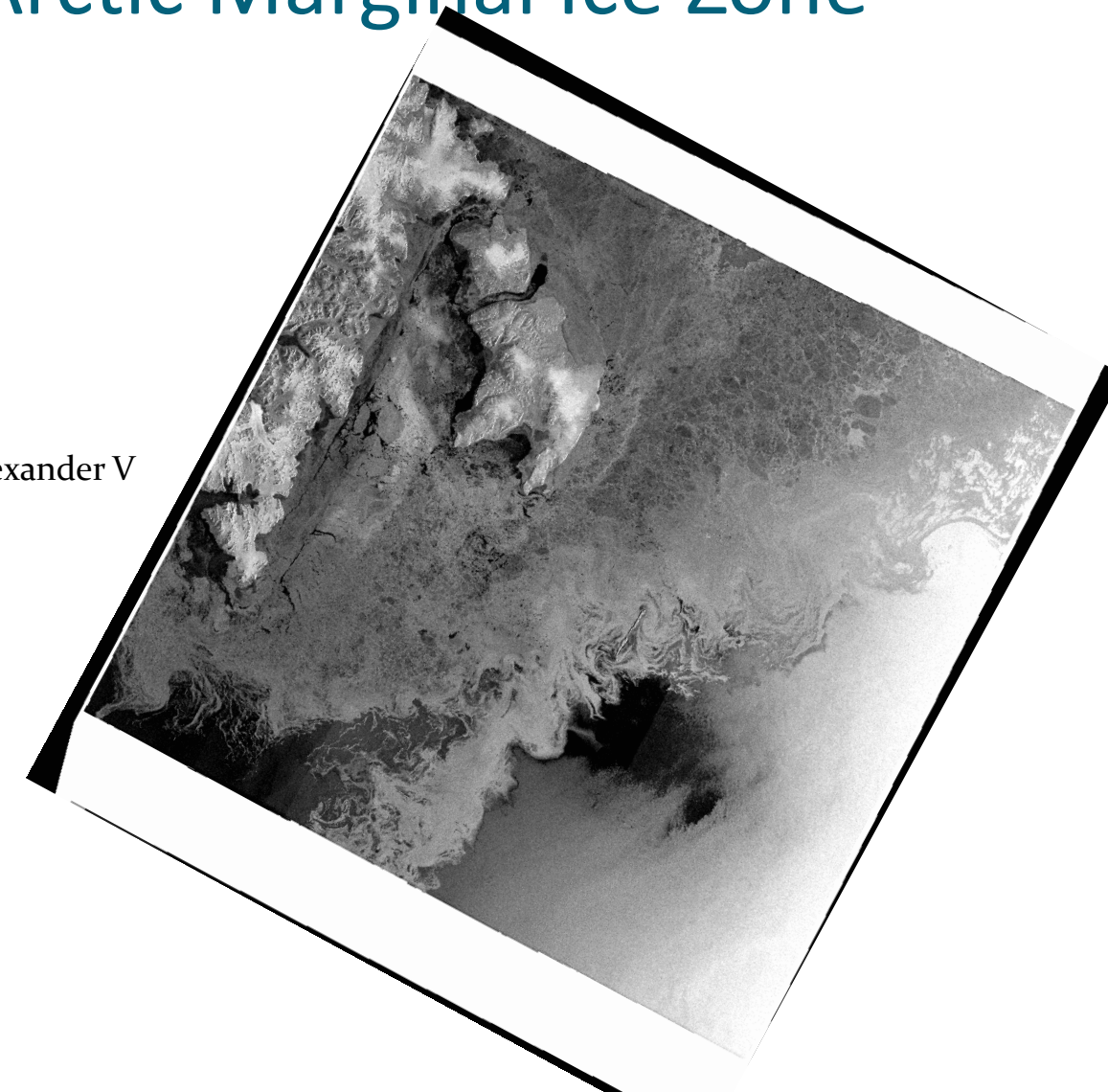
In Situ Measurements of an Energetic Wave Event in the Arctic Marginal Ice Zone



14th Wave Workshop - 11/09/2015

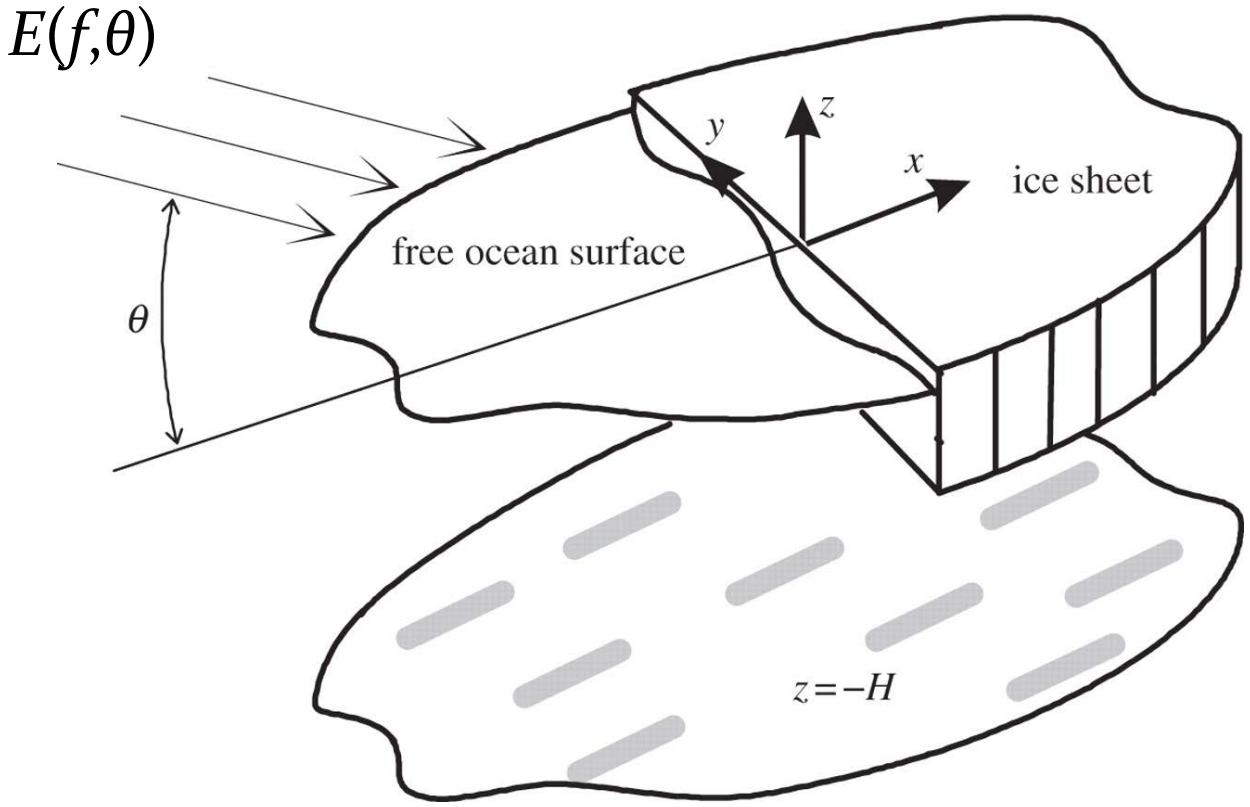
CO "Tripp" Collins III
ASEE Postodoctal Fellow, NRL - SSC

W Erick Rogers[1], Aleksey Marchenko[2], Alexander V Babanin[3]

[1]Oceanographer, NRL –SSC
[2]Professor, the University Center in Svalbard
[3]Professor, Swinburn University of Technology

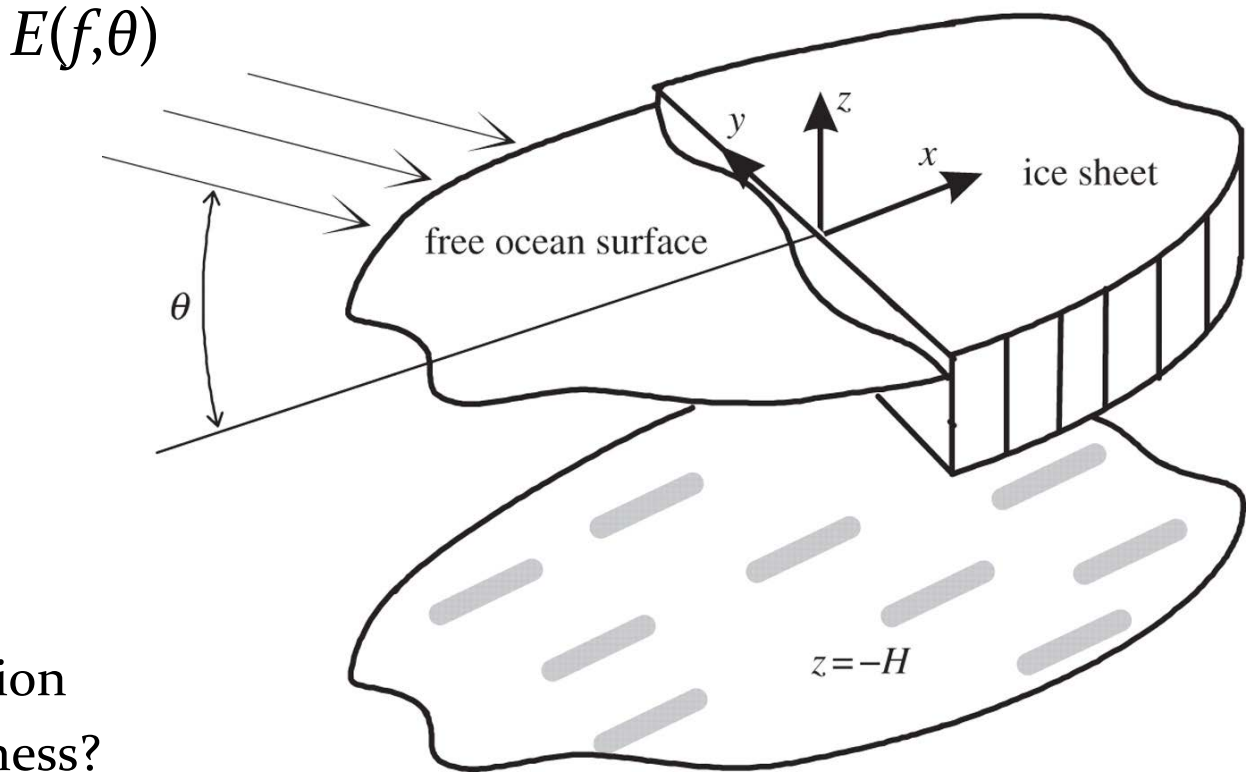
Wave-Ice Interaction: Wave effects on ice

- Stress / Strain
- Creep
- Fatigue
- Failure
- Fracture
- Force Collisions
- Transport
- Compress



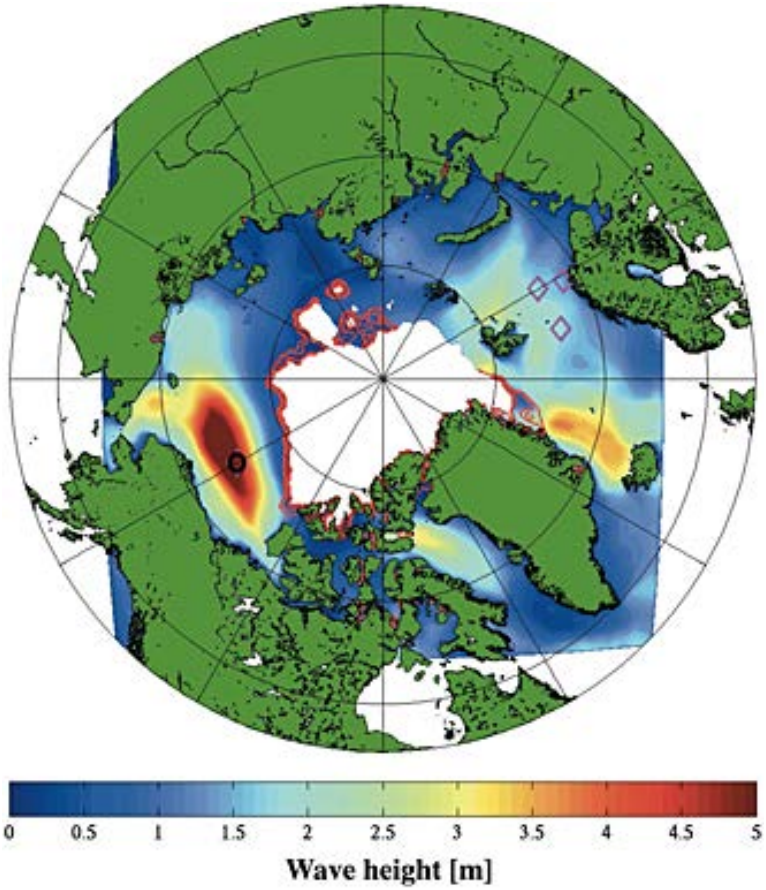
Wave-Ice Interaction: Ice effects on waves

- Scattered
- Reflected
- Transmitted
- Attenuated
- Change in dispersion
- Change in groupiness?




JON PHOTOGRA

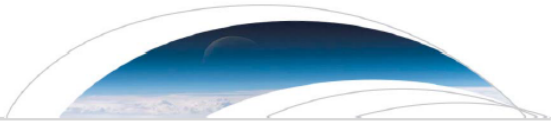
Thomson & Rogers (2014)



Geophysical Research Letters
Volume 41, Issue 9, pages 3136-3140, 5 MAY 2014 DOI: 10.1002/2014GL059983
http://onlinelibrary.wiley.com/doi/10.1002/2014GL059983/full#grl51656-fig-0001

Feedback Loop

Less ice cover



Larger waves

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2014GL059847

Key Points:

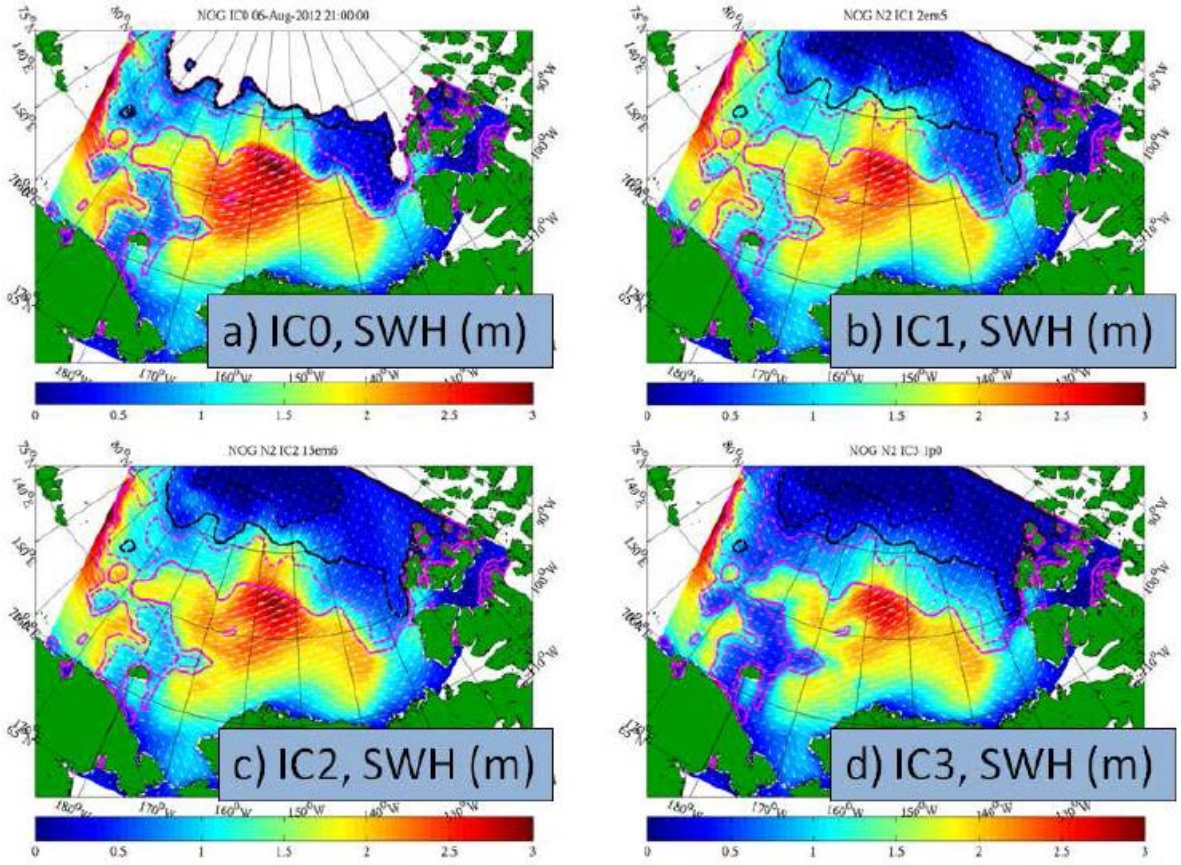
- Significant wave height will increase over the Arctic Ocean in the 21st century
- Reduction in wave height is expected for the Atlantic sector and the Barents Sea

Wave heights in the 21st century Arctic Ocean simulated with a regional climate model

V. C. Khon[1,2], I. I. Mokhov[1], F. A. Pogarskiy[1], A. Babanin[3], K. Dethloff[4], A. Rinke[4], and H. Matthes[4]

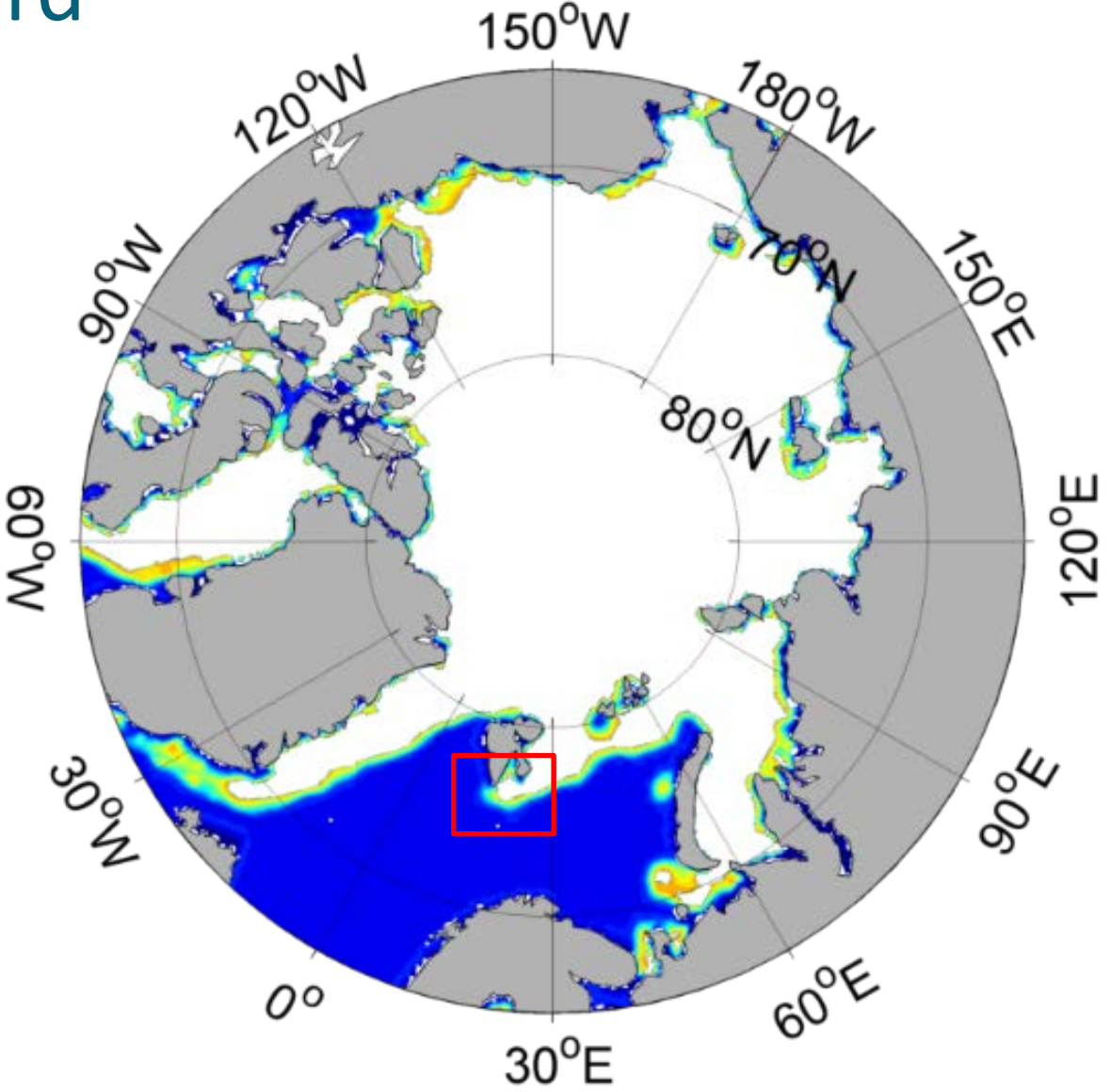
[1]A. M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow, Russia, [2]Institute of Geosciences at Kiel University, Kiel, Germany, [3]Swinburne University of Technology, Melbourne, Australia, [4]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Potsdam, Germany

Evaluating S_{ICE}

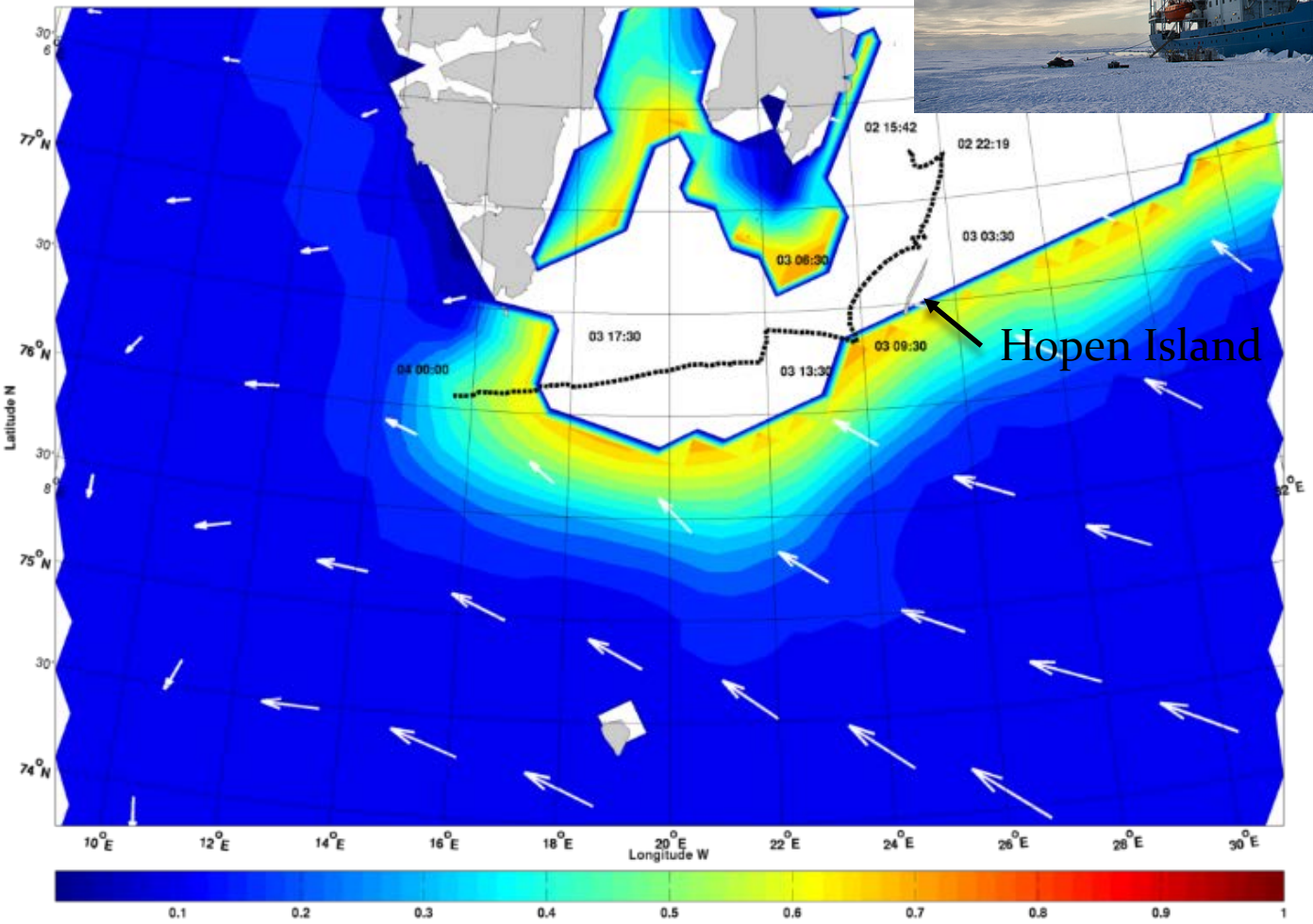


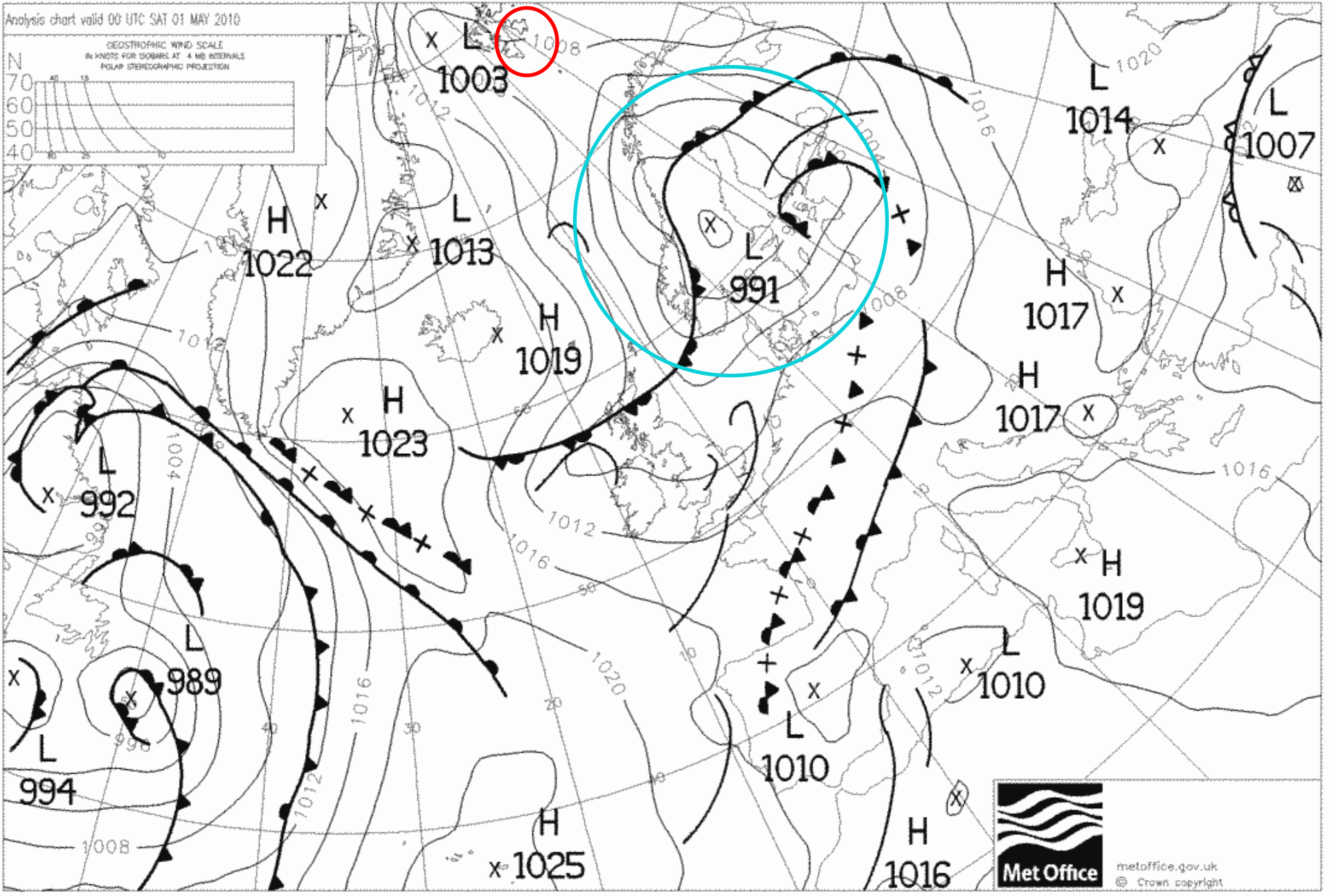
Rogers and Zeiger (2014) New Wave-Ice Interaction Physics in WAVEWATCH III®

Svalbard



UNIS Cruise Synopsis




Analysis chart valid 00 UTC SAT 01 MAY 2010
GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
POLAR STEREOGRAPHIC PROJECTION
N
70
60
50
40
L 1003
H 1022
L 1013
H 1019
L 991
H 1023
L 992
L 989
L 994
H 1025
L 1010
H 1016
L 1014
L 1007
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1008
1012
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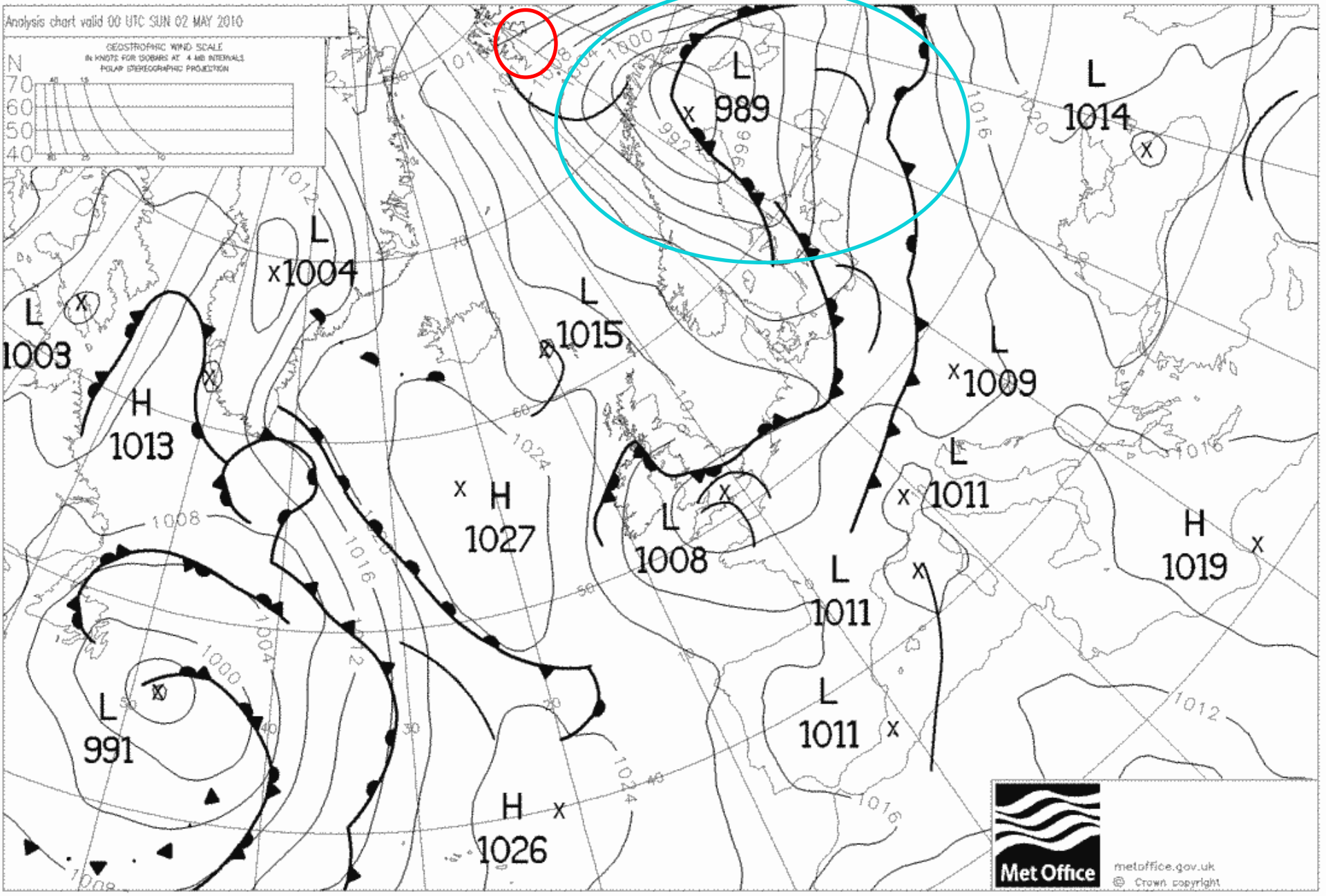
Analysis chart valid 00 UTC SUN 02 MAY 2010
GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
POLAR STEREOGRAPHIC PROJECTION
N
70
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1014
L
1004
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1003
L
1015
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H
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Met Office
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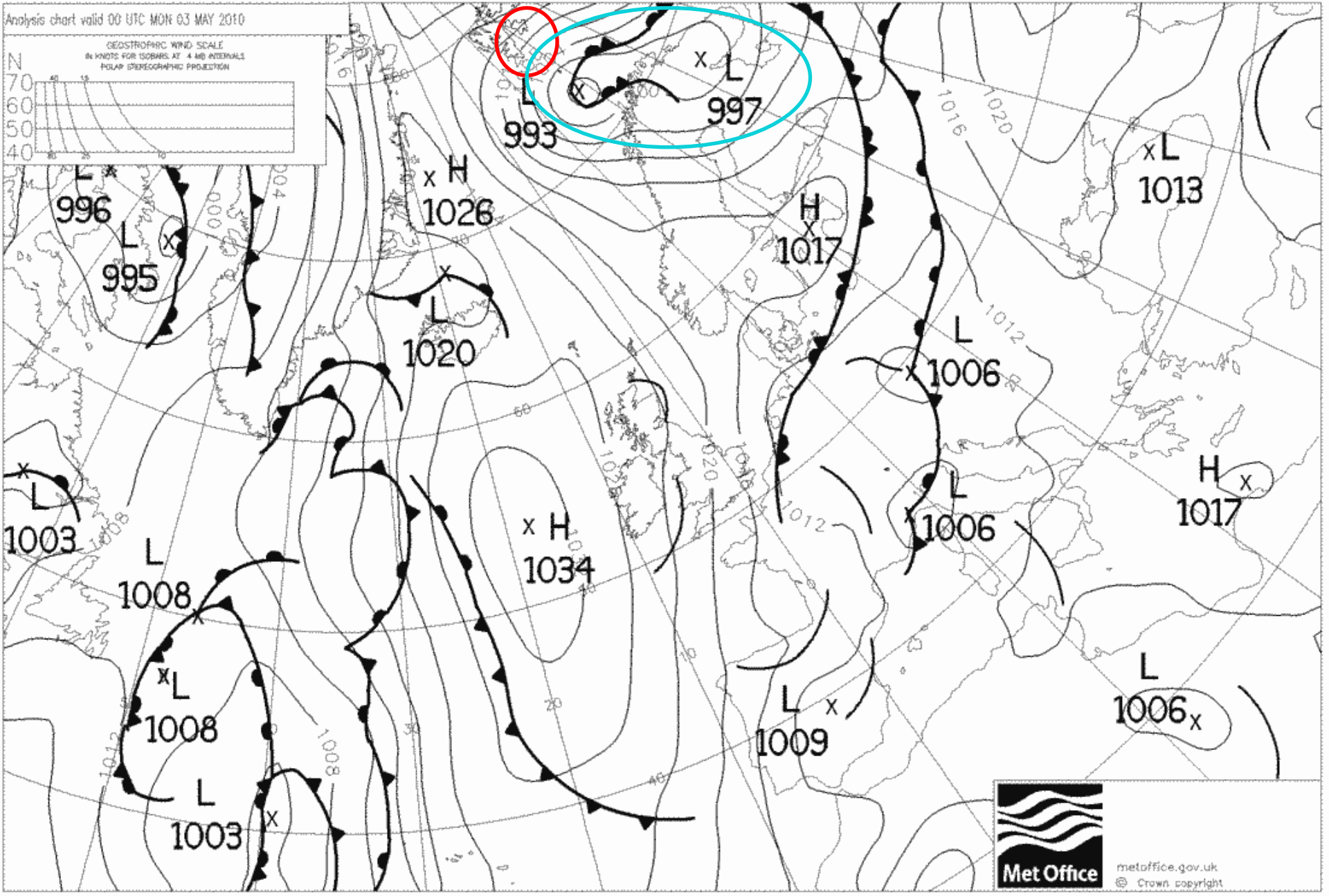
Analysis chart valid 00 UTC MON 03 MAY 2010
GEOSTROPHIC WIND SCALE
IN KNOTS FOR ISOBARS AT 4 MB INTERVALS
POLAR STEREOGRAPHIC PROJECTION
N
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997
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996
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995
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1006
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H
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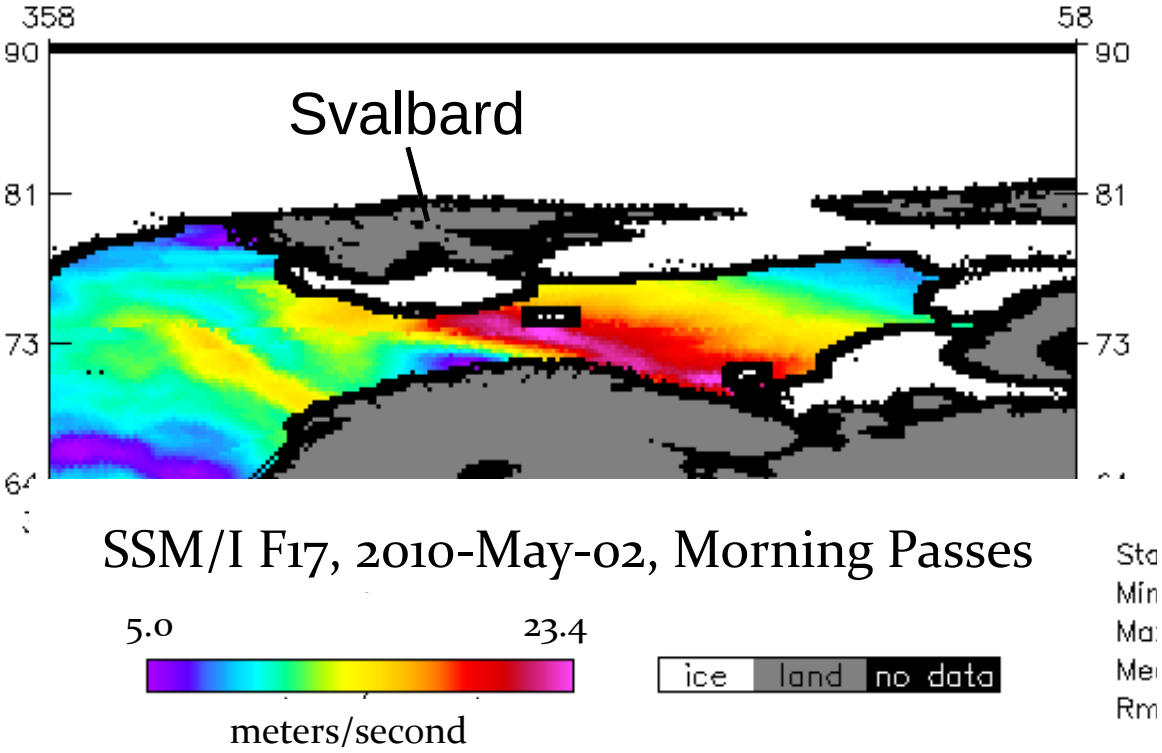
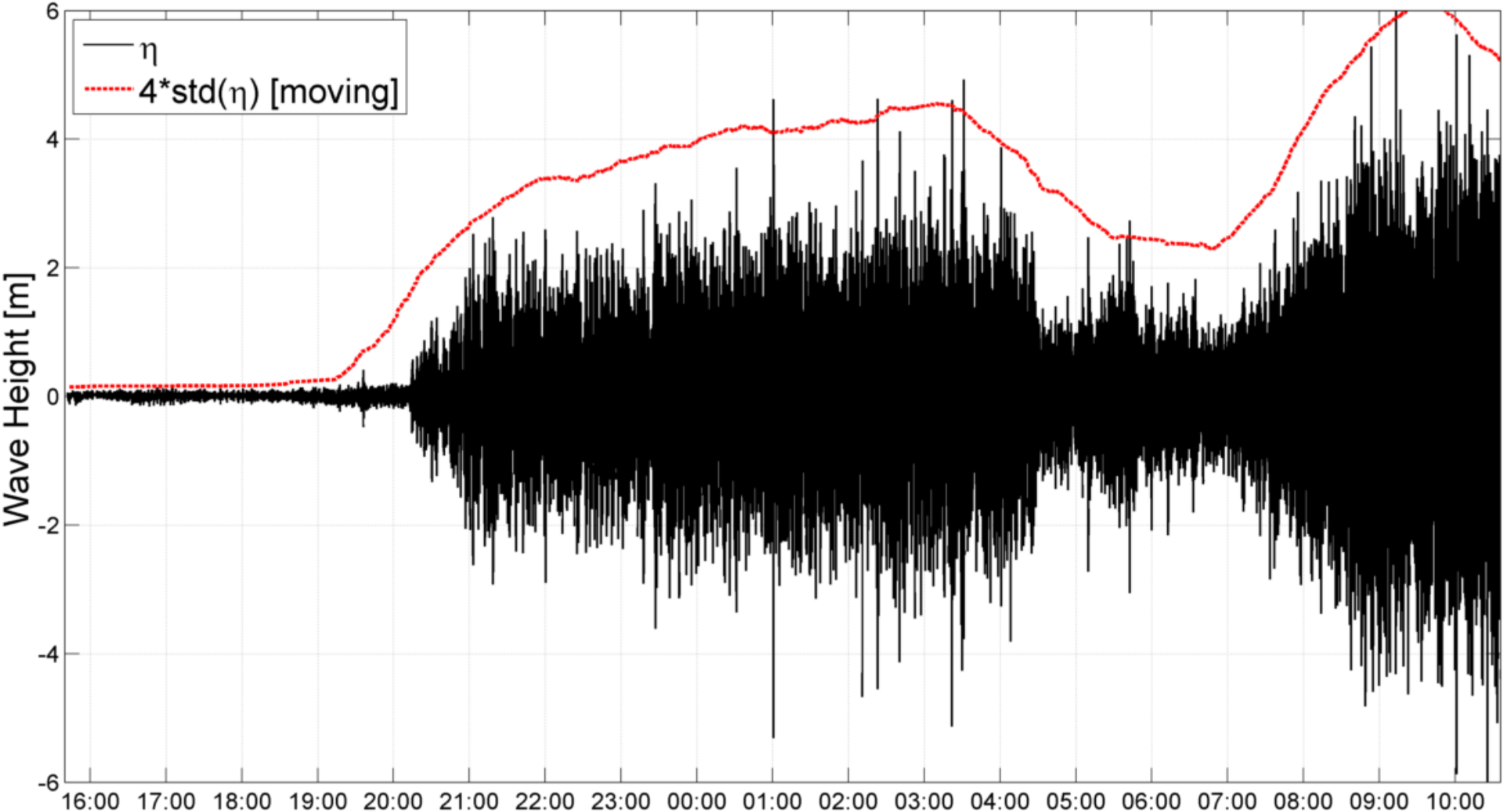
Available Fetch



R/V Lance

Wave Data Preview



Analysis

Significant Wave Height

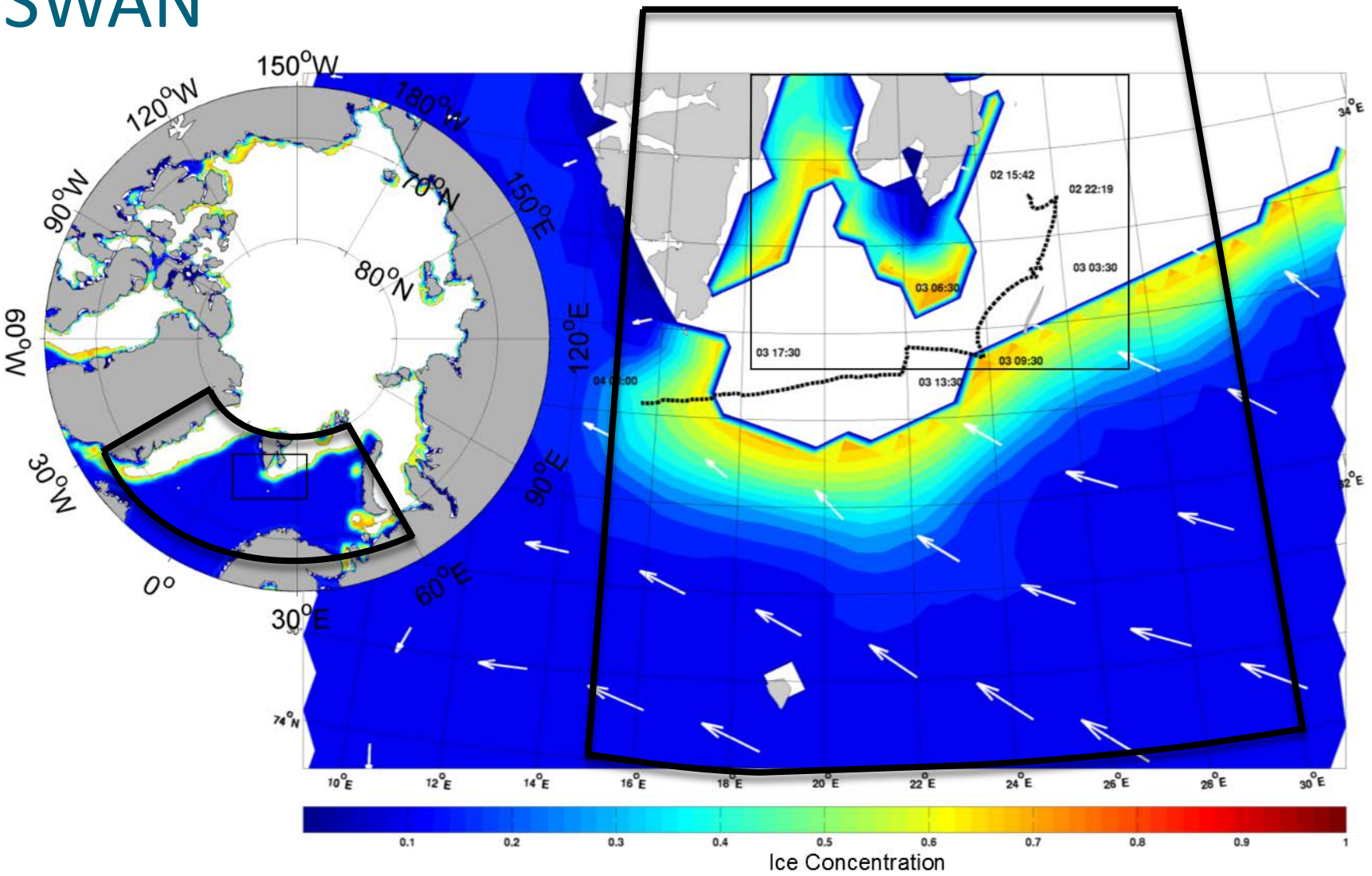
$$H_s = 4\left[\int S(f)df\right]^{1/2}$$

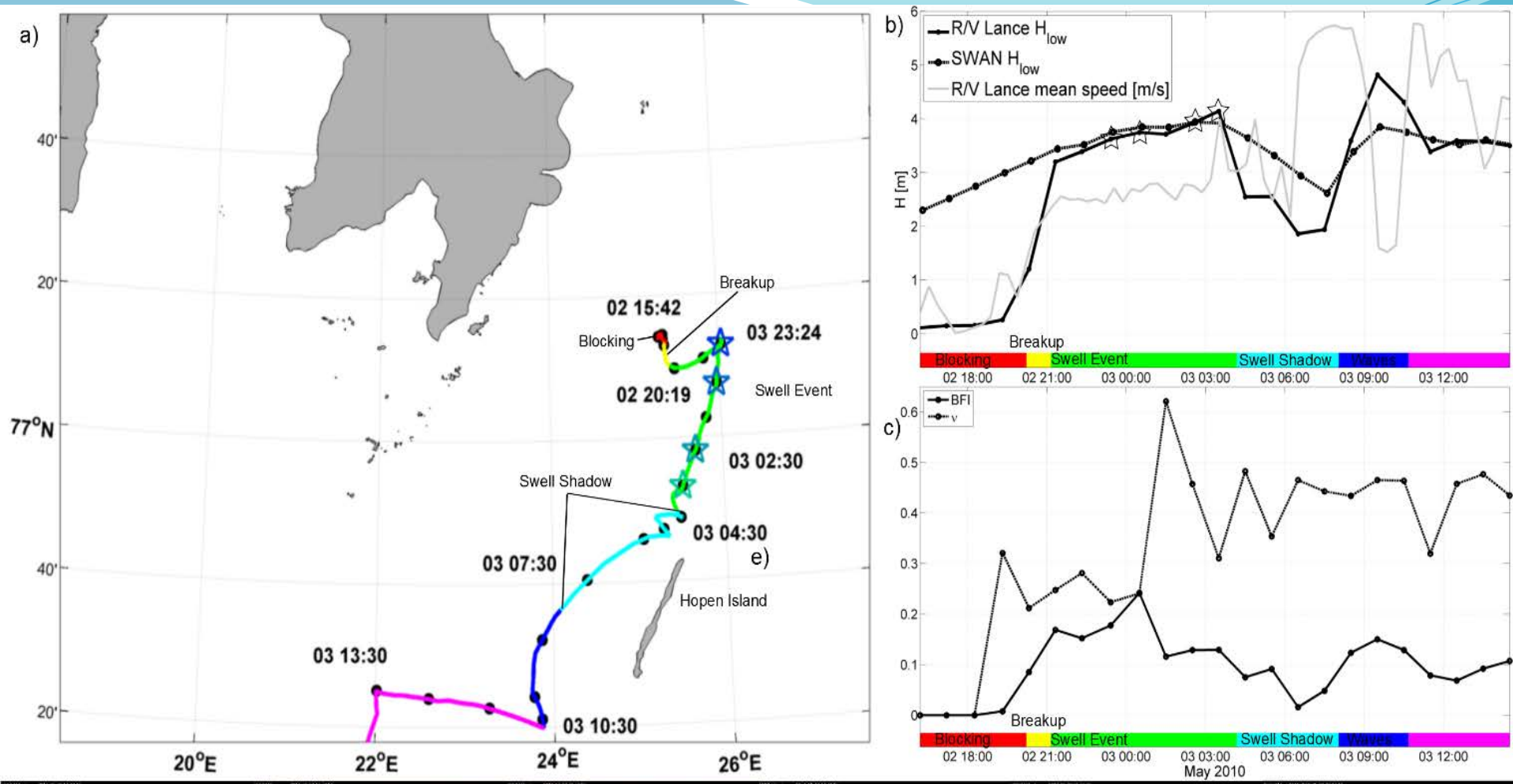
Low Frequency Wave Height

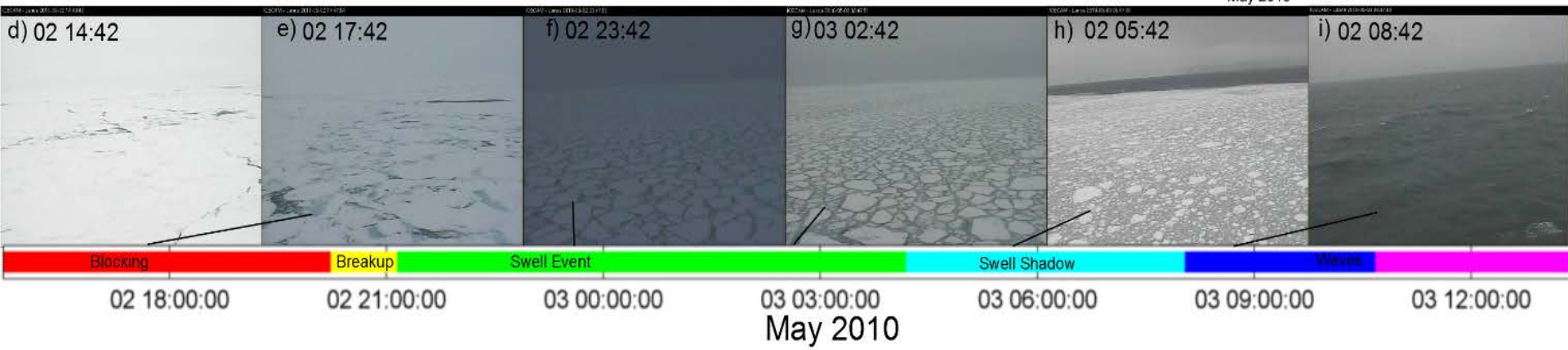
$$H_{low} = 4\left[\int_0^{0.12} S(f)df\right]^{1/2}$$

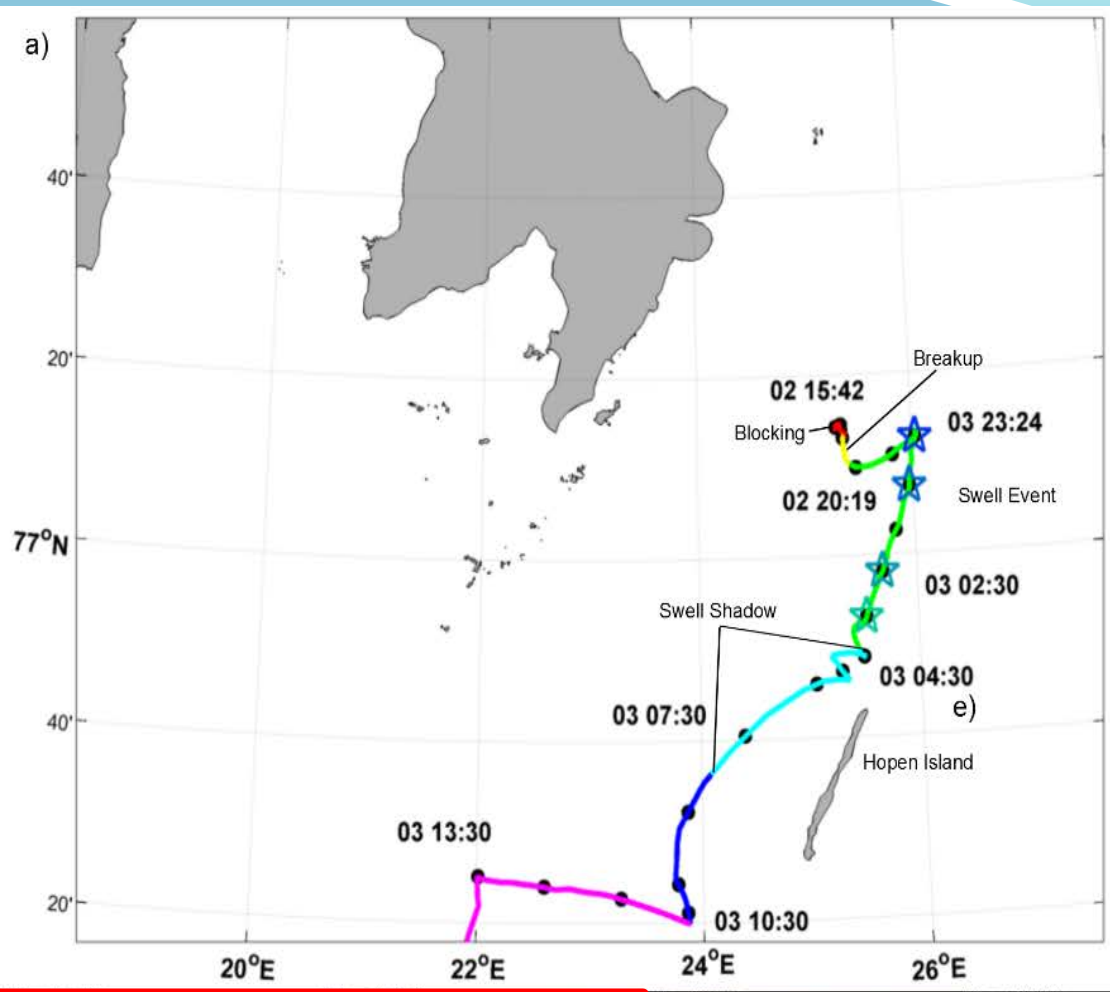
Hourly Photos

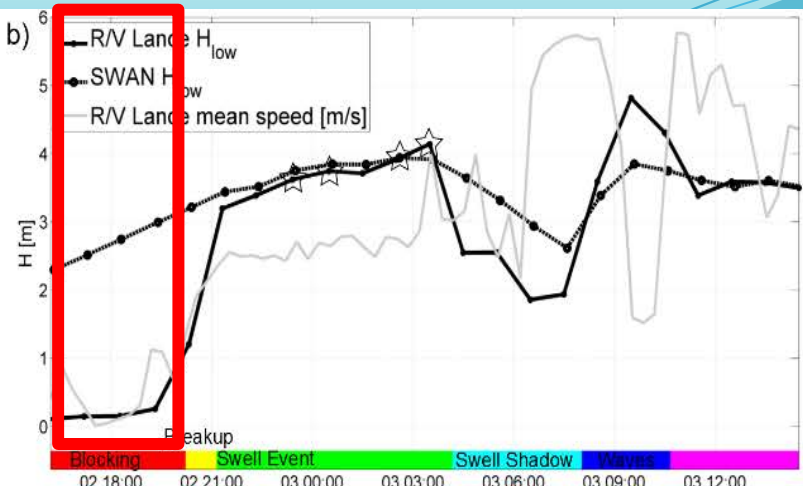
SWAN


150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°W
70°N
80°N
74°N
02 15:42
02 22:19
03 03:30
03 06:30
03 09:30
03 13:30
03 17:30
10°E
12°E
14°E
16°E
18°E
20°E
22°E
24°E
26°E
28°E
30°E
34°E
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Ice Concentration


a)
40'
20'
77°N
40'
20'
20°E
22°E
24°E
26°E
Breakup
02 15:42
Blocking
03 23:24
02 20:19
Swell Event
03 02:30
Swell Shadow
03 04:30
03 07:30
e)
Hopen Island
03 13:30
03 10:30
b)
R/V Lance H low
SWAN H low
R/V Lance mean speed [m/s]
H [m]
Breakup
Blocking
Swell Event
Swell Shadow
Waves
02 18:00
02 21:00
03 00:00
03 03:00
03 06:00
03 09:00
03 12:00
c)
BFI
v
Breakup
Blocking
Swell Event
Swell Shadow
Waves
02 18:00
02 21:00
03 00:00
03 03:00
03 06:00
03 09:00
03 12:00
May 2010


d) 02 14:42
e) 02 17:42
f) 02 23:42
g) 03 02:42
h) 02 05:42
i) 02 08:42
Blocking
Breakup
Swell Event
Swell Shadow
Waves
02 18:00:00
02 21:00:00
03 00:00:00
03 03:00:00
03 06:00:00
03 09:00:00
03 12:00:00
May 2010


a)
40'
20'
77°N
40'
20'
20°E
22°E
24°E
26°E
Breakup
02 15:42
Blocking
03 23:24
02 20:19
Swell Event
03 02:30
Swell Shadow
03 04:30
03 07:30
e)
Hopen Island
03 13:30
03 10:30


b)
R/V Lance H low
SWAN H
R/V Lance mean speed [m/s]
H [m]
Breakup
Blocking
Swell Event
Swell Shadow
Waves
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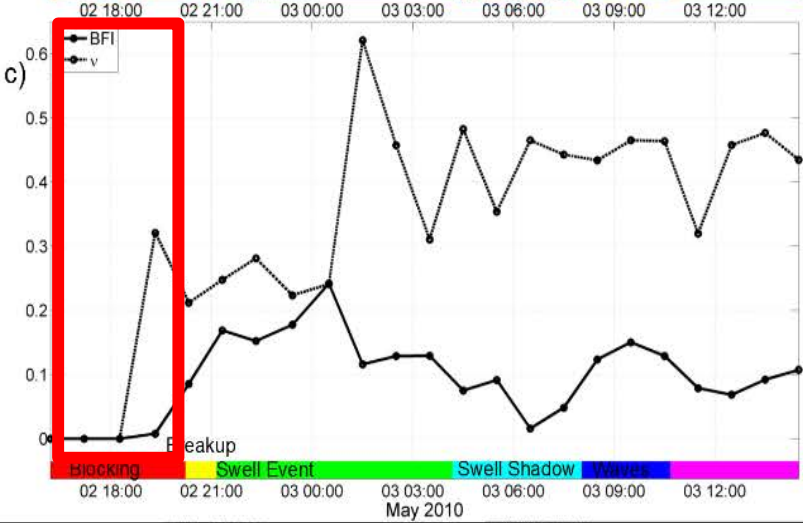
03 06:00
03 09:00
03 12:00


c)
BFI
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Breakup
Blocking
Swell Event
Swell Shadow
Waves
02 18:00
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May 2010
03 06:00
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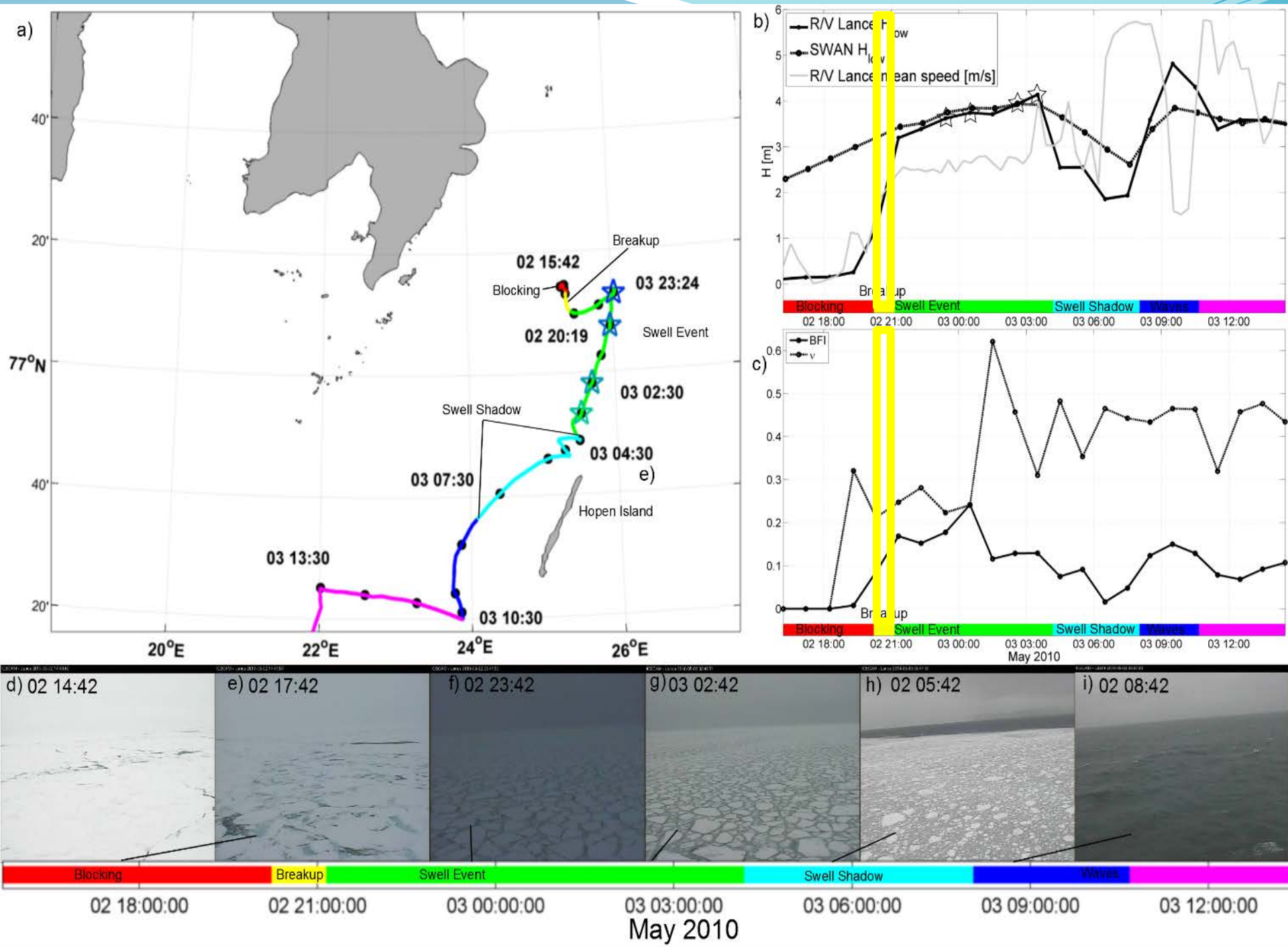
d) 02 14:42
e) 02 17:42


f) 02 23:42
g) 03 02:42


h) 02 05:42
i) 02 08:42

Blocking
Breakup
Swell Event
Swell Shadow
Waves
02 18:00:00
02 21:00:00
03 00:00:00
03 03:00:00
03 06:00:00
03 09:00:00
03 12:00:00
May 2010


a)
40'
20'
77°N
40'
20'
20°E
22°E
24°E
26°E
Breakup
02 15:42
Blocking
03 23:24
02 20:19
Swell Event
03 02:30
Swell Shadow
03 04:30
03 07:30
e)
Hopen Island
03 13:30
03 10:30
b)
R/V Lance
SWAN H
R/V Lance ean speed [m/s]
H [m]
Br up
Blocking
Swell Event
Swell Shadow
Waves
02 18:00
02 21:00
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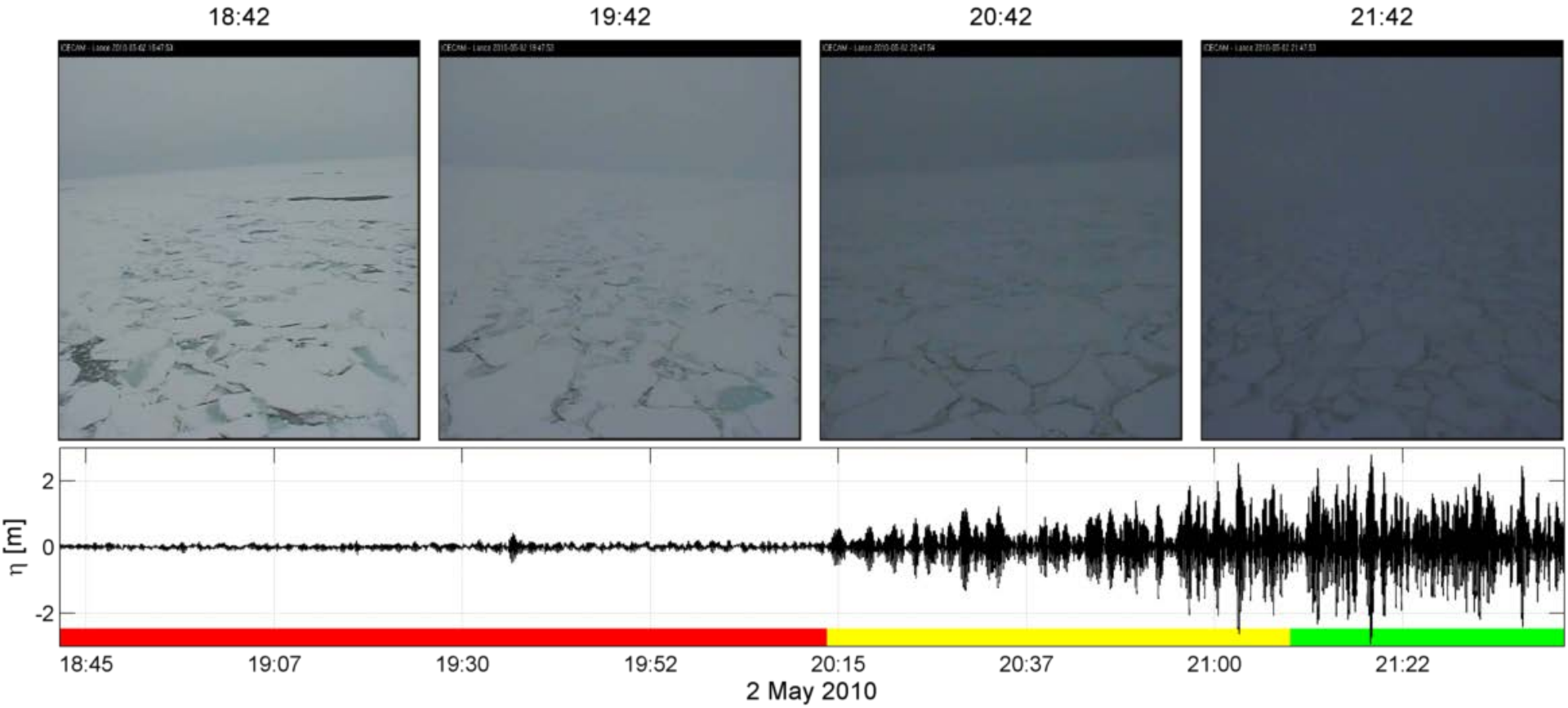
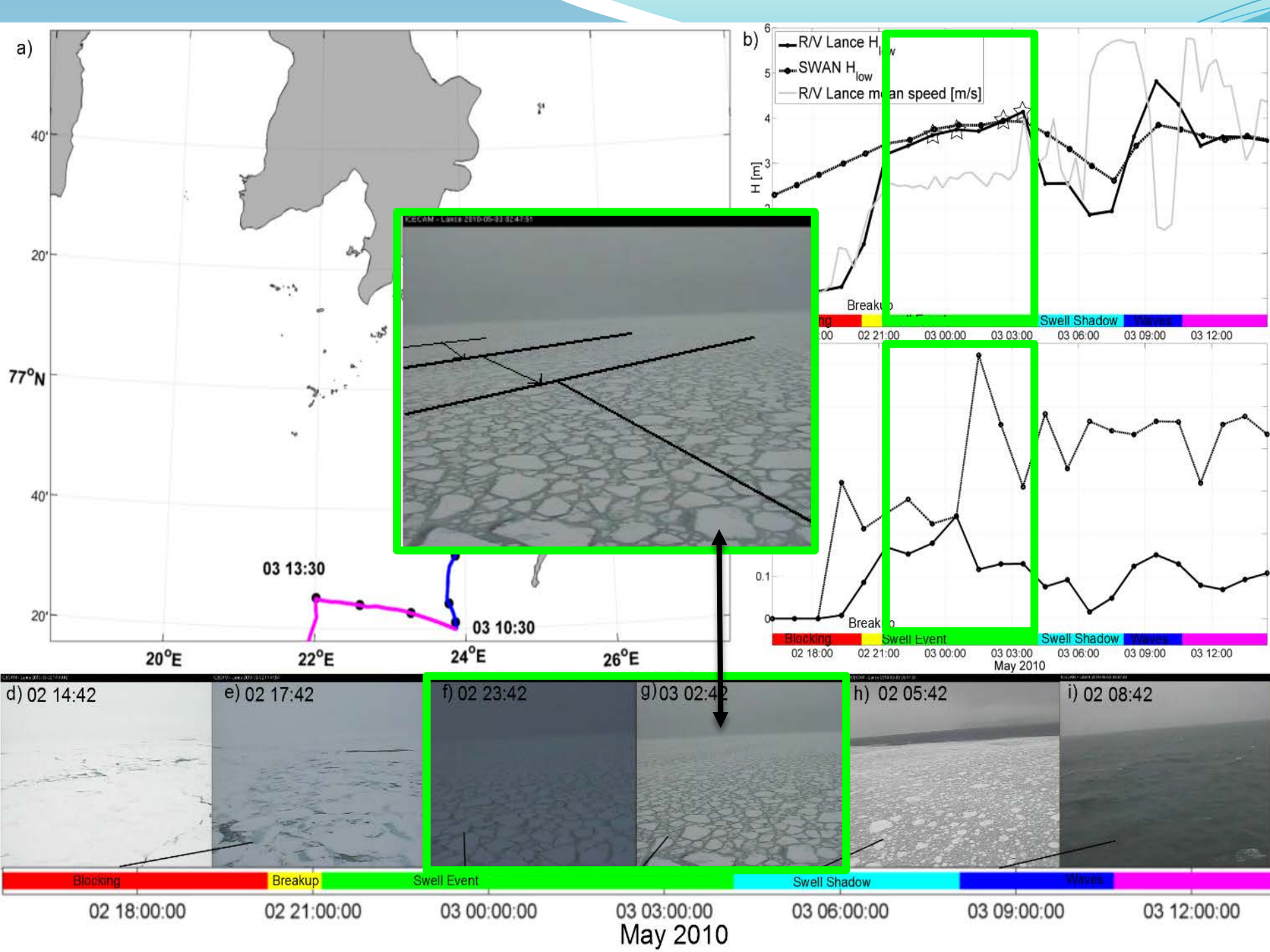
c)
BFI
Br up
May 2010
d) 02 14:42
e) 02 17:42
f) 02 23:42
g) 03 02:42
h) 02 05:42
i) 02 08:42
Blocking
Breakup
Swell Event
Swell Shadow
Waves
02 18:00:00
02 21:00:00
03 00:00:00
03 03:00:00
03 06:00:00
03 09:00:00
03 12:00:00
May 2010

Fracturing


18:42
19:42
20:42
21:42
η [m]
2
0
-2
18:45
19:07
19:30
19:52
20:15
20:37
21:00
21:22
2 May 2010


a)
40°
20°
77°N
40°
20°
03 13:30
03 10:30
20°E
22°E
24°E
26°E
b)
R/V Lance H low
SWAN H low
R/V Lance mean speed [m/s]
H [m]
Breakup
Swell Shadow
Waves
02 21:00
03 00:00
03 03:00
03 06:00
03 09:00
03 12:00
Blocking
Swell Event
02 18:00
May 2010
d) 02 14:42
e) 02 17:42
f) 02 23:42
g) 03 02:42
h) 02 05:42
i) 02 08:42
Blocking
Breakup
Swell Event
Swell Shadow
Waves
02 18:00:00
02 21:00:00
03 00:00:00
03 03:00:00
03 06:00:00
03 09:00:00
03 12:00:00
May 2010

Arctic Wave Measurement Survey

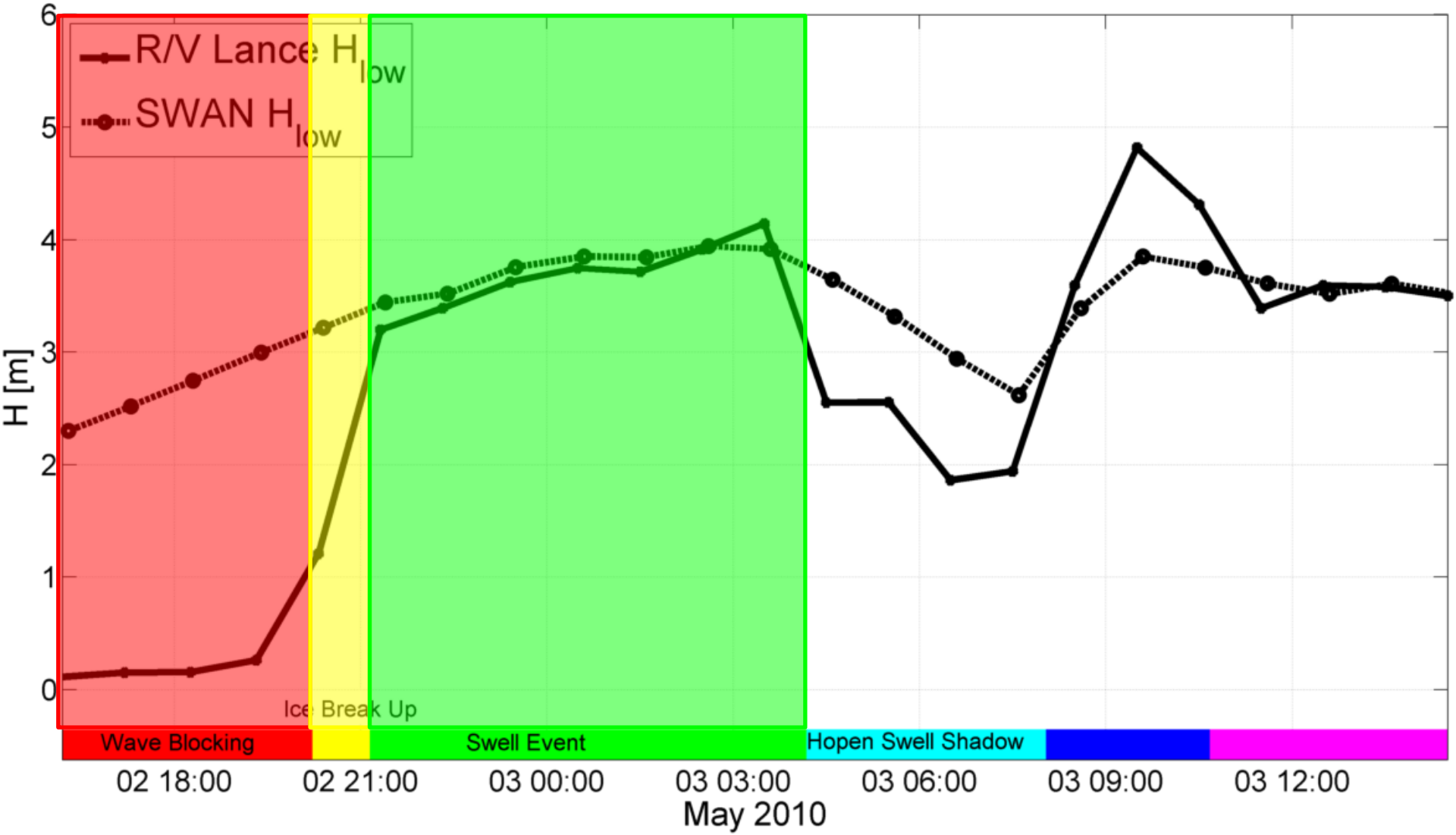
PUBLICATION	STUDY YEAR	LOCATION	METHOD	WAVE HEIGHT (H_{M_0})
[Fakidov, 1934]	1933-1934	Arctic Ocean	Visual	<< 1 m
[Crary et al., 1952]	1951	Arctic Ocean	Gravity Meter[1]	5×10^{-4} m
[Hunkins, 1962]	1957-1958	Beaufort Sea	Gravity Meter	<< 1 m
[Wadhams, 1975]	1972	Canadian North Atlantic[2]	Airborne Laser	~2 m
[Squire and Moore, 1980]	1979	Bering Sea	floe-borne accelerometers	~1.5 m
[Wadhams et al., 1986; Wadhams et al., 1988]	1978, 1979, & 1983	Bering Sea and Greenland Sea	Buoys	~1 m
[Liu et al., 1991]	1989	Labrador Sea	Buoy	~2.6 m
[McKenna and Crocker, 1992]	1989	Labrador Sea	floe-borne accelerometers	~0.5 m
[Rottier, 1992]	1989	Barents Sea and Fram Straight	Buoy	~0.75 m
[S. Frankenstein et al., 2001][3]	1990	Barents Sea	floe-borne accelerometers	< 1 m
[Marko, 2003]	1998	Sea of Okhotsk[4]	ADCP	~1.5 m
[Asplin et al., 2012]	2009	Beaufort Sea	3-D ship-borne recorder	~0.75 m
This Study	**2010**	**Barents Sea**	**Ship GPS**	**4-5 m**

[1] There are other studies which analyze the observations of gravity meters, seismometers, or tiltmeters deep in the ice field (see the references in Wadhams, 1975), all of which record small (O(1×10^{-4} m)) vibrations of the ice.

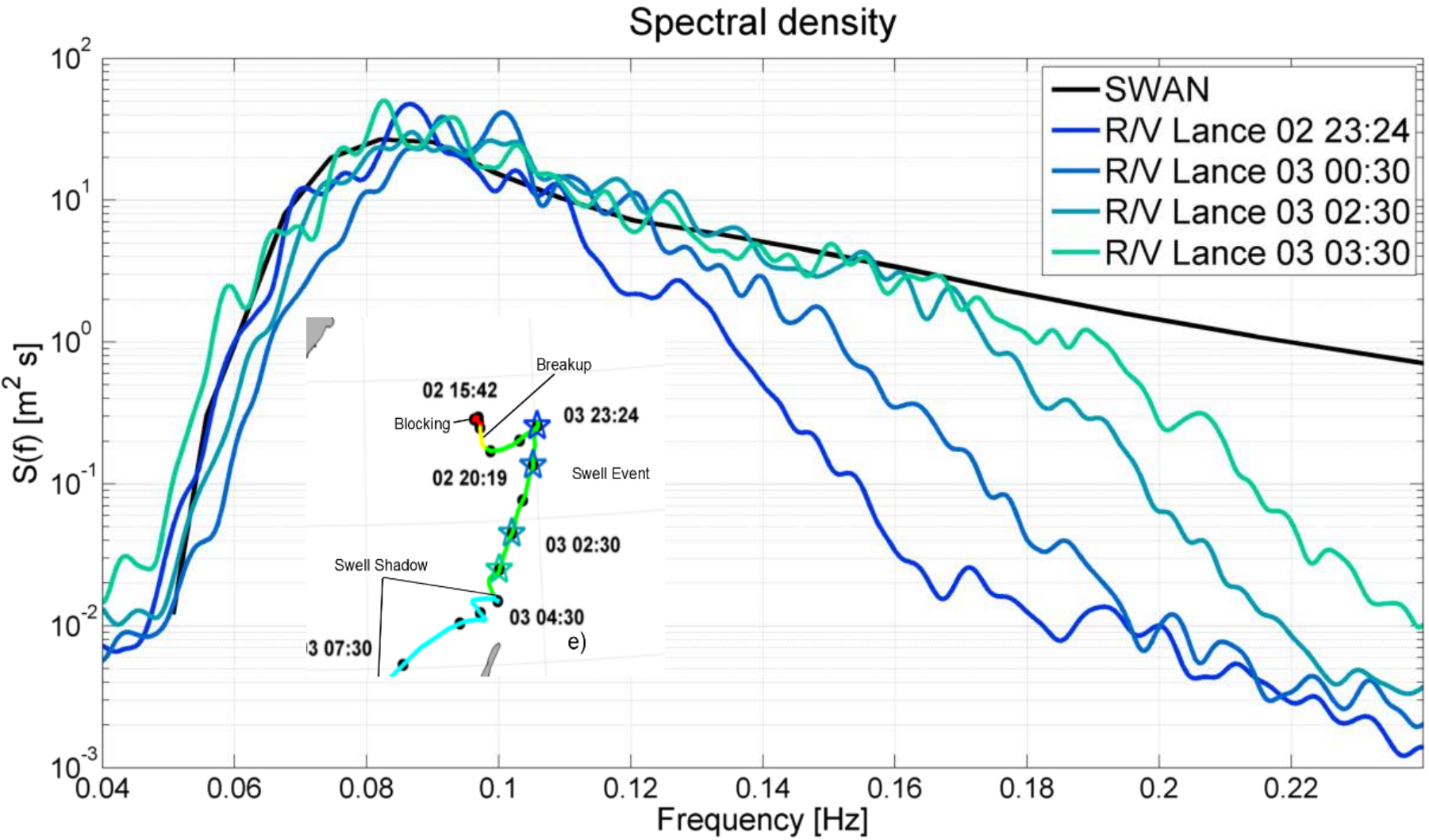
[2] Not within the Arctic region

[3] An event very similar to the one reported in out manuscript was described, but measurements were not made during it

[4] Not within the Arctic region


R/V Lance H low
SWAN H low
H [m]
0
1
2
3
4
5
6
Ice Break Up
Wave Blocking
Swell Event
Hopen Swell Shadow
02 18:00
02 21:00
03 00:00
03 03:00
03 06:00
03 09:00
03 12:00
May 2010

Ice as low pass filter



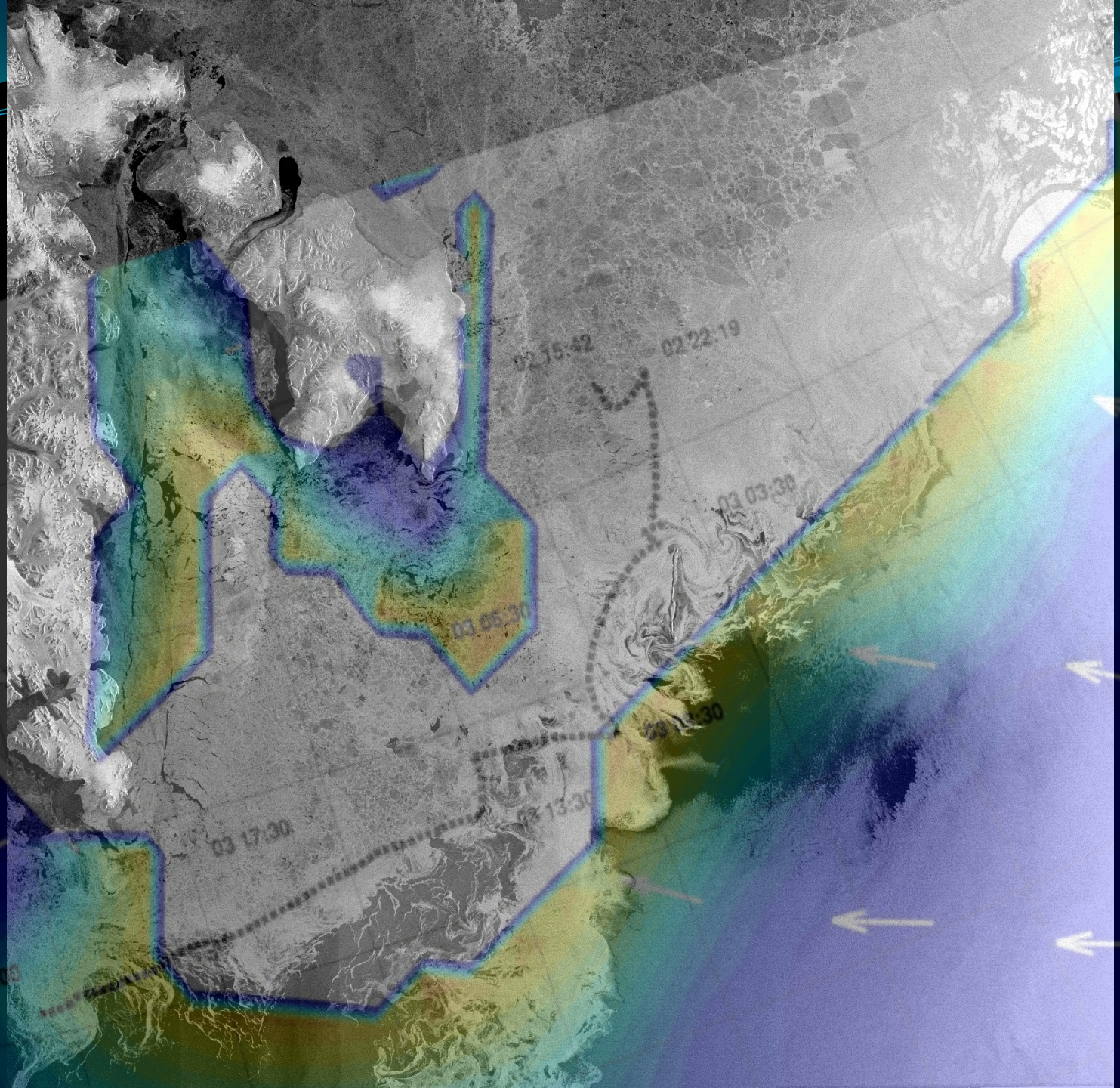
Summary

- (1) Largest waves measured in Arctic Ice
- (2) Waves present bi-nary behavior
- (3) Ice acts as a low pass filter

- As climate warms waves become more important in the Arctic

- Future Work
  - Continue to develop S_{ICE}
  - Field work underway for testing and validation

- Evidence of small-scale O(km, H) change in wave-ice interaction
  - Can we run coupled models at this scale? What does this imply for operational wave prediction in icy conditions?


02 15:42
02 22:19
03 03:30
03 06:30
03 13:30
03 17:30
04 00:00

Thanks!

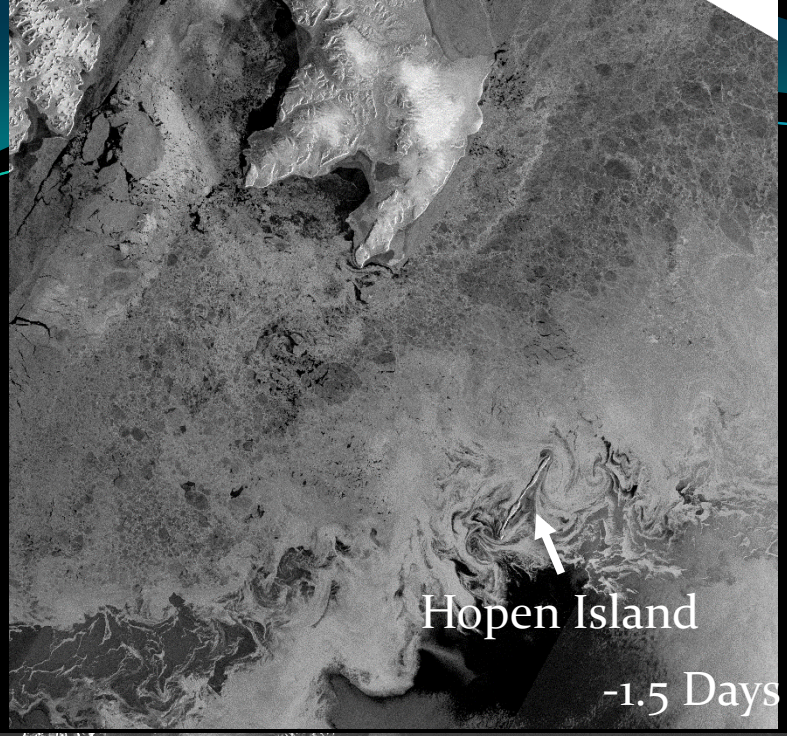
Further Reading:

Scientific American (online): **Giant Waves Quickly Destroy Arctic Ocean Ice and Ecosystems**

Collins, Rogers, Marchenko, & Babanin (2015) In Situ Measurement of an Energetic Wave Event in the Arctic Marginal Ice Zone

Thomson & Rogers (2014) Wind Sea and Swell in the Emerging Arctic Ocean

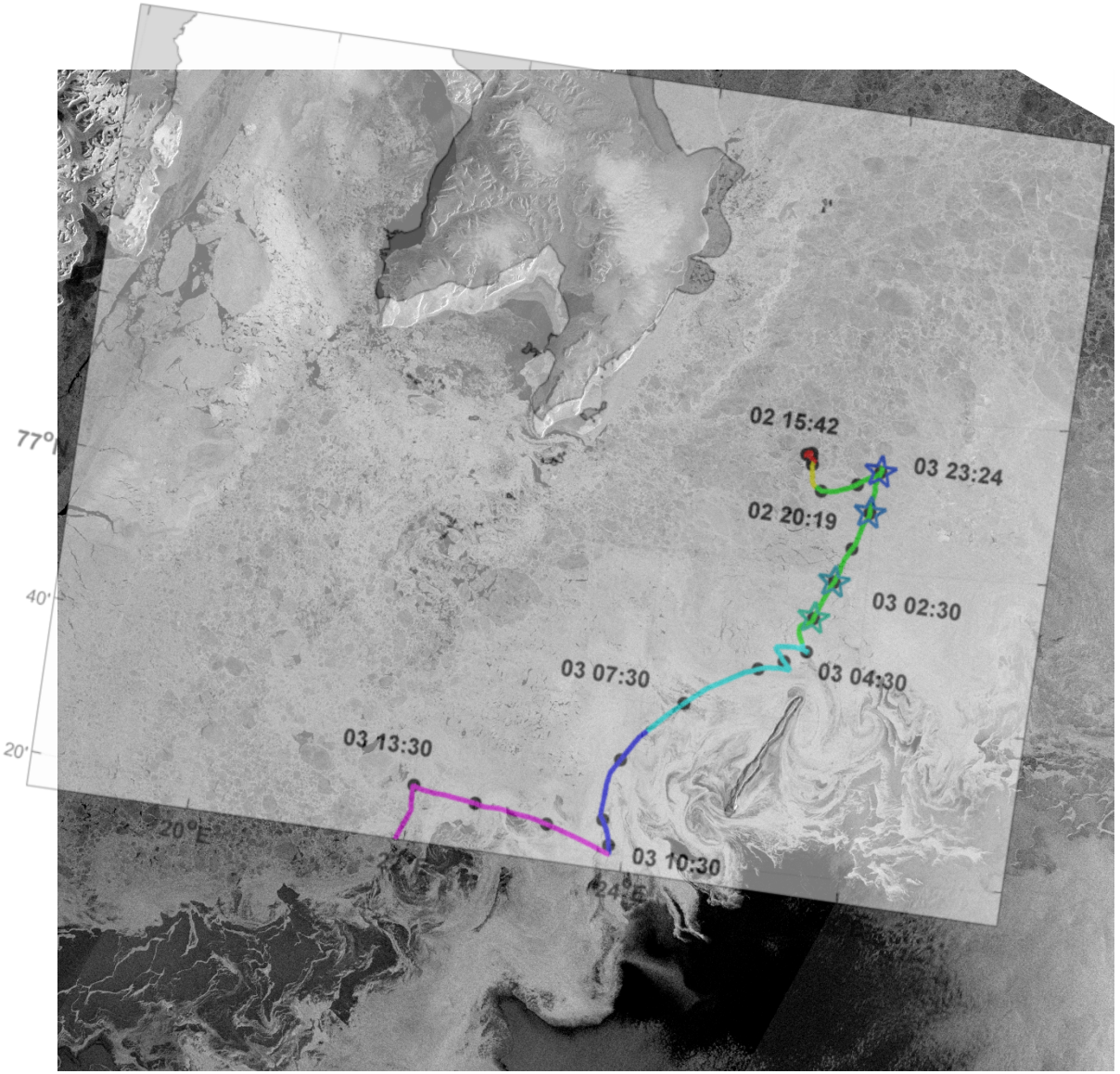
Squire (2007) Of Ocean Waves and Sea Ice Revisited


Hopen Island
-1.5 Days


Hopen Island
May 2


Hopen Island
+1 Days


Hopen Island
+ 1.5 Days


02 15:42
03 23:24
02 20:19
03 02:30
03 07:30
03 04:30
03 13:30
03 10:30
77°
40'
20'
20°E
24°E