Burning oil on ice

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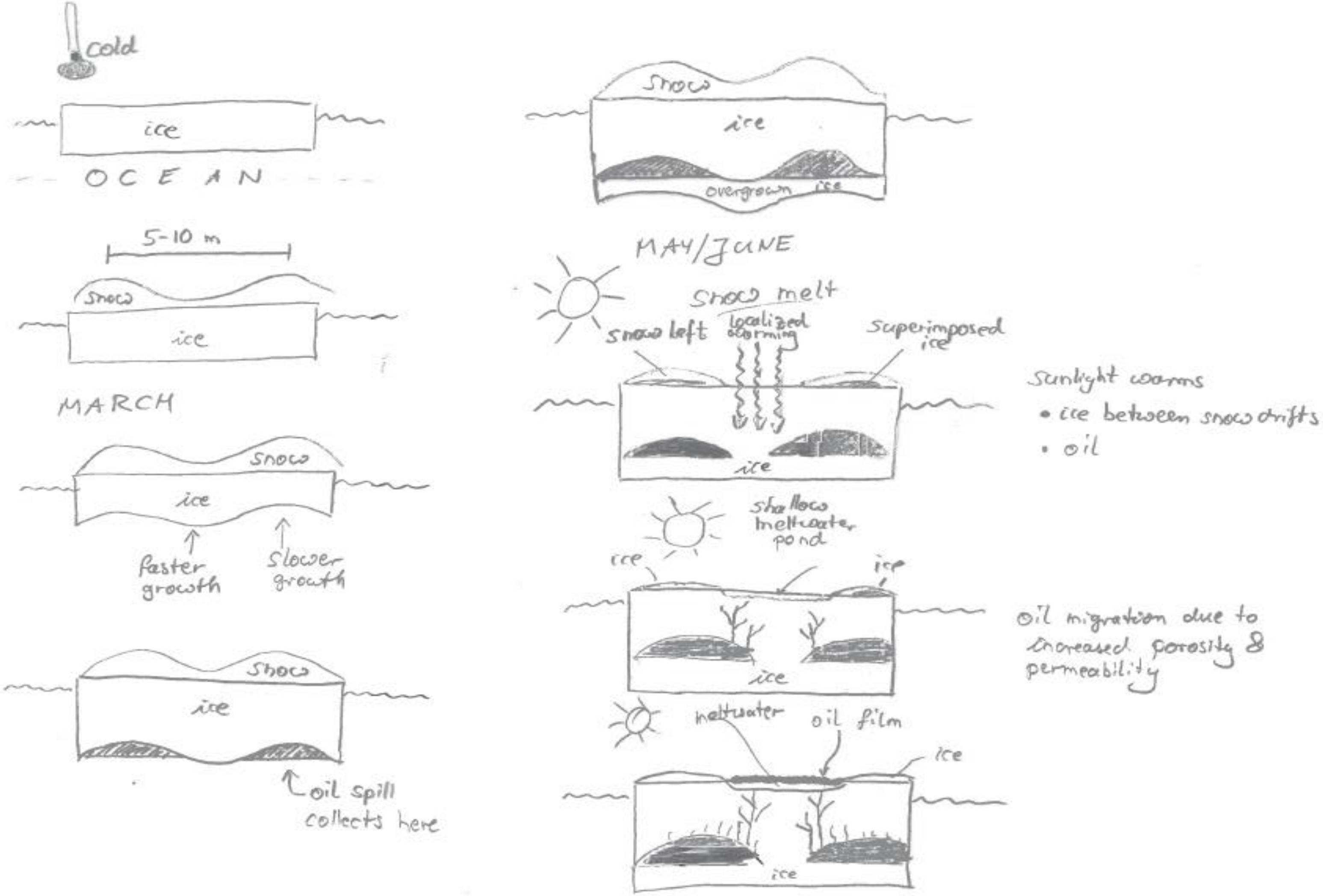
GRACE

http://www.grace-oil-project.eu/

Background

- Sea ice is porous - the porosity and connectivity of pores increases as the ice warms
- Oil moves upward through the connected pore space if pores are sufficiently large



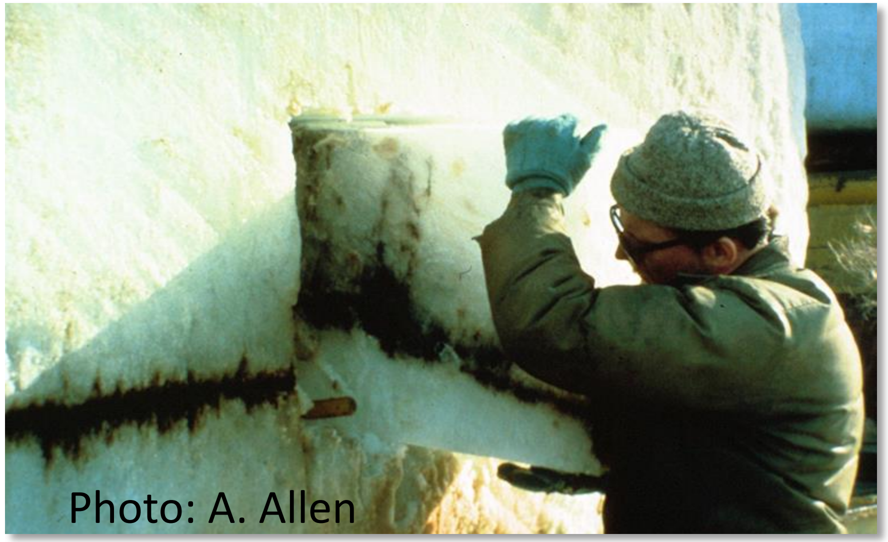
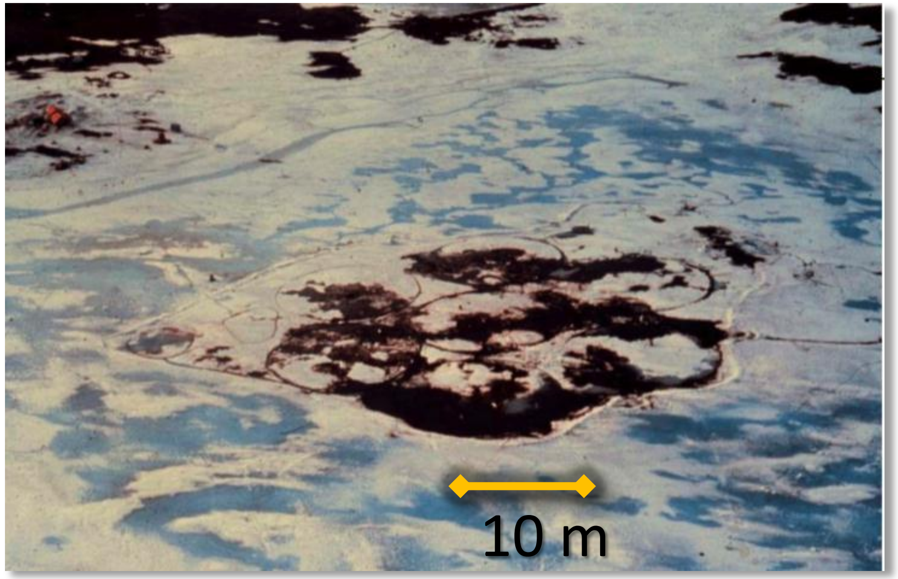


Photo: A. Allen

Schematic of the melt process from the perspective of oil. C. Petrich (Fritt-Rasmussen and Petrich 2017)

Background



NORCOR 1975 in Dickins (2011)

D. Dickins

Purpose of project and burning experiments

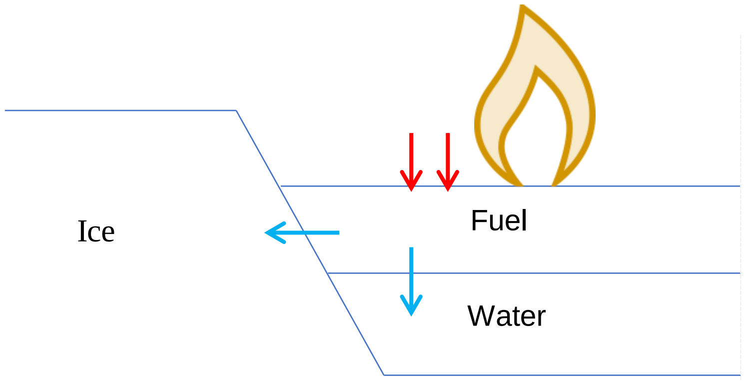
- Guiding question from proposal:

  How much oil can we expect to remove by in situ burning given the conditions of oil and ice at a certain time?

- Assess [...] (c) **feedbacks of burning oil** (heat release) on **ice surface** properties (affecting the lateral extent of pools, merging of pools, and change in oil slick thickness), and **internal ice deterioration** (affecting the rate of oil release to the surface).

...In other words study:

- Spreading of a burning oil pool
- Melt/warming of ice



Heat loss: conduction through the sides and bottom →
Heat input: heat from flames by convection and radiation →

Simple outline of the heat release transfer mechanisms of burning fuel (Fritt-Rasmussen and Petrich 2017).

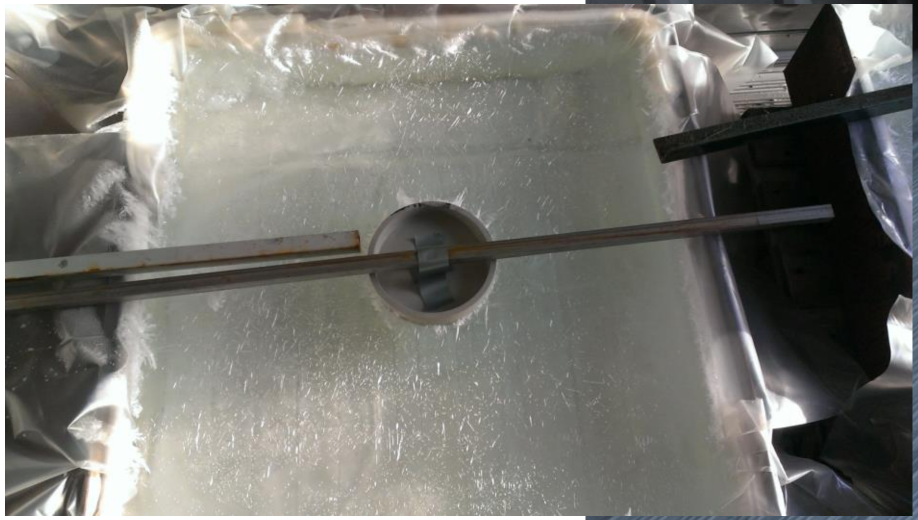
In situ burning on ice - Experiments

- Spreading of a burning oil pool
- Melt/warming of ice

Experiments took place on freshwater ice to facilitate thermal analysis (heat flux, energy budget etc.).

In situ burning on ice - Experiments

Ice growth
with
prepared pool for oil

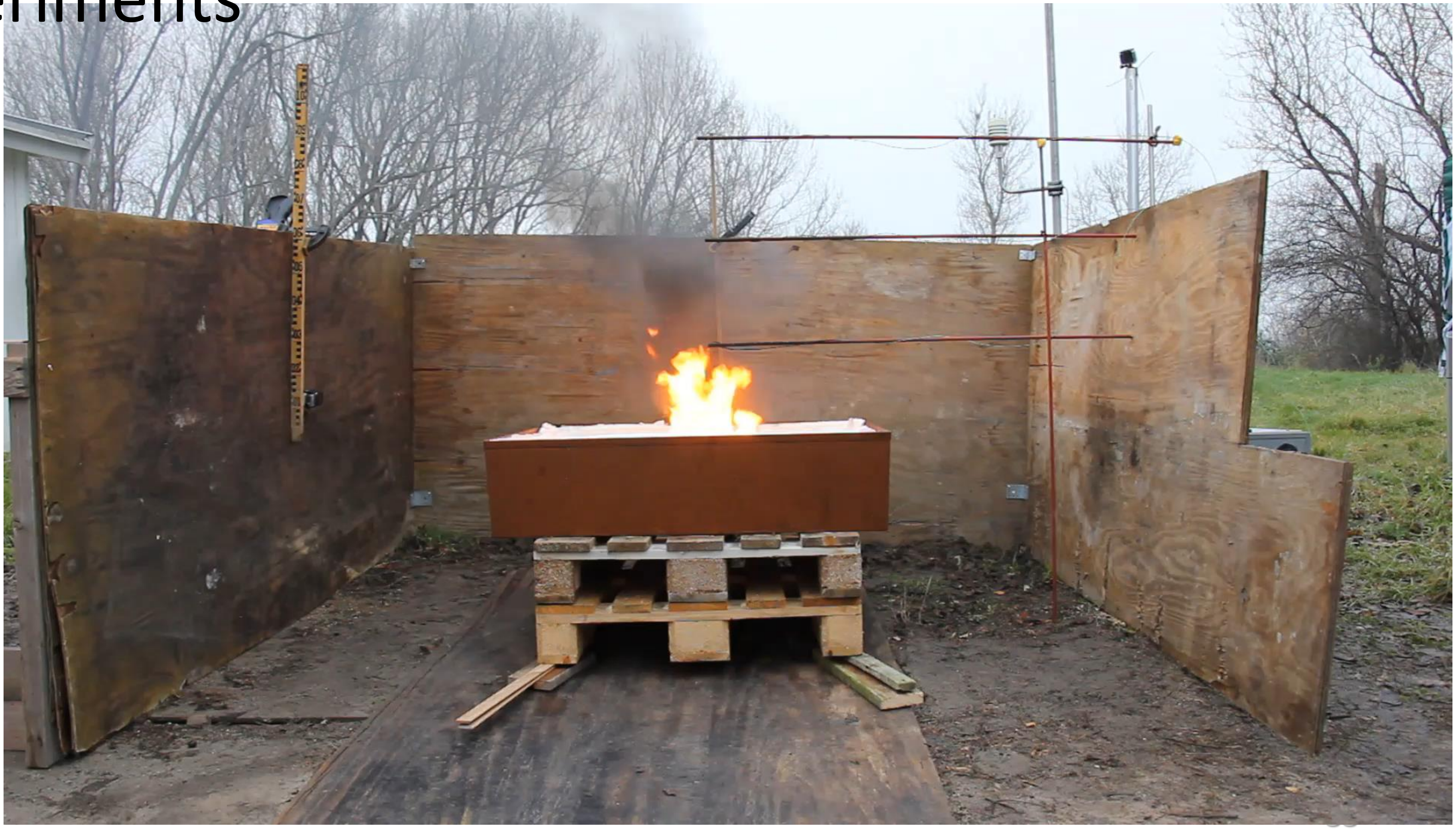


In situ burning on ice - Experiments

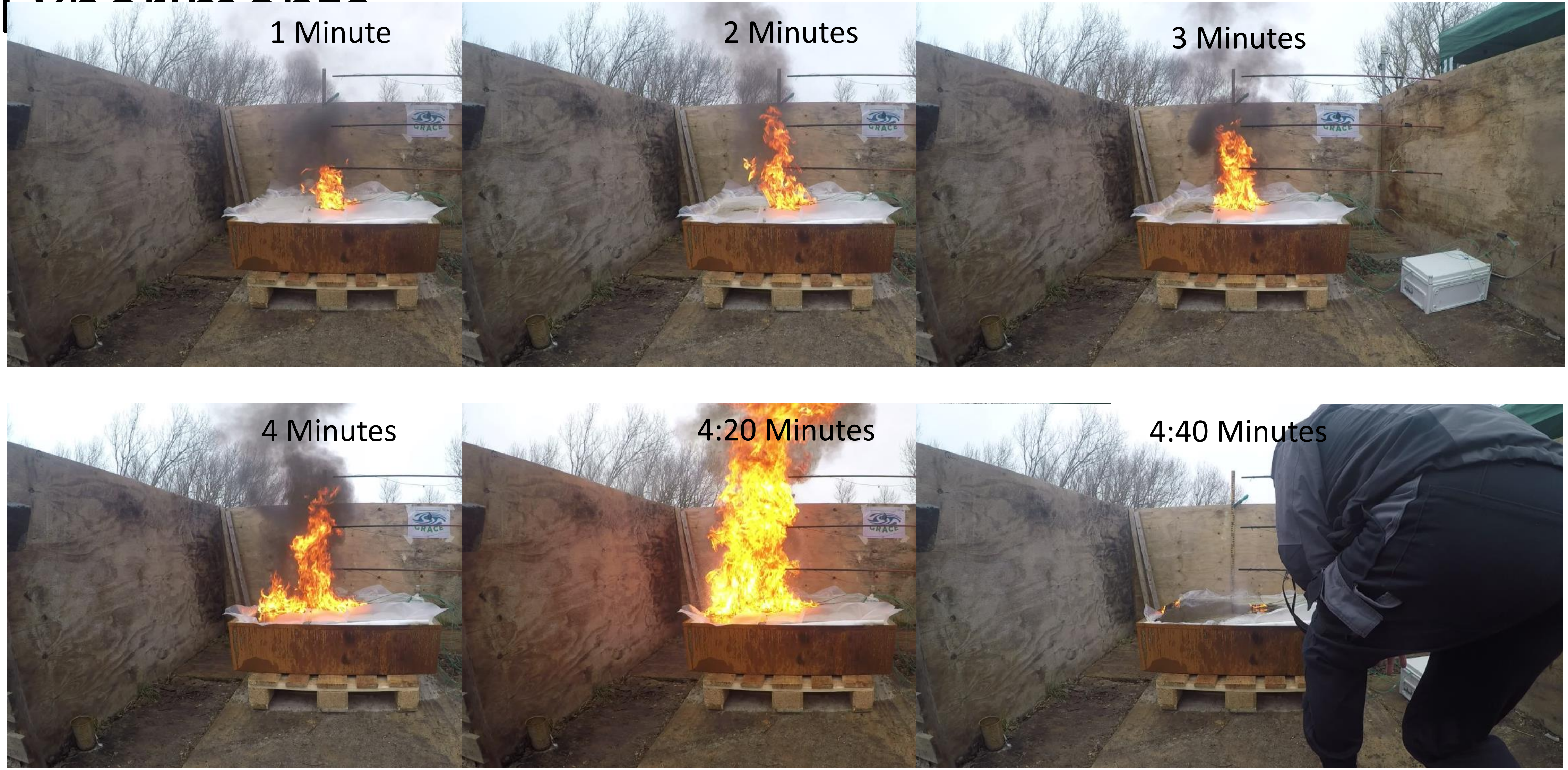
Connection of 20+ temperature sensors

Measurement of two surface profiles each before and after the burn

In situ burning on ice - Experiments



In situ burning on ice - Experiments



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In situ burning on ice - Experiments

Oil residue collection

In situ burning on ice - Experiments

Test completed

- Initial run October 2017
  - Set-up design, dry run due to wind from wrong direction
- First oil on ice test October 2017 (burn #1)
  - Buckled ice surface
- 4 tests in November 2017 (burn #2,#3,#4,#5)
  - Flat surface ice, Naphtenic crude oil
- 21 Mar 2018 (burn #6,#7)
  - Flat surface ice, Naphtenic crude oil
- *December 2018 (burn #8,#9,#10,#11)*
  - *Flat surface ice, Naphtenic crude oil*
- *February 2019 (burn #12,#13,#14,#15)*
  - *Flat surface ice, Naphtenic crude oil*

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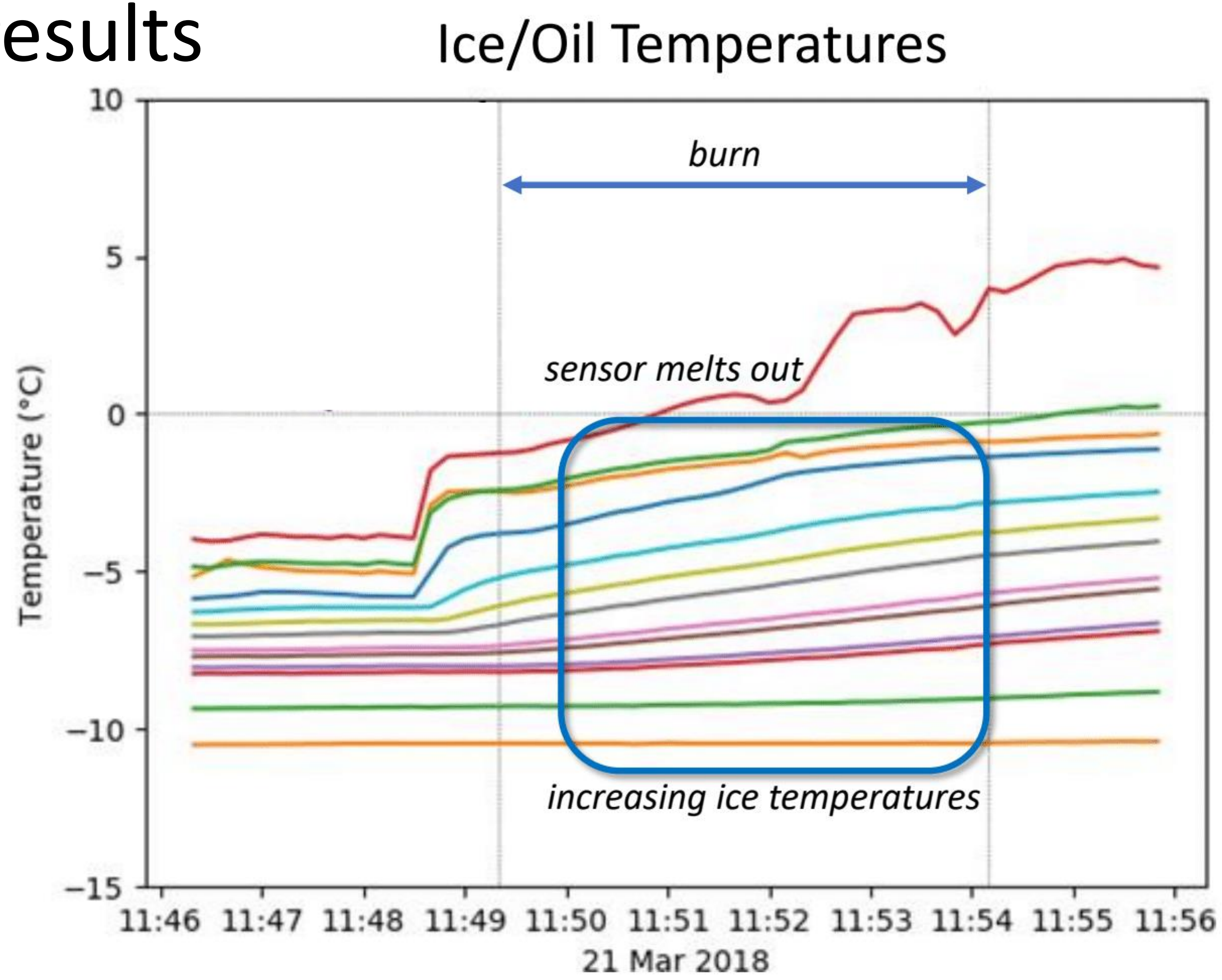
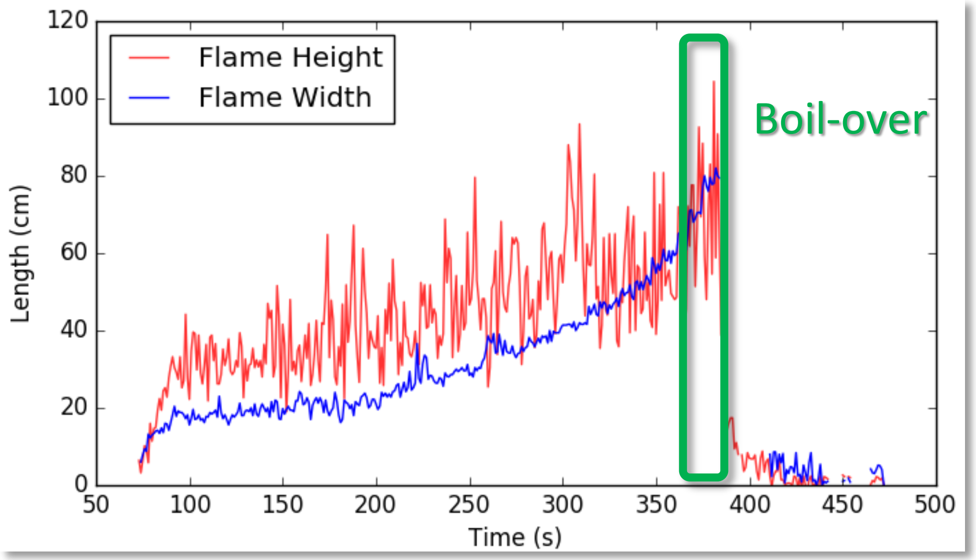
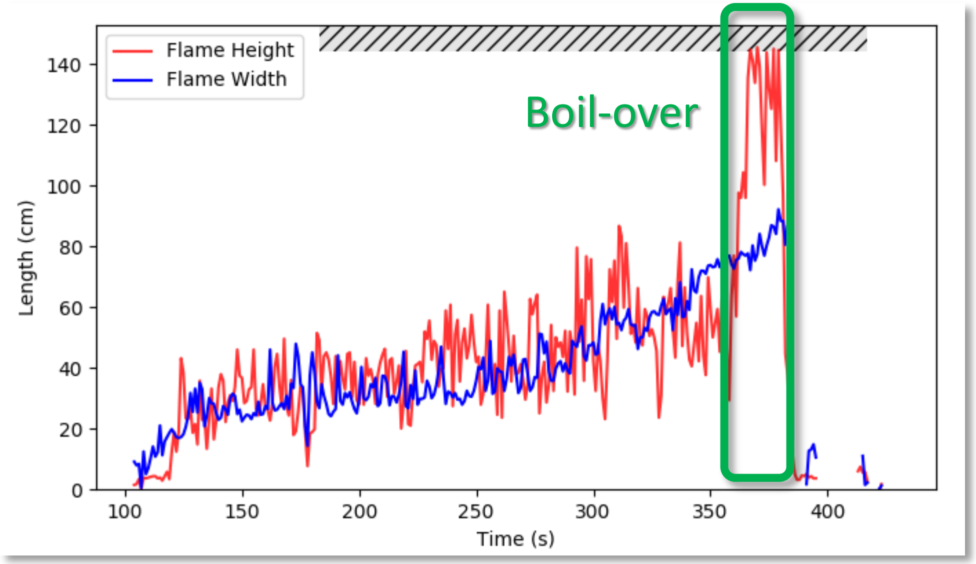
In situ burning on ice – Selected results



In situ burning on ice – Selected results

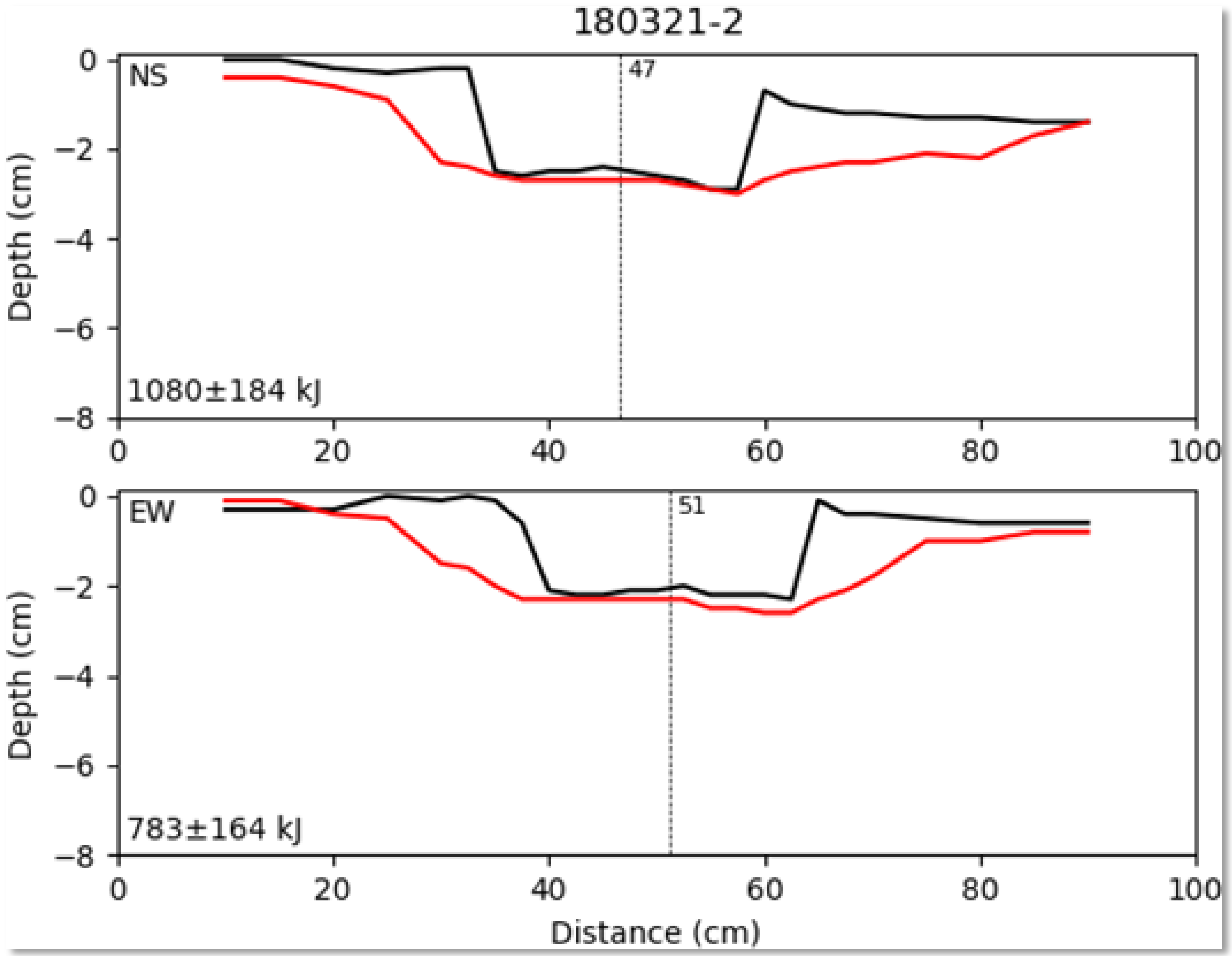
Flame Dimensions





In situ burning on ice – Selected results

Ice Surface Profiles



In situ burning on ice – Selected results

Burn	Fitted Pool Spread Rate *w* (cm/min)	Fitted Burn Rate *v* (mm/min)
171024	-	-
171115-1	6.2	0.8
171115-2	7.0	0.7
171116-1	-	-
171116-2	6.4	0.4
180321-1	5.6	1.0
180321-2	5.9	0.4

- Developed a simple oil pool spread model
  - Constant burn rate (mm/min)
  - Constant rate of lateral spread of pool (cm/min)
  - End-of-burn at specified film thickness (mm)

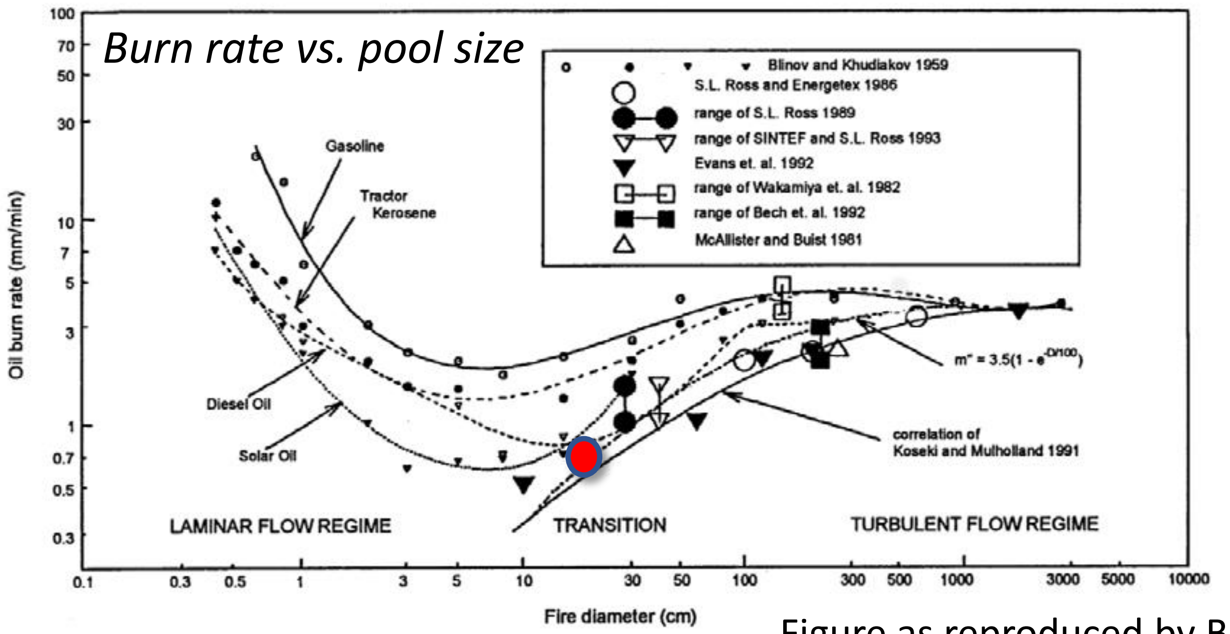


Figure as reproduced by Buist et al. (2013)

In situ burning on ice – Selected results

Burn	Ambient temperature	Pool size	Oil mass	Burn time	Initial oil slick thickness	Burn efficiency
	°C	m	g	min	mm	mass %
171024	11	0.2	357	01:50	13	*
171115-1	10	0.2	424	04:00	15	53
171115-2	9	0.2	708	05:20	25	54
171116-1	7	0.2	496	*	18	*
171116-2	8	0.2	326	04:00	12	35
180321-1	3	0.3	807	04:30	13	64
180321-2	3	0.3	484	03:50	8	42
181218-1	3.7	0.2	180	04:25	6	69
181218-2	4	0.2	153	06:01	5	64
181218-3	3.9	0.2	51	03:00	2	33
181218-4	8.1	0.2	62	03:00	2	74
190208-1	6	0.2	355	04:34	13	43
190208-2	6.5	0.2	341	04:11	10	29**
190208-3	6.1	0.2	691	*	25	*
190208-4	5.9	0.2	702	05:00	25	*

*incomplete burn due to run-off of oil

**approximately

Conclusions

- the low burn efficiencies in the experiments resulted from a significant increase of the pool diameter during the burn forced by a relatively thin initial oil pool

→ *avoid spread of thin pools to maximize efficiency*

- pool spreading and associated surface melt has the potential to dislodge a significant amount of oil during burn (*however, probably not enough to sustain a burn 'indefinitely'*)

- coming up next: Last data processing and writing manuscript
- future work: more work on up-scaling and transfer to <u>sea</u> ice