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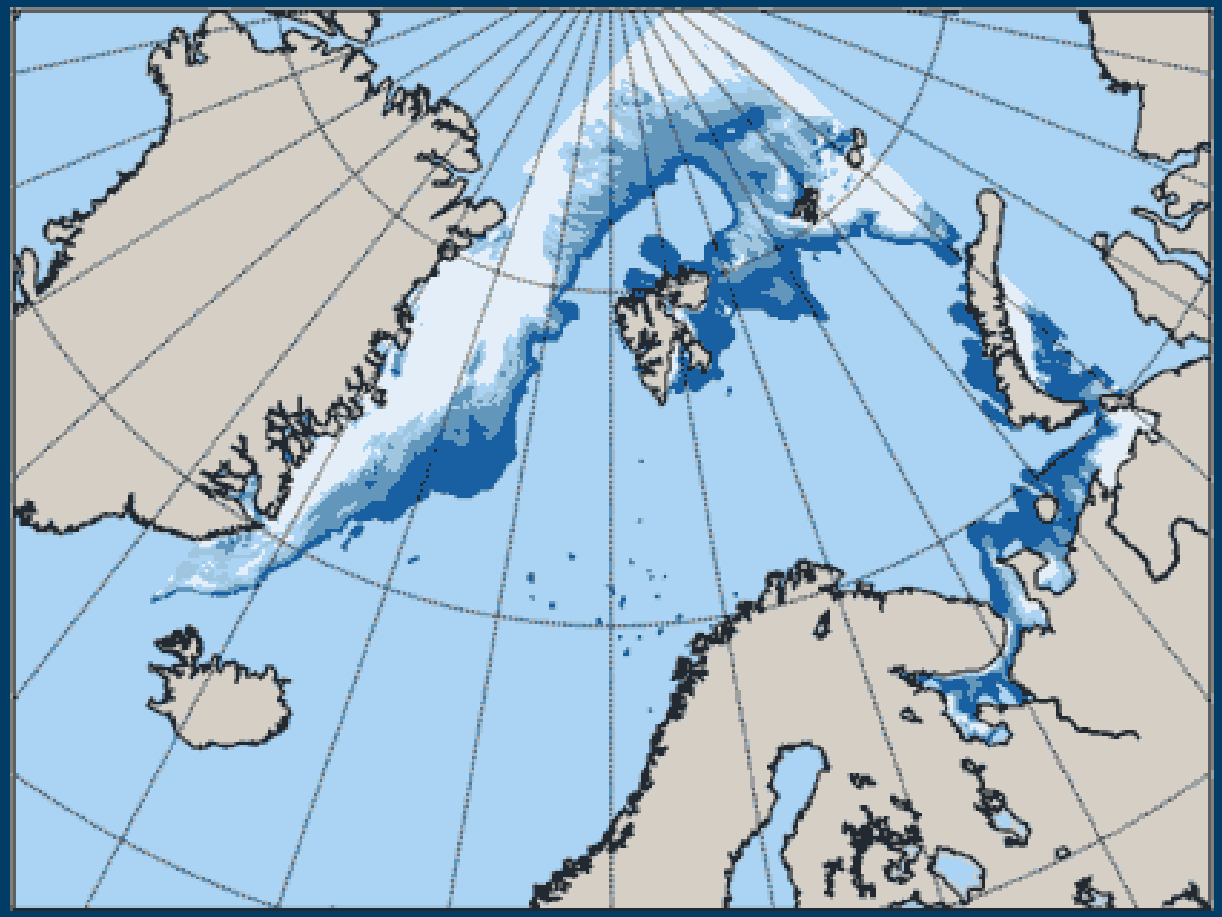
Status and advances for modelling of oil spills in cold and icy waters



Jørgen Skancke

Presentation overview

- Modelling of sea ice (Morten Alver et al.)
- Oil transport and fate (Tor Nordam et al.)
- Oil biodegradation (Odd Gunnar Brakstad et al.)

Recent contributing research projects

- Oil spill dispersant strategies and biodegradation efficiency (NFR PETROMAKS, 2013-2017)
- Nunaat (Statoil-funded, 2016-2017)
- FateIce (NFR PETROMAKS, 2016-2019)

Field trip to Greenland (Nunaat project)

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Oil spill research and modelling at SINTEF

-- a timeline

1980s:
Ancestor models:

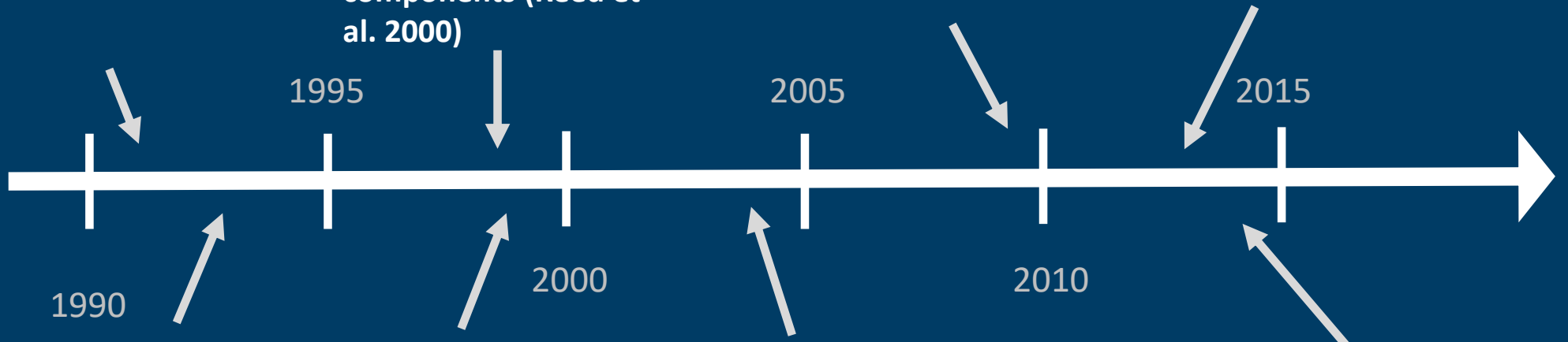
OSFIM
COZOIL
NRDAM/CME

1992: OSCAR arrives to Norway from the US with Mark Reed

AMOS (1998-2001): Dissolution and biodegradation for 25 oil pseudo-components (Reed et al. 2000)

OS3D (2009-2011): Stochastic simulations for environmental risk assessment with MIRA

BP + DROPPS (2012): Modified Weber model for droplet size in subsea blowouts (Johansen et al. 2013)



Petroleumsforskning (1994-1995): Integrated SINTEF's Oil Weathering Model (Daling et al. 1997)

DeepSpill (1999-2001): First ever deepwater blowout experiment (Johansen et al. 2003)

ERMS (2003–2006): Full integration of DeepBlow/Plume3D model (DREAM)

GASTRACK (2013-2014): Gas blowouts: surface flux and fountain height

Funding: oil companies, government agencies (Norway and US), and the Norwegian research council

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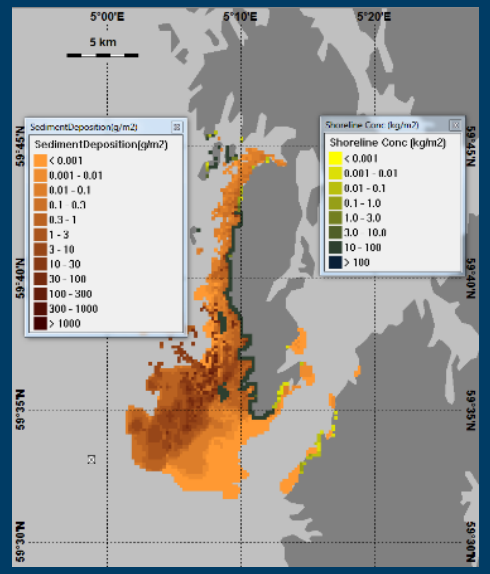
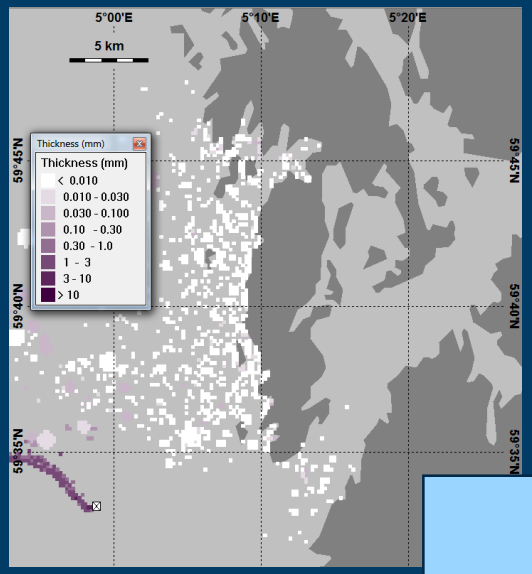
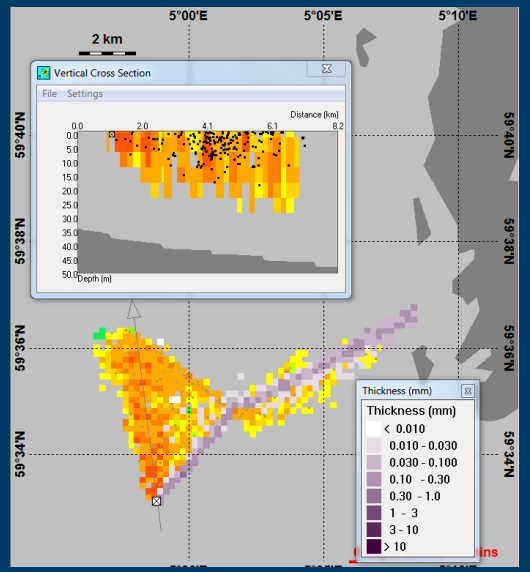
Shoreline and sediment



Surface oil



Subsurface dispersed oil



Input to environmental risk assessment

ERAAcute

MIRA

SYMBIOSES

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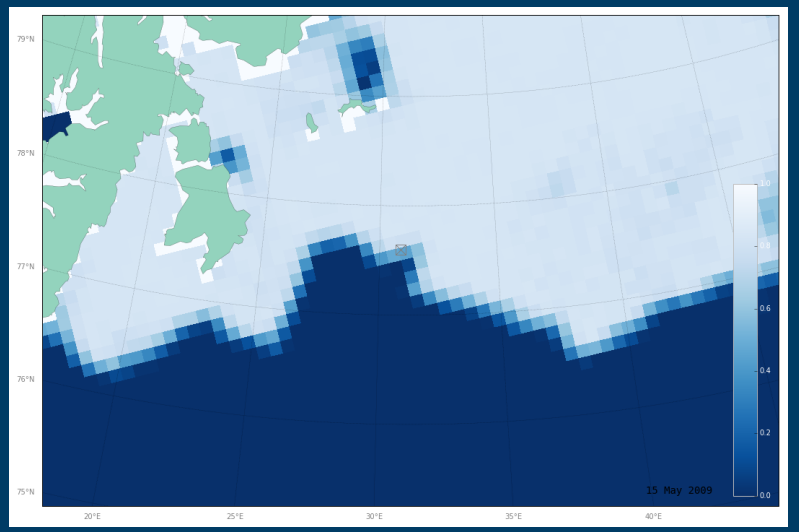
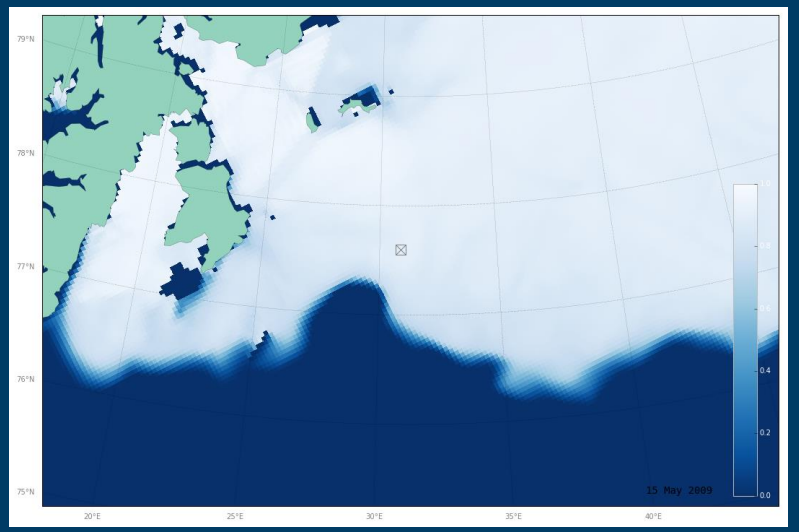
Modelling of sea ice

- Essential input to OSCAR
- Modelled in hydrodynamic models along with ocean currents (SINMOD, met.no)
- Satellite data provides "sea truth" for input and comparison
- OSCAR can use ice fields from SINMOD and met.no's models



Satellite



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Good match between observed and modelled ice in the SINMOD model (see Sundfjord et al. 2008 for more)

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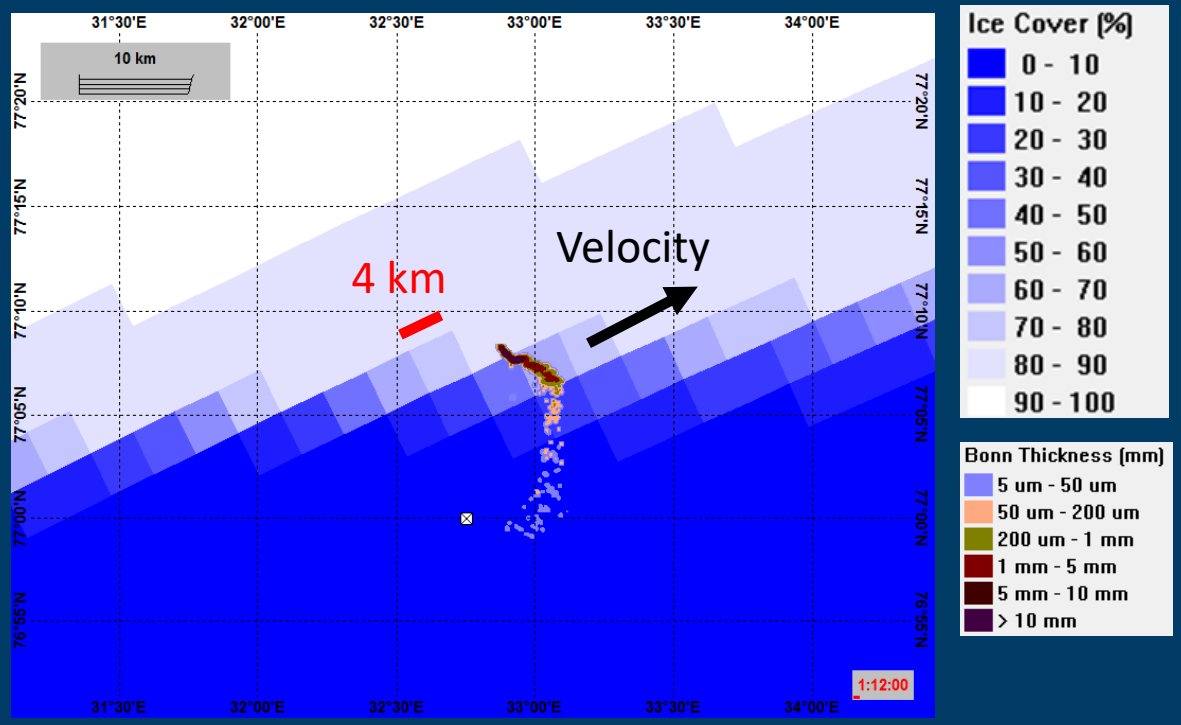
Modelling of sea ice – input to OSCAR

- Quality of ice data important for modelling oil-ice interactions and effects
- Ice models give gridded data – often 1-4 km, 1-2 hour resolution
- Two ice data variables are used:
  - Ice coverage (0 to 100 %)
    - Progressively reduces oil spreading, evaporation, and effect of waves
  - Ice velocity (may differ from currents)
    - Ice-locked oil is transported with the ice



Example view from OSCAR of oil that has drifted into ice.

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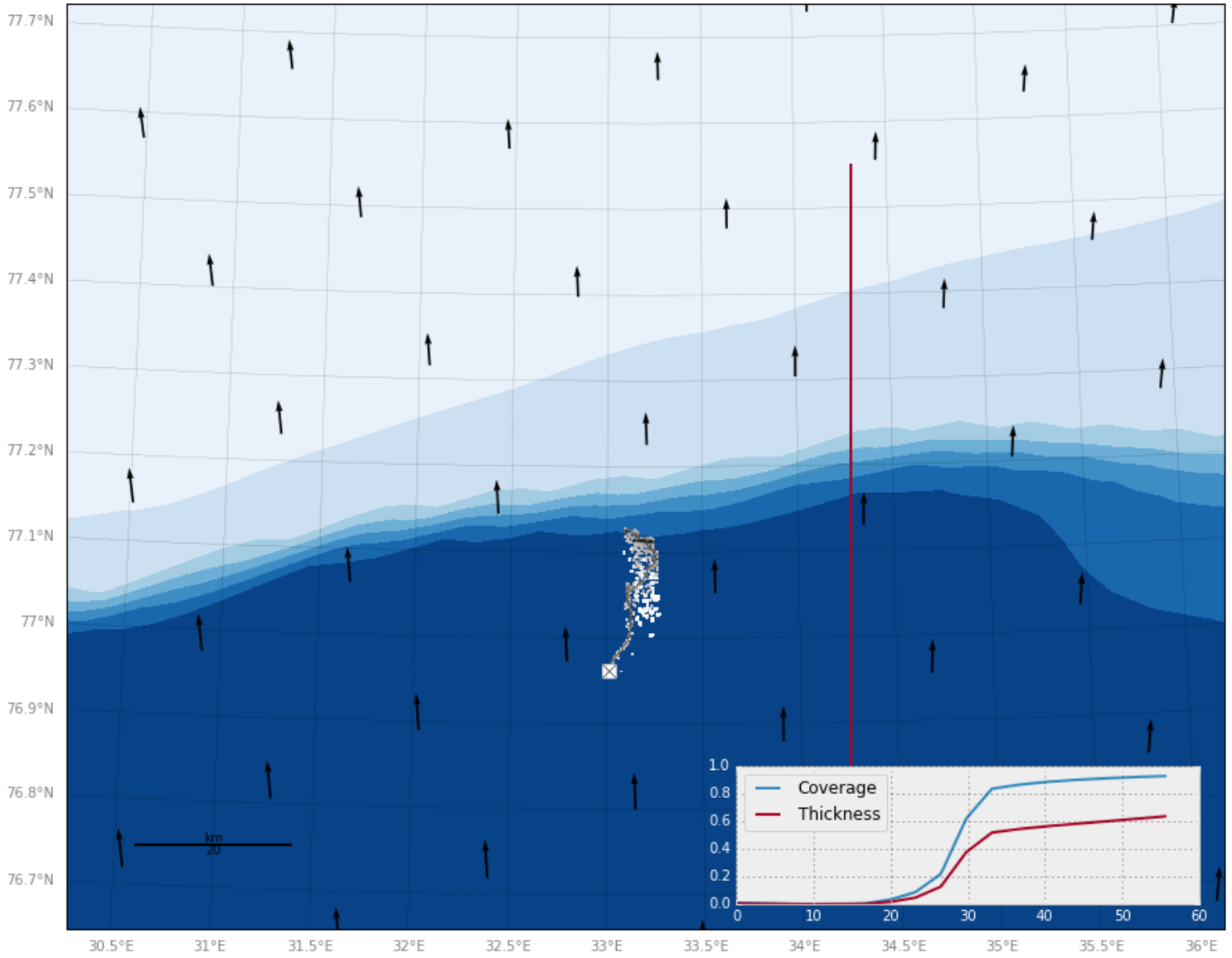
Oil transport and fate

Example simulation: Oil drifts into marginal ice zone with the wind and becomes entrenched as the wind changes direction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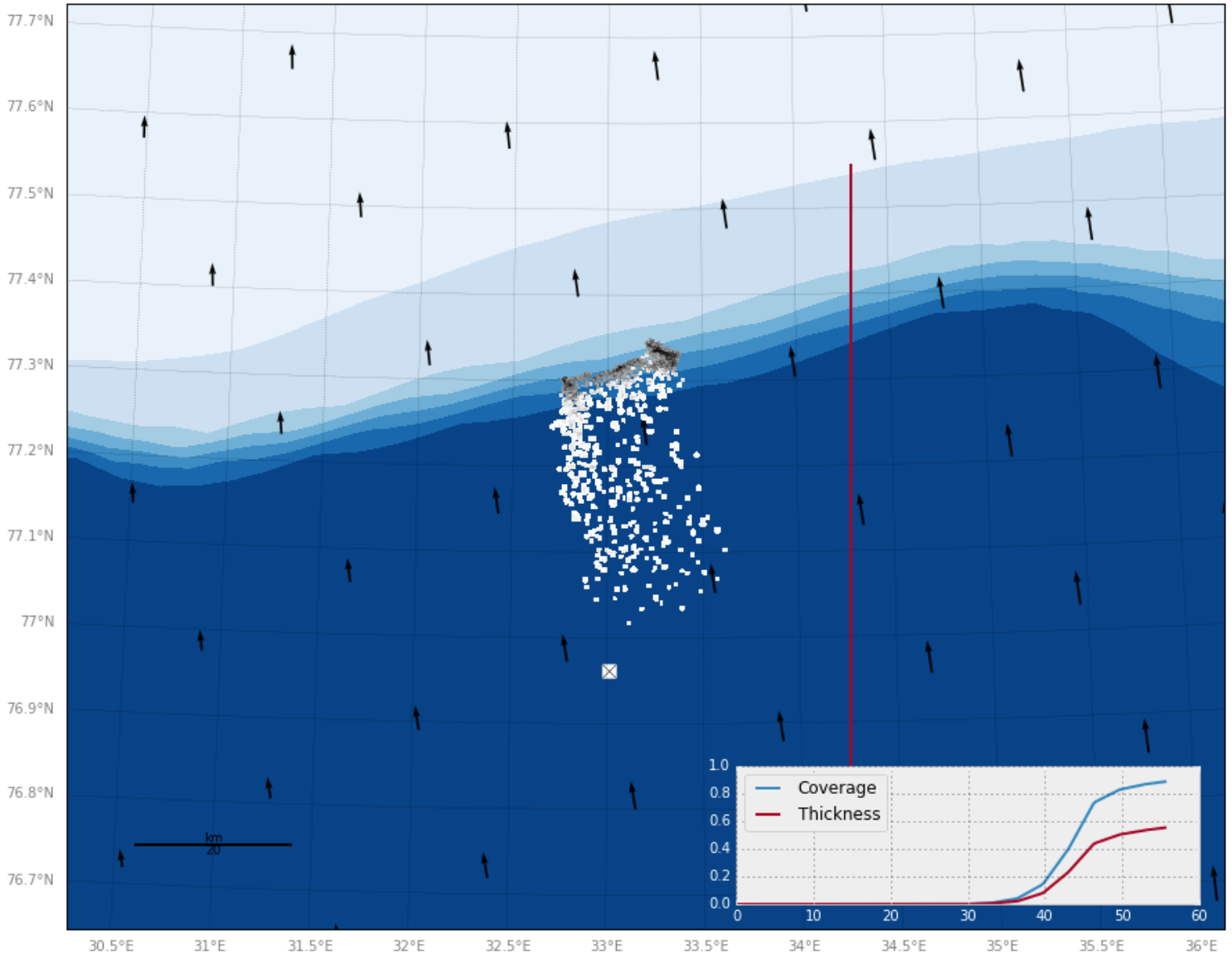
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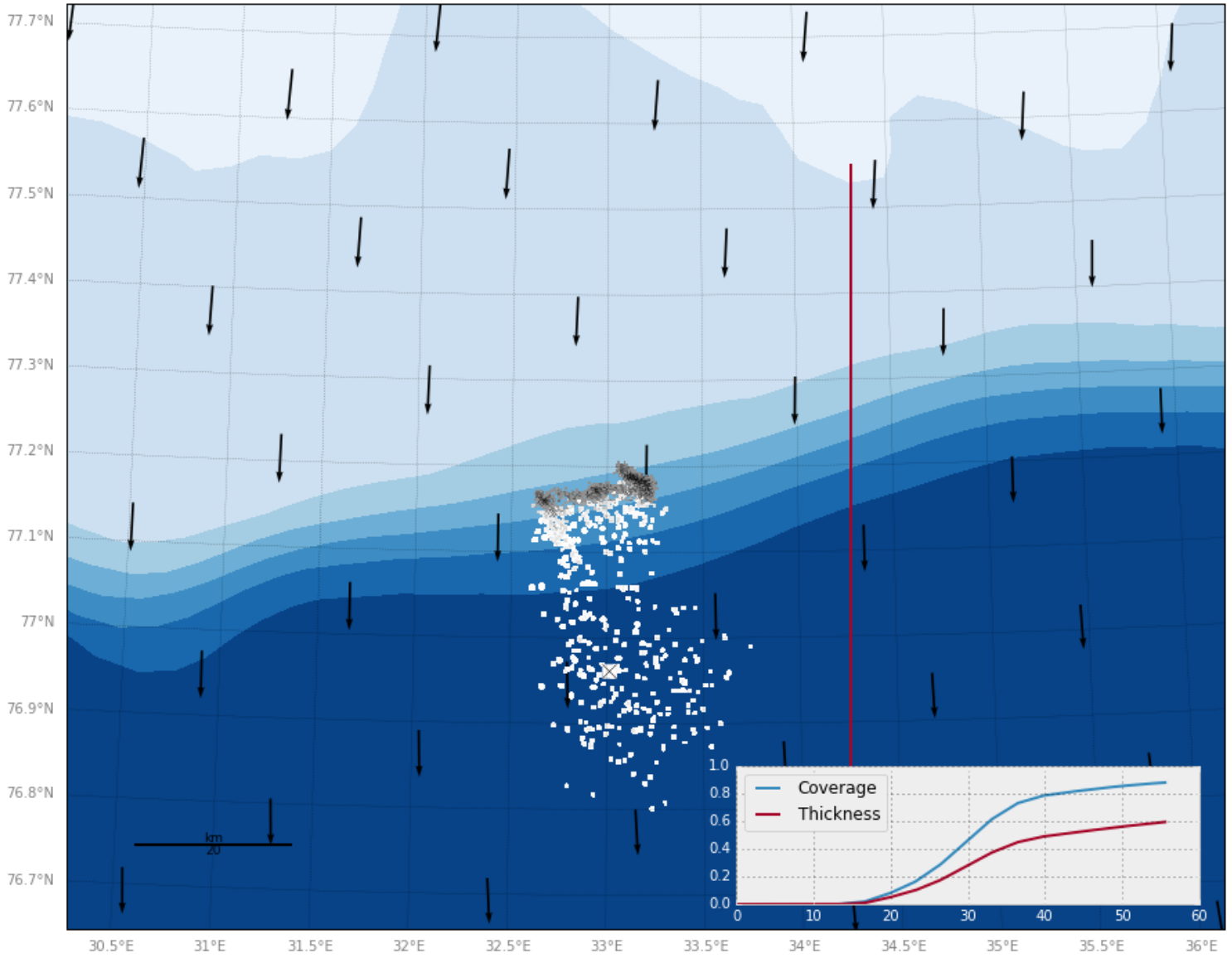
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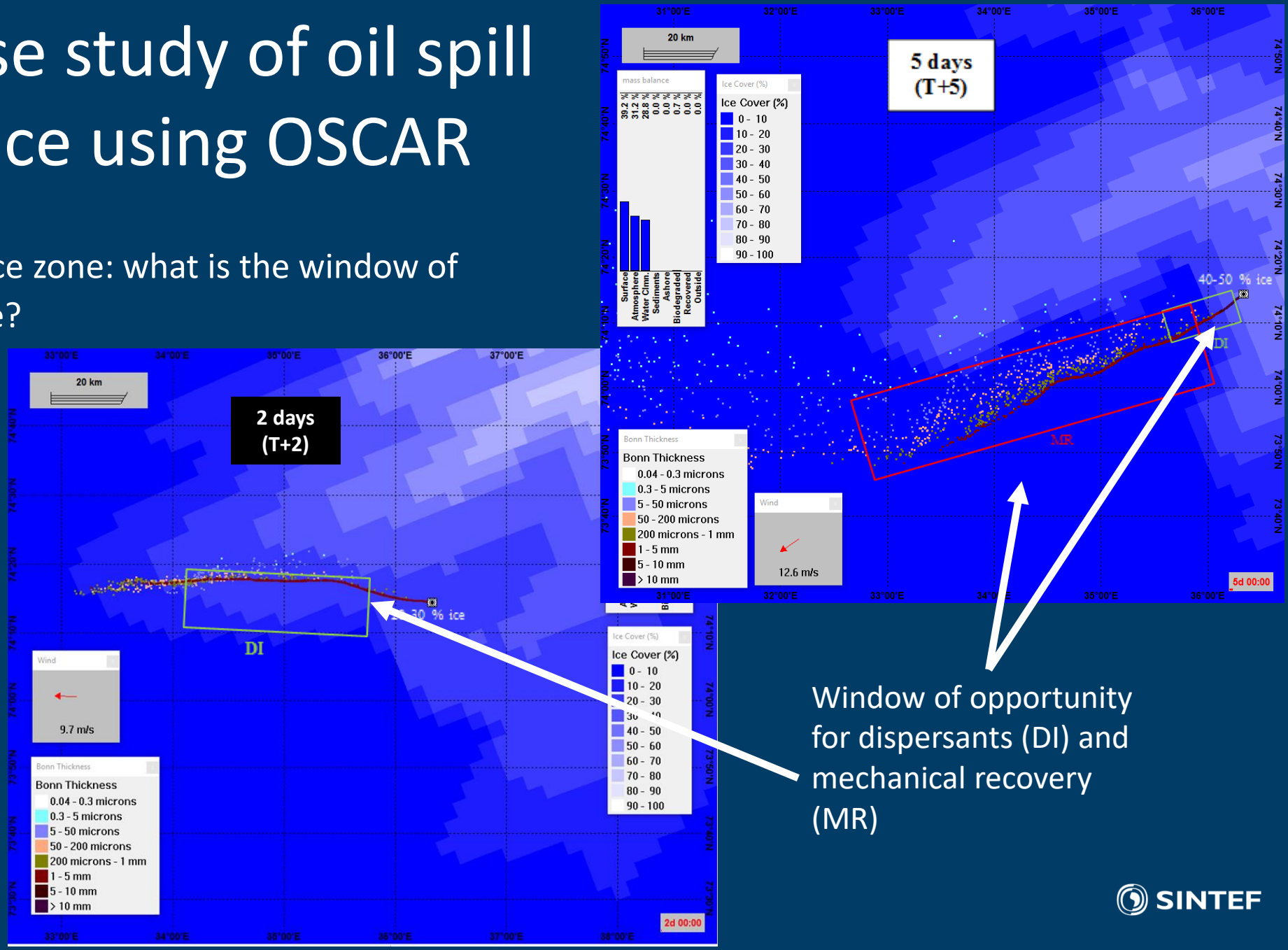
Example: case study of oil spill response in ice using OSCAR

Oil spill in the marginal ice zone: what is the window of opportunity for response?

Surface release: 1900 m^3/d over 14 days

Snapshots shown 2 and 5 days after start of release



Window of opportunity for dispersants (DI) and mechanical recovery (MR)

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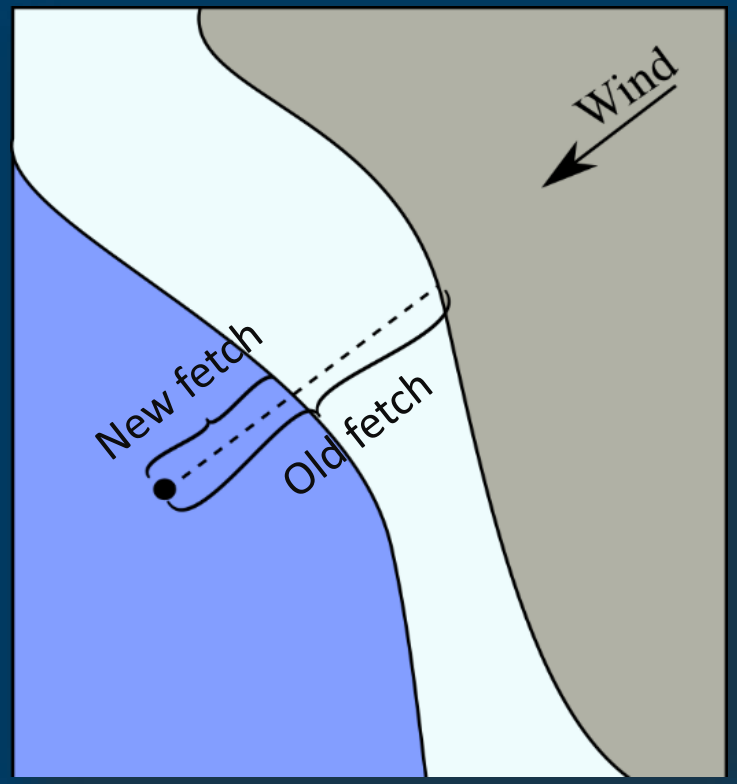
Recent improvements to oil/ice modelling from the Nunaat project

- Using ice-velocity from SINMOD to transport ice-locked oil
- Using temperature and salinity depth profiles for vertical transport (Richardson-number for turbulent diffusivity, Sundfjord et al., 2008)
- Adjusting wave calculations by taking ice cover into account when finding fetch
- All effects of ice in OSCAR described in Nordam et al. 2018 (in preparation)



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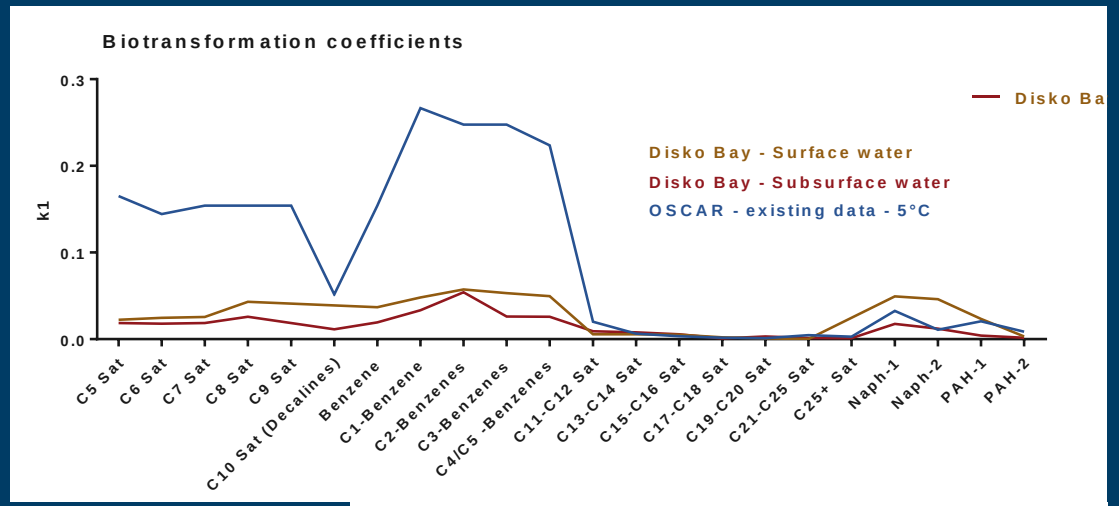
Oil biodegradation

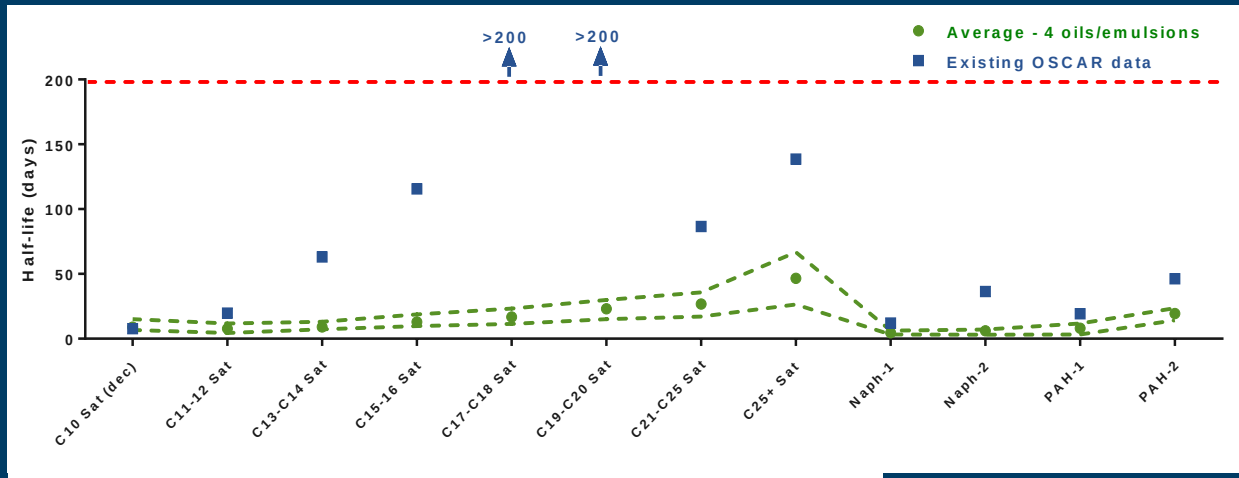
- OSCAR calculates biodegradation of oil based on experimental data using 13 deg. C water from the Trondheimsfjord (Brakstad & Faksness 2000, Reed et al. 2000)
- Effect of temperature is modelled with a standard Q10 model: 10 degrees colder gives 2 x lower rates
- Previously unknown how well this scales in very cold water

New knowledge about biodegradation in cold water

- Determinants of biodegradation rates
  - Nutrients
  - Starting-culture
  - Temperature
  - Oil droplet size
- Experiments with Greenland and Svalbard water help increase our understanding of these effects



Biodegradation (rate) in cold, Greenland water compared to Q10 scaling in OSCAR (Nunaat project)



Biodegradation (half-life) for chemically dispersed oil compared to half-life in OSCAR (PETROMAKS Biodegradation project)

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What can we do today with OSCAR?

OSCAR can predict the fate of an oil spill in cold and icy waters

- Uses the latest available (dynamic; 1-2 hour, 1-4 km) ocean current, wind and ice data
- Accounts for oil that drifts into and remains in ice
- Adjusts oil weathering and spreading with increasing ice cover
- Transports ice-locked oil with ice
- Calculates concentration in the water column of different oil compound groups

Future work

Norway has always been at the leading edge of research of transport, fate and effects of spilled oil

- Modelling of sea ice
  - Higher resolution spatial domain and more detailed ice state (slush, frazil, pancake, old, young)
- Oil transport and fate
  - Spreading/thickness/mixing of oils near their pour point (change of fluid behavior) and ice-encapsulation
- Oil biodegradation
  - Improve description in cold waters, especially for chemically dispersed oil

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THANK YOU

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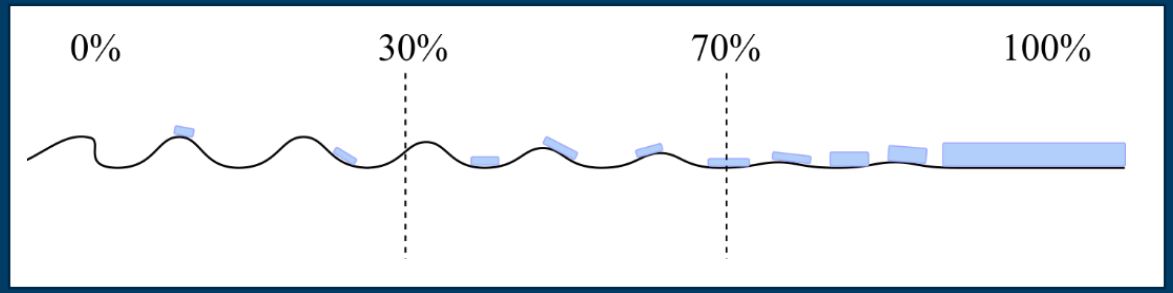
Technology for a better society

The 30 % - 80 % rule

- Effect of ice on oil in models commonly follows a simple rule (Venkatesh et al. 1990)
  - Less than 30 % coverage: no or little effect
  - Between 30 % and 80 %: linearly increasing effect
  - Above 80 %: same effect as full ice cover



- OSCAR follows this rule for the effect of ice on transport, spreading, and weathering (Nordam et al. 2018, in preparation)

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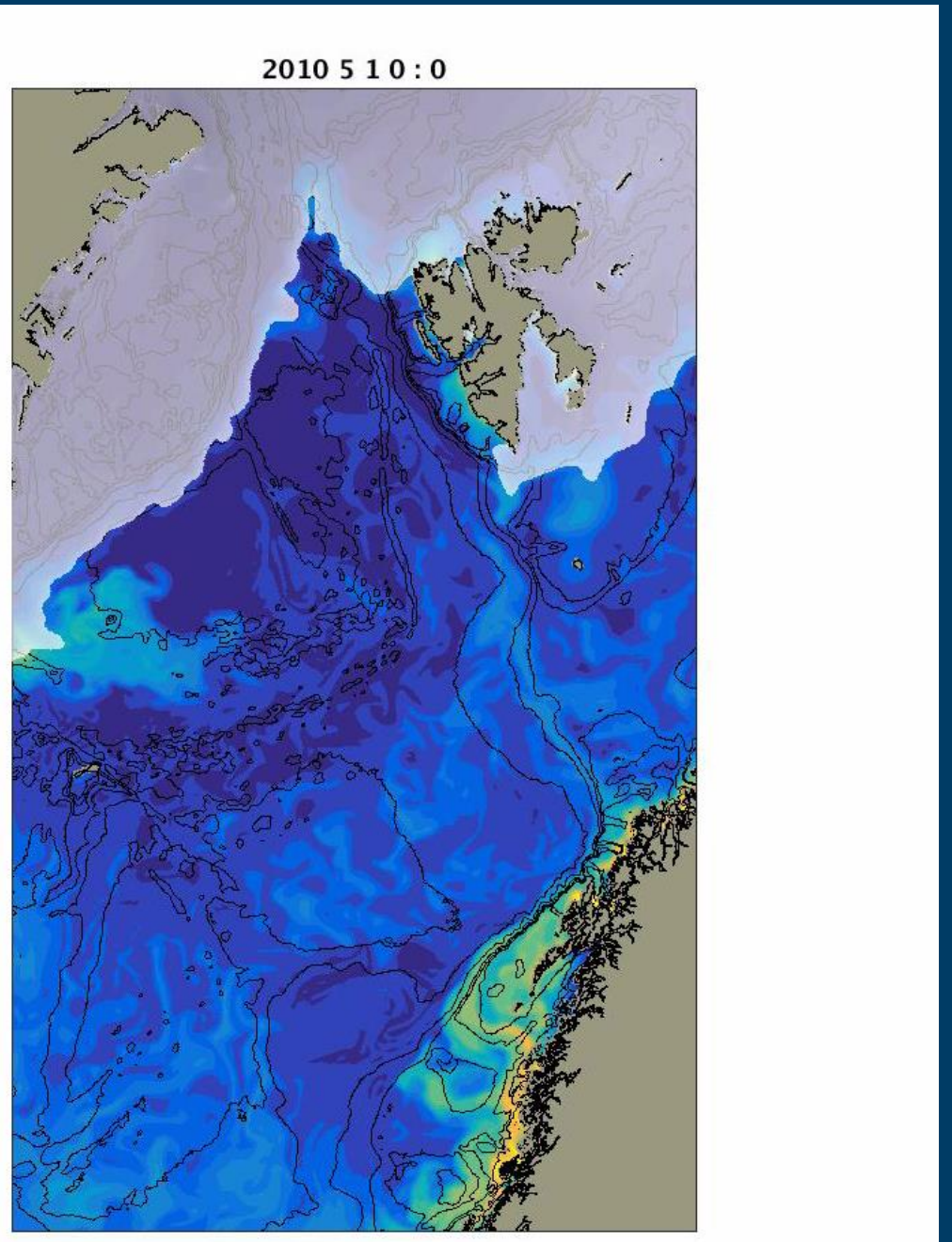
High-resolution, dynamic data is the future for environmental impact assessment



Ice and phytoplankton biomass simulated in the SINMOD model

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