CLASSIFICATION OF AQUACULTURE LOCATIONS IN NORWAY WITH RESPECT TO WIND WAVE EXPOSURE

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SINTEF Ocean

EXPOSED

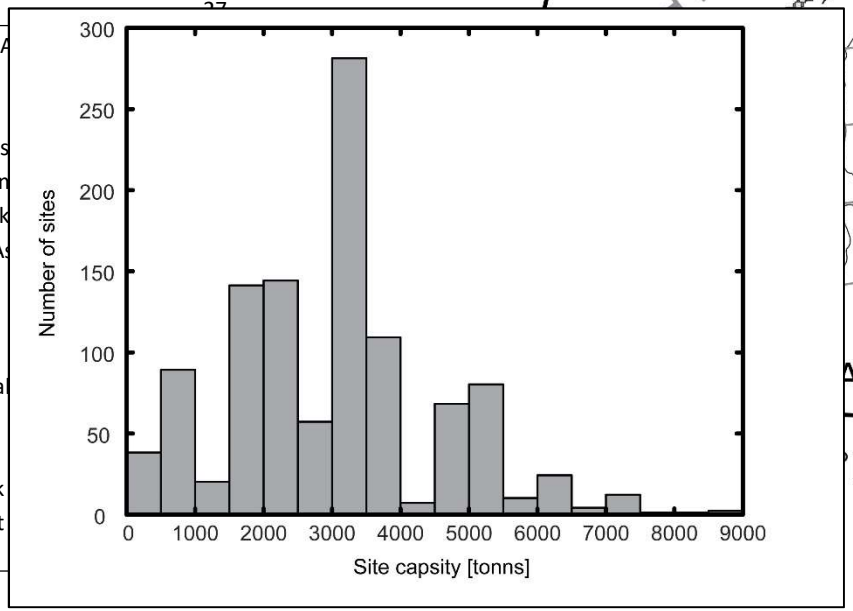
AQUACULTURE OPERATIONS

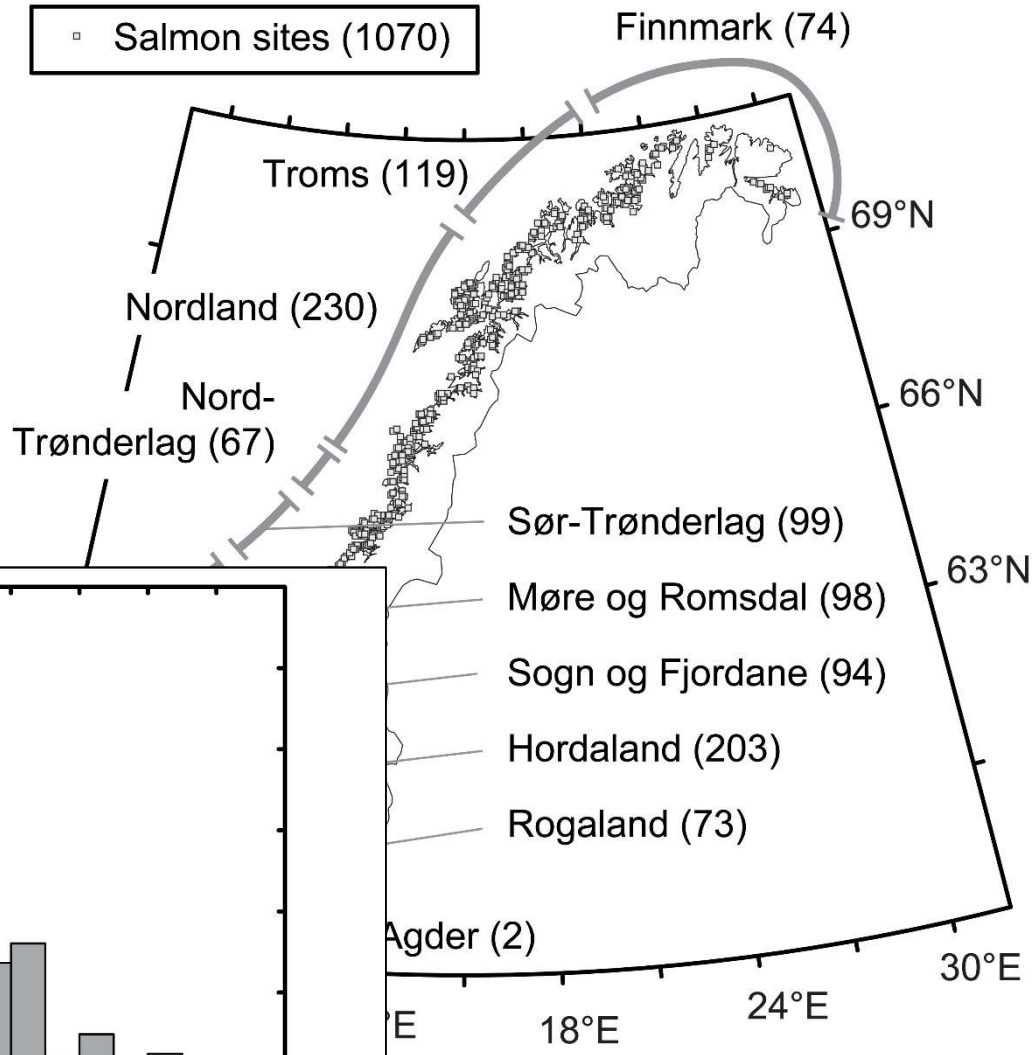
CENTRE FOR RESEARCH-BASED INNOVATION

Norwegian salmon sites

Number of sites			Owners	Sites	
	>	50	3	304	28 %
49	-	25	3	108	10 %
24	-	10	16	233	22 %
9	-	5	40	251	23 %
5	>		83	174	16 %
			145	1070	

Owner	Sites
Marine Harvest Norway As	159
Lerøy As (Samlet)	83
Salmar As (Samlet)	62
Cermaq As (Samlet)	43
Nordlaks Oppdrett As	38
Nova Sea As	
Bremnes Seashore A	
Sjøtroll Havbruk As	
Bolaks As	
Eidsfjord Sjøfarm As	
Grieg Seafood Finnn	
Midt Norsk Havbruk	
Ellingsen Seafood As	
Erko Seafood As	
Firda Sjøfarmer As	
Salmar Organic As	
Grieg Seafood Rogal	
Lingalaks As	
Nrs Finnmark As	
Rogaland Fjordbruk	
Blom Fiskeoppdrett	
Gratanglaks As	





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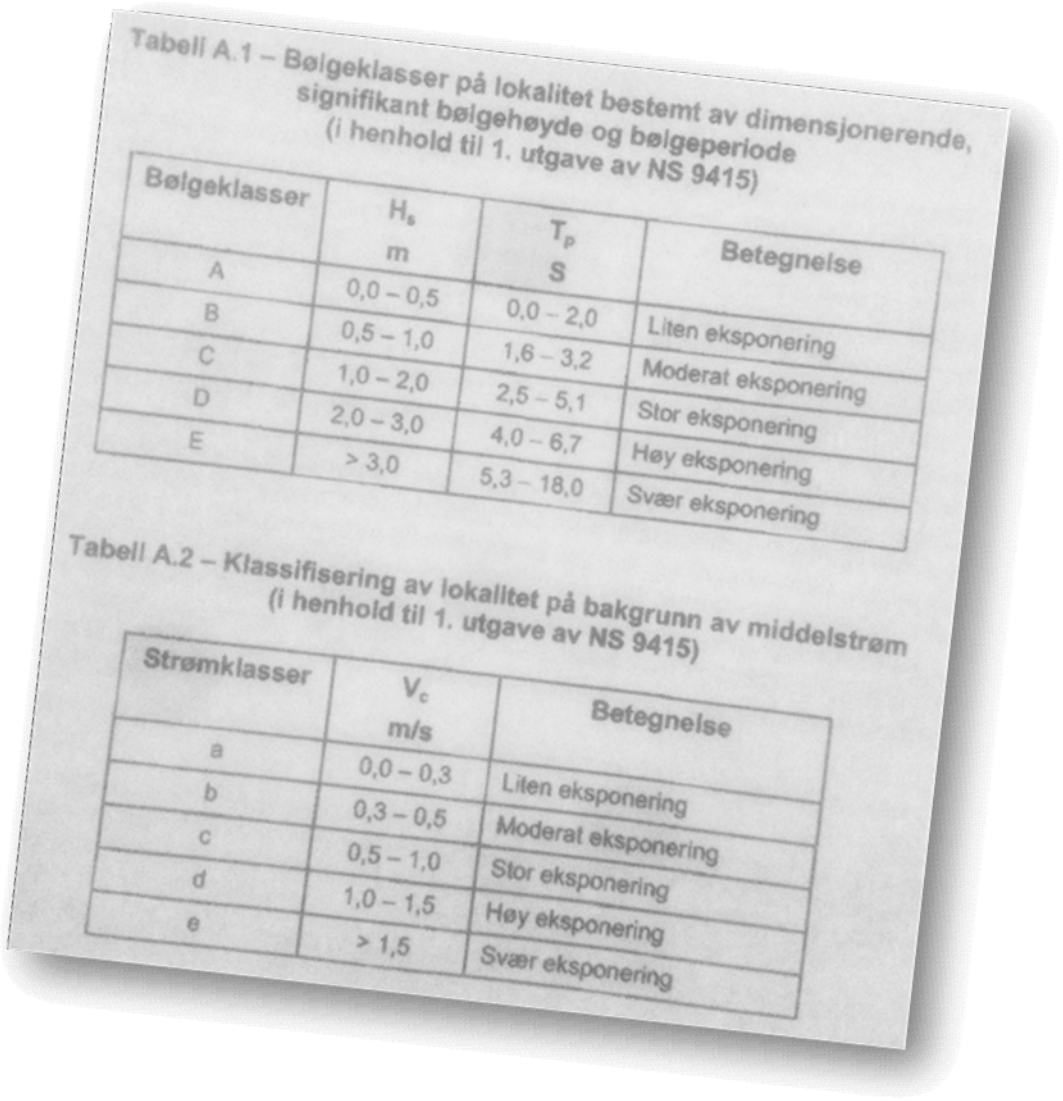
What is an exposed site?

- NS 9415



Tabell A.1 – Bølgeklasser på lokalitet bestemt av dimensjonerende, signifikant bølgehøyde og bølgeperiode (i henhold til 1. utgave av NS 9415)

Bølgeklasser	H_s m	T_p S	Betegnelse
A	0,0 – 0,5	0,0 – 2,0	Liten eksponering
B	0,5 – 1,0	1,6 – 3,2	Moderat eksponering
C	1,0 – 2,0	2,5 – 5,1	Stor eksponering
D	2,0 – 3,0	4,0 – 6,7	Høy eksponering
E	> 3,0	5,3 – 18,0	Svær eksponering

Tabell A.2 – Klassifisering av lokalitet på bakgrunn av middelstrøm (i henhold til 1. utgave av NS 9415)

Strømklasser	V_c m/s	Betegnelse
a	0,0 – 0,3	Liten eksponering
b	0,3 – 0,5	Moderat eksponering
c	0,5 – 1,0	Stor eksponering
d	1,0 – 1,5	Høy eksponering
e	> 1,5	Svær eksponering

Wind waves


Fetch
Wind at sea
(some time ago...)
Site
Local wind
Swell
Wind sea

Method overview

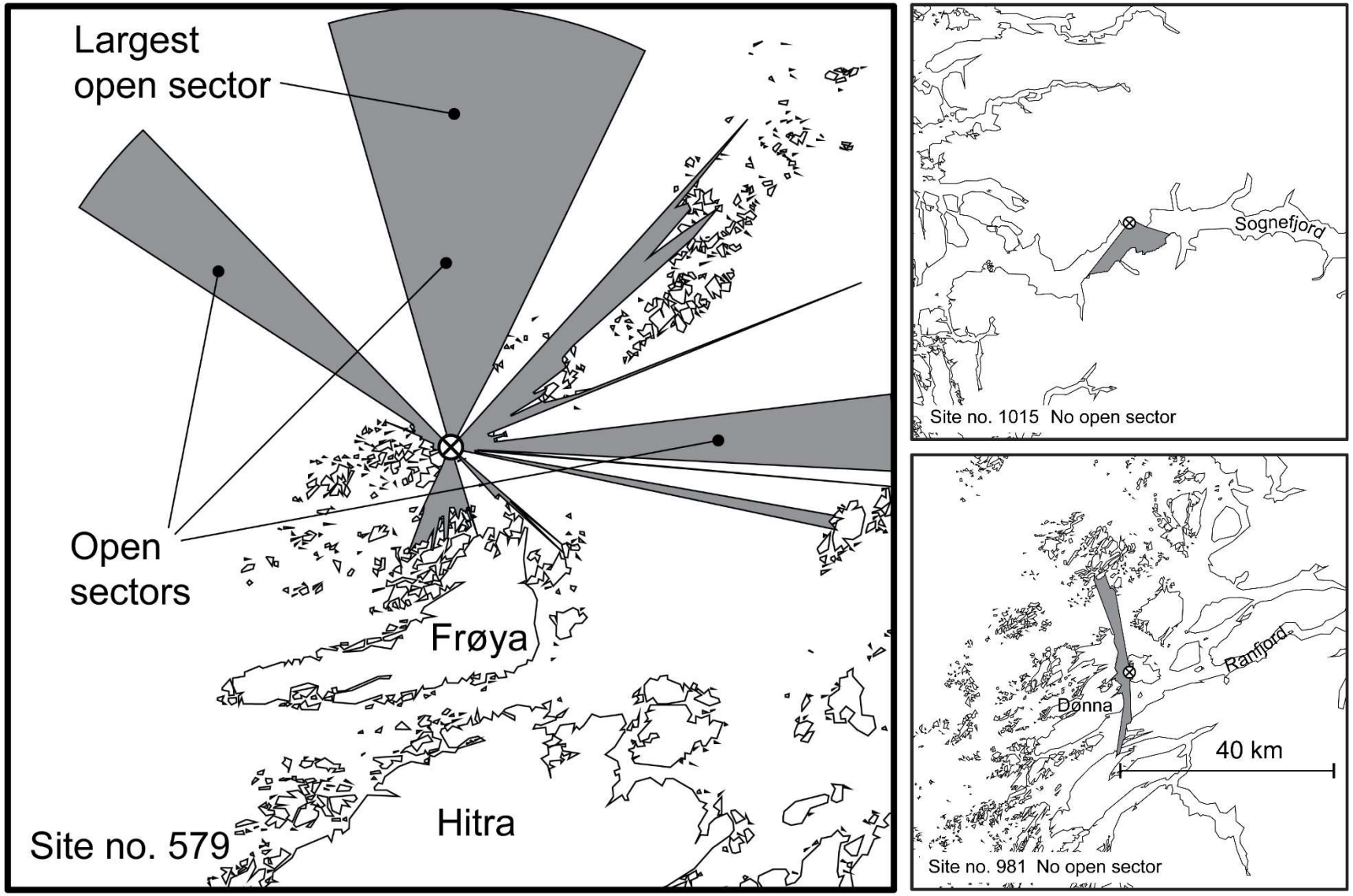
Step 1. Fetch Analysis

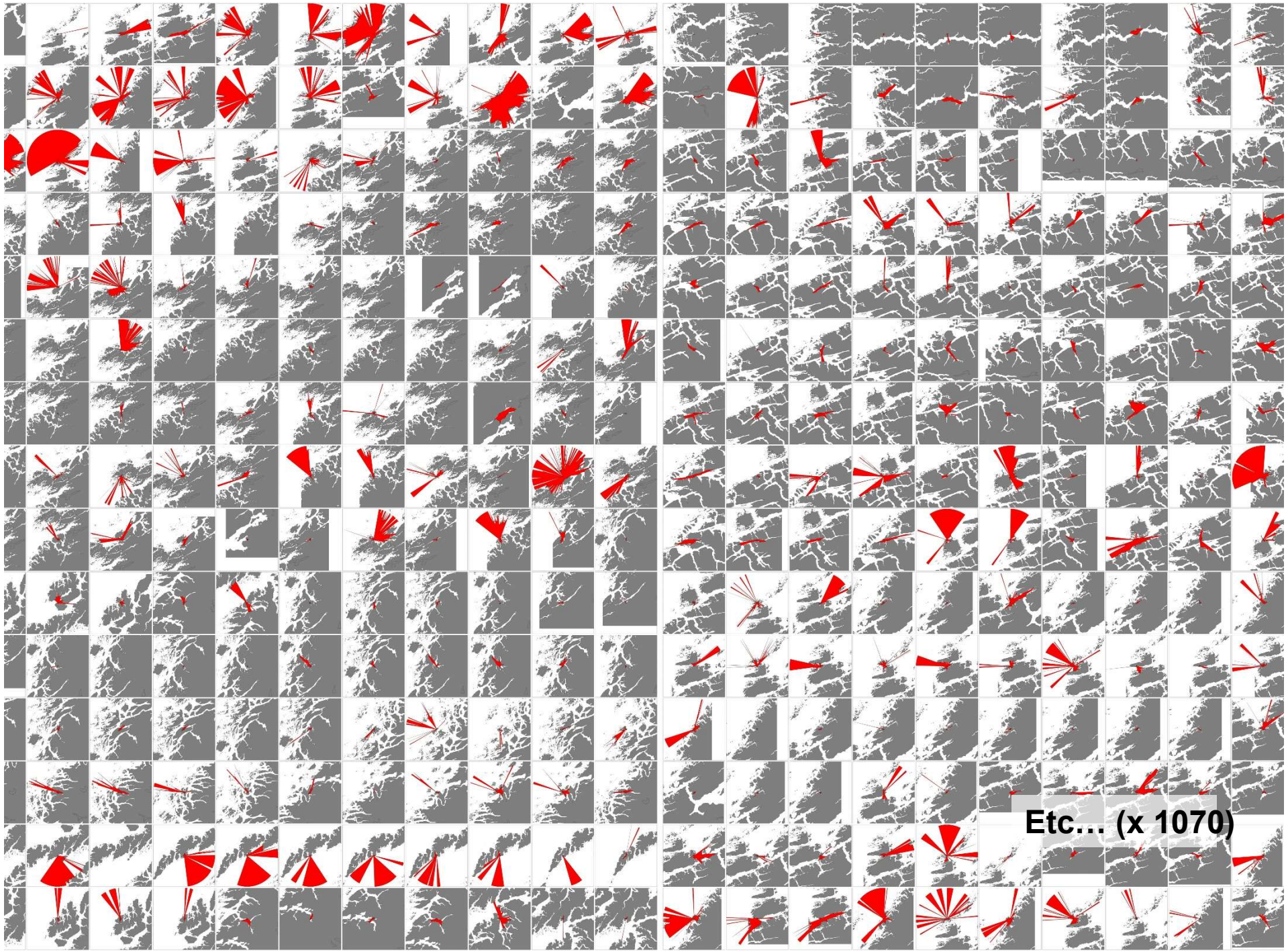
Step 2. Wind data

Step 3. Estimation of wave parameters H_s and T_p

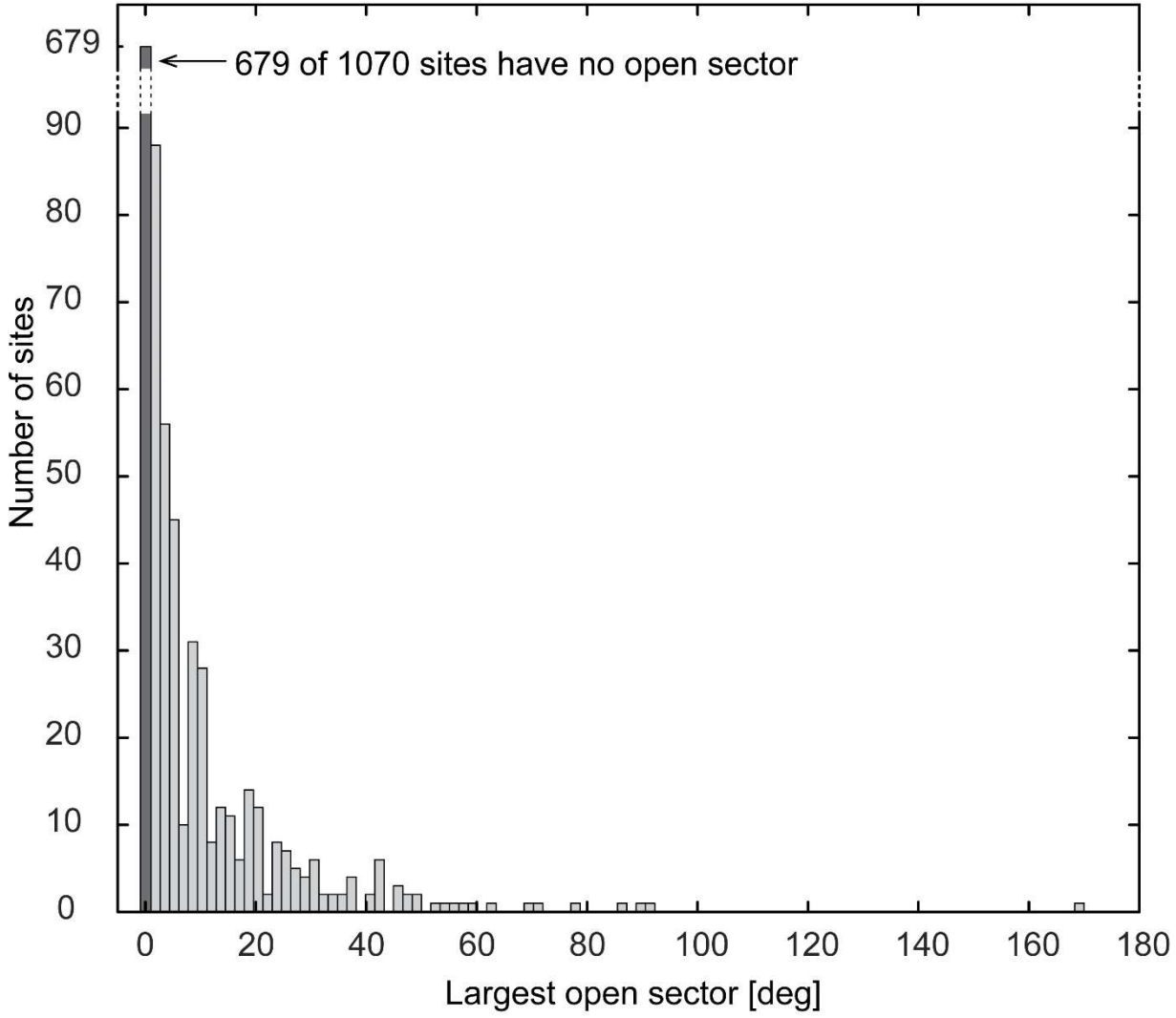
Step 4. Wave statistics

Step 1. Fetch Analysis



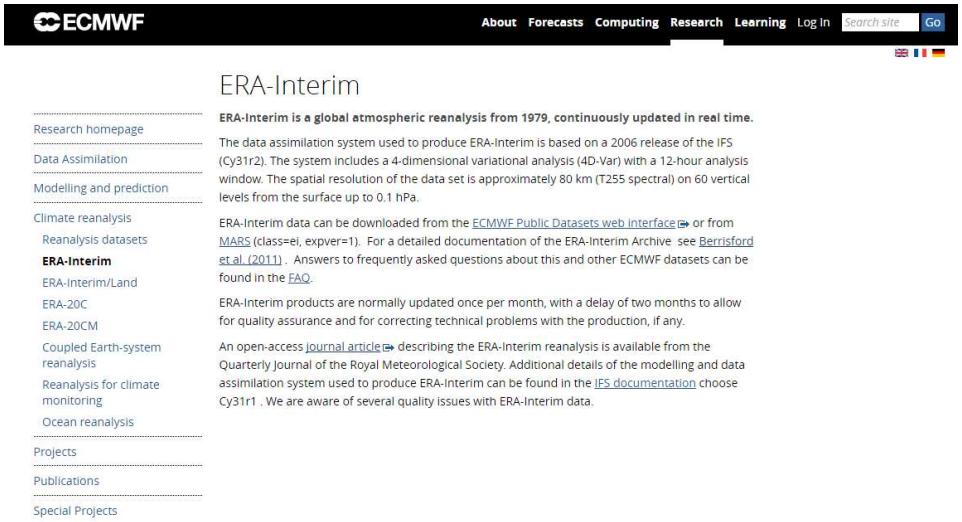

Etc… (x 1070)

Swell / open sectors

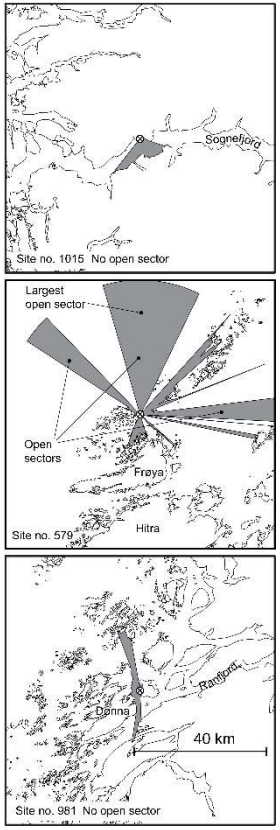


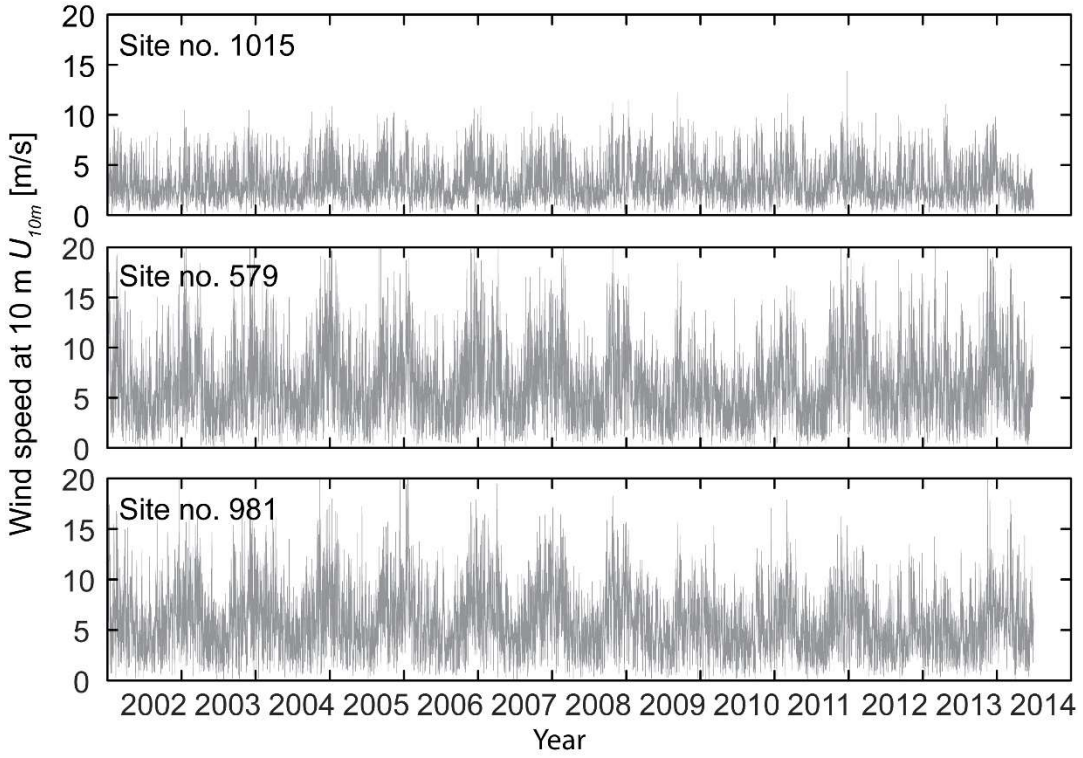
Step 2. Wind data

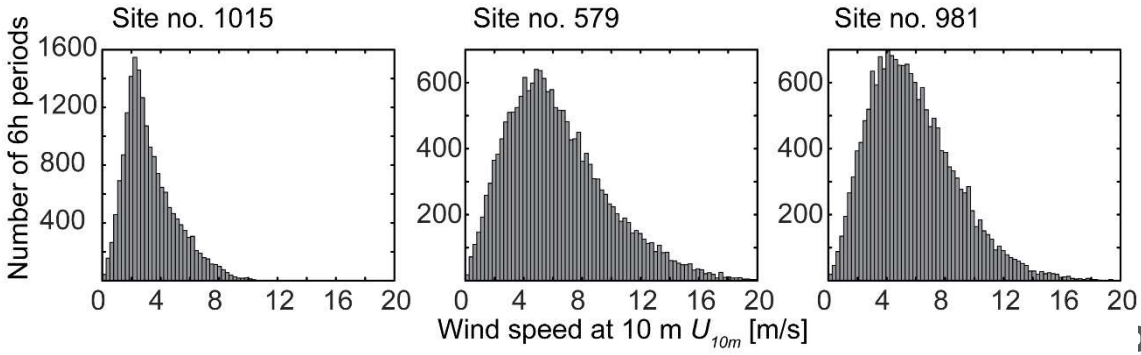
- Wind data is taken from *ERA-interim reanalysis* (European Centre for Medium-Range Weather Forecasts)
- Wind data (U_{10}) is available in 6 hours intervals with a resolution of .75x.75 deg ($\approx$ 50x50kmish)
- Wind at each site is found with linear interpolation
- 12 year of date is used (2002-2014)



Example wind data







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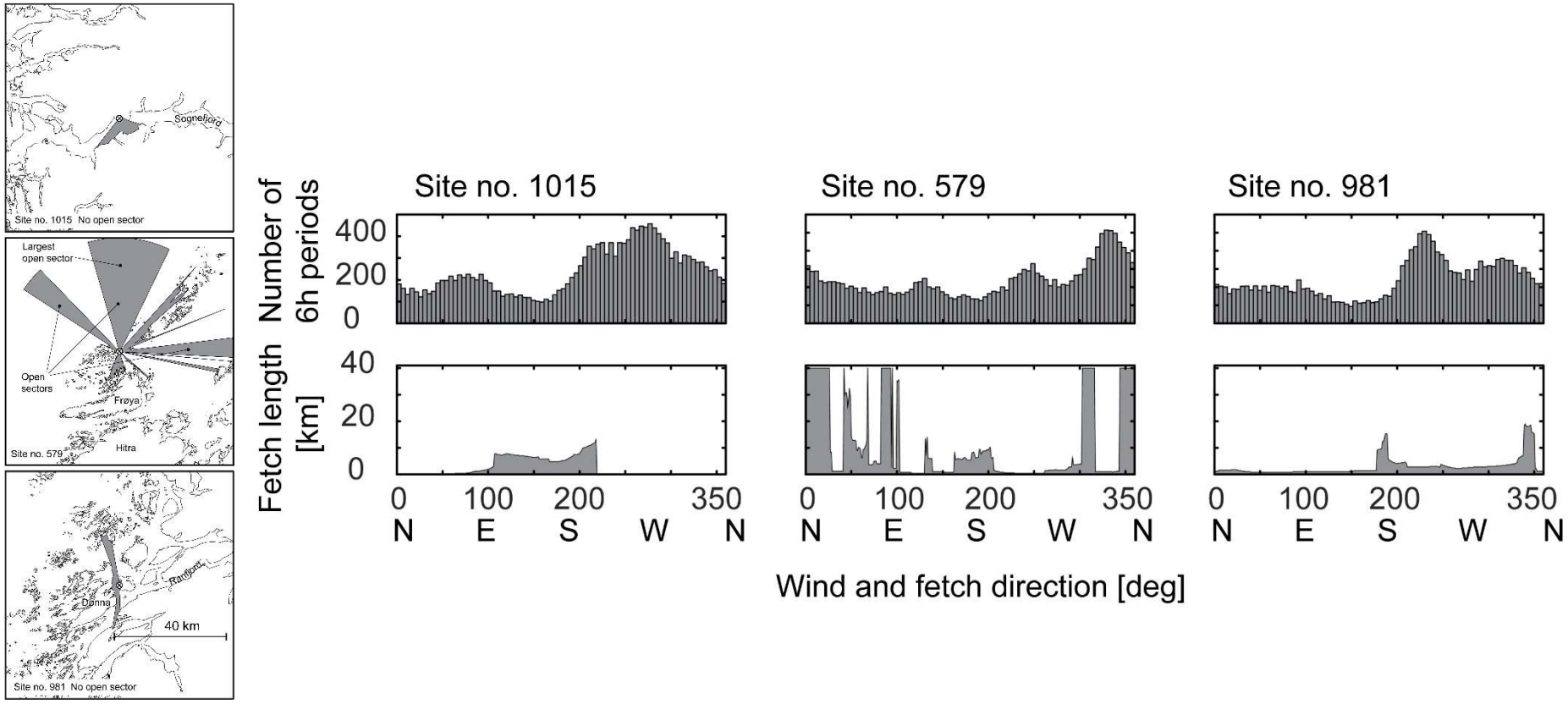
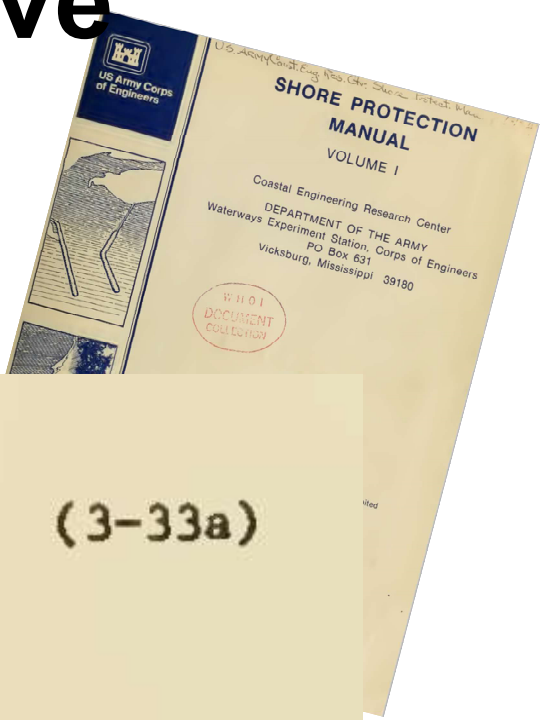
Fetch / wind direction



Step 3. Estimation of wave parameters H_s and T_p



Significant wave height

$$H_{m_o} = 5.112 \times 10^{-4} \, U_A \, F^{1/2} \qquad (3\text{-}33a)$$

Peak period

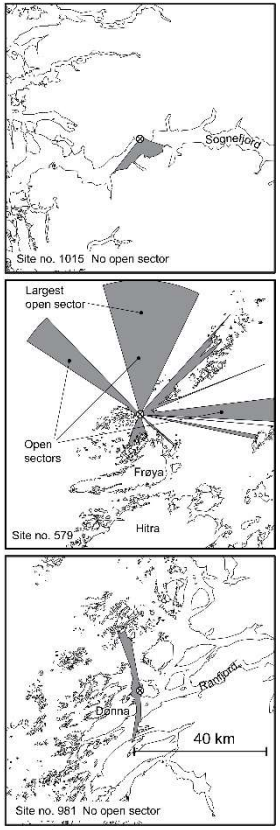
$$T_m = 6.238 \times 10^{-2} \left(U_A F \right)^{1/3} \qquad (3\text{-}34a)$$

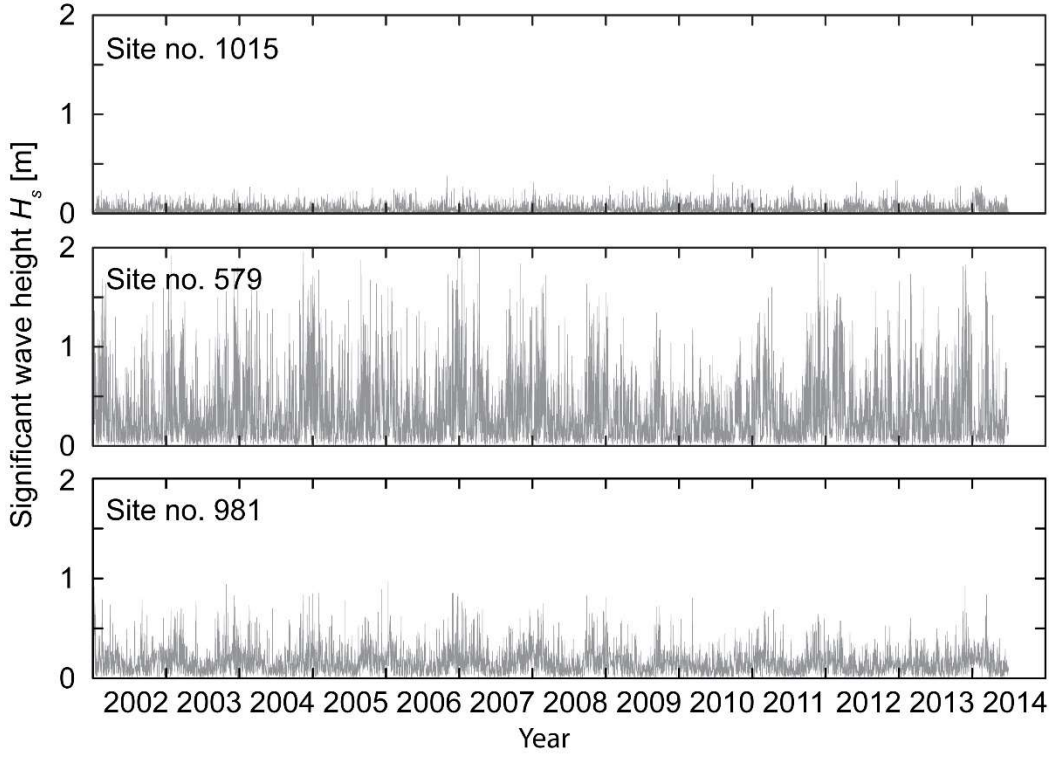
Wind speed

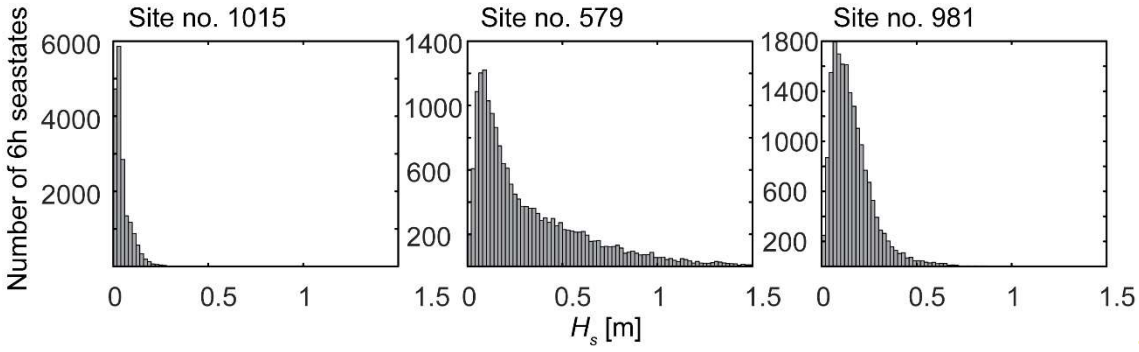
Fetch

$$U_A = 0.71 \, U_{10m}{}^{1.23}$$

Example H_s







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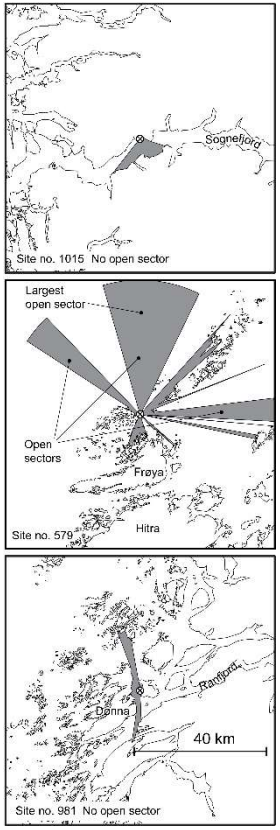
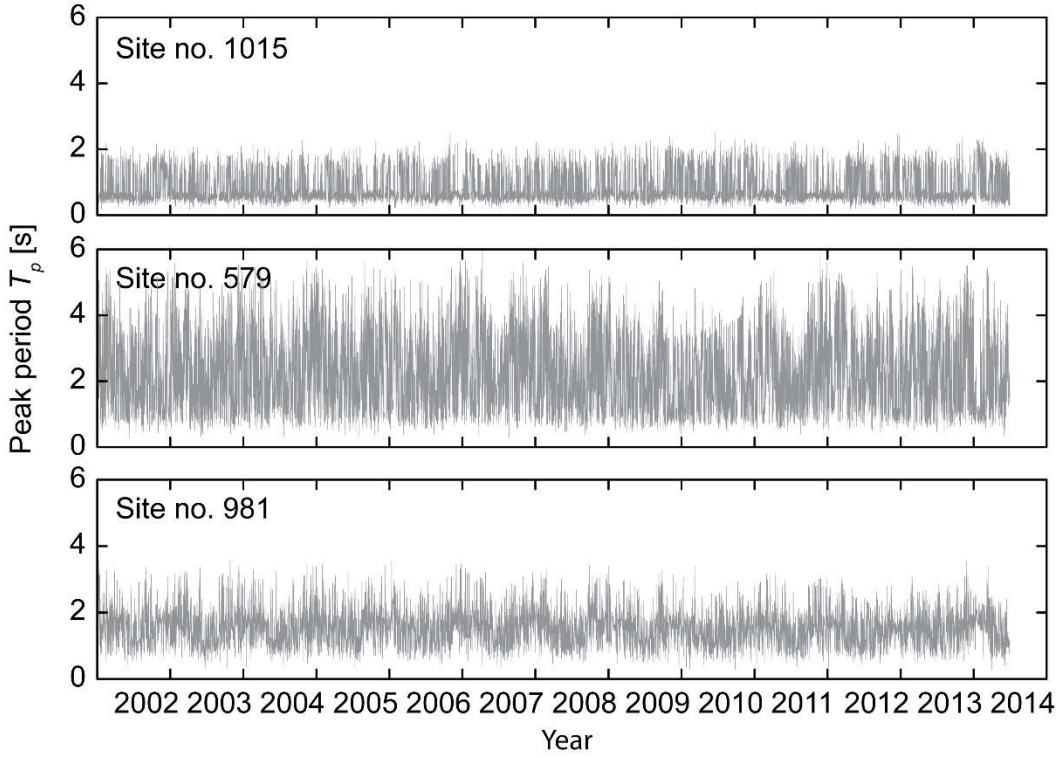
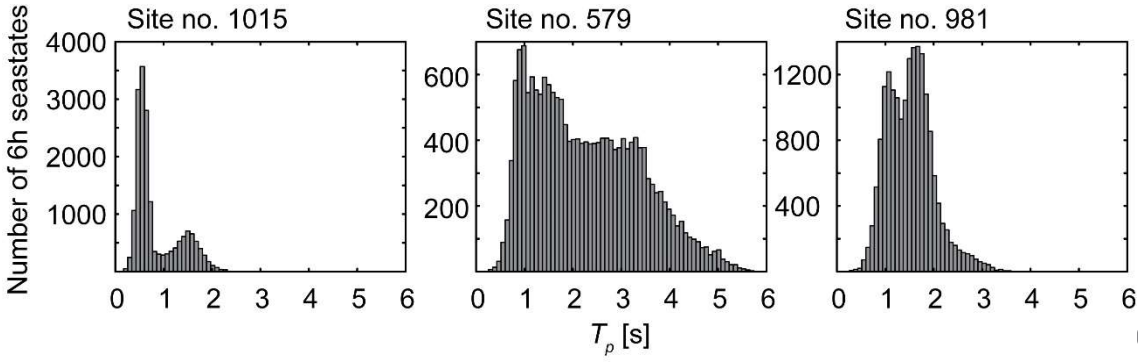
Example T_p







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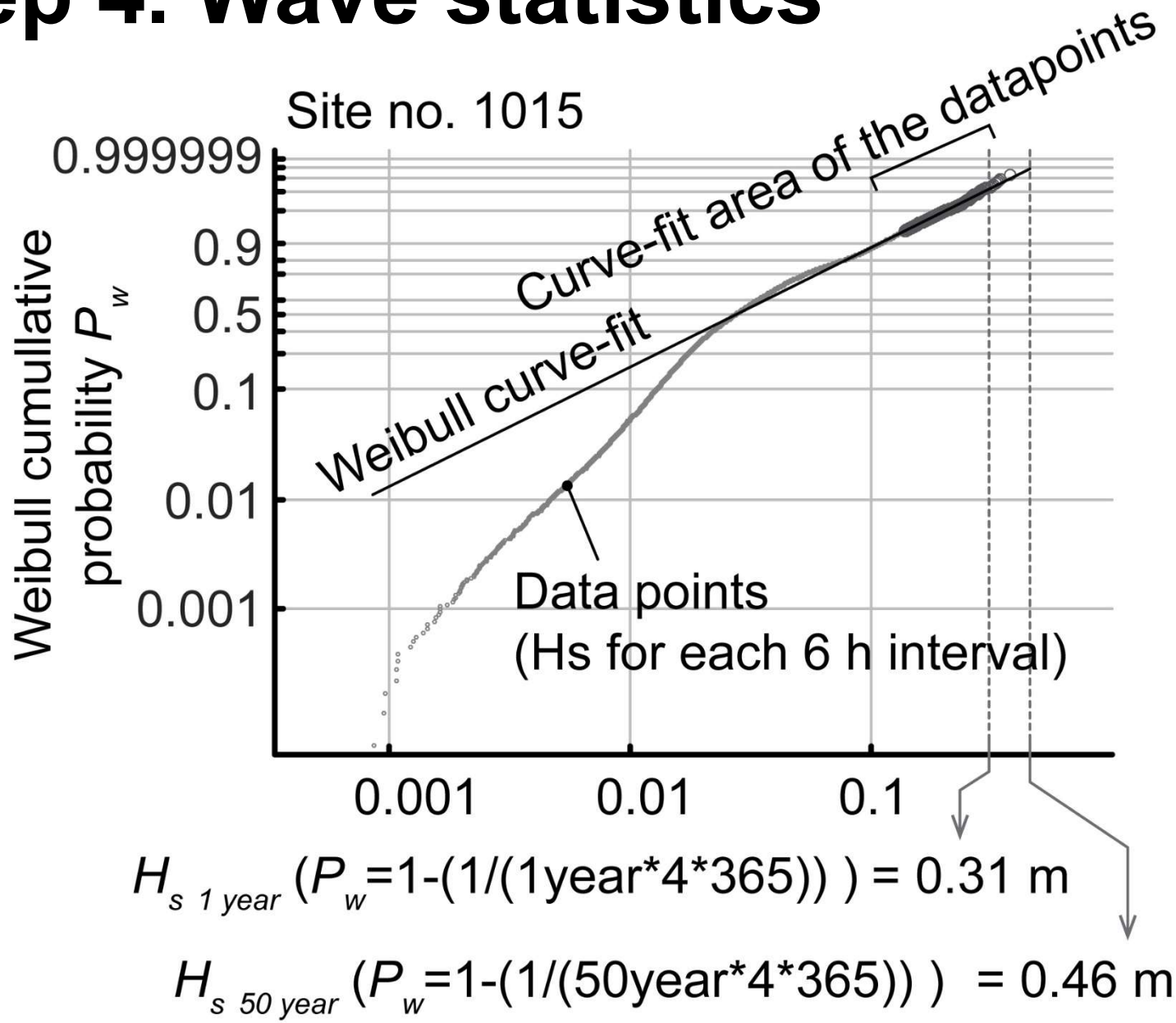
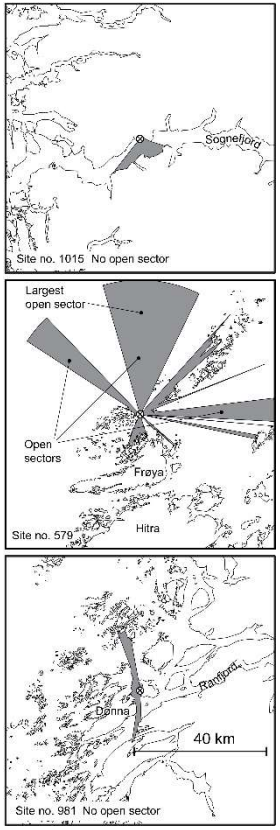
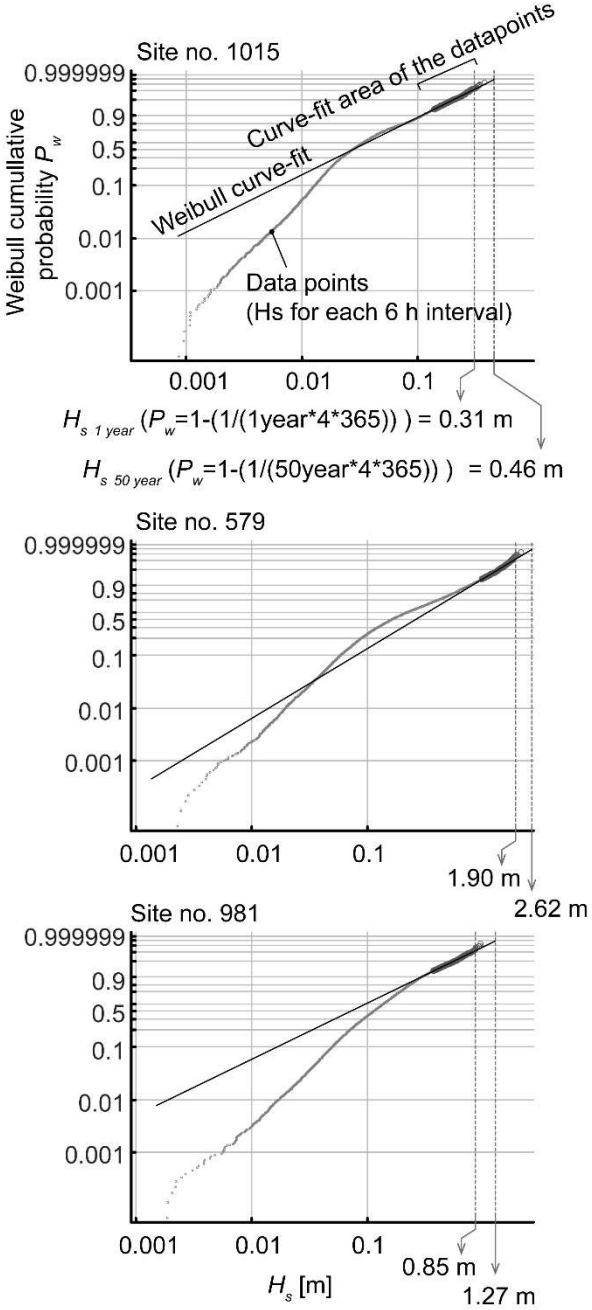
Step 4. Wave statistics



Example





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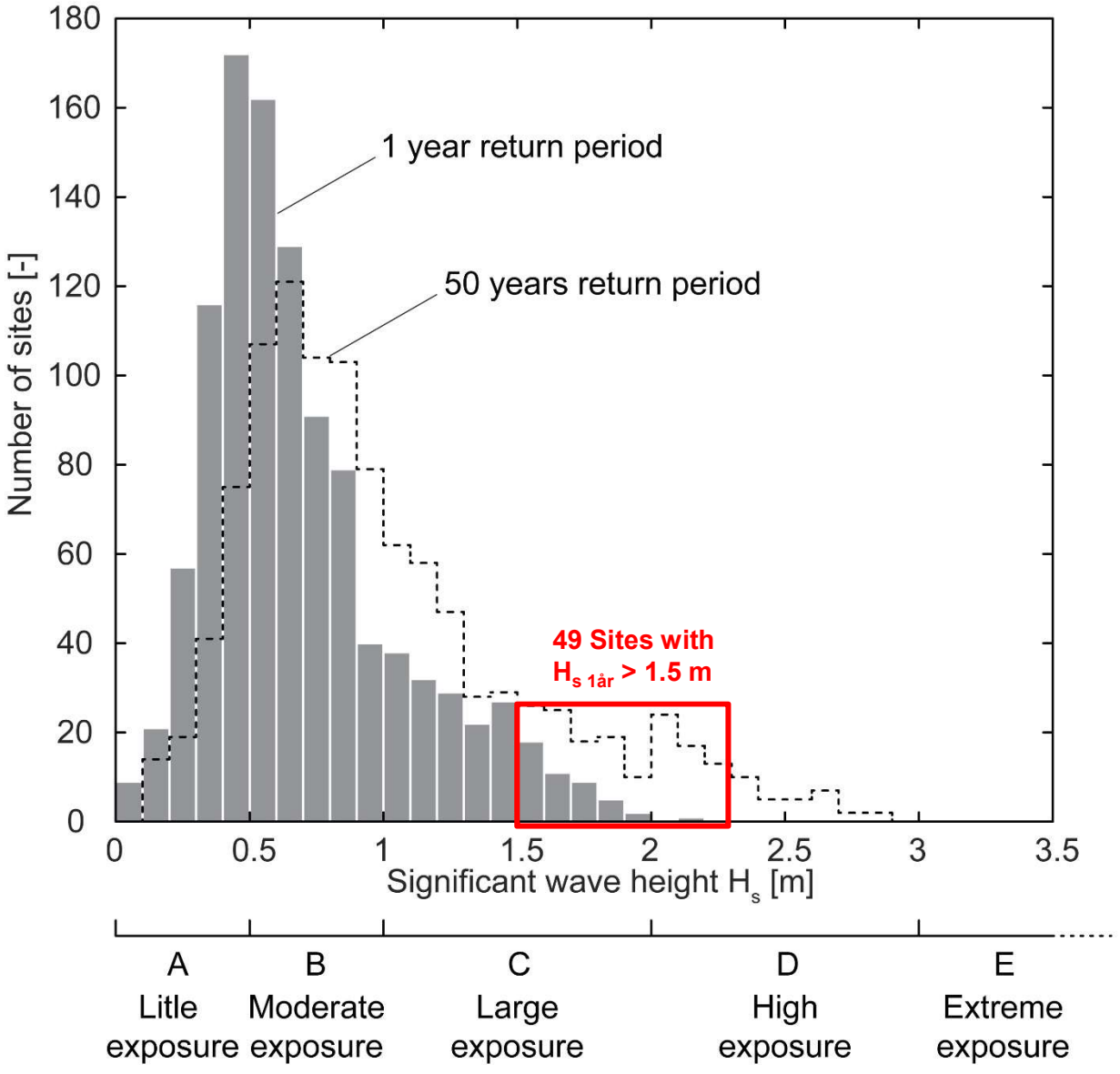
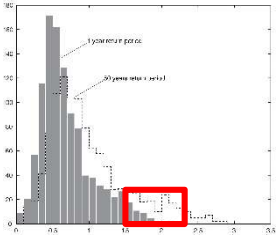
H_s distribution for all sites

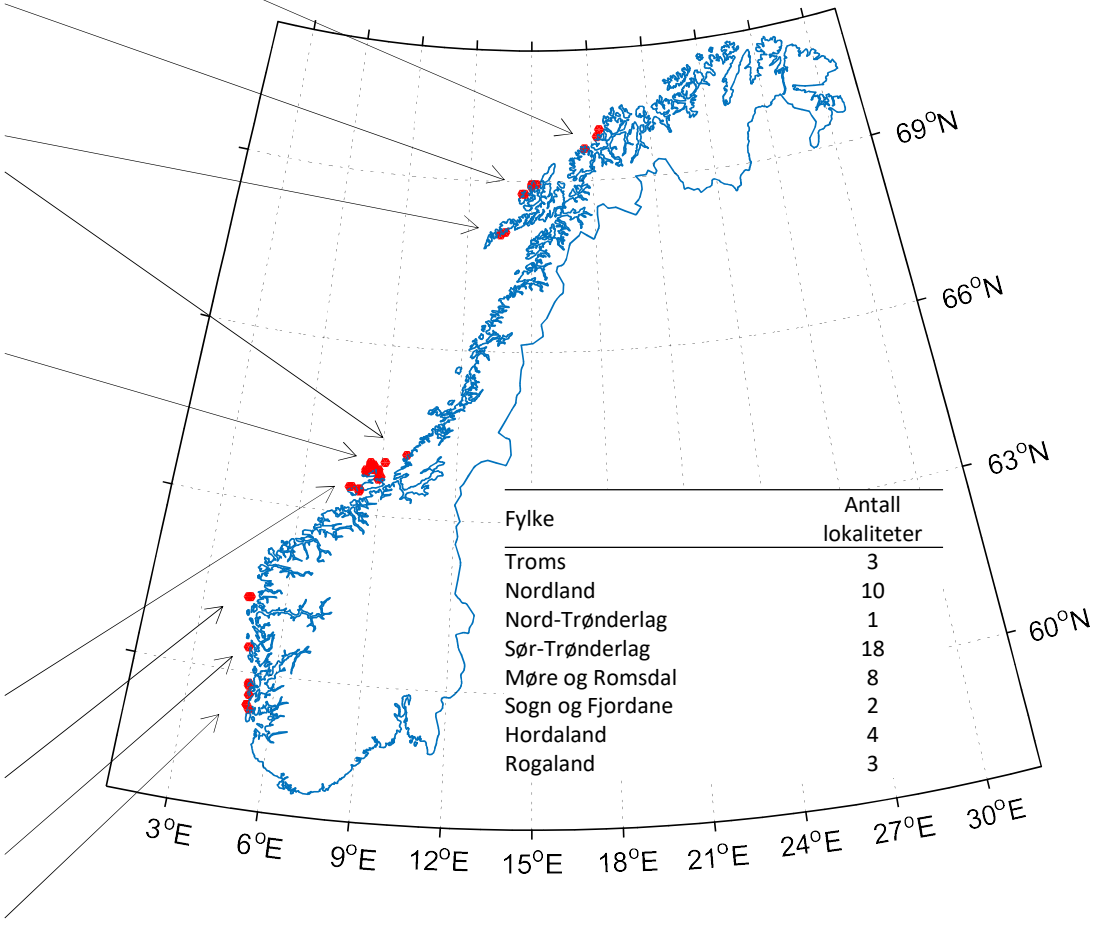


Sites with $H_{s\ 1år}$ > 1.5m



	Lokalitet	Fylke	Eier	Hs 1y [m]	Hs 50y [m]
13	Småvær	Troms	Salmar Nord As	1.8	2.4
45	Sessøya	Troms	Lerøy Aurora As	1.5	2.3
39	Hundbergan	Troms	Flakstadvåg Laks As	1.5	2.3
7	Gisløy Nø	Nordland	Øyfisk As	1.8	2.6
47	Gisløy S	Nordland	Cermaq Norway As	1.5	2.4
5	Høydalsvika	Nordland	Øyfisk As	1.9	2.7
36	Juvågen	Nordland	Øyfisk As	1.6	2.9
48	Bonhammaren	Nordland	Kristoffersen Egil & Sønner As	1.5	2.8
15	Skatleia	Nordland	Kristoffersen Egil & Sønner As	1.7	2.6
19	Hysjorda	Nordland	Kristoffersen Egil & Sønner As	1.7	2.5
32	Vedvika	Nordland	Kristoffersen Egil & Sønner As	1.6	2.8
42	Æsøya	Nordland	Isqueen As	1.5	2.0
35	Sandholman	Nordland	Eidsfjord Sjøfarm As	1.6	2.1
49	Eldviktaren	Nord-Trønderlag	Midt Norsk Havbruk As	1.5	2.1
46	Gjæsingen	Sør-Trønderlag	Salmar Farming As	1.5	2.0
38	Håbranden	Sør-Trønderlag	Salmar Farming As	1.5	2.1
1	Salatskjæra	Sør-Trønderlag	Salmar Farming As	2.1	2.6
30	Slettholmene	Sør-Trønderlag	Marine Harvest Norway As	1.6	2.0
8	Grøttingsøy	Sør-Trønderlag	Marine Harvest Norway As	1.8	2.4
3	Kattholmen	Sør-Trønderlag	Salmar Farming As	1.9	2.6
9	Kattholmen Ii	Sør-Trønderlag	Salmar Farming As	1.8	2.6
26	Langskjæra	Sør-Trønderlag	Lerøy Midt As	1.6	2.2
28	Langskjæra Ii	Sør-Trønderlag	Lerøy Midt As	1.6	2.1
27	Tennøya	Sør-Trønderlag	Marine Harvest Norway As	1.6	2.1
29	Aursøysva	Sør-Trønderlag	Erviks Laks Og Ørret As	1.6	2.1
24	Raskjæret	Sør-Trønderlag	Erviks Laks Og Ørret As	1.6	2.1
37	Seiballskjæret	Sør-Trønderlag	Erviks Laks Og Ørret As	1.6	2.3
25	Ørnøya	Sør-Trønderlag	Salmar Farming As	1.6	2.3
21	Ørnøya Ii	Sør-Trønderlag	Salmar Farming As	1.7	2.3
43	Ulvan	Sør-Trønderlag	Marine Harvest Norway As	1.5	2.1
44	Ilsøya Ø	Sør-Trønderlag	Knutshaugfisk As	1.5	2.5
41	Flesa	Sør-Trønderlag	Knutshaugfisk As	1.5	2.6
4	Gråøya	Møre og Romsdal	Nekton Havbruk As	1.9	2.4
2	Andholmen 1	Møre og Romsdal	Salmar Farming As	2.0	2.6
14	Andholmen 2	Møre og Romsdal	Salmar Farming As	1.8	2.7
6	Hjortholman 2	Møre og Romsdal	Salmar Farming As	1.9	2.7
10	Hjortholman	Møre og Romsdal	Salmar Farming As	1.8	2.6
12	Reiråklakken	Møre og Romsdal	Salmar Farming As	1.8	2.4
18	Fuglåsen	Møre og Romsdal	Salmar Farming As	1.7	2.3
34	Bremnessvaet	Møre og Romsdal	Marine Harvest Norway As	1.6	2.3
11	Kalvøya N	Sogn og Fjordane	Landøy Fiskeoppdrett As	1.8	2.3
16	Guriøyna	Sogn og Fjordane	Landøy Fiskeoppdrett As	1.7	2.3
33	Oksen	Hordaland	Marine Harvest Norway As	1.6	2.2
22	Trettholmosen	Hordaland	Bolaks As	1.7	2.1
17	Krossholmen	Hordaland	Bolaks As	1.7	2.2
20	Sølvøyane	Hordaland	Bolaks As	1.7	2.3
40	Flatholmen	Rogaland	Toftøy Fjordbruk As	1.5	2.1
23	Bryggelandsholmane	Rogaland	Rogaland Fjordbruk As	1.6	2.3
31	Tuholmane Ø	Rogaland	Hellesund Fiskeoppdrett As	1.6	2.2

Geografisk



Fylke	Antall lokaliteter
Troms	3
Nordland	10
Nord-Trønderlag	1
Sør-Trønderlag	18
Møre og Romsdal	8
Sogn og Fjordane	2
Hordaland	4
Rogaland	3

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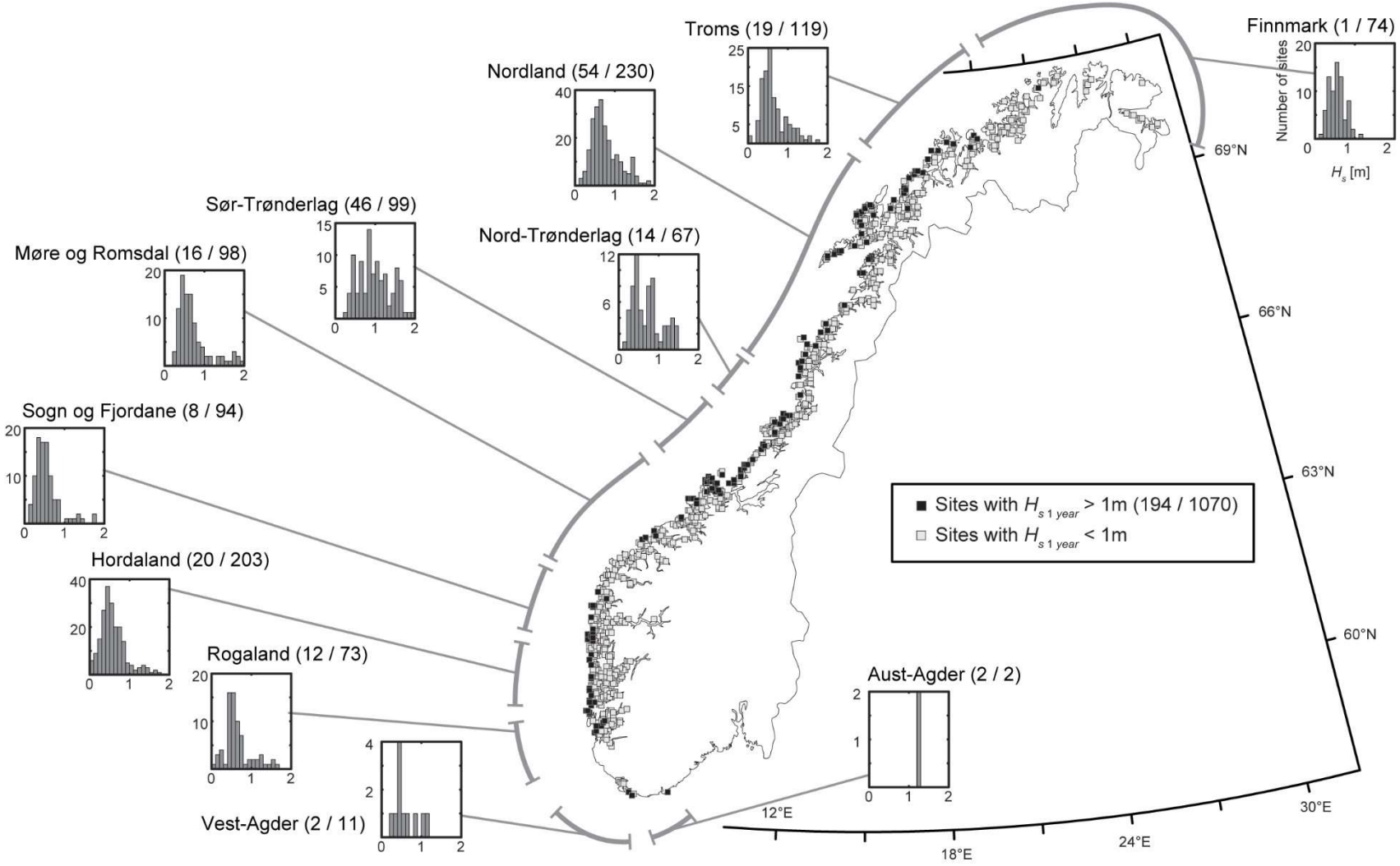
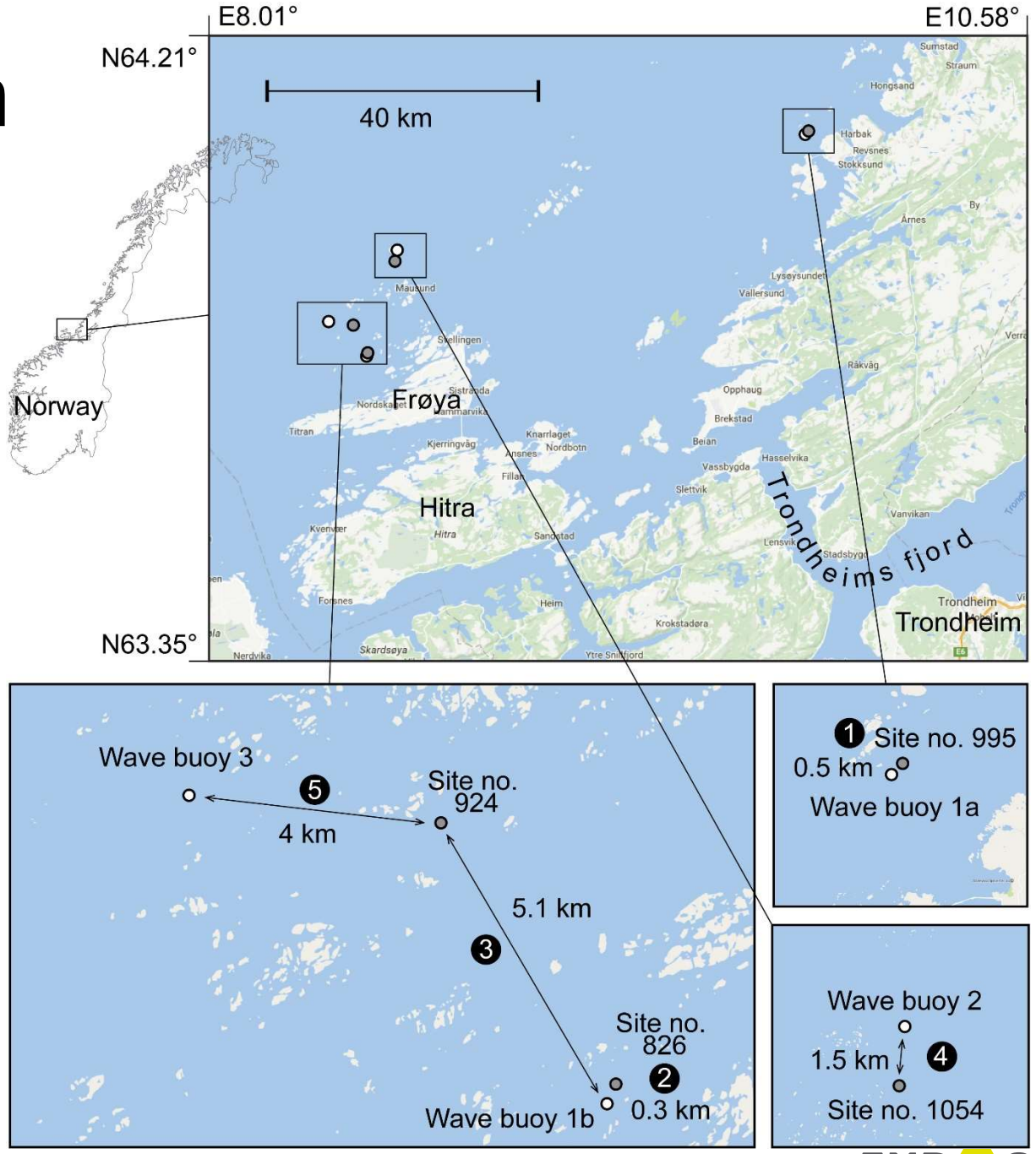
By *fylke*


Troms (19 / 119)
Finnmark (1 / 74)
Nordland (54 / 230)
Sør-Trønderlag (46 / 99)
Nord-Trønderlag (14 / 67)
Møre og Romsdal (16 / 98)
Sogn og Fjordane (8 / 94)
Hordaland (20 / 203)
Rogaland (12 / 73)
Vest-Agder (2 / 11)
Aust-Agder (2 / 2)
Number of sites
H_s [m]
Sites with $H_{s\,1\,year}$ > 1m (194 / 1070)
Sites with $H_{s\,1\,year}$ < 1m
69°N
66°N
63°N
60°N
12°E
18°E
24°E
30°E

Validation

	Wave buoy	Measurement period	
1a	N64.0822 E9.87781	06.11.2014 - 30.06.2015	(8 months)
1b	N63.7782 E8.5148	02.07.2015 - 08.11.2016	(1.4 years)
2	N63.91959 E8.59268	10.03.2016 - 08.11.2016	(8 months)
3	N63.82144 E8.38239	25.01.2016 - 08.11.2016	(10 months)



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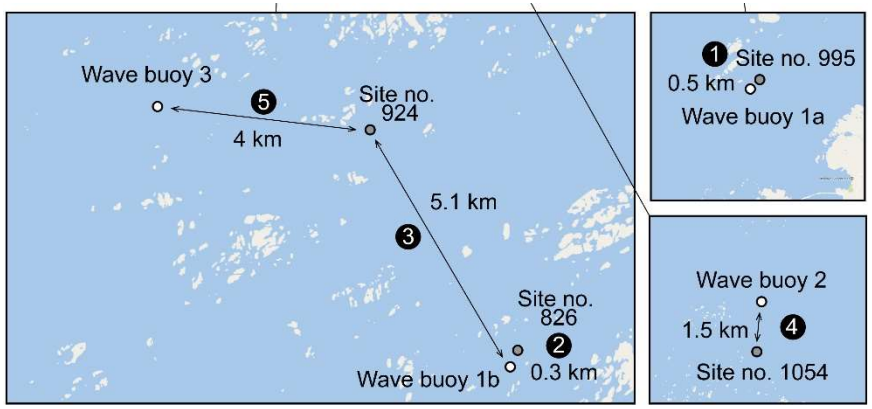
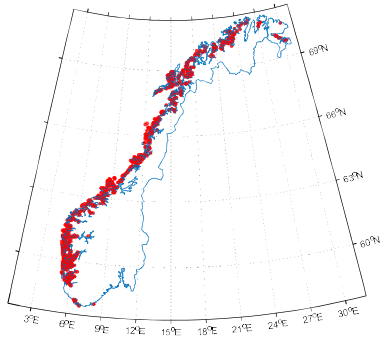
Validation

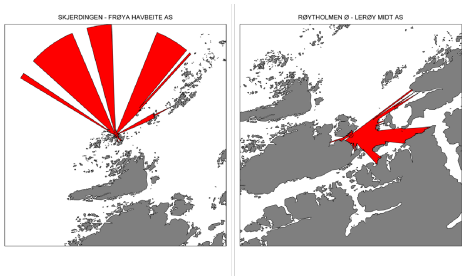


	1		2		3		4		5	
[m]	H_s 1y	H_s 50y	H_s 1y	H_s 50y	H_s 1y	H_s 50y	H_s 1y	H_s 50y	H_s 1y	H_s 50y
Wave buoy recording	Wave buoy 1a		Wave buoy 1b		Wave buoy 1b		Wave buoy 2		Wave buoy 3	
	2.79	3.56	1.05	1.39	1.05	1.39	1.69	2.07	3.59	4.73
Fetch analysis (2002-2013)	Site no. 995		Site no. 826		Site no. 924		Site no. 1054		Site no. 924	
	1.34	1.77	1.05	1.41	1.15	1.57	2.12	2.63	1.15	1.57
Individual years sorted in increasing order	1.02	1.26	0.87	1.18	0.09	0.13	1.60	2.05	0.90	1.17
	1.22	1.50	0.92	1.25	0.90	1.17	1.93	2.41	0.93	1.17
	1.22	1.60	0.96	1.30	0.93	1.17	2.01	2.42	0.94	1.17
	1.23	1.61	1.00	1.31	0.94	1.17	2.02	2.49	0.98	1.29
	1.26	1.61	1.01	1.32	0.98	1.29	2.03	2.49	1.08	1.42
	1.26	1.61	1.04	1.35	1.08	1.42	2.08	2.50	1.09	1.46
	1.28	1.66	1.07	1.40	1.09	1.46	2.08	2.58	1.17	1.63
	1.29	1.70	1.07	1.41	1.17	1.63	2.15	2.70	1.20	1.68
	1.29	1.70	1.07	1.45	1.20	1.68	2.18	2.72	1.26	1.73
	1.31	1.76	1.09	1.47	1.26	1.73	2.22	2.79	1.27	1.85
	1.31	1.76	1.15	1.58	1.27	1.85	2.25	2.82	1.30	1.88
	1.35	1.80	1.15	1.59	1.30	1.88	2.26	2.88	1.32	1.94

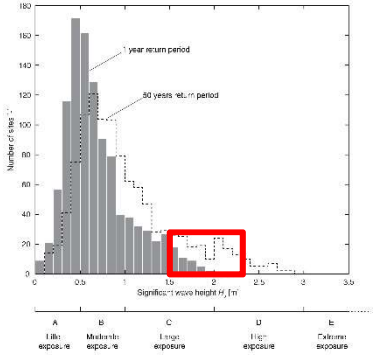
Summary



- Challenge
  - What is an exposed site?
  - 1070 salmon sites in Norway
- Method
  - Wind sea: Fetch + Wind = Waves
  - Crude approach, lots of assumptions
  - Efficient



- Results
  - Significant wave heigh (H_s) for all salmon sites in Norway (2002-2014)
  - The 5% most exposed sites: 1.5 m < $H_{s\ 1år}$ < 2.2m
  - Most exposed:
    - Sør-Trøndelag
    - Salmar AS



Further work

- Presentation at OMAE 2017 (Trondheim)
- Expand the analysis to include
  - Swell
  - Current
- Compare with sites in other countries
  - Scotland, Chile, Canada, Faero Islands etc.
- Suggest new classification of exposed sites
  - Objective
  - Quantitative