Gefördert durch:

Bundesministerium
für Verkehr und
digitale Infrastruktur

aufgrund eines Beschlusses
des Deutschen Bundestages

The Arctic Transportation Challenge: Improved Sea Ice Situation Awareness for Ship Navigation in Polar Waters by Fusing SAR and Optical Data from the Sentinel Satellite Fleet in the EisKlass2 Project

Dr. Sven Jacobsen

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mFUND
Das Startkapital für die Mobilität 4.0

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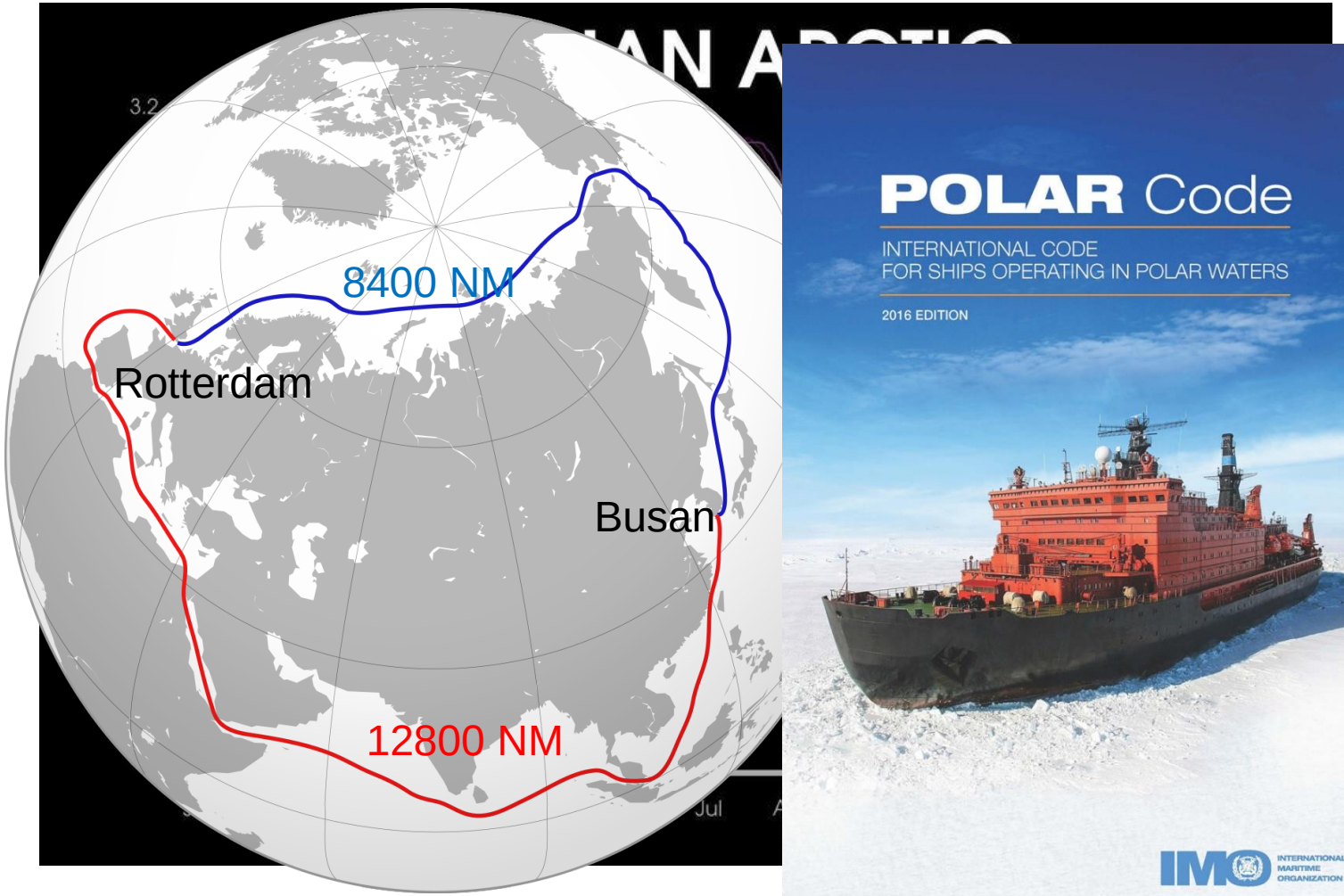
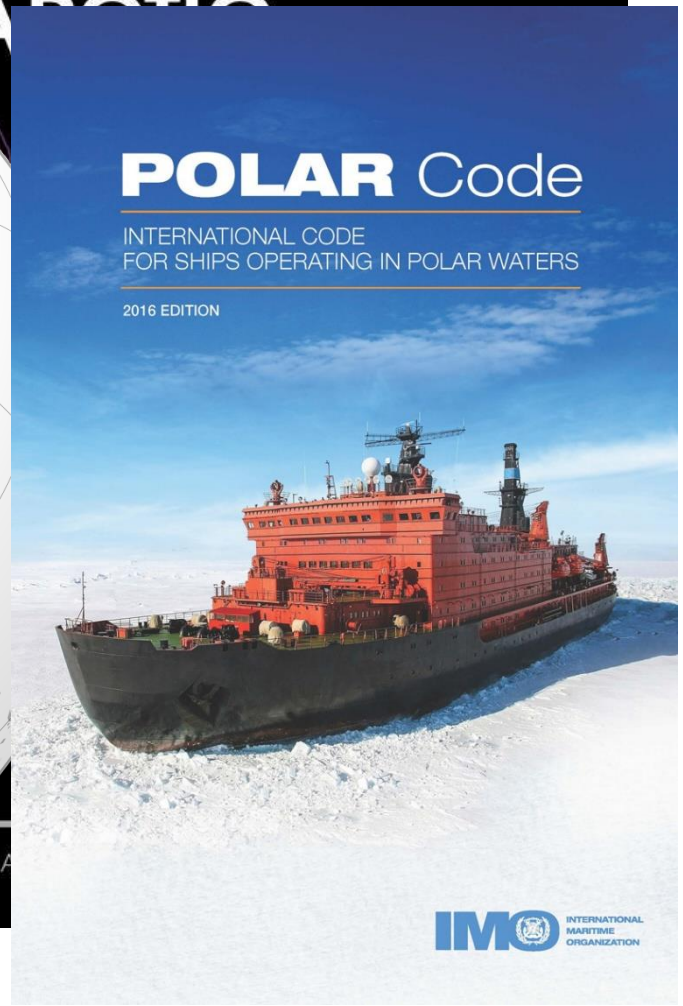
Motivation

- Fact: sea ice coverage and thickness decreasing
- Attractive new seaways are opening up (e.g. north-east passage)
- Distance Hamburg Hong-Kong by 1/3 shorter (14500km instead of 22500km) + No Channel fees
- Saving time, fuel and money are drivers that will ultimately lead to traffic increase on arctic passages
- Detailed sea ice class information crucial for strategic route planning
- IMO Polar Code: Detailed and up-to date sea ice information mandatory for navigation in polar waters





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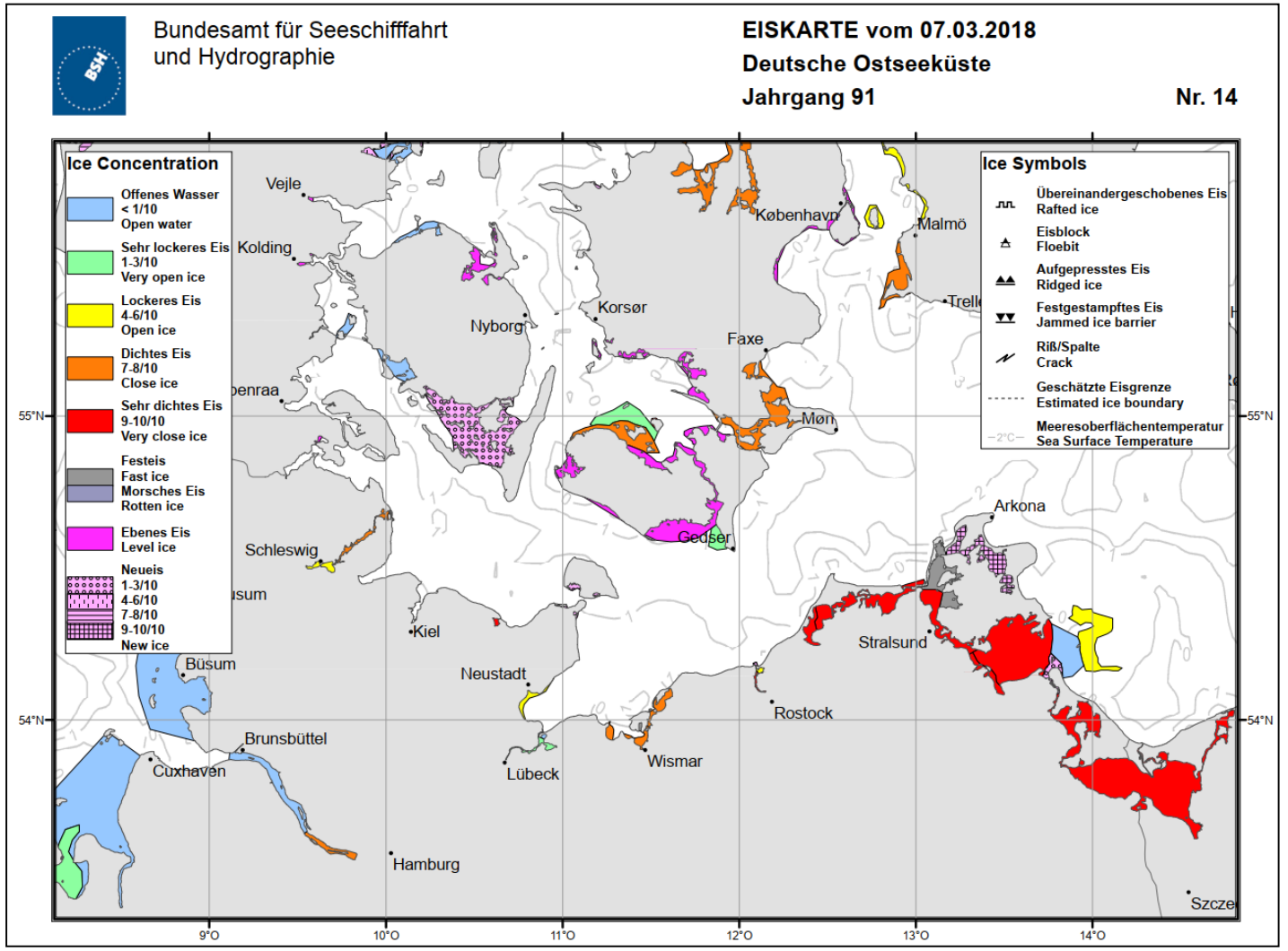
Motivation

- Passages are **not ice free**, but partly and temporarily navigable
- Sea ice situation (e.g. ice type, drift, etc.) determine navigability: Especially the **ice class**
- Different ice classes can be identified on satellite remote sensing data (Radar and Optical)

State of the Art

- BSH: Ice charts available for large areas, update every 2-3 days (region dependent)
- Ice services of other countries: similar
- Ice charts commonly
  - Have poor resolution
  - Are a couple of days old
- Possible consequences:
  - Route-planning needs to take extra safety margins (e.g. detours even if not necessary)
  - Ice dynamics can still render planned routes impossible
  - Additional costs (detours, ice-breaker services, contract penalties



Sattelite Data

- High-resolution
- Large spatial coverage
- Available in Near-Real Time (NRT)

- Synthetic Aperture Radar (SAR)
  - Independent of clouds and sunlight
  - High resolution (12-60m)
  - Depending on frequency: Mainly sensitive to ice surface roughness => Same ice type looks different if covered with frost flowers or melting ponds

- Optical / Multi- / Hyperspectral
  - Visible color and IR information
  - Lower spatial resolution (500m)
  - Sensitive to clouds and sunlight

TerraSAR-X Acquisitions delivered in near-real time during AWI Polarstern-Campaing (TerraSAR-X ScanSAR: 17 m Resolution)

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Sattelite Data

TerraSAR-X Acquisitions delivered in near-real time during AWI Polarstern-Campaing (TerraSAR-X ScanSAR: 17 m Resolution)

State of the Art

- Previous projects and scientific campaign support demomstrated time- and fuel-saving capabilities of ice information based on satellite data

- Important information for shipping companies, ice and weather services, search and rescue, catasptrophy management, climate research

- Challenges:
  - Reliability of ice classification
  - Size and timelyness of information products
    - Fast processing of large amounts of data
    - Data-saving information products (poor internet)
  - Best usability of information on the bridge (human-machine interface)

TerraSAR-X Acquisitions delivered in near-real time during AWI Polarstern-Campaing (TerraSAR-X ScanSAR: 17 m Resolution)

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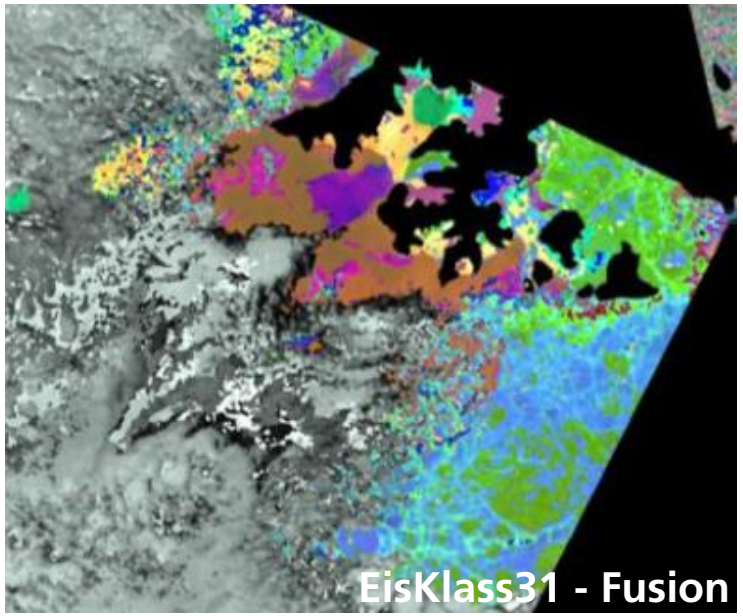
Project EisKlass2: Goals

- Fast and reliable high-resolution sea ice information
  - Fusion of optical and radar information
  - Application of machine-learning to develop an AI-based sea ice classification algorithm
  - Validation with in-situ data and numerical models
  - Quantification of benefit of more acurate information for national ice charting services and numerical modelling

- User Software
  - Intuitive interface with ice chart visualization
  - NRT availability of sea ice information by an operationalized data processing and delivery chain

- User Interaction
  - Few „big“ demonstrations with ships, 1:1 data delivery, interaction and feedback
  - Many „small“ test users, beta-testing of user interface and software, possible users/customers after project completion



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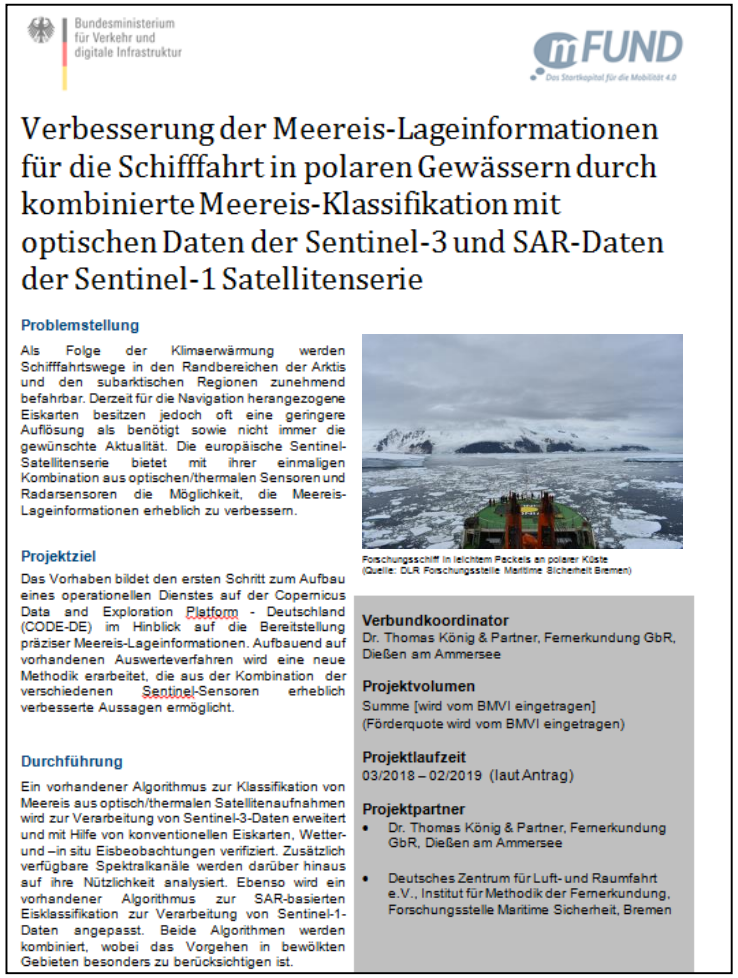
Project Partners and Expertise

▪ German Aerospace Center (DLR) (*Project Coordination*) • Maritime Safety and Security Lab, Bremen • Maritime Safety and Security Lab, Neustrelitz (NZ)	SAR remote sensing and ice classification, data fusion, AI-based classification algorithms, operational services
▪ Drift+Noise Polar Services GmbH (DNPS)	AWI spin-off, first-hand experience in ice navigation, test-user community
▪ Ocean Atmosphere Systems GmbH (OASys)	AWI spin-off, sea ice modelling and validation
○ Dr. Thomas König & Partner, Remote Sensing GbR (K&P) *Subcontractor of DLR*	Experts in optical sea ice classification
○ The Inversion Lab Thomas Kaminski Consulting (iLab) *Subcontractor of OASys*	Experts in benefit analysis / quantifying model improvement

Background: mFUND Project „EisKlass31“ (feasibility study - Förderlinie 1)

- 08/2018-08/2019
- Partners K&P (*lead*), DLR, DNPS (*associated partner*)
- Key Question:
  - Can we improve sea ice situation awarenss via combining Sentinel-3 optical and Sentinel-1 SAR data?
- Key Results:
  - ✓Yes! Manual combination of optical and SAR data gives improved ice information
  - ✓General scheme of data fusion identified



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Verbesserung der Meereis-Lageinformationen für die Schifffahrt in polaren Gewässern durch kombinierte Meereis-Klassifikation mit optischen Daten der Sentinel-3 und SAR-Daten der Sentinel-1 Satellitenserie

Problemstellung

Als Folge der Klimaerwärmung werden Schifffahrtswege in den Randbereichen der Arktis und den subarktischen Regionen zunehmend befahrbar. Derzeit für die Navigation herangezogene Eiskarten besitzen jedoch oft eine geringere Auflösung als benötigt sowie nicht immer die gewünschte Aktualität. Die europäische Sentinel-Satellitenserie bietet mit ihrer einmaligen Kombination aus optischen/thermalen Sensoren und Radarsensoren die Möglichkeit, die Meereis-Lageinformationen erheblich zu verbessern.

Projektziel

Das Vorhaben bildet den ersten Schritt zum Aufbau eines operationellen Dienstes auf der Copernicus Data and Exploration Platform - Deutschland (CODE-DE) im Hinblick auf die Bereitstellung präziser Meereis-Lageinformationen. Aufbauend auf vorhandenen Auswerteverfahren wird eine neue Methodik erarbeitet, die aus der Kombination der verschiedenen Sentinel-Sensoren erheblich verbesserte Aussagen ermöglicht.

Durchführung

Ein vorhandener Algorithmus zur Klassifikation von Meereis aus optisch/thermalen Satellitenaufnahmen wird zur Verarbeitung von Sentinel-3-Daten erweitert und mit Hilfe von konventionellen Eiskarten, Wetter- und –in situ Eisbeobachtungen verifiziert. Zusätzlich verfügbare Spektralkanäle werden darüber hinaus auf ihre Nützlichkeit analysiert. Ebenso wird ein vorhandener Algorithmus zur SAR-basierten Eisklassifikation zur Verarbeitung von Sentinel-1-Daten angepasst. Beide Algorithmen werden kombiniert, wobei das Vorgehen in bewölkten Gebieten besonders zu berücksichtigen ist.

Forschungsschiff in leichtem Packeis an polarer Küste
(Quelle: DLR Forschungsstelle Maritime Sicherheit Bremen)

Verbundkoordinator
Dr. Thomas König & Partner, Fernerkundung GbR, Dießen am Ammersee

Projektvolumen
Summe [wird vom BMVI eingetragen]
(Förderquote wird vom BMVI eingetragen)

Projektlaufzeit
03/2018 – 02/2019 (laut Antrag)

Projektpartner
- Dr. Thomas König & Partner, Fernerkundung GbR, Dießen am Ammersee
- Deutsches Zentrum für Luft- und Raumfahrt e.V., Institut für Methodik der Fernerkundung, Forschungsstelle Maritime Sicherheit, Bremen

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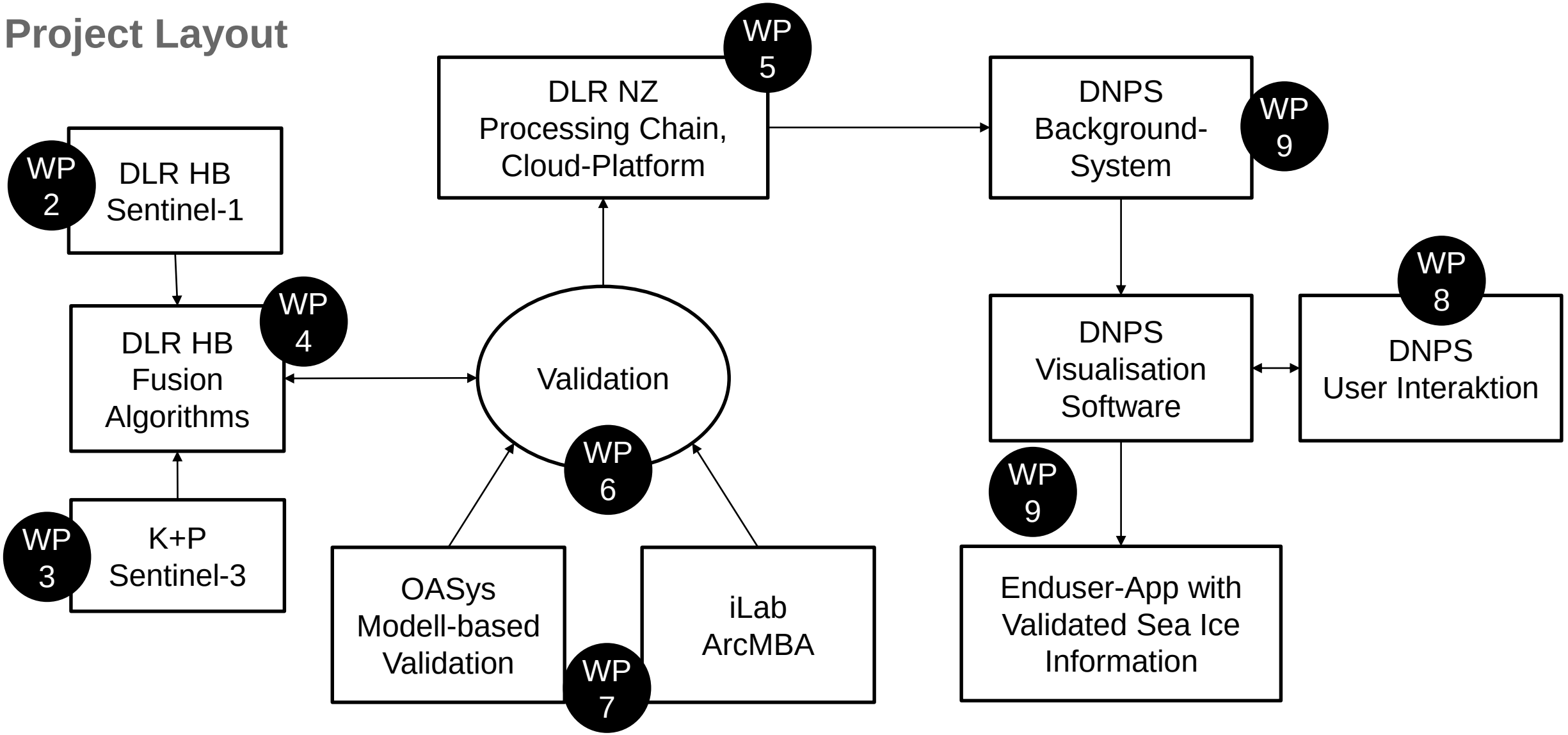
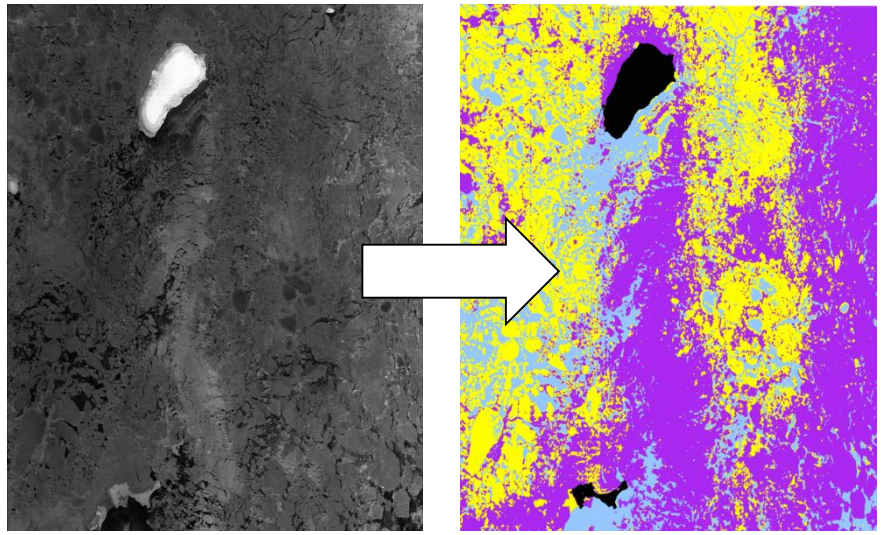
Project Layout



Data and Information Availability (Provider Perspective)

- Present
  - Sea ice classifications for Sentinel-1 (Prototype)
    - Sentinel-1-SAR-Data since 2014 (S1-A) and 2016 (S1-B)
  - Sea ice classifications for Sentinel-3
    - Sentinel-3-SLSTR-Data since 2016 (S3-A) and 2018 (S3-B)

- Goal
  - Improved sea ice classification for Sentinel-1
  - Improved sea ice classification for Sentinel-3
  - Sea ice classification based on fusion of Sentinel-1 and Sentinel-3
    - Implemented in an operational processing chain
    - Exploiting machine-learning methods
  - Modell-based validation e.g. with PIOMAS 2.1, TOPAZ4, NAOSIM, FESOM
  - Validation with official ice charts
  - Validation with in-situ observations
  - Suitable data formats for final service



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Data and Information Availability (User Perspective)

- Present
  - Official ice charts (BSH and other national ice services)
    - Mainly manually produced from remote sensing data
    - Temporal and spatial resolution varies depending on region
  - Per request (primarily in emergencies): detailed local ice charts by national ice services

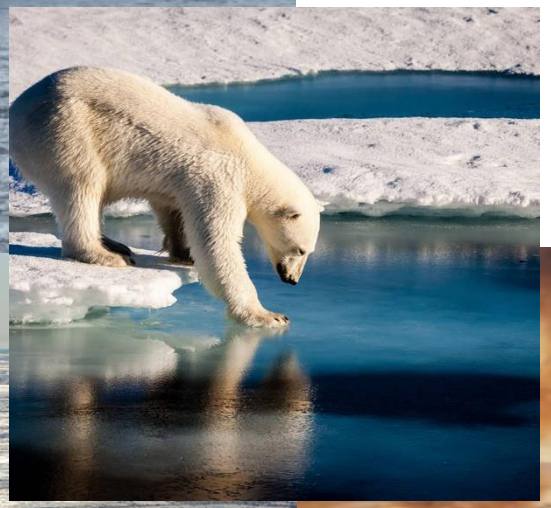
- Goal
  - Largely automatic sea ice classification information via *Artificial Intelligence*
  - Available shortly after satellite overpass
  - Resolution of ice information equivalent to original satellite data resolution (10m / 500m)
  - Easy access fur users – simple download in browser or app

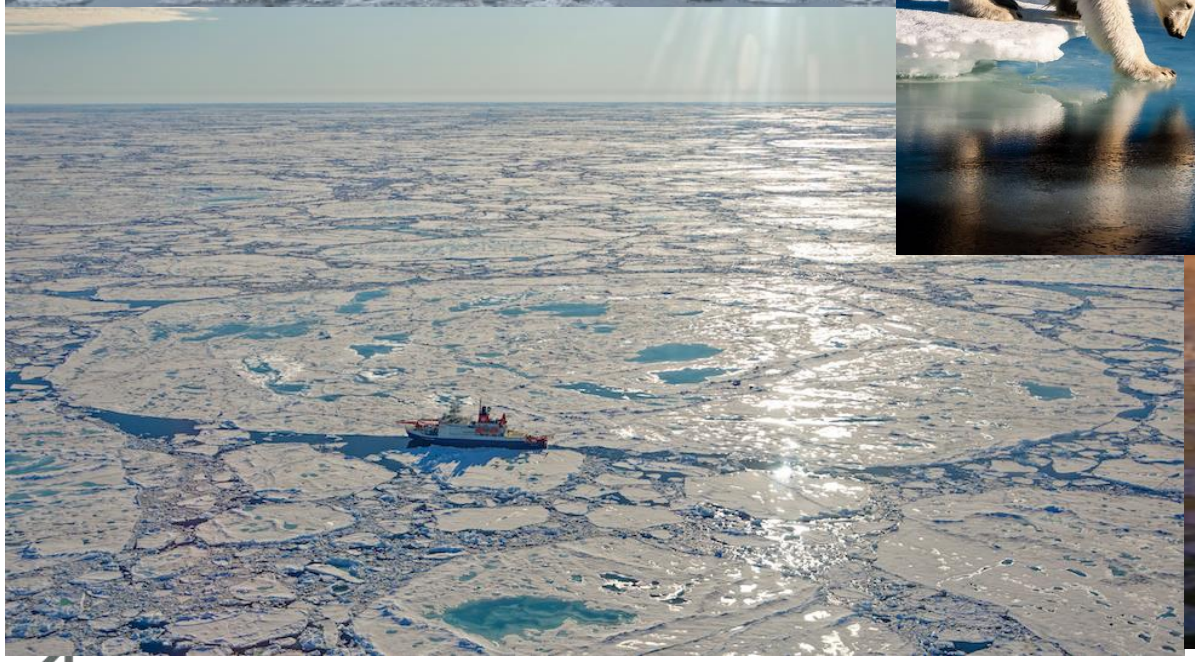
Research areas

- Data acquisition, model validation
  - All arctic
  - Depending on data availability and model coverage
- Demo projects
  - Central arctic (TBD)
  - Spitzbergen and surroundings (TBD)
- Test user
  - Dense traffic areas
  - St. Lawrence estuary
  - Barents sea

Targeted Users

- Shipping companies, natural resources exploration, local communities
  - Navigation support, route planning and optimization, collision prevention via safe navigation
  - Ecological hazard prevention (e.g. post-accident oil spills)
  - Reduction of fuel use and CO2 and other Emissions
- Ice services
  - Additional data source to improve ice charts
- Weather services
  - Improved forecast models (more accurate specification of fluxes)
- Police, coastguard, search and rescue, regulating and advisory maritime entities and bodies
  - Coordination of forces and counter-measures in case of accidents
  - Detection of Pollution and drift prognosis
  - Monitoring of exploration activities
- Climate and environmental research
  - Improved long-term observation of arctic sea ice and its‘ properties for climate modelling and e.g. improved calculation of radiation transfer





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Thank you!

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