Leveraging AIS Data and Field Knowledge for Making Spray Icing Risk-Informed Decisions (SPRISK)

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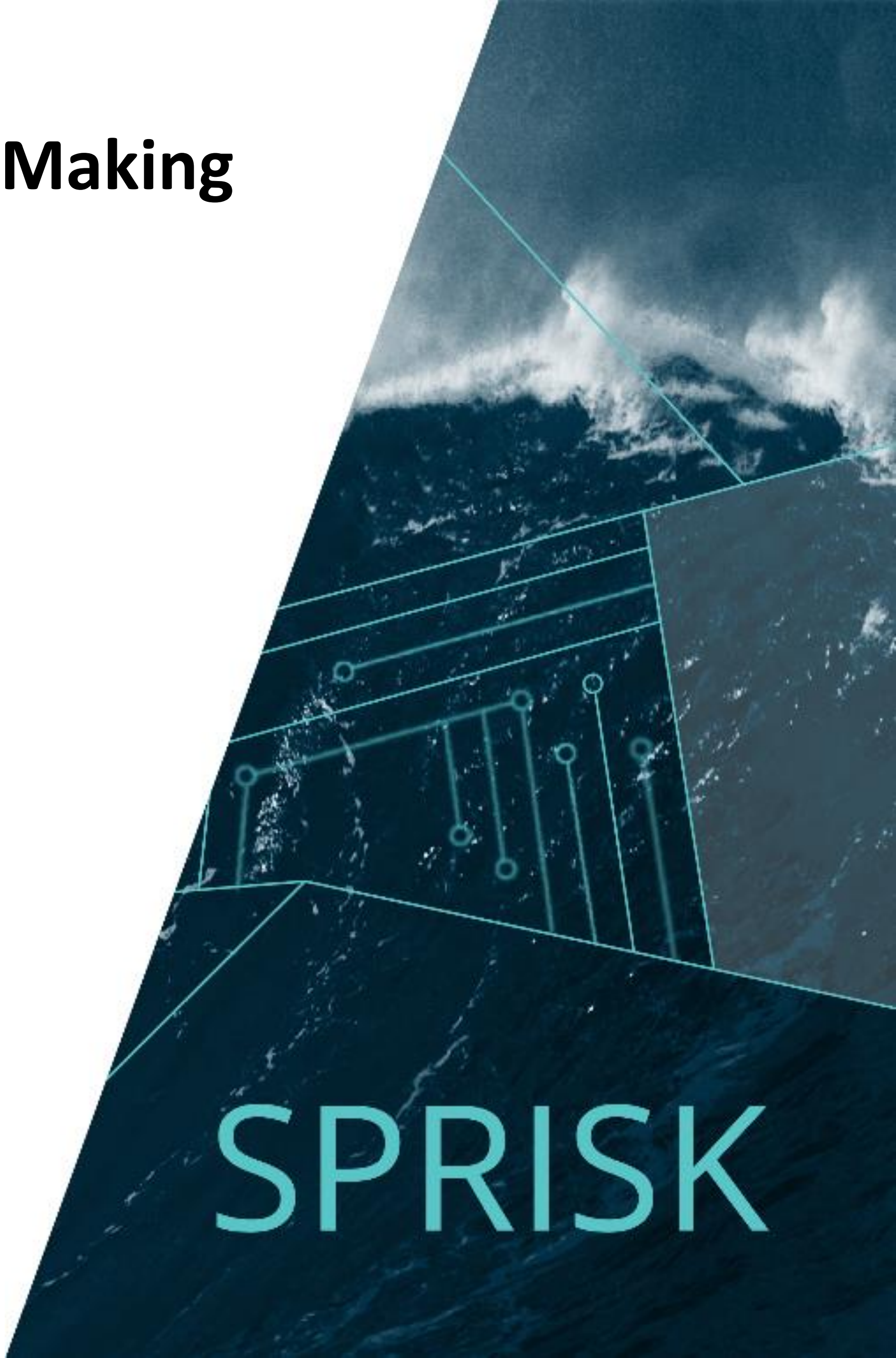
Masoud Naseri, PhD

Associate Professor of Societal Safety and Environment

UiT The Arctic University of Norway

Visiting Fellow, Department of Energy, Politecnico di Milano, Italy

msoud.Naseri@uit.no



Motivation

- **Spray icing risks**
  - How to define the risk and acceptance criteria
  - What does previous accident and near-miss data suggest?
  - How frequent does icing occur?
  - What are safety barriers and procedures (active/passive)
- **What criteria do we have for making risk-informed decision?,**
  - Cost
  - Safety of facility/fish/operators
  - Regulations
  - Ensuring operational routines
  - ...
- **What sorts of operational alternatives do we have to choose** (Anti-icing/de-icing techniques, design modification, operational/organisational)?
- **…?**

Employing spray icing estimation model (MINCOG)

Meteorological and oceanographic conditions

Field knowledge in fishery industry

Historical data for accidents and near-misses

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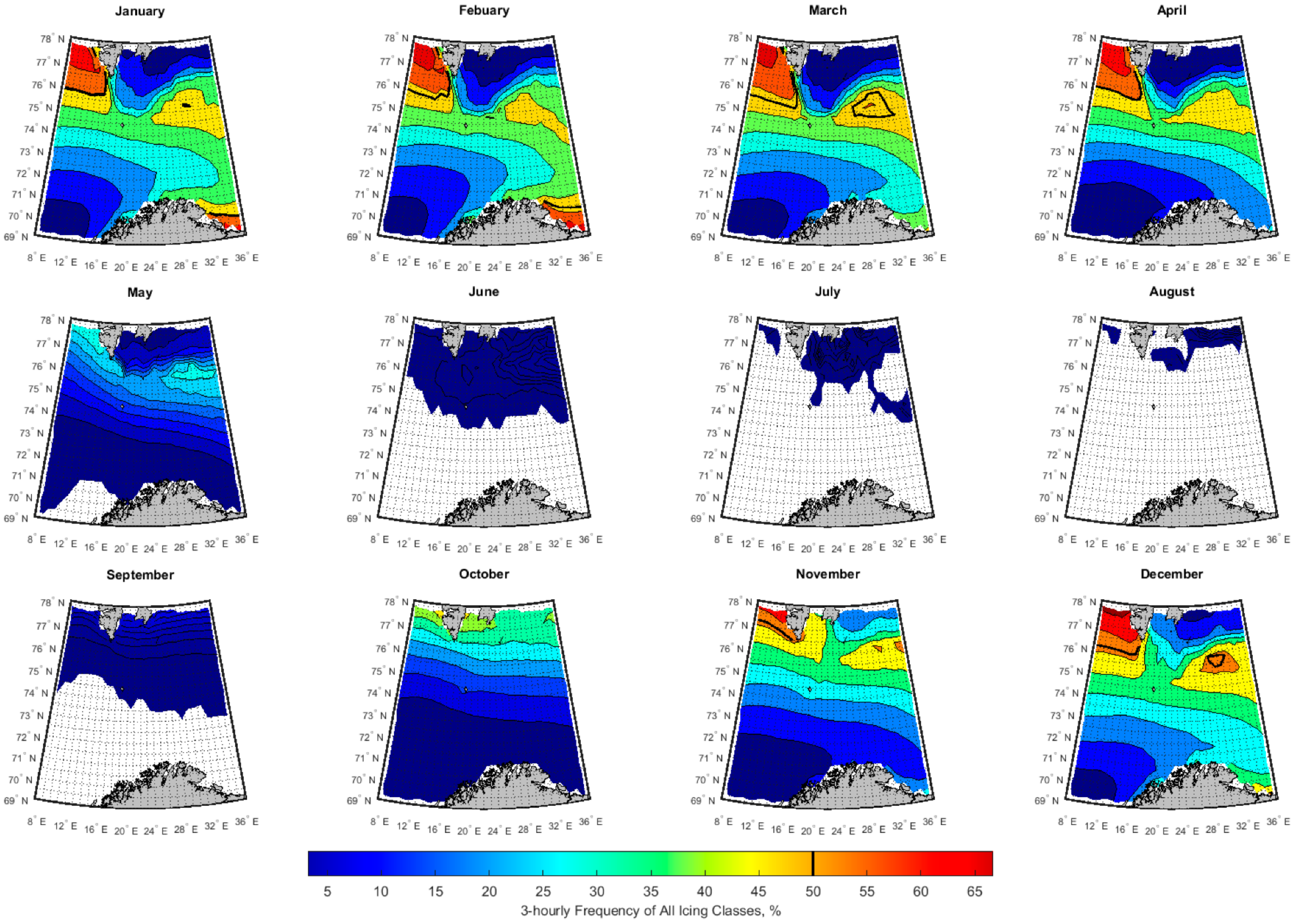
- **Employing spray icing estimation model (MINCOG)**
- **Meteorological and oceanographic conditions**

- Probabilistic study of spray icing (frequencies and severity)
- Spatial and temporal variations



Automatic Identification System(AIS) data

Automatic Identification System (AIS) broadcasts the vessel's status, consisting of (directly/indirectly)

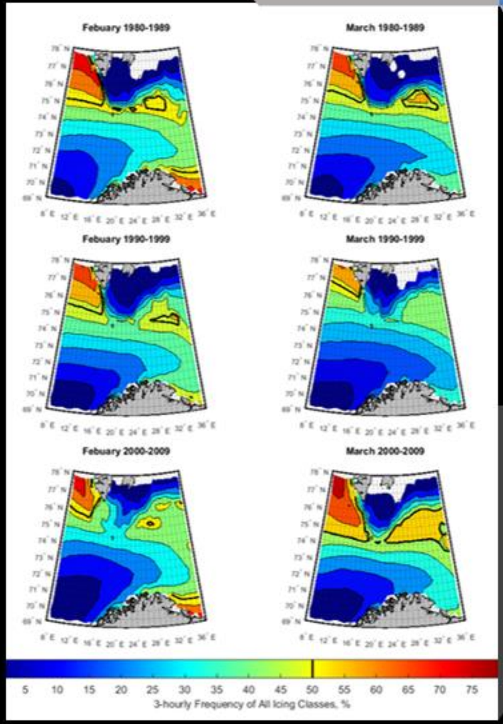
Historical data for accidents and near-misses

Vessel information
(e.g., identification numbers, a name, dimensions, and a type)

Trajectory information
(e.g., position, time, velocity, course, destination, navigational status, etc.).

- Insiting into insight into historical ship behavior
- Insight into maritime traffic patterns.
- Applied in ship collision risk assessment by employing a variety of machine learning techniques (e.g., for trajectory prediction).

- **Mapping the available operational experience**
- **AIS data mining and knwoledge discovery using advanced ML tools**
- **Risk-informed decision-making framework**



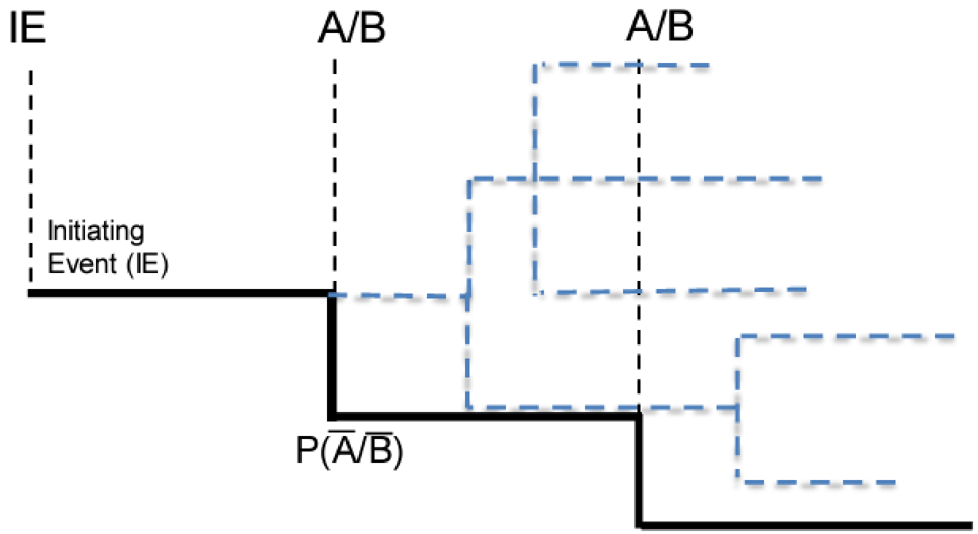
SPRISK - Goal

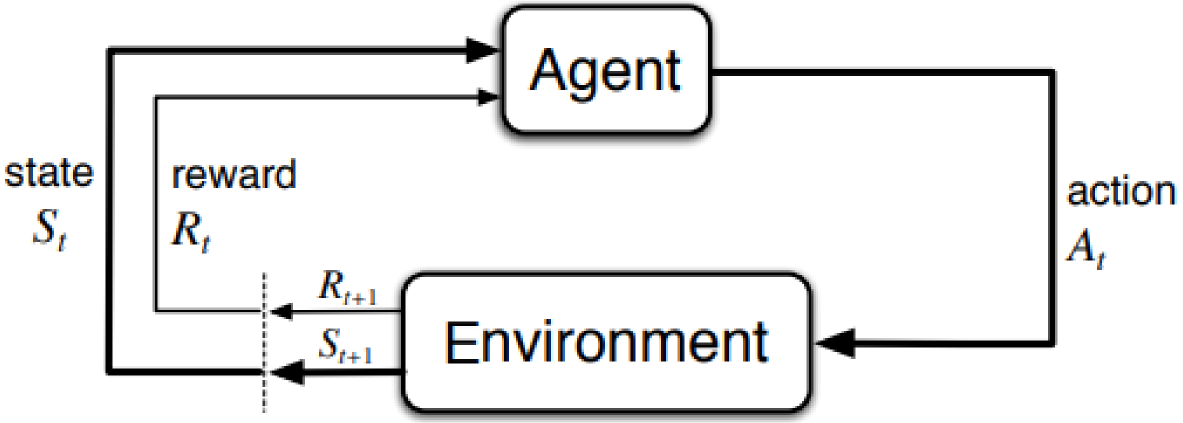
- **Project goal**

*Proposing **risk-informed decision-making** frameworks developed by leveraging historical **AIS data**, employing **spray icing estimation model, meteorological and oceanographic conditions**, and **field knowledge** in fishery industry.*

Decision-Making Under Uncertainty

Sequential decisions under uncertainties related to met-ocean parameters





- Dynamic risk assessment
- Markov Decision Process

Sequential Decision-Making Under Uncertainty

World/Environment

A geographical region Ω in the Arctic offshore, be divided into $v \times w$ cells,

$$\Omega = \begin{bmatrix} \omega_{11} & \omega_{12} & \cdots & \omega_{1w} \\ \omega_{21} & \omega_{22} & \cdots & \omega_{2w} \\ \vdots & \vdots & \ddots & \vdots \\ \omega_{v1} & \omega_{v2} & \cdots & \omega_{vw} \end{bmatrix}$$

$$x_t^{(\omega_{ij})} = \left[wind_t^{(\omega_{ij})}, wave_t^{(\omega_{ij})}, temp_t^{(\omega_{ij})} \right]$$

$$rate_{ice_t}^{(\omega_{ij})} = MINCOG\left(\boldsymbol{x}_t^{(\omega_{ij})}, \boldsymbol{y}^{(\omega_{ij})} \right)$$

$\boldsymbol{y}^{(\omega_{ij})} = \left[\phi^{(\omega_{ij})}, V^{(\omega_{ij})} \right]$, with $\phi^{(\omega_{ij})}$ and $V^{(\omega_{ij})}$ being the heading and speed of the vessel

Actions

- The vessel (agent) moves across the cells ω_{ij}, $1 \leq i \leq v, 1 \leq j \leq w$. From the current location, the ship can sail
  - to the adjacent cell on its right a_r (i.e., $\omega_{i,j} \rightarrow \omega_{i,j+1}$),
  - to the adjacent cell on its left, a_l, (i.e., $\omega_{i,j} \rightarrow \omega_{i,j-1}$),
  - forward, a_f, (i.e., $\omega_{i,j} \rightarrow \omega_{i+1,j}$),
  - backward, a_b, (i.e., $\omega_{i,j} \rightarrow \omega_{i-1,j}$),
- Activating anti-icing measures by turning up the heating, a_h,
- Activate de-icing techniques such as removing ice by bats, a_d, reducing the vessel speed to a certain amount, a_s.
- Abort the whole operation, a_a.

Sequential Decision-Making Under Uncertainty

States

The actions taken at each decision time point t, $a_t \in A$, result in a stochastic transition of its states with a transition probability of

$$P(s_{t+1} = s' | s_t = s, a_t = a) \quad \forall a \in A, \forall s \in S$$

ω_{11}	ω_{12}	ω_{13}	…	ω_{1w}
ω_{21}	ω_{22}	ω_{23}	…	ω_{2w}
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
ω_{v1}	ω_{v2}	ω_{v3}	…	ω_{vw}

Transitions

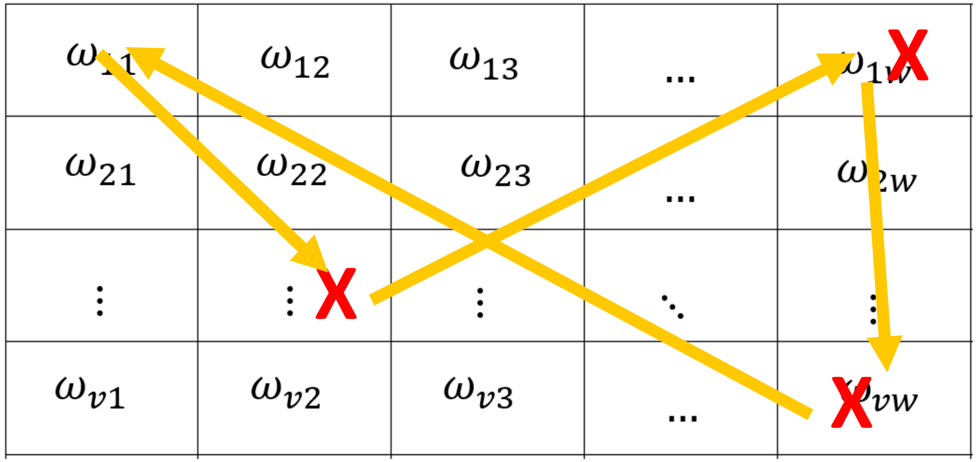
The transition probability matrix $T(s', s, a)$ is given by,

$$T(s', s, a) = \begin{bmatrix} P_{11} & P_{11} & \cdots & P_{1N} \\ P_{21} & P_{22} & \cdots & P_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ P_{N1} & P_{N2} & \cdots & P_{NN} \end{bmatrix}$$

Sequential Decision-Making Under Uncertainty

Reward

- Cost of fuel consumption
- Cost of vessel operation
- Icing risk reduction
- Completing some activities of interest
- De-icing / Anti-icing
- Aborting the mission



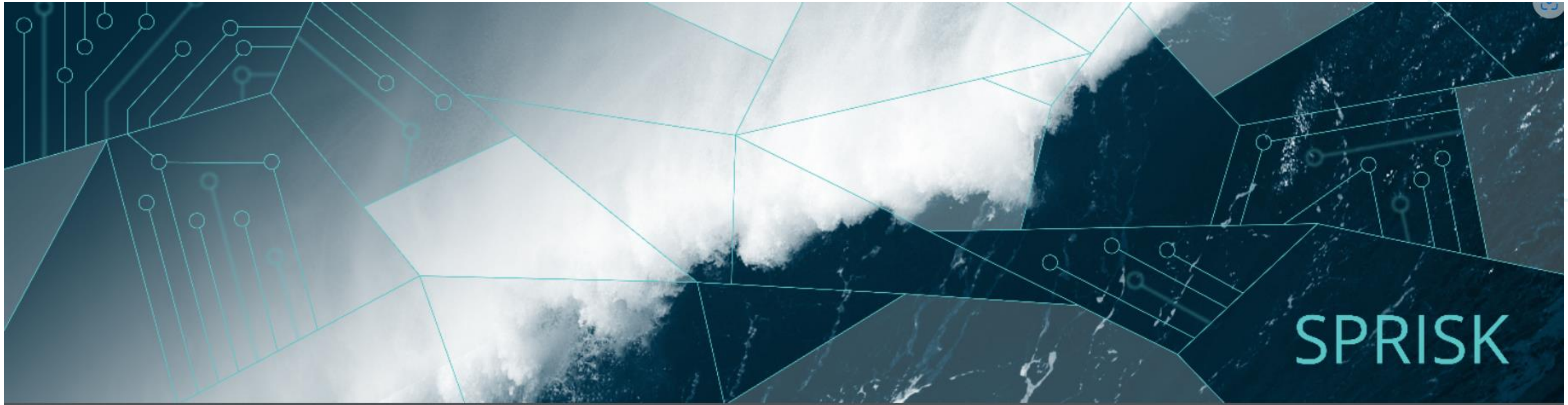
$$G_t = R_{t+1} + \gamma R_{t+2} + \ldots = \sum_{k=0}^{\infty} \gamma^k R_{t+k+1}$$

The value of receiving reward R after $k + 1$ time-steps is $\gamma^k R$

$$v(s) = \mathbb{E}\left[G_t \mid S_t = s\right]$$

Optimal policy - The policy that chooses the maximum optimal value while considering the present state is referred to as the optimal policy.

- Policy evaluation
- Value iteration
- Q-learning



Leveraging AIS Data and Field Knowledge for Making Spray Icing Risk-Informed Decisions (SPRISK)

This project develops a risk-informed decision-making (RIDM) framework with regards to the sea-spray icing risks associated with navigation and vessel operations in the Norwegian Arctic waters. Such a RIDM framework will be

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Meteorologisk institutt

The Research Council of Norway

KYSTVERKET

SINTEF

https://en.uit.no/project/sprisk

Multidisciplinary approach for spray icing modelling and decision support in the Norwegian maritime sector

(**SPRICE**)

The Research Council of Norway

UiT The Arctic University of Norway

HERMES

SINTEF

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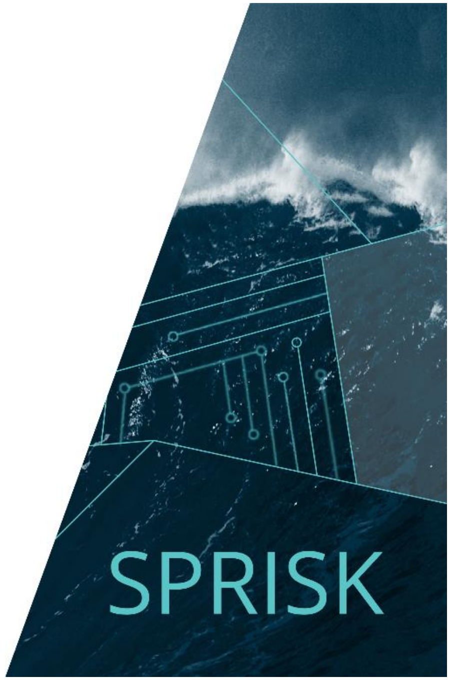
Norwegian Meteorological Institute

Gratanglaks

Leveraging AIS Data and Field Knowledge for Making Spray Icing Risk-Informed Decisions

(**SPRISK**)



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