Increased need for Arctic oil spill prevention and response

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NOAA's Office of Response and Restoration

Coastal Response Research Center

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Impact of an Ice-Diminishing Arctic on Naval and Maritime Operations

Presentation Outline

- New threats for oil spills in the Arctic
- NOAA's preparation for understanding and responding to spills in the Arctic
- International Research Collaboration on oil spill response best practices and new research
- NOAA's research on the behavior, biodegradation and exposure potential of oil spills in Arctic Waters

New Threats for Oil Spills in the Arctic

- Increased Arctic Exploration/Exploitation Activity → Increased Spill Risk
- Longer access to the Arctic and Northern Routes Open to Shipping
- Are we prepared?

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NOAA’s preparation for oil spills in the Arctic

- International Coordination & Planning
  - Defining State of the Art and Best Practices
- International Polar Year Collaborations
- Research Funding toward understanding risks to Arctic Environment (ecosystem and cultures)

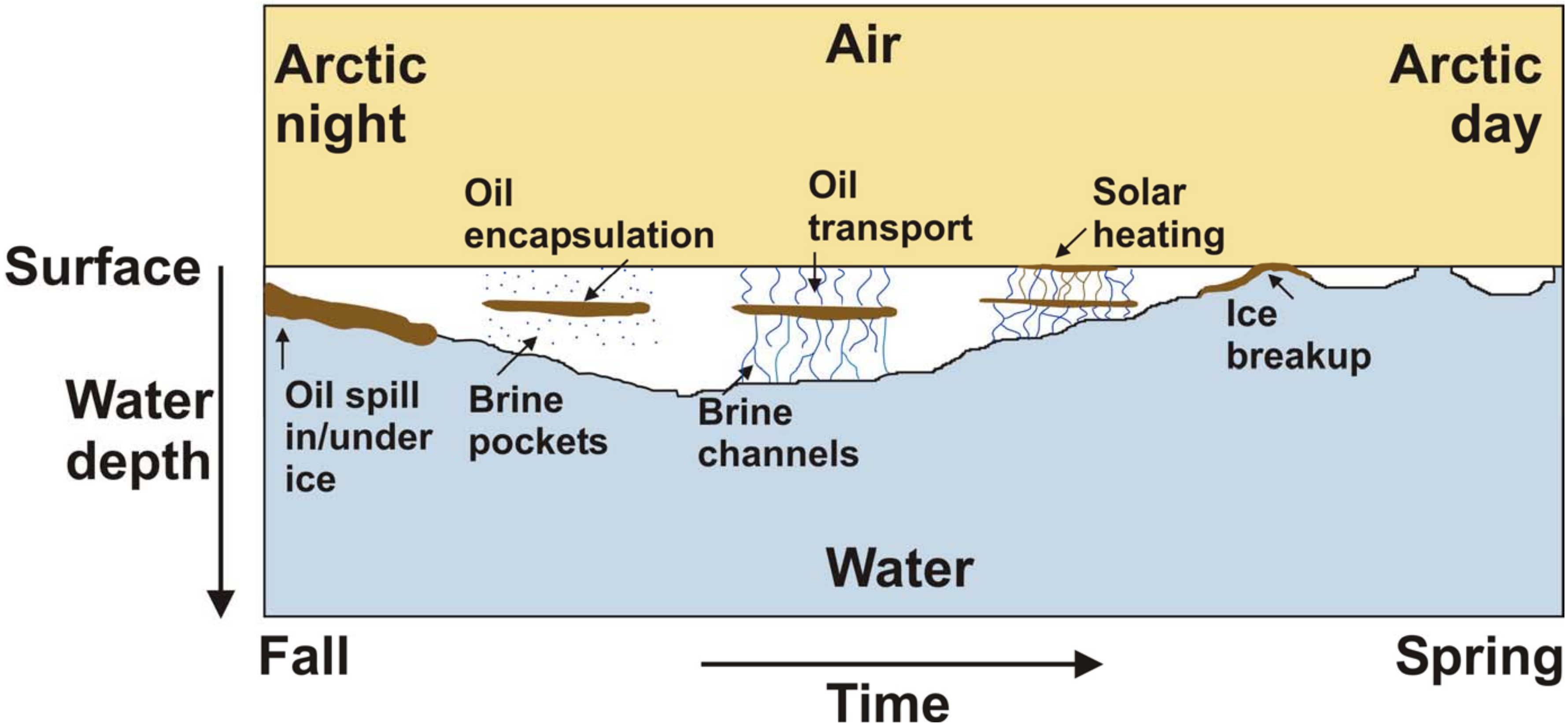
Overall Center Mission

- Joint Partnership between NOAA's Office of Response and Restoration (ORR) and the University of New Hampshire
- Develop new approaches to spill response and restoration through research/synthesis of information
- Serve as a resource for ORR and NOAA
- Serve as a hub for spill research, development, and technical transfer
  - Oil spill community (national and international)

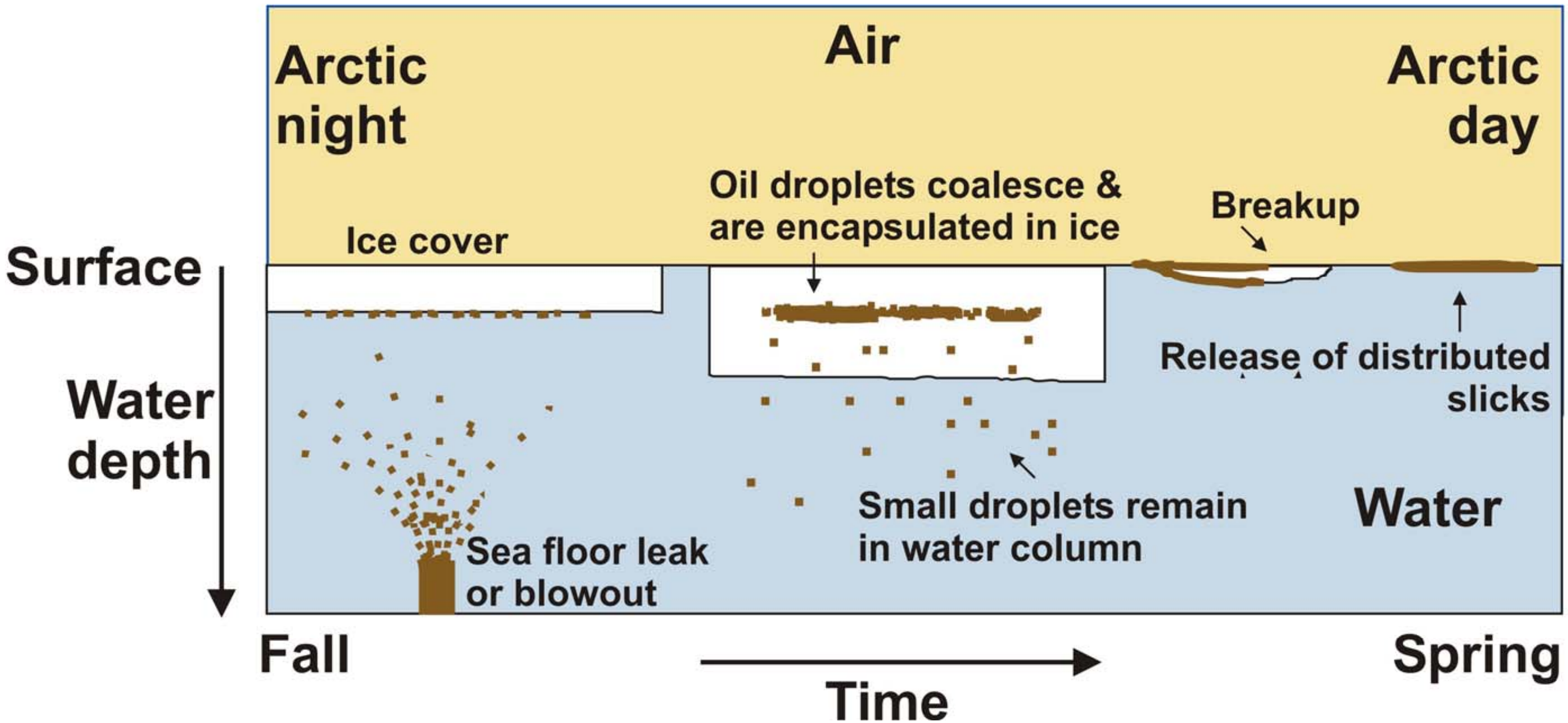
Specific Center Mission

- Conduct and oversee basic and applied research and outreach on spill response and restoration
- Transform research results into standards of practice
- Encourage strategic partnerships to achieve mission
- Conduct outreach to improve preparedness and response
- Create a learning center to promote awareness of capabilities and realistic expectations about risks and benefits

Seasonal Progression of Oil Frozen into Ice Field in Winter, and Released During Melting and Breakup in Spring



Oil May Enter the Ice from a Sub Sea Release or a Surface Release



Overall objective of Joint Industry Project Oil in Ice

Develop tools and technologies for environmental beneficial oil spill response strategies for ice-covered waters

The program will utilize existing Arctic and oil spill technology and the deliverables can directly be used in oil spill contingency plans for Arctic and ice covered areas.

Organisation

- **Steering Committee**

  Oil Companies
  - **Agip KCO** Mark Shepherd
  - **Chevron Norge AS**, Gunnar H Lille
  - **Norske ConocoPhillips AS**, Eimund Garpestad
  - **Shell Technology Norway A/S**, Gina Ytteborg
  - **Statoil ASA** , Hanne Greiff Johnsen
  - **Total E&P Norge**, Ulf Einar Moltu

  - **Program coordinator**; Stein E Sørstrøm, SINTEF

  Cooperating Organisations
  - NOFO, Hans V Jensen
  - Alaska Clean Seas, Lee Majors
  - Norw. Coastal Admin., Johan M. Ly
  - MMS, Joe Mullins/Sharon Buffington
  - OSRI, Scott Pegau
  - CRRC/NOAA, Amy Merten

- **R&D Organisations**
  - SINTEF
  - Dave Dickins Associates
  - S L Ross
  - ++++

- **Projects**
  - **1 Fate and behaviour,** Per J Brandvik
  - **2 In-situ burning,** Ian Buist
  - **3 Mechanical recovery**, Ivar Singsaas
  - **4 Chemical dispersants,** Per Daling
  - **5 Remote sensing,** Dave Dickens
  - **9 Biological Effects,** Amy Merten, NOAA

  - **8 Field experiments,** Stein E Sørstrøm
  - **6 Generic guideline,** Gina Ytteborg
  - **7 Coordination,** Stein E Sørstrøm

Program

9 projects, 25 tasks,
approximately US$ 7 (8) mill, 3,5 years from September 2006

- **P1 Fate and behaviour**
  - Compile existing data
  - Upgrade oil weathering model
  - Meso scale experiments
  - Field experiments on Svalbard
  - Full scale experiment
- **P2 In situ burning**
  - Mapping of burnability as a result of weathering
  - Field test of herding agents
  - Test fire resistant booms
  - Weathering and window of opportunity.
- **P3 Mechanical recovery**
  - Test existing concepts – winterisation
  - Develope new concepts
- **P4 Chemical dispersants**
  - Effectivness by use of dispersants
  - Improve application technology
- **P5 Monitoring and remote sensing**
  - Dev and test remote sensing systems
  - Test Shell methane detection system
  - Develop detection and tracking concept
  - Field verification of Laser Fluorosensor system
- **P6 Generic Guide**
  - Describe a set of relevant (typical) ice regimes (scenarios)
  - Generic plan (scenarios and a set of recepies?)
- **P7 Field experpiments**
  - Field experiments at Svalbard
  - Offshore field experiments
- **P8 JIP Coordination**
  - Coordination and managment
  - Workshops and steering comittee meetings
  - Communication and publishing
- **P9 Biological effects**
  - Oil-ice interaction vs biological effects
  - Biological survey during field experiments
    - Birds, mammals

Coordination, Management and Communication

Basic input

FATE AND BEHAVIOUR
Compiling recent weathering data
Modification/upgrading of OWM

Meso-scale weathering (laboratory
Long term experiments (Svalbard)
Large-scale field verification

ICE REGIMES

Combat methods

IN-SITU BURNING:
Burnability as a function of weathering
Field test of herding agents
Testing of fire-resistant booms
Oil weathering model upgrading on burning

MECHANICAL RECOVERY:
Testing of existing recovery systems
Development of new concepts and units

USE OF DISPERSANTS:
Effectiveness by use of dispersants
Improved application technology

Detection

MONITORING AND REMOTE SENSING:

Development/testing of remote sensing system

Testing SGS LightTouch

Verification of airborne LFS

Lab, mesoscale and field experiments and tests

Experiments at Svalbard, 2007 and 2008
Offshore field experiments, 2008 and 2009

Generic oil spill contingency plan/guideline

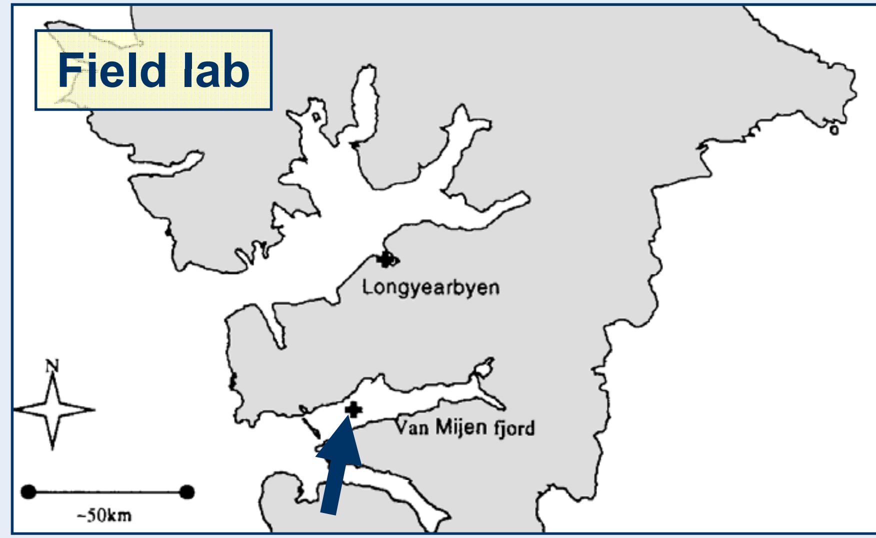
Develop knowledge, tools and technologies for oil spill response for ice-infested waters

Time schedule

Pre-project	Lab/basin/field experiments and tests	Full scale field trial

→

2005	2006	2007	2008	2009



A chain of lab- and field experiments
will establish the basis for making final recomendations

Laboratory tests

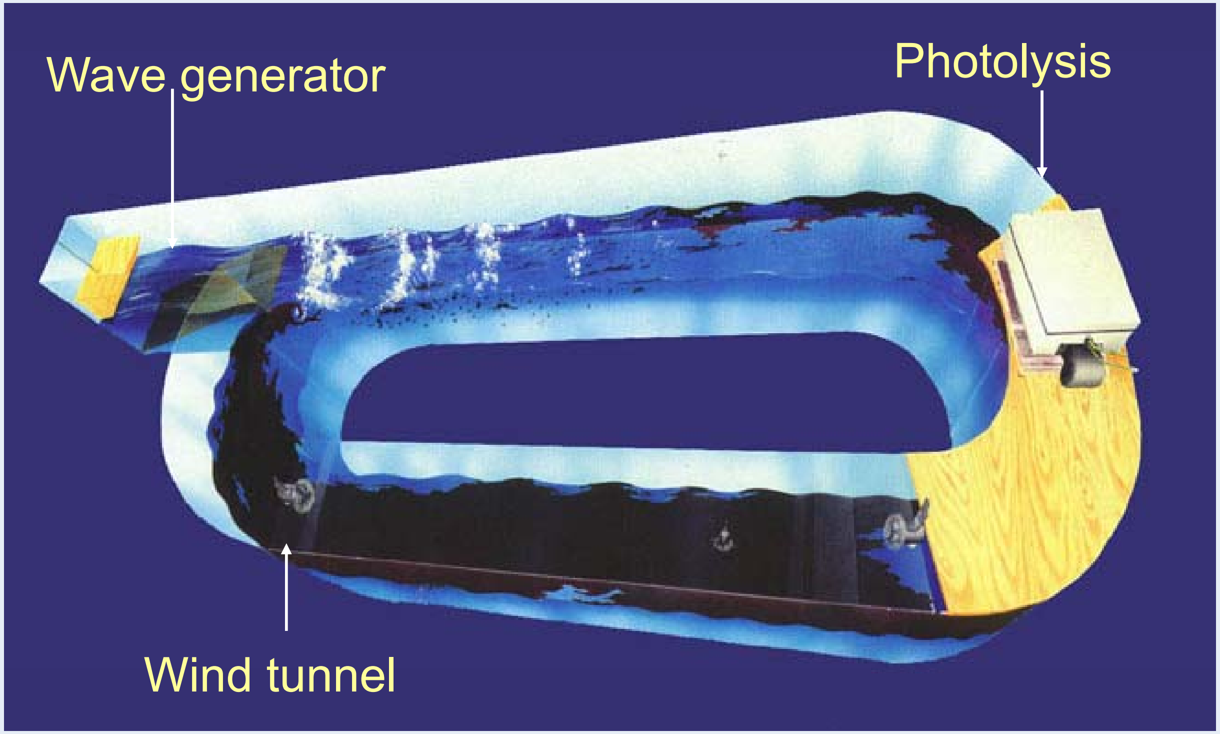
Large number of tests

Screening

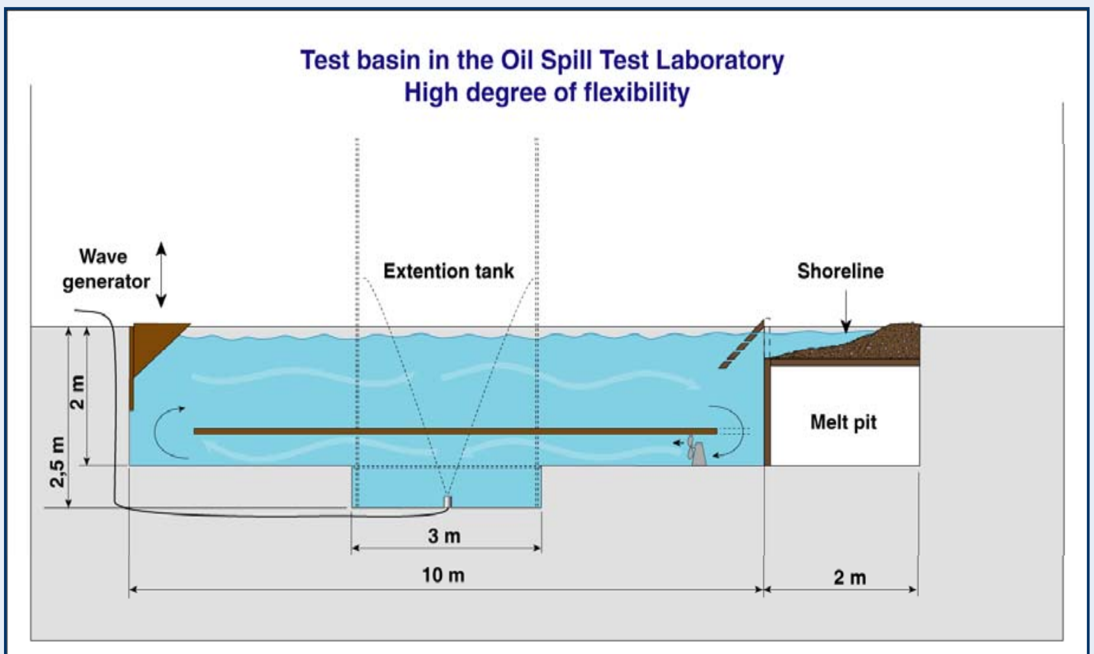
Establish basic weathering data

Related to effectiveness of different combat methods

SINTEF lab-scale flume basin



Large scale. Cold climate lab.



Waves
Currents

Low temperature
Ice conditions

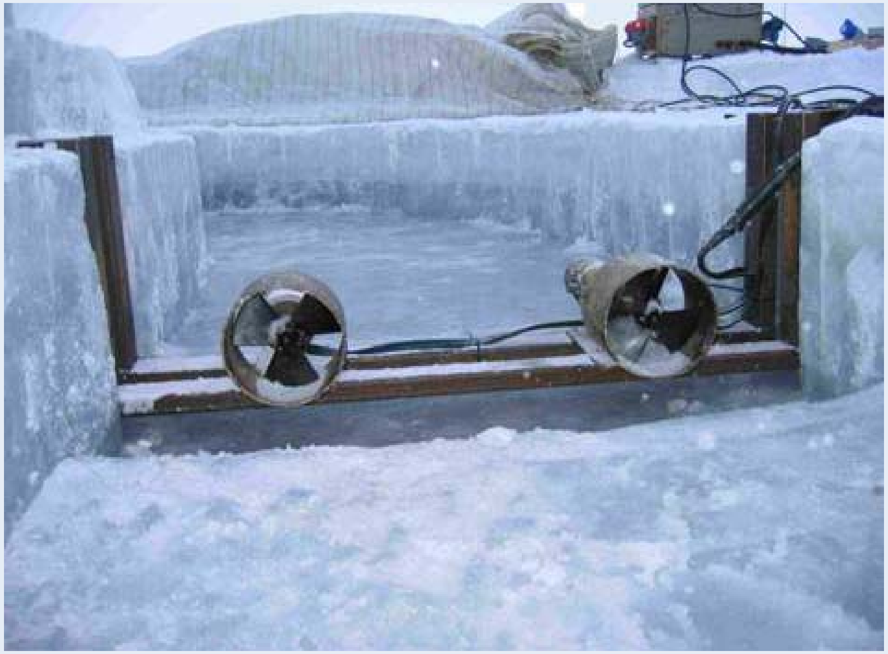
With / without oil

Fate and behavior of oil in ice

From lab to field conditions

Meso-scale oil weathering experiments on Svalbard

Experimental weathering of oil in ice

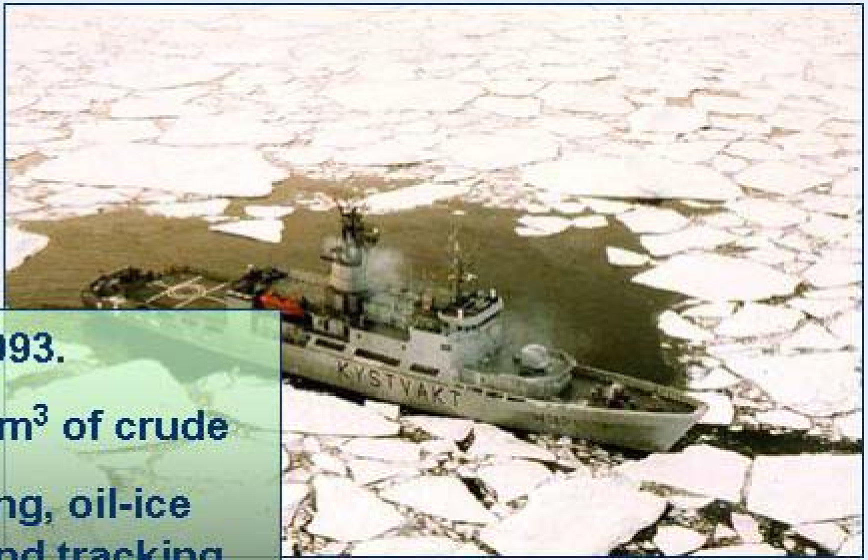


Meso-scale oil weathering on Svalbard – Wave and Current generators

- As well as under ice

Divers used for inspection, thickness measurements and photos

Full scale field trials – Marginal Ice Zone (pictures from 1993)

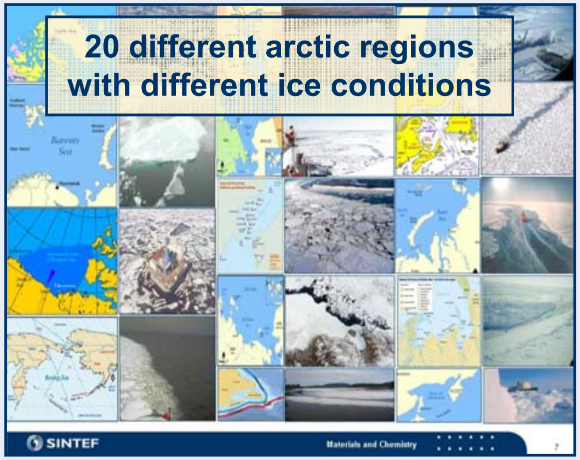


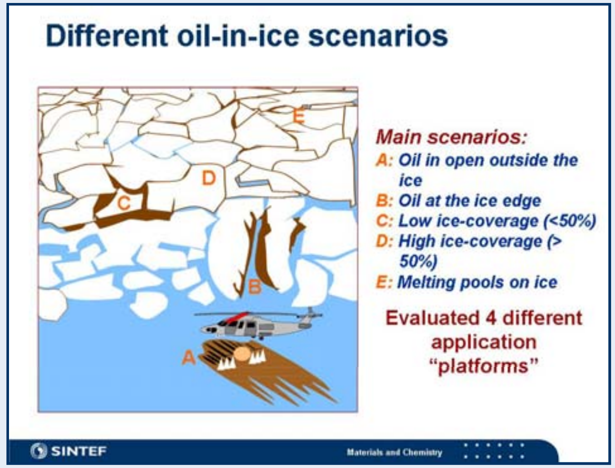
MIZ 1993.

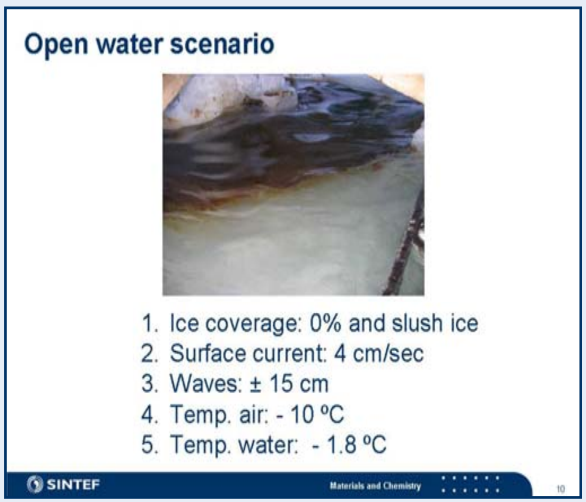
Release of 27 m^3 of crude

Oil weathering, oil-ice interactions and tracking methods.

Basic input – ice conditions



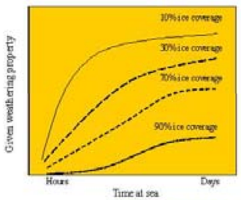




Recreate these scenarios and apply them in further testing - as far as possible

Basic input – oil quality and weathering

Oil weathering – ice scenarios utilized trough-out the entire JIP



- SINTEF OWM update (P1.2)
- SINTEF OWM update for ISB (P2.4)
- Dispersant effectiveness – application technology (P4.2)
- Enhanced mechanical recovery (P3.1 – 3.2)
- Remote sensing – oil in ice (P5.2 – 5.3)
- Generic OSR plan (P6.2)

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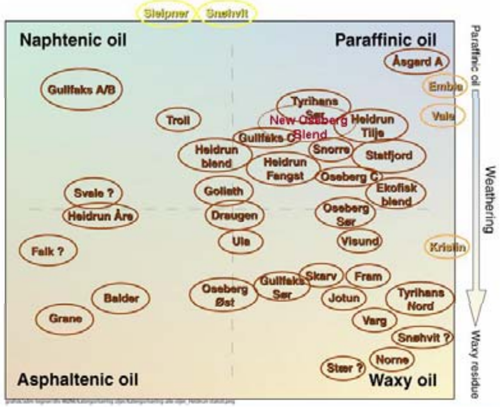
Categorization of crude oils



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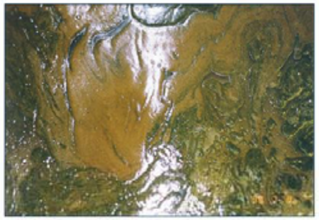
Behavior / properties of different North Sea crudes

(after 3 days weathering in SINTEF's Meso-scale Flume Basin)



Norne - waxy crude, form solidified oil lumps (35 % water)

Jotun - paraffinic crude form yellow / light brown emulsions (58% water)

Grane - asphalthenic crude form viscous lumps, (70% water)

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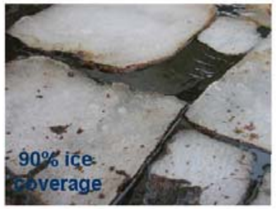
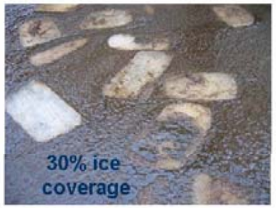
Weathering of oil vs. ice coverage





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Methods for oil spill response.

- **Mechanical recovery**

- **In-situ burning**

- **Oil spill dispersants**

Mechanical recovery

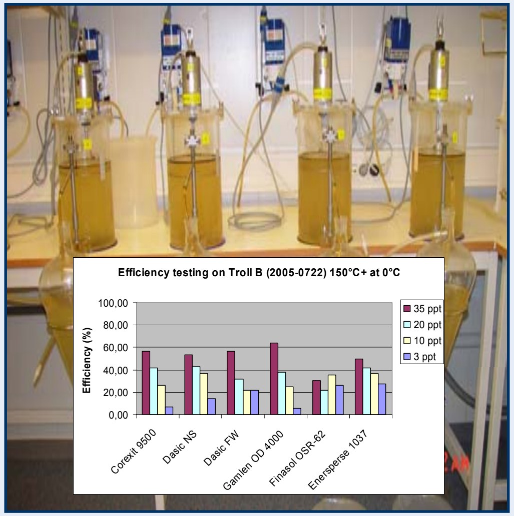
MIZ-Experiment, Barents Sea, 1993

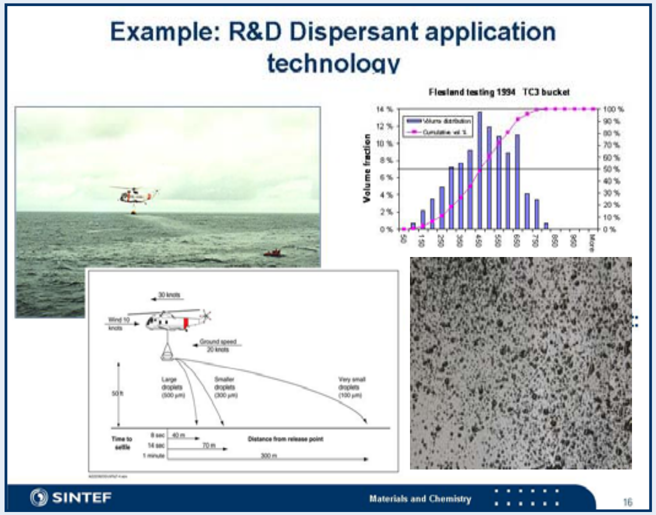
It works, but is it good enough?

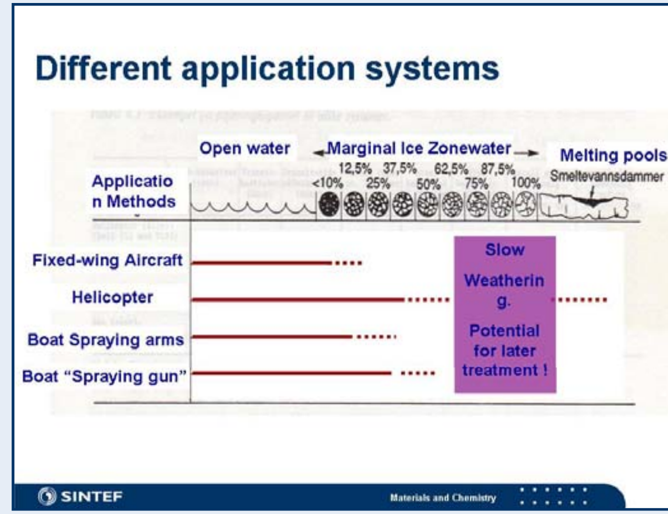
Lab – meso scale – full scale testing

In cooperation with suppliers of tech from Norway, Finland, Denmark

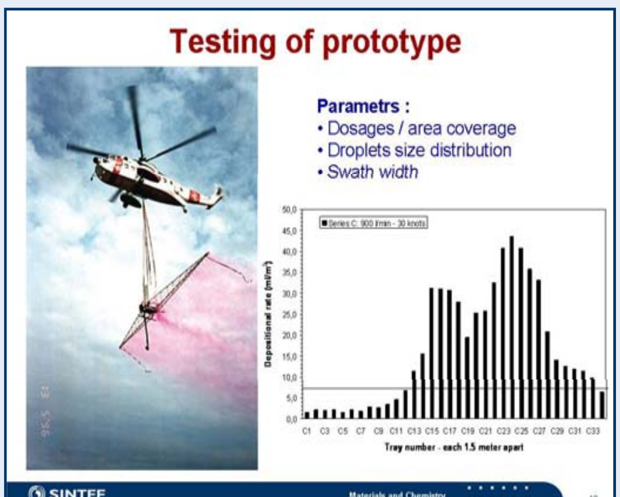
Dispersants

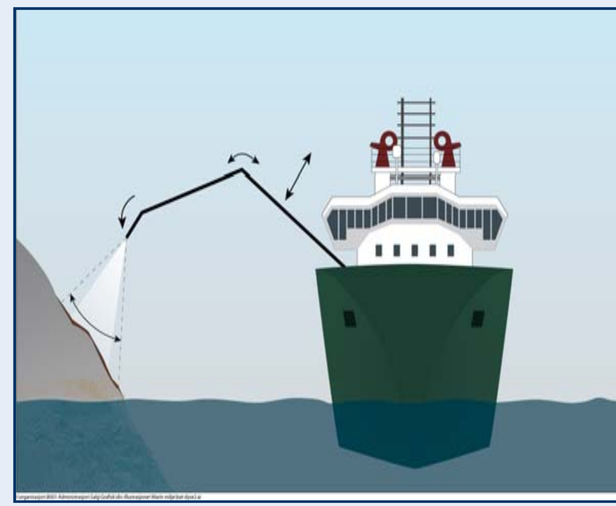




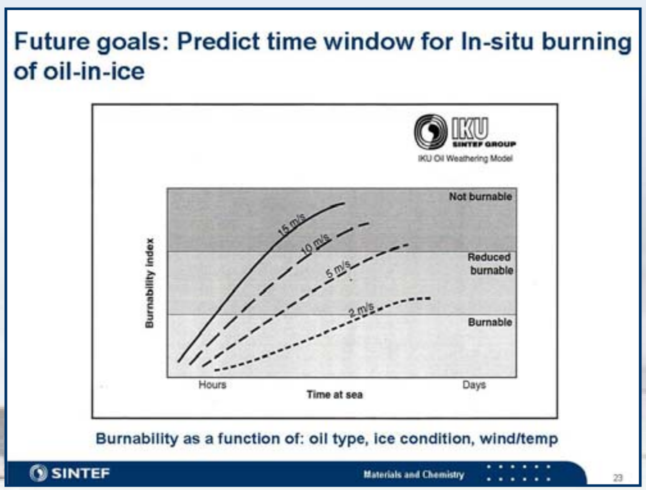


When ? - How ? - Develop and test new concepts - Implement



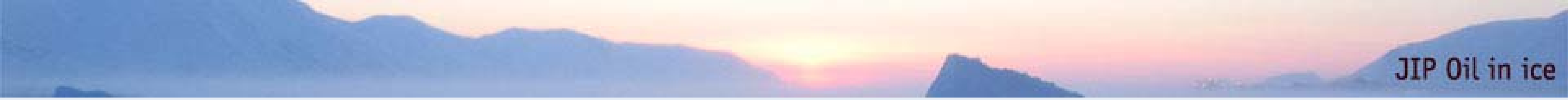


Burning of Arctic oil spills

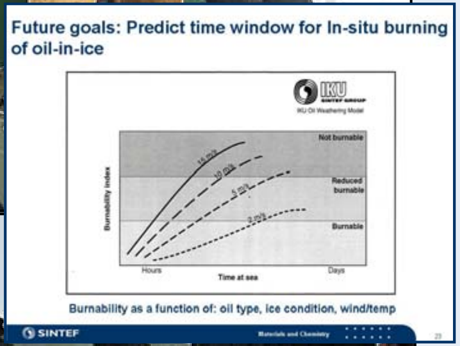


It works, when can we use it?

In-situ burning "removes" oil in ice with high effectiveness (rate and efficiency)



Weathering vs burning of oil spills



Remote sensing

Pollution Surveillance Aircraft

German Federal Ministry of Transport Dornier 228-212

- Infrared/Ultraviolet Linescan (IR/UV-LS)
- Microwave Radiometer
- Imaging Laser Fluorosensor (IALFS)
- Forward Looking Infrared (FLIR)

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Radar Imagery - Oil Spills on Open Water

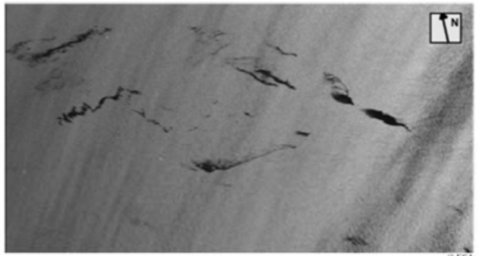

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Figure 3: Oil polluted area in the Mediterranean Sea northwest of Port Said (near the entrance to the Suez Canal). Visible are several oil spills of different size and age which apparently originate from tanker cleanings. The analysis of a large number of ERS SAR images has revealed that this area is a "hot spot" for tanker cleaning.

Alpers - University of Hamburg

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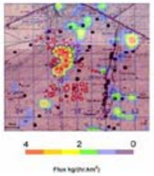
Shell Global LightTouch™ Ethane Sensor - Tuneable Diode Laser Spectrometer

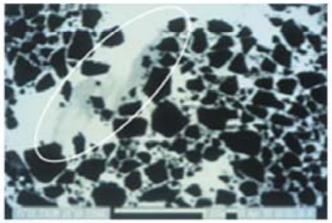


- TDLS capable of measuring ethane concentrations down to 50 parts per trillion or better
- Sensitivity equivalent to a flux of 1 micron of gas per square km per hour over dist to 10 km

BOISE STATE UNIVERSITY Materials and Chemistry 29

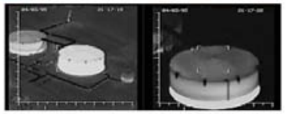
It's dark,
it's ice covered
Where is the oil?

Infrared Sensors



MIZ 93 - SINTEF

Arco Aviation 1995



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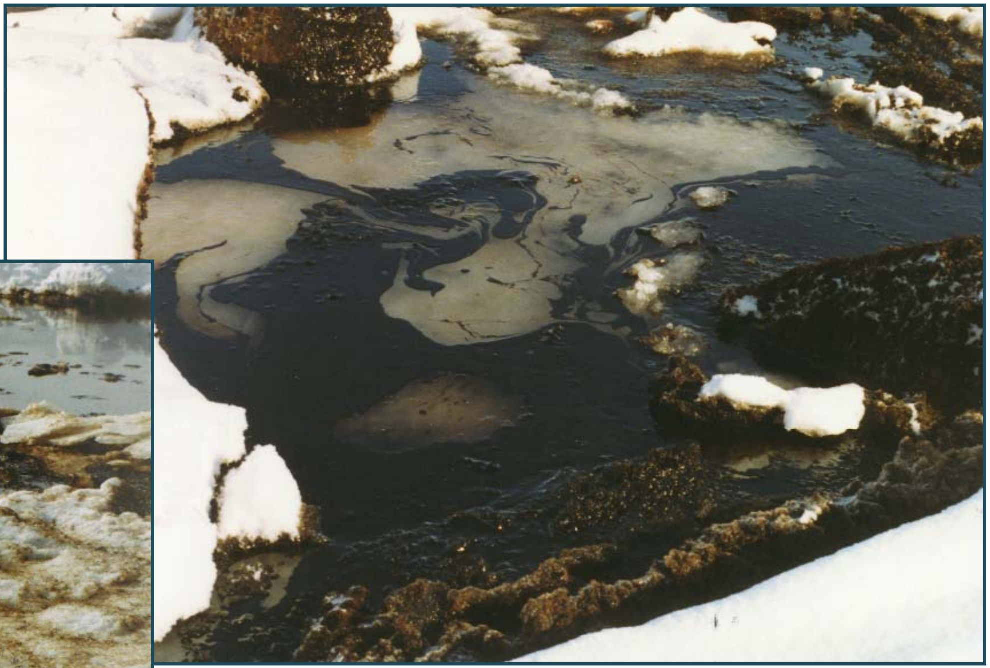
Detection of oil under sea ice in Svea

Testing radar (GPR, 500Mhz) to detect oil under ice by Boise State University

Plus
New project;

Dogs for sniffing

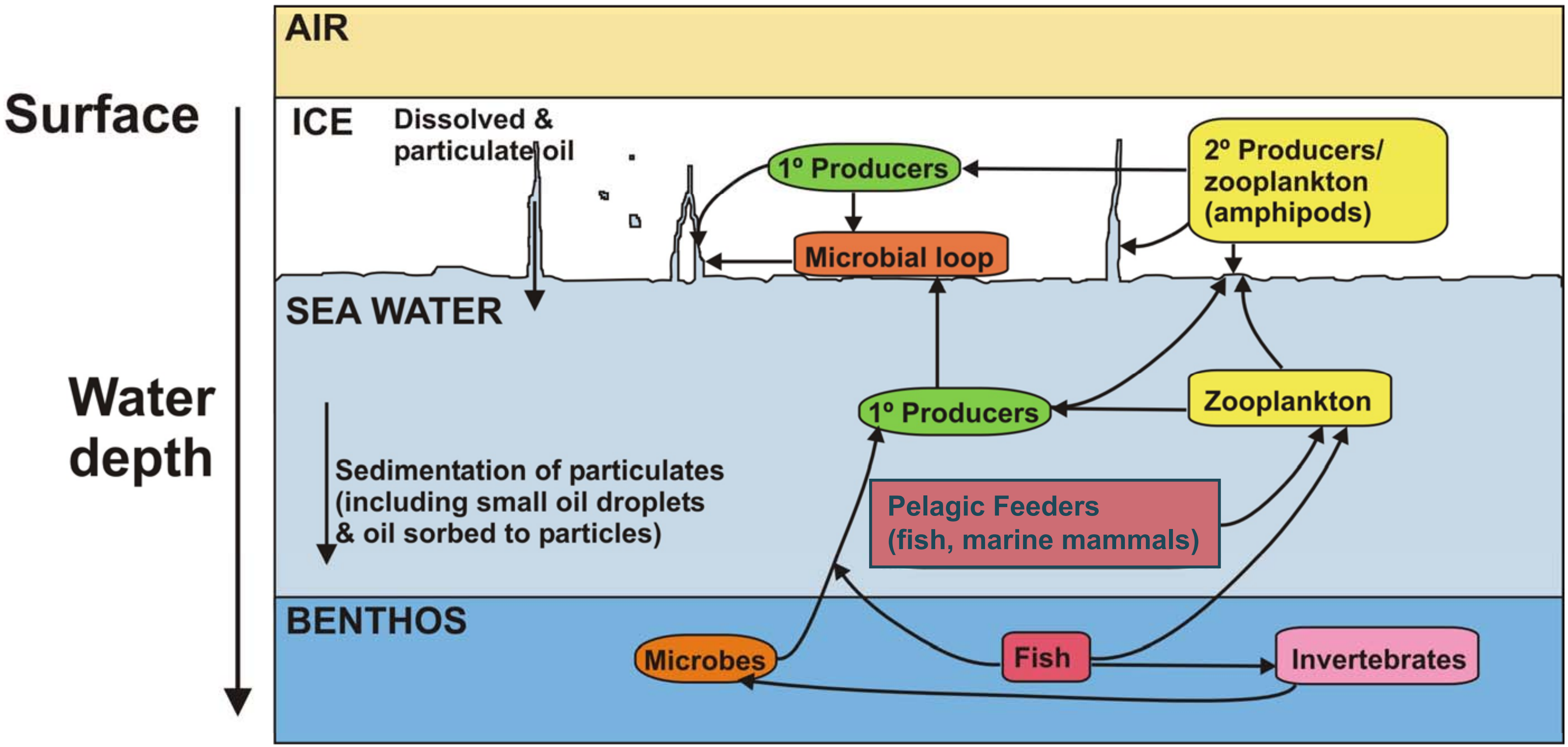
Oil-in-Ice: Behavior, Biodegradation and Potential Exposure



Oil-in-Ice in the Barents Sea Marginal Ice Zone (1993)

Conceptual Model

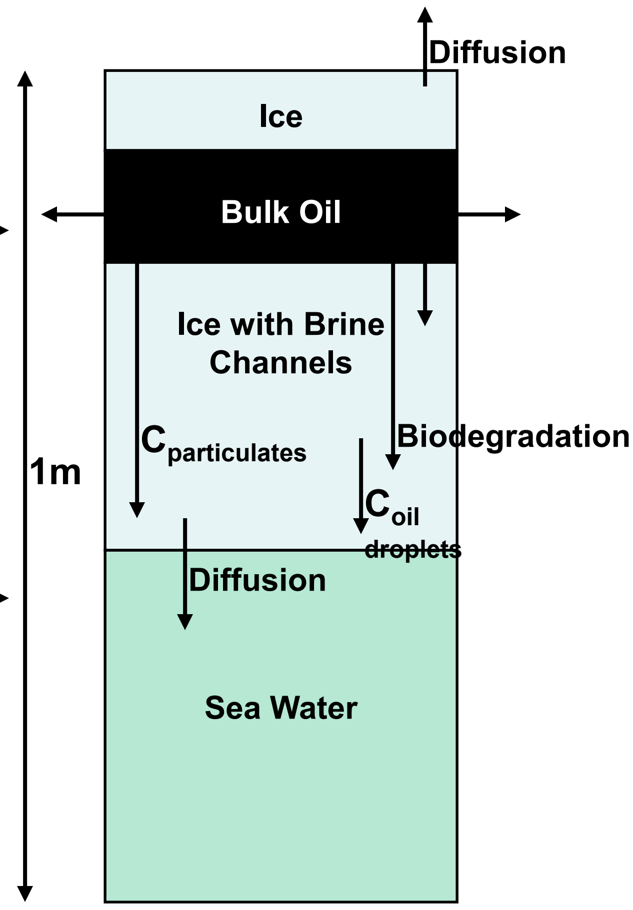
Food Web Cycle



Transport/Exposure

Bulk oil encapsulated in ice from below
→measure dissolved constituents
(WAF - e.g., PAHs)

Density of brine transport downward
→will transport dissolved (bioavailable)
components of oil downward



Oil-in-Ice: Behavior, Biodegradation and Potential Exposure

- NOAA/CRRC Focus:
  - Identified gaps in understanding transport of oil components in sea ice
  - Need improved understanding in order to define risks of exposure to biological communities associated with sea ice
  - Focus of study: transport through ice during freezing-thawing cycle
  - Historically, oil in ice research focused on bulk oil; limited studies on dissolved components (bioavailable & toxic form) except for Brandvik & Faksness, 2005 & Payne *et. al.*, 1991)

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Oil-in-Ice: Behavior, Biodegradation and Potential Exposure

- Questions We Want to Answer?
  - What is the behavior of oil in ice?
  - What are the transport & degradation (physical, chemical, and biological) processes and rates that govern the fate of oil frozen in ice?
  - How does the change of the structure of the ice affect transport?
  - What are the exposures (e.g., composition, concentrations, durations) to which ice-related organisms may be exposed?
  - What are the potential effects of these exposures?
  - How will response options affect transport/biodegradation processes and exposure pathways?

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Oil-in-Ice: Behavior, Biodegradation and Potential Exposure

- Focused on "Oil-in-Ice"

1) Transport/exposure
   - → Brine rejection, cycling
   - → Diffusion
2) Biodegradation
3) Modeling

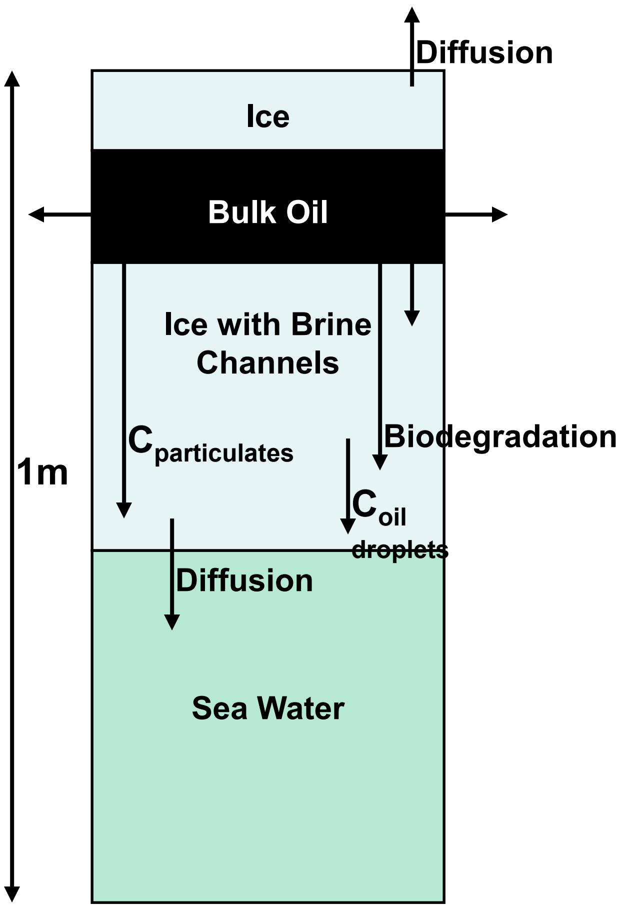
Assumption: Once oil (dissolved, particulates, bulk droplets) leaves ice structure → go to other models & databases (hydrodynamic, toxicity models, etc.)

Transport/Exposure Lab Experiments

– Series of columns

Bulk oil encapsulated in ice from below
→measure dissolved constituents
(WAF - e.g., PAHs)

Density of brine transport downward
→will transport dissolved (bioavailable) components of oil downward



Transport/Exposure Lab Experiments (cont.)

- Focus on 1 oil – Prudoe Bay or Goliath
- Quantify changes in concentrations across time through freezing & thawing cycles
- 3 Temps (-5°C, -10°C, -20°C), 3 reps each treatment
- Size of columns still in question
  - Volume for organic chemistry is constraining
  - Exploring semi-permeable micro extraction (SPME) techniques
  - Sample vertically
- Field experiment design (2009) will be based on lab findings

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Biodegradation Experiments

- Assumption:
  1) Microbes need water to be active
  2) Most microbial activity in ice will occur in brine pockets/channels
- Focus: Heterotrophic bacteria because of their potential to degrade WAF
- Objective:
  1) Does bioremediation of WAF occur in brine pockets/channels?
  2) What are the biodegradation rates of WAF as a function of brine strength, temperature, light levels, particulate content in ice, and WAF concentration?
  3) What are the rates of WAF biodegradation relative to WAF transport out of ice?

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Biological Effects of Oil-in-Ice JIP Project

- Biodegradation Experiments
  - Batch factorial design studies in brine using indigenous microbes
    - 3 Temps (-5°C, -10°C, -20°C)
    - 2 Brine strengths
    - 2 Particulate concentrations
    - 2 Light levels
  - Time series sampling of replicate flasks
  - Analysis:
    - Light levels
    - Chemistry: salinity, WAF 25 components, terminal electron acceptors (TEA), TOC, SS, nutrients
    - Microbial Communities:
      - Epifluorescent counting: bacteria, protists, algae; hydrocarbon degraders, sulfate reducing bacteria
      - Molecular methods: DGGE, RT-PCR
    - Rates: $^{12}C/^{13}C$ and various naphthalene based ratios, change in concentrations vs. time

A Model of Oil Encapsulation & Release in First Year Ice

Model Attributes and Processes:

- 1- or 2-Dimensional (Vertical-Horizontal)
  - 1-D is simpler
  - 2-D will allow uneven distribution of oil under and in ice
- Focus on Microscale (mm) to Mesoscale (~1 m) Processes
- Time-Dependent: Will Simulate Annual Freezing-Thawing Cycle
- Ice State Variables:
  - Porosity/permeability (not the same; the latter is a function of the connectivity of the porosity)
  - Thickness
  - Temperature gradient (vertical)
  - Salinity
- Capability for Eventual Inclusion as Module in 3-D Oil Spill Models

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Model Attributes and Processes (continued):

- Radiative Heat Transfer (Insolation)
  - Changes due to presence of oil
  - May require experimental data
- Vertical Transport in Brine Channels
  - Snow load induces transport upwards
  - Ice accretion induces transport downwards
- Oil Representation as Multiple Components
  - More accurate calculation of evaporation, biodegradation, dissolution, toxicity
- Produces Time Series of Exposures at the Ice-Water Interface
- Oil May Enter Ice as Surface or Subsurface Release
- Boundary Conditions:
  - Oil entering and leaving ice
  - Water and air temperatures, insolation, snowfall

Conclusions

- Active Involvement in International R&D and operational efforts for preparing for spills in Arctic waters
- Opportunities for increased collaborations at the field-scale assessment level
- Building a foundation for Risk Assessment of Spills in Arctic environments
  - New Model for Coastal Response Research Center
  - $300 K to support International Collaboration
  - Leveraging UNH and UNIS student/post-doc capabilities
- Need for comprehensive, environmental sensitivity mapping and monitoring strategy for prioritizing efforts in the Arctic
- Need to focus on societal consequences of increased spill risks in the Arctic

Acknowledgments

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- Dr. Scott Pegau (Oil Spill Recovery Institute, Cordova, AK)
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- Dr. John Whitney (NOAA Scientific Support Coordinator, Alaska Region)

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