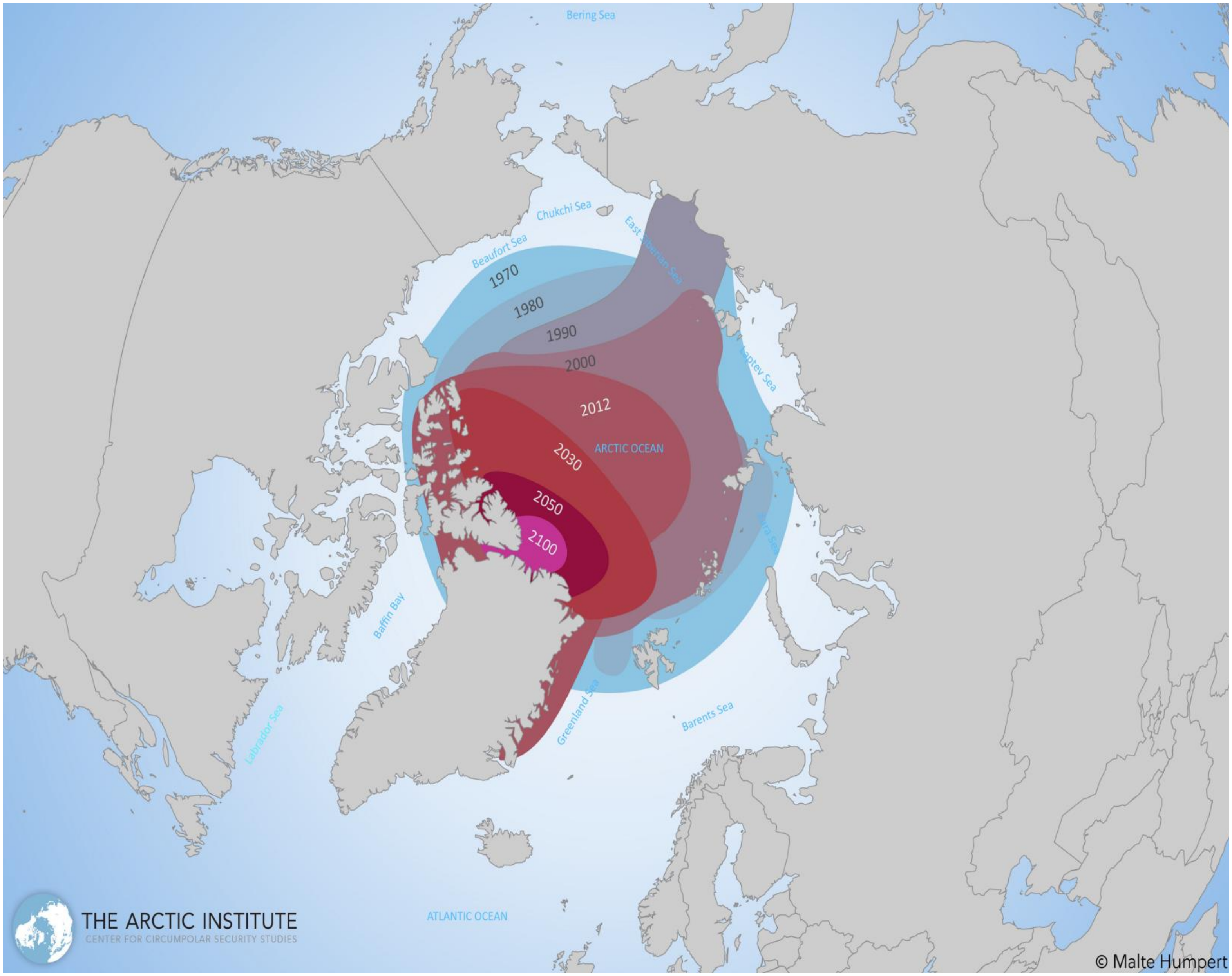
Arctic Shipping Routes



Key Reference Maps

Arctic Search and Rescue Zones

Summer Ice Extent: 1970 - 2100



WAGENINGEN UNIVERSITY & RESEARCH
UMEÅ UNIVERSITY
UNIVERSITY OF TROMSØ
Danmarks Meteorologiske Institut
Norwegian Meteorological Institute

Appendix

SALIENSEAS scenario workshop: Supporting maritime stakeholders' metocean and sea ice service needs until 2035 in European Arctic waters

Agenda and detailed schedule of activities

8:30 – 9:00 **Registration, coffee**

9:00 – 9:05 **Host's welcome**
S. Olsen

9:05 -9:30 **Introductions**
M. Lamers

9:30 – 10:00 **Activity 1 | Process Introduction and focal question:**
"What information is needed for optimal decisions toward safe and sustainable maritime activities now and through 2035?"
D. Cost and M. Lamers

Description:
This initial activity is intended to explore the scenario process and the focal question. Following a brief presentation on the workshop and expectations, the focal question is considered by the whole group. In the final minutes, participants are asked to write down, on post-it notes, words that complete the sentences "The things that enhance safety in maritime activities include..." and/or "The things that promote sustainability in maritime activities include..." Post-it notes are collected at the end and put on display.

Activity Goal:
Participants feel welcome and understand the point of the workshop and its outcomes
People begin to consider (i) the interplay between metocean information and safe operations, and (ii) larger systemic factors that impact this interplay.

Results
Notes taken during the icebreaker and discussion of focal question, and participant sticky notes finishing the sentence

10:00 – 10:15 **Plenary Presentation | Introduction to Activity 2**
D. Cost

10:15 – 11:15 Activity 2 | Key Factors: Small Group Exercise

Description:
Participants are divided into 4 groups. Small groups deliberate and come up with 4-8 important drivers of change in each group (minimum 4, maximum 8), that impact the interplay between metocean services needs and safe & sustainable maritime operations (optimal decision making environment). These are planned and discussed through writing on flip charts with markers to allow room for bullet list of ideas and any notes. The final list is written on 8 post-it notes (one key factor per) in each group, affixed to a flip chart page. At the end of the exercise, group leaders hang their sheet on the wall for next activity.

Activity Goal:
Participants identify the most important drivers of change that impact currently, and will continue to do so, the type of services and information that create the most optimal decision making environments for maritime sectors.

Results
Collection of 30-40 key factors produced by participants on post-it notes, and notes taken during the small group discussions.

11:15 – 11:30 Break

11:30 – 12:00 Activity 3 | Key Factors: Plenary

M. Lamers and J. Jeuring

Description:
Plenary discussion about the list of key factors identified in small groups: duplicates are collated to eliminate redundancy.

Activity Goal:
This activity will result in a list of key factors that impact currently, and will continue to do so, the type of services and information that create the most optimal decision making environments for maritime sectors. proposed by participants without duplicates.

RESULTS:
List of 20-25 unique key factors identified by participants that impact currently, and will continue to do so, the type of services and information that create the most optimal decision making environments for maritime sectors.

12:00 – 12:30 Activity 4 | Voting on most influential key factors: Plenary

D. Cost

Description:
Each participant works on their own. Using color dot stickers that represent key factor impact (green dots) and key factor uncertainties (red dots) participants rank each key factor based on how much they impact information needs for safe/sustainable marine activities, and the level of uncertainty they pose. Participants may put several (or all) color dots on one key factor, or distribute across several.

Guiding questions:

- Which of the drivers most influence metocean / sea ice forecast needs in the region?
- Which drivers have a high level of uncertainty?
- Which drivers have the most influence over future change?

Activity Goal:

Identify the key drivers and relationships among these key drivers that will have the most influence upon the future of maritime operations and metocean service needs in the region. This activity will organize this group of key factors by their relative levels of influence on change and by their level of uncertainty. The participants will have a list in mind of what key factors are affecting service / information needs; what they know about as important and less important; what they feel is most uncertain about our knowledge.

RESULTS:
Key factors ranked by level of impact and level of uncertainty.

12:30 – 13:30 Lunch

13:30 – 13:45 Plenary Presentation | Future projections small group exercise: Introduction to Activity 5

D. Cost

13:45 - 15:15 Activity 5 | Future projections: Small groups exercise

13:45 – 15:00 Activity 5 Part I: Future projections, plausibility

Description:
Participants are divided into 4 groups, each group is tasked with 3 key factors and their future states. This activity will identify a number of possible future states (2-4 depending on expert input) for each key factor. A very simplified example: if *marine traffic* is determined as a key factor in driving Arctic metservices demands, and is one of the top 10, participants might identify 3 possible future states for this driver of change: (i) increased traffic, (ii) unchanged levels of traffic, (iii) decreased traffic. Participants are encouraged to make a bullet list of what maritime operations would look like under each future projection especially with regards to any impacts on the type of metservices decision makers will need.

To finish the activity, each participant completes a plausibility scoring sheet for the future projections in their group. Participants consider the future projections they designed for their assigned key factors, and give a plausibility score for each. Example: taking 1.0 as the total sum plausibility score, the key factor marine traffic may see future projections increased traffic; unchanged levels of traffic; and decreased traffic receive plausibility scores of 0.8, 0.1, and 0.1 respectively.

Activity Goal:
Identify the possible evolutions of each key factor, taking into account the system as a whole (six-system view).

Results
List of key factors and their future projections. Each future projection receives a plausibility score, which is vital to later stages of WP2 simulation tool development. Notes taken during group discussions by note takers on description of future projections (these should have descriptive titles, nevertheless more detail is useful)

15:00 – 15:15 Activity 5 Part II: Indicators

Activity Goals:
Participants consider and reflect on indicators for future projections: for each, what are measurable variables that allow us to track decision points, thresholds, signal points?

Results: Each future projection receives a list of indicators that can be used to observe, measure (simulate) phenomenon.

15:15 – 15:30 Break

15:30 – 16:00 Activity 6 | Plenary Reflections

M. Lamers and D. Cost

Description:
In the first half of the activity, each group reports to the whole group on their final list of future projections, with a very brief description. Activity ends with group reflection on the day's activities.

----Scenarios process concludes here

16:00 – 17:00 DMI and MET.no take the floor | Presentation and discussion of ongoing projects and next steps from service provider perspective

M. Mueller, S. Olsen, M. Lamers

17:00 Adjourn