Revision of the Offshore Continental Shelf Oil Weathering Model: Phases II and III

for

U.S. Department of the Interior

Minerals Management Service

Anchorage, Alaska

by

SINTEF

Division of Marine Environmental Technology

Trondheim, Norway

Presentation Overview

- Project Summary
- Oil weathering studies
- Data sets for model testing and validation

Project Summary

Primary Objectives

1. Deliver and adapt the SINTEF Oil Weathering Model (OWM) to MMS needs;
2. Expand the OWM oil library to include oils of interest to MMS;
3. Develop and collate data sets identified in Phase I from experimental oil spills for validation testing of algorithms and OWM's.

Delivery and Adaptation the SINTEF Oil Weathering Model

- Delivered the SINTEF OWM Windows 95/NT Version 1+, manuals (1999)
- Training session, and license for Department of Interior-wide internal use
- Provided scheduled updates
  - Version 2.0 (2001)
  - Version 3.0 (2004)

Delivery and Adaptation the SINTEF Oil Weathering Model

Model improvements:

- Windows of opportunity for dispersant spill response
- Updating of the oil database
- Improved spreading algorithms for surface and sub-surface releases
- Simplified export to spreadsheets
- Arctic conditions (sea ice)
- Undersea blowouts and pipeline spills
- Import tool for external wind files
- Additional query options to filter oils from the database
- Revised user’s manual

Expansion of OWM database to include oils of interest to MMS

Weathering studies performed for crudes from Alaska and the Gulf of Mexico:

- Alaskan North Slope: 4 crude oils
- Gulf of Mexico: 2 crude oils

Development of Data Sets from Experimental Oil Spills for Model Testing and Validation

- Haltenbanken 1989
- Barents Sea Marginal Ice Zone (MIZ-experiment in ice) 1993
- NOFO-trial 1994
- NOFO-trial 1995
- NOFO-trial 1996 (limited data)
- UK trials 1997 (AEA-trials)
- Surface oil data from the Deep spill 2000 experiment

Final Report, Technical Summary, and Journal Article

Individual reports combined behind an Executive Summary in the Final Report.

- Final Report andTechnical Summary submitted in Draft and Final versions
- Bibliographic references supplied in Procite-importable format.

Summary Weathering Properties Alaskan North Slope and Gulf of Mexico Oils

- Alaskan North Slope
  - Alpine Composite
  - Endicott
  - Milne Point Unit (not tested, water content in the crude oil too high)
  - North Star
- Gulf of Mexico
  - High Island Composite
  - Neptune Field Composite

Knowledge about oil properties, fate and weathering behaviour is important for :

- Environmental Risk Analysis
- Contingency analysis and planning
- NEBA-analysis (Net Environmental Benefit Analysis)
  - Weighing of advantages and disadvantages of alternative oil spill responses for all aspects of environmental effects, <u>compared with “no response”</u>
- Oil spill response operations

  ⇒ rapid and right decision-making during combat operations

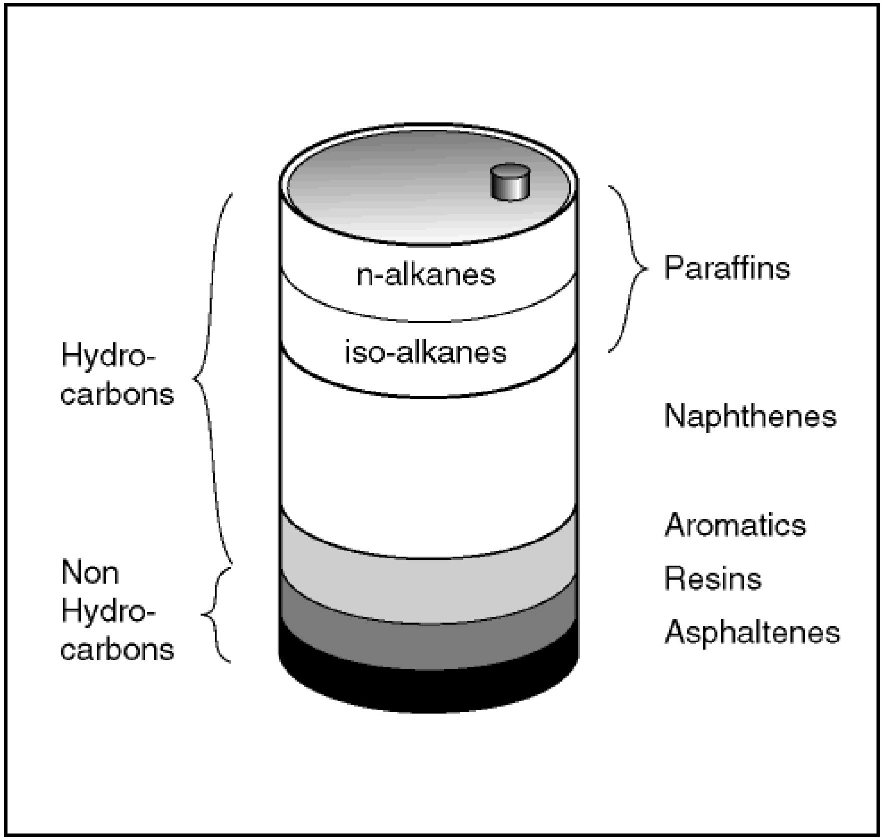
Objectives

Alaskan and Gulf of Mexico crude oils tested in order to :

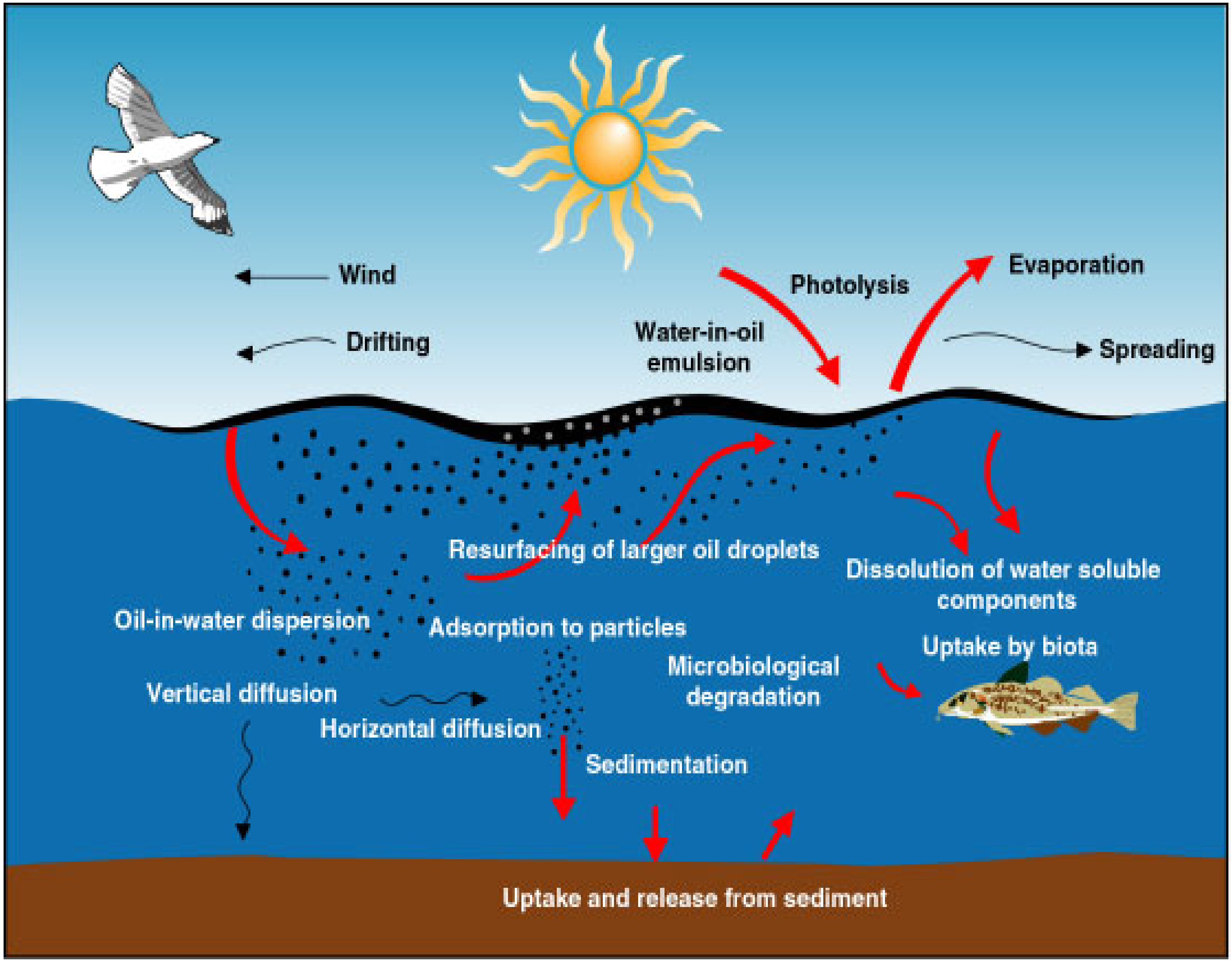
- investigated the weathering behaviour of the oils and discuss the properties related to respone
- expand the SINTEF OWM oil library to include the oils of interest to MMS

Crude oils

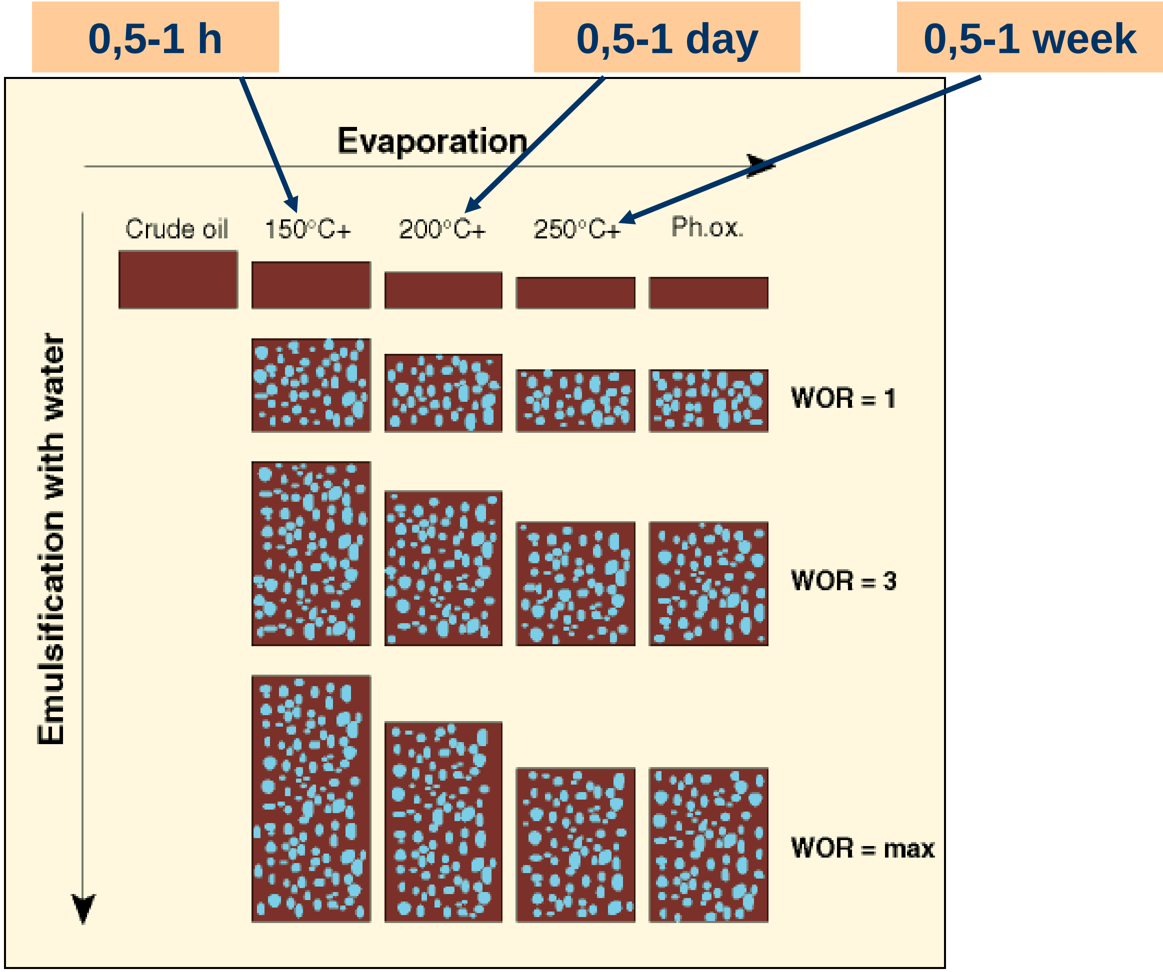
- Mixture of thousands of components
- Relative composition vary
- Physical properties of various crude oils are very different due to differences in chemical composition
- Crude oils may be accidentally spilt during production or transportation



Oils at sea – weathering processes



Bench-scale step-wise weathering study of an oil



16 different weathering samples from a fresh crude oil
Representing various weathering times at sea

Temperature conditions

- Alaskan North Slope crude oils
  - Tested at 10°C
  - Weathering predictions made at 0 and 10°C

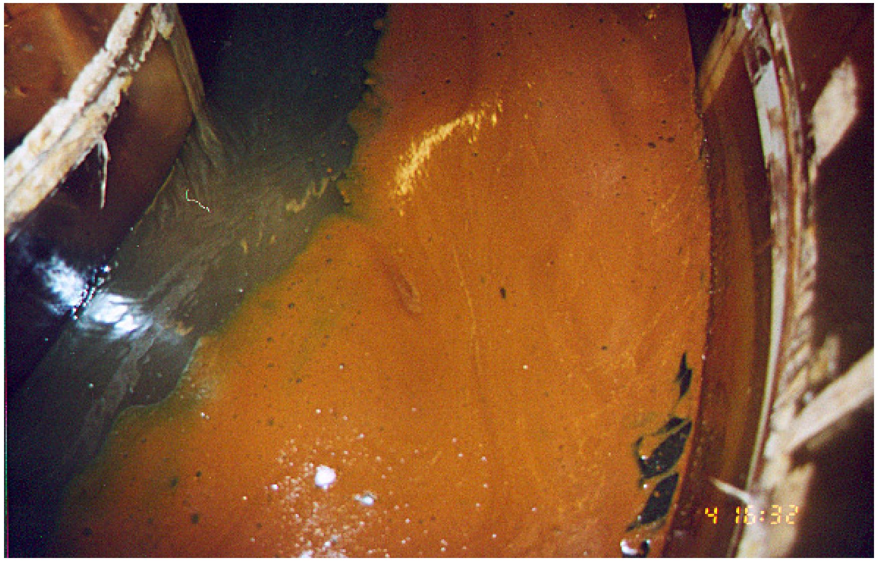
- Gulf of Mexico crude oils
  - Tested at 23°C
  - Weathering predictions made at 20 and 29°C

Crude oil properties

Oil type	Category of crude oil	Density (g/mL)
Alaskan North Slope crude oils		
Alpine Composite	Paraffinic	0,834
Endicott	Asphaltenic	0,913
Milne Point Unit	Naphthenic, biodegraded	approx. 0,95
North Star	Paraffinic	0,816
Gulf of Mexico crude oils		
High Island Composite	Naphthenic, biodegraded	0,85
Neptune Field Composite	Paraffinic	0,869

North Star - emulsification studies

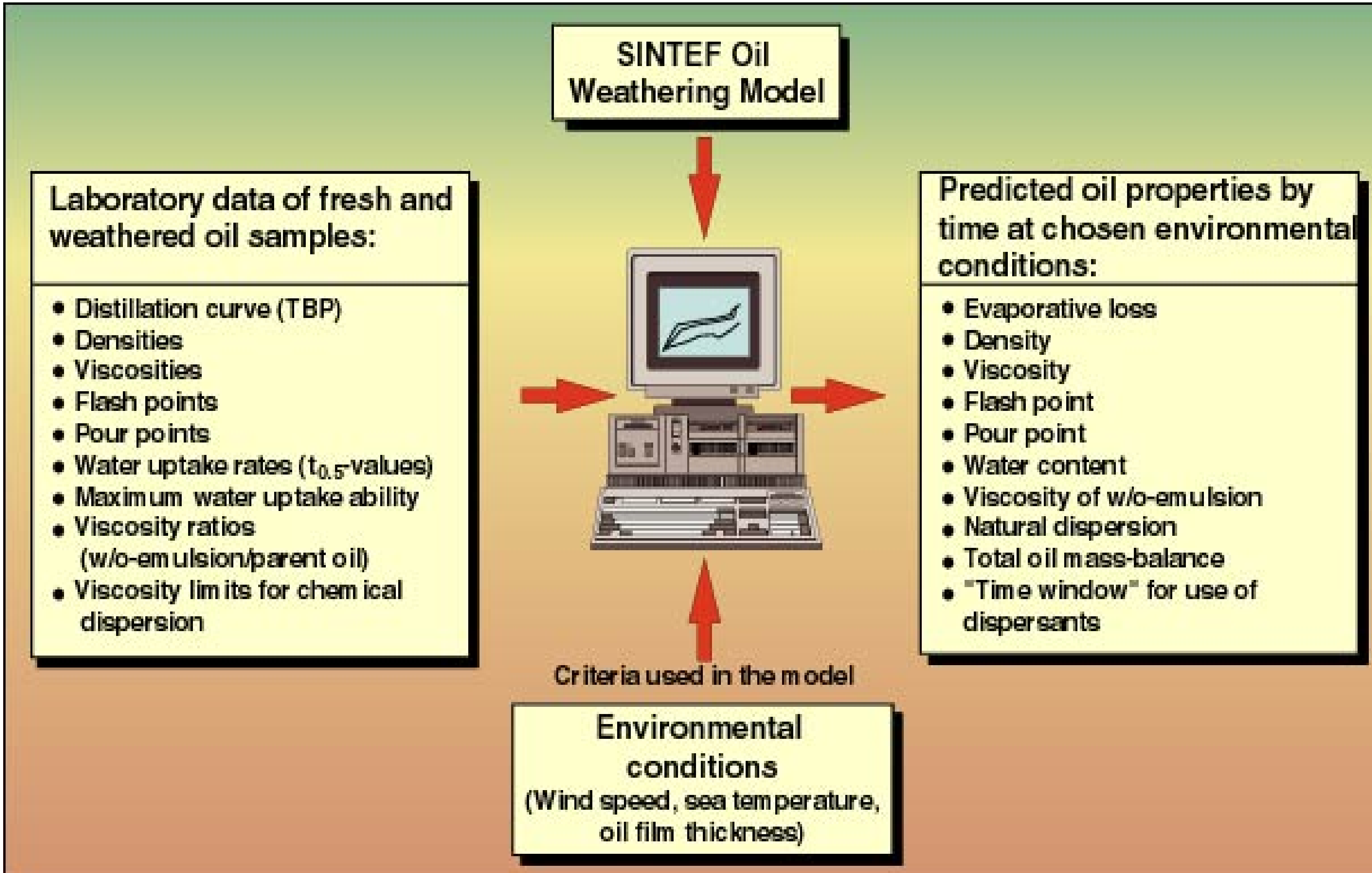
High Island in the meso scale flume



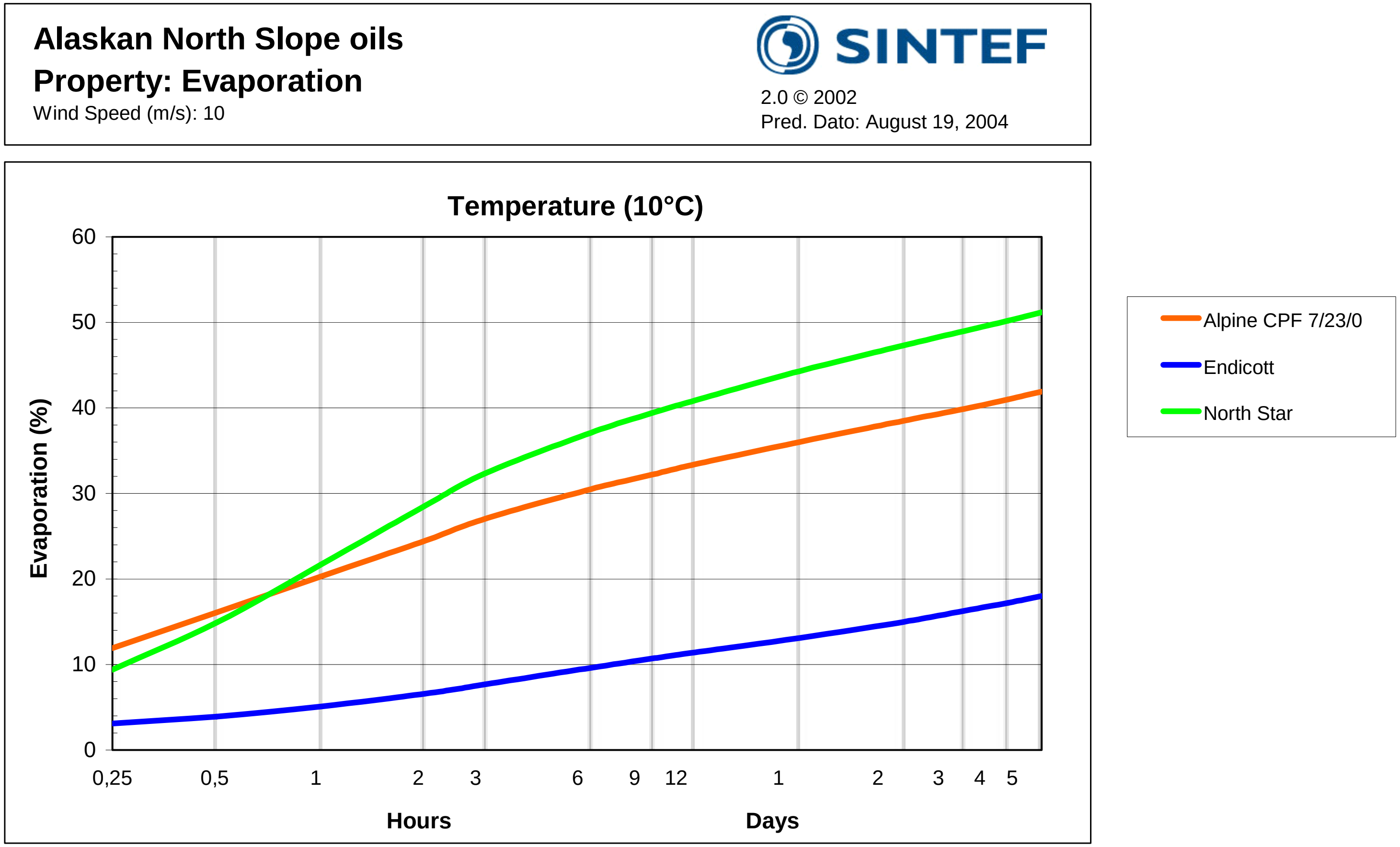
After 6 hours weathering

After 72 hours weathering

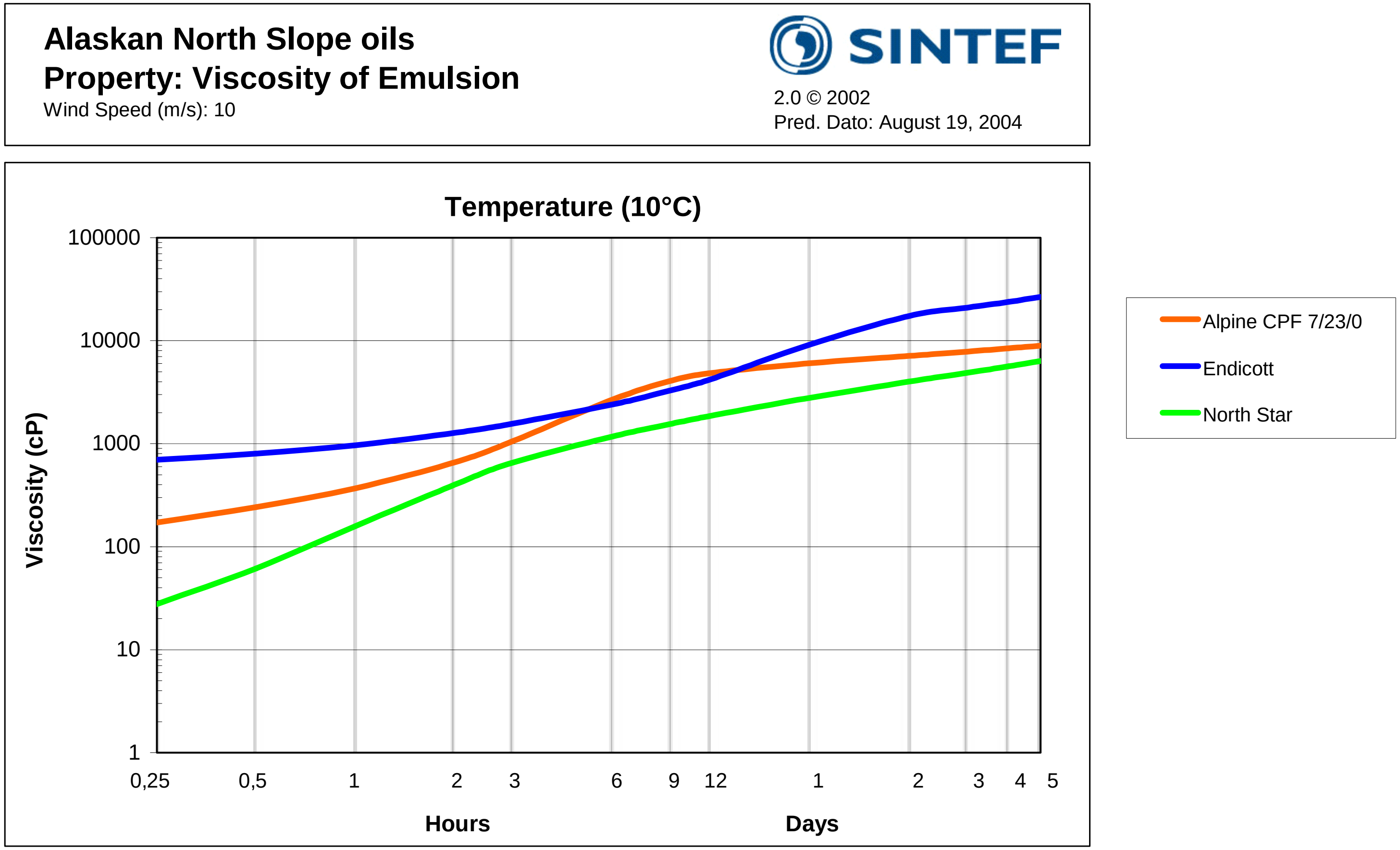
SINTEF Oil Weathering Model



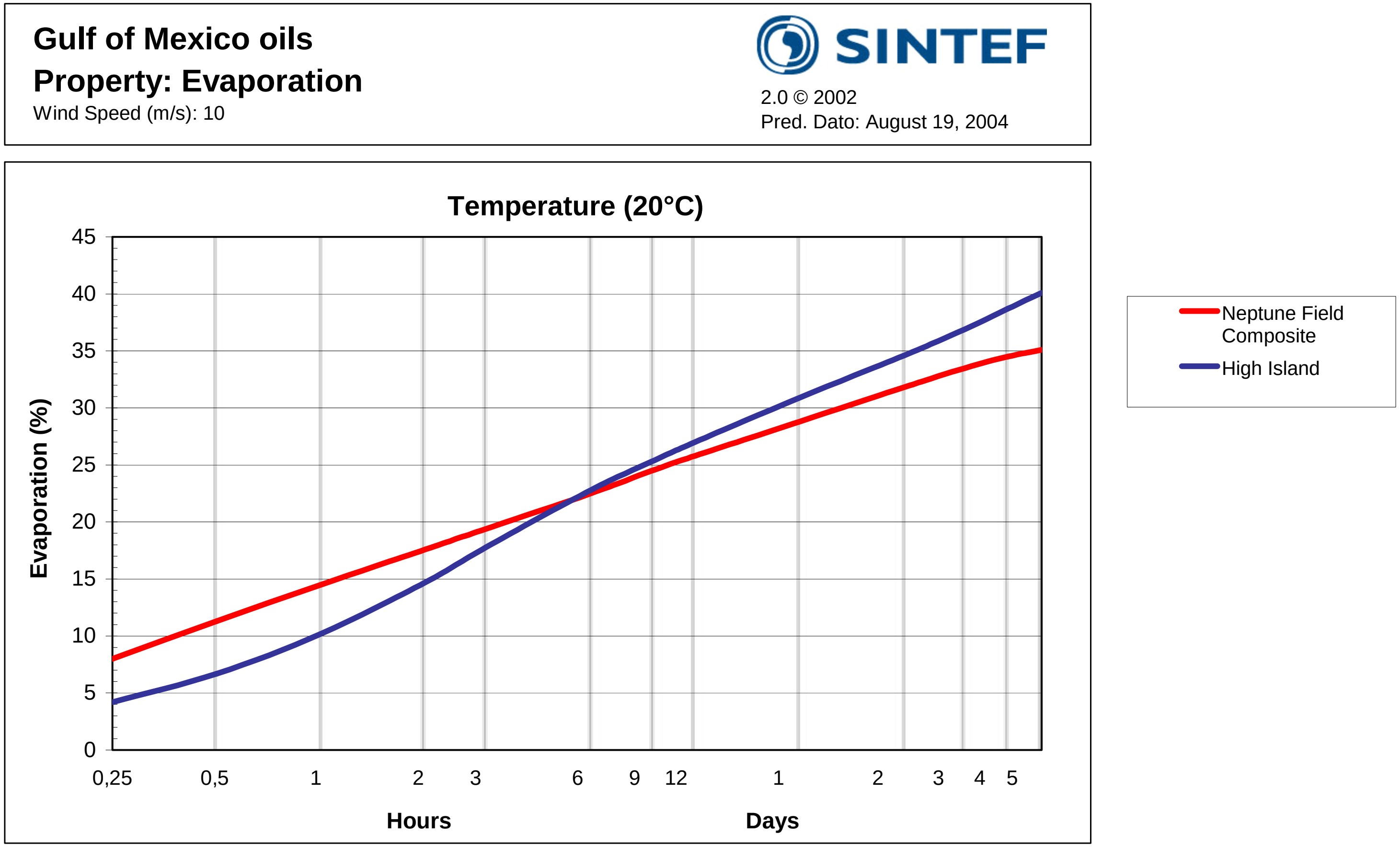
Alaskan North Slope oils - evaporation



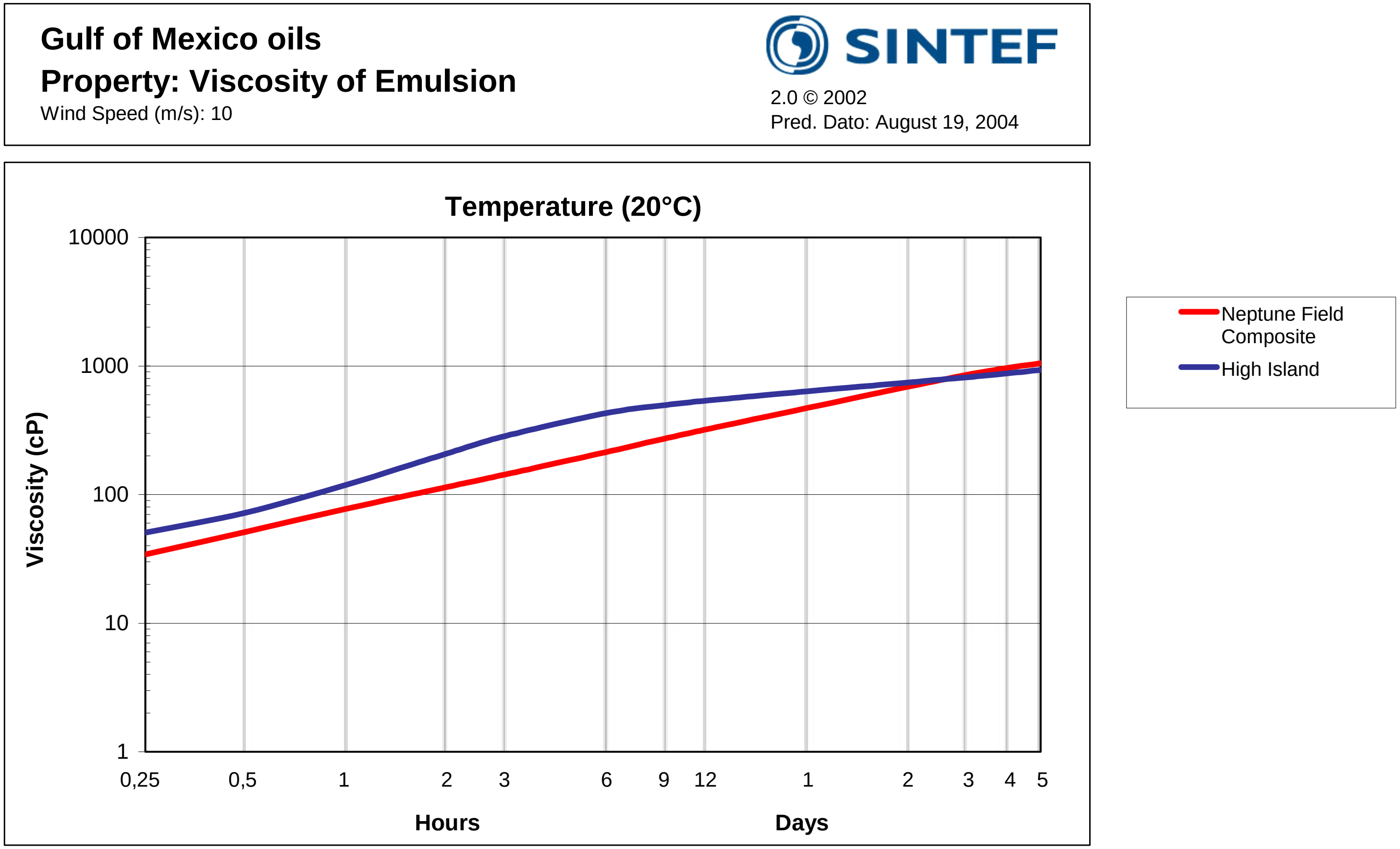
Alaskan North Slope oils – emulsion viscosity



Gulf of Mexico oils - evaporation



Gulf of Mexico oils - emulsion viscosity



Data sets for model testing and validation

- Haltenbanken 1989
- Barents Sea Marginal Ice Zone (MIZ-experiment in ice) 1993
- NOFO-trial 1994
- NOFO-trial 1995
- NOFO-trial 1996 (limited data)
- UK trials 1997 (AEA-trials)
- Surface oil data from the Deep spill 2000 experiment

Haltenbanken 1989

Full-scale experimental oil spill carried out to study several objectives:

- Evaluation of different types of oil spill drifters (Argos positioned buoys) versus oil drift
- Inter-calibration of different aerial surveillance systems
- Study of weathering processes of the Sture Blend crude (also here called Oseberg Blend)
- Study interactions between a drifting oil slick and sea birds

Haltenbanken 1989

Property: Emulsion viscosity
Temperature (°C) : 10
Wind Speed (m/s): Wind file
Initial film thickness (mm) : 20
Terminal film thickness (mm) : 2

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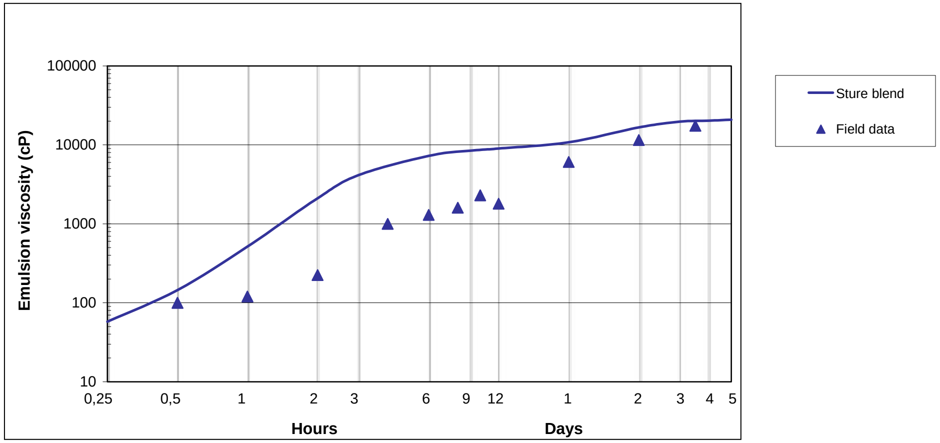

Property: Evaporation
Temperature (°C) : 10
Wind Speed (m/s): Wind file
Initial film thickness (mm) : 20
Terminal film thickness (mm) : 2

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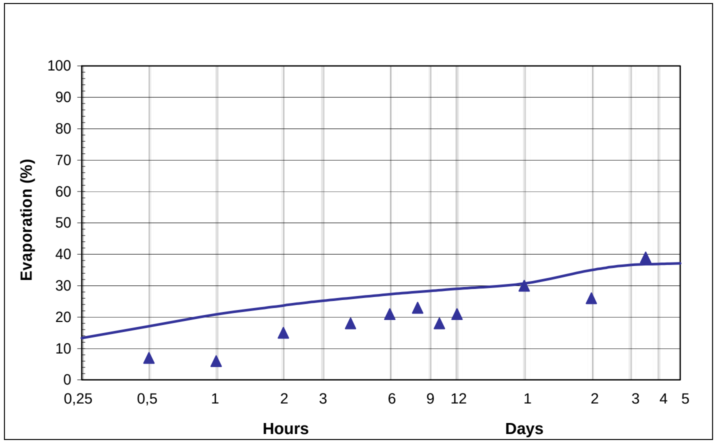

Property: Water uptake
Temperature (°C) : 10
Wind Speed (m/s): Wind file
Initial film thickness (mm) : 20
Terminal film thickness (mm) : 2

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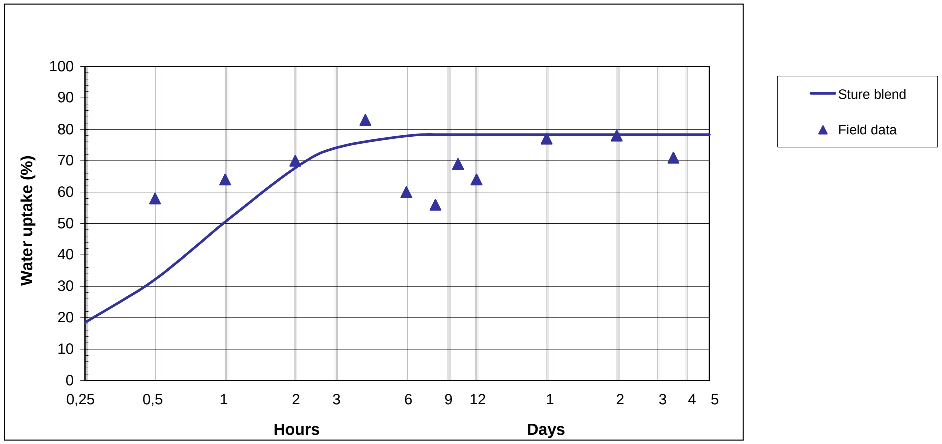

Good data time series:

- Evaporation
- Emulsification
- Water uptake

Barents Sea Marginal Ice Zone 1993

Objectives

- The intention of the experimental oil spill in the marginal ice zone was to contribute further to existing knowledge about the behaviour of oil under Arctic conditions and to acquire knowledge about the specific conditions (wind, waves, ice conditions, drift and spreading) in the marginal ice zone.

Barents Sea Marginal Ice Zone 1993

Property: Emulsion viscosity

Temperature : 0°C
Wind Speed (m/s): 8
Initial film thickness (mm) : 8 (in ice) and 20 (open waters)
Terminal oil film thickness (mm) : 8 (in ice) and 1 (open waters)

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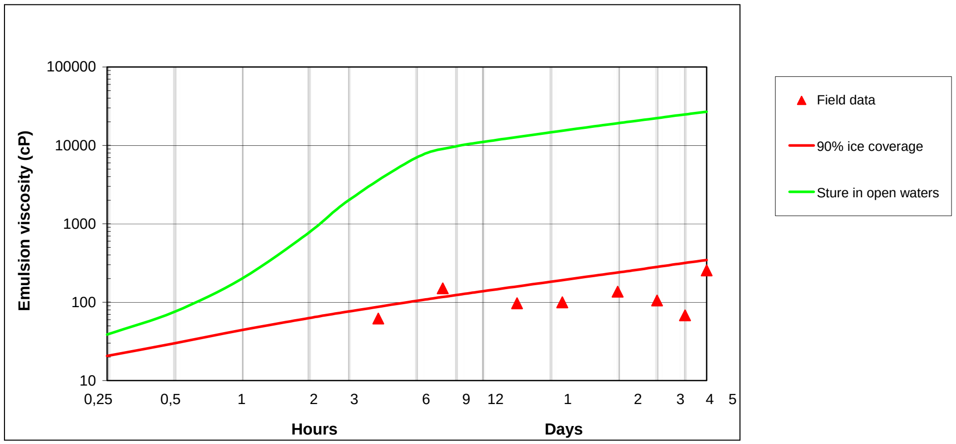
Pred. Dato: November 25, 2003



Property: Evaporation

Temperature : 0°C
Wind Speed (m/s): 8
Initial film thickness (mm) : 8 (in ice) and 20 (open waters)
Terminal oil film thickness (mm) : 8 (in ice) and 1 (open waters)

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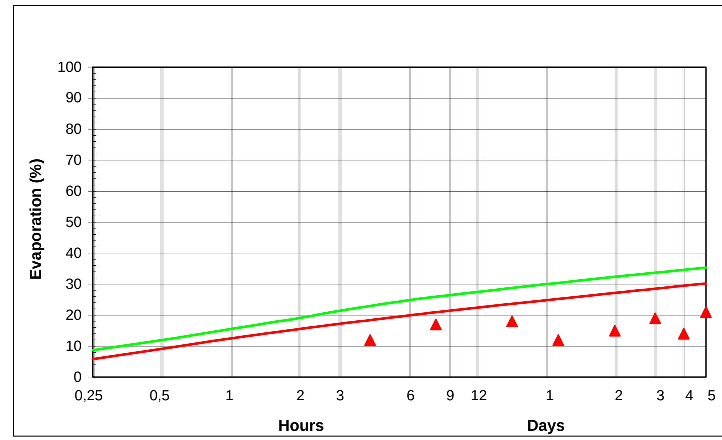
Pred. Dato: November 25, 2003



Property: Water uptake

Temperature : 0°C
Wind Speed (m/s): 8
Initial film thickness (mm) : 8 (in ice) and 20 (open waters)
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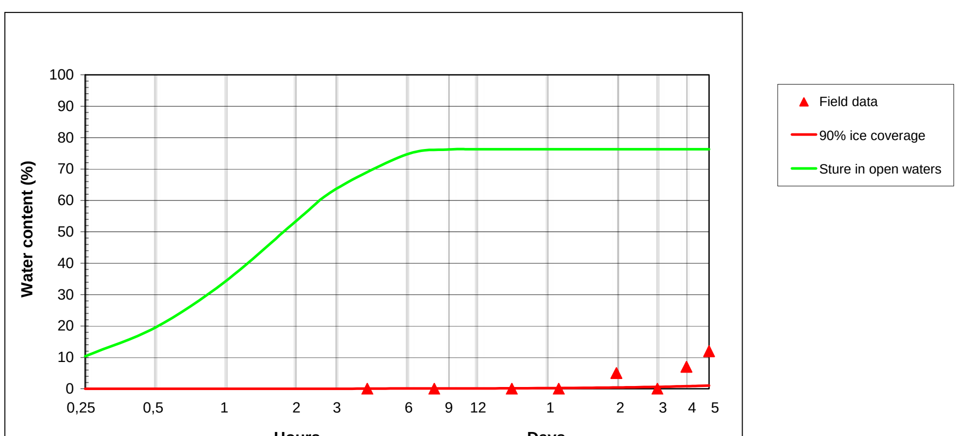

Data reveal significant differences in weathering rates as compared to open water conditions

NOFO Field Exercise 1994

The main objectives of the field trials were:

- To verify laboratory studies on rate of weathering (evaporation, natural dispersion and emulsification) of Sture Blend crude oil and determine the extent of changes in these processes caused by the application of dispersant.
- To assess quantitatively the effectiveness of aerially applied dispersant by following the fate and weathering properties of two slicks of partially weathered North Sea crude oil (one treated and one control slick).
- To define the operational parameters required for practical dispersant treatment strategies.
- To provide a realistic training scenario for oil spill combat personnel.

NOFO Field Exercise 1994

Property: Evaporation

Temperature (°C) : 10
Wind Speed (m/s): 7,5 - 10
Initial film thickness (mm) : 10
Termianl film thickness (mm) : 1

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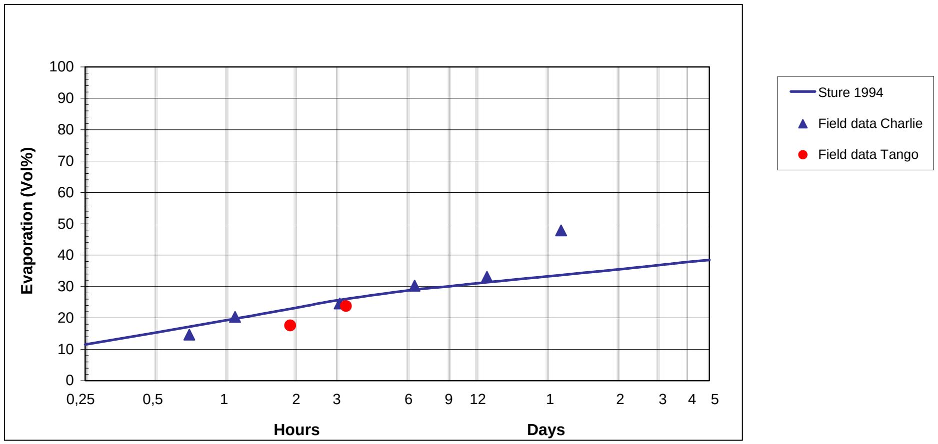

Property: Emulsion viscosity

Temperature (°C) : 10
Wind Speed (m/s): 7,5 - 10
Initial film thickness (mm) : 10
Terminal film thickness (mm) : 1

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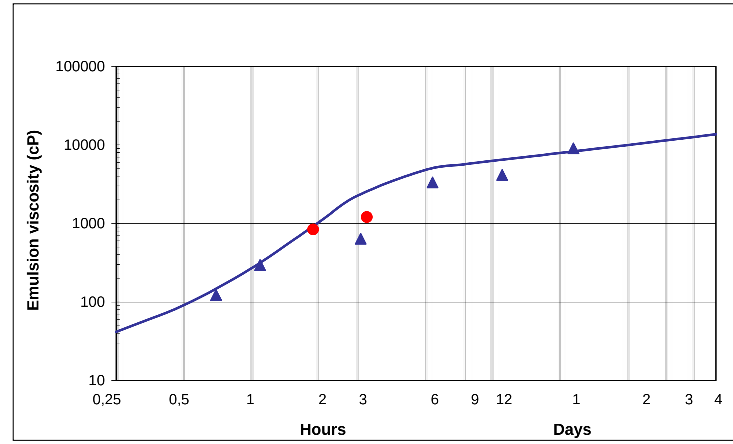

Property: Water content

Temperature (°C) : 10
Wind Speed (m/s): 7,5 - 10
Initial film thickness (mm) : 10
Terminal film thickness (mm) : 1

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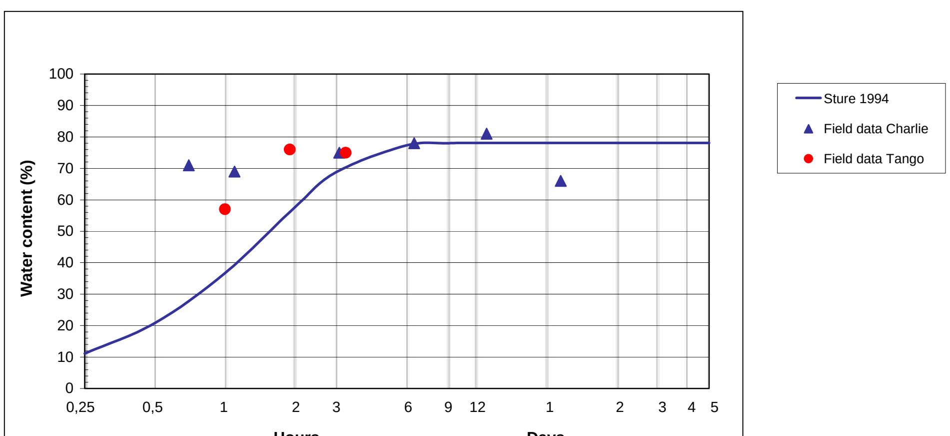


Dispersant applications resulted in decreased water content and viscosity of emulsion.

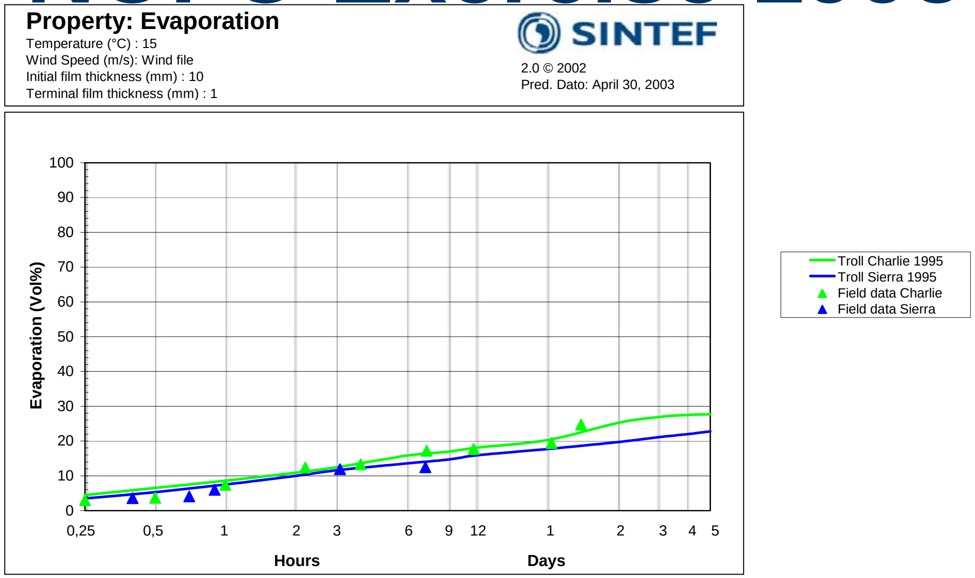
Emulsion disappeared totally into the water column.

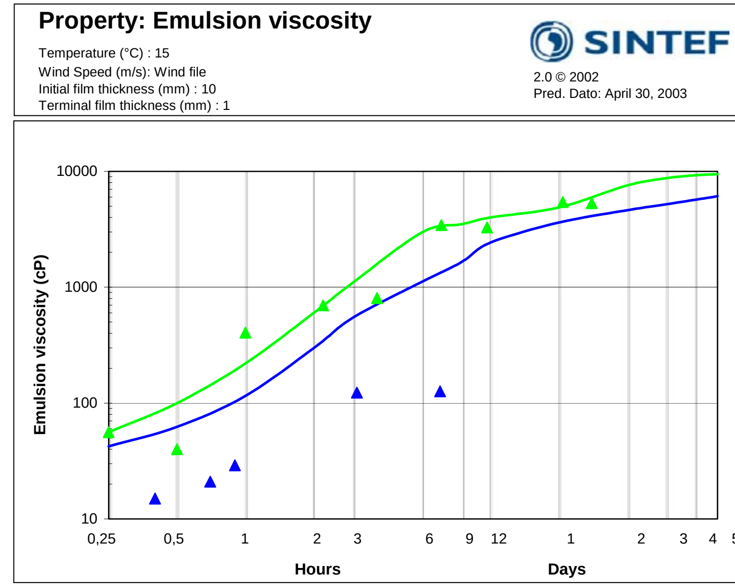
NOFO Exercise 1995

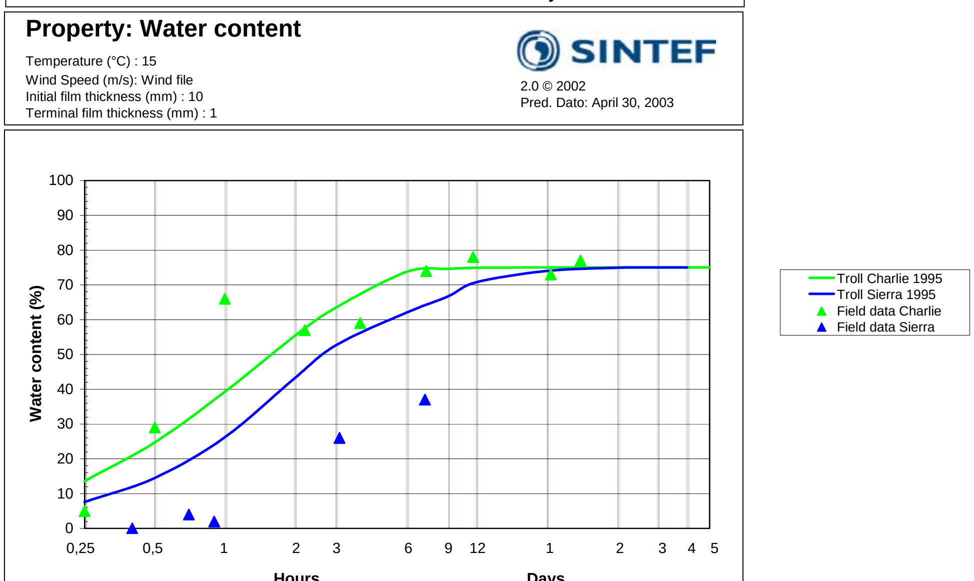
Objectives (dispersant application and underwater releases)

- Study the behavior, rate of spreading and weathering (evaporation, emulsification, natural dispersion etc.) of crude oil slicks released both from surface and sub-surface (107 meters depth simulating sub-sea pipeline leakage).
- Provide input data to the SINTEF OWM, as the basis for further refinements of algorithms in the model.
- Assess the effectiveness of different methods of applying dispersant concentrates on oil slicks (from boat and helicopter).
- Study the capability of satellite-tracked drifting buoys to simulate the drift of surface and dispersed oil under various environmental conditions.
- Calibrate aerial remote sensing sensors (in aircraft, helicopter, and satellites) with ground truth data of the surface oil slicks.

NOFO Exercise 1995







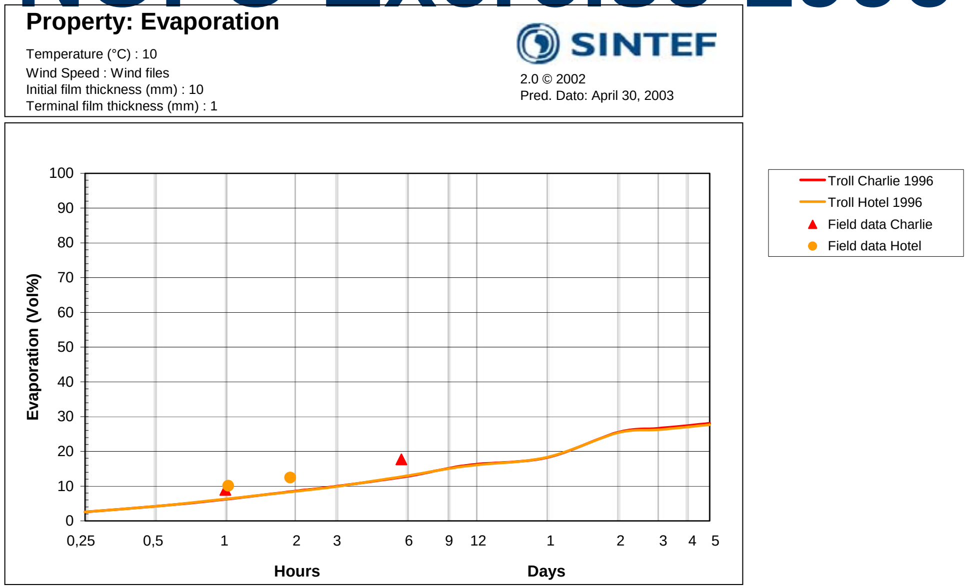
- A modern dispersant, correctly applied with a helicopter bucket or with spray arms from a ship, within the “window of opportunity” for dispersant use, is capable of dispersing thick oil completely, within 10-30 minutes.
- No significant emulsification of the oil in the underwater plume was observed.

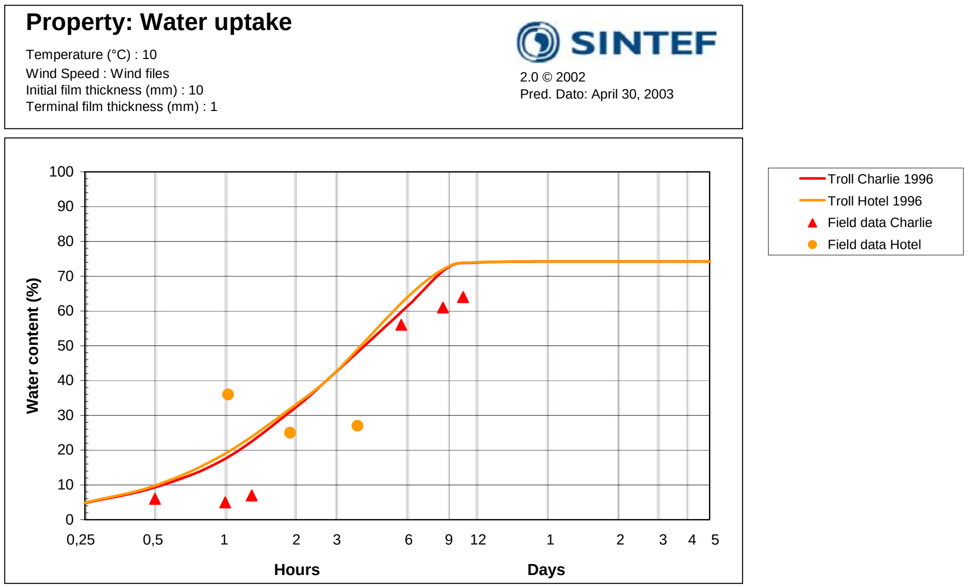
NOFO Exercise 1996

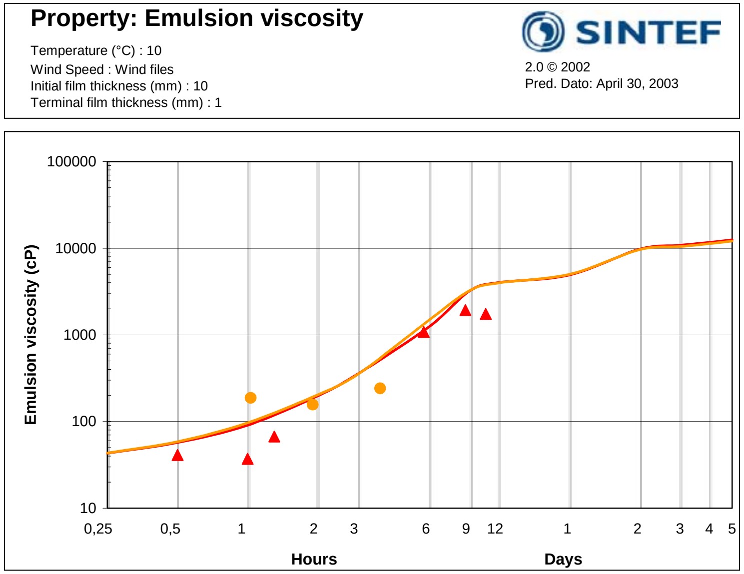
Objectives

- To determine how the weathering processes (evaporation, water-in-oil emulsification and natural dispersion) of Troll crude oil proceeded in the control (Charlie) and the treated slick (Hotel, treated by helicopter with the new “Response 3000” bucket) after dispersant application.
- To determine how the surface slick resulting from the underwater release (designated Uniform) of Troll crude oil combined with gas (GOR of 1:67), behaved.
- The field trials in both 1995 and 1996 were performed in order to form basis for building up an operational and cost-effective dispersant response in Norway (for terminals, refineries, offshore oil fields etc.).

NOFO Exercise 1996







Troll crude oil emulsified slowly and reached a maximum water content of approximately 60 vol.% and a viscosity of 2000 cP (shear rate 10 s-1) after 10 hours weathering at the sea surface. These measured values were lower than the predicted values due to unstable emulsions. The weather conditions were rather calm, with an average wind speed of about 4 to 5 m/s, and too low to cause breaking waves. The same situation occurred during the August 1995 trials when the Sierra slick was monitored on Day 2 (5 to 6 m/s wind).

AEA field experiments UK 1997

Purpose

- to measure changes in oil properties during weathering at sea, and
- to determine the period of time during which Corexit 9500 can be considered as a viable response option for these oils:
  - 50 m^3 Forties oil weathered for 2 days at sea prior to treatment with 2.5m^3 Corexit 9500
  - 20 m^3 IFO-180 Heavy bunker fuel weathered for 4.5 hours at sea prior to treatment of 0.9 m^3 Corexit 9500 followed by a 2nd treatment 23-25 hours at sea (2.0 m^3 Corexit 9500)
  - 31 m^3 Alaska North Slope (ANS) crude (designated "Alpha") weathered for 2.5 days at sea prior to treatment of 1.0 m^3 Corexit 9500

AEA field experiments UK 1997

Property: Emulsion viscosity
Temperature (°C) : 15
Wind Speed (m/s): Wind file
Initial film thickness (mm) : 20
Terminal film thickness (mm) : 1

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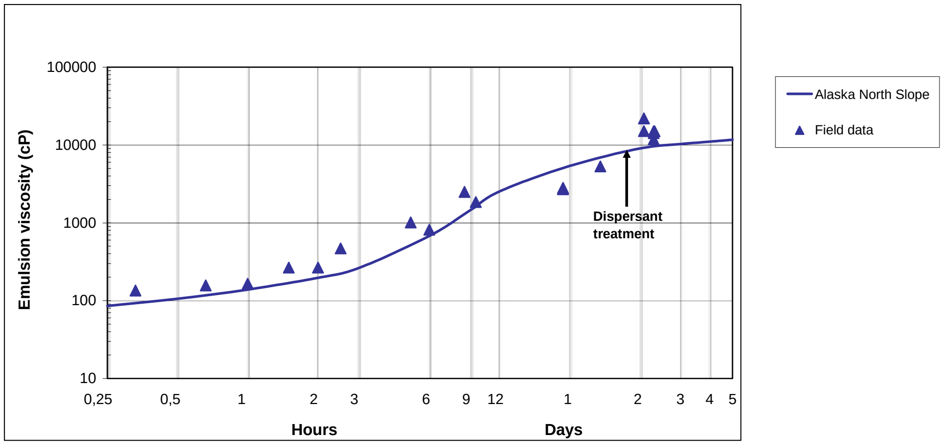

Property: Water content
Temperature (°C) : 15
Wind Speed (m/s): Wind file
Initial film thickness (mm) : 20
Terminal film thickness (mm) : 1

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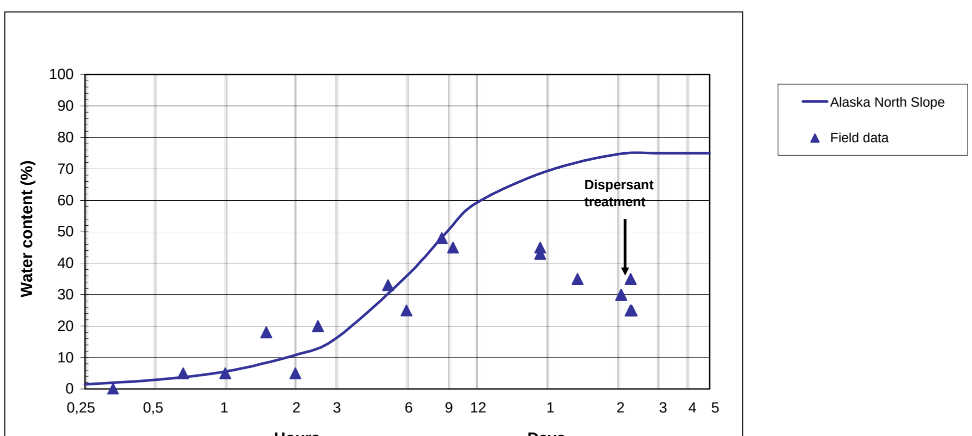


Compared to earlier studies carried out with Corexit 9527 at SINTEF, Corexit 9500 shows an improvement in the dispersibility up to a viscosity of 20.000 cP on the ANS emulsions.

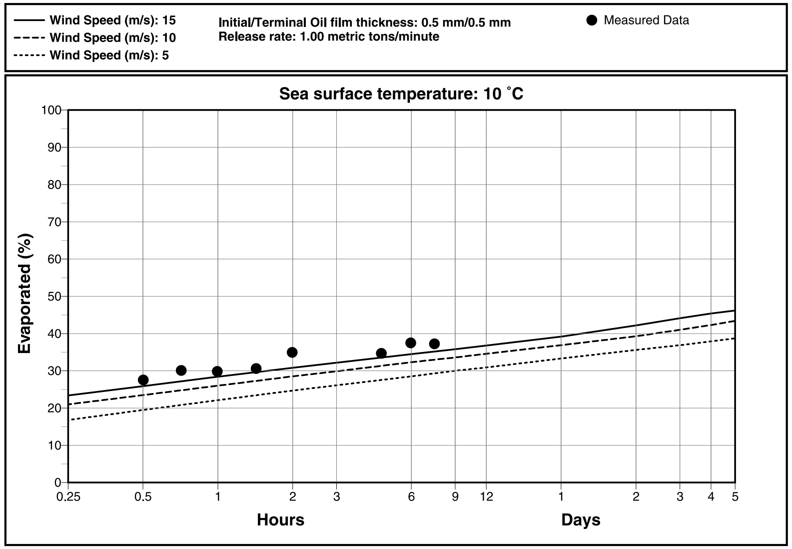
This gives a significant increase in the "time window" for effective use of dispersant on the ANS crude.

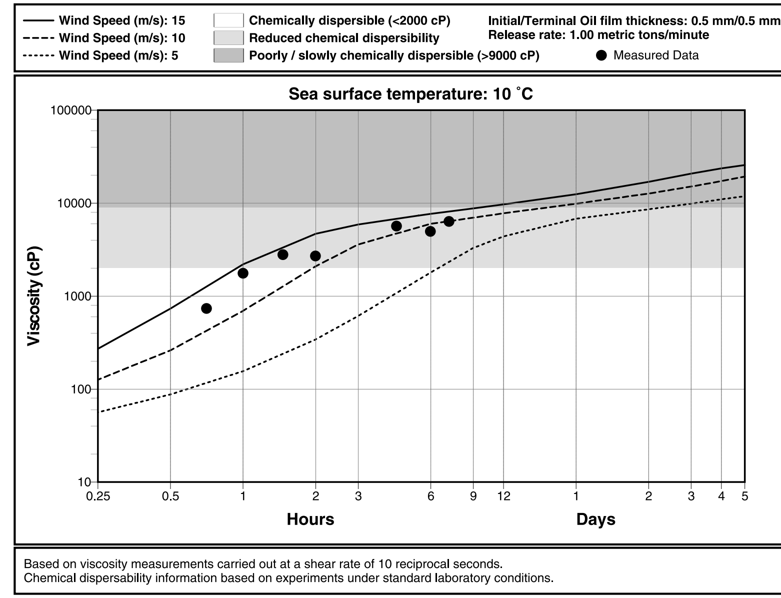
Deep Spill JIP 2000

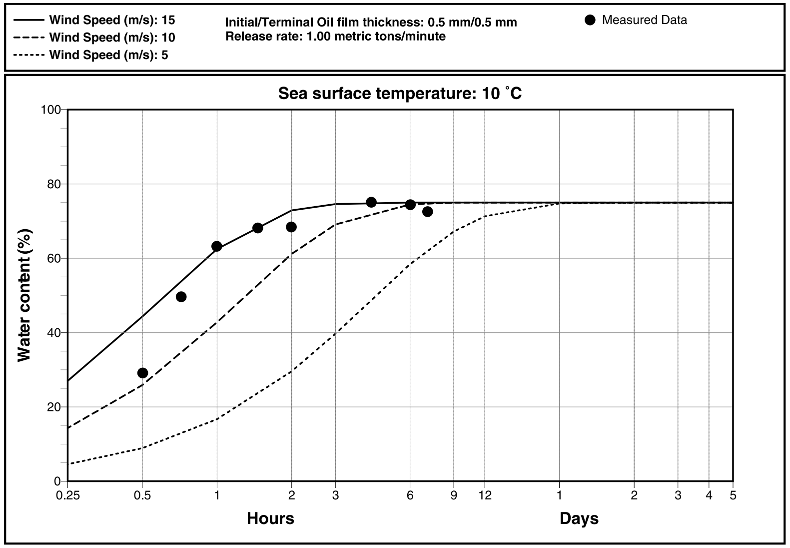
Primary objectives

- to obtain data for verification and testing of numerical models for simulating accidental releases in deep waters;
- to test equipment for monitoring and surveillance of accidental releases in deep waters;
- to evaluate the safety aspect of accidental releases of gas and oil in deep waters.

Deep Spill JIP 2000







Experiments were conducted at 844 m depth in the Helland Hansen region in the Norwegian Sea.

60 m3 marine diesel and 60 m3 Sture blend together with 18 m3 liquefied natural gas (LNG) equivalent to 10 000 m3 of gas at atmospheric pressure released from a discharge platform lowered to the seabed

Data sets for model testing and validation: summary

Input data and field measurements are supplied in the report for each field trial

- Wind data
- Distillation curves for oils
- Crude assay data
- Oil weathering data
- Field measurements
  - Emulsion
    - Density
    - Water content
    - Viscosity
    - Stability
  - Surface film thickness