Response Options for an Offshore Deep-Water Oil & Gas Release – A Generic Evaluation of both Individual and Combined Response Strategies

Technical project description by
Brandvik, Skancke, Daae, Sørheim & Daling
SINTEF Ocean

Study Objectives:

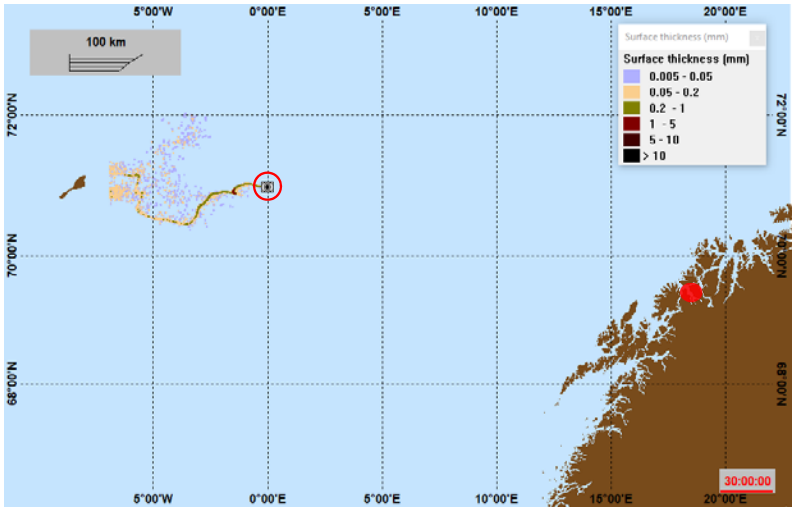
Compare response options available on the Norwegian continental shelf including:

- Large-scale mechanical recovery
- Surface dispersant application (by vessels and aerial)
- Subsea mechanical dispersant injection (SSDI)

Individual response options are compared as well as combinations of response options. Response effectiveness is estimated based on remaining oil volume- and coverage on the surface.

Case study: Deepwater blowout release

- Offshore location (900 km Tromsø)
- Release depth: 2000 m
- Continuous release for 30 days (8 000 m^3/d)
- GOR: 200 Sm^3/Sm^3 (1.2 at release depth)
- Release diameter: 25.4 cm (10")
- Release velocity: 4.1 m/s (adj. for gas & buoyancy)
- Oseberg blend
  - ✓ 0.826 kg/L
  - ✓ 0.7 mPas at release (full gas saturation)
- Low & High wind scenarios (Spring/Autumn)

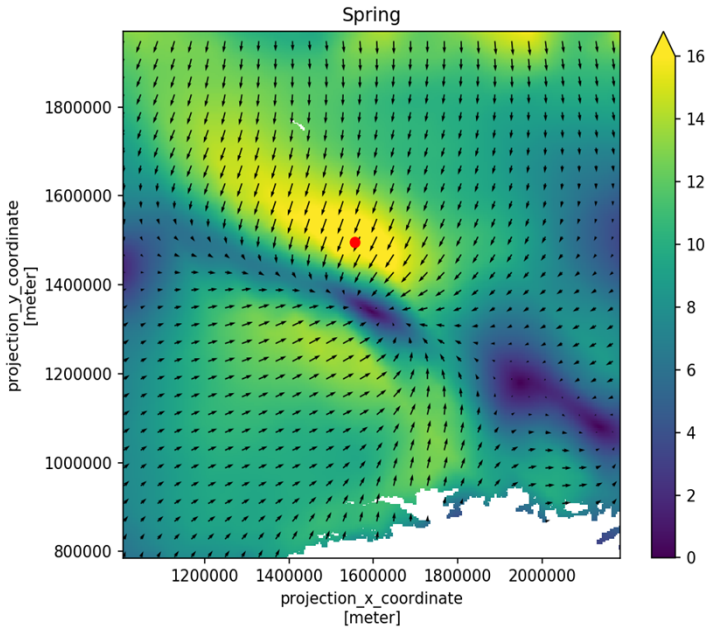


MetOcean data for complete period:

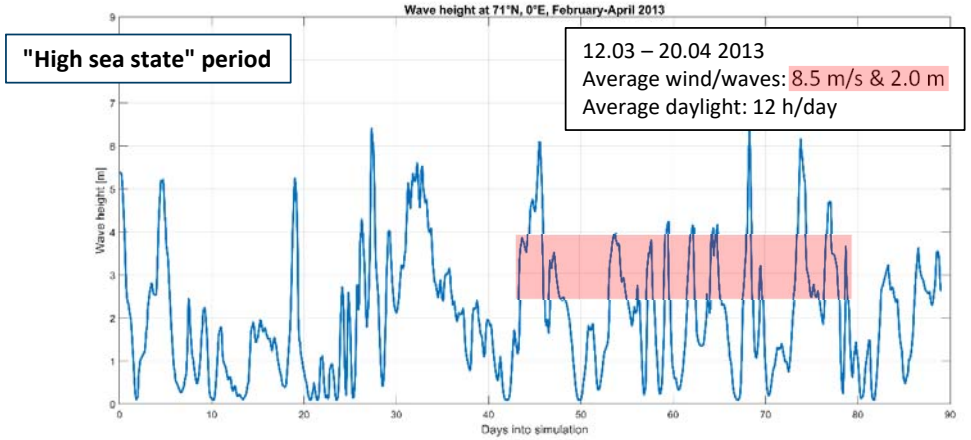
- Salinity and temperature profiles
- 3D current data 2h resolution
- 2D wind data 2h resolution

Response in High- & Low-wind scenarios

Centred on spring/autumn equinox

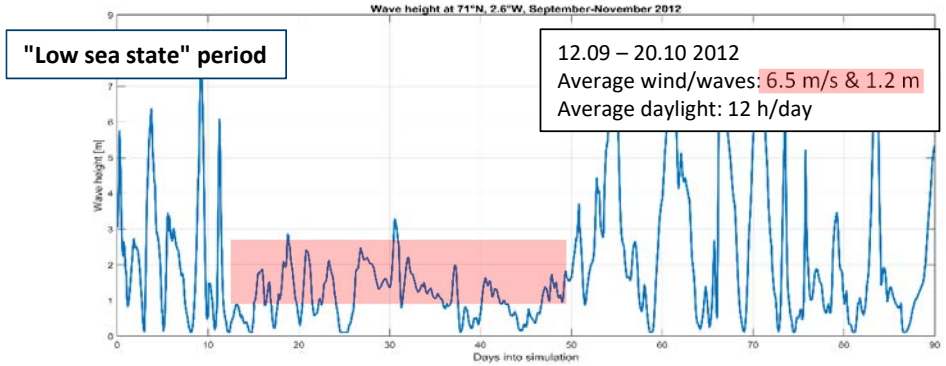


Wind state at the start of the release for high sea state conditions.



"High sea state" period

12.03 – 20.04 2013
Average wind/waves: 8.5 m/s & 2.0 m
Average daylight: 12 h/day



"Low sea state" period

12.09 – 20.10 2012
Average wind/waves: 6.5 m/s & 1.2 m
Average daylight: 12 h/day

Response scenarios (OSCAR Modelling)

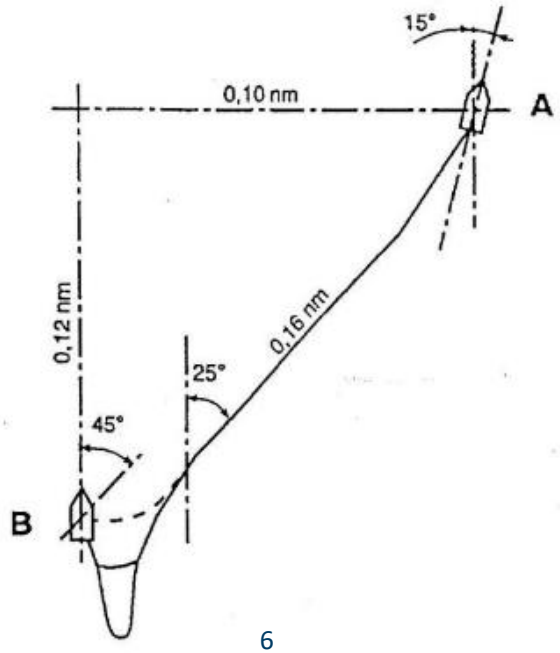
The individual response options are combined to define modelling scenarios

	Low wind & sea state	High wind & sea state
1. No response	x	x
2. Mechanical recovery	x	x
2a. Large – NCS approach	x	x
2b. Medium - Fewer NCS units	x	x
2c. Small – Lower capacity units	x	x
3. SSDI – modified OSRL Disp kit	x	x
4. Surface disp application	x	x
4a. Multiple vessels	x	x
4b. Medium aircrafts (DC4)	x	x
4c. Large aircrafts (727)	x	x
5. Combined approaches:	x	x
5a. Main focus on SSDI + MeckRec	x	x
5b. Main focus on MeckRec + Aerial Disp	x	x
5c. MeckRec + Vessel Disp	x	x
5d. Mainl focus on SSDI + Aerial Disp	x	x
5e. Vessel Disp + MeckRec	x	x

Scenario 2 - Mechanical recovery

- State-of-the-art NCS offshore equipment (NOFO)
- Remote sensing: night operation with 60% effectiveness
- Three different operation sizes: small, medium, large

Towing speeds and boom openings
Towing speeds: 0.7 & 2.5 Kn
Boom opening: 30, 50 & 185 m



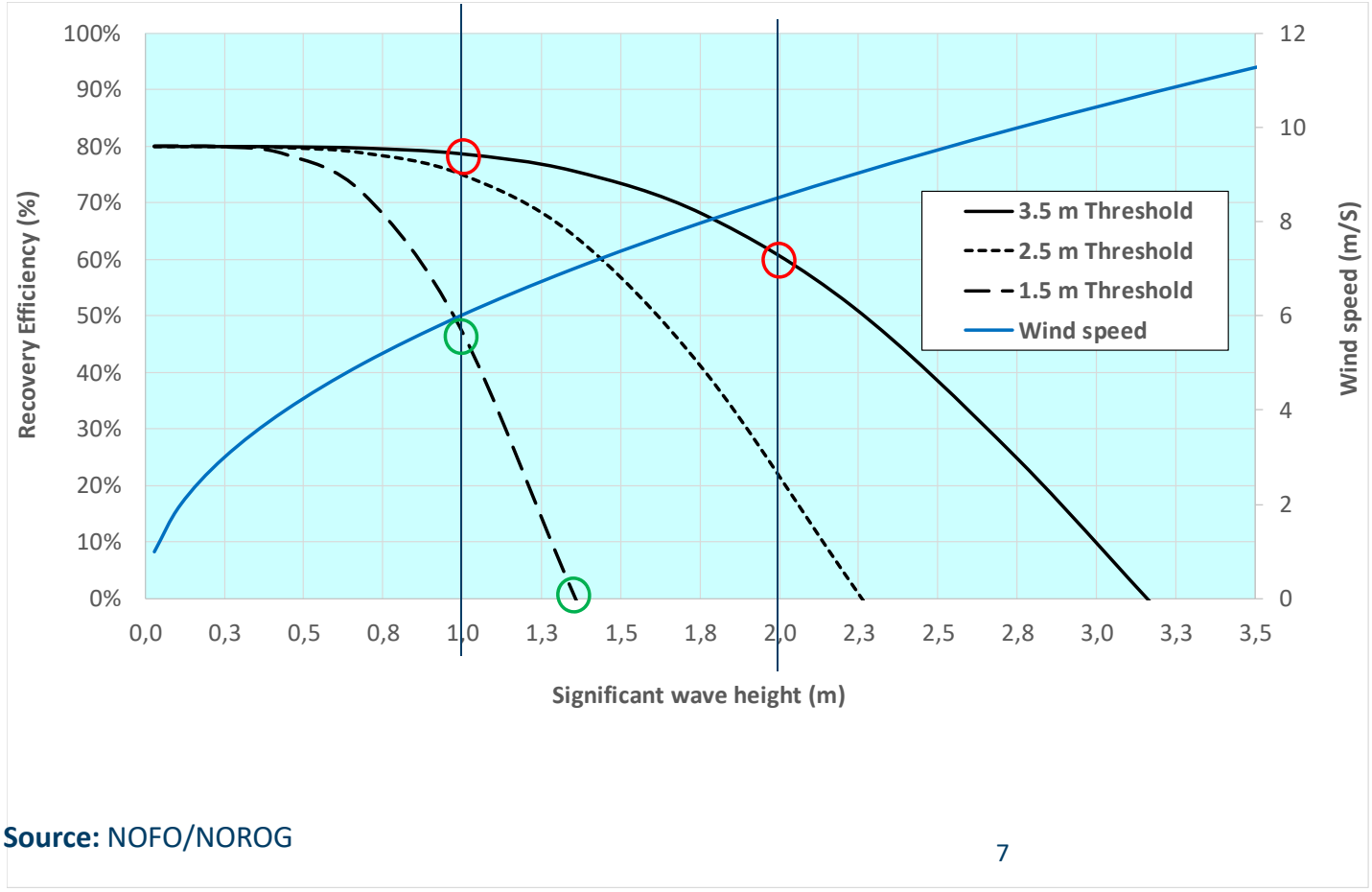
NB: Assuming 20% "Boom leakage" at low wind, no waves

Skimmer specifications:
- 100 – 200 m^3/t
- Pump viscosity limit
- Minimum thickness: 0.1 mm

Source: NOFO

Scenario 2 – Boom wave tolerance

Booming effectiveness versus wind & waves



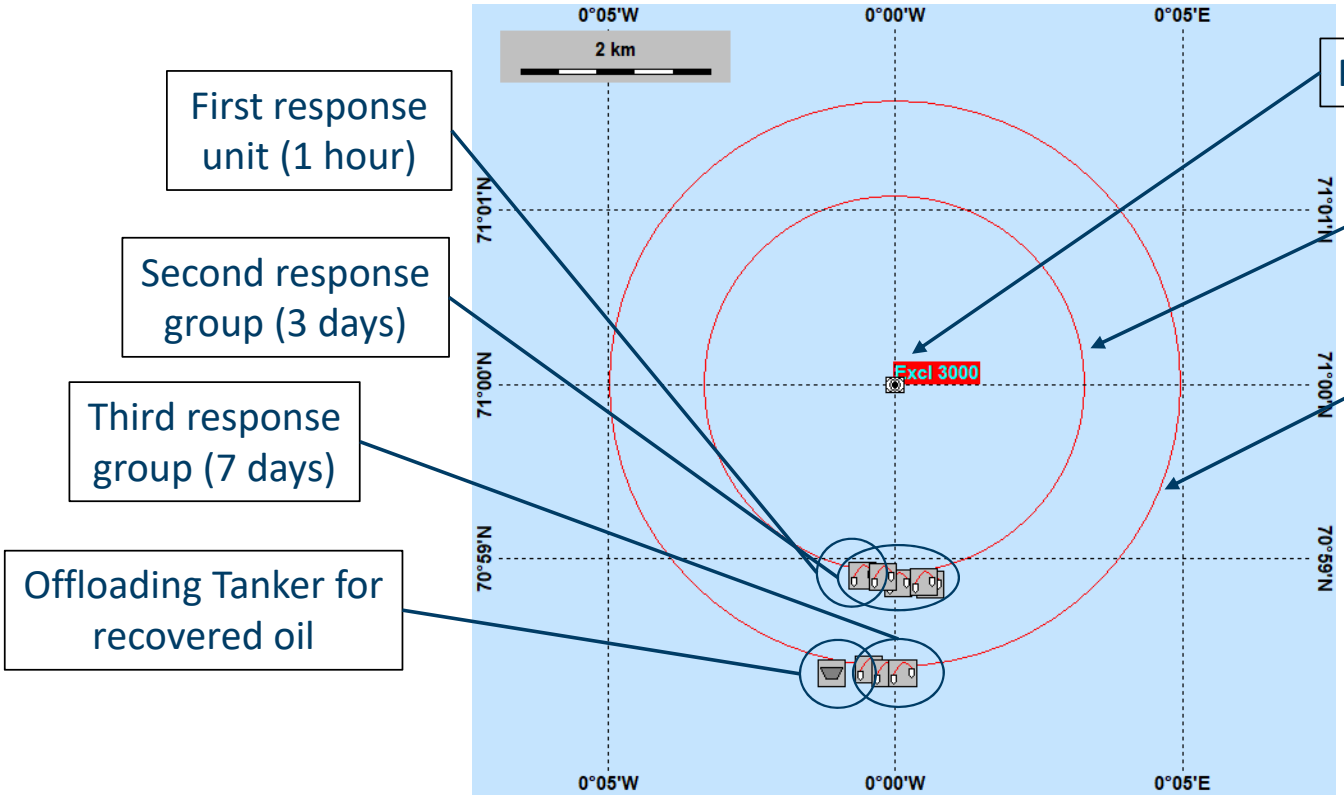
Source: NOFO/NOROG

Effectiveness at 1 & 2 m waves:

- Large booms (3.5 m): 78% & 60%
- Small booms (1.5 m): 45% & 0%

Scenario 2 - Mechanical recovery

Booming & skimming strategy:



Grouping resources to avoid conflict between different response equipment

Scenario 4a - Vessel disp. application


Troms Pollux

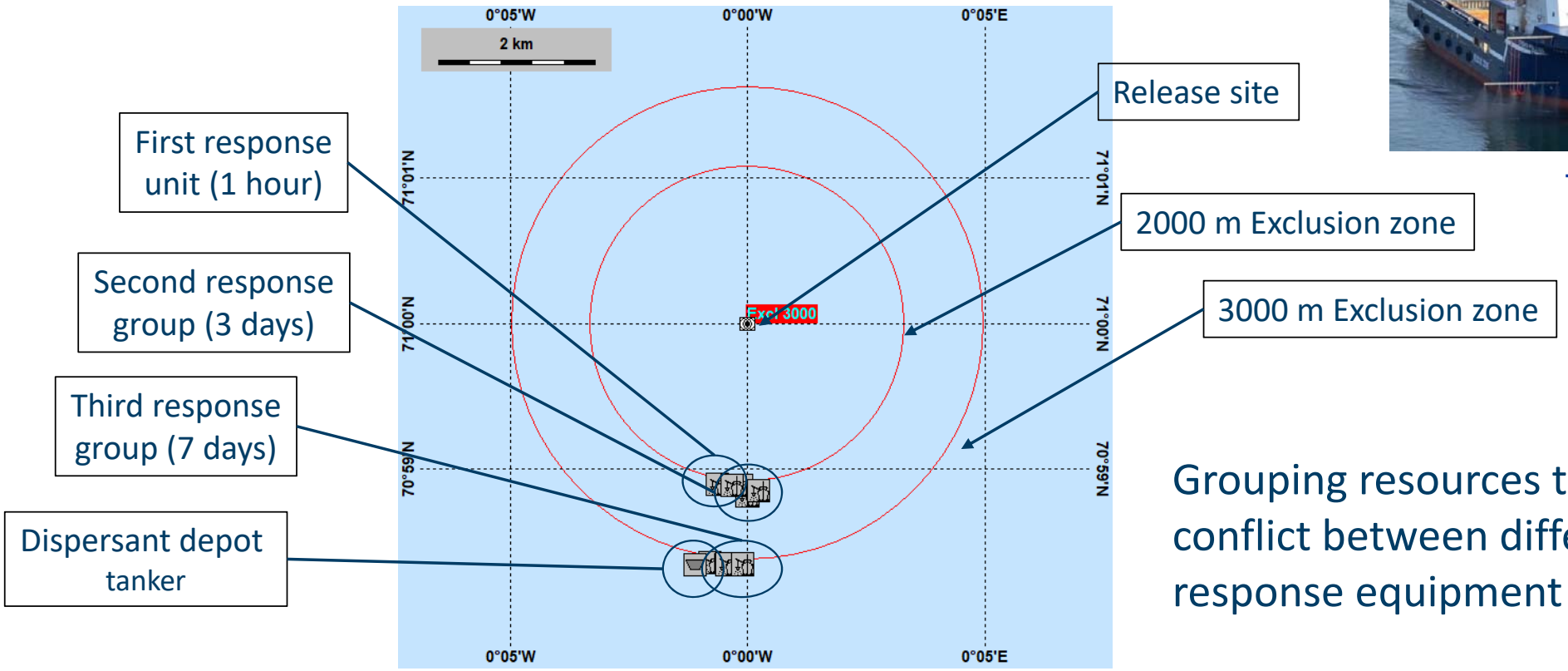
- State-of-the-art NCS offshore equipment (NOFO)
- Remote sensing: night operation at 60% effectiveness
- 8 vessels in operation after 7 days (5 with remote sensing support)
- 50 m^3 onboard, additional dispersant supplied offshore (6 hour operation + transit)

Source: NOFO

Scenario 4a – Vessel Disp. Application

Dispersant strategy (8 vessels):

Troms Pollux



Grouping resources to avoid conflict between different response equipment

Scenario 4bc - Areal disp. application

- Medium and large aircrafts (Scenario 4b & 4c)
  - DC4: 150 knots cruise speed & 7.6 m^3 dispersant
  - 727: 450 knots cruise speed and 15 m^3 dispersant
- Reduced number of sorties due to remote offshore location, 900 km (485 nm)
- No night operation
- Dispersant supplied for total 30 day period

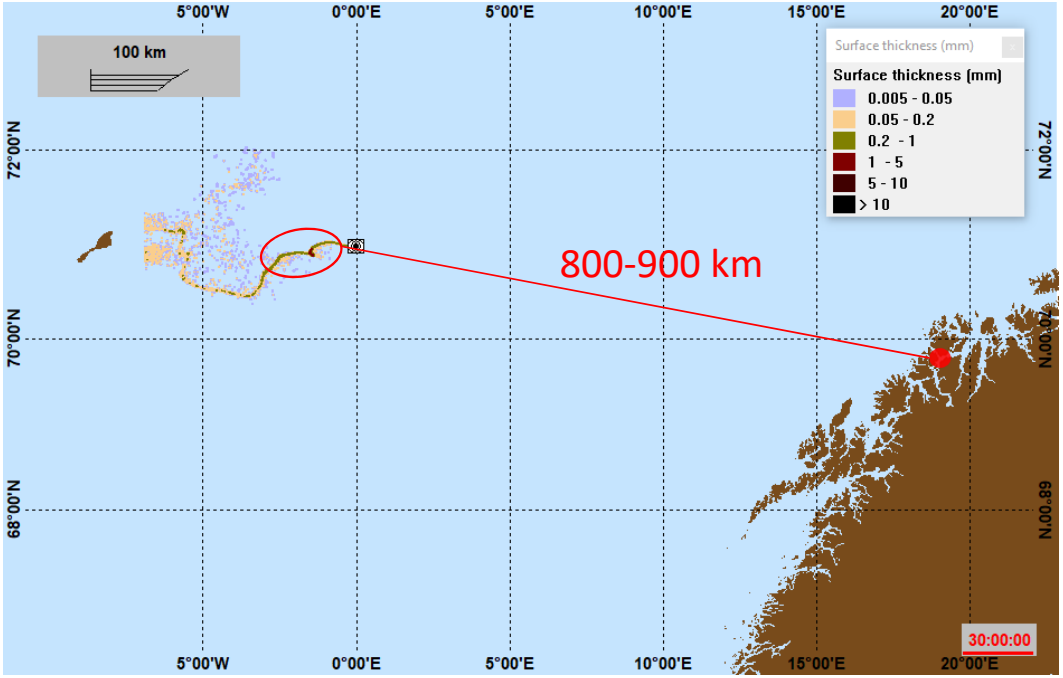
OSRL Boing 727

DC 4

Source: OSRL & BSEE response calculator

Scenario 4bc - Areal disp. application

- Remote location gives up to 2-3 sorties per day (727)



OSRL Boing 727

- 2 hours are used for refuelling and dispersant loading at airport.
- Average daylight in both 30 day periods: 12 hours (equinox).
- No limitation due to weather

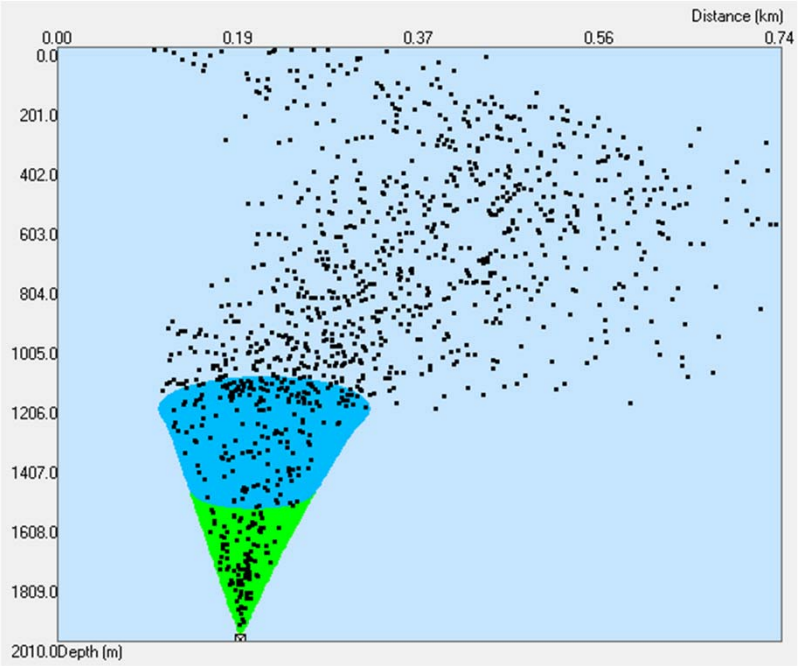
Source: OSRL & BSEE response calculator

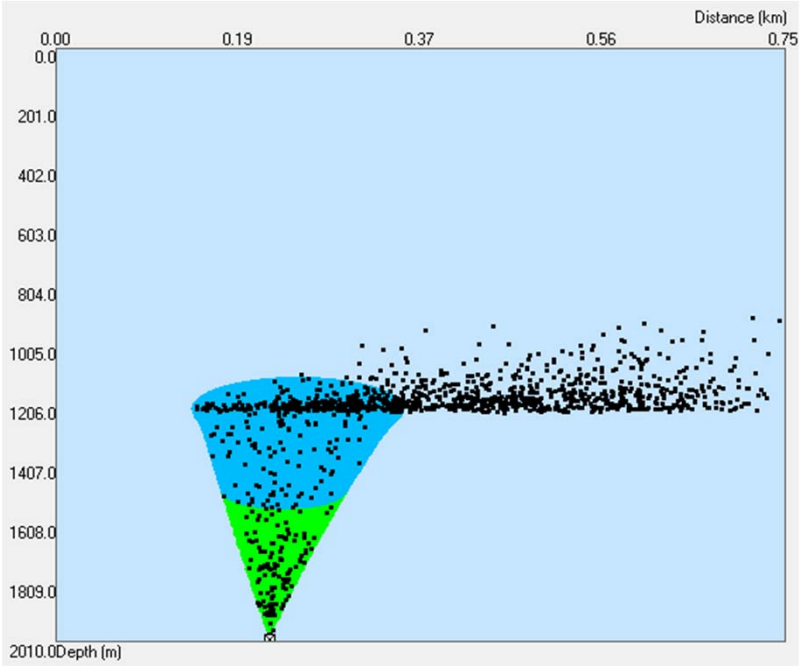
OSRL Boing 727 – Flight record

Boeing 727 OSRL 1	0 16:16	2012.09.14 04:16	7.283	Idle due to darkness
Boeing 727 OSRL 1	0 17:27	2012.09.14 05:27	1.169	Cruising
Boeing 727 OSRL 1	0 17:52	2012.09.14 05:52	0.366	Working
Boeing 727 OSRL 1	0 18:45	2012.09.14 06:45	0.879	Going to Refill
Boeing 727 OSRL 1	1 00:45	2012.09.14 08:45	1.995	Refilling
Boeing 727 OSRL 1	1 01:36	2012.09.14 09:36	0.851	Cruising
Boeing 727 OSRL 1	1 01:53	2012.09.14 09:53	0.294	Working
Boeing 727 OSRL 1	1 02:46	2012.09.14 10:46	0.878	Going to Refill
Boeing 727 OSRL 1	1 08:45	2012.09.14 12:45	1.977	Refilling
Boeing 727 OSRL 1	1 01:36	2012.09.14 13:36	0.851	Cruising
Boeing 727 OSRL 1	1 01:53	2012.09.14 13:53	0.294	Working
Boeing 727 OSRL 1	1 02:46	2012.09.14 14:46	0.878	Going to Refill
Boeing 727 OSRL 1	1 08:45	2012.09.14 16:45	1.977	Refilling
Boeing 727 OSRL 1	0 16:16	2012.09.14 16:++		Idle due to darkness

OSRL Boing 727

Secenario 3: Subsea dispersant injection





Untreated oil:

- IFT: 15.5 mN/m
- Viscosity: 0.7 cP (full gas saturation)
- Large oil droplets: d_{50}: 3.8 mm

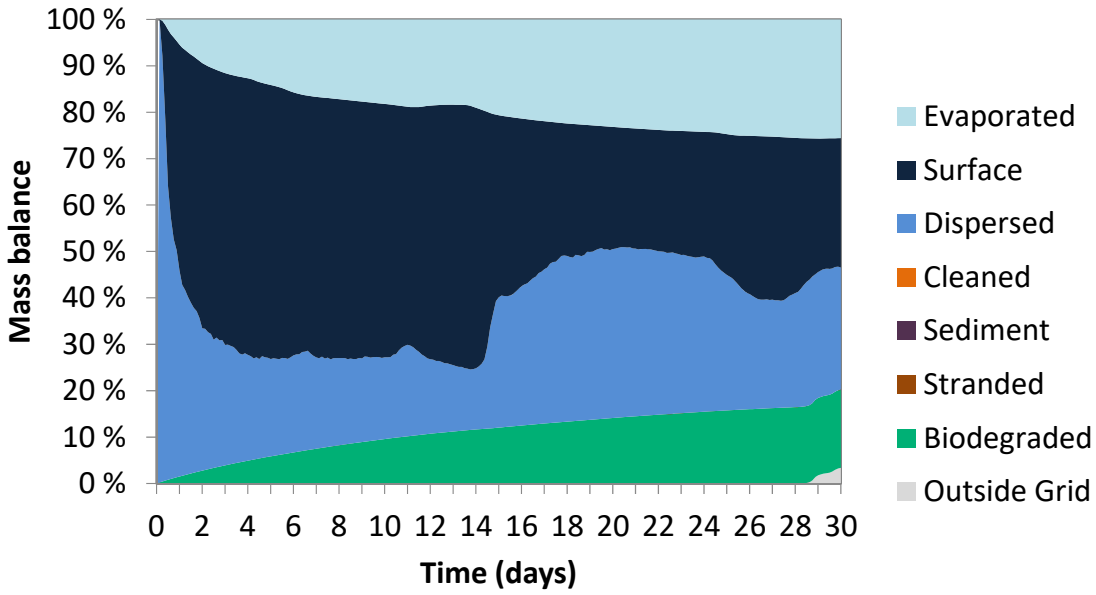
Treated oil:

- Initiated after 5 days
- 2% dispersant dosage
- IFT: 0.3 mN/m
- Reduced oil droplets: d_{50}: 0.373 mm

Scenario 1 – No response, mass balance

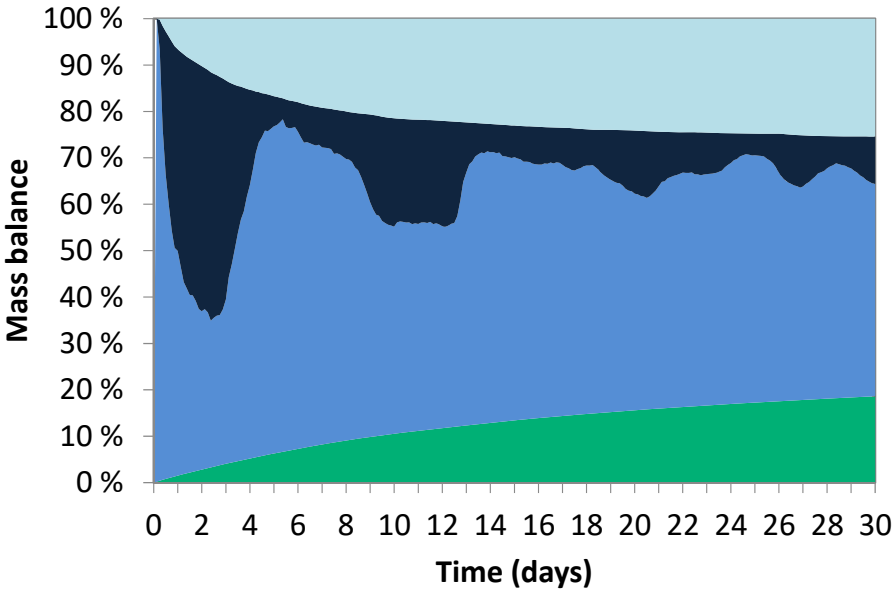
LOW sea-state

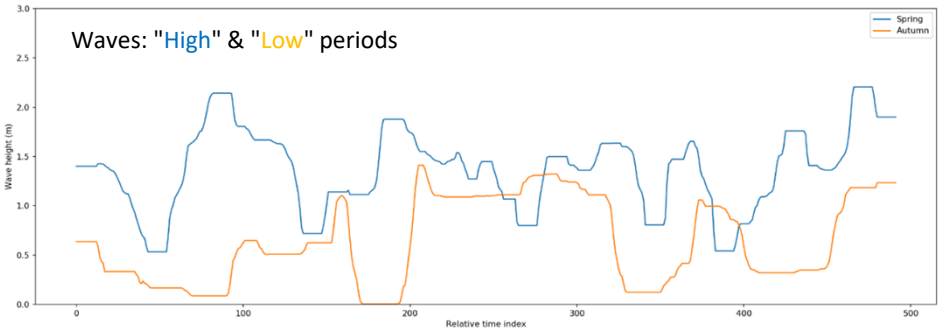
28% on Surface after 30 days



HIGH sea-state

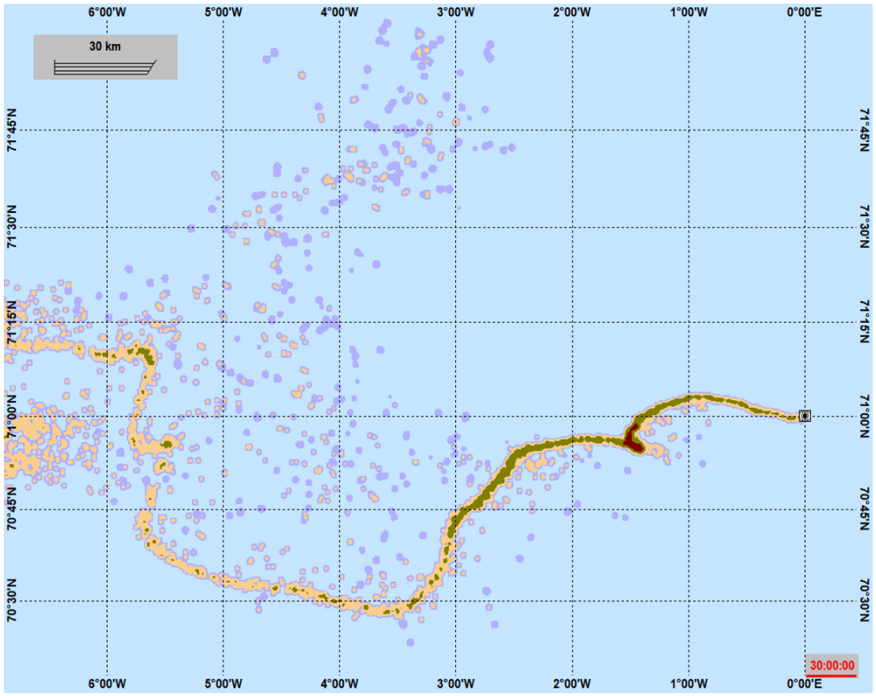
10% on Surface after 30 days

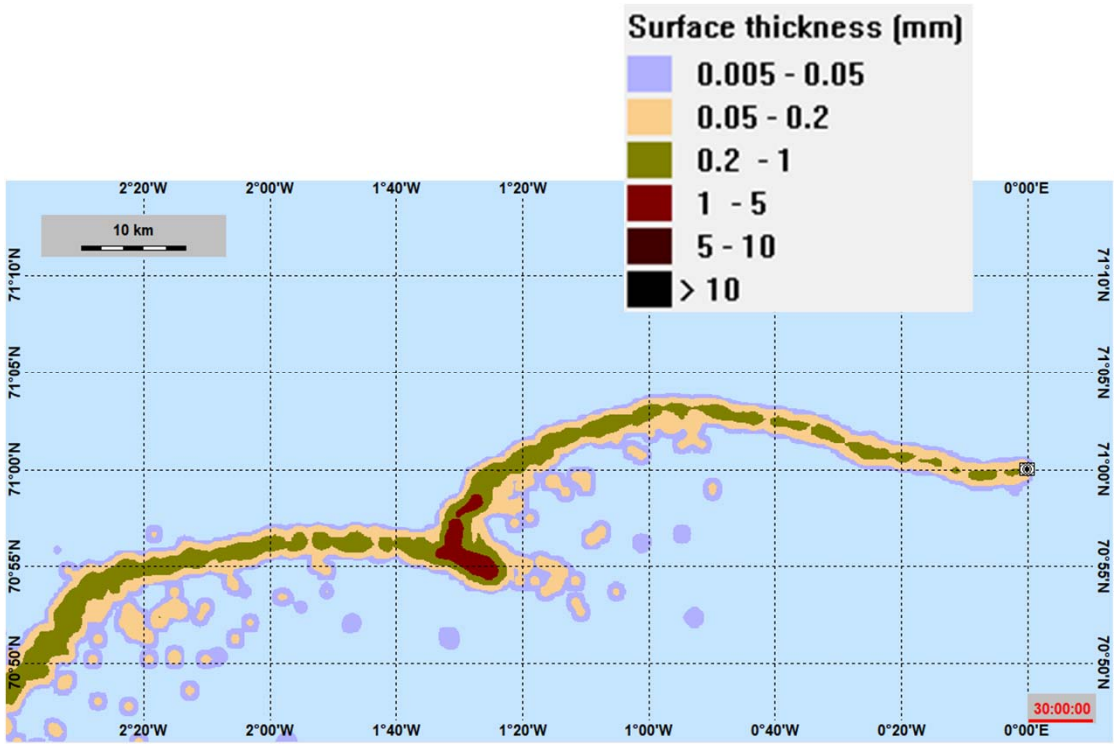




- Release depth 2000 meter with 8000 m^3/day
- GOR: 200 Sm^3/Sm^3 (1.2 at release depth)
- Release diameter: 25.4" cm (10")
- Release velocity: 4.1 m/s (adjusted for gas void & buoyancy)

Scenario 1 – No response, surface thickness



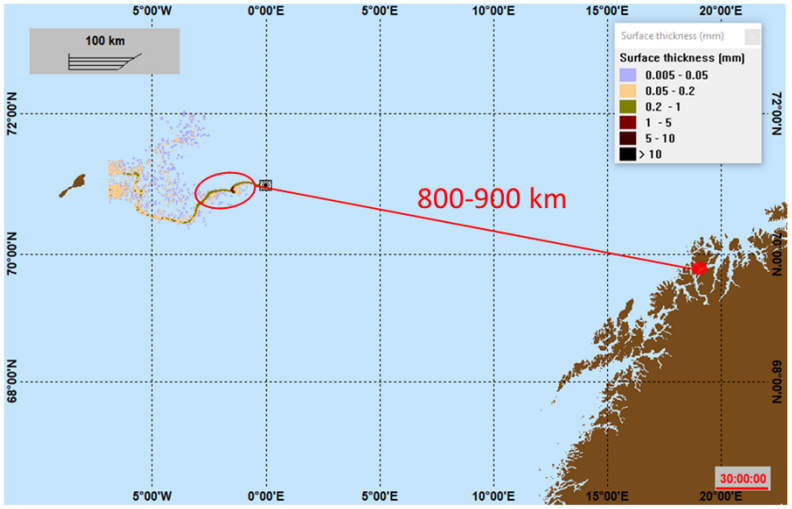


- 67 200 m^3 of oil (or 255 000 m^3 emulsion, 60-70% water) on the surface after 30 days (28%)
- Large variation in oil film thickness

	Total	**Thick (> 0.1 mm)**
• Surface area covered (km^2):	2 000	600
• Surface oil volume (m^3 emulsion)	255 000	250 000

Next: Results, Discussion and Conclusions…..

Response Options for an Offshore Deep-Water Oil & Gas Release – A Generic Evaluation of both Individual and Combined Response Strategies



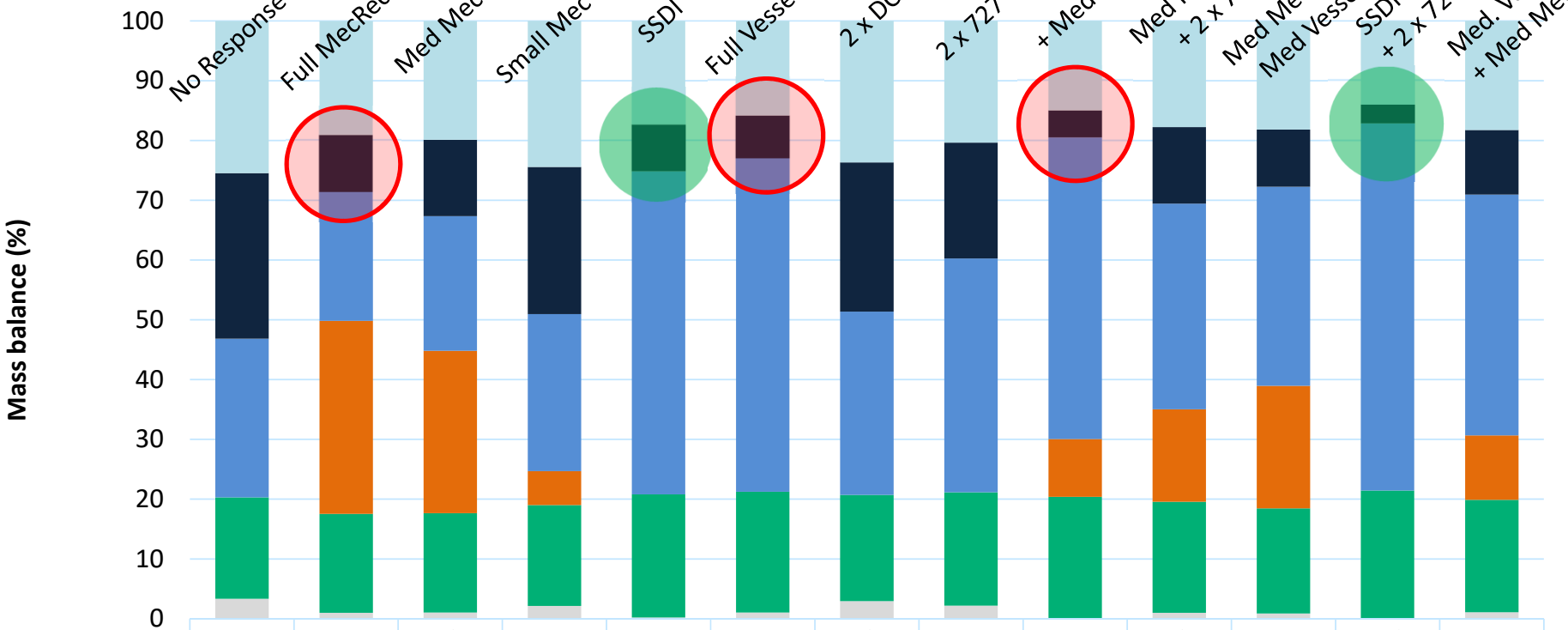
Map showing release and surface oil after 30 days.
Flying distance from Tromsø is indicated.

Results presented by Karina Heitnes Hofstad, Equinor

Response scenarios (OSCAR Modelling)

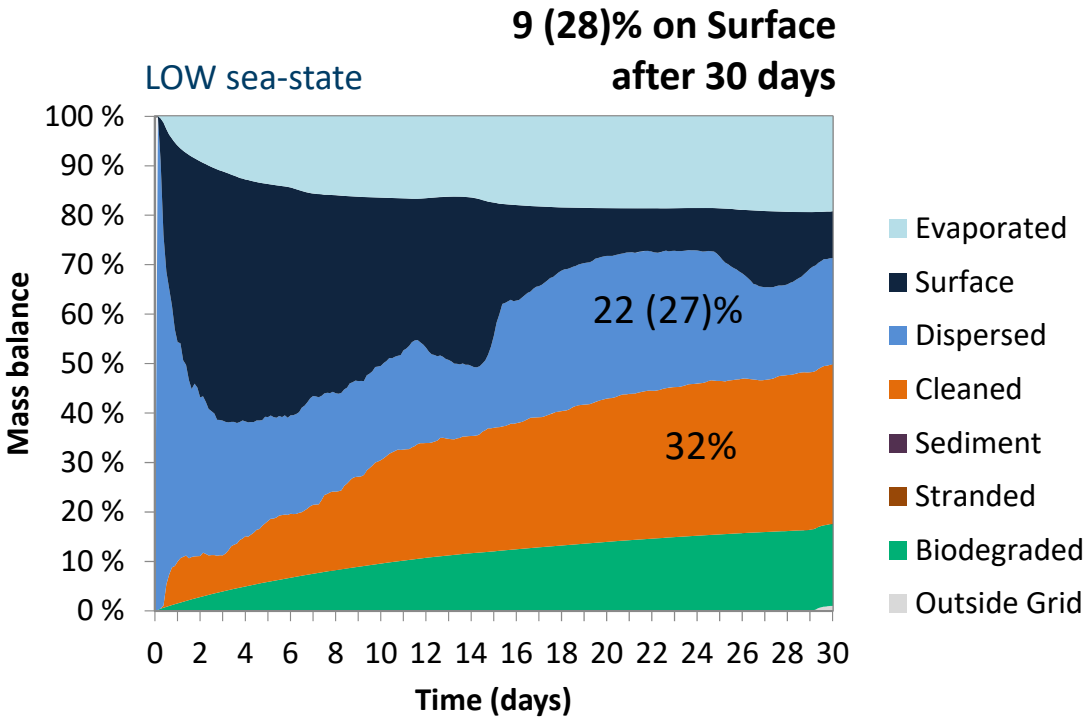
The individual response options are combined to define modelling scenarios

	Low wind & sea state	High wind & sea state
1. No response	x	x
2. Mechanical recovery	x	x
2a. Large – NCS approach	x	x
2b. Medium - Fewer NCS units	x	x
2c. Small – Lower capacity units	x	x
3. SSDI – modified OSRL Disp kit	x	x
4. Surface disp application	x	x
4a. Multiple vessels	x	x
4b. Medium aircrafts (DC4)	x	x
4c. Large aircrafts (727)	x	x
5. Combined approaches:	x	x
5a. Main focus on SSDI + MeckRec	x	x
5b. Main focus on MeckRec + Aerial Disp	x	x
5c. MeckRec + Vessel Disp	x	x
5d. Mainl focus on SSDI + Aerial Disp	x	x
5e. Vessel Disp + MeckRec	x	x

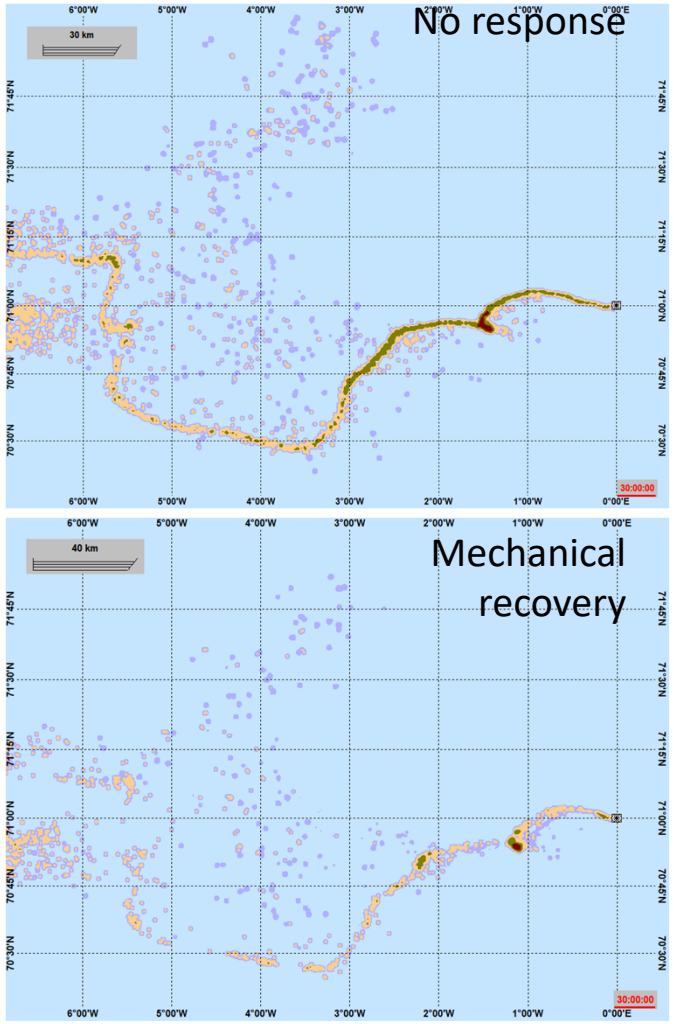


	1	2a	2b	2c	3	4a	4b	4c	5a	5b	5c	5d	5e
Evaporated	25	19	20	24	17	16	24	20	15	18	18	14	18
Surface	28	9	13	25	8	7	25	19	4	13	10	3	11
Dispersed	27	22	23	26	54	56	31	39	50	34	33	61	40
Recovered	-	32	27	6	-	-	-	-	10	15	21	-	11
Biodegraded	17	17	17	17	21	20	18	19	20	19	18	21	19

Scenario 2a – Full Mech Recovery

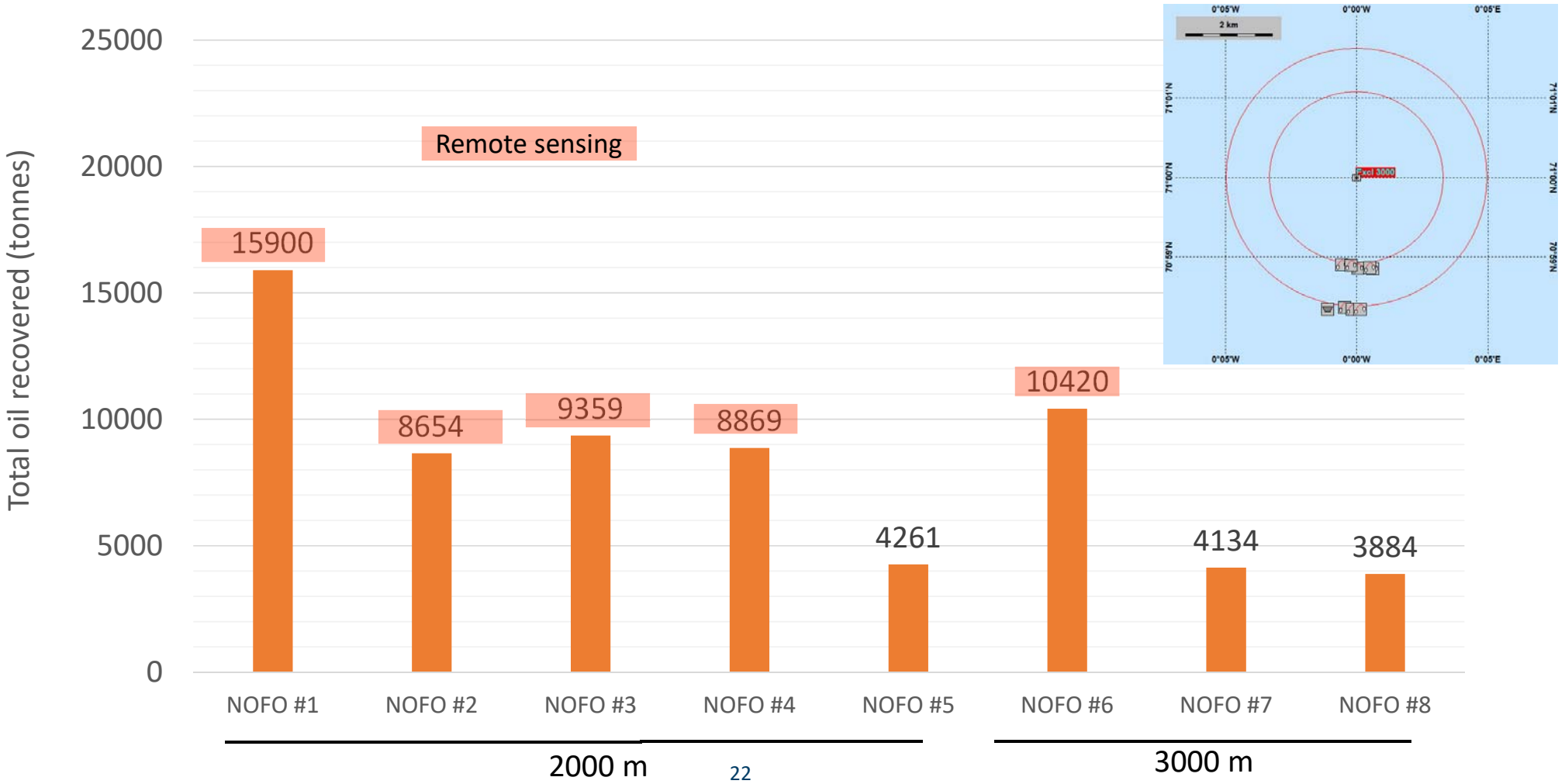


- 8 large system in operation after 7 days
- Offshore offloading of recovered oil



Distribution of surface oil after 30 days

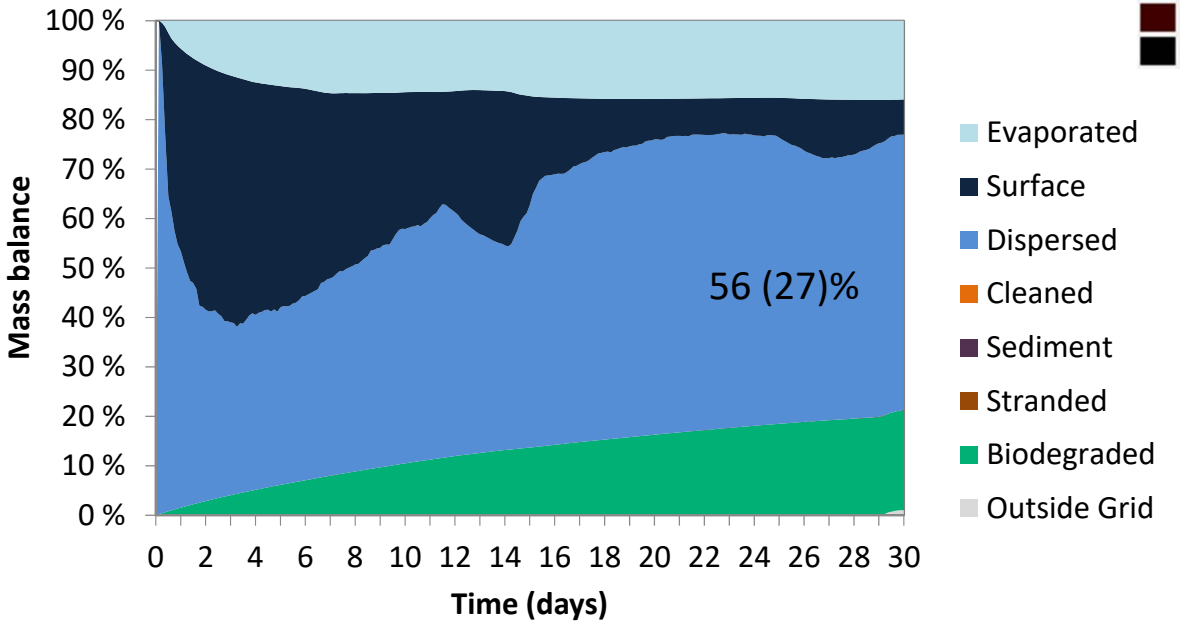
Scenario 2a – Full Mechanical Recovery

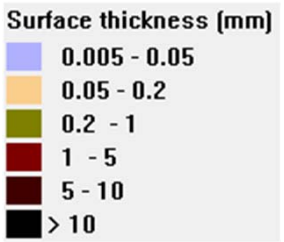


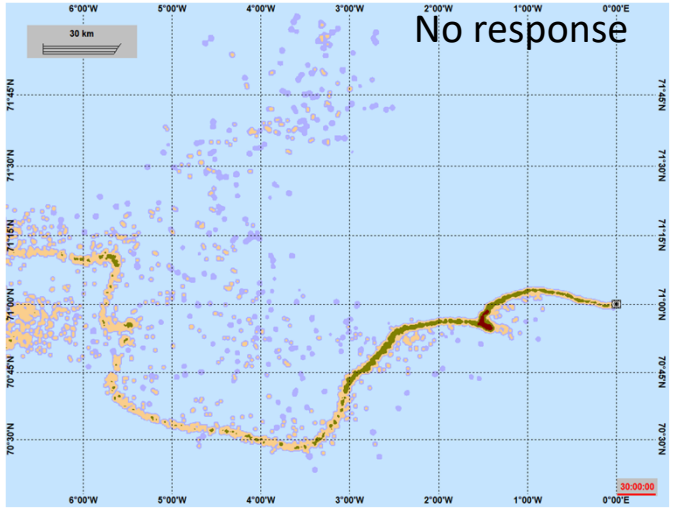
Scenario 4a – Full Vessel application

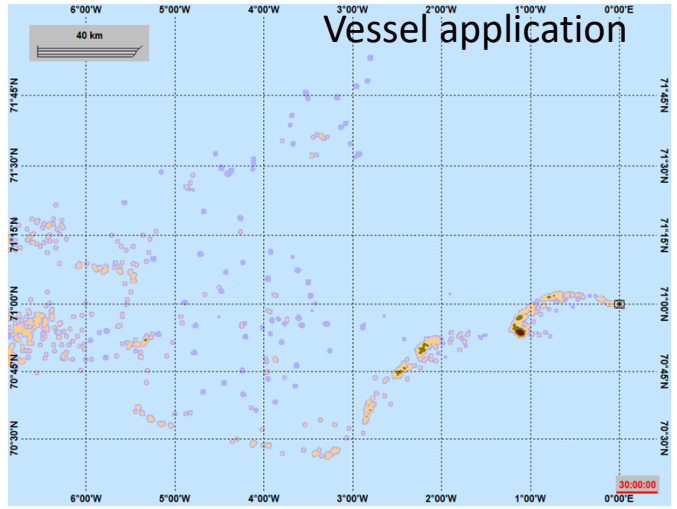
LOW sea-state

7 (28)% on Surface after 30 days





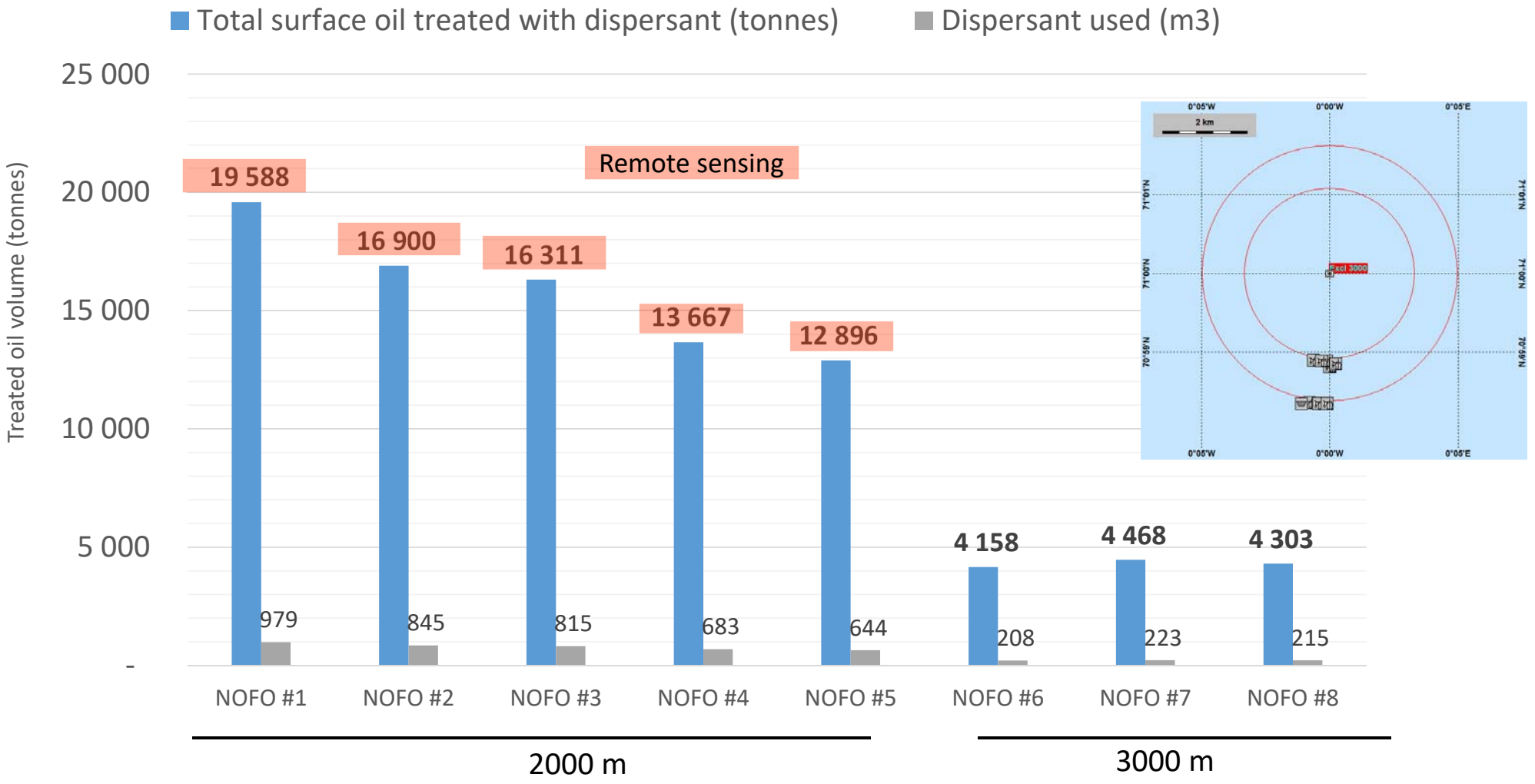




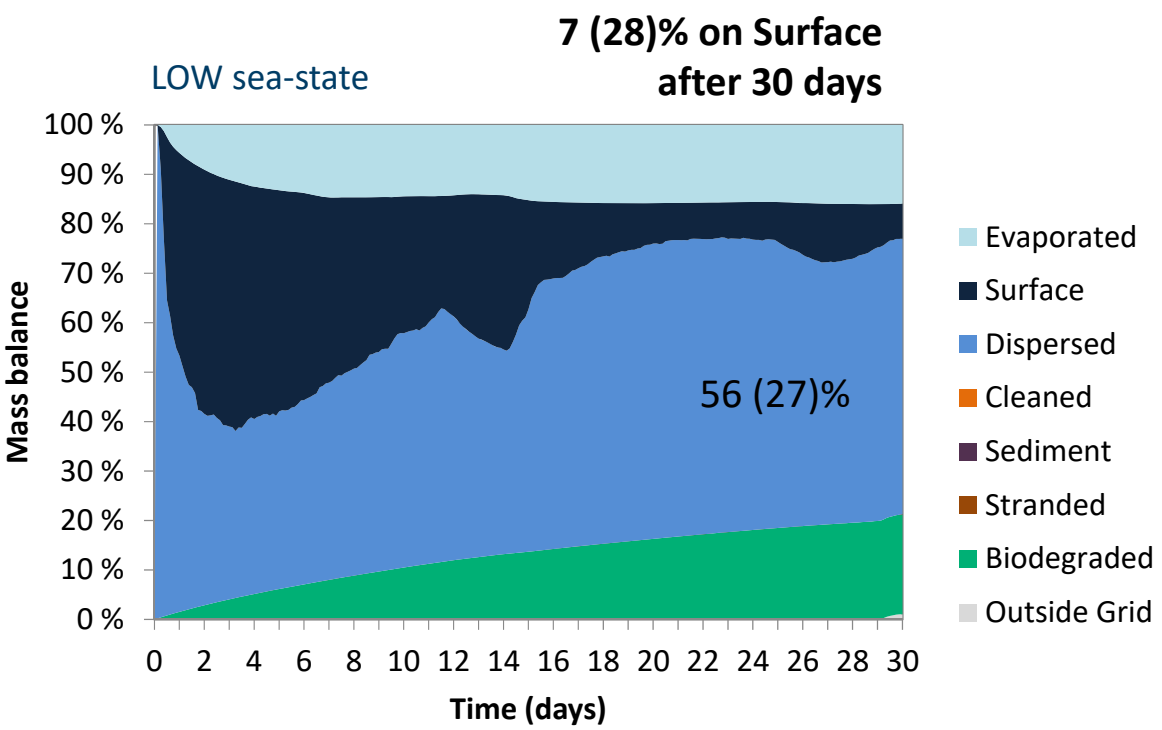
Distribution of surface oil after 30 days

- 8 large system in operation after 7 days
- Dispersant dosage: 4%
- Full access to both Norwegian and OSRL dispersant storages
  ➔ no limitation in dispersant supply for 30 days

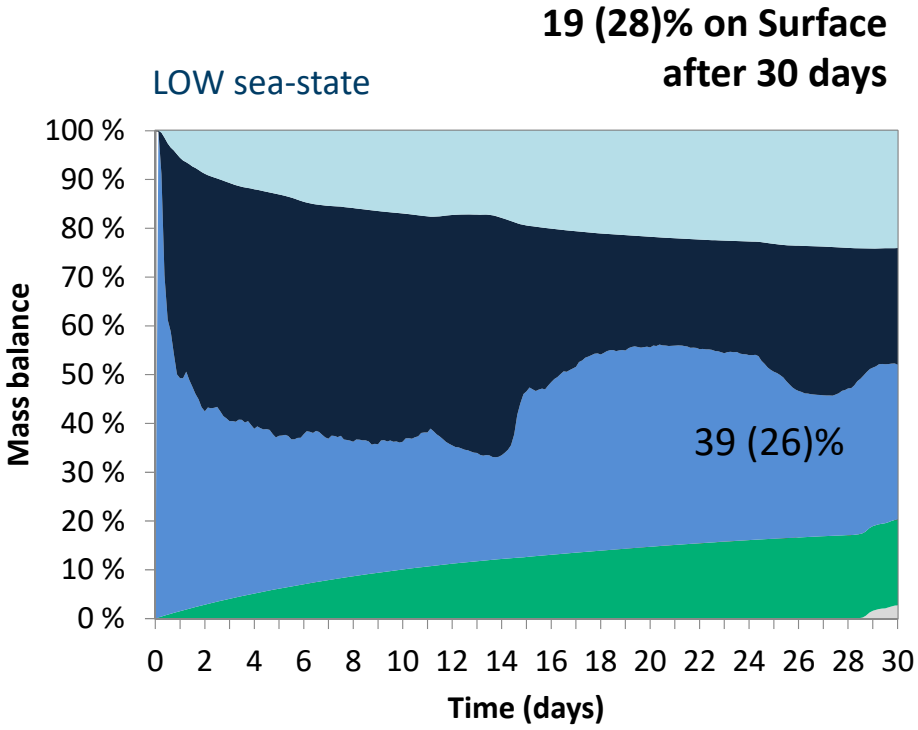
Scenario 4a – Full Vessel application



Scenario 4ac – Vessel vs. large aircrafts

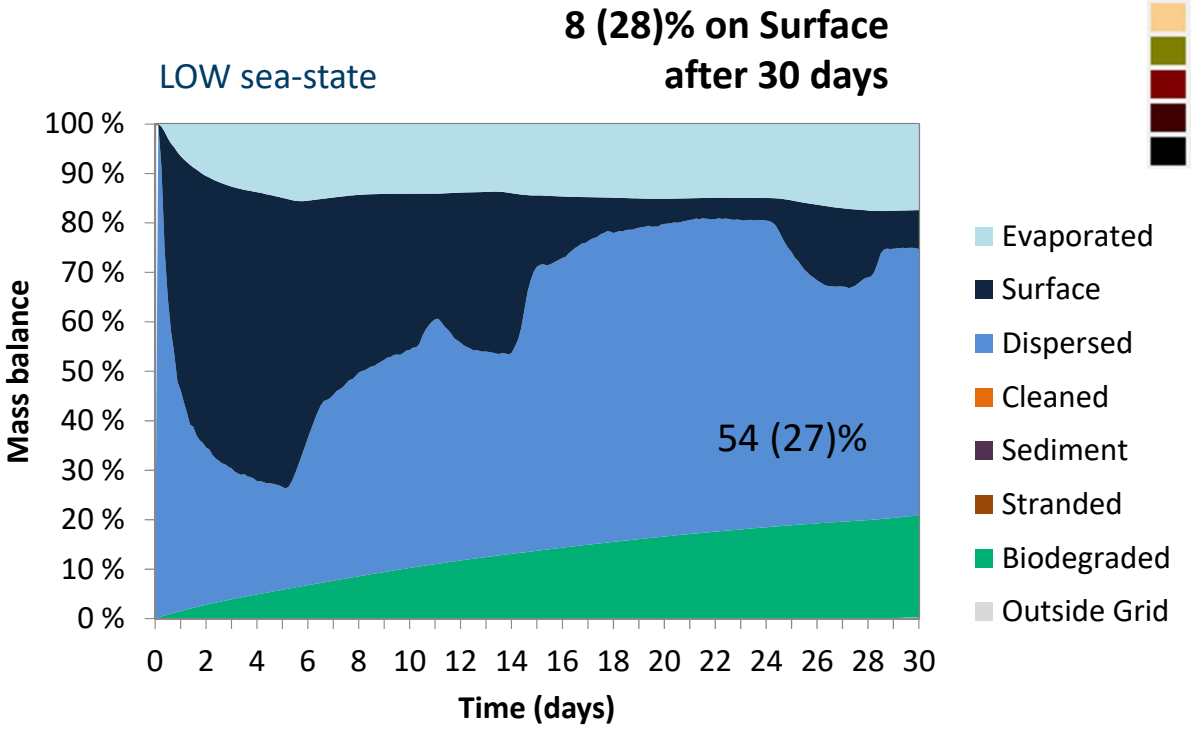


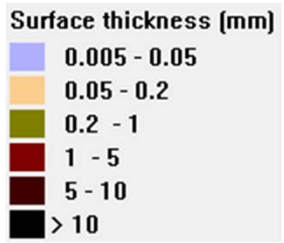
- 8 large system in operation after 7 days (1 h, 3 & 7d).
- Dispersant dosage: 4%.
- Full dispersant supply for 30 days.

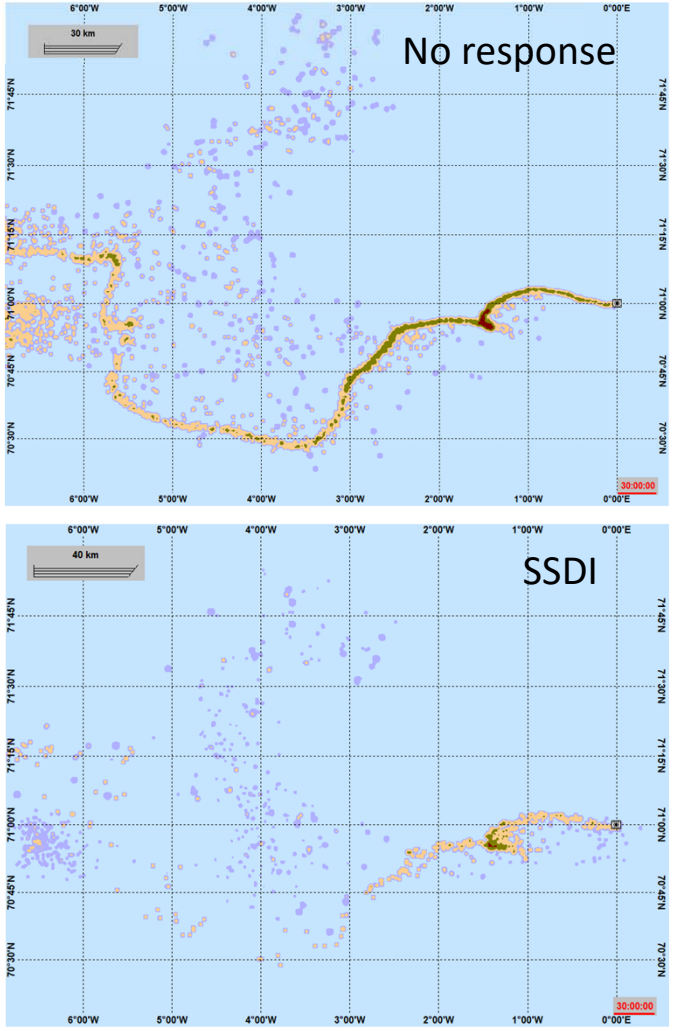


- 2 large airplanes in operation after 2 days.
- Each plane makes only 2-3 sorties per day due to long transit distance.
- Full dispersant supply for 30 days.

Scenario 3 – SSDI





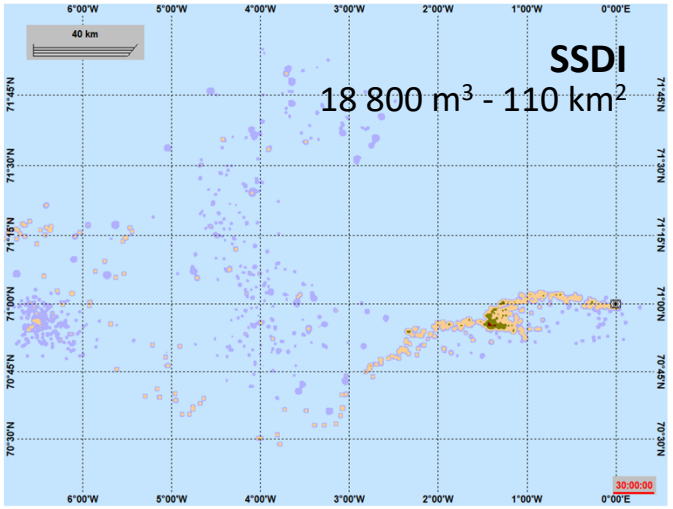


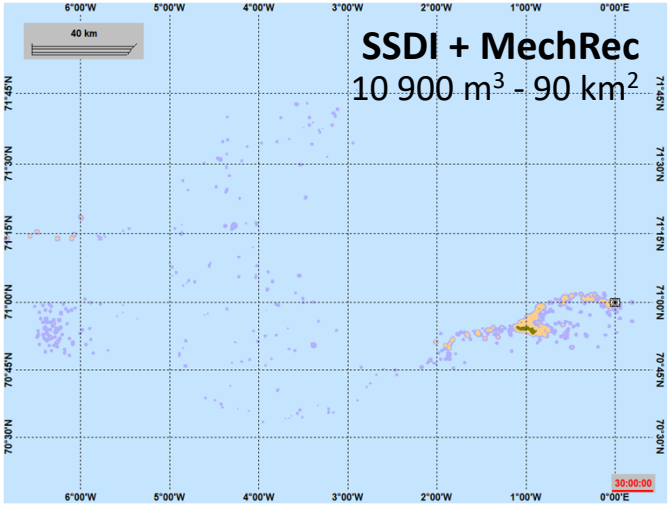
Distribution of surface oil after 30 days

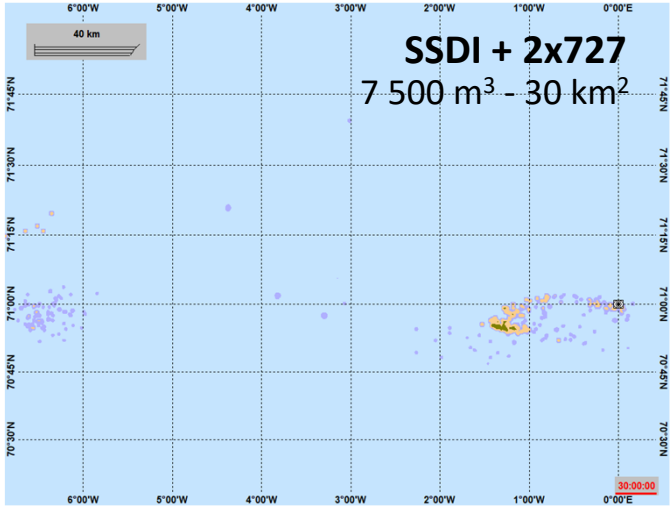
- Mobilization time dispersant kit: 5 days (2% dosage).
- New equipment for dosage control and effectiveness monitoring implemented (Oceaneering/SINTEF).

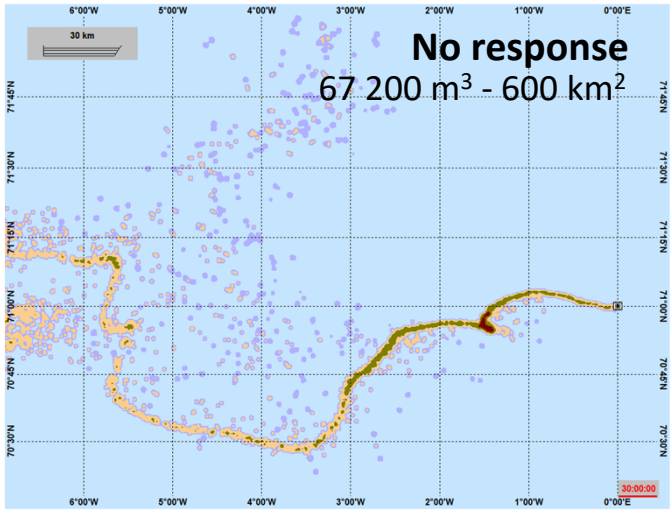
SSDI alone and combined

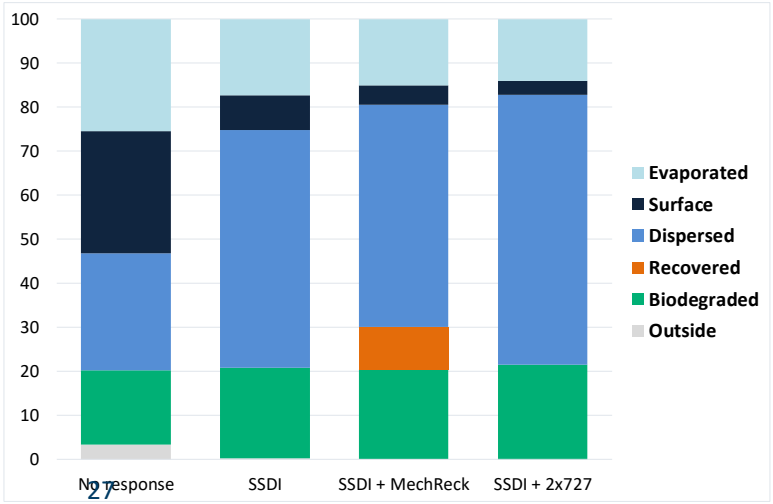
Distribution of surface oil after 30 days











Main conclusions

All response methods reduced remaining surface oil from 28% (no response) to 5-15%, except from:

a. Large-scale aerial dispersant application (19%), due to long transit distance.
b. Small booms (25%), due to low wave tolerance.
c. Small aircrafts (25%), due to a combination of both long distance and low speed.

Both:

a. Mechanical recovery specialised for demanding offshore conditions and
b. Dispersant spraying from specialised offshore vessels

gave response capacity (recovered or treated volumes) comparable with SSDI and aerial dispersant spraying.

All response methods showed low effectiveness at high sea-states, where high natural dispersion dominated the fate of the surface oil.