ICCE 2018
36TH INTERNATIONAL CONFERENCE ON COASTAL ENGINEERING 2018
Baltimore, Maryland | July 30 – August 3, 2018
The State of the Art and Science of Coastal Engineering

Generation of Unusually Large Runup Events

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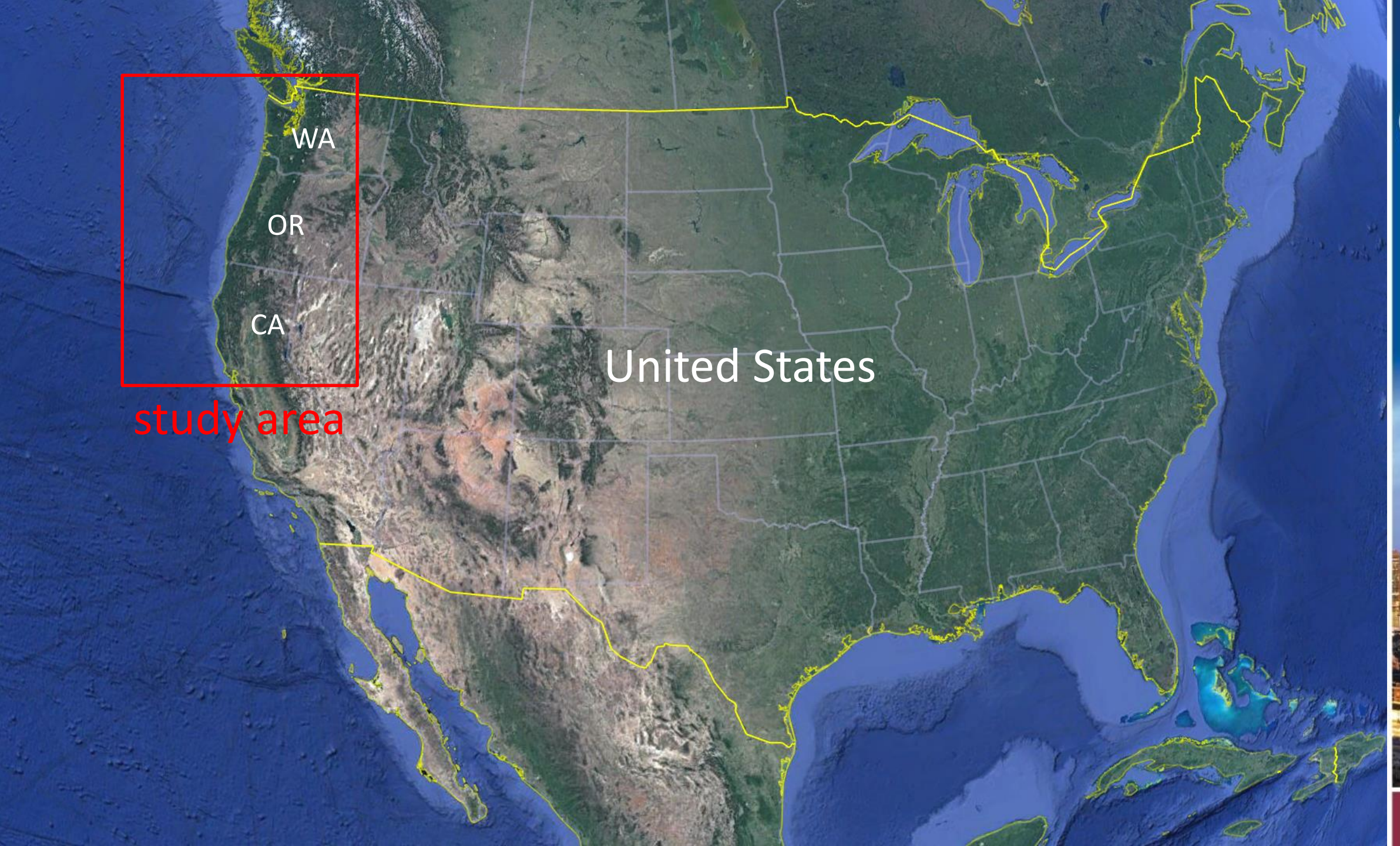
*Oregon State University, *Pacific Northwest National Lab*

Treena Jensen, David Elson, William R. Schneider

National Weather Services



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All times in UTC

~00:55 Jan 17

WA

OR

CA

966 m

ICCE 2018

All times in UTC

~00:55 Jan 17

~00:52 Jan 17

966 m

WA

OR

CA

ICCE 2018

All times in UTC

~00:55 Jan 17

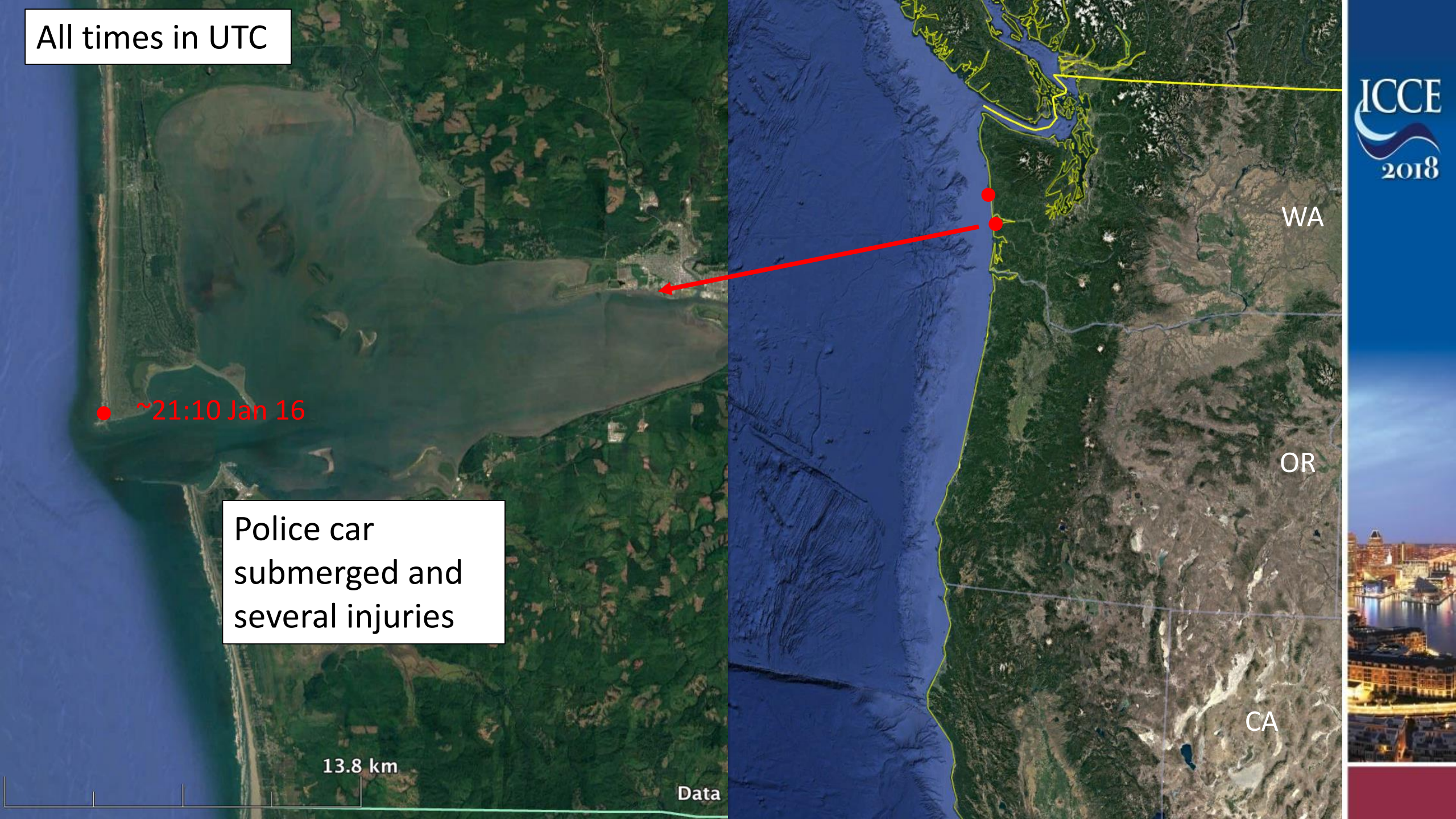
00:52 Jan 17

~00:30 Jan 17

966 m

WA

ICCE 2018


All times in UTC
~21:10 Jan 16
Police car submerged and several injuries
13.8 km
Data
WA
OR
CA
ICCE
2018


~22:30 Jan 16
2065 m
Data

WA
OR
CA


ICCE
2018

All times in UTC

~22:30 Jan 16

WA

OR

CA

2065 m

Data

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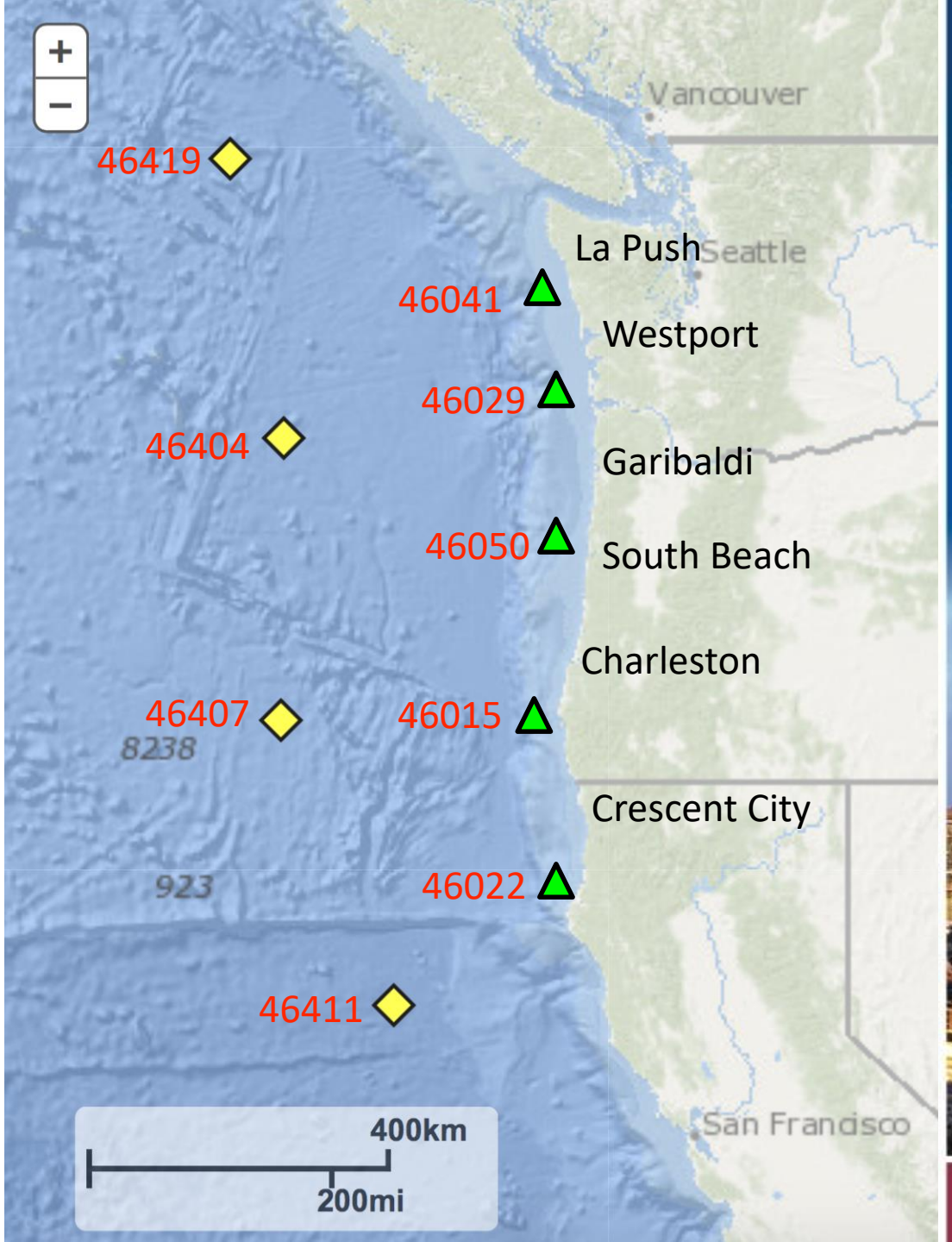
All times in UTC
"A woman was washed off of the South Jetty and recovered from the water by people on the scene, but is bleeding profusely. She is possibly suffering from hypothermia and a head injury."
- California Highway Patrol Dispatch Scanner
~22:20 Jan 16
WA
OR
CA
2033 m
Data

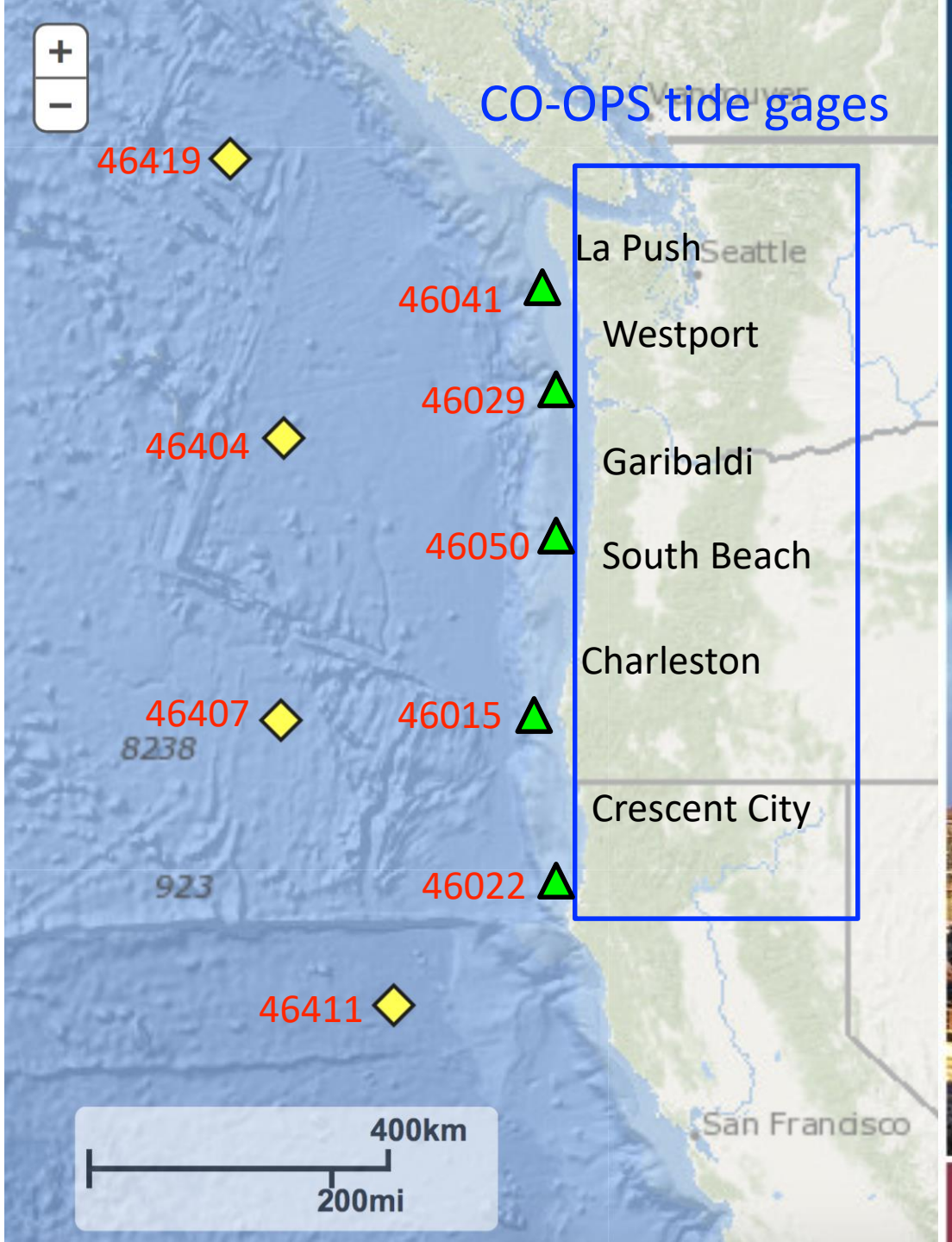
Study goal

To better understand the conditions that generated these unusually large runup events



Observations

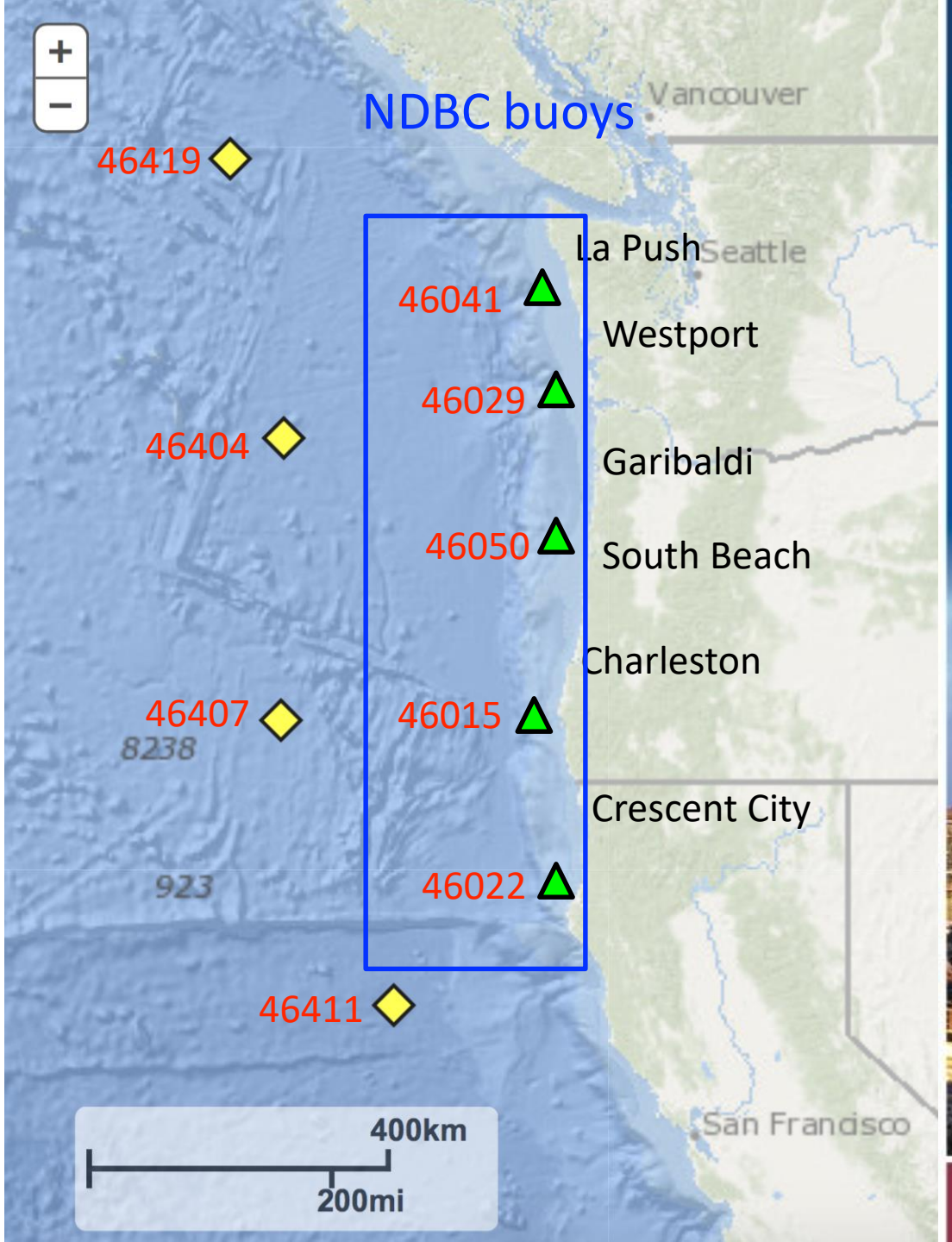
- CO-OPS tide gages
  – water level, wind speed, atmospheric pressure



Observations

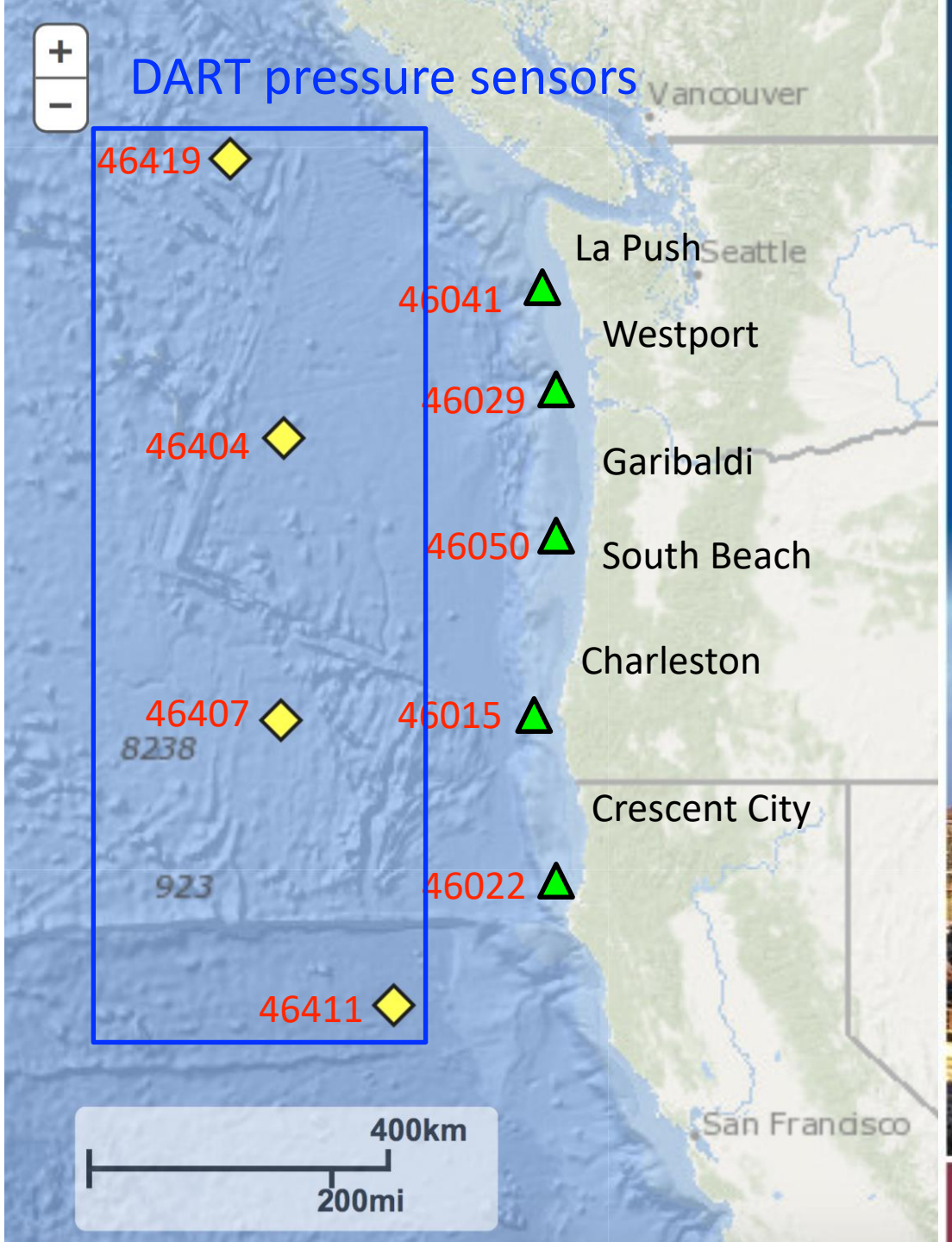
- CO-OPS tide gages
  – water level, wind speed, atmospheric pressure

- NDBC buoys
  – wave height, wave period, wave energy spectra



Observations

- CO-OPS tide gages
  – water level, wind speed, atmospheric pressure
- NDBC buoys
  – wave height, wave period, wave energy spectra
- DART pressure sensors
  – water level



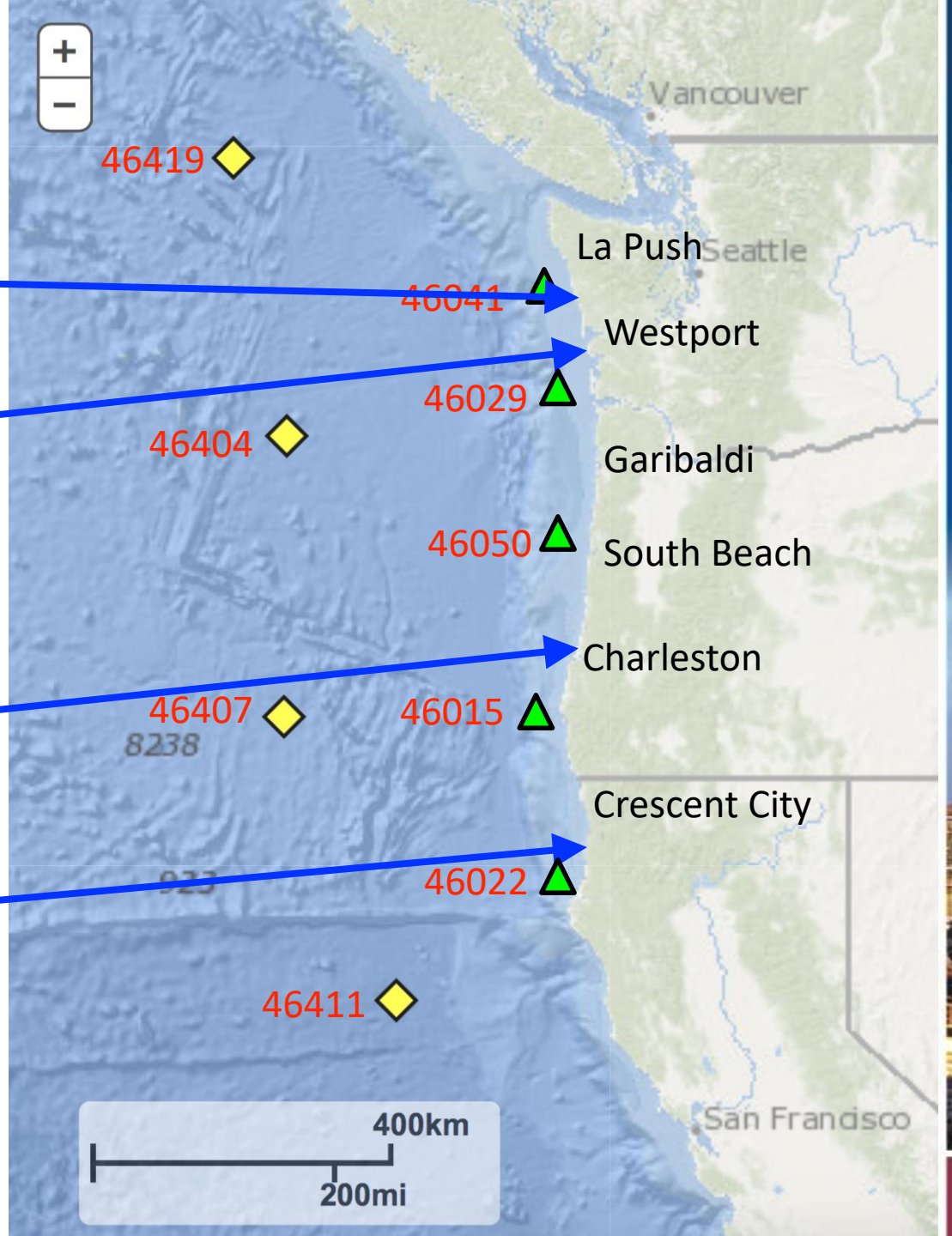
Summary of videos and reports

3 videos 01/17 ~01:00 UTC

Injury reports 01/16 ~21:00 UTC

1 video 01/16 ~22:30 UTC

Injury report 01/16 ~22:20 UTC



Summary of videos and reports

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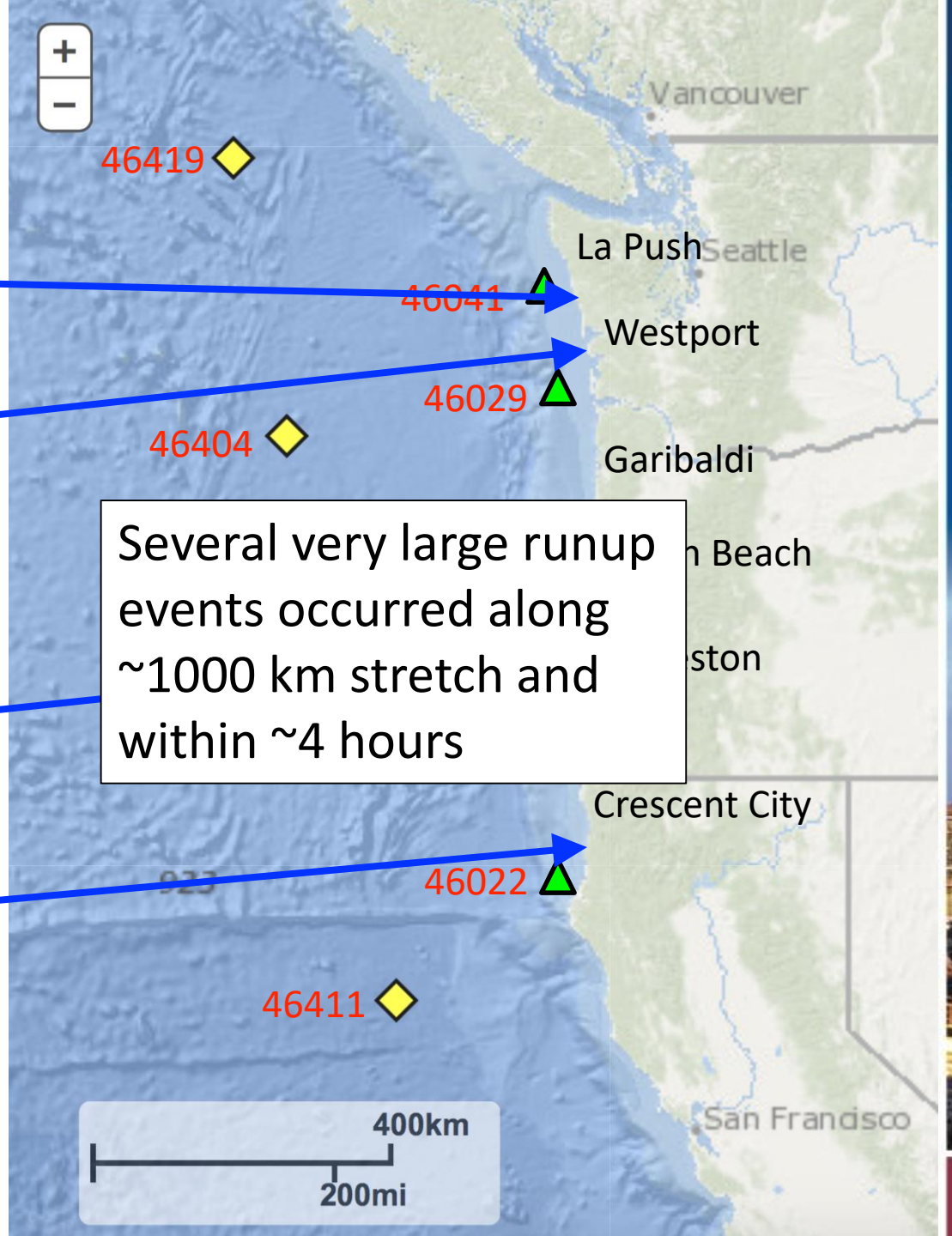
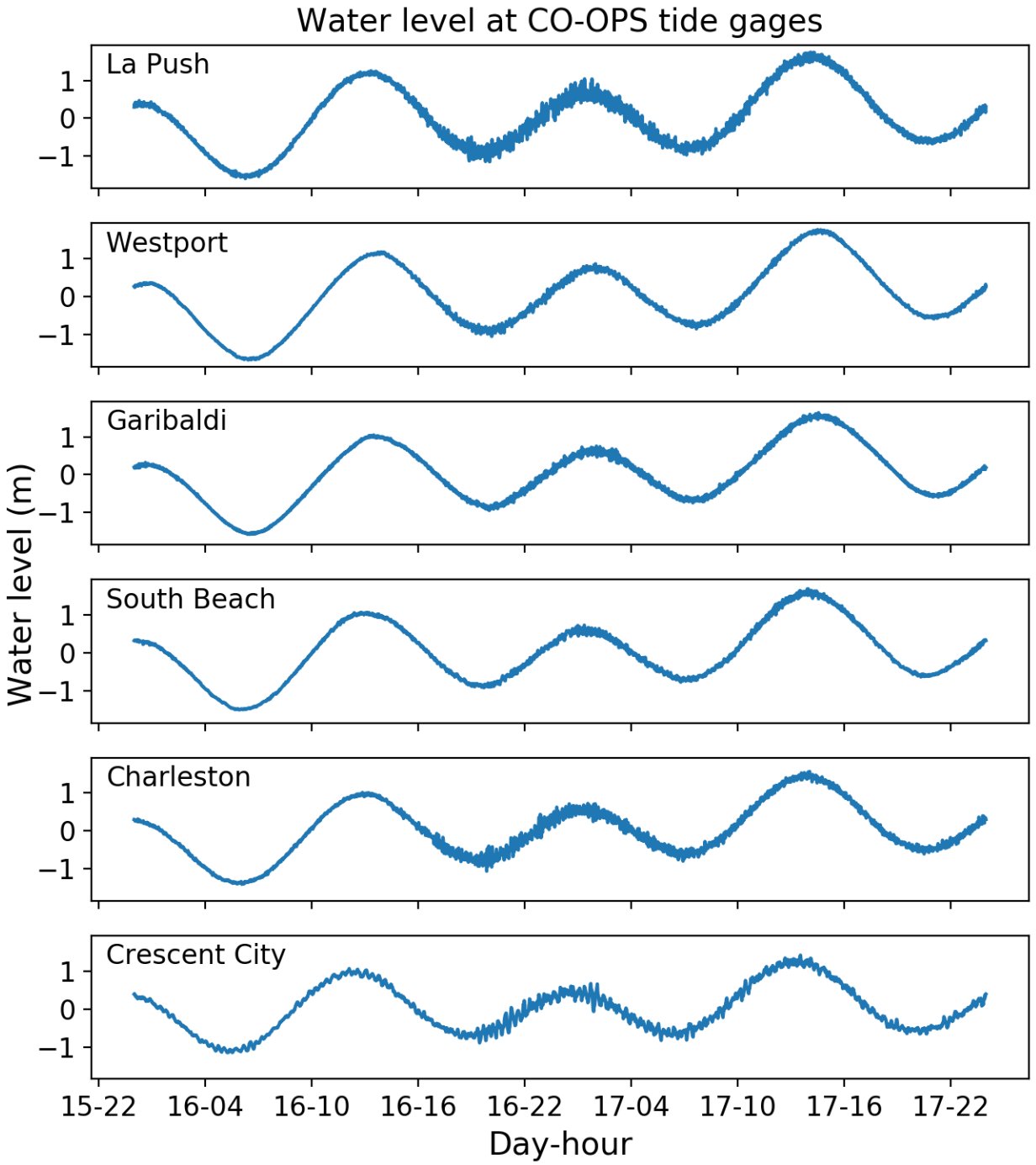
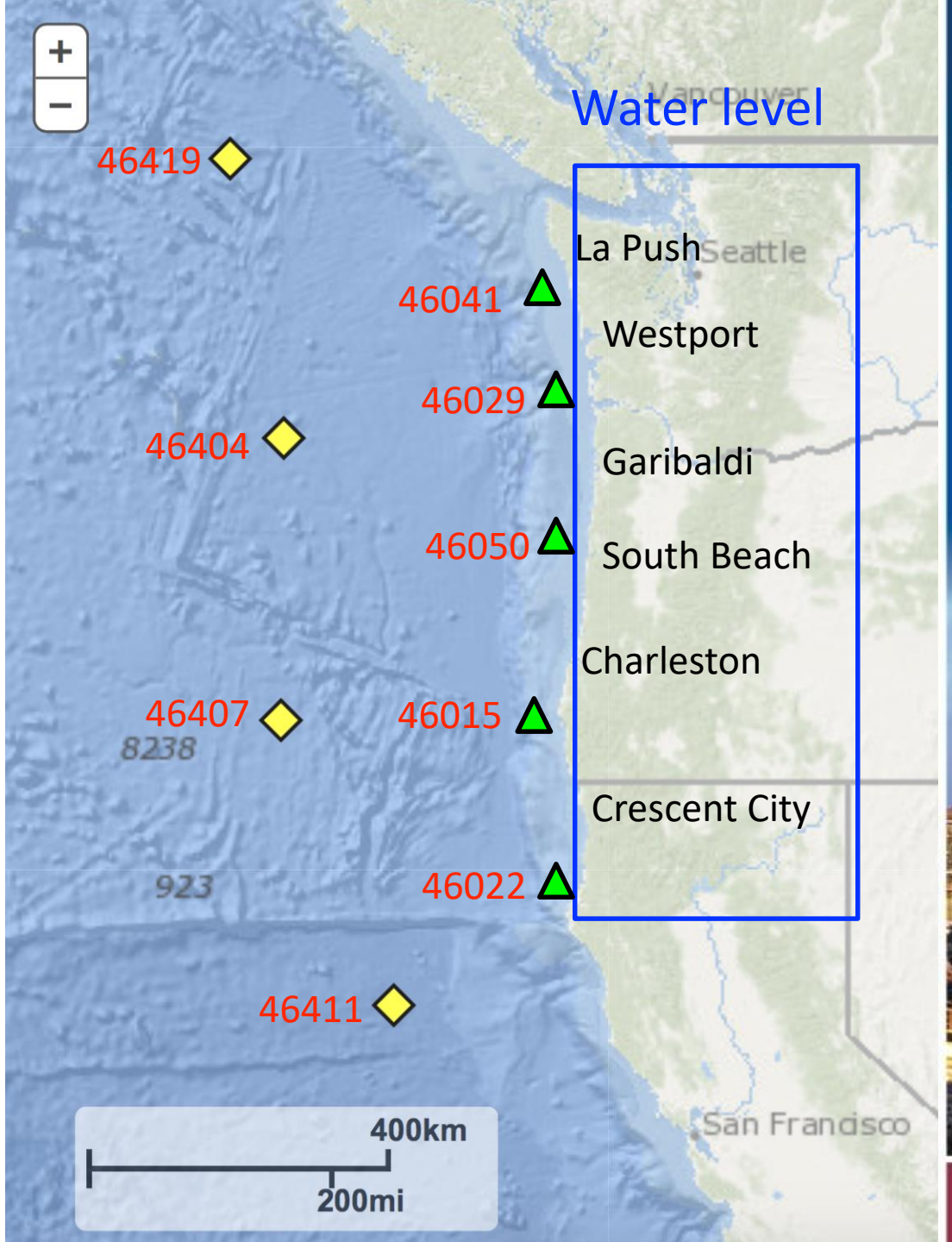
Injury report 01/16 ~22:20 UTC




Water level at CO-OPS tide gages
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Water level (m)
1
0
−1
15-22
16-04
16-10
16-16
16-22
17-04
17-10
17-16
17-22
Day-hour


Water level
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Seattle
San Francisco
400km
200mi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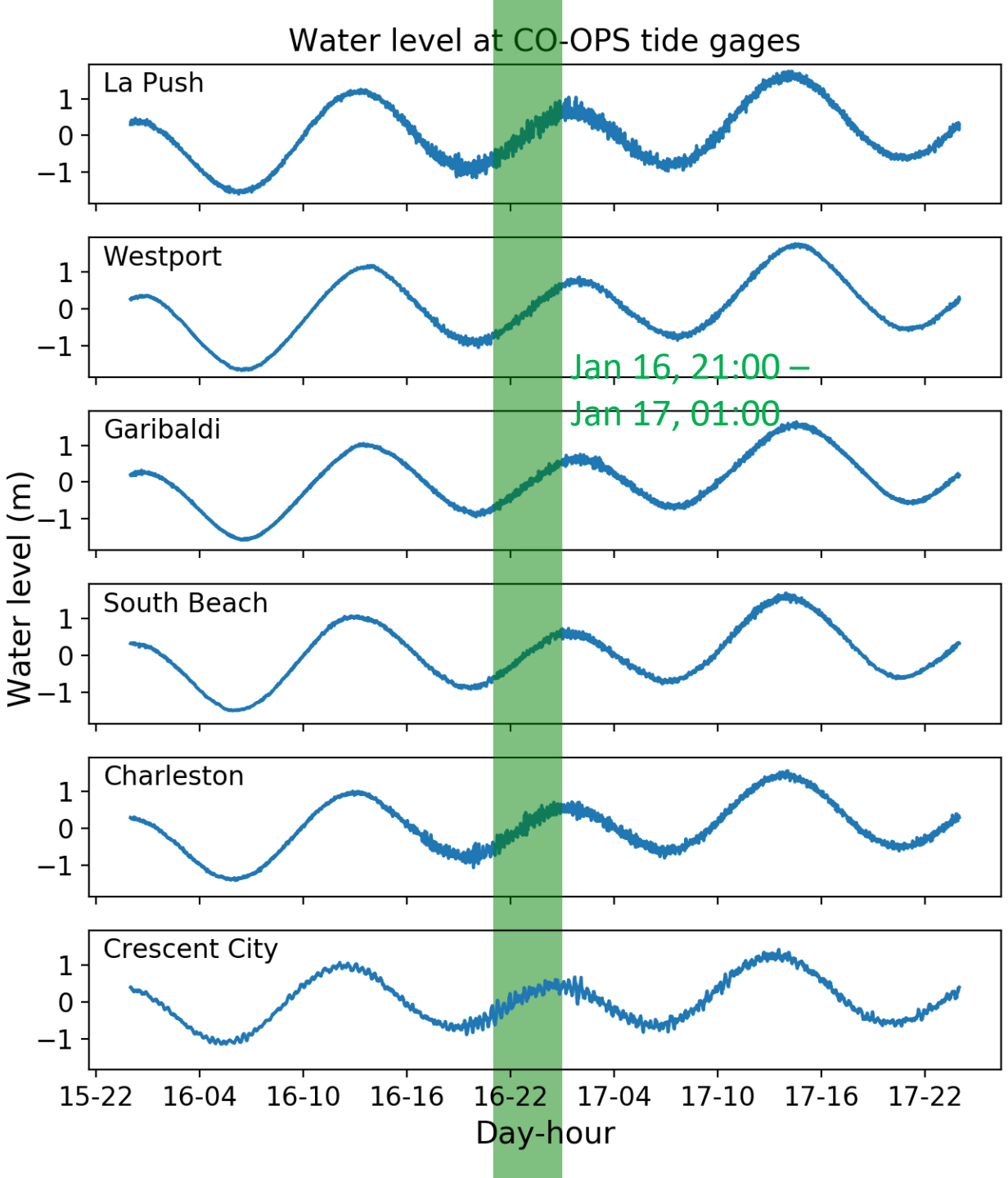
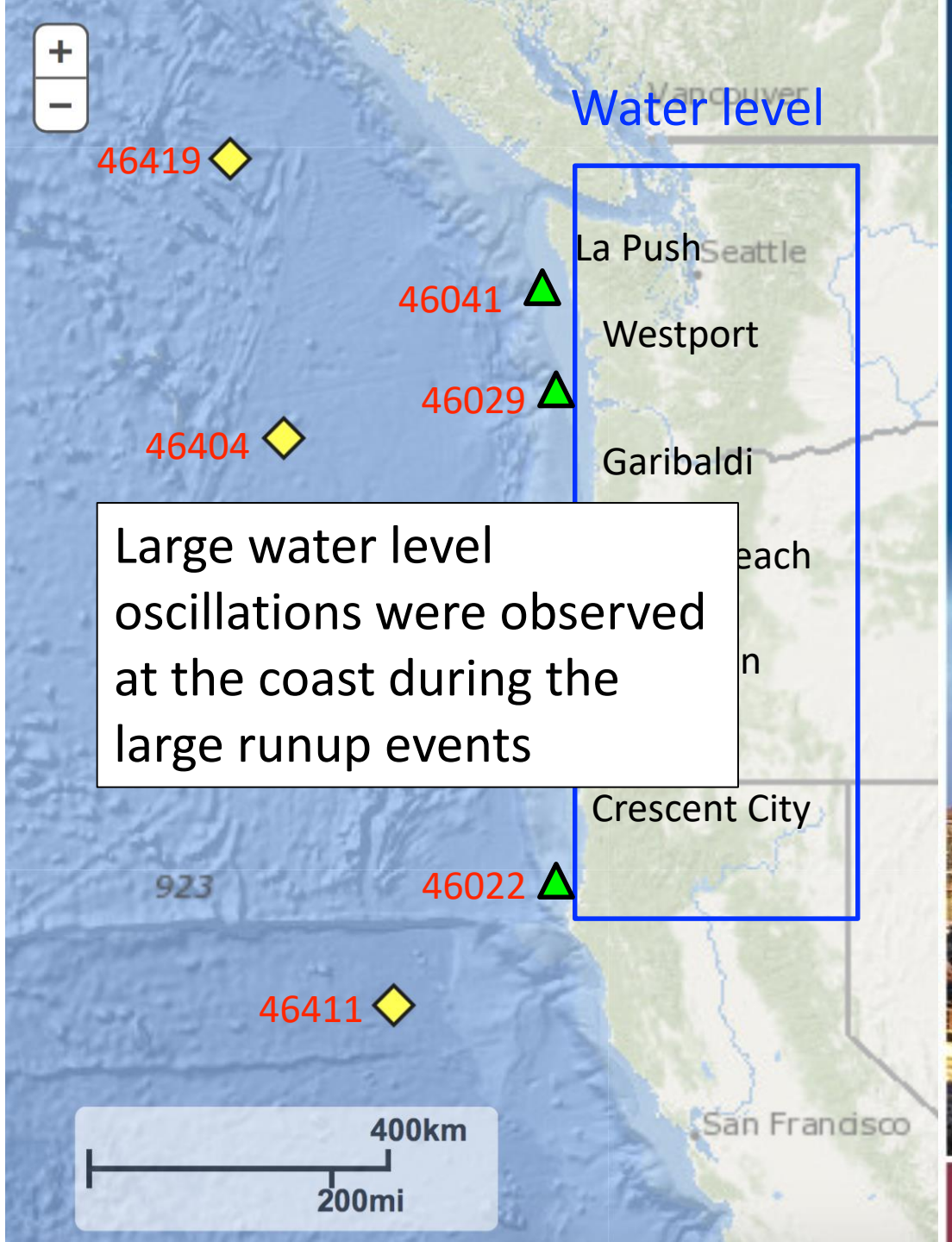
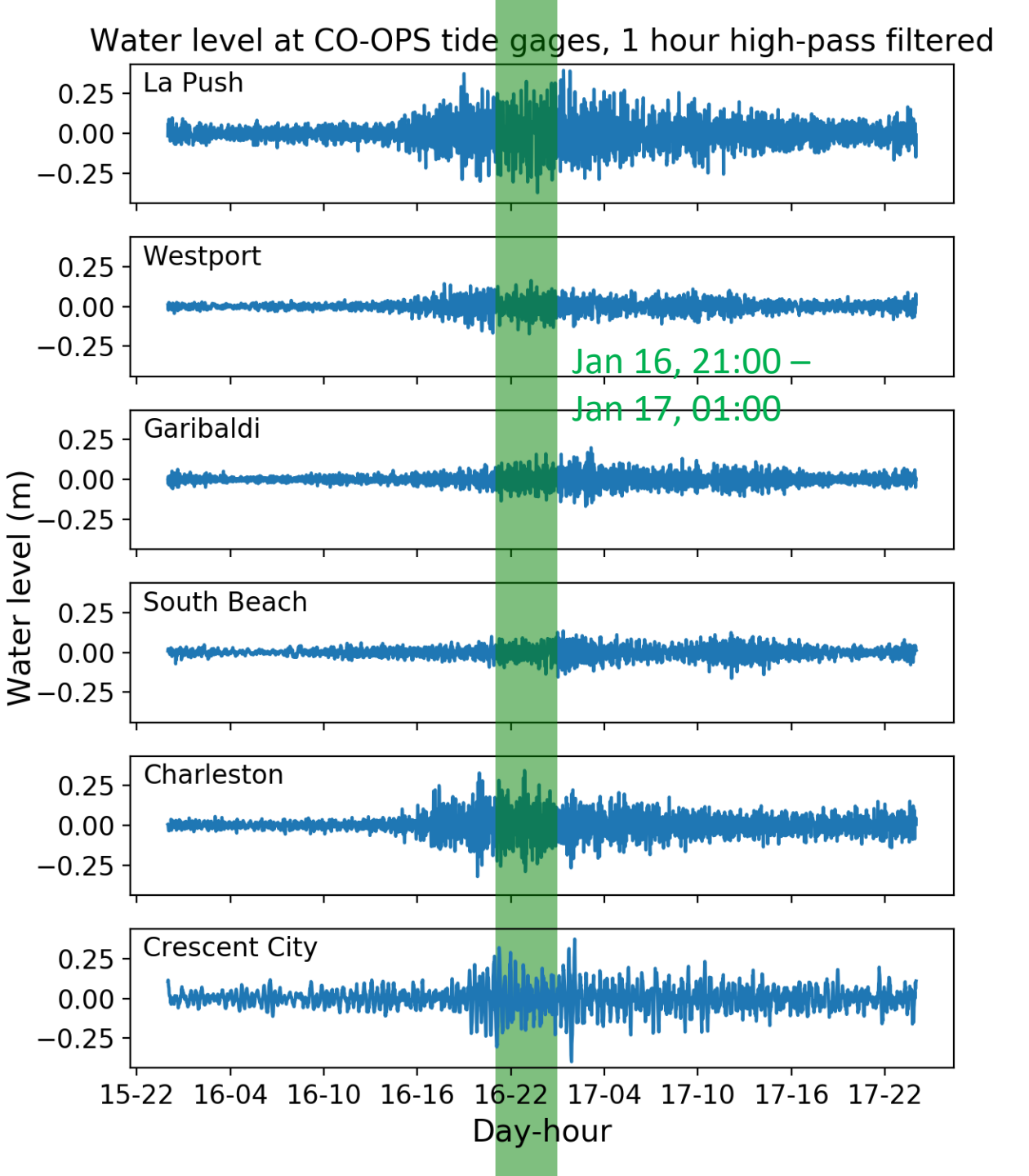
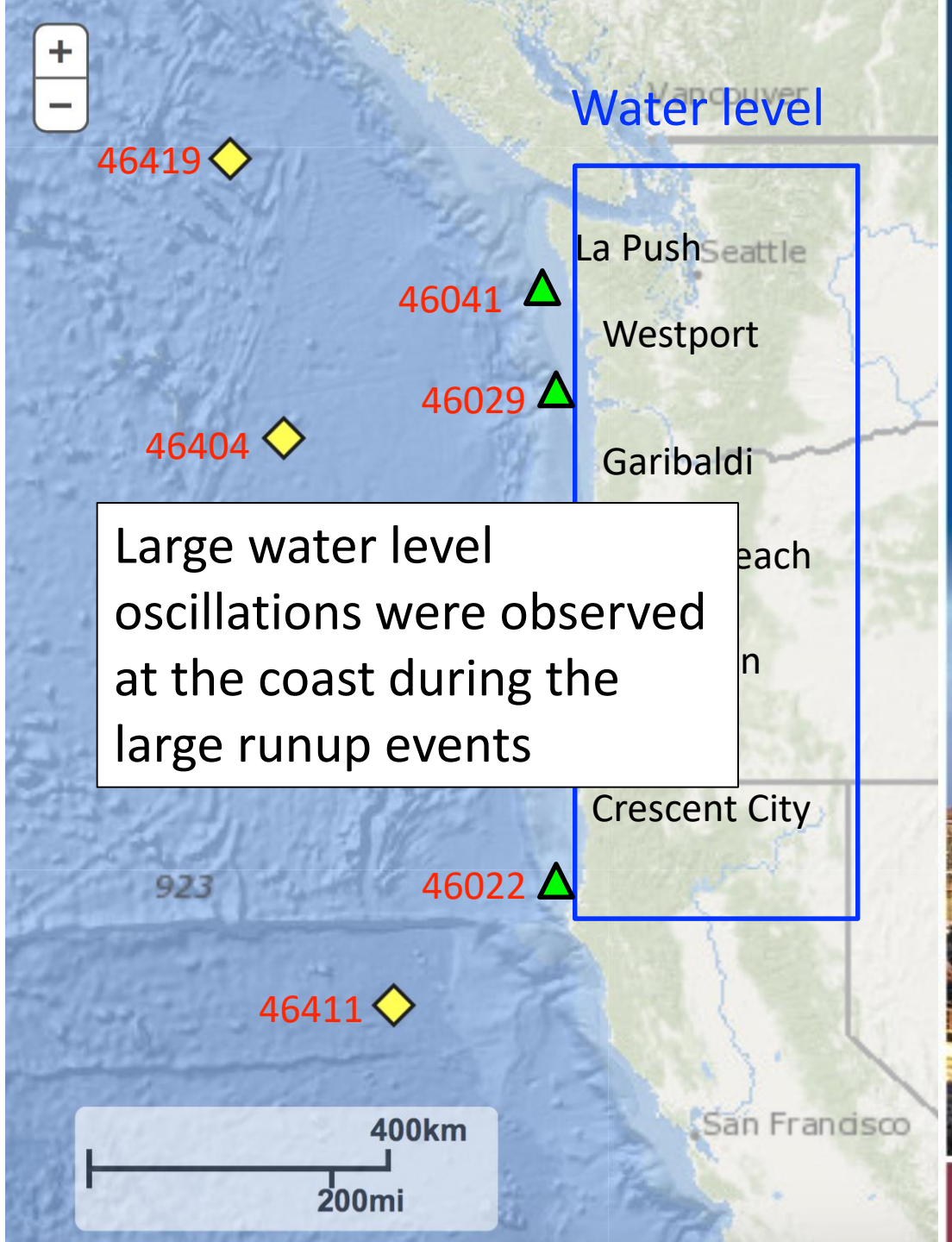

Water level at CO-OPS tide gages
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Water level (m)
Jan 16, 21:00 –
Jan 17, 01:00
15-22
16-04
16-10
16-16
16-22
17-04
17-10
17-16
17-22
Day-hour

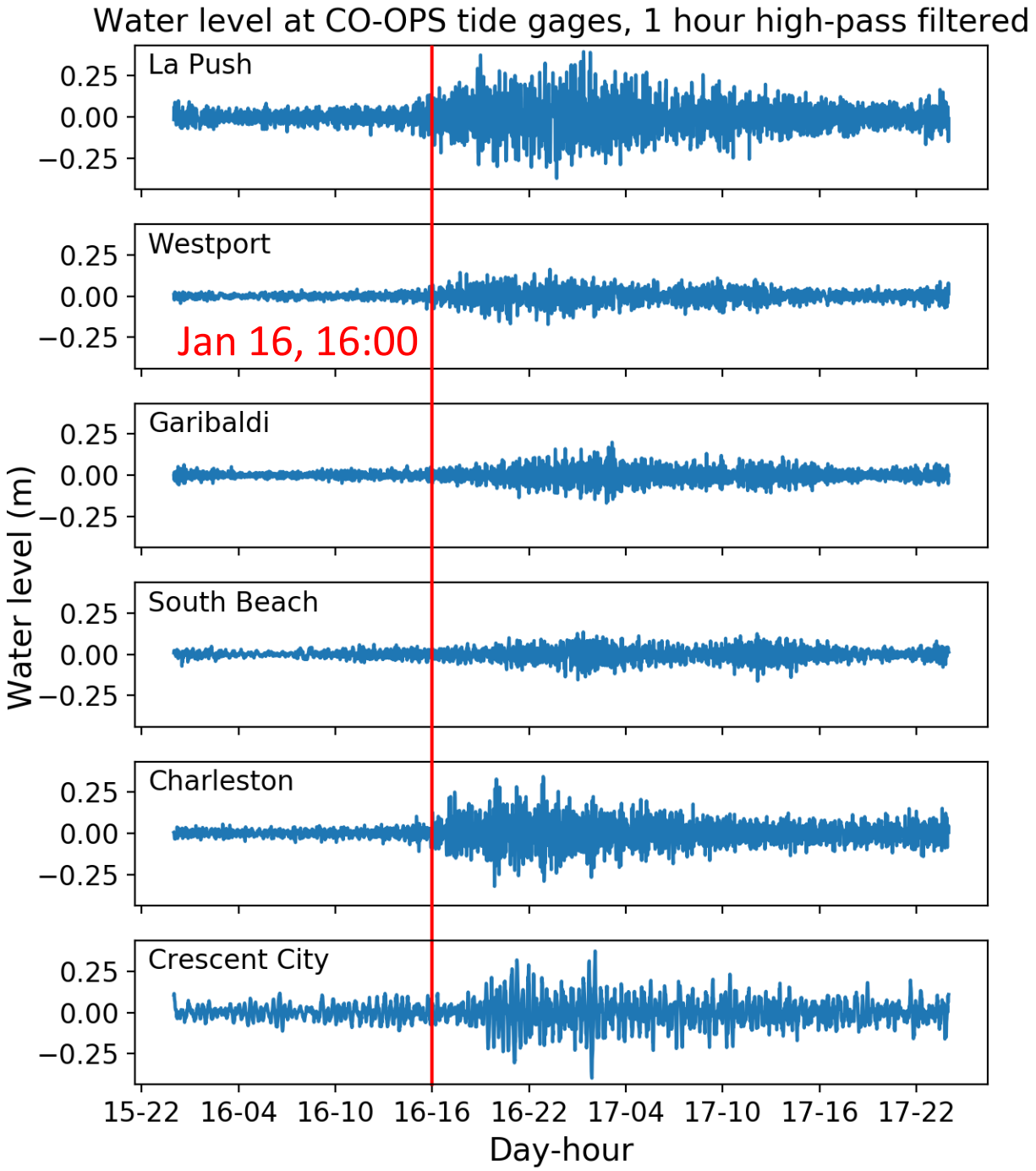

Water level
46419
46041
46029
46404
46411
46022
La Push
Westport
Garibaldi
Crescent City
Large water level oscillations were observed at the coast during the large runup events
400km
200mi
Seattle
San Francisco

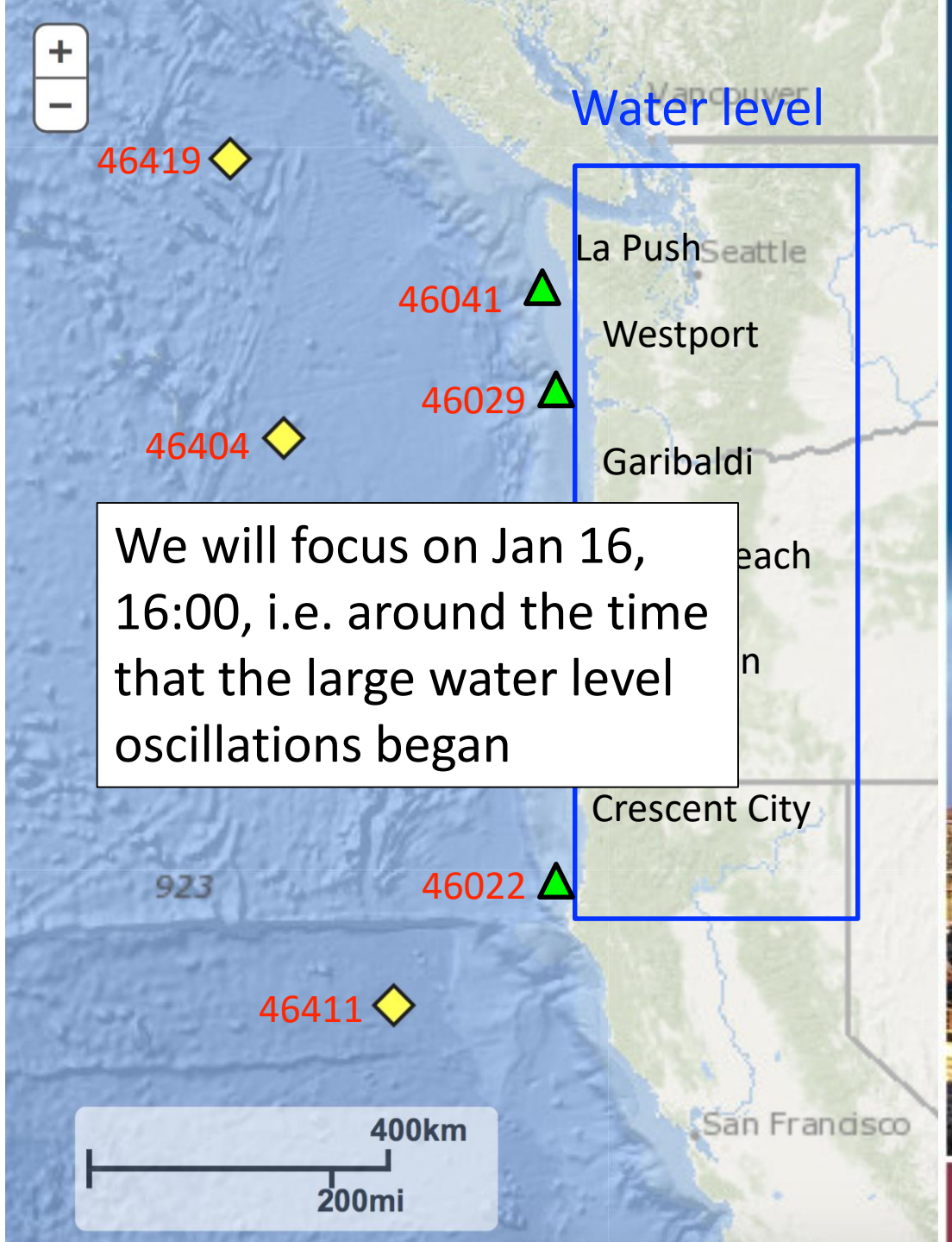

ICCE
2018


Water level at CO-OPS tide gages, 1 hour high-pass filtered
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
0.25
0.00
−0.25
Water level (m)
Jan 16, 21:00 –
Jan 17, 01:00
15-22
16-04
16-10
16-16
16-22
17-04
17-10
17-16
17-22
Day-hour


Water level
46419
46041
46029
46404
46022
46411
La Push
Westport
Garibaldi
Crescent City
Large water level oscillations were observed at the coast during the large runup events
400km
200mi
San Francisco


ICCE
2018





We will focus on Jan 16, 16:00, i.e. around the time that the large water level oscillations began

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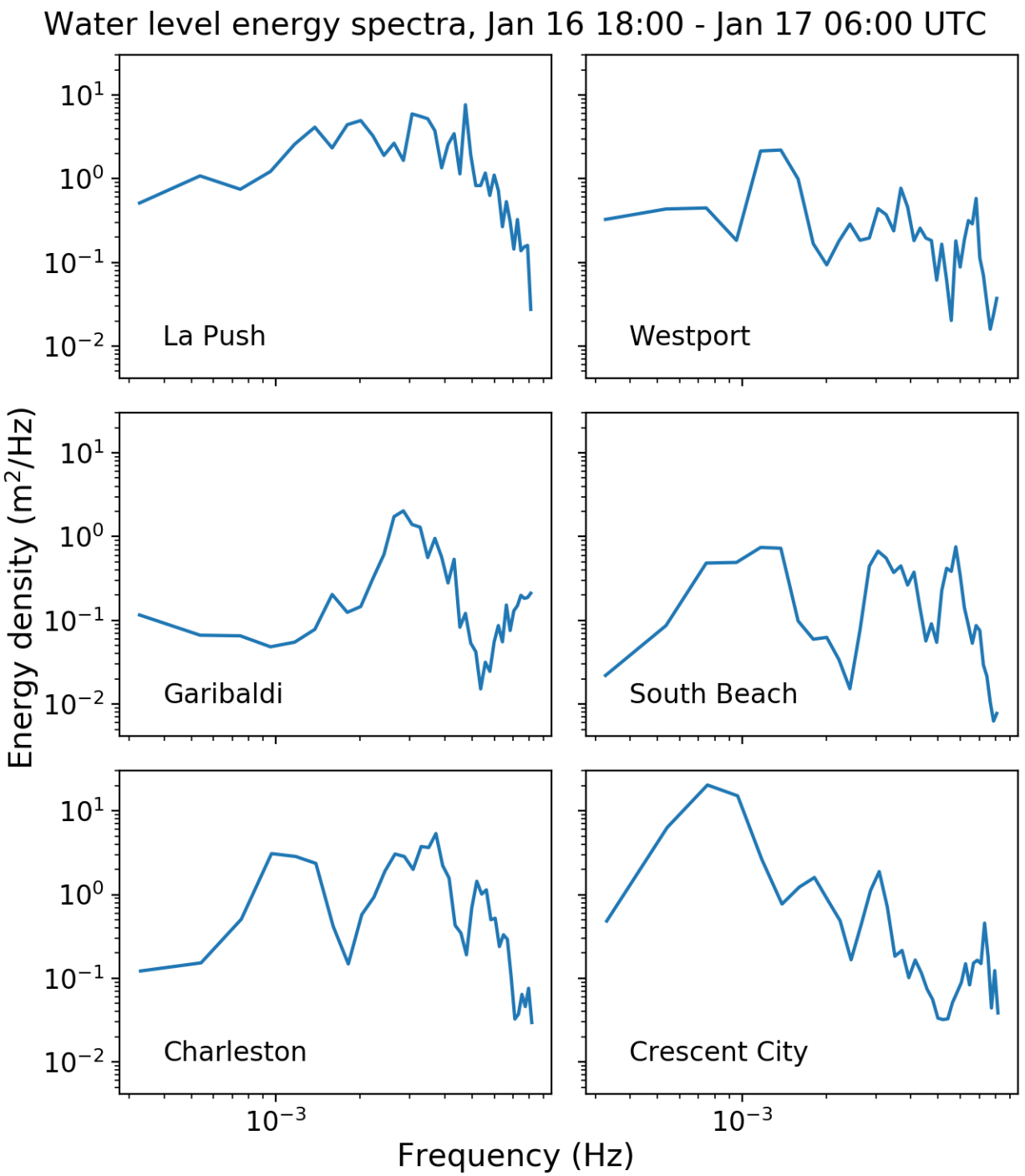
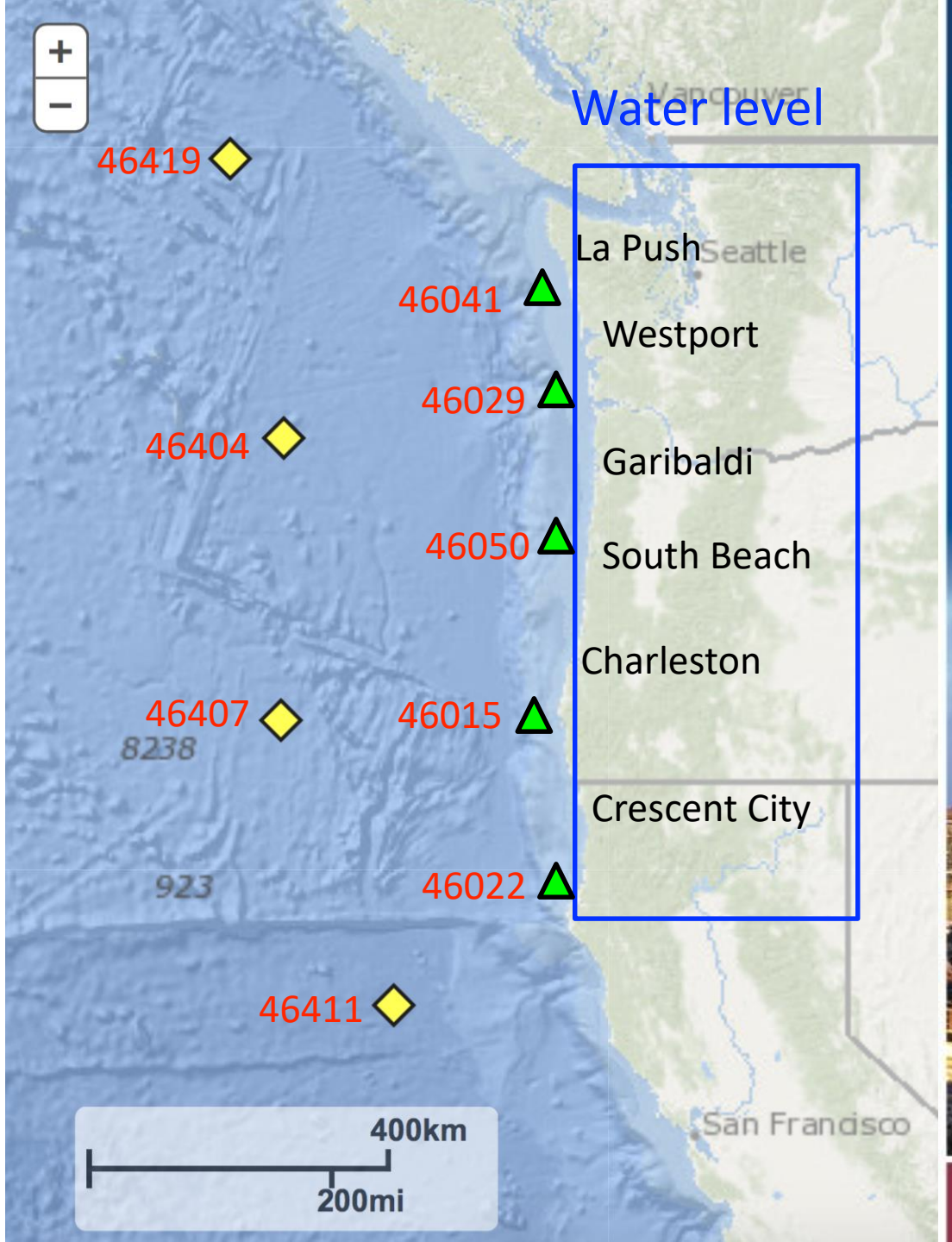
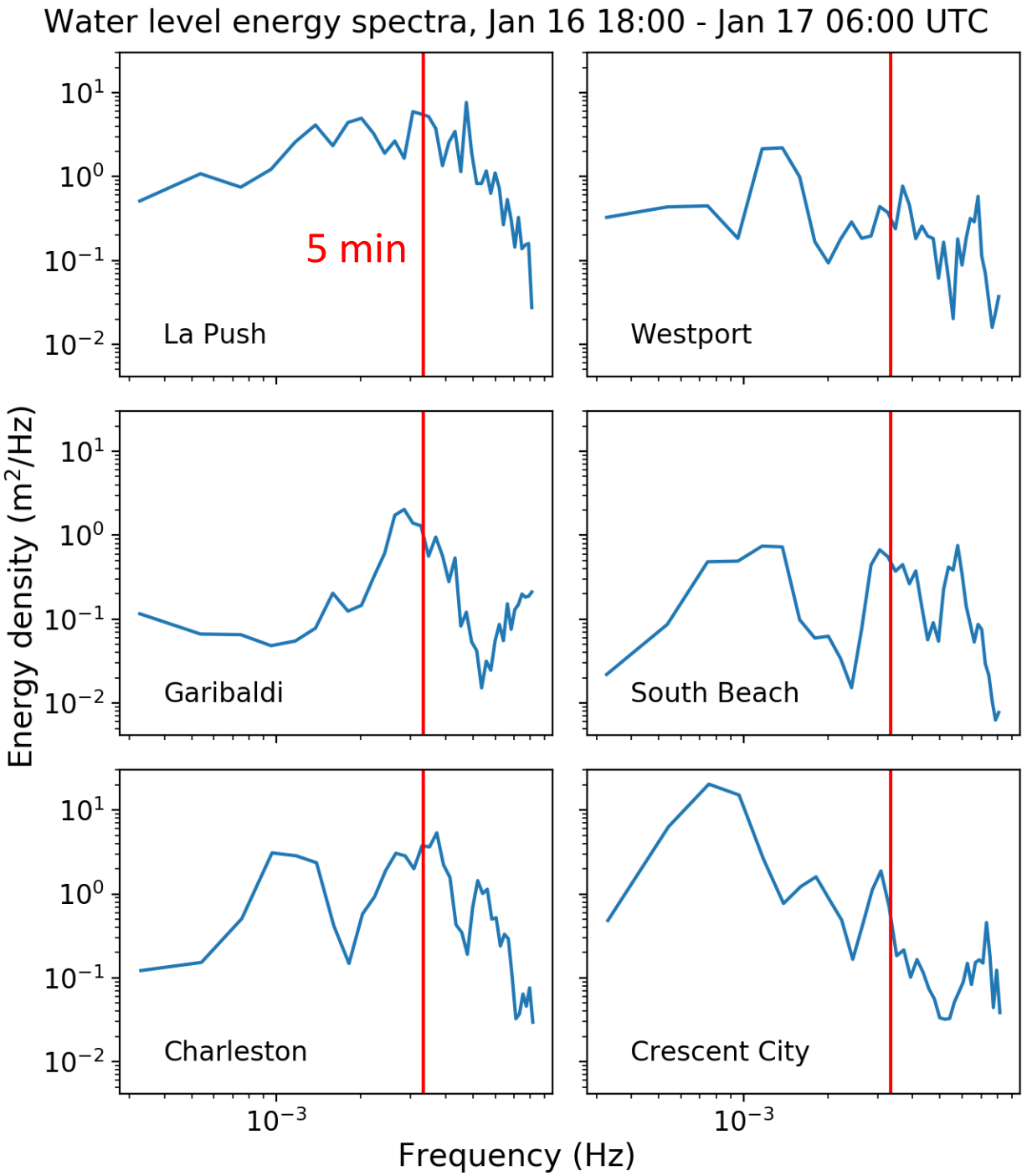
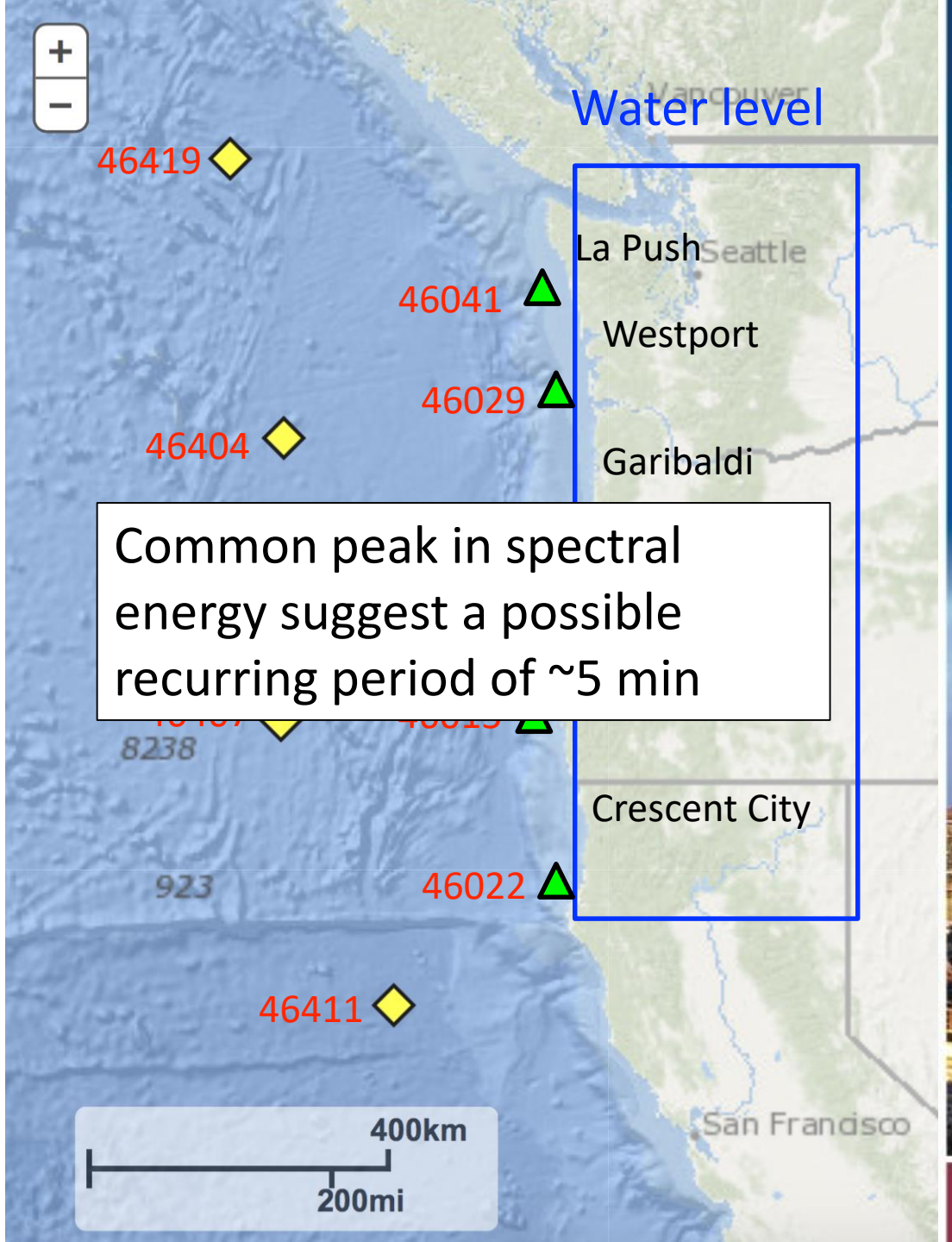

Water level energy spectra, Jan 16 18:00 - Jan 17 06:00 UTC
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Energy density (m²/Hz)
Frequency (Hz)


Water level
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Seattle
San Francisco
400km
200mi


ICCE
2018


Water level energy spectra, Jan 16 18:00 - Jan 17 06:00 UTC
5 min
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Energy density (m²/Hz)
Frequency (Hz)


Water level
46419
La Push
46041
Westport
46029
46404
Garibaldi
Common peak in spectral energy suggest a possible recurring period of ~5 min
Crescent City
46022
46411
Seattle
San Francisco
400km
200mi

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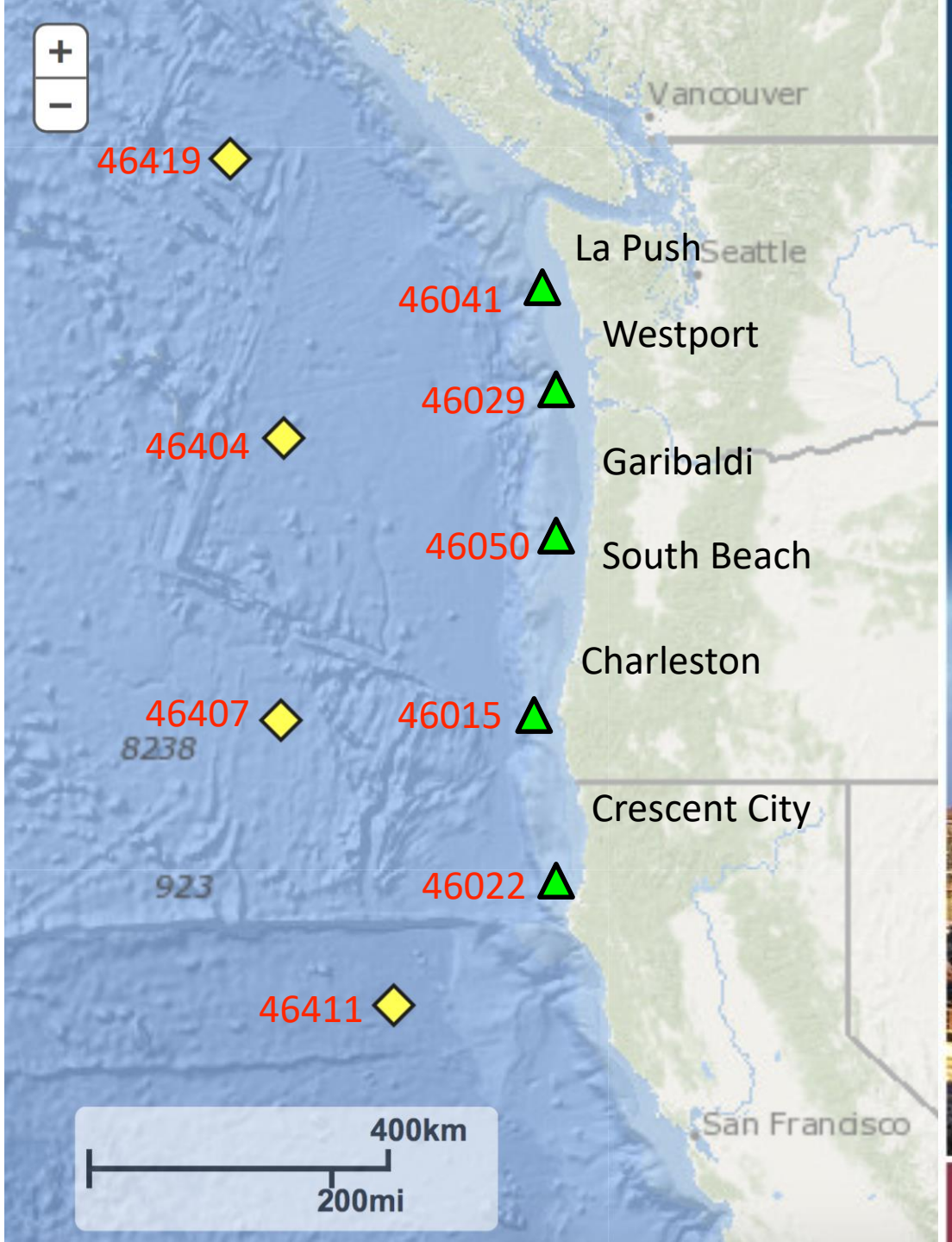
Possible Causes

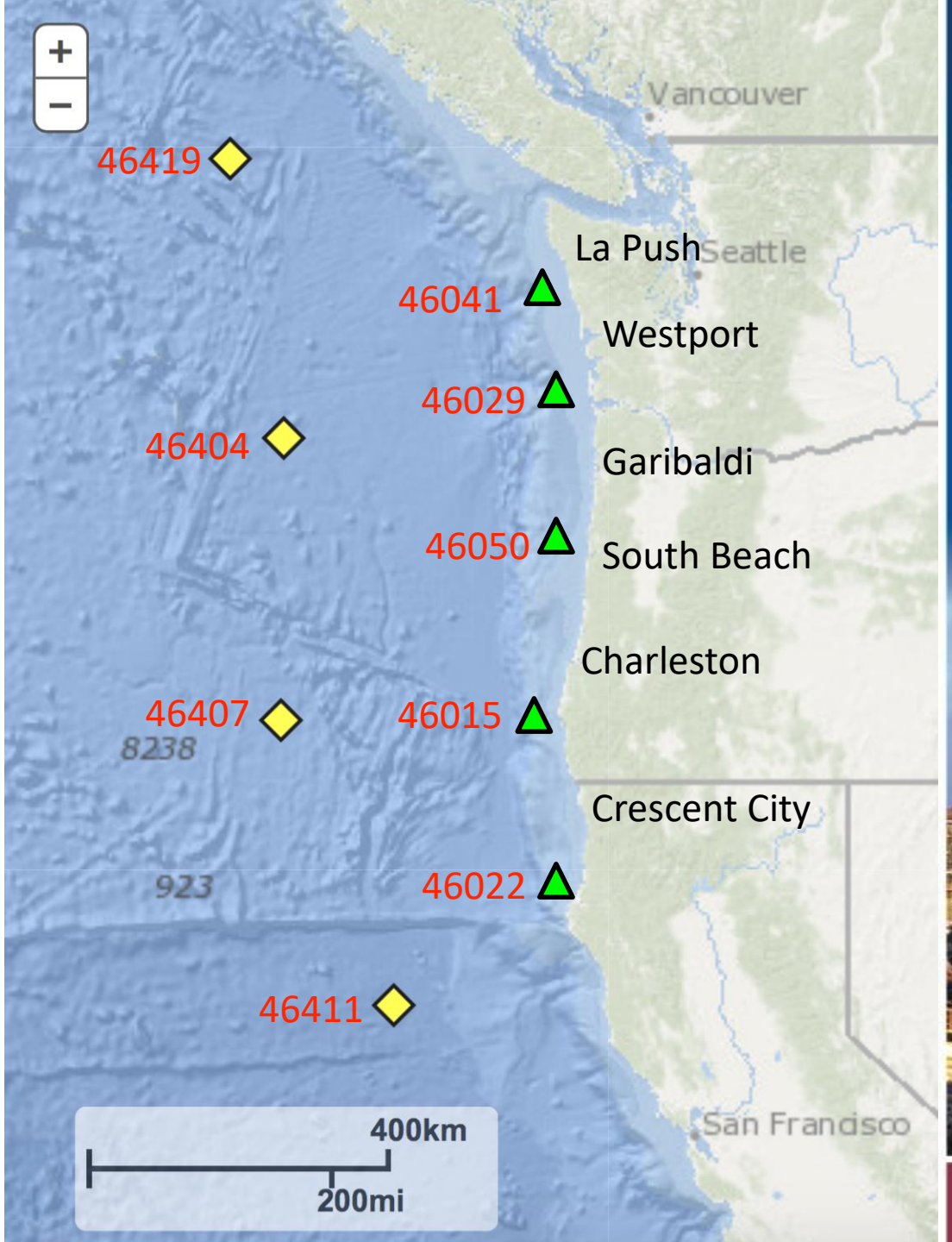
- Earthquake
  – no seismic activities detected



Possible Causes

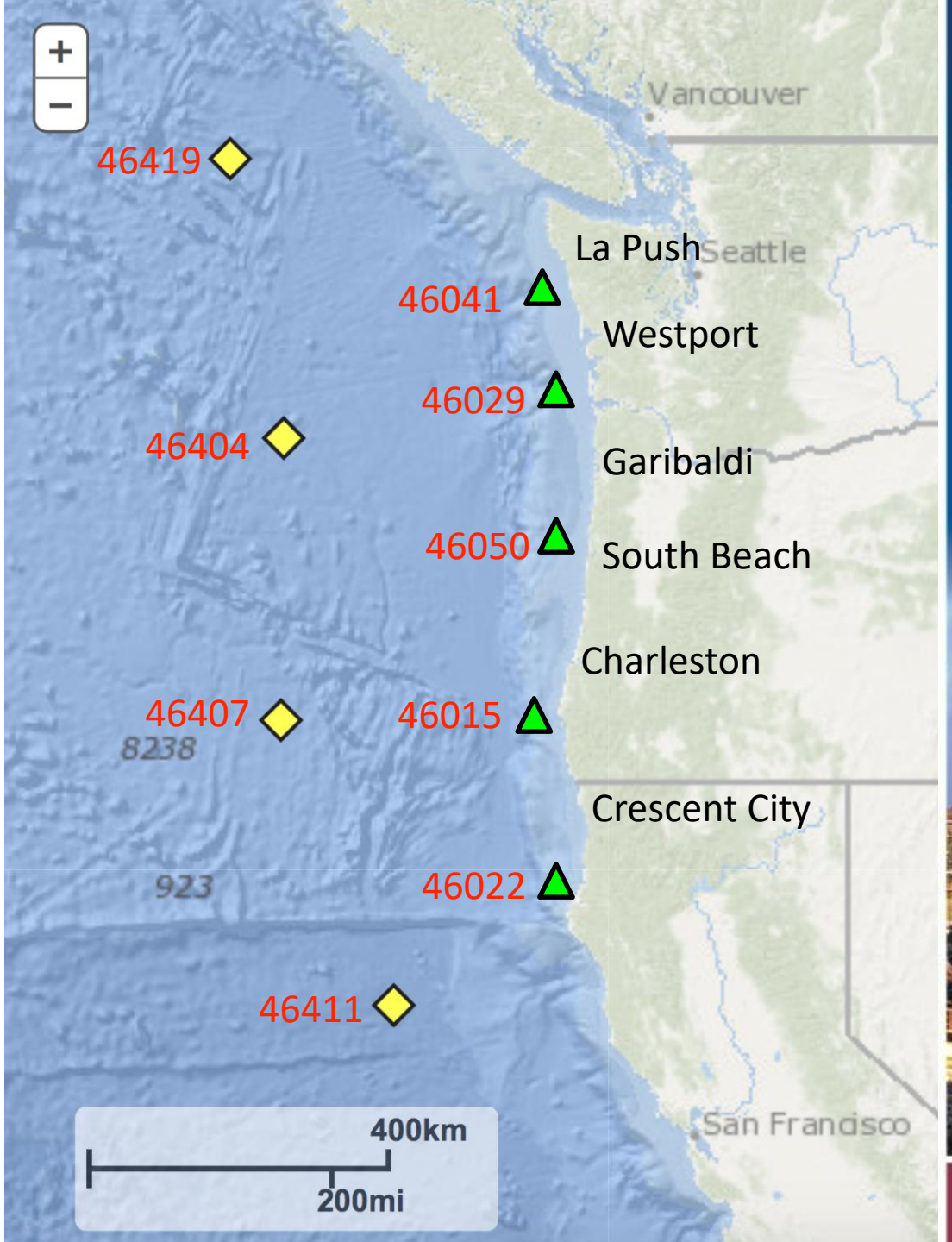
- Earthquake
  – no seismic activities detected

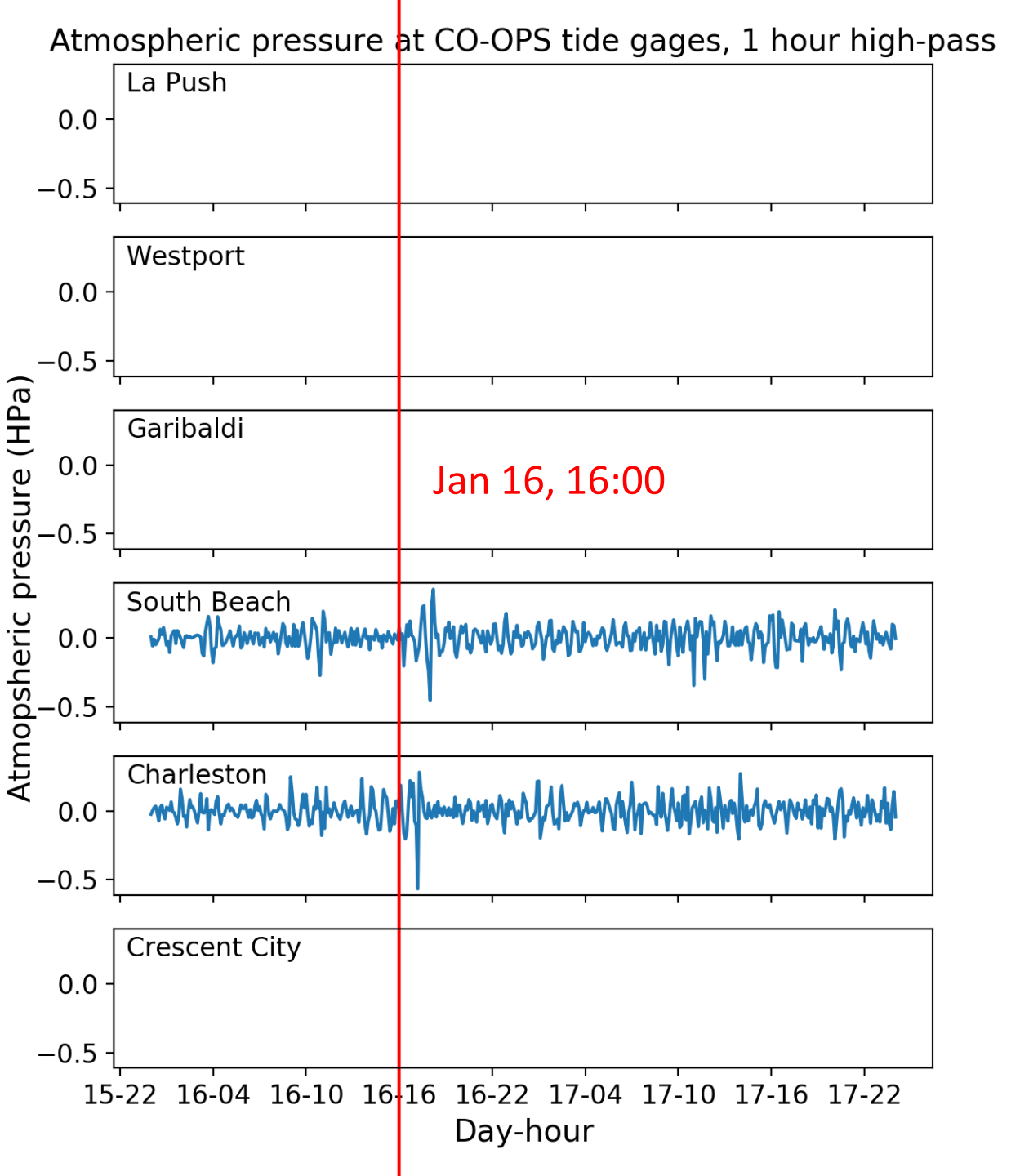
- Meteotsunami
  – generated by low pressure front moving at shallow water wave speed

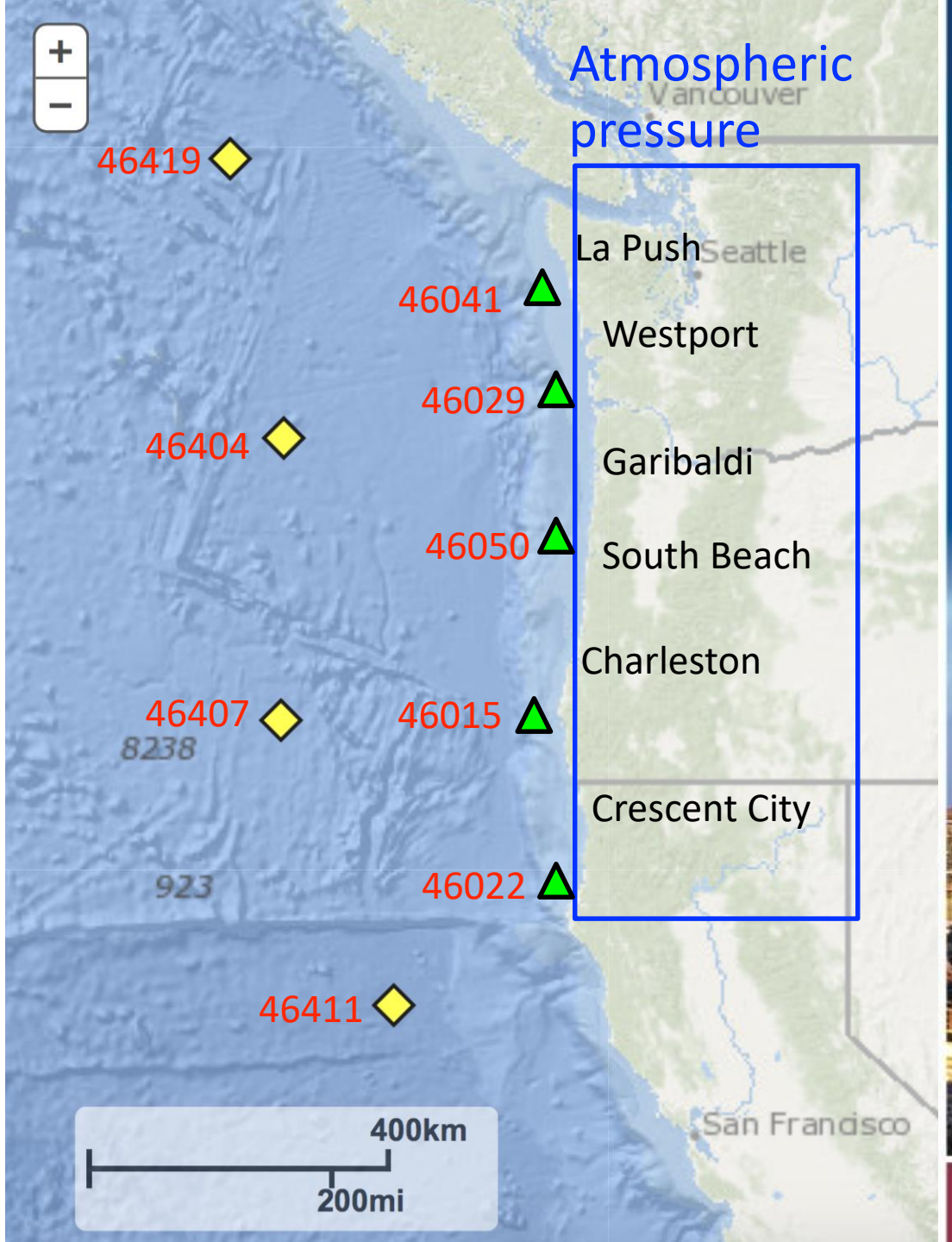


Possible Causes

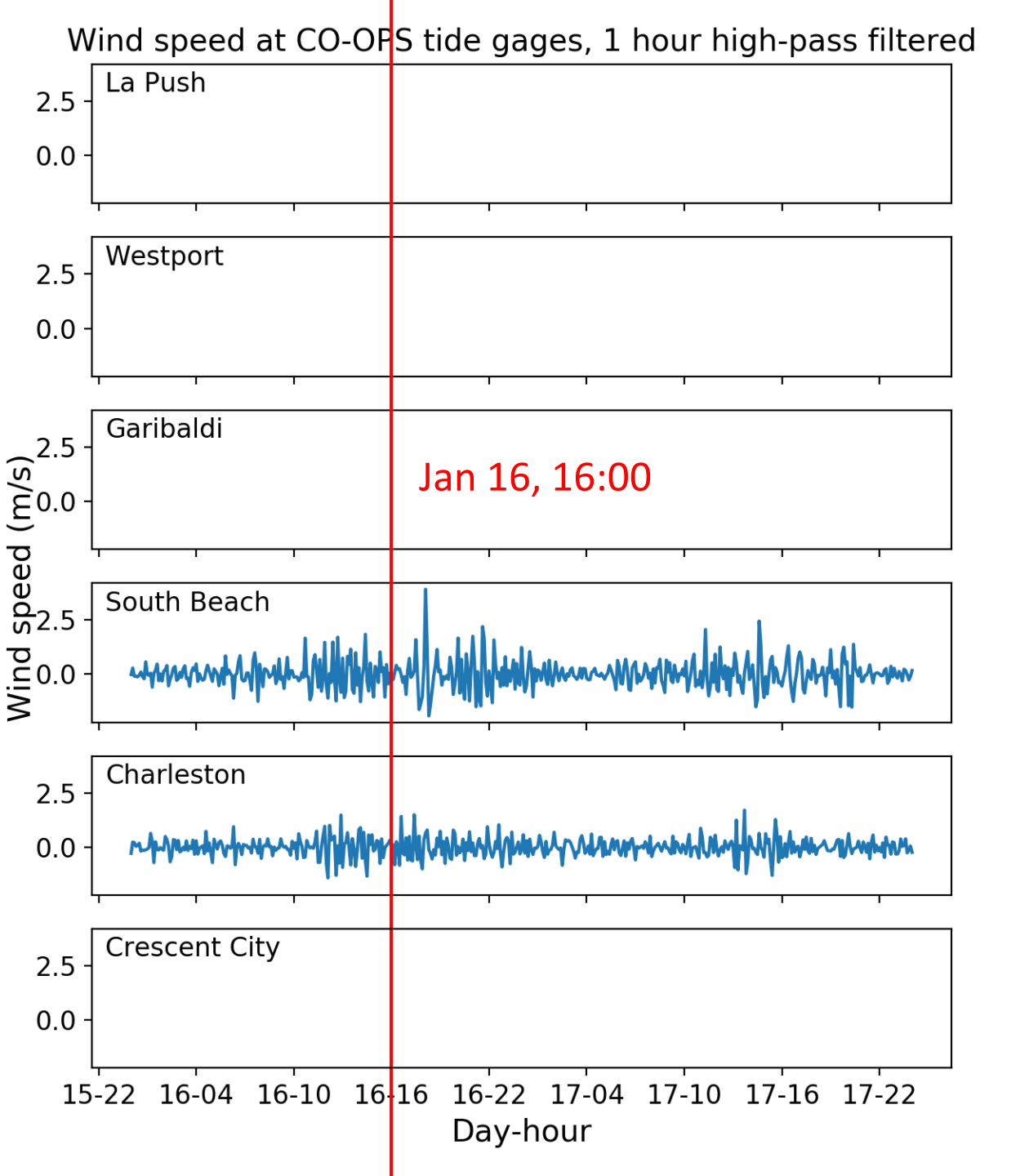
- Earthquake
  – no seismic activities detected
- Meteotsunami
  – generated by low pressure front moving at shallow water wave speed
- Other causes?

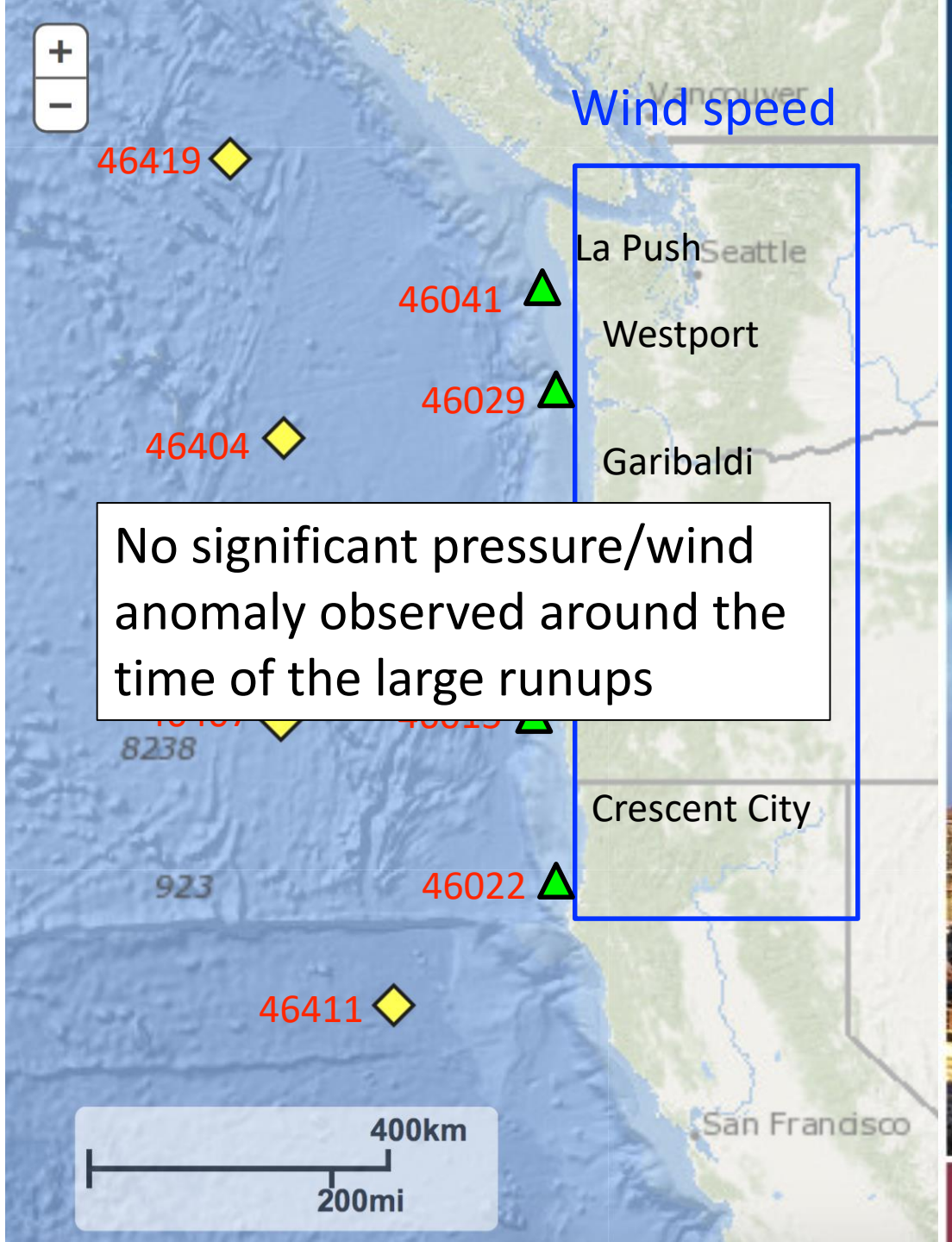



Atmospheric pressure at CO-OPS tide gages, 1 hour high-pass
La Push
Westport
Garibaldi
Jan 16, 16:00
South Beach
Charleston
Crescent City
0.0
−0.5
Atmopsheric pressure (HPa)
15-22
16-04
16-10
16-16
16-22
17-04
17-10
17-16
17-22
Day-hour


Atmospheric pressure
Vancouver
Seattle
46419
La Push
46041
Westport
46029
46404
Garibaldi
46050
South Beach
Charleston
46407
46015
8238
Crescent City
923
46022
46411
San Francisco
400km
200mi


ICCE
2018


Wind speed at CO-OPS tide gages, 1 hour high-pass filtered
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
2.5
0.0
Wind speed (m/s)
Jan 16, 16:00
15-22
16-04
16-10
16-16
16-22
17-04
17-10
17-16
17-22
Day-hour


Wind speed
46419
La Push
Seattle
46041
Westport
46029
46404
Garibaldi
No significant pressure/wind anomaly observed around the time of the large runups
8238
Crescent City
923
46022
46411
San Francisco
400km
200mi

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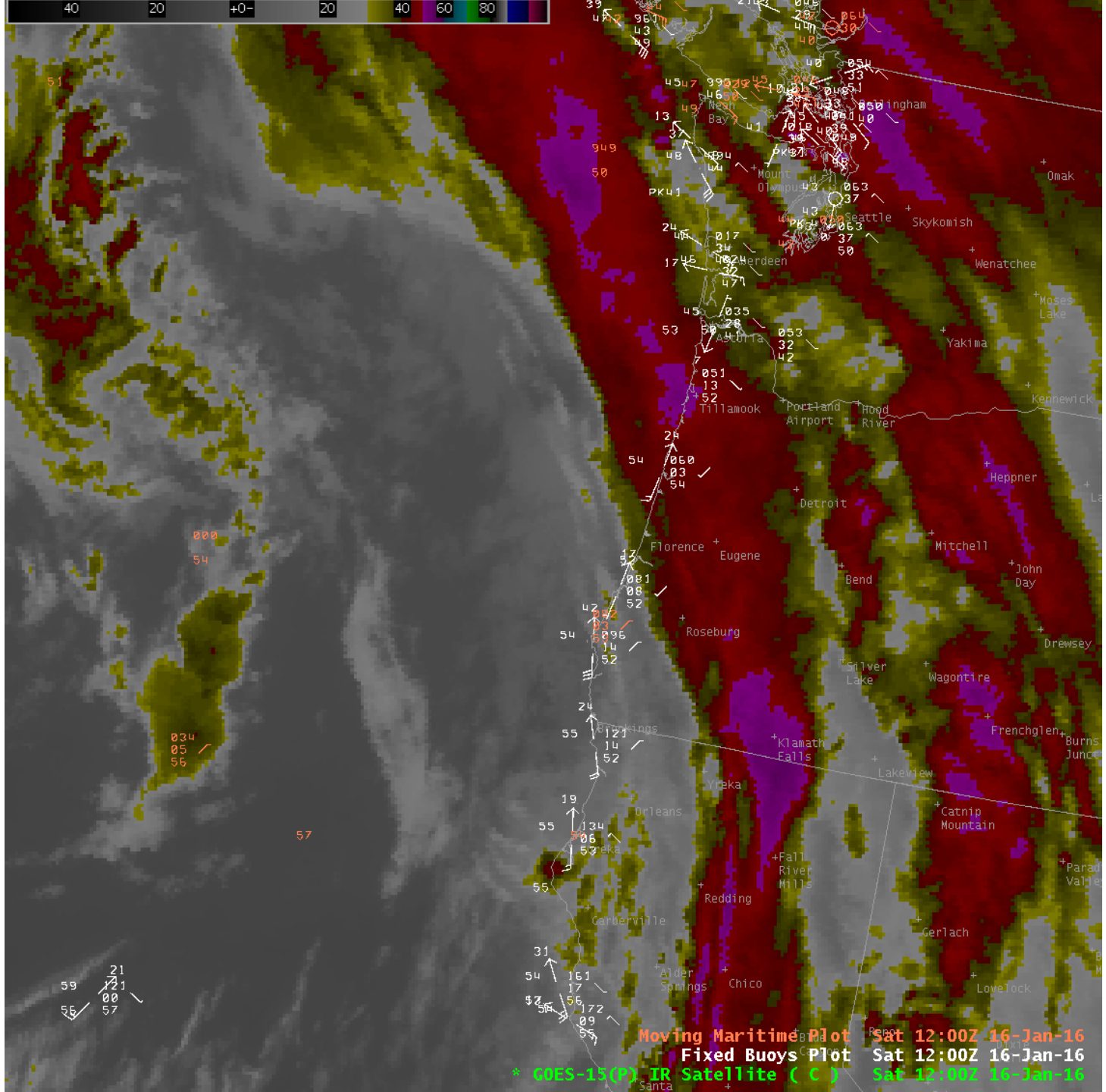
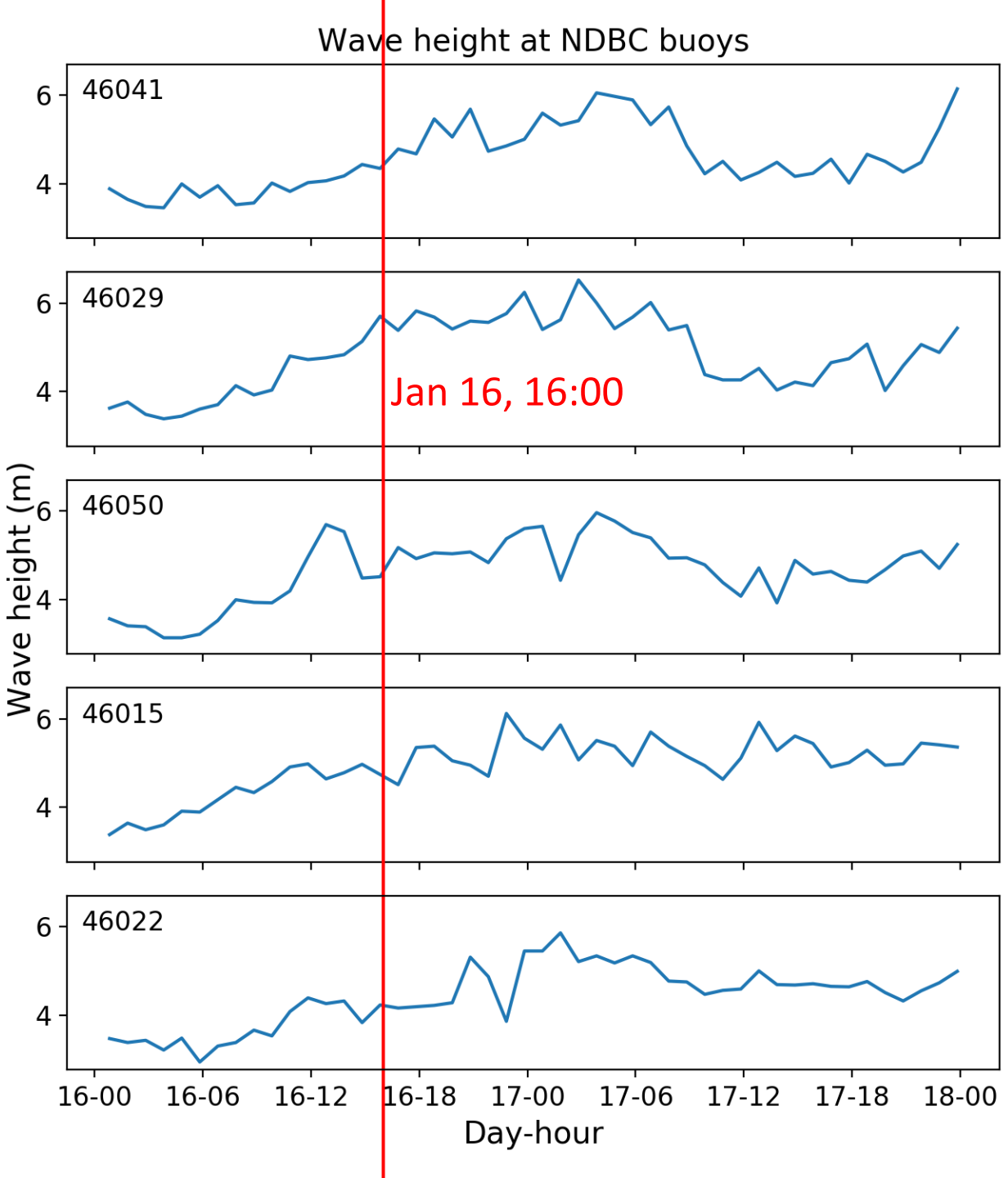
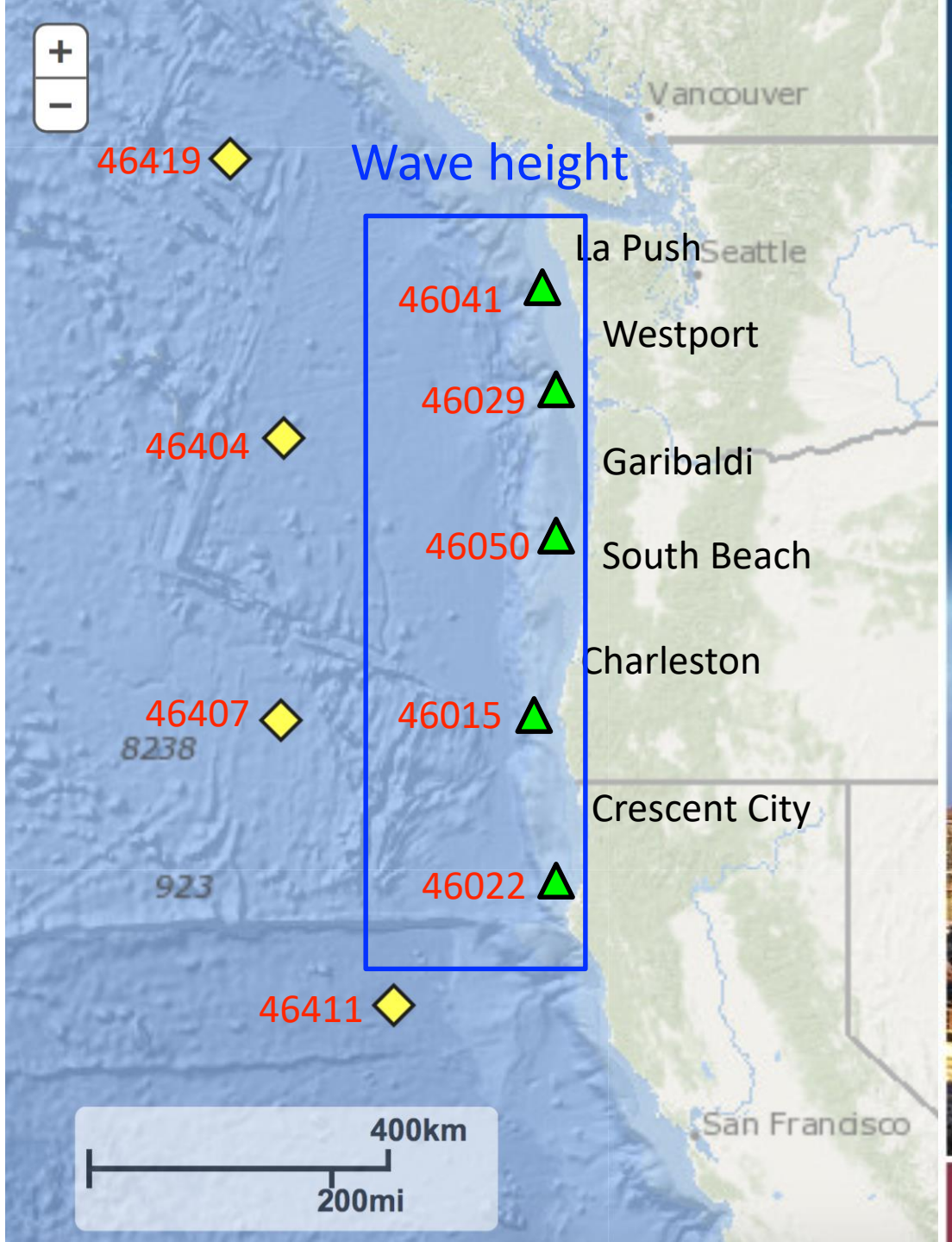
Satellite IR

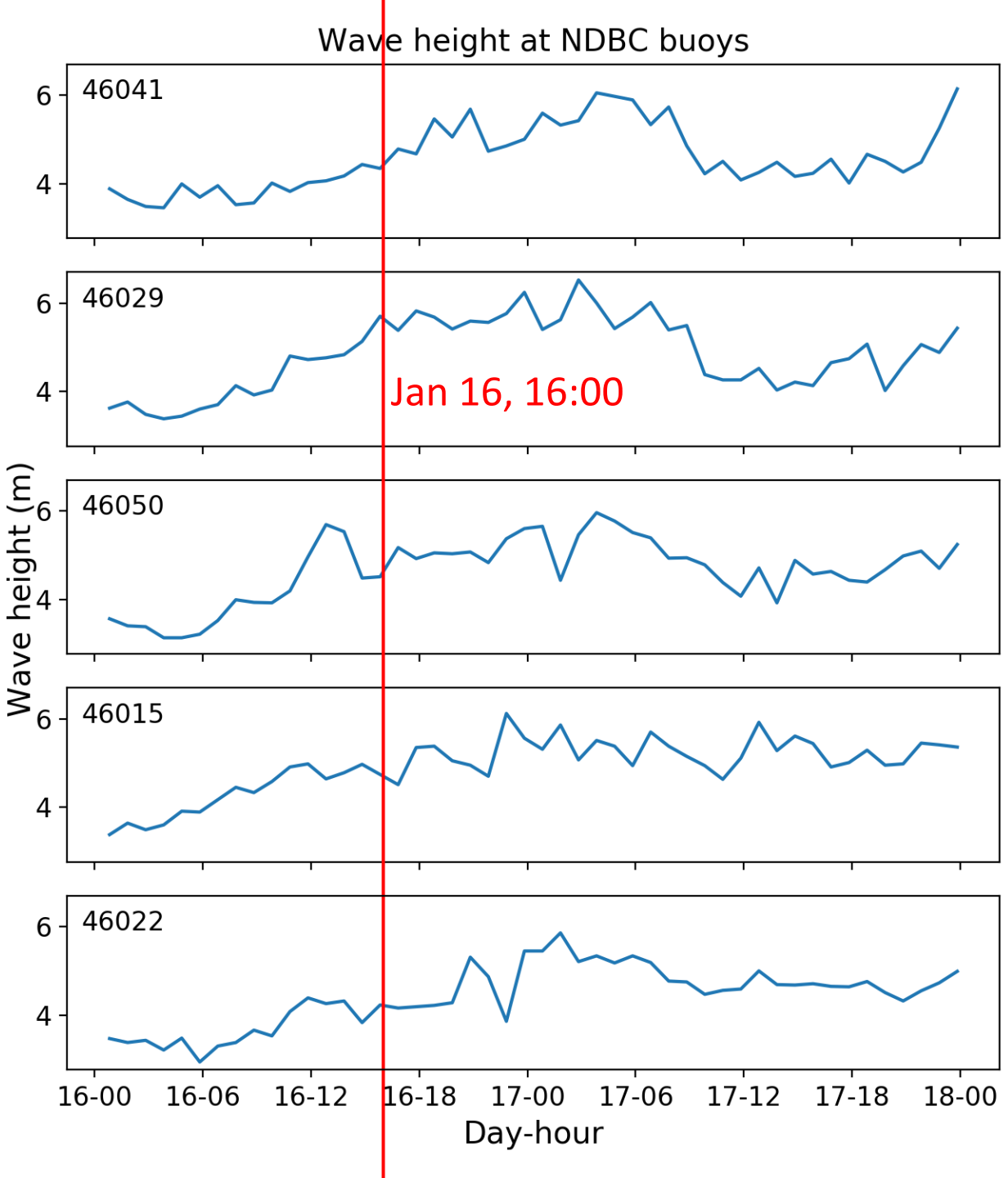
Jan 16, 12:00 –
Jan 16, 17:00

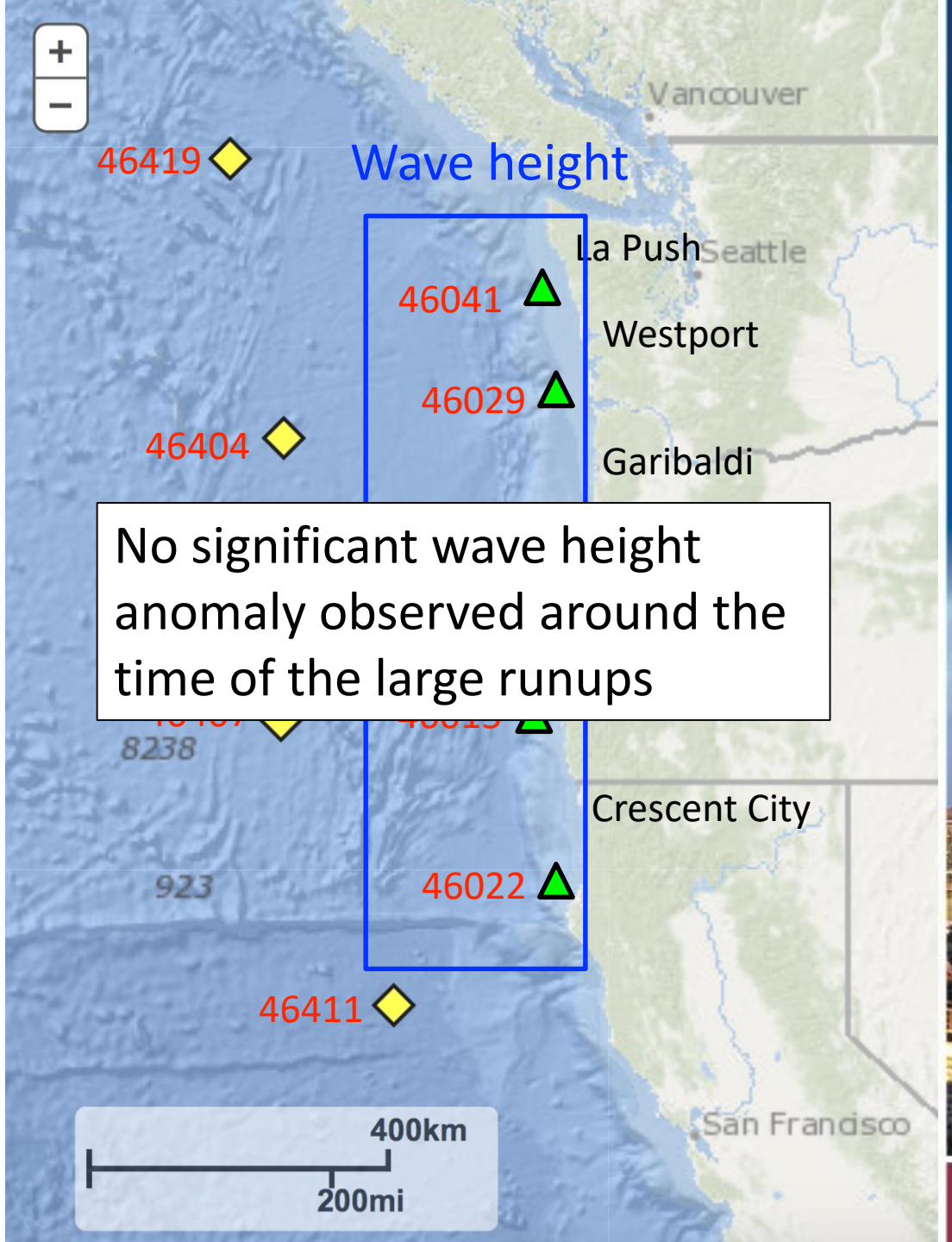



Wave height at NDBC buoys
46041
46029
46050
46015
46022
Jan 16, 16:00
Wave height (m)
6
4
16-00
16-06
16-12
16-18
17-00
17-06
17-12
17-18
18-00
Day-hour


Wave height
46419
46404
46407
46411
46041
46029
46050
46015
46022
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi


ICCE
2018





No significant wave height anomaly observed around the time of the large runups

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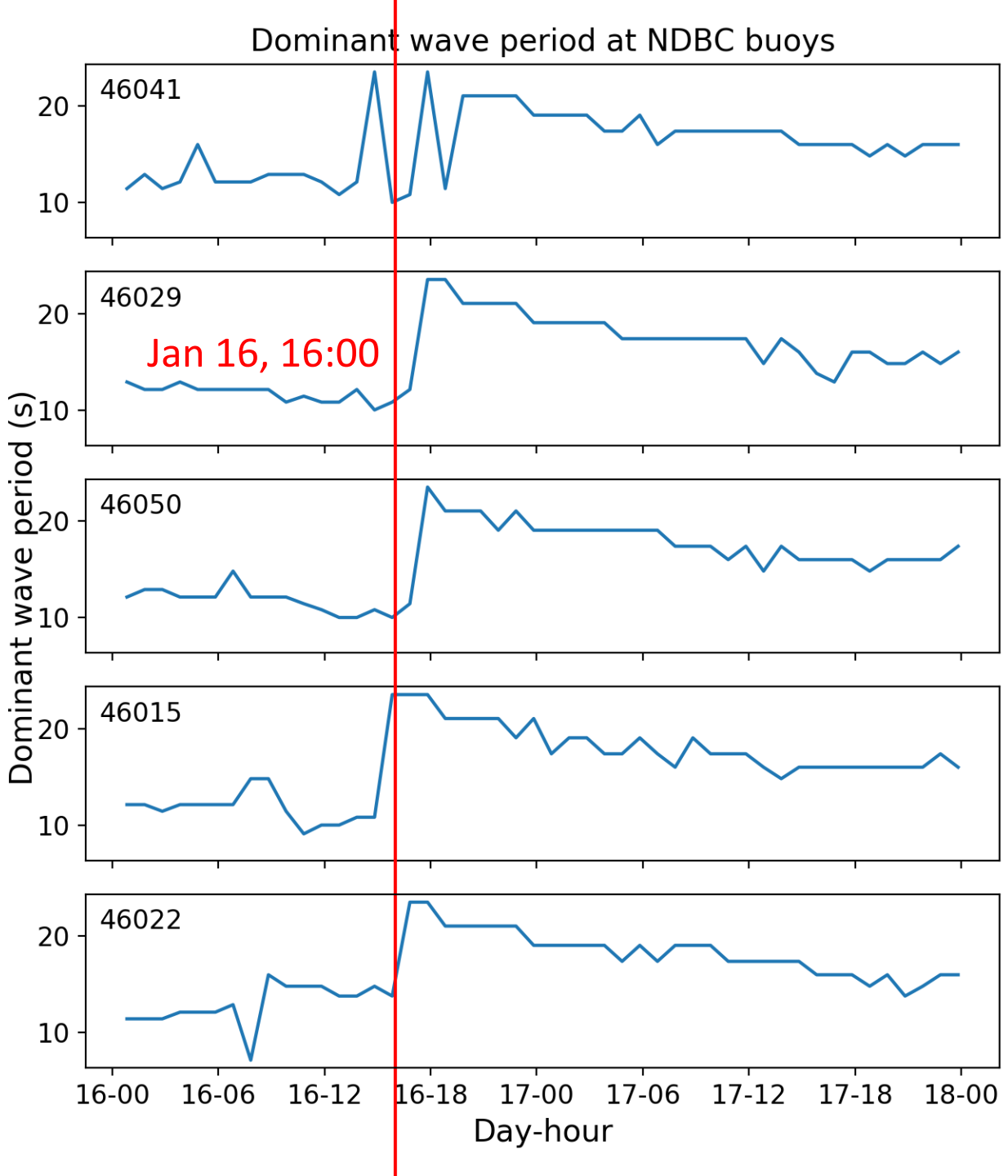
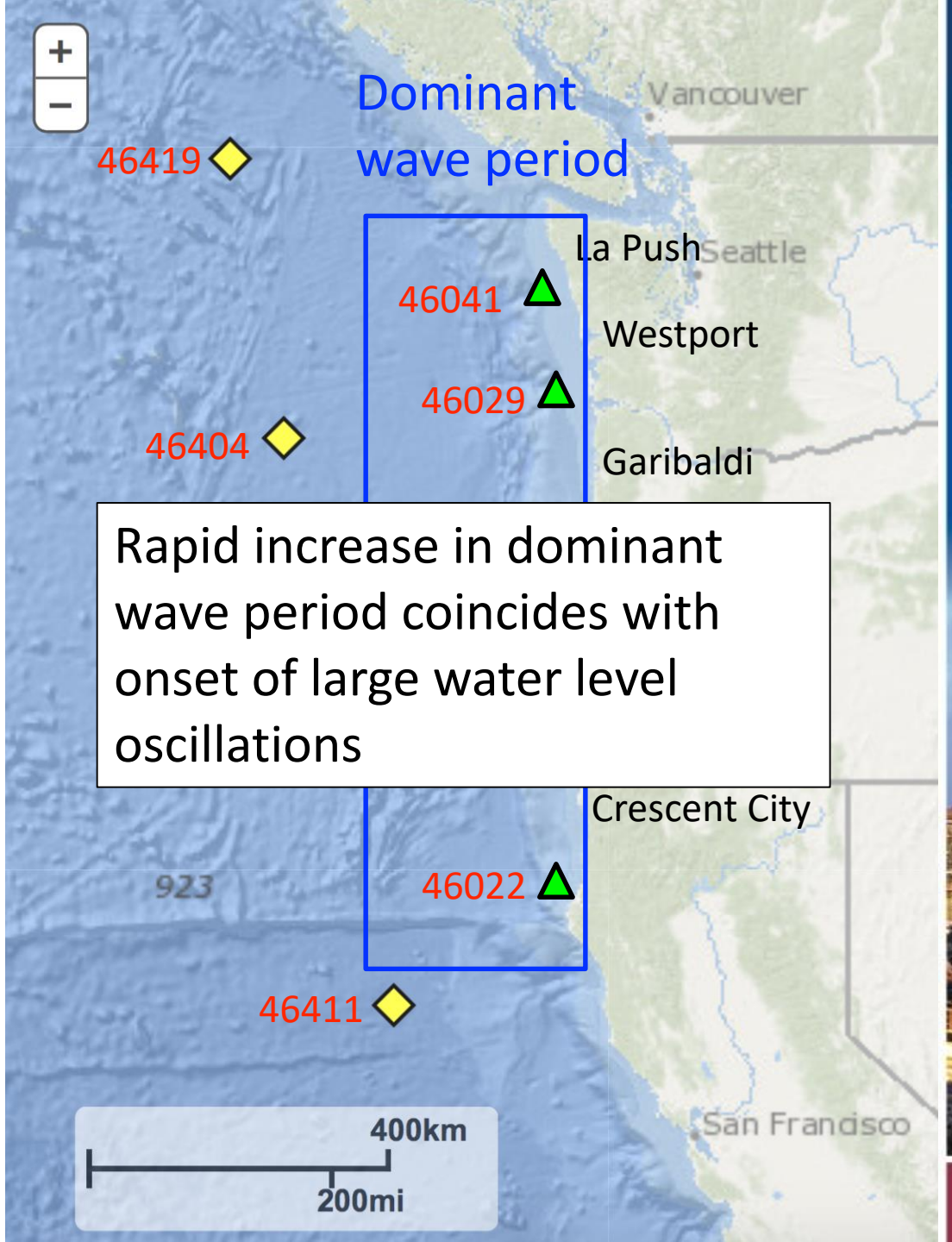
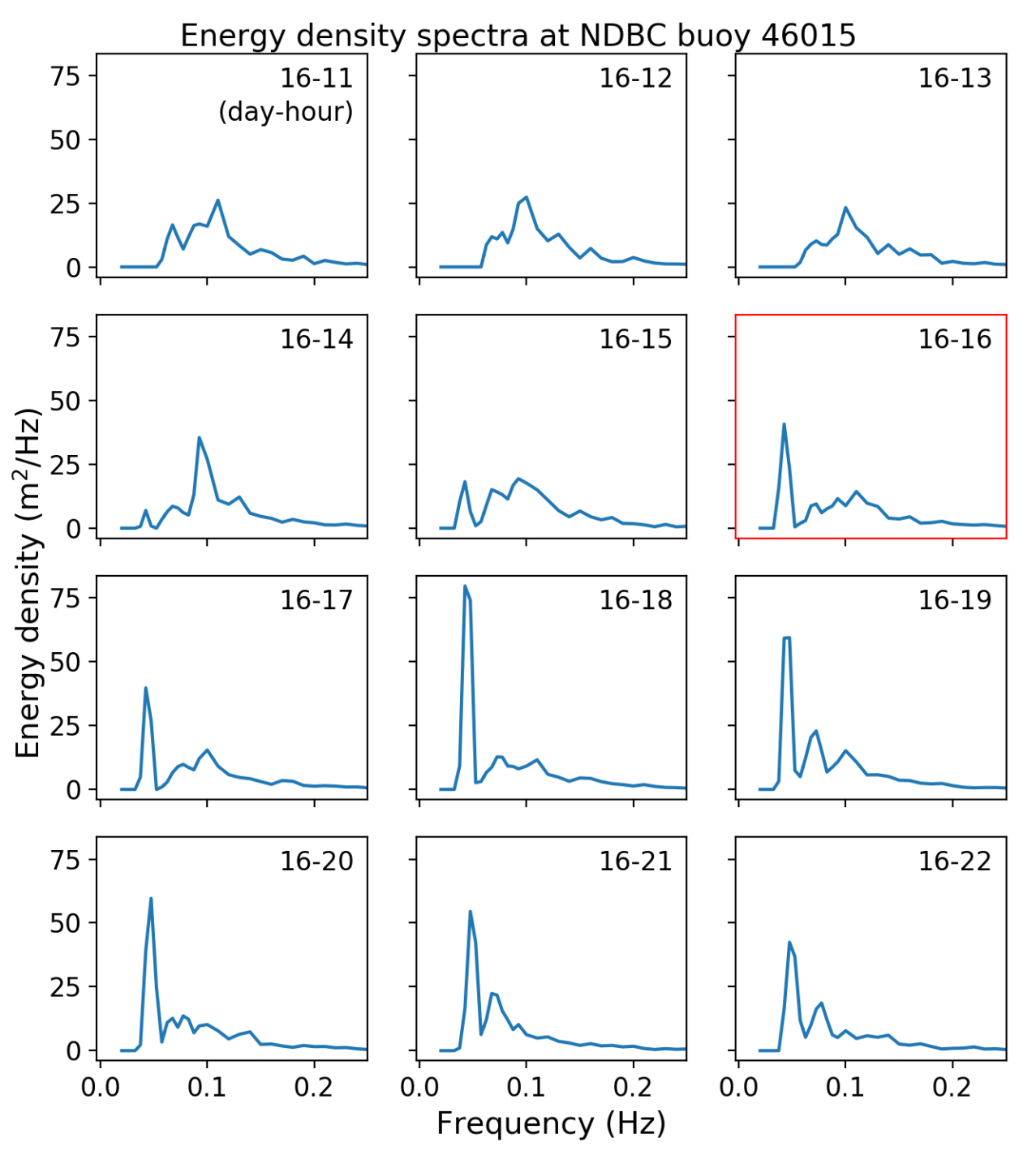
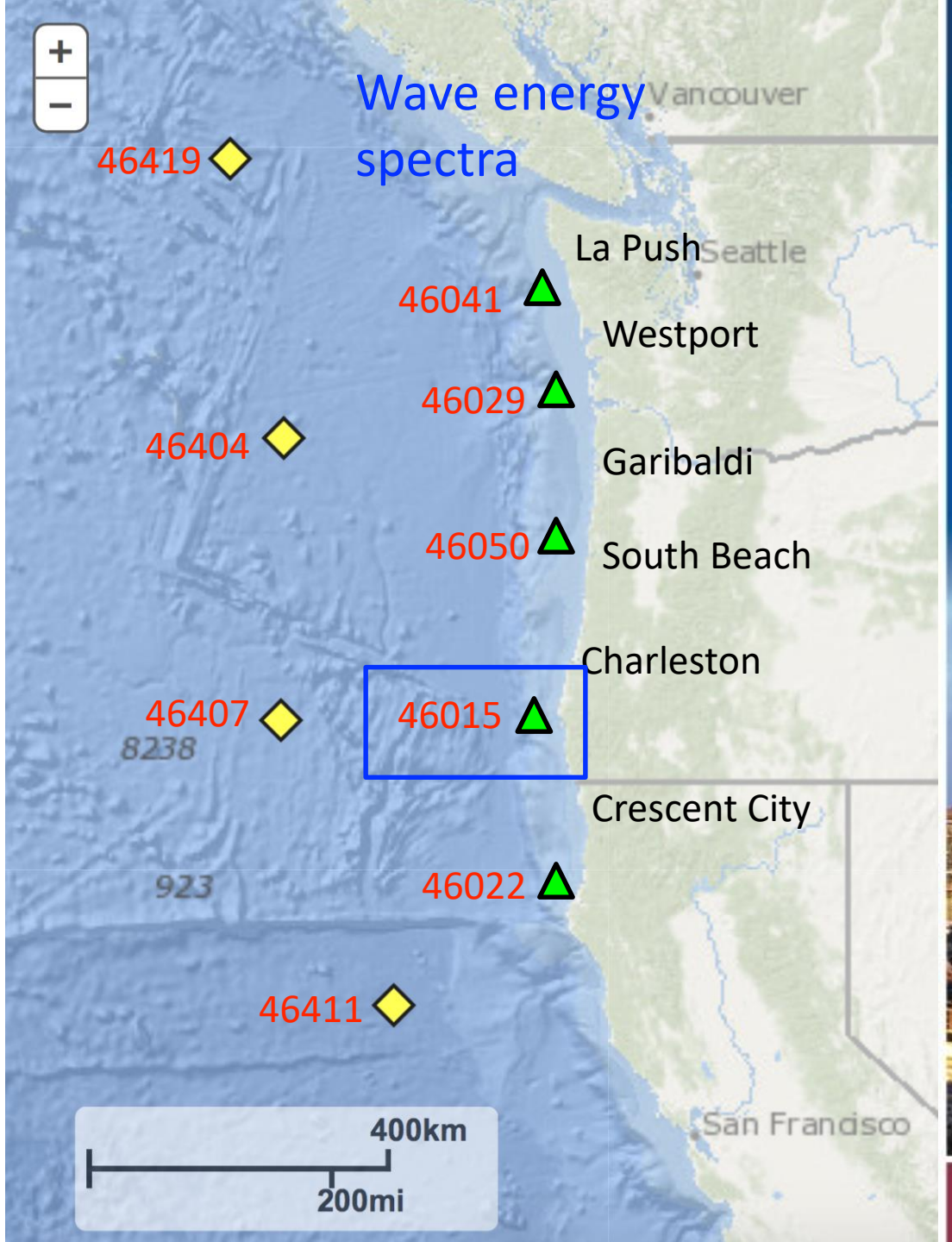

Dominant wave period at NDBC buoys
46041
46029
Jan 16, 16:00
46050
46015
46022
Dominant wave period (s)
20
10
16-00
16-06
16-12
16-18
17-00
17-06
17-12
17-18
18-00
Day-hour

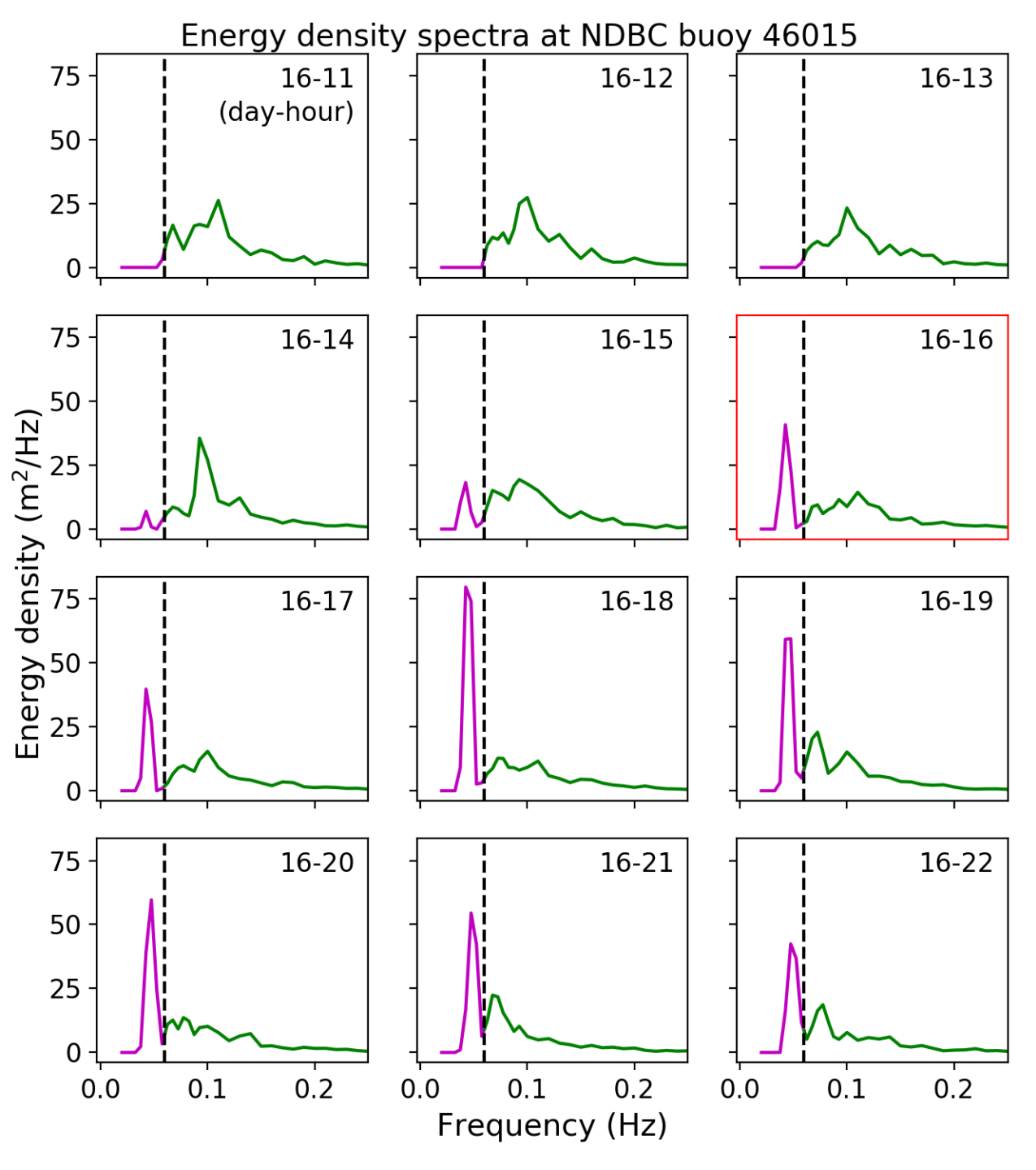

Dominant
wave period
Vancouver
46419
La Push
Seattle
46041
Westport
46029
46404
Garibaldi
Rapid increase in dominant wave period coincides with onset of large water level oscillations
Crescent City
923
46022
46411
San Francisco
400km
200mi

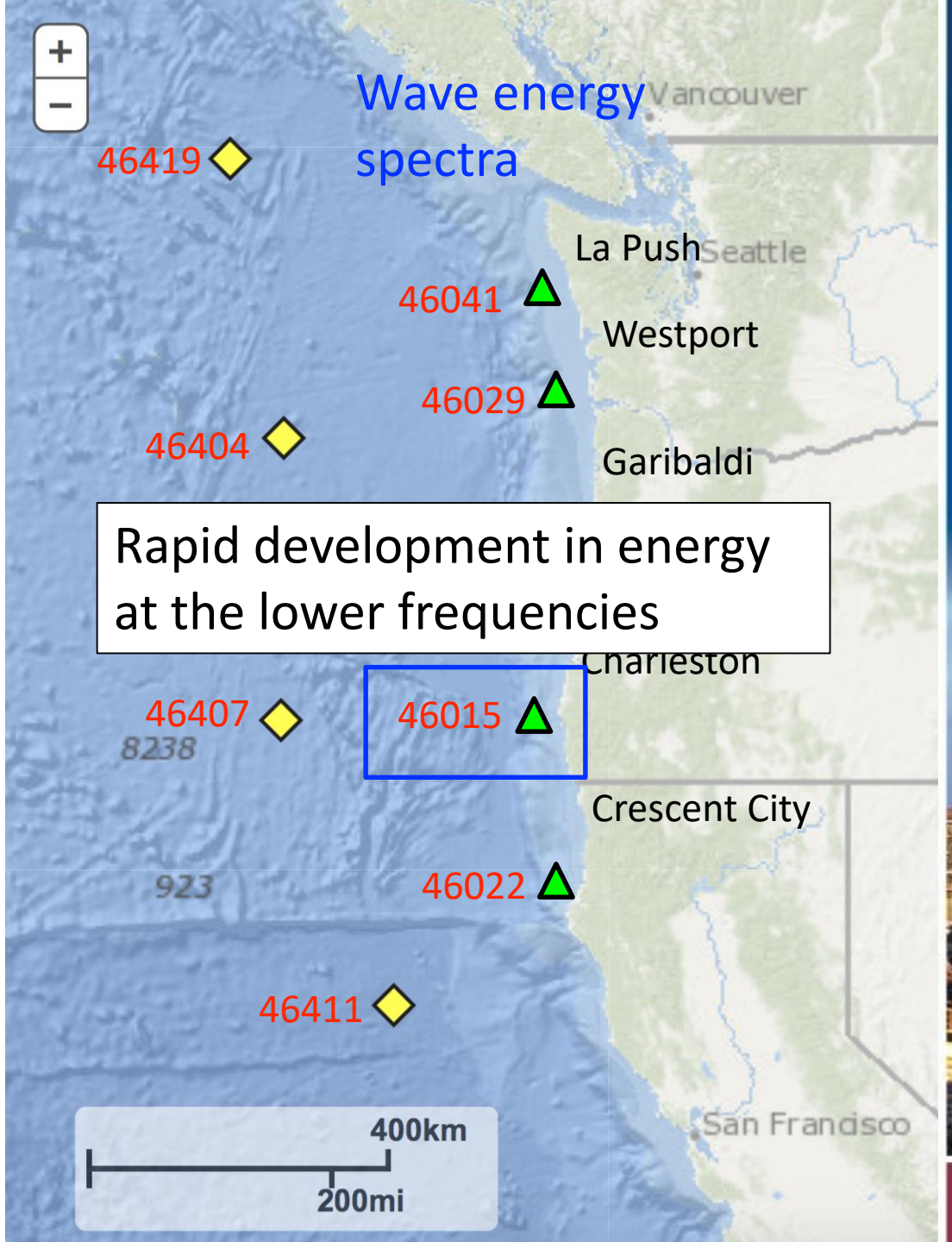

ICCE
2018


Energy density spectra at NDBC buoy 46015
16-11
(day-hour)
16-12
16-13
16-14
16-15
16-16
16-17
16-18
16-19
16-20
16-21
16-22
Energy density (m²/Hz)
Frequency (Hz)
0.0
0.1
0.2
0
25
50
75

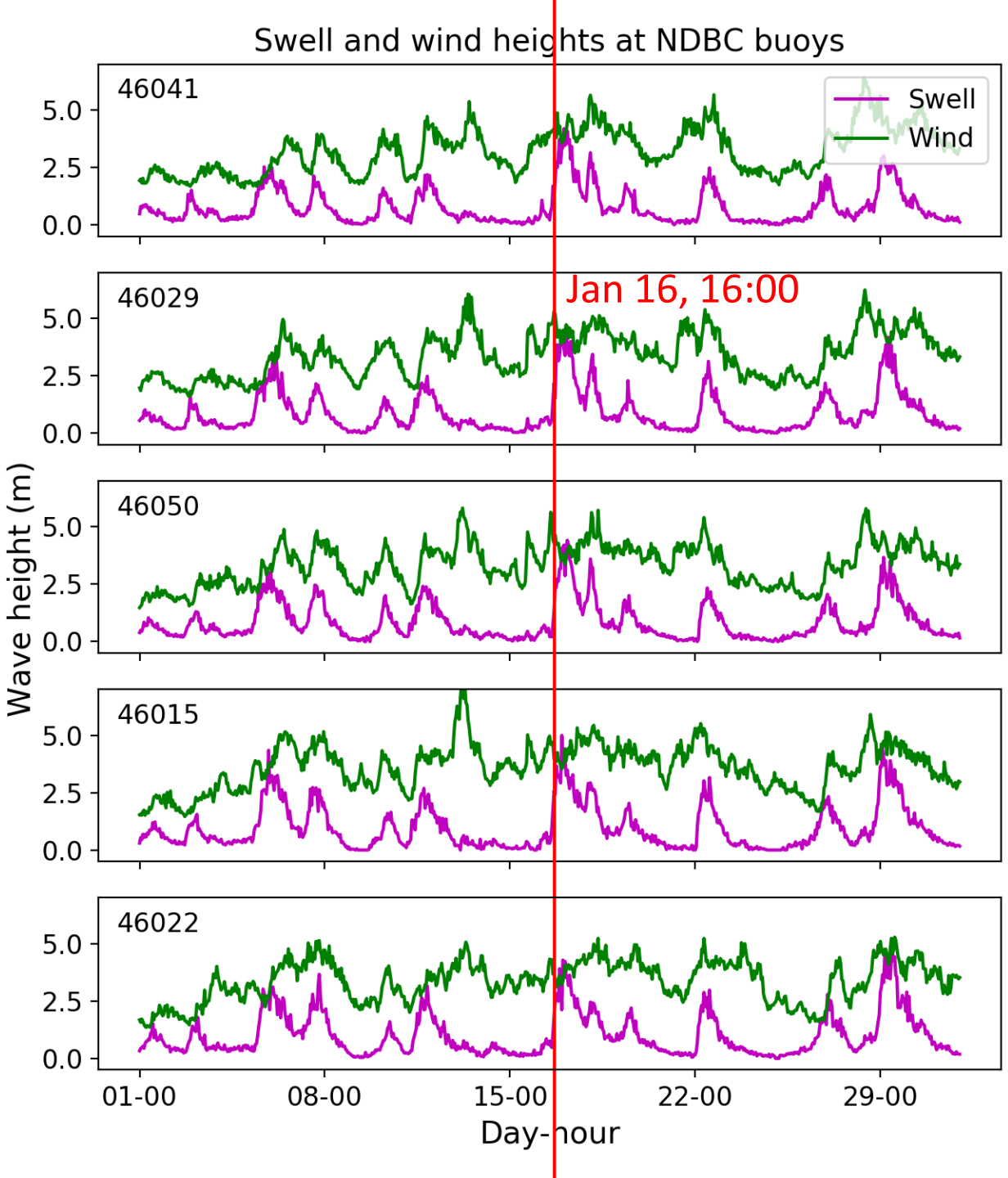

Wave energy spectra
46419
La Push
46041
Westport
46029
46404
Garibaldi
46050
South Beach
Charleston
46407
46015
Crescent City
46022
46411
Vancouver
Seattle
San Francisco
400km
200mi

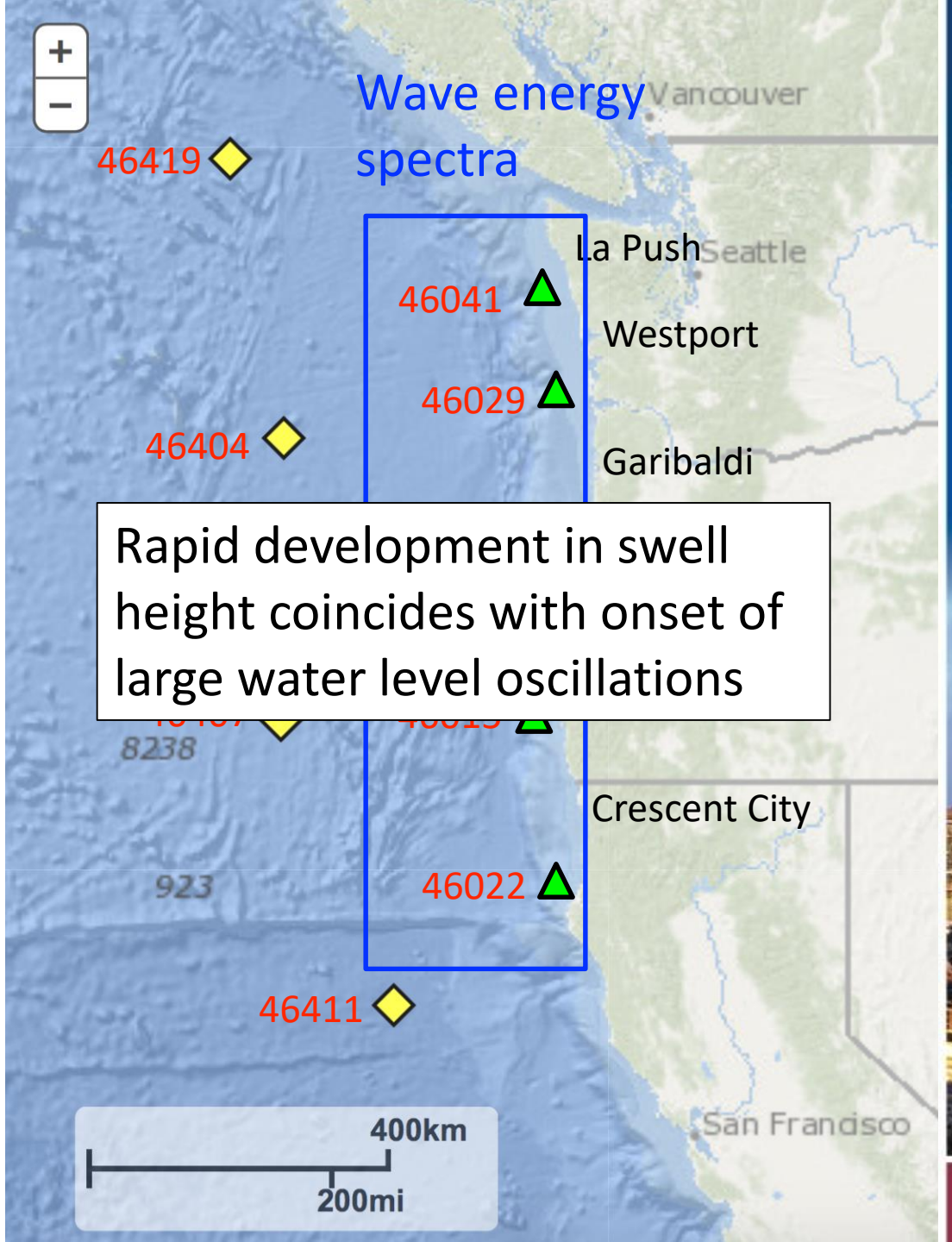

ICCE
2018


Energy density spectra at NDBC buoy 46015
16-11
(day-hour)
16-12
16-13
16-14
16-15
16-16
16-17
16-18
16-19
16-20
16-21
16-22
Energy density (m²/Hz)
Frequency (Hz)
0
25
50
75
0.0
0.1
0.2

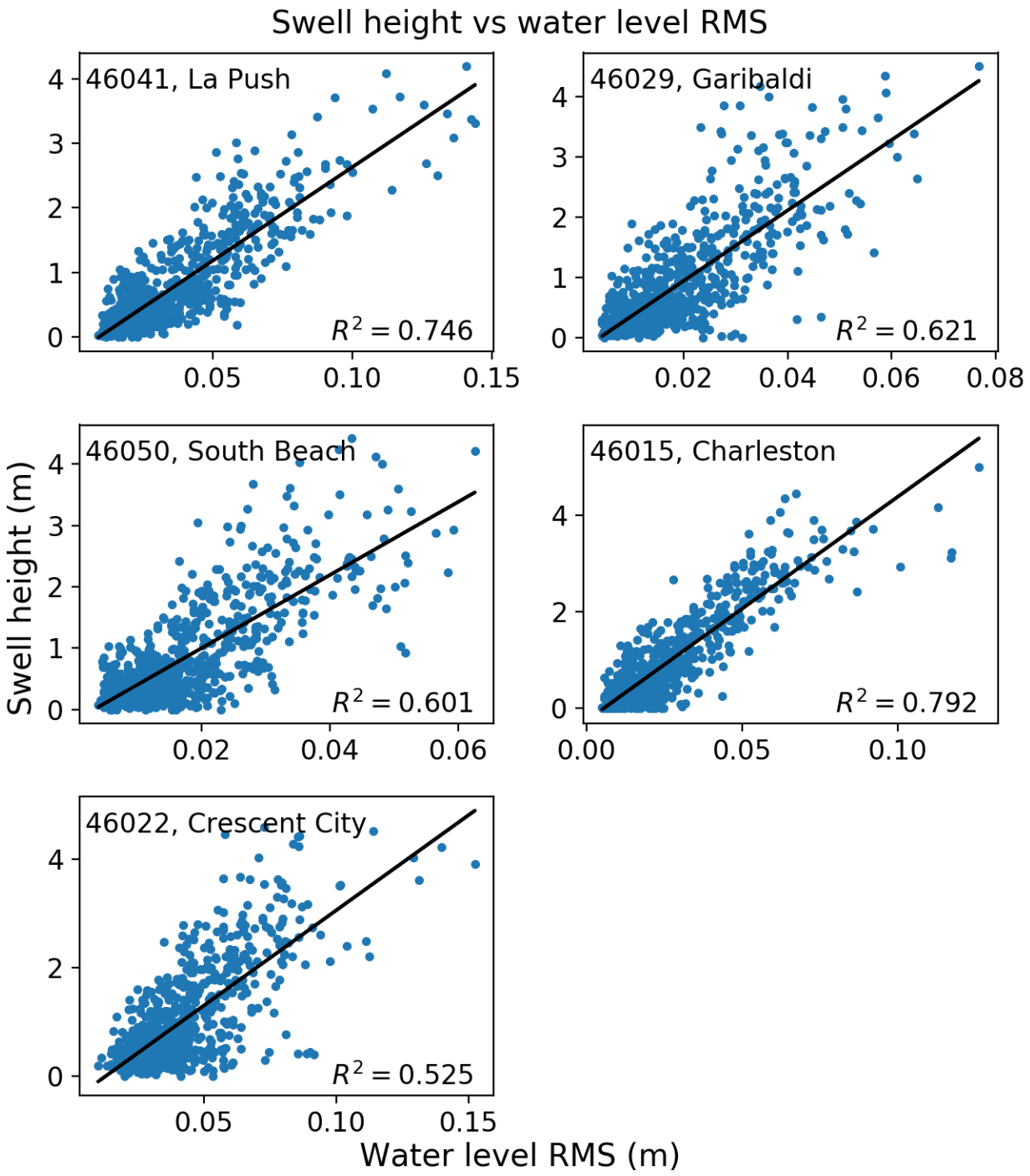

Wave energy spectra
46419
La Push
46041
Westport
46029
46404
Garibaldi
Rapid development in energy at the lower frequencies
Charleston
46407
46015
8238
Crescent City
923
46022
46411
San Francisco
400km
200mi

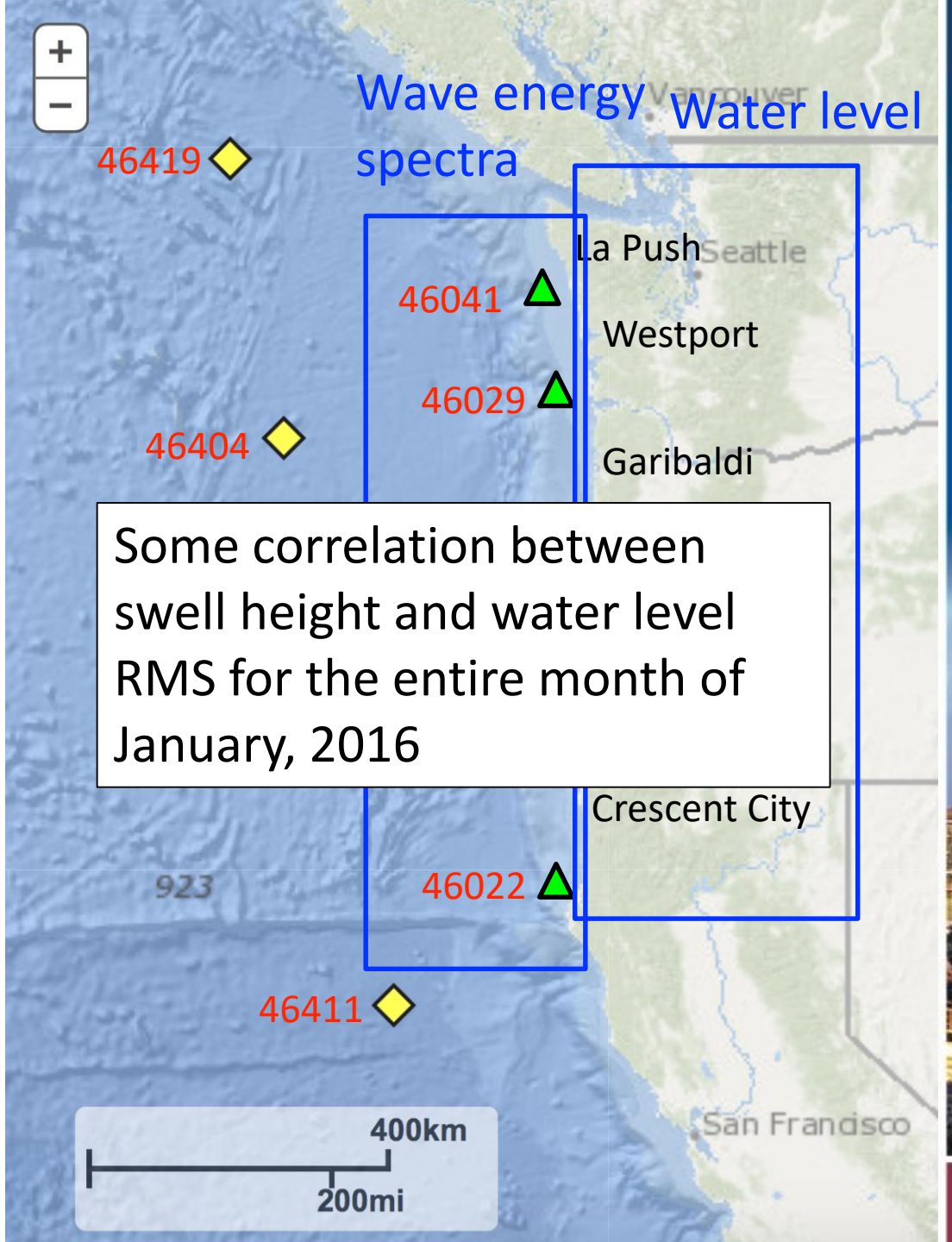

ICCE
2018



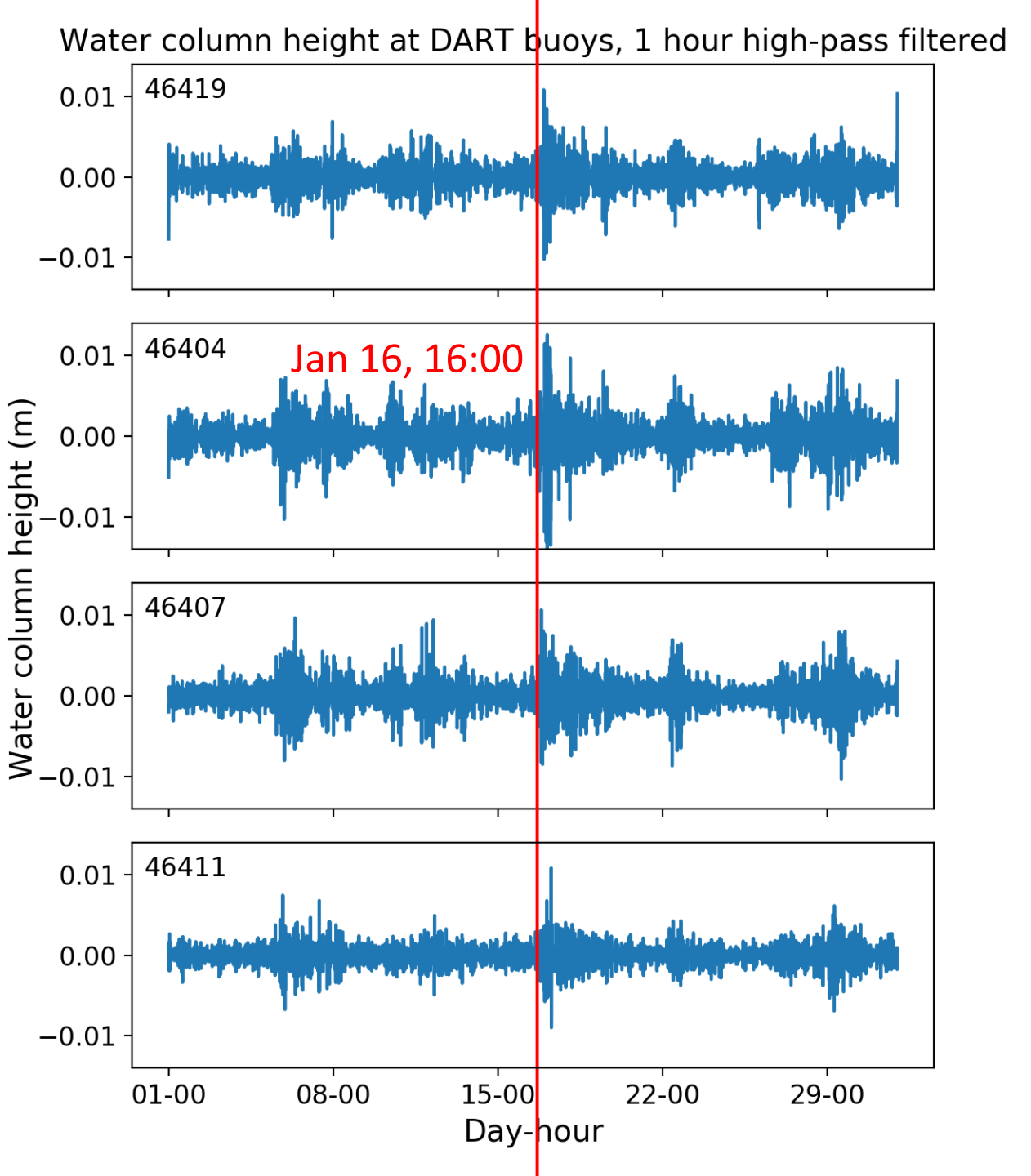


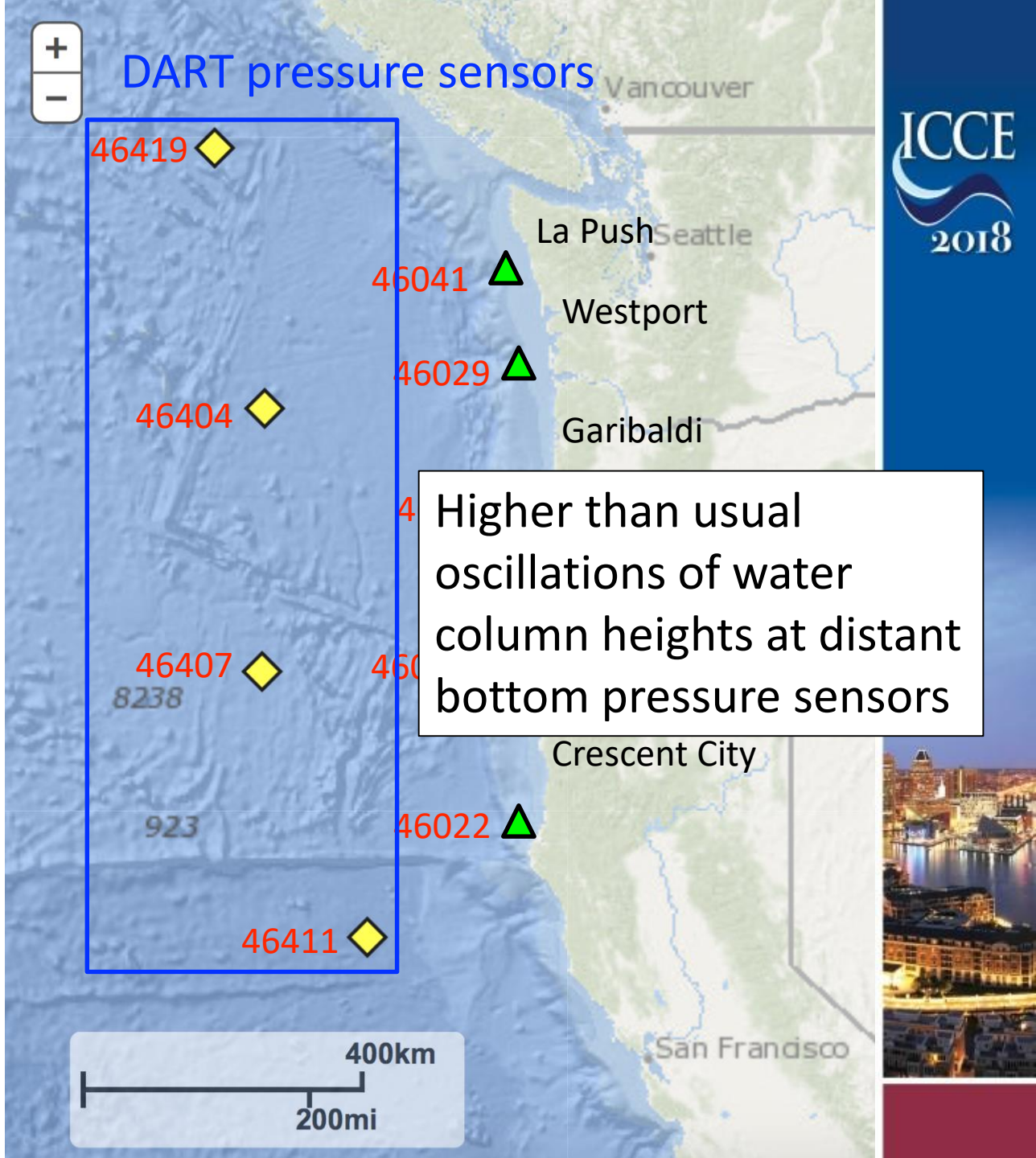
Rapid development in swell height coincides with onset of large water level oscillations


Swell height vs water level RMS
46041, La Push
$R^2 = 0.746$
46029, Garibaldi
$R^2 = 0.621$
46050, South Beach
$R^2 = 0.601$
46015, Charleston
$R^2 = 0.792$
46022, Crescent City
$R^2 = 0.525$
Swell height (m)
Water level RMS (m)


Wave energy spectra
Water level
46419
La Push
46041
Westport
46029
46404
Garibaldi
Some correlation between swell height and water level RMS for the entire month of January, 2016
Crescent City
46022
46411
Vancouver
Seattle
San Francisco
400km
200mi


ICCE
2018


Water column height at DART buoys, 1 hour high-pass filtered
46419
46404
Jan 16, 16:00
46407
46411
0.01
0.00
−0.01
Water column height (m)
01-00
08-00
15-00
22-00
29-00
Day-hour


DART pressure sensors
46419
46404
46407
46411
46041
46029
46022
La Push
Westport
Garibaldi
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi
Higher than usual oscillations of water column heights at distant bottom pressure sensors
ICCE
2018

Summary of Jan 16, 2016

- Very large runup events were observed along Washington, Oregon, and northern California.

Summary of Jan 16, 2016

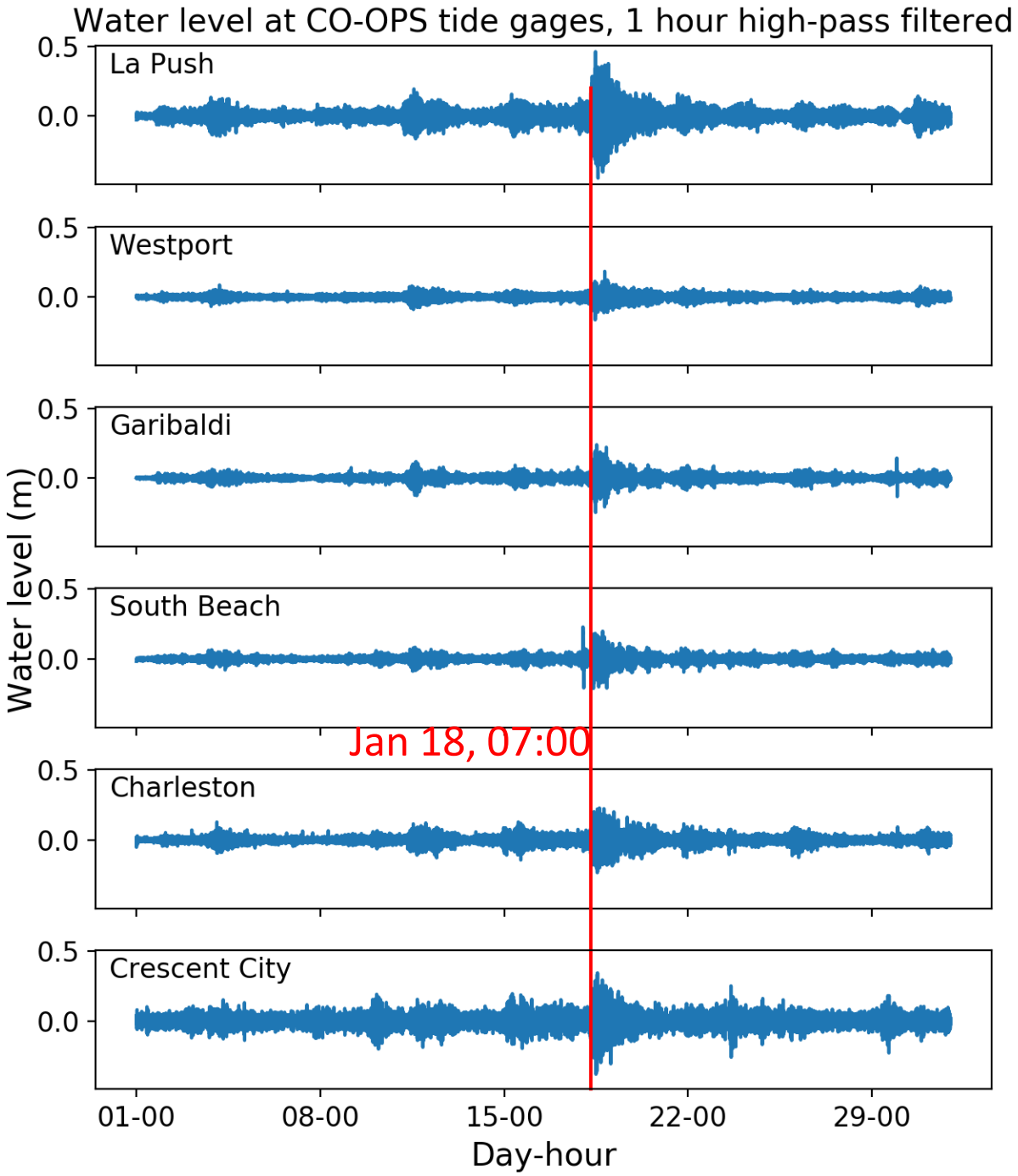
- Very large runup events were observed along Washington, Oregon, and northern California.

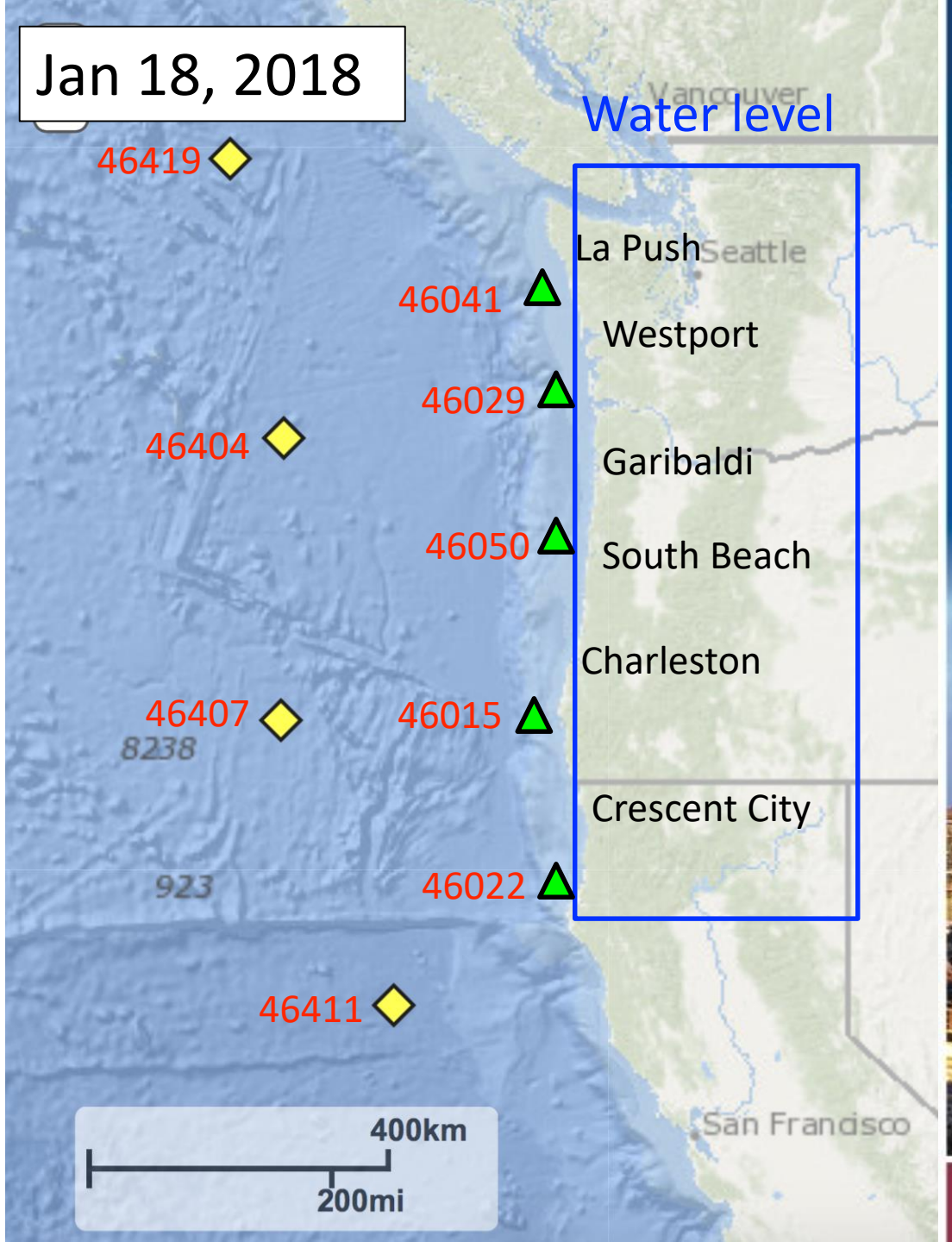
- The timing of the initial events align with arrival of sharp swell fronts

Summary of Jan 16, 2016

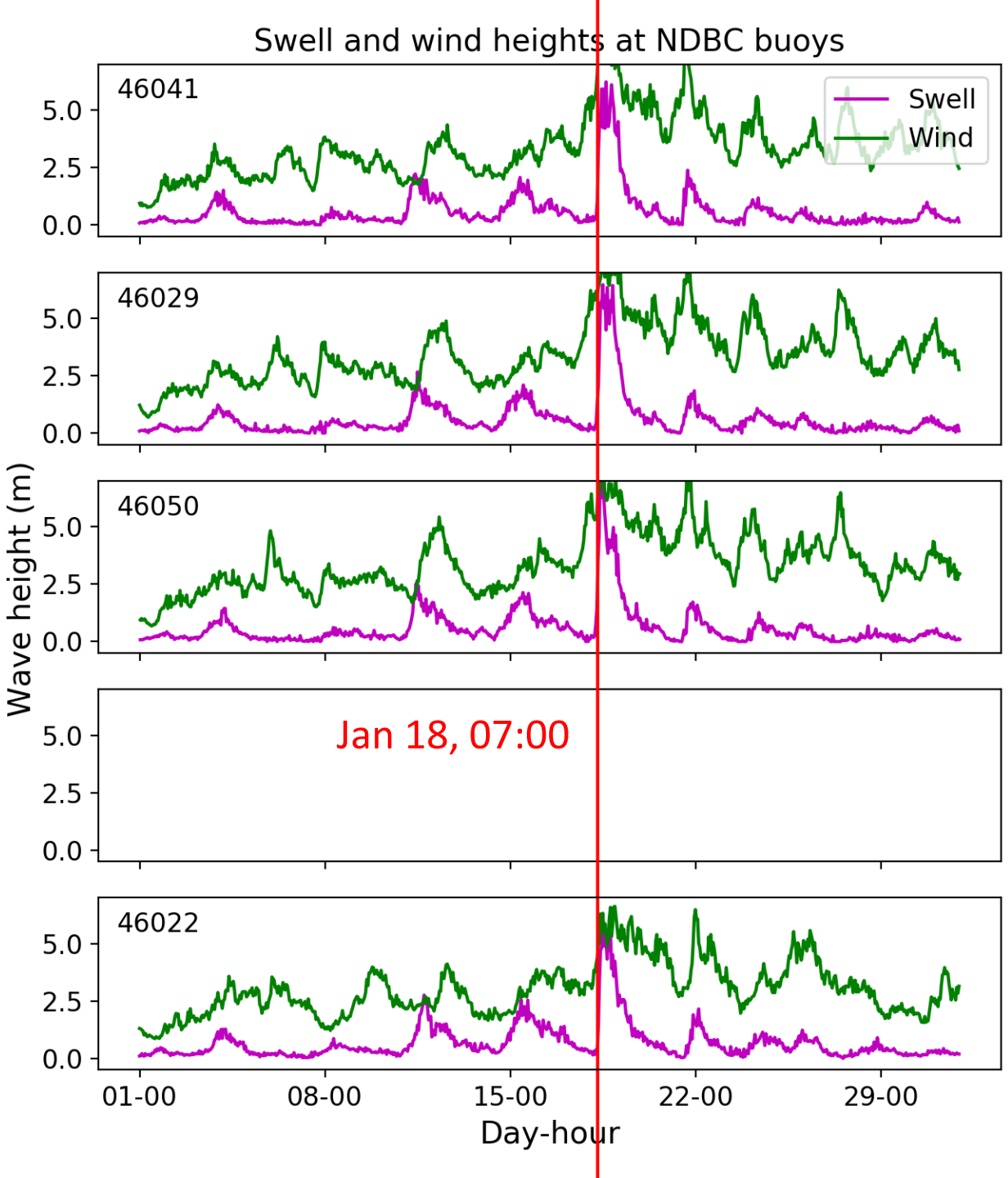
- Very large runup events were observed along Washington, Oregon, and northern California.
- The timing of the initial events align with arrival of sharp swell fronts
- Are similar relationships between large runups and sharp swell fronts observed at other times?

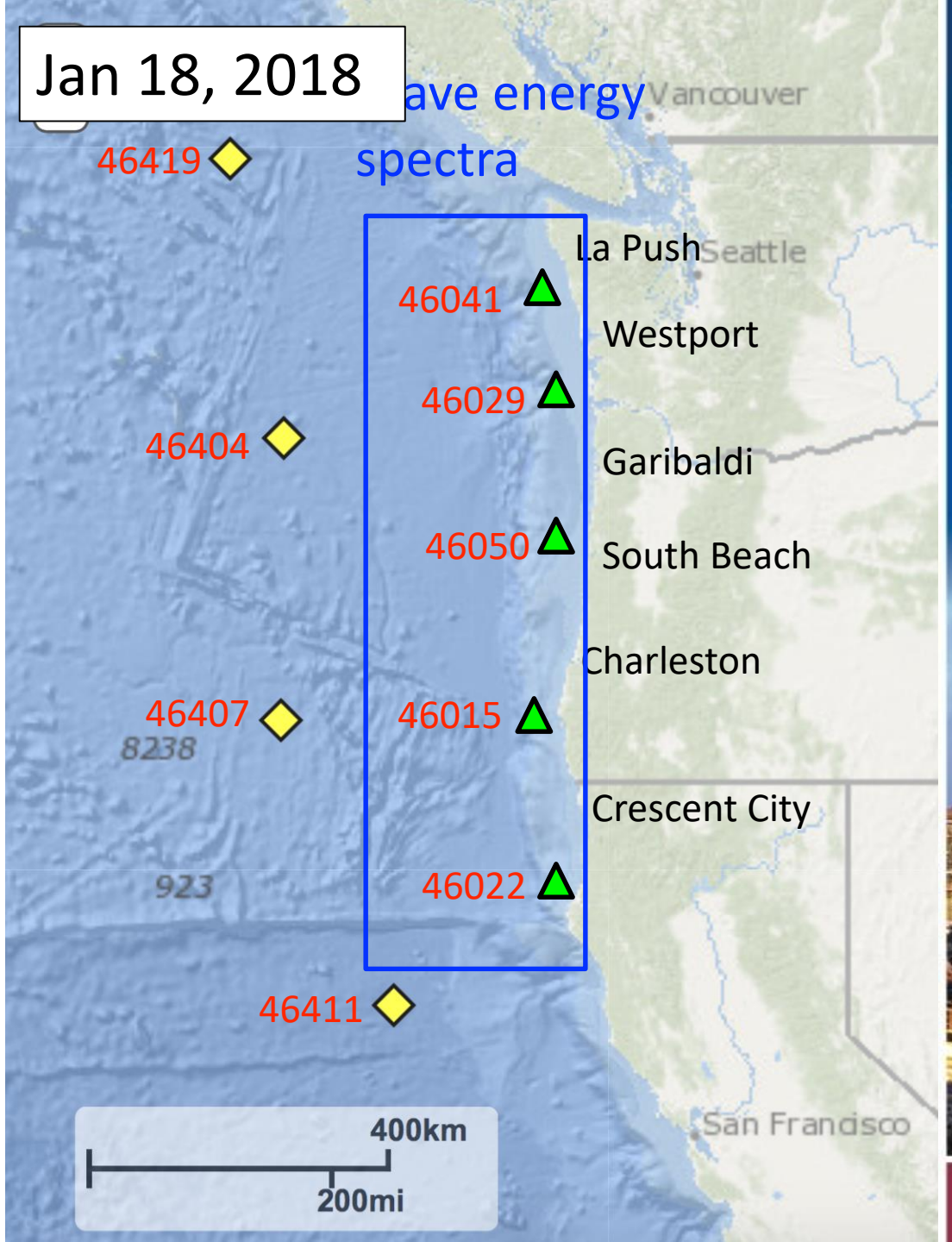
Another occurrence of large runup events: January 18, 2018


Water level at CO-OPS tide gages, 1 hour high-pass filtered
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
0.5
0.0
Water level (m)
Jan 18, 07:00
01-00
08-00
15-00
22-00
29-00
Day-hour

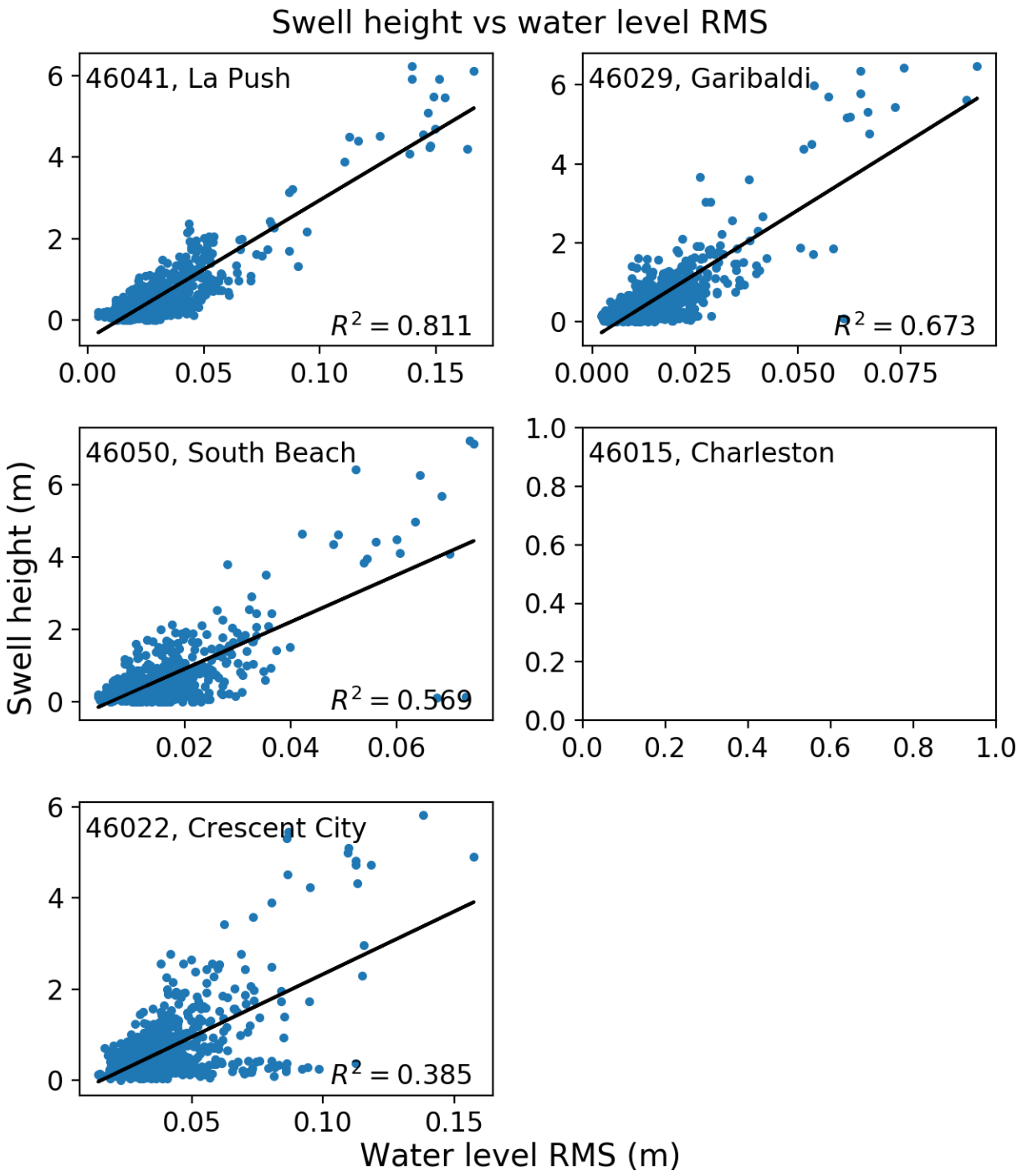

Jan 18, 2018
Water level
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi

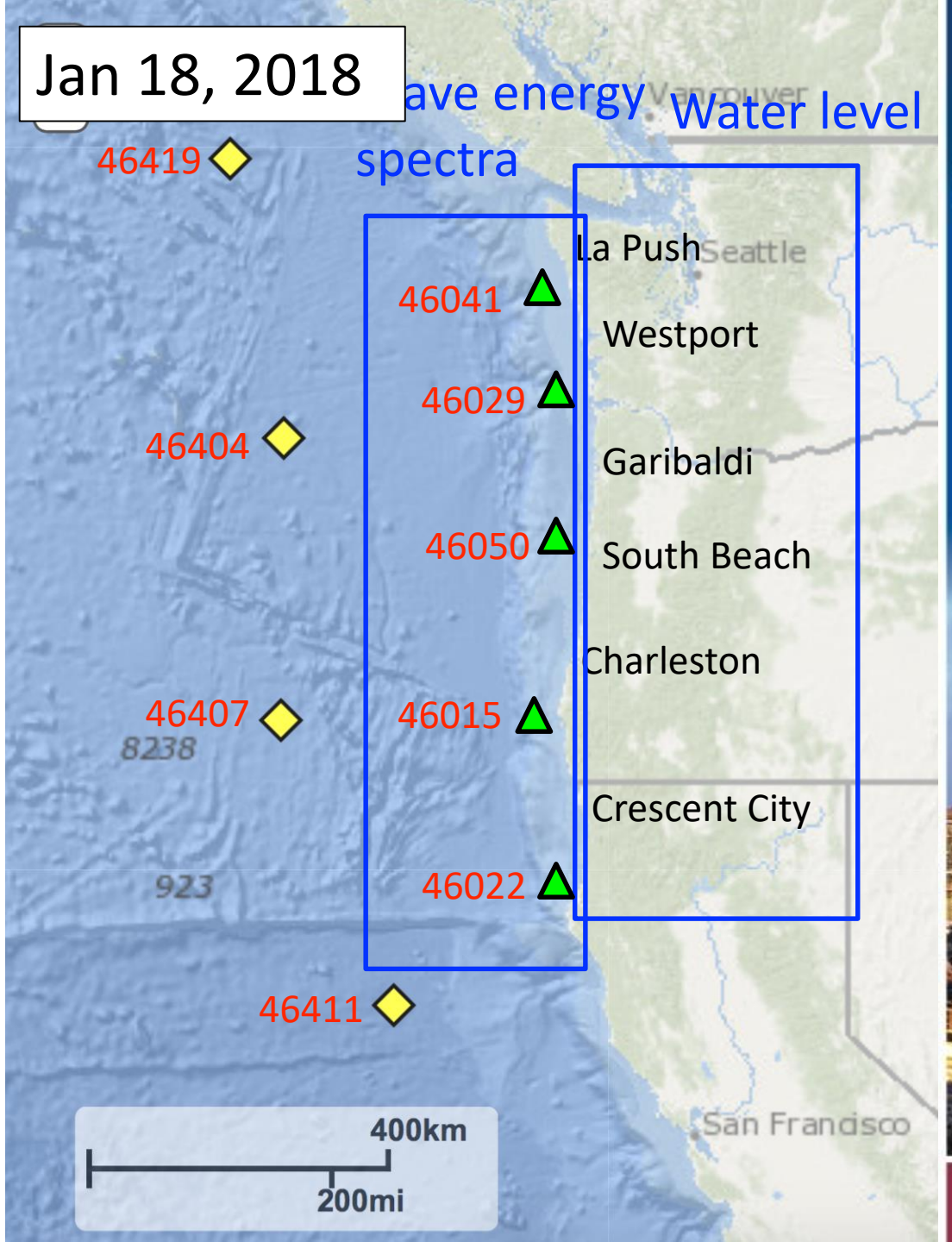

ICCE
2018


Swell and wind heights at NDBC buoys
46041
46029
46050
46022
Swell
Wind
Wave height (m)
5.0
2.5
0.0
Jan 18, 07:00
01-00
08-00
15-00
22-00
29-00
Day-hour

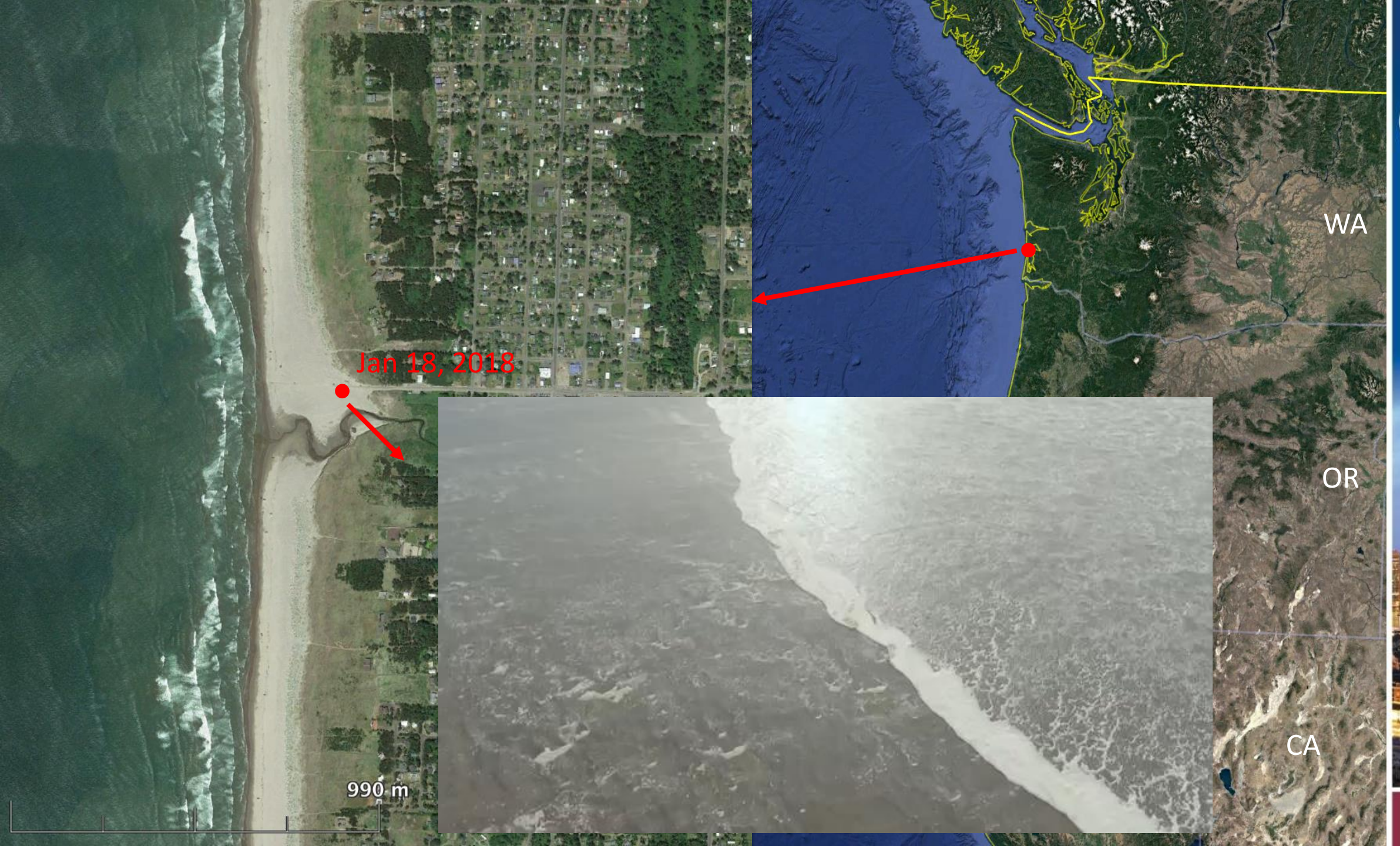

Jan 18, 2018
ave energy
spectra
46419
46404
46407
46411
46041
46029
46050
46015
46022
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi


ICCE
2018


Swell height vs water level RMS
46041, La Push
$R^2 = 0.811$
46029, Garibaldi
$R^2 = 0.673$
46050, South Beach
$R^2 = 0.569$
46015, Charleston
46022, Crescent City
$R^2 = 0.385$
Swell height (m)
Water level RMS (m)

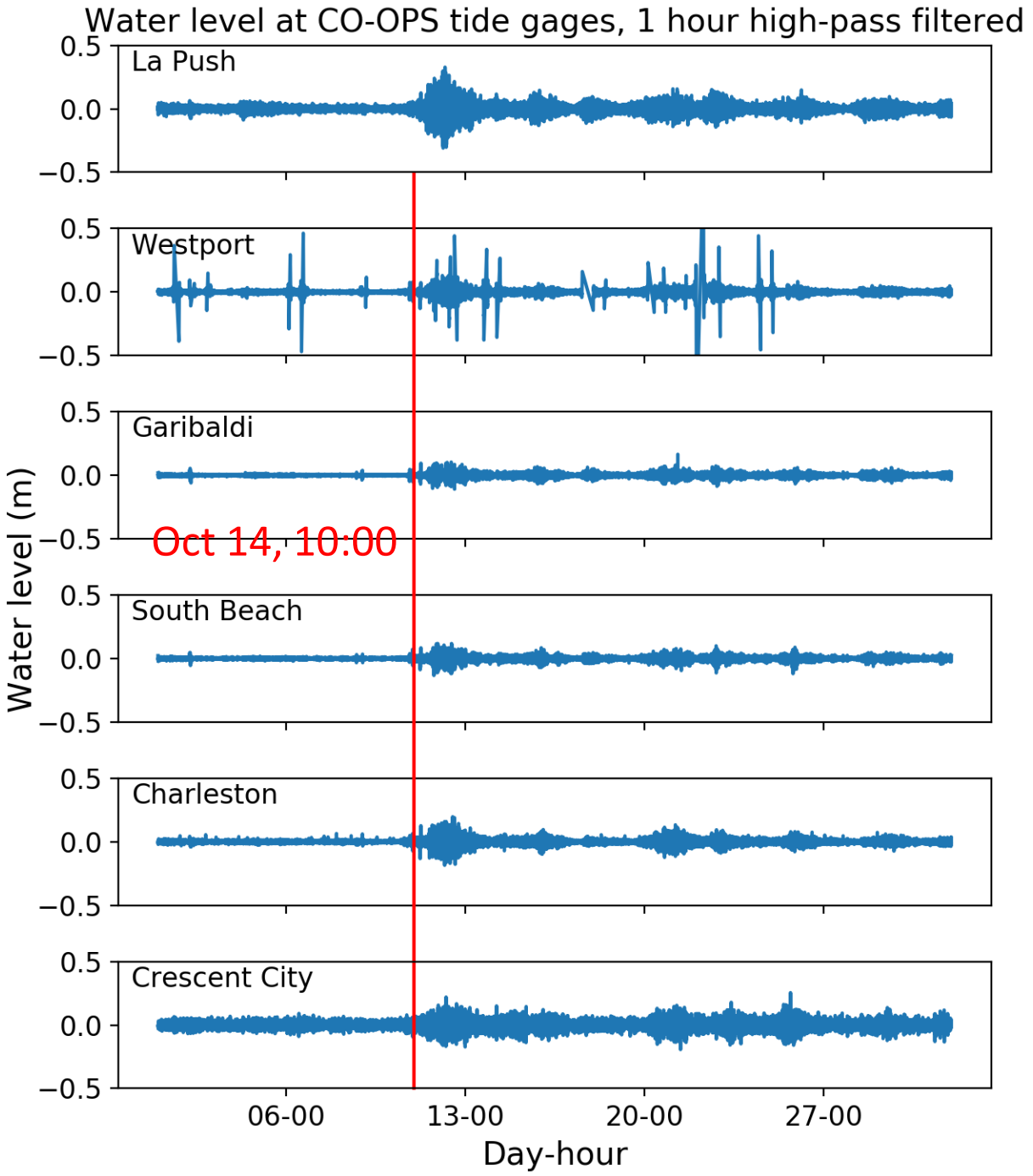

Jan 18, 2018
ave energy spectra
Water level
46419
46404
46407
46411
46041
46029
46050
46015
46022
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Seattle
San Francisco
400km
200mi

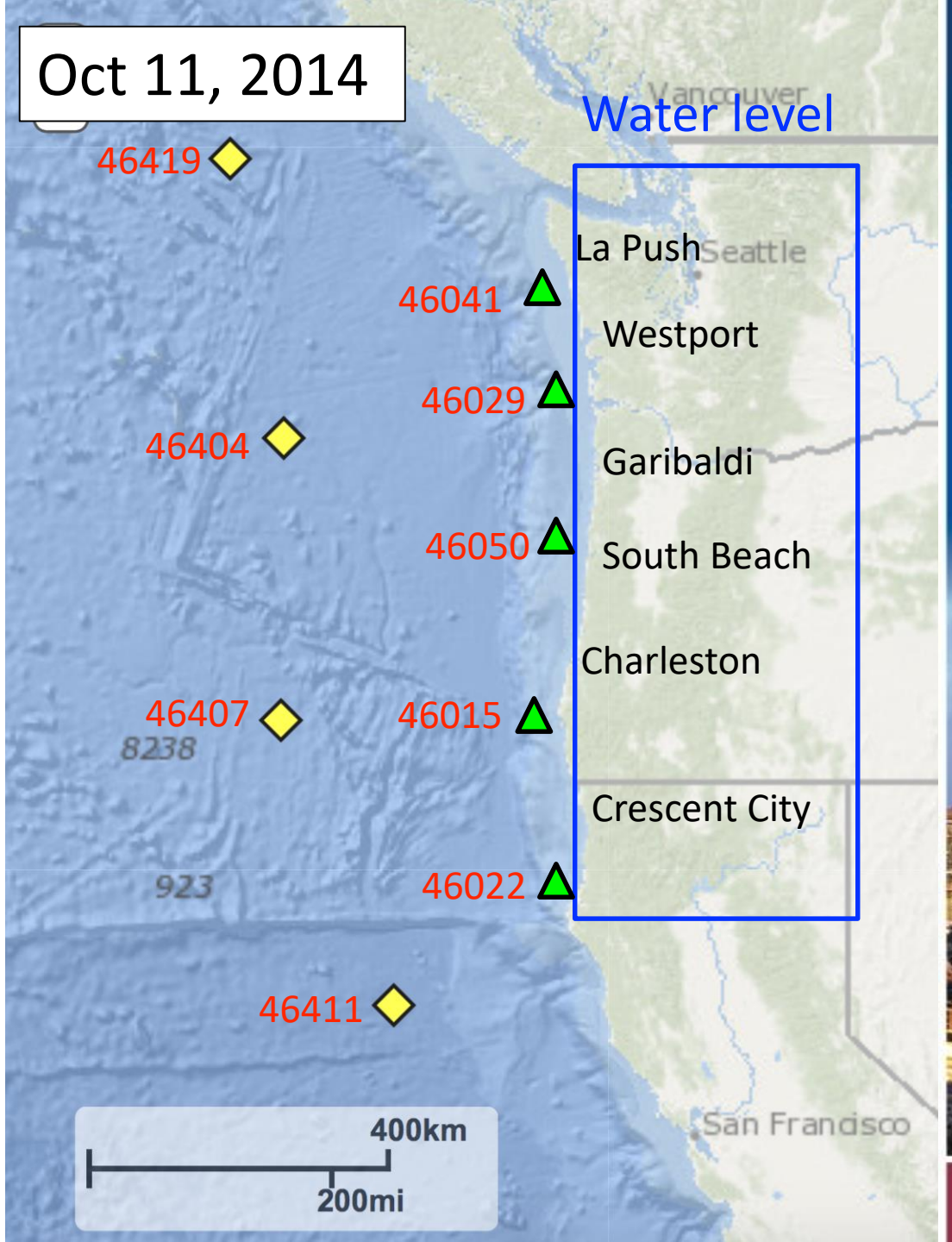
ICCE 2018



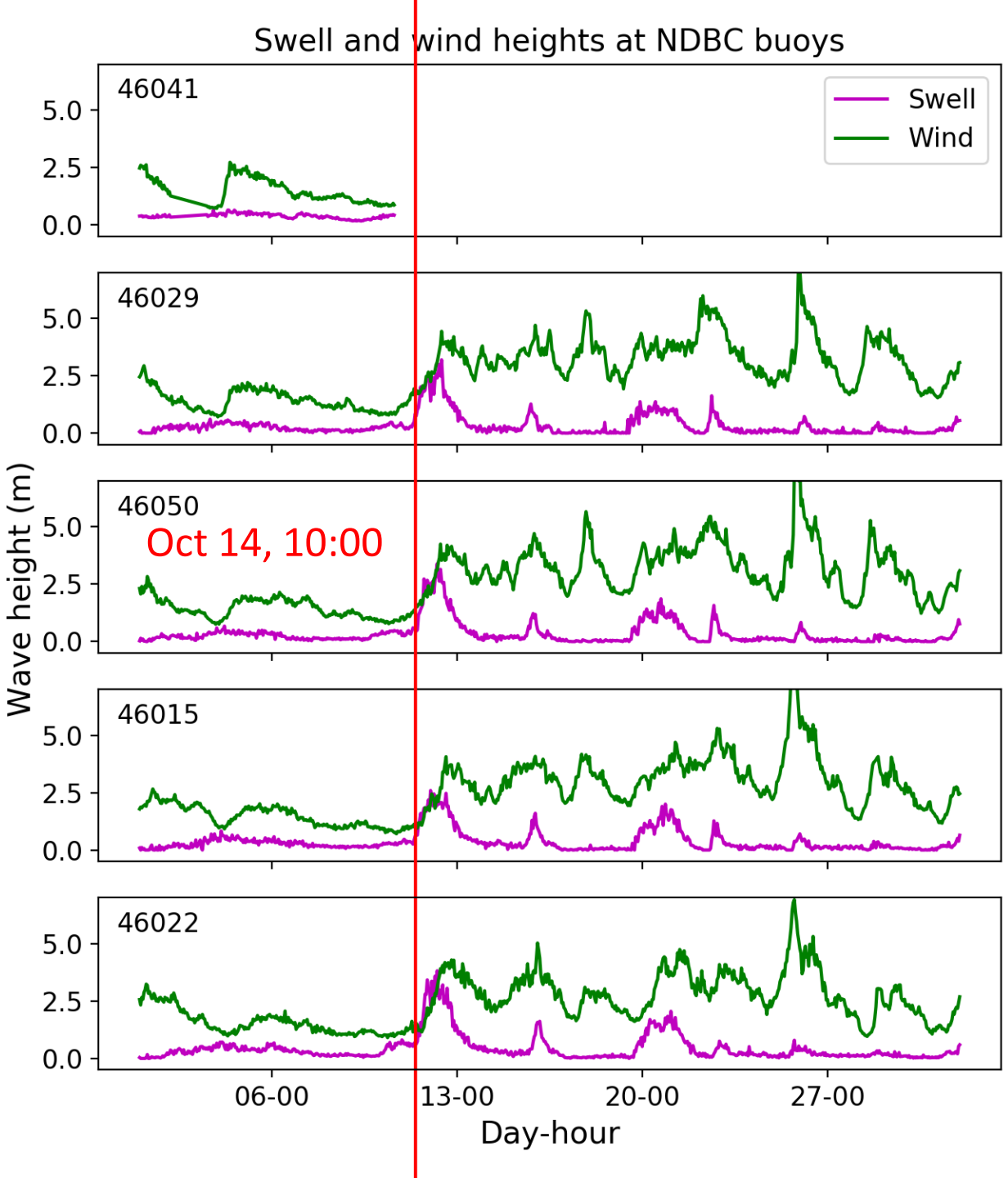
ICCE 2018

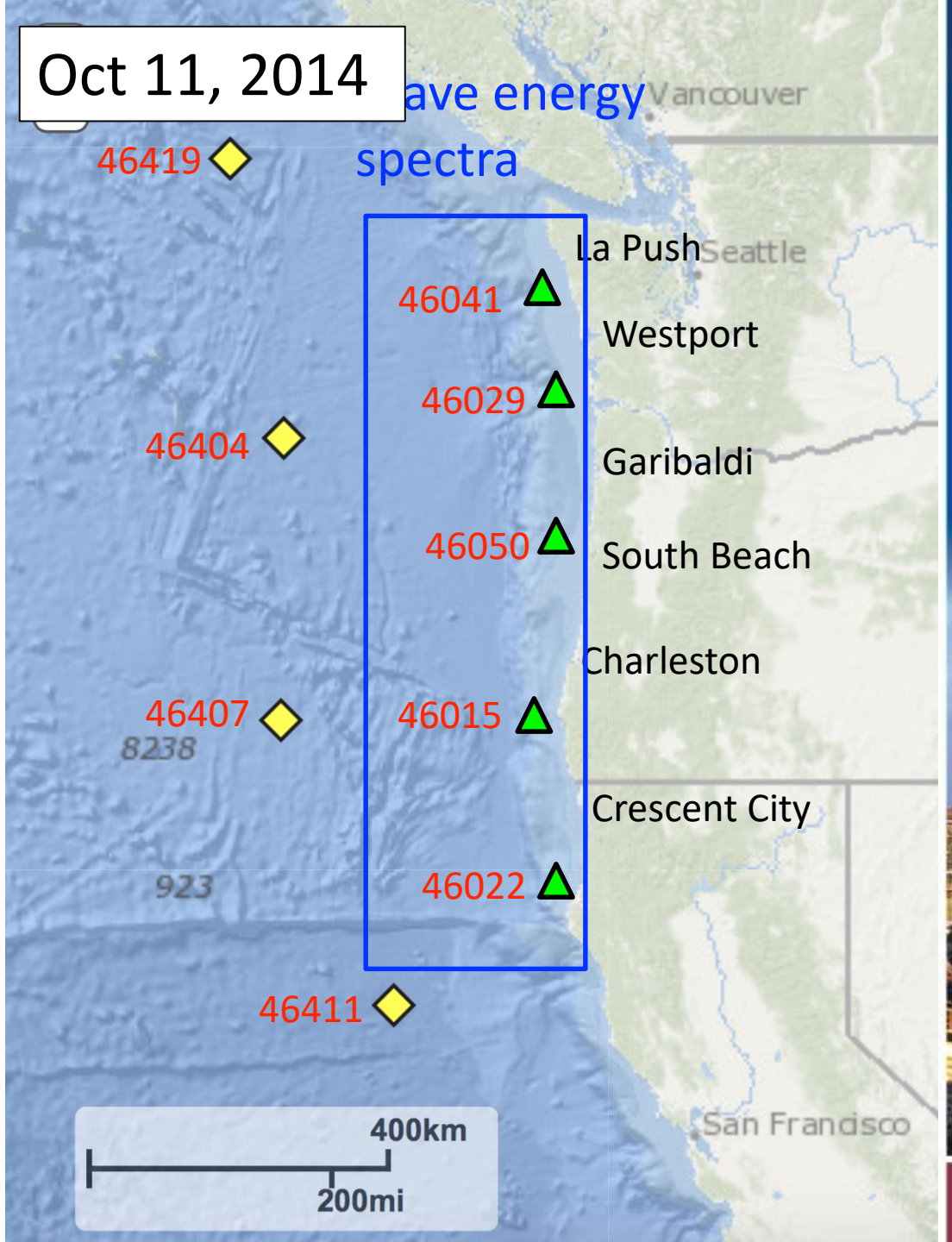
Another occurrence of large runup events: October 11, 2014


Water level at CO-OPS tide gages, 1 hour high-pass filtered
La Push
Westport
Garibaldi
Oct 14, 10:00
South Beach
Charleston
Crescent City
Water level (m)
0.5
0.0
−0.5
06-00
13-00
20-00
27-00
Day-hour

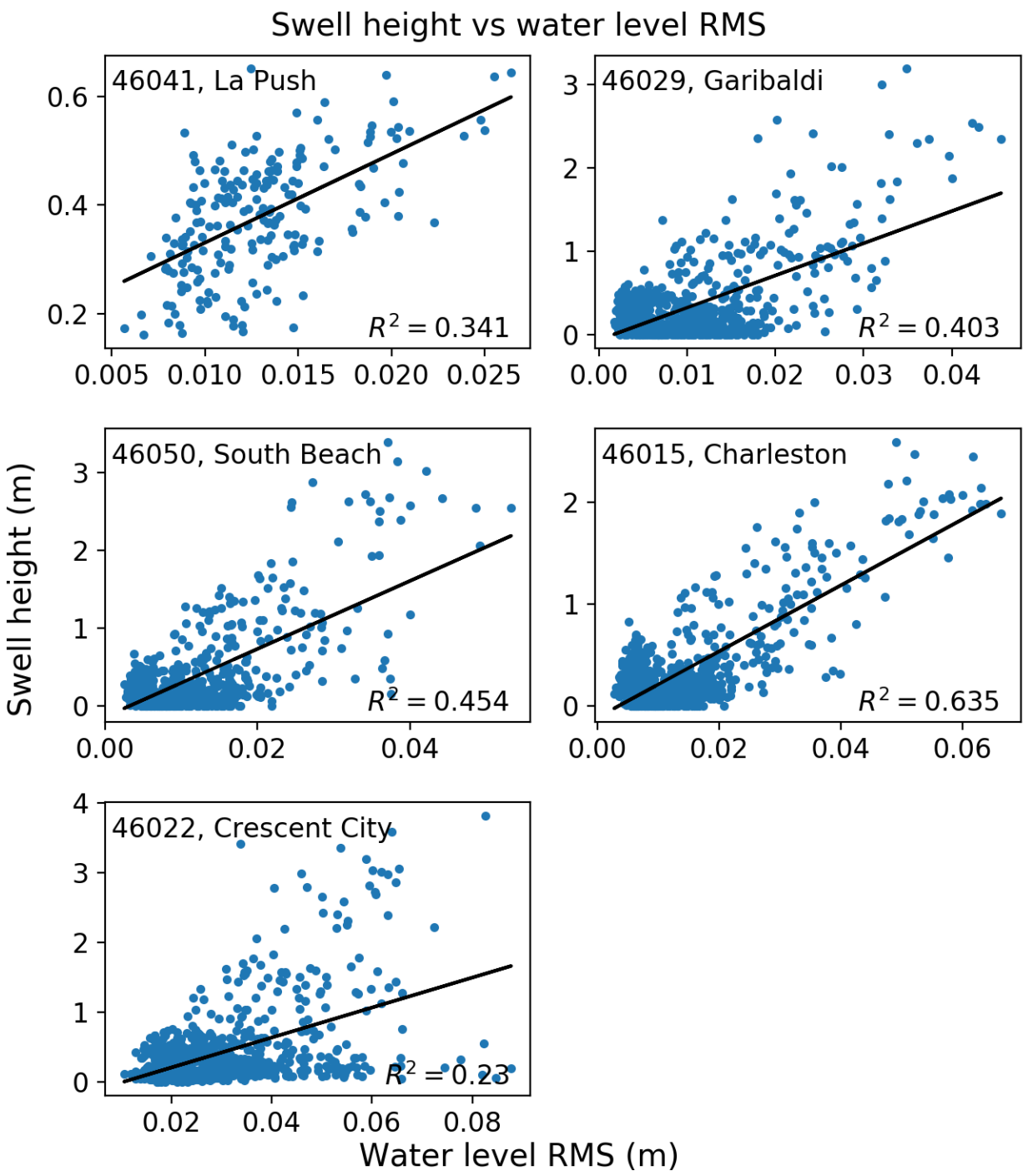

Oct 11, 2014
Water level
46419
46041
46404
46029
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi

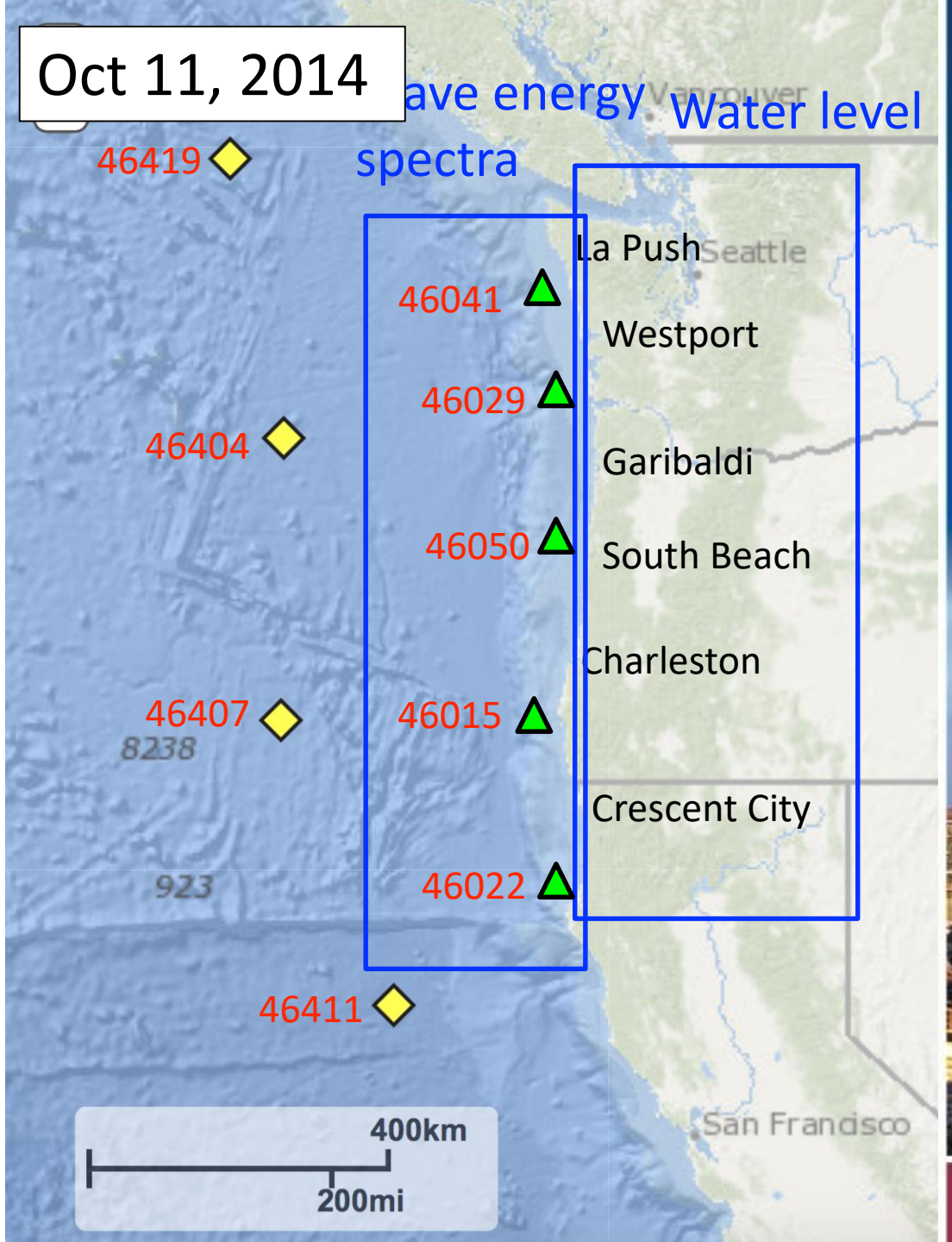

ICCE
2018


Swell and wind heights at NDBC buoys
46041
46029
46050
46015
46022
Swell
Wind
Oct 14, 10:00
Wave height (m)
5.0
2.5
0.0
06-00
13-00
20-00
27-00
Day-hour

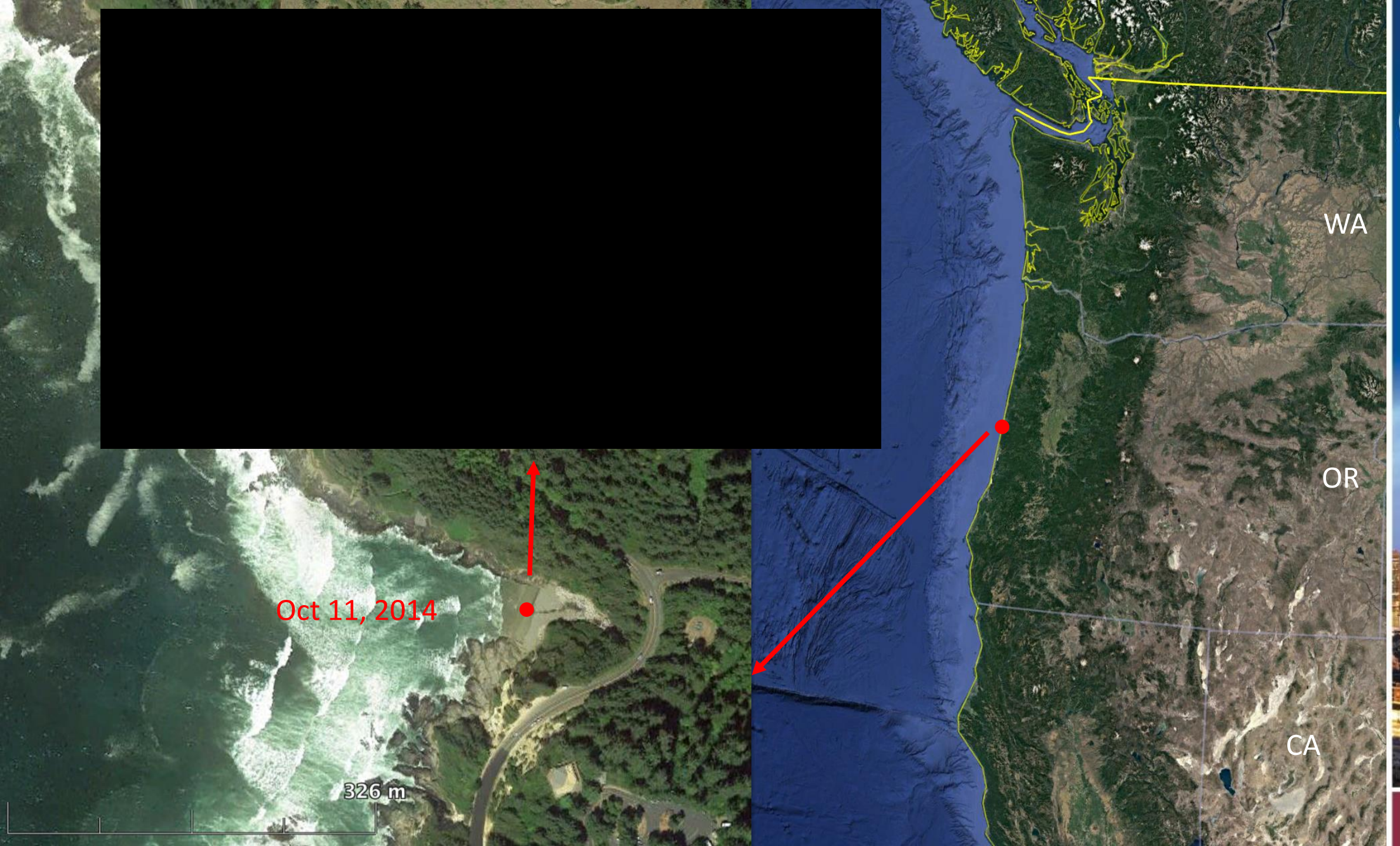

Oct 11, 2014
ave energy
spectra
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi


ICCE
2018


Swell height vs water level RMS
46041, La Push
$R^2 = 0.341$
46029, Garibaldi
$R^2 = 0.403$
46050, South Beach
$R^2 = 0.454$
46015, Charleston
$R^2 = 0.635$
46022, Crescent City
$R^2 = 0.23$
Swell height (m)
Water level RMS (m)

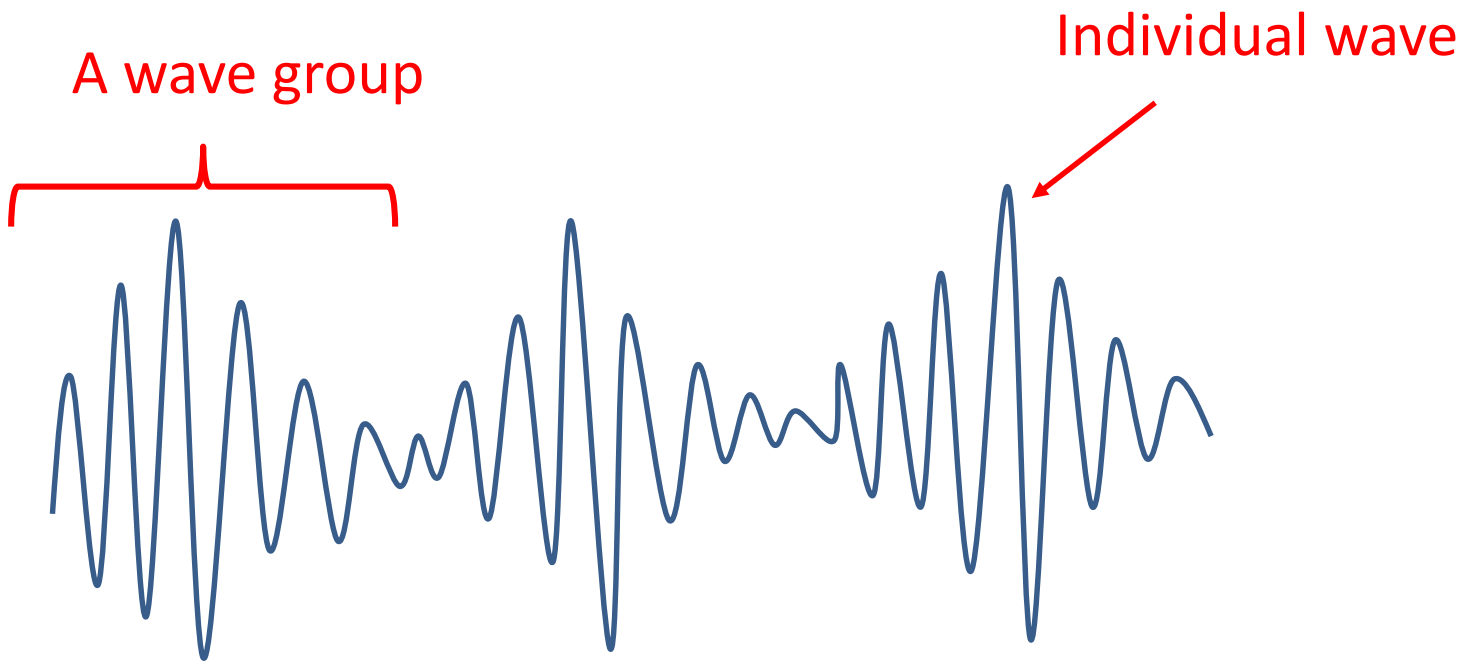

Oct 11, 2014
ave energy spectra
Water level
46419
46404
46407
46411
46041
46029
46050
46015
46022
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
8238
923
400km
200mi


ICCE
2018


WA
OR
CA
Oct 11, 2014
326 m

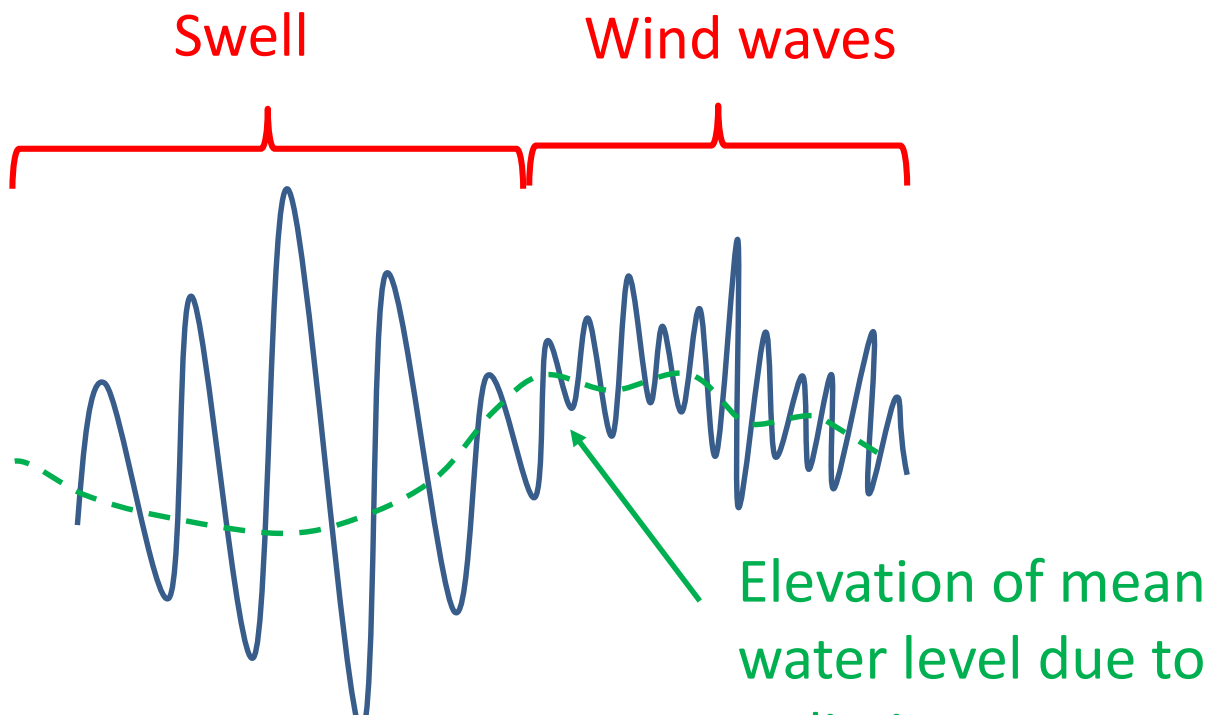
On generation mechanism

- Period of ~5 min suggests possible link to wave groups



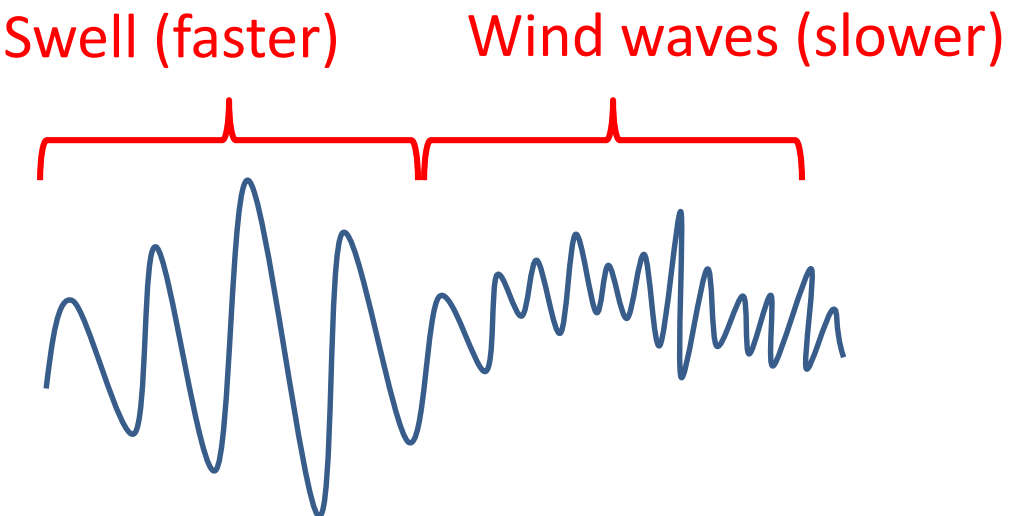
On generation mechanism

- Period of ~5 min suggests possible link to wave groups
- Possibly from large elevation of mean water level at the swell front due to radiation stress



On generation mechanism

- Period of ~5 min suggests possible link to wave groups
- Possibly from large elevation of mean water level at the swell front due to radiation stress
- Possibly from interaction of faster swells and slower wind waves over a large distance, analogous to bore-bore captures



Summary and Conclusions

- Several very large runup events were observed, captured on videos, and described in injury reports on January 16, 2016 along Washington, Oregon, and northern California.

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- These events were not caused by earthquakes and unlikely caused by meteotsunamis
- The timing of the initial events align with arrival of sharp swell fronts
- Water level changes at the coast corresponds with swell energy offshore

Thank you!

Questions/comments?

References

Monserrat, S., Vilibić, I., Rabinovich, A. B. 2006. Meteotsunamis: atmospherically induced destructive ocean waves in the tsunami frequency band. *Natural Hazards and Earth System Sciences*. 1035-1051

García-Medina, G., Özkan-Haller, H. T., Holman, R. A., Ruggiero, P. 2017. Large runup controls on gently sloping dissipative beach. *Journal of Geophysical Research: Oceans*. 10.1002/2017JC012862

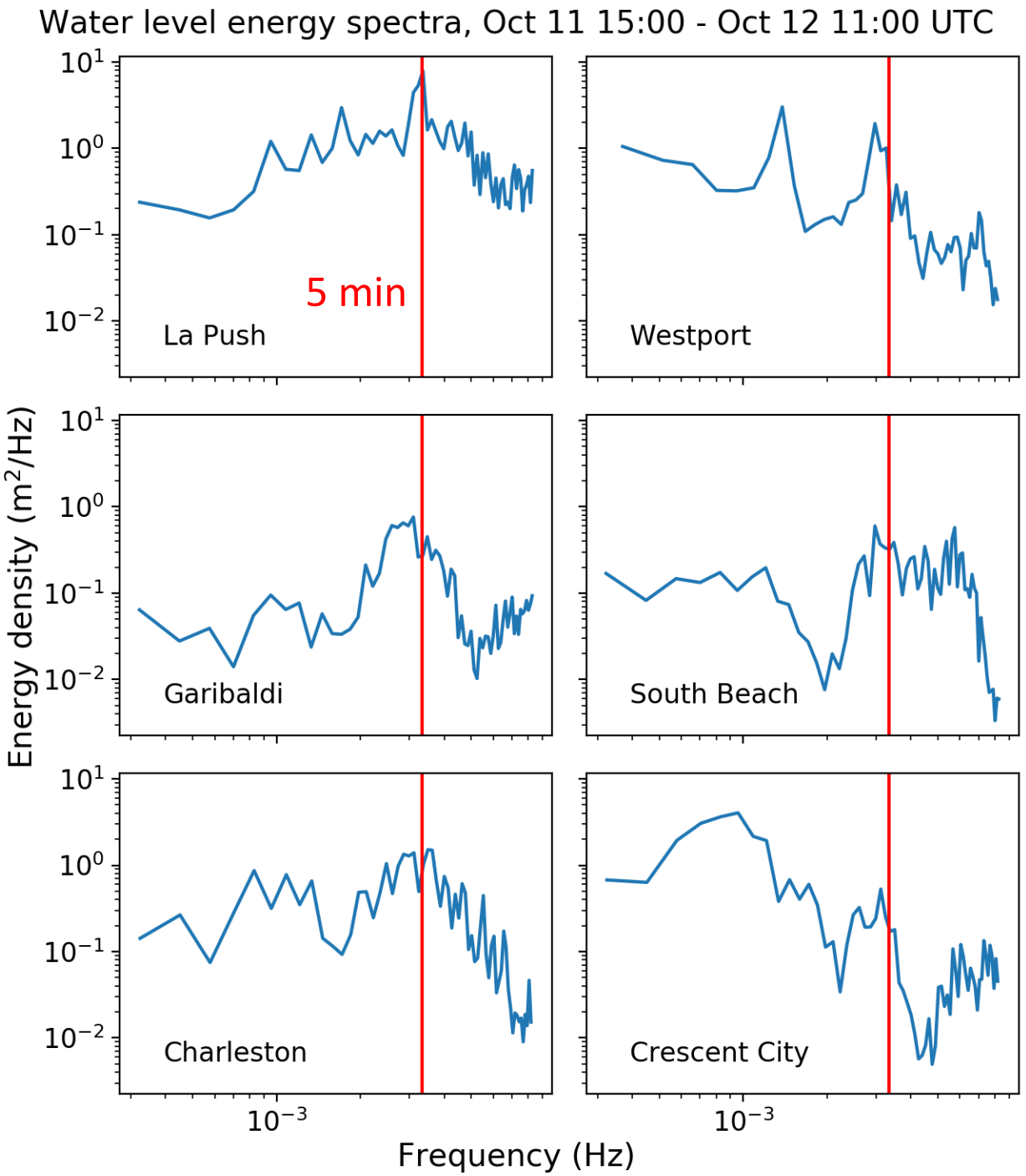
NOAA Tides and Currents: https://tidesandcurrents.noaa.gov/tide_predictions.html

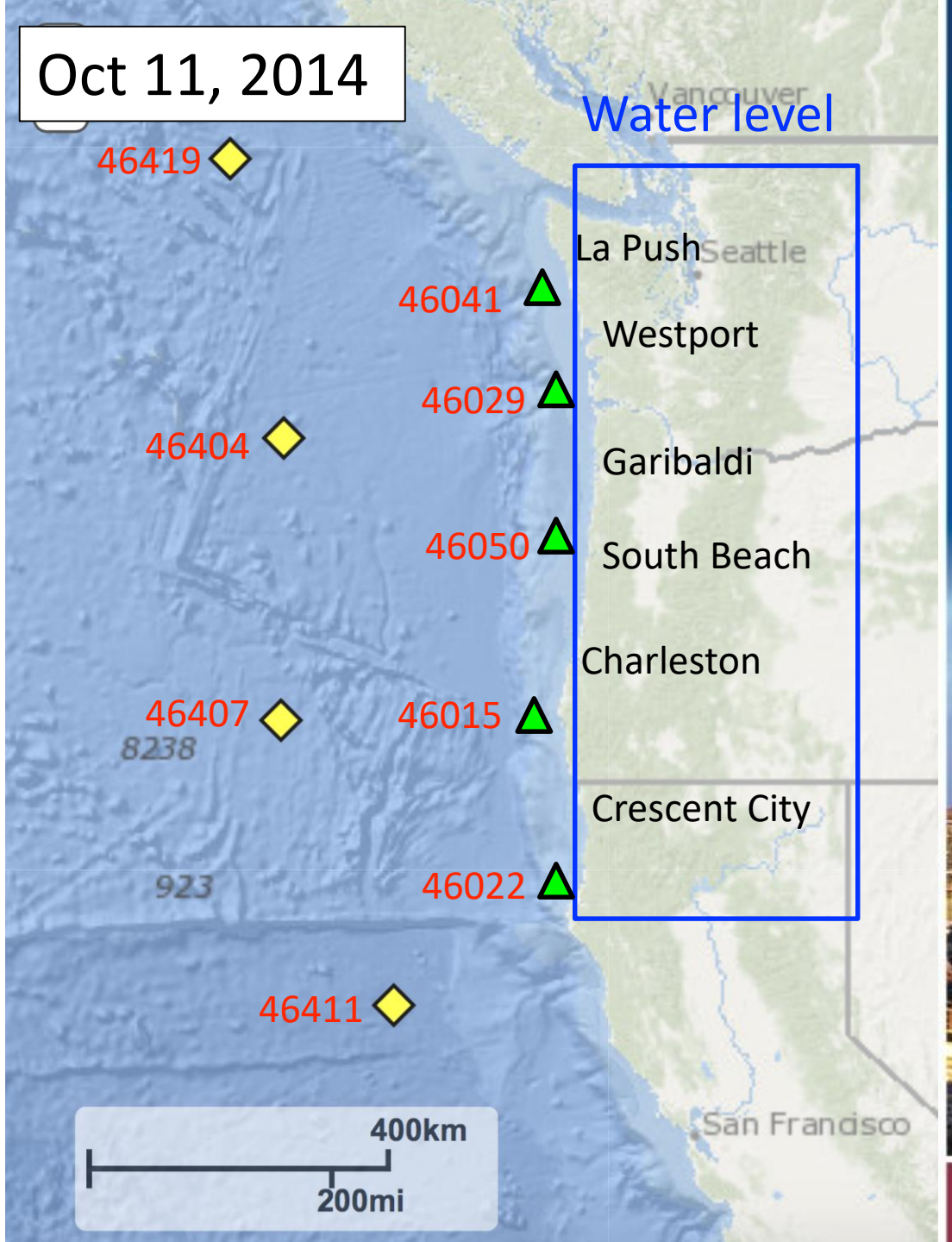
National Data Buoy Center: https://www.ndbc.noaa.gov

References

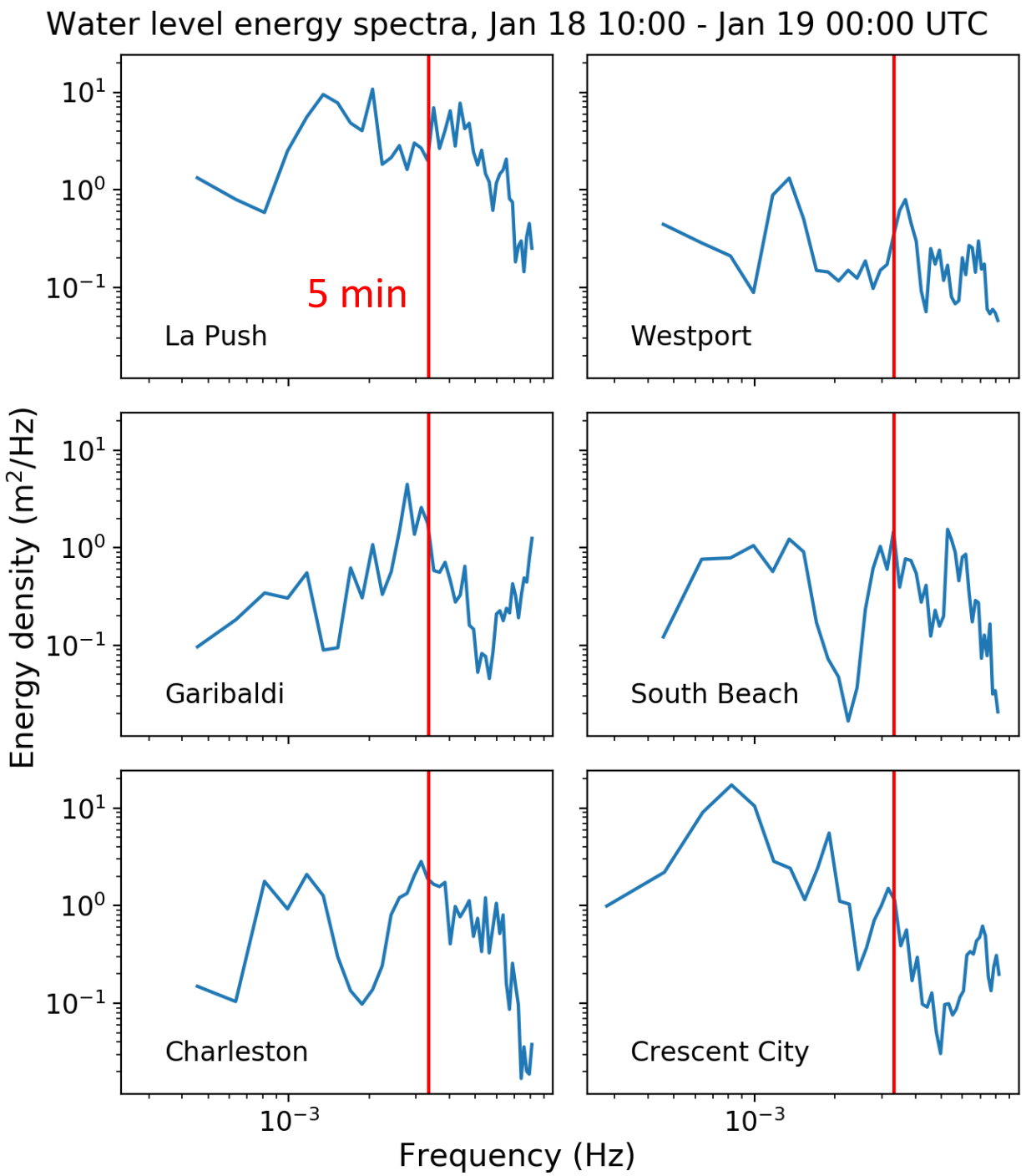
YouTube videos:

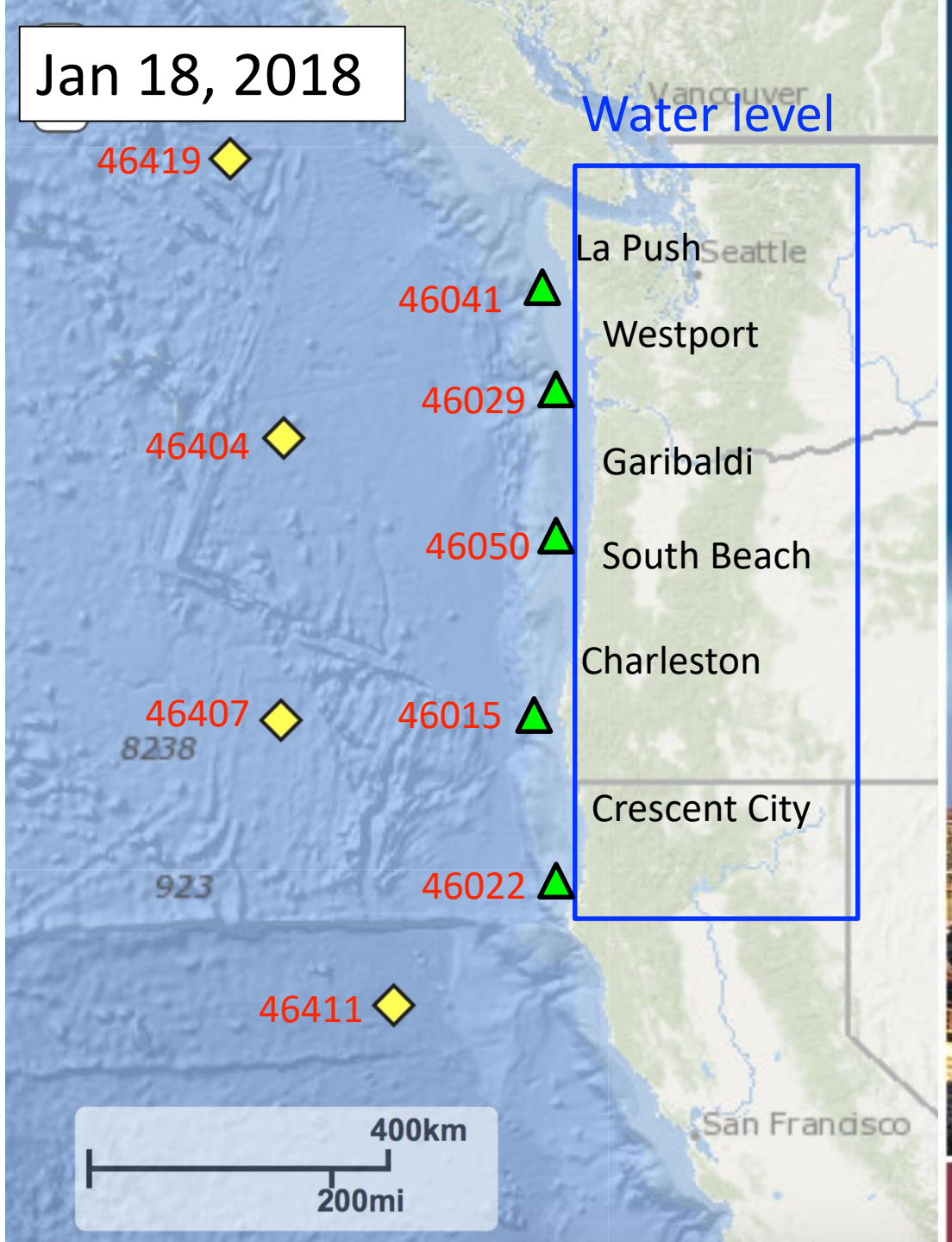
https://youtu.be/S6GJI6i6c1k
https://youtu.be/HSCCe1y6-b8
https://youtu.be/F0a_DDzEk-c
https://www.youtube.com/watch?v=RPypT9dOvSY
https://youtu.be/JMYLvSsWR_g
https://www.youtube.com/watch?v=IGSGNpfRFqQ
https://www.youtube.com/watch?v=87NlwSVnevI


Water level energy spectra, Oct 11 15:00 - Oct 12 11:00 UTC
5 min
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Energy density (m²/Hz)
Frequency (Hz)

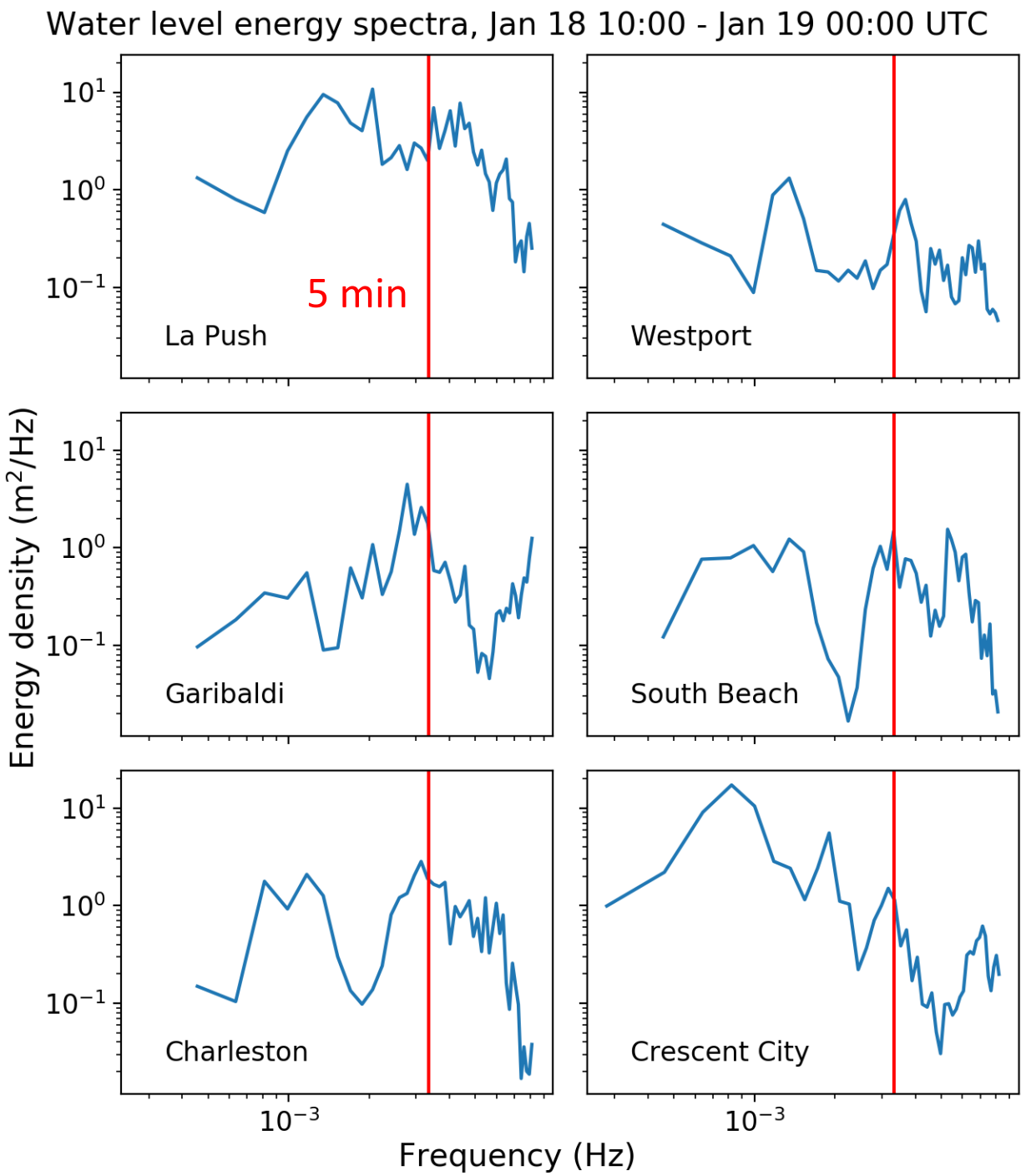

Oct 11, 2014
Water level
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
400km
200mi

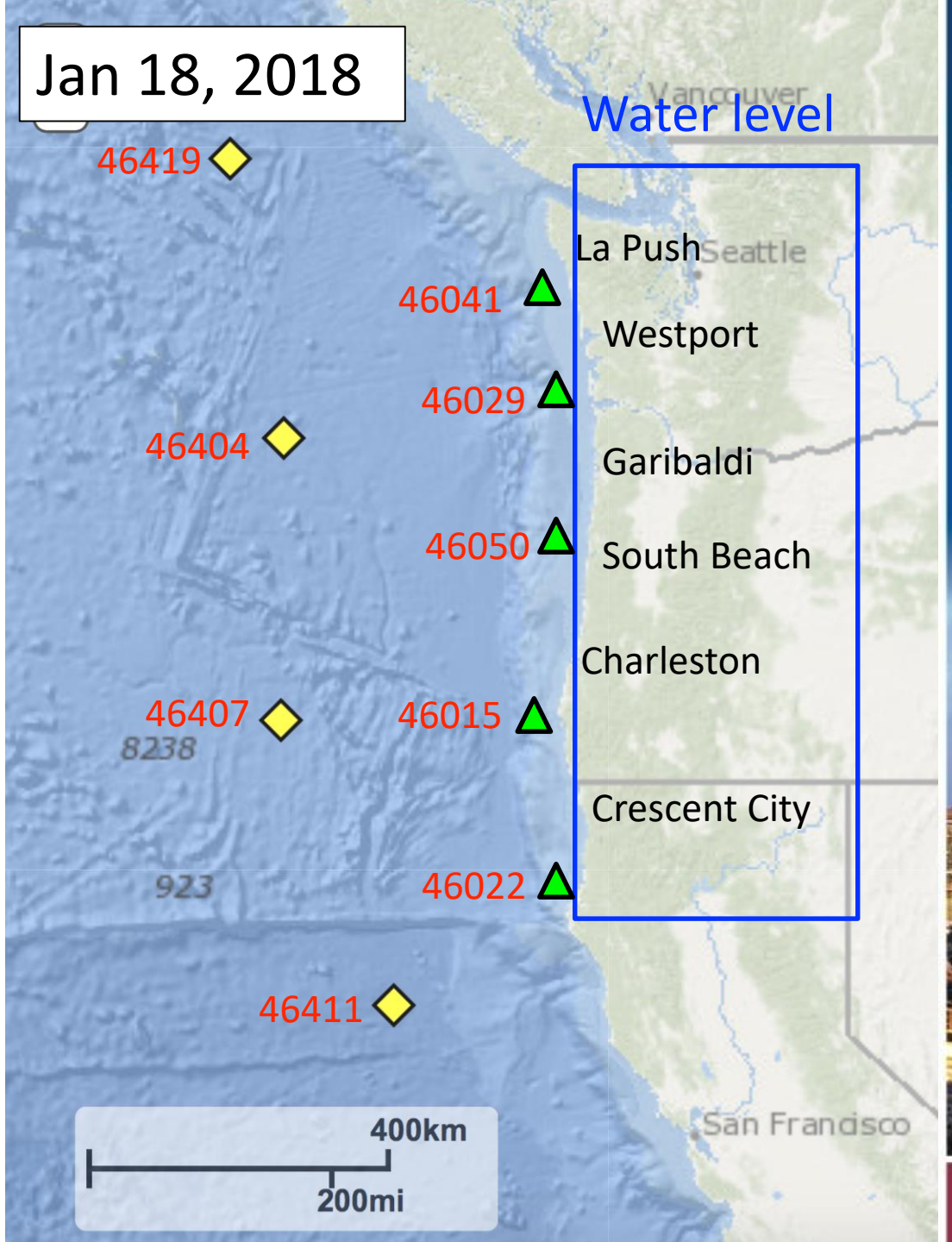

ICCE
2018


Water level energy spectra, Jan 18 10:00 - Jan 19 00:00 UTC
5 min
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Energy density (m²/Hz)
Frequency (Hz)

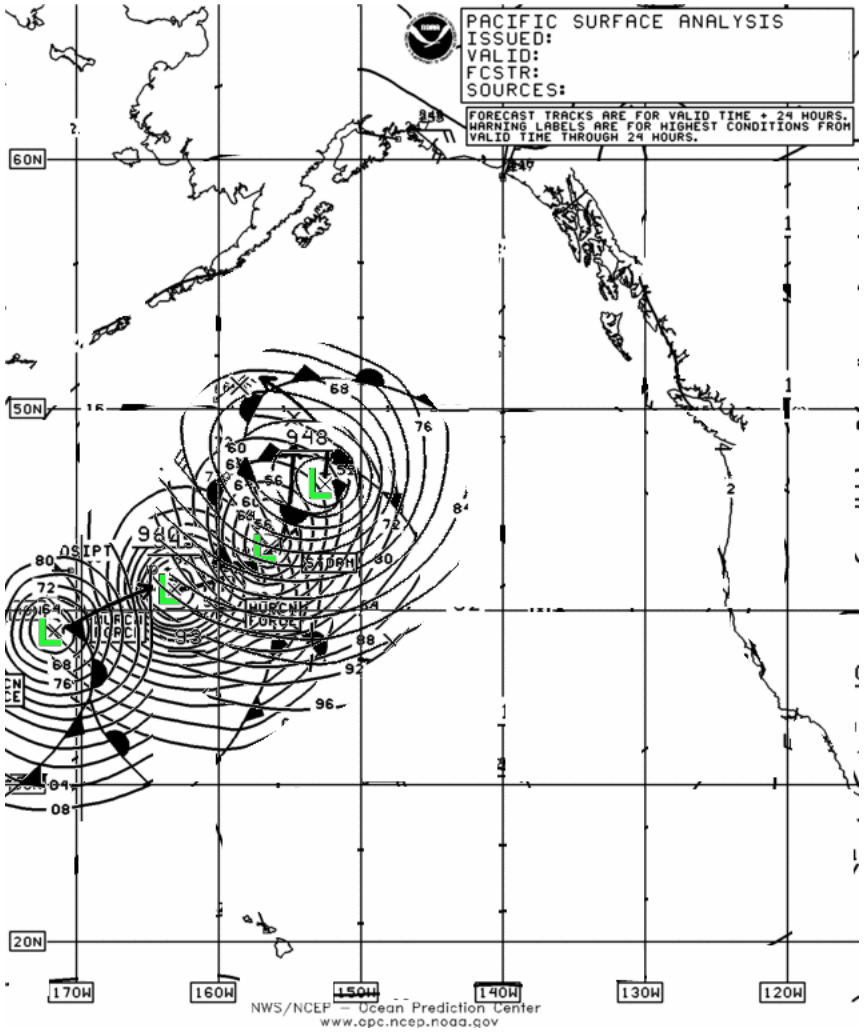

Jan 18, 2018
Water level
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
400km
200mi

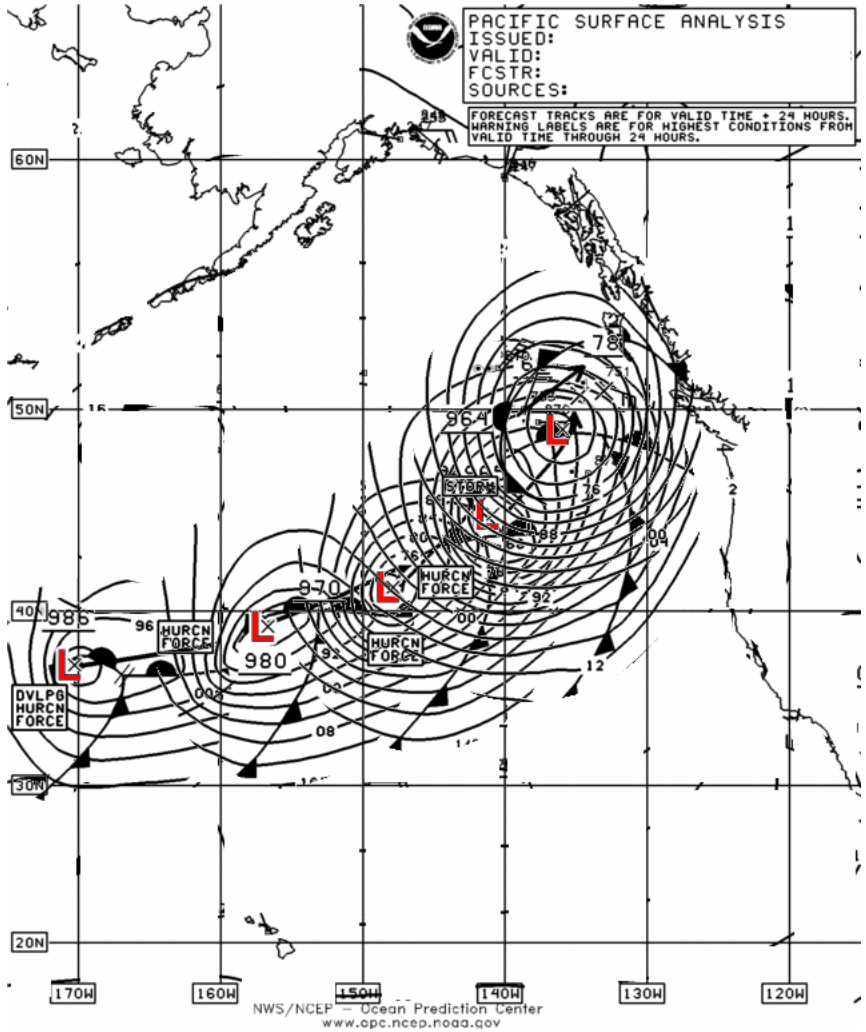

ICCE
2018


Water level energy spectra, Jan 18 10:00 - Jan 19 00:00 UTC
5 min
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Energy density (m²/Hz)
Frequency (Hz)


Jan 18, 2018
Water level
46419
46041
46029
46404
46050
46407
46015
46022
46411
La Push
Westport
Garibaldi
South Beach
Charleston
Crescent City
Vancouver
Seattle
San Francisco
400km
200mi


ICCE
2018


PACIFIC SURFACE ANALYSIS
ISSUED:
VALID:
FCSTR:
SOURCES:
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
60N
50N
40N
30N
20N
170W
160W
150W
140W
130W
120W
948
980
HURCN FORCE
NWS/NCEP – Ocean Prediction Center
www.opc.ncep.noaa.gov


PACIFIC SURFACE ANALYSIS
ISSUED:
VALID:
FCSTR:
SOURCES:
FORECAST TRACKS ARE FOR VALID TIME + 24 HOURS.
WARNING LABELS ARE FOR HIGHEST CONDITIONS FROM VALID TIME THROUGH 24 HOURS.
60N
50N
40N
30N
20N
170W
160W
150W
140W
130W
120W
964
STORM
970
985
980
HURCN FORCE
DVLPG HURCN FORCE
NWS/NCEP – Ocean Prediction Center
www.opc.ncep.noaa.gov

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