Analyzing and combining directional wave spectra retrieved from in-situ and remote sensors.

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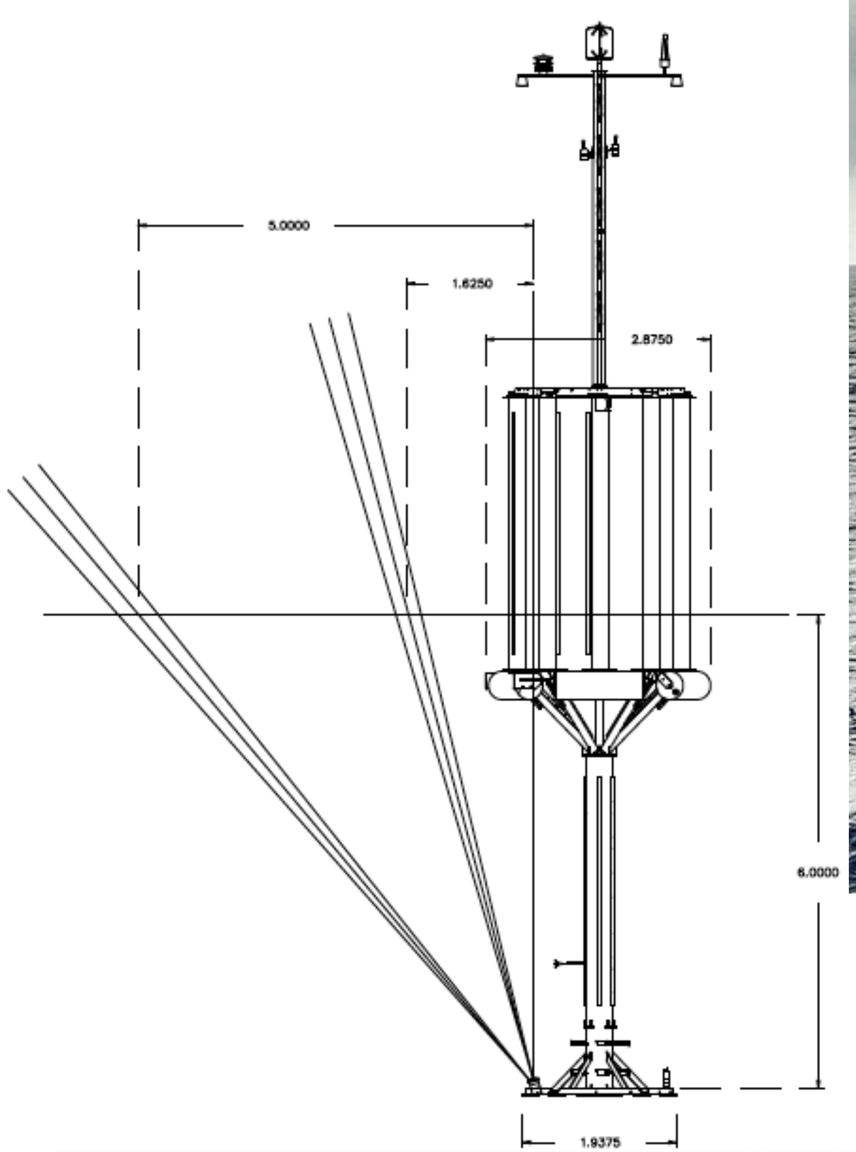
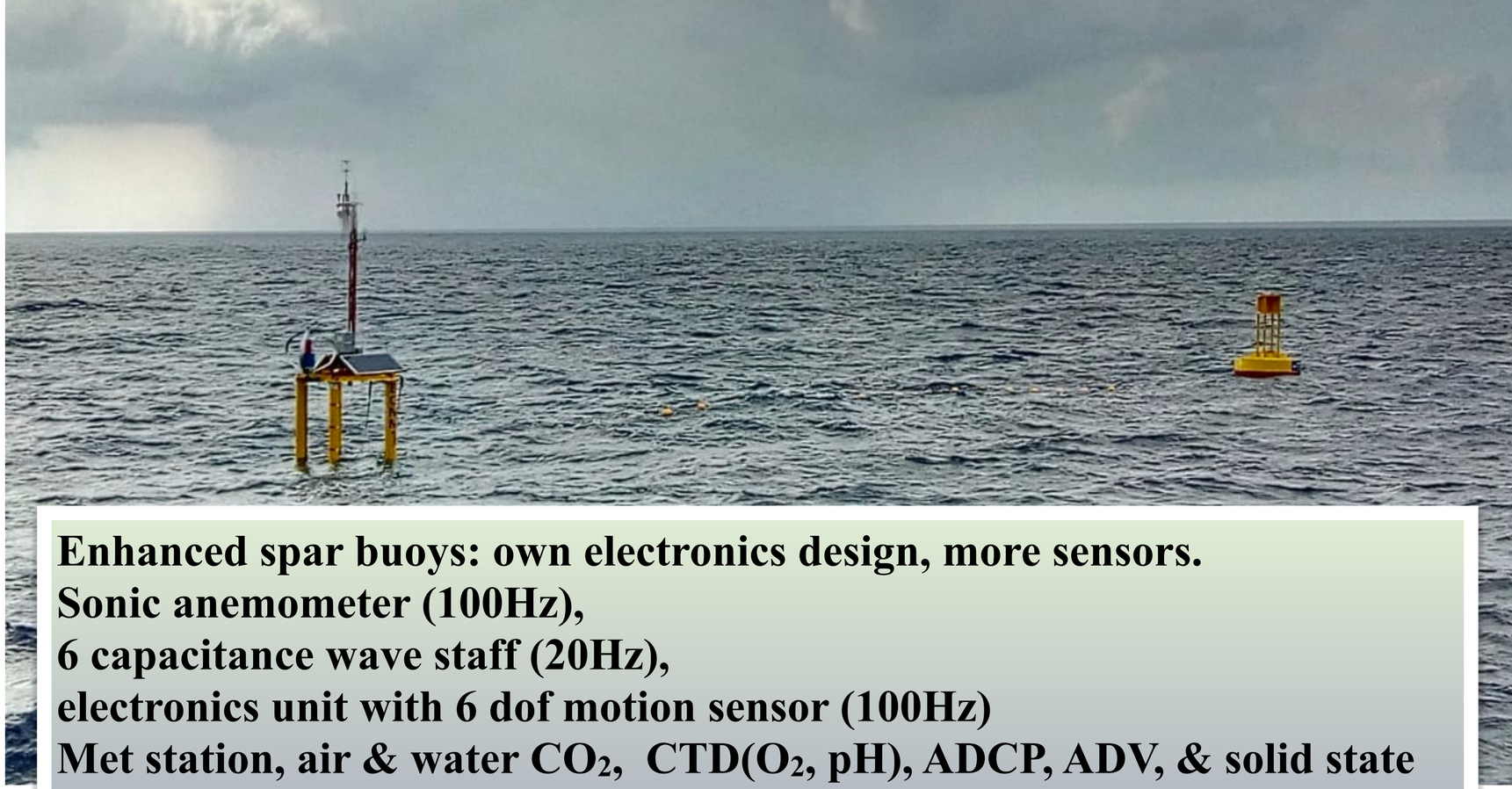
4th Workshop on Waves, Storm Surges and Coastal Hazards, Incorporating the 18th International Waves Workshop, September 22-26, 2025, Santander, Spain





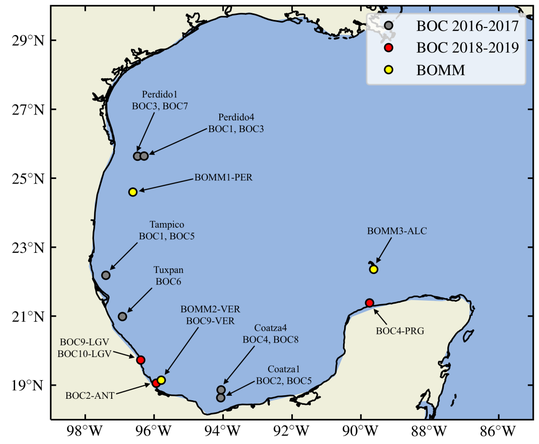
Enhanced spar buoys: own electronics design, more sensors.
Sonic anemometer (100Hz),
6 capacitance wave staff (20Hz),
electronics unit with 6 dof motion sensor (100Hz)
Met station, air & water CO_2, CTD(O_2, pH), ADCP, ADV, & solid state drives, rechargeable batteries, wind generator and solar panels [LiCor CO_2 sensor, 2 video cameras: still under plan].
Simultaneous measurements are really needed.

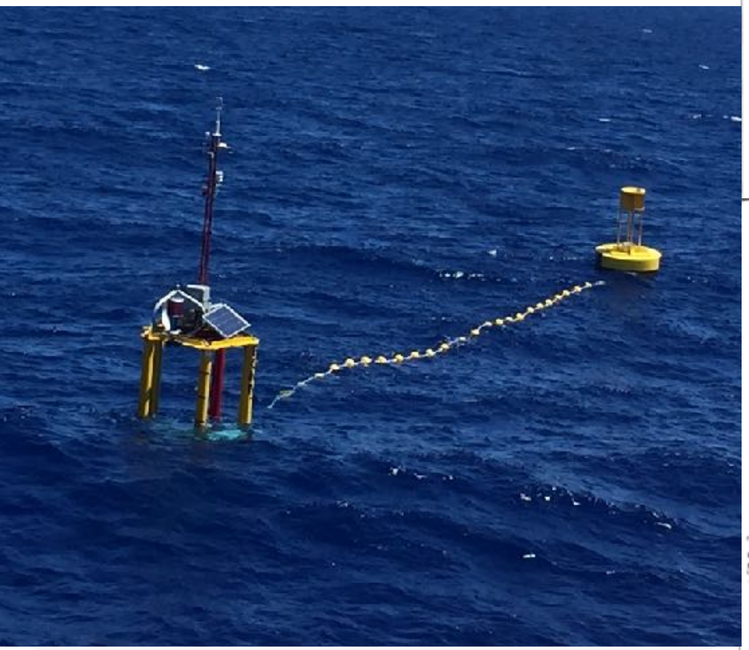
Graber, Terray, Donelan, Drennan, Leer, Peters (2000). ASIS a new air-sea interaction spar buoy: design and performance at sea, JAOT.

Ocampo-Torres et al., (2011). The INTOA Experiment: A study of ocean-atmosphere interactions under moderate to strong offshore winds and opposing swell conditions, in the Gulf of Tehuantepec, Mexico. Boundary-Layer Meteorol.

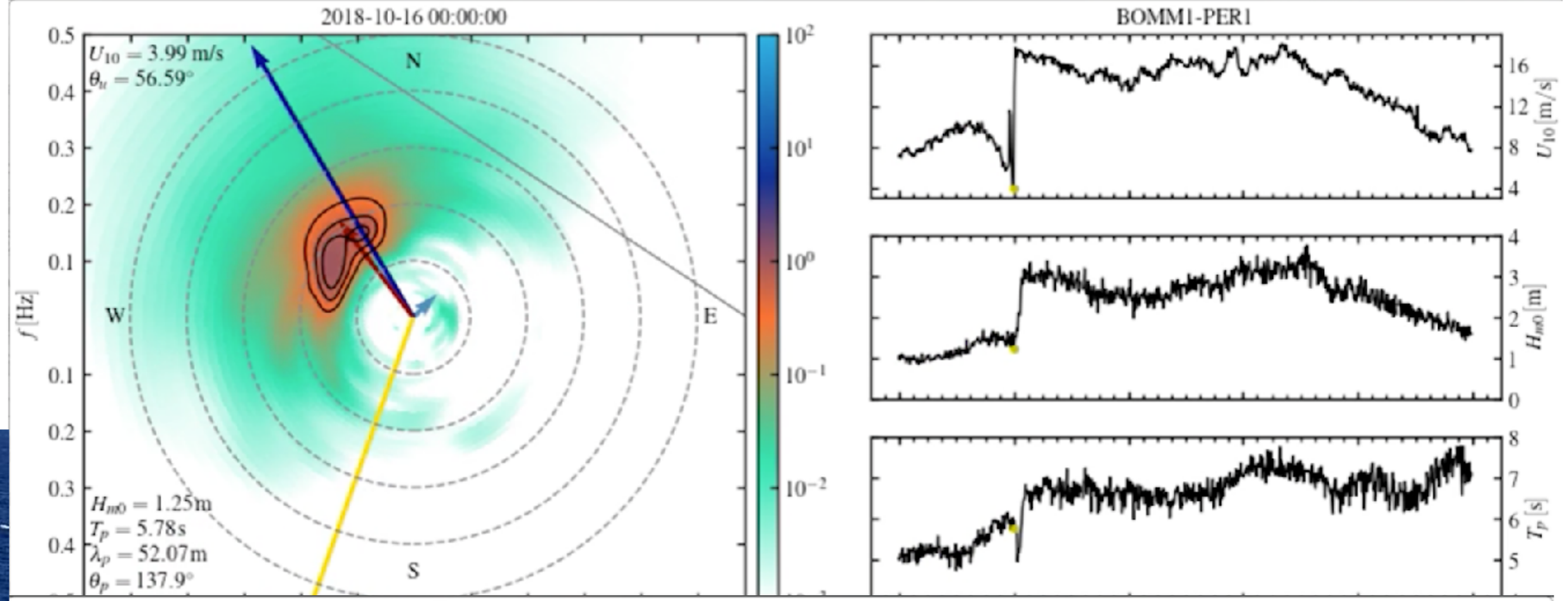
Collins III, Lund, Ramos, Drennan, Graber (2014). Wave measurement intercomparison and platform evaluation during the ITOP (2010) Experiment, JAOT.

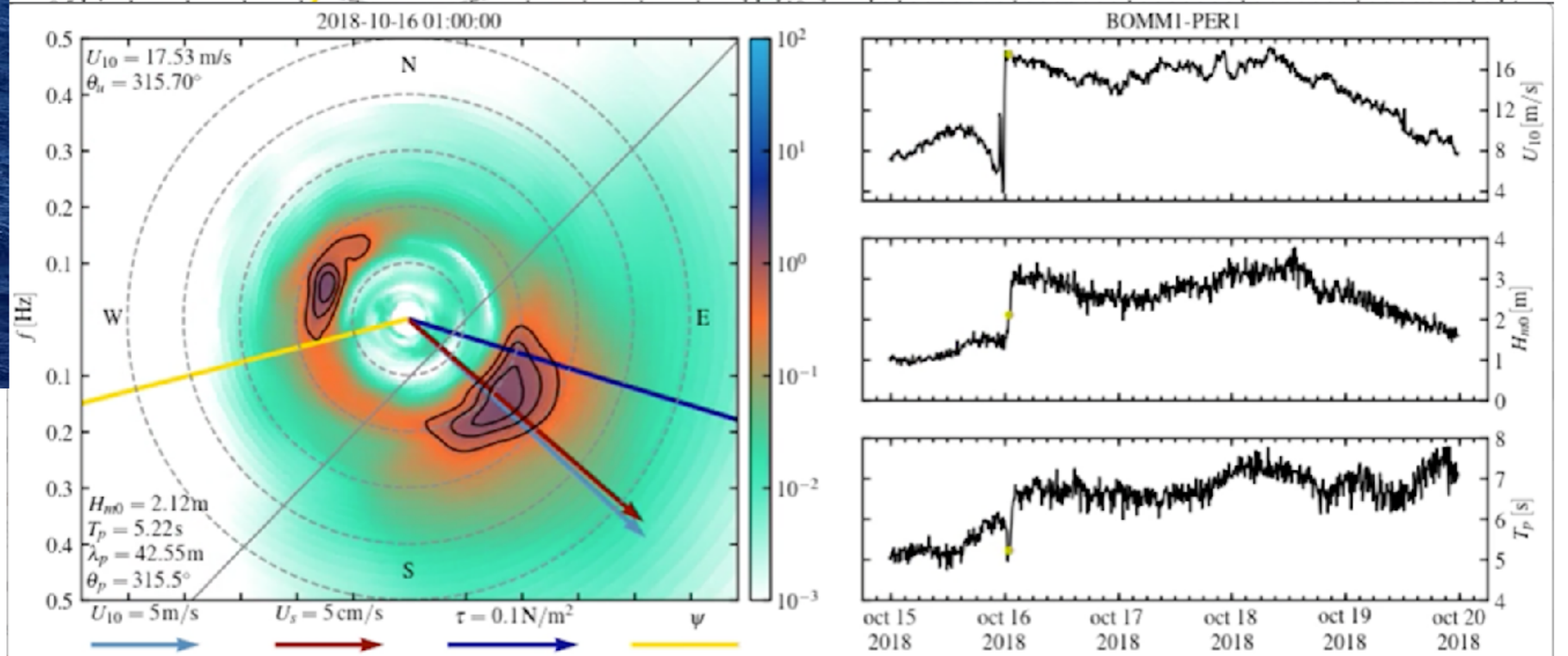
Drennan, Graber, Collins III, Herrera, Potter, Ramos, Williamns (2014). EASI: An Air–Sea Interaction Buoy for high winds, JAOT.



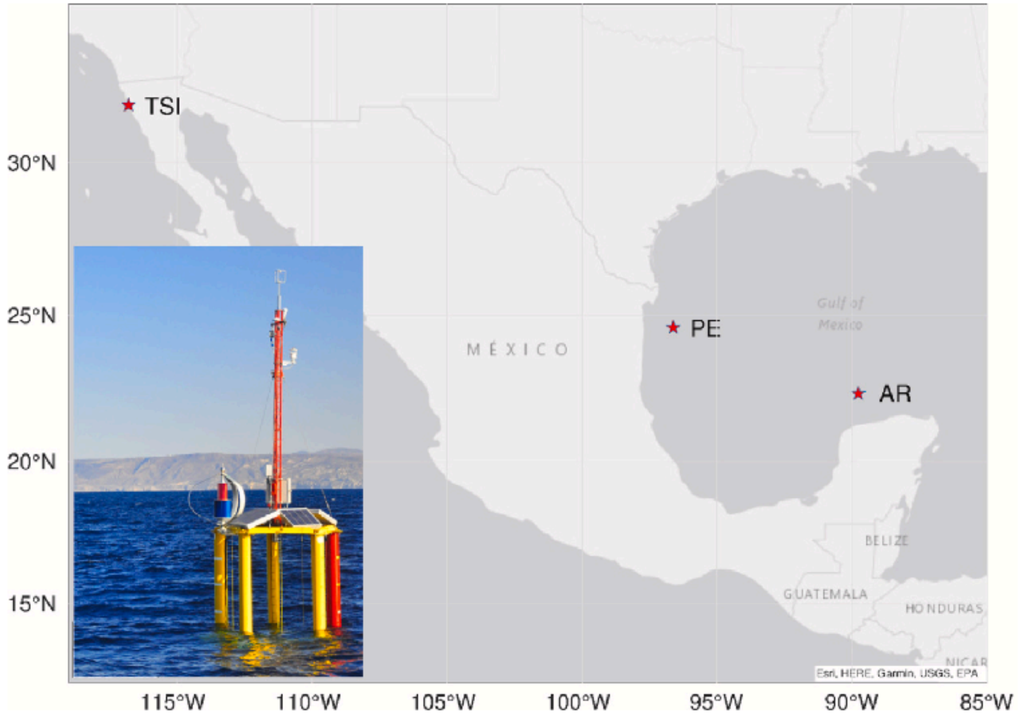


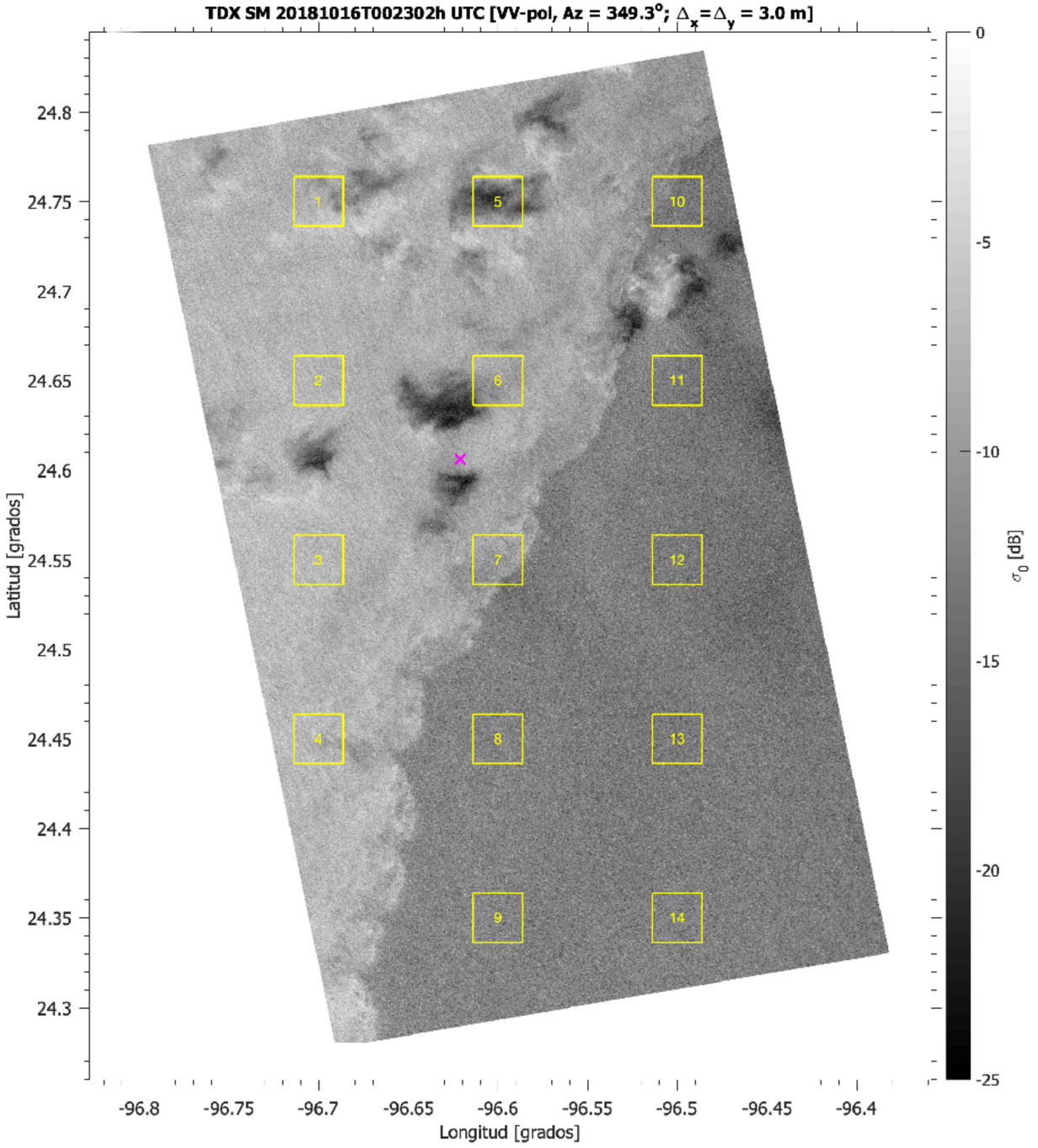
Donelan, Drennan and Magnuson, 1996. Non stationary analysis of the directional properties of propagating waves. JPO.





CIGoM
Consorcio de Investigación del Golfo de México





CIGoM
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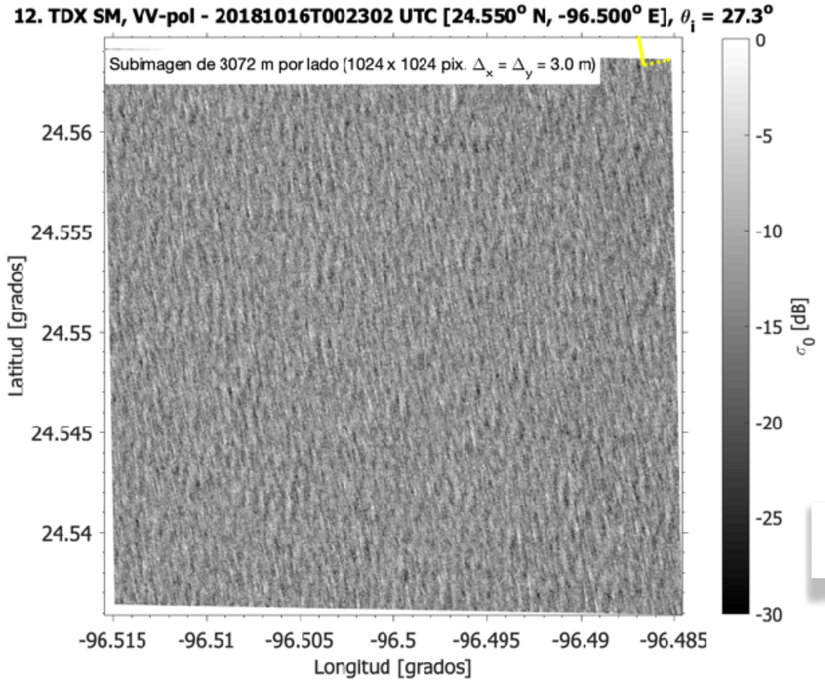
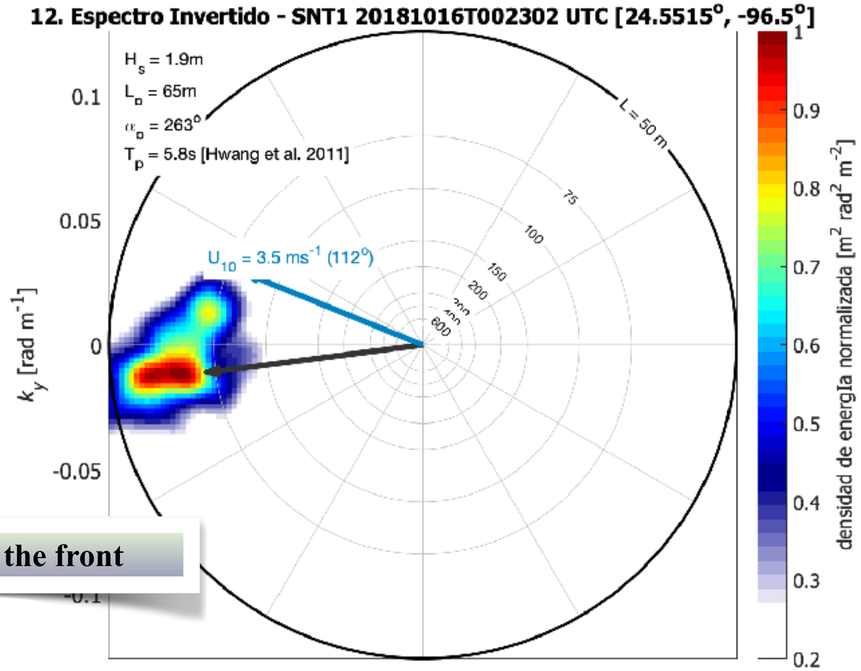
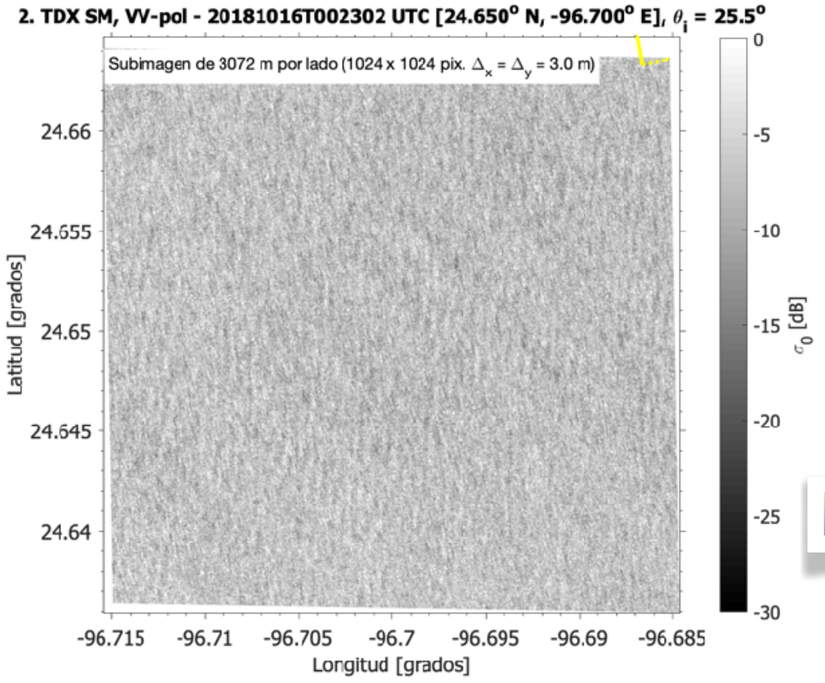
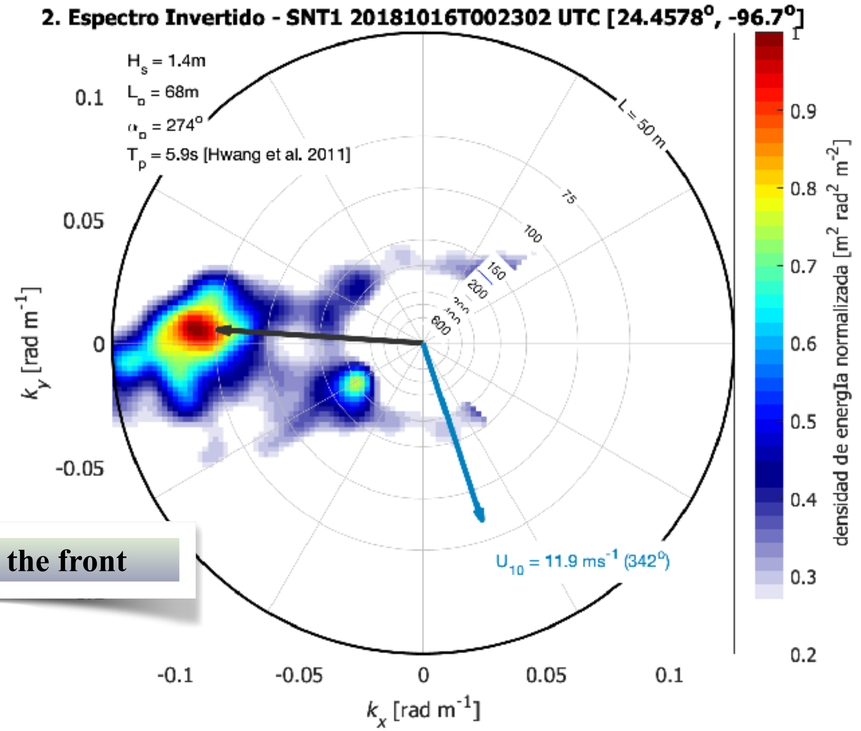




Eastward from the front





Westward from the front

Preliminary version of wave spectrum (Lai, D. Y. and D. P. Delisi, 2010).

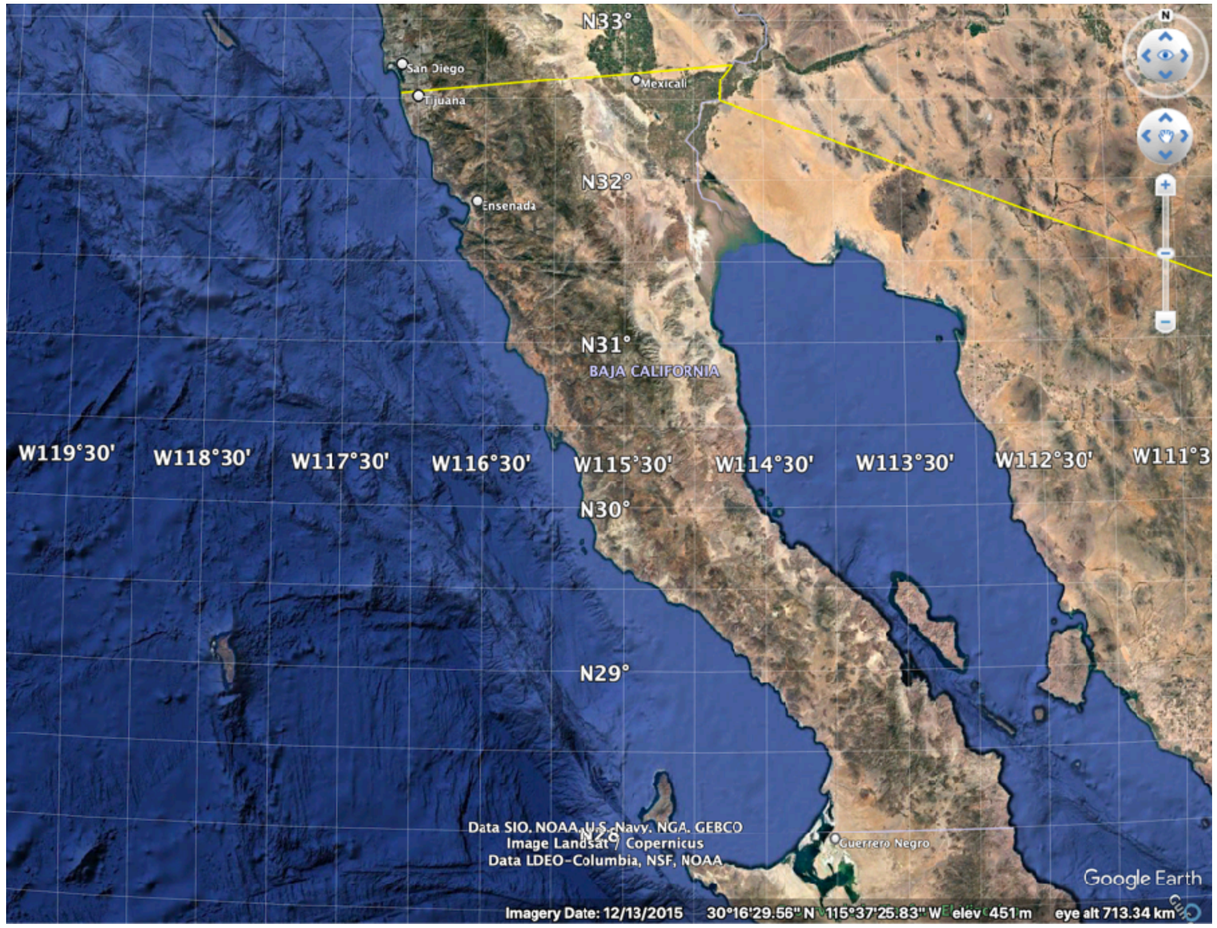
Investing further efforts to estimate the wave spectrum from the inversion of the image spectrum.
****Developing new code to be useful under various image modes and microwave frequencies.**
Adopting method proposed by Vachon et al. (1994) y Krogstad et al. (1994).

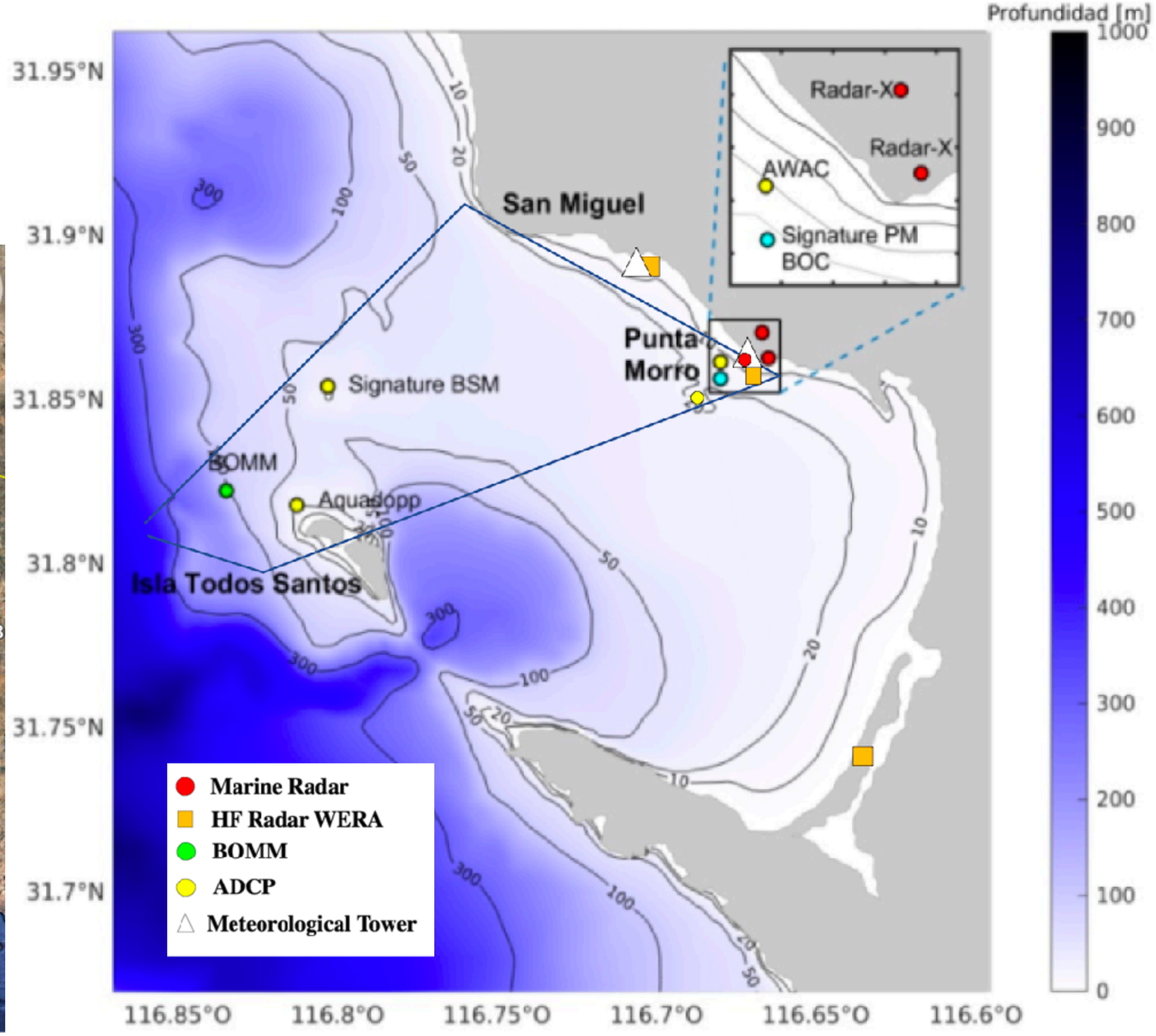
Dealing with SAR images limitations.
SAR image degraded quality associated to the reflectors motion induced by wave orbital velocities.
Azimuthal cut-off in image spectrum.

****Comparisons with wave spectrum from BOMM1.**

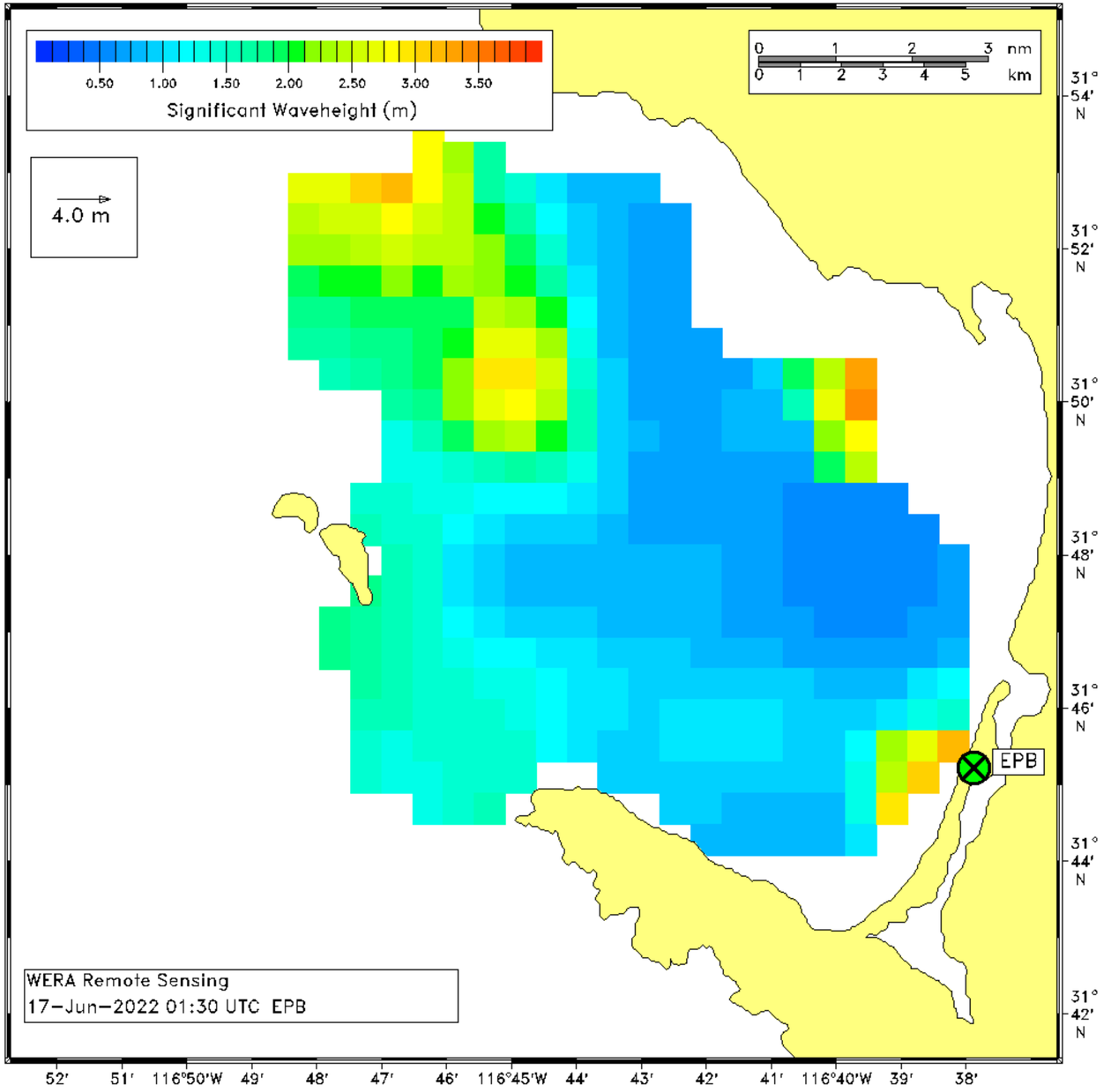
Natural Laboratory BTS

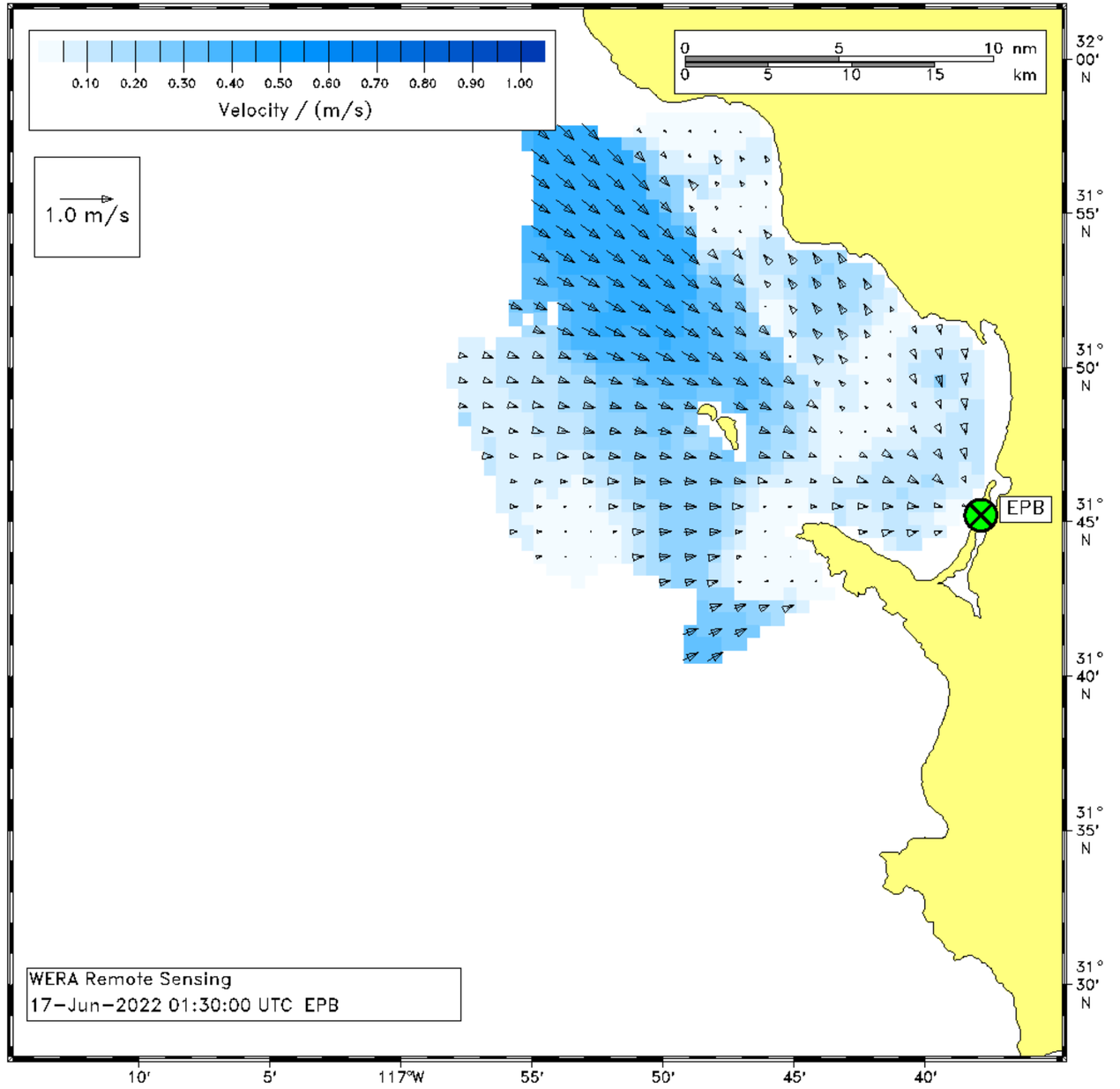
Direct Measurements (in-situ) and with Remote Sensors: Radar (Coastal and Satellite-borne).



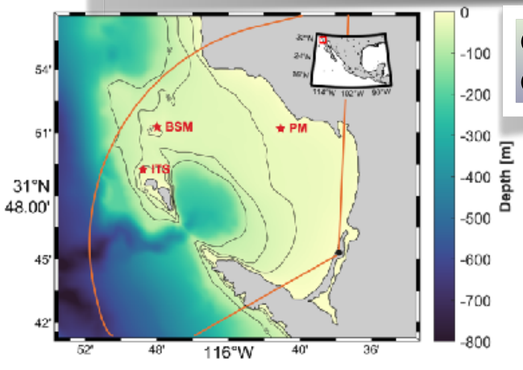


Natural Laboratory BTS: HF Radar (WERA) at EPB, Hs & Surface Currents

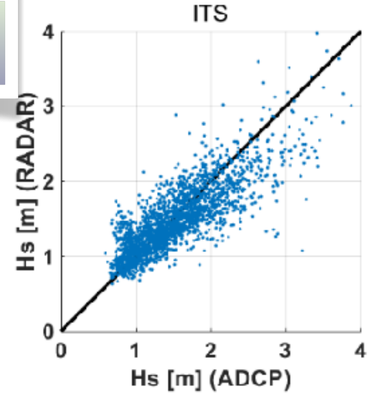


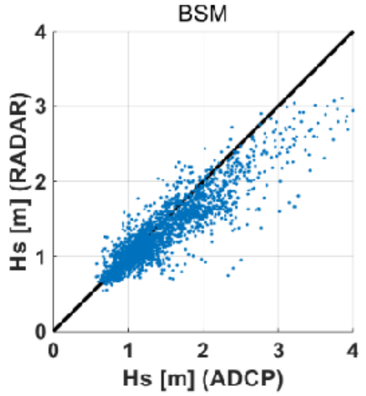


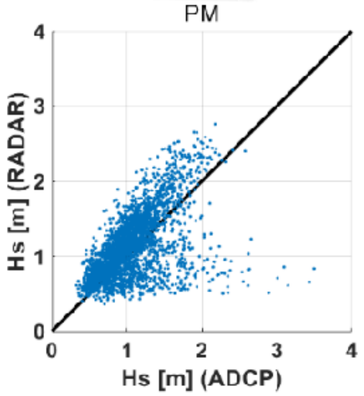
Natural Laboratory BTS: HF Radar (WERA) at EPB, Hs & Surface Currents

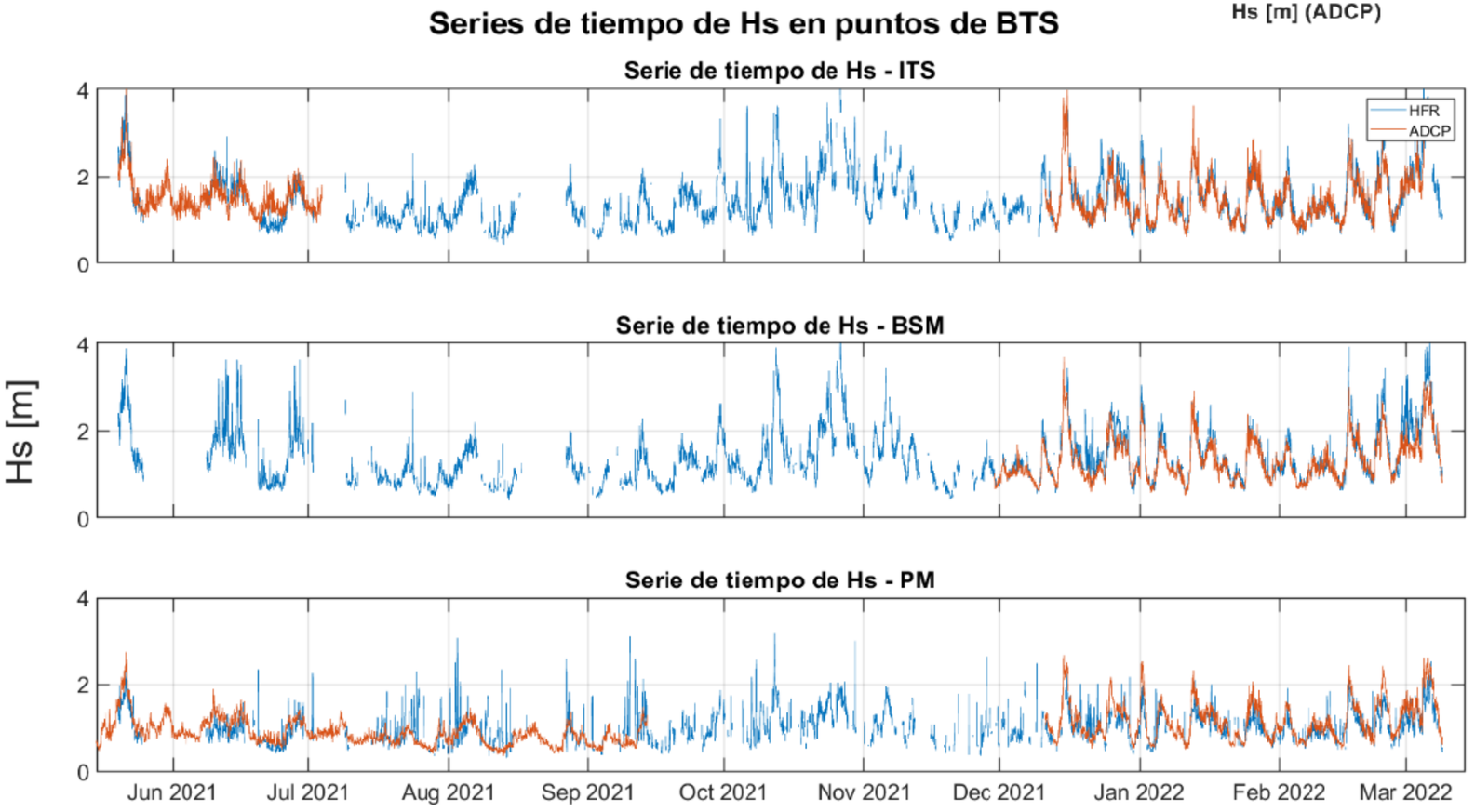


Guevara Aguirre, J. C. (2023), M.Sc. Thesis
Coastal Oceanography, FCM, IIO, UABC



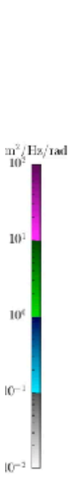


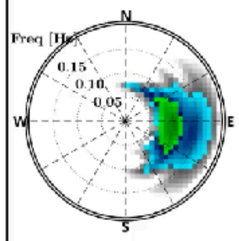




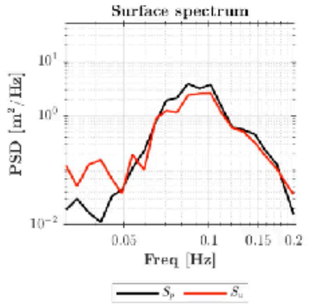
Efforts towards
***Estimation of frequency spectrum.**
****Directional wave spectrum.**

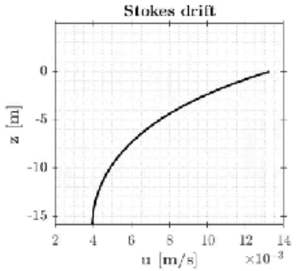
Based upon: Hashimoto N, M. Tokuda (1999). A Bayesian approach for estimating directional spectra with HF radar. Coast. Eng. 41: 137–149.





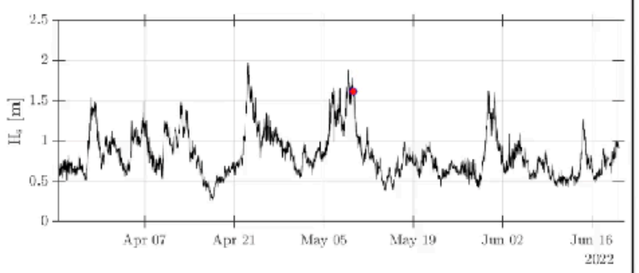
Bajo San Miguel (BSM)

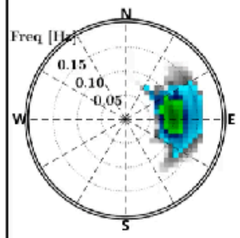




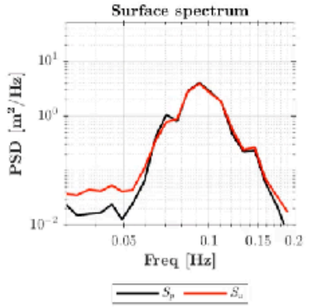
Wave Parameters

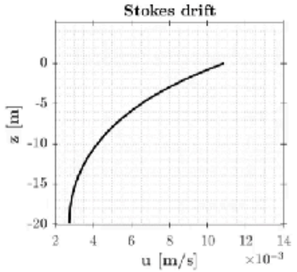
$H_s^p = 1.62$ m $\quad H_s^u = 1.38$ m
$f_p^p = 0.08$ Hz $\quad f_p^u = 0.10$ Hz
$f_m^p = 0.10$ Hz $\quad f_m^u = 0.10$ Hz
$\bar{\theta} = 96°$ $\quad \theta_p = 94°$ $\quad \bar{\sigma} = 21°$
$u_{s0} = 0.10$ m/s





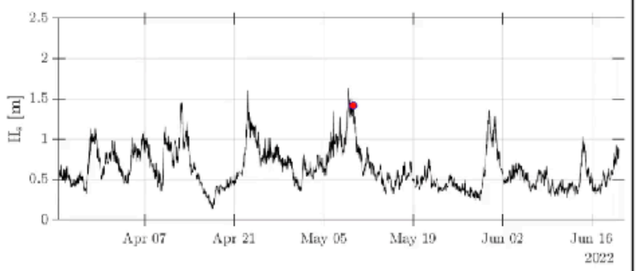
Punta Morro (PM)

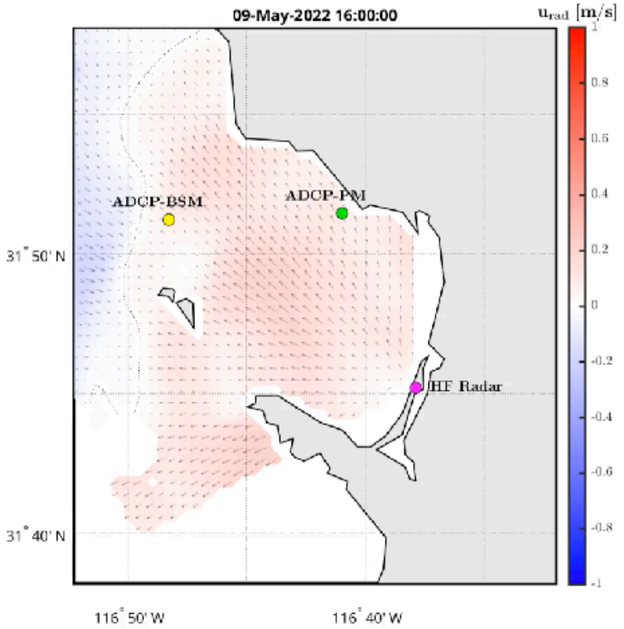




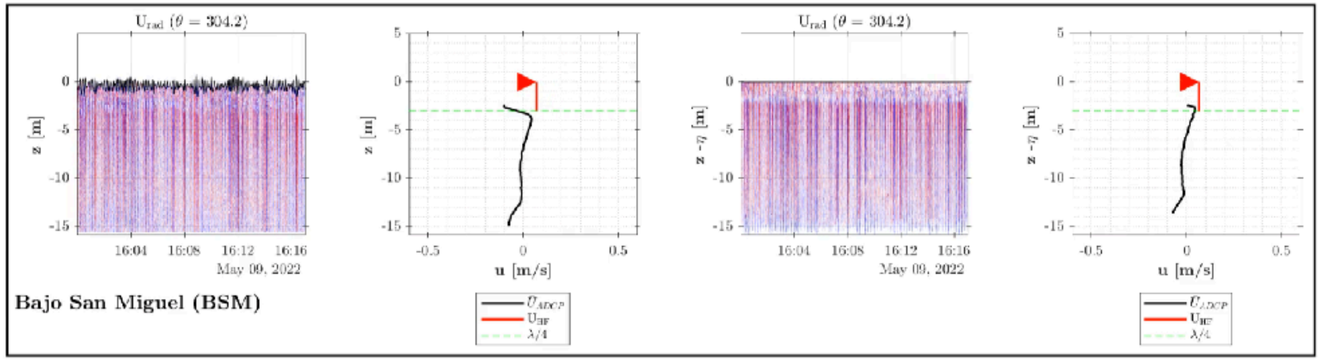
Wave Parameters

$H_s^p = 1.42$ m $\quad H_s^u = 1.41$ m
$f_p^p = 0.09$ Hz $\quad f_p^u = 0.09$ Hz
$f_m^p = 0.10$ Hz $\quad f_m^u = 0.10$ Hz
$\bar{\theta} = 88°$ $\quad \theta_p = 88°$ $\quad \bar{\sigma} = 13°$
$u_{s0} = 0.10$ m/s

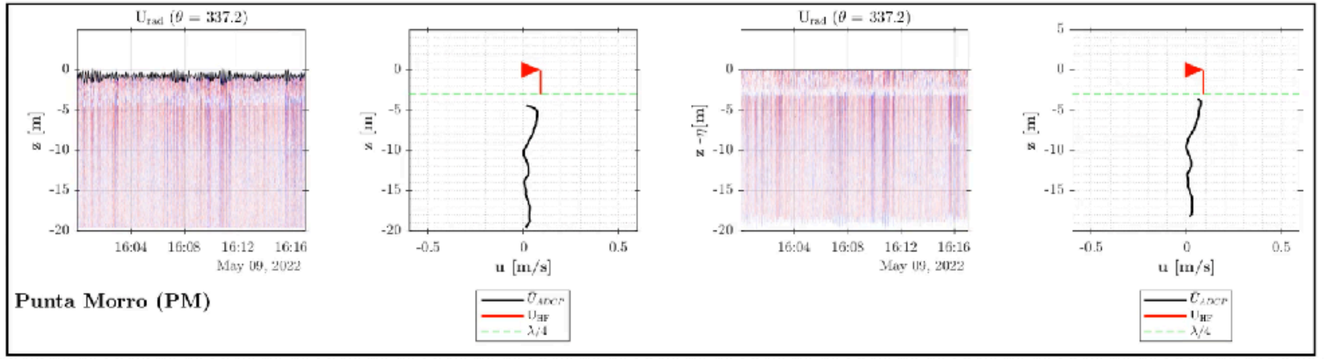




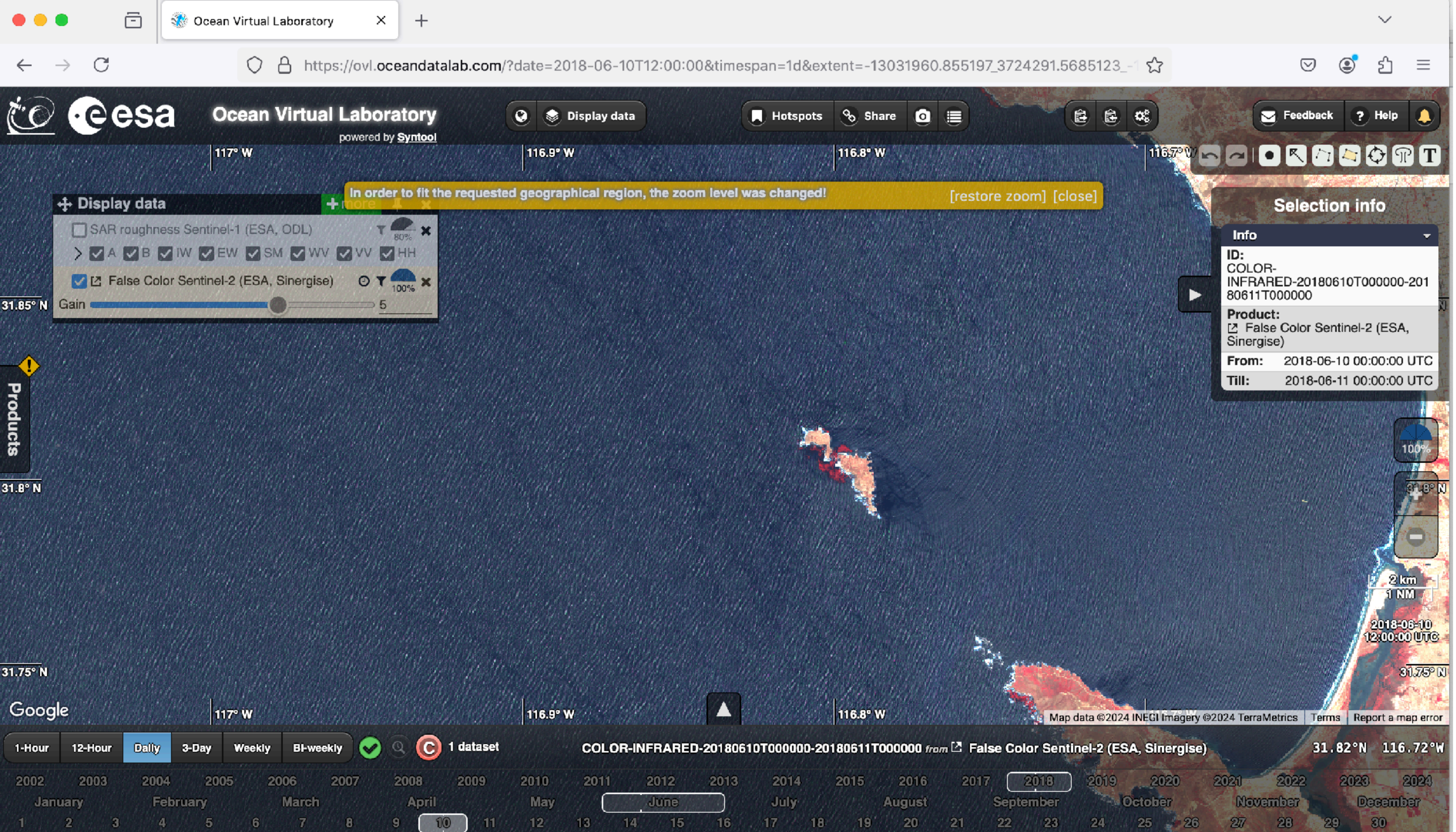
HF Radar (freq: 25 MHz, $\lambda = 11.99$ m)

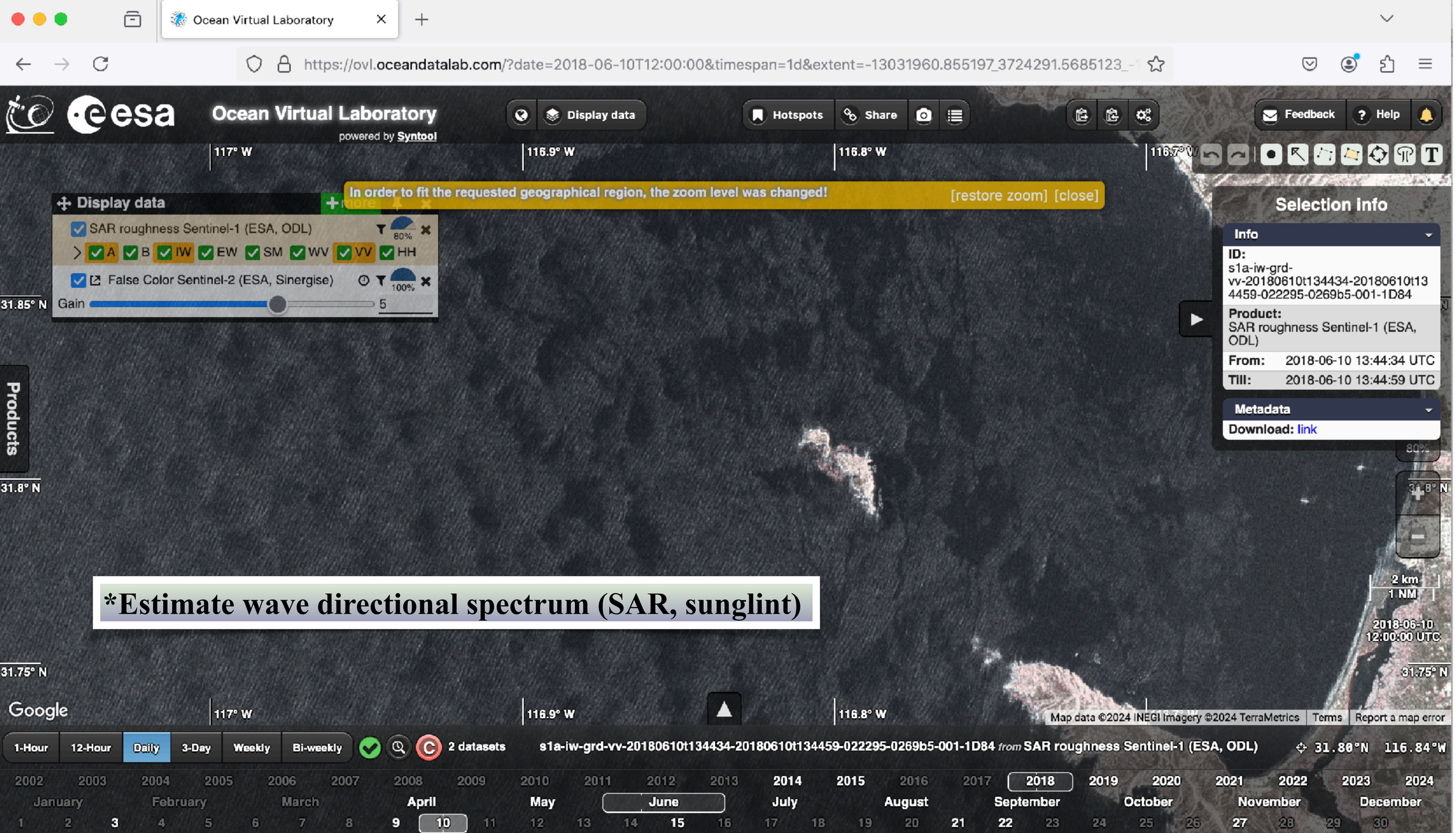


Bajo San Miguel (BSM)



Punta Morro (PM)


Ocean Virtual Laboratory
https://ovl.oceandatalab.com/?date=2018-06-10T12:00:00&timespan=1d&extent=-13031960.855197_3724291.5685123_
esa
Ocean Virtual Laboratory
powered by Syntool
Display data
Hotspots
Share
Feedback
Help
117° W
116.9° W
116.8° W
116.7° W
In order to fit the requested geographical region, the zoom level was changed!
[restore zoom] [close]
Display data
more
SAR roughness Sentinel-1 (ESA, ODL)
80%
A B IW EW SM WV VV HH
False Color Sentinel-2 (ESA, Sinergise)
100%
Gain
5
Selection info
Info
ID:
COLOR-INFRARED-20180610T000000-20180611T000000
Product:
False Color Sentinel-2 (ESA, Sinergise)
From: 2018-06-10 00:00:00 UTC
Till: 2018-06-11 00:00:00 UTC
Products
31.85° N
31.8° N
31.75° N
2 km
1 NM
2018-06-10
12:00:00 UTC
Google
Map data ©2024 INEGI Imagery ©2024 TerraMetrics
Terms
Report a map error
1-Hour
12-Hour
Daily
3-Day
Weekly
Bi-weekly
1 dataset
COLOR-INFRARED-20180610T000000-20180611T000000 from False Color Sentinel-2 (ESA, Sinergise)
31.82°N 116.72°W
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
January February March April May June July August September October November December
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Ocean Virtual Laboratory
https://ovl.oceandatalab.com/?date=2018-06-10T12:00:00&timespan=1d&extent=-13031960.855197_3724291.5685123_
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117° W
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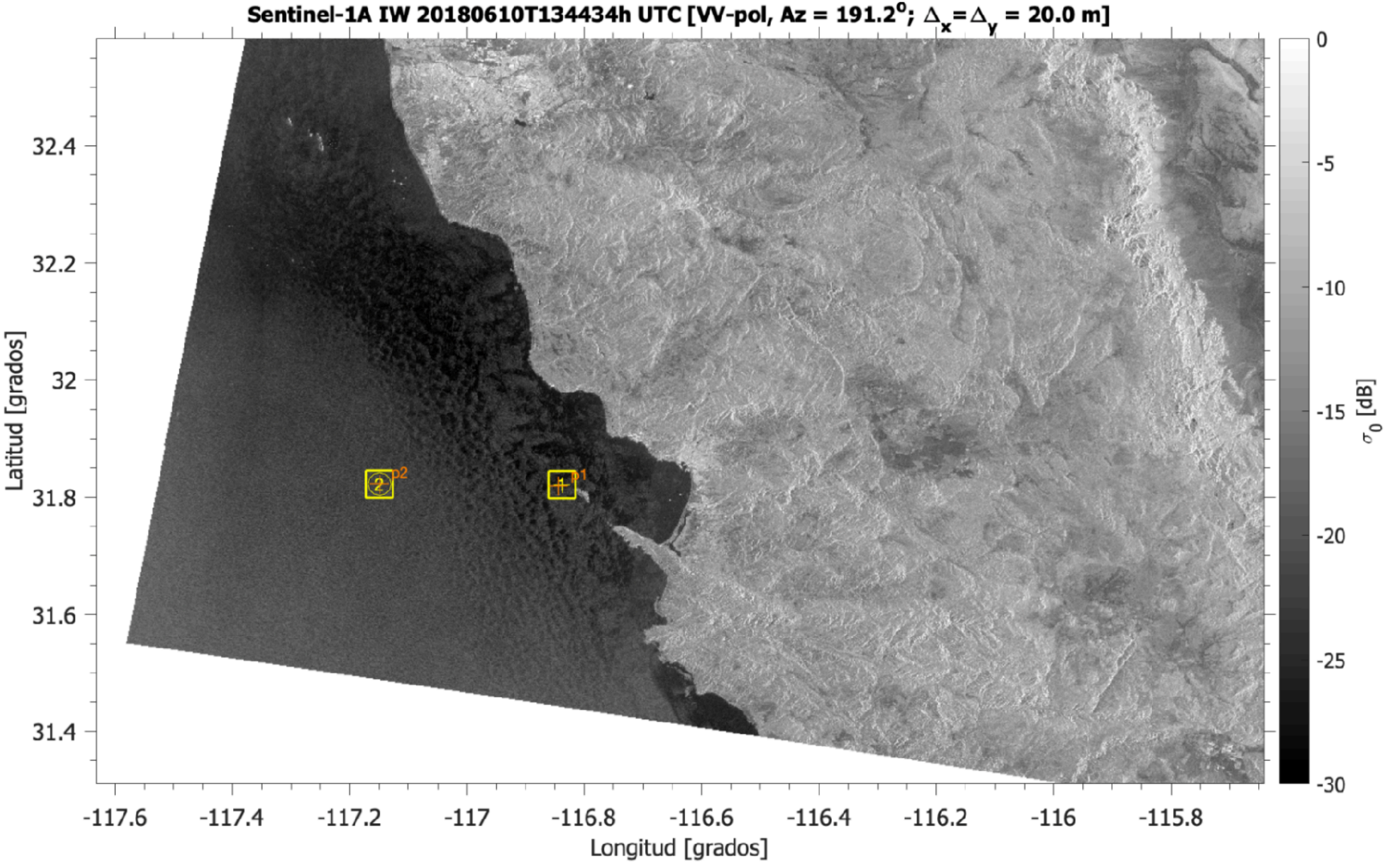
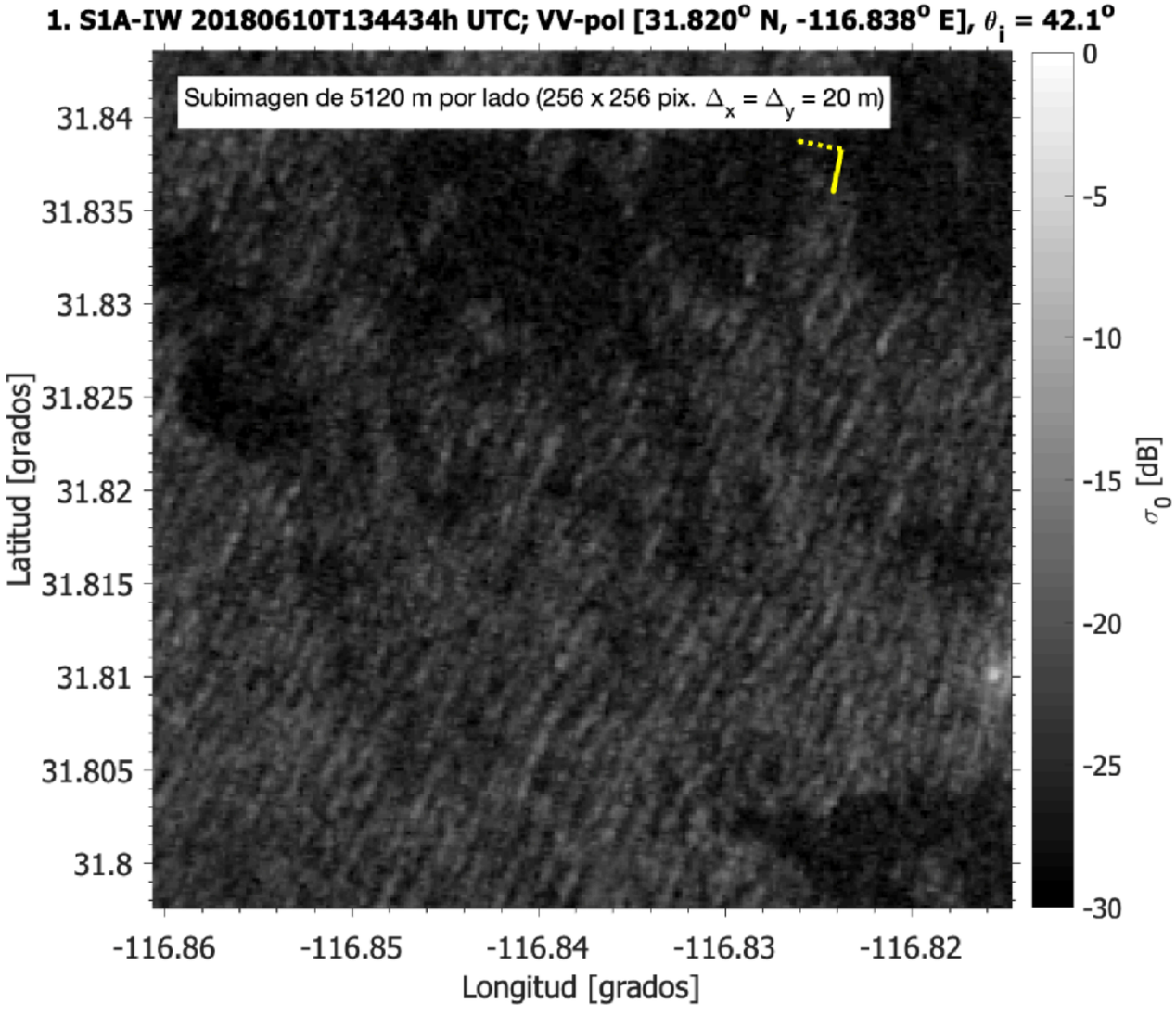
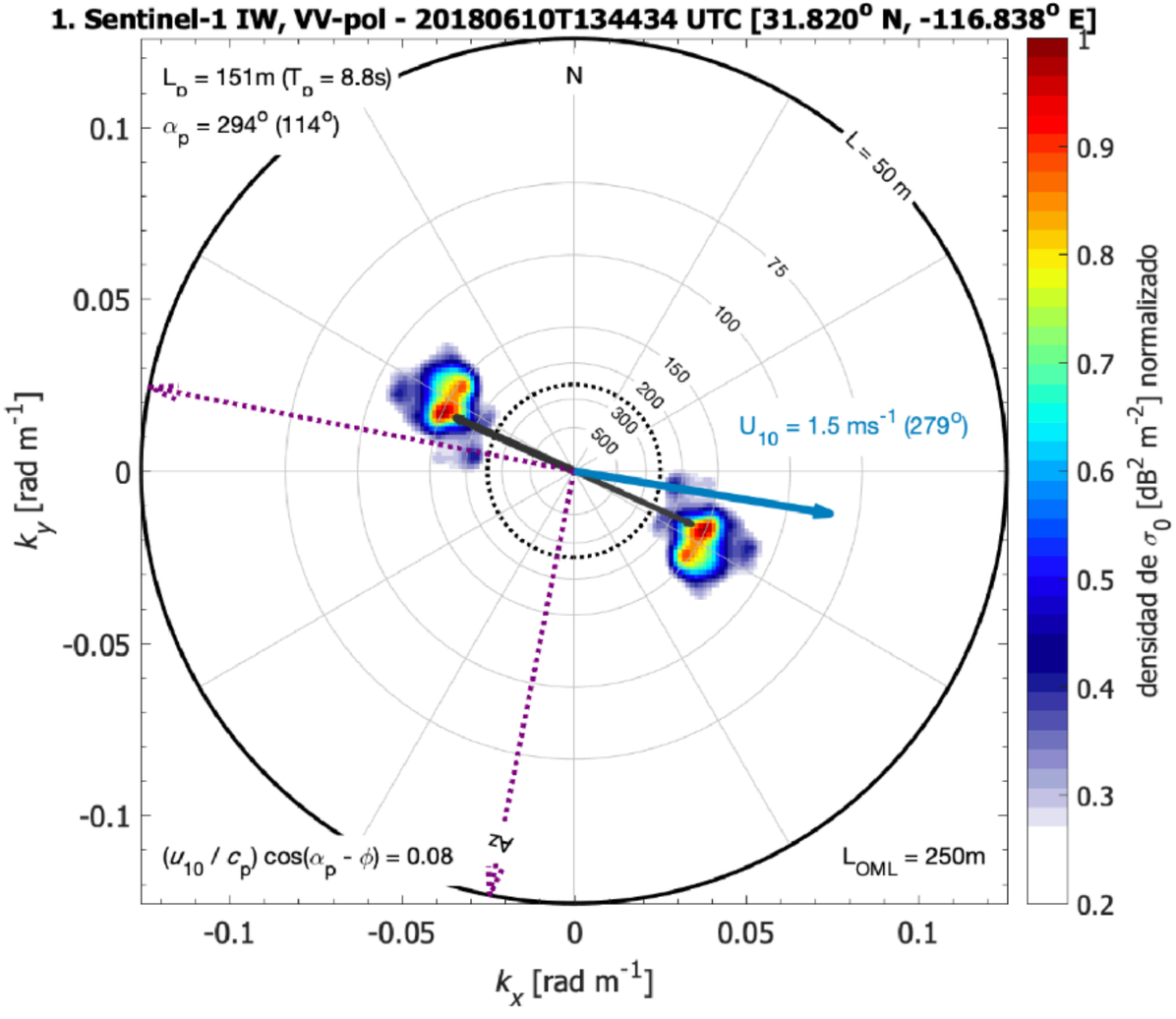
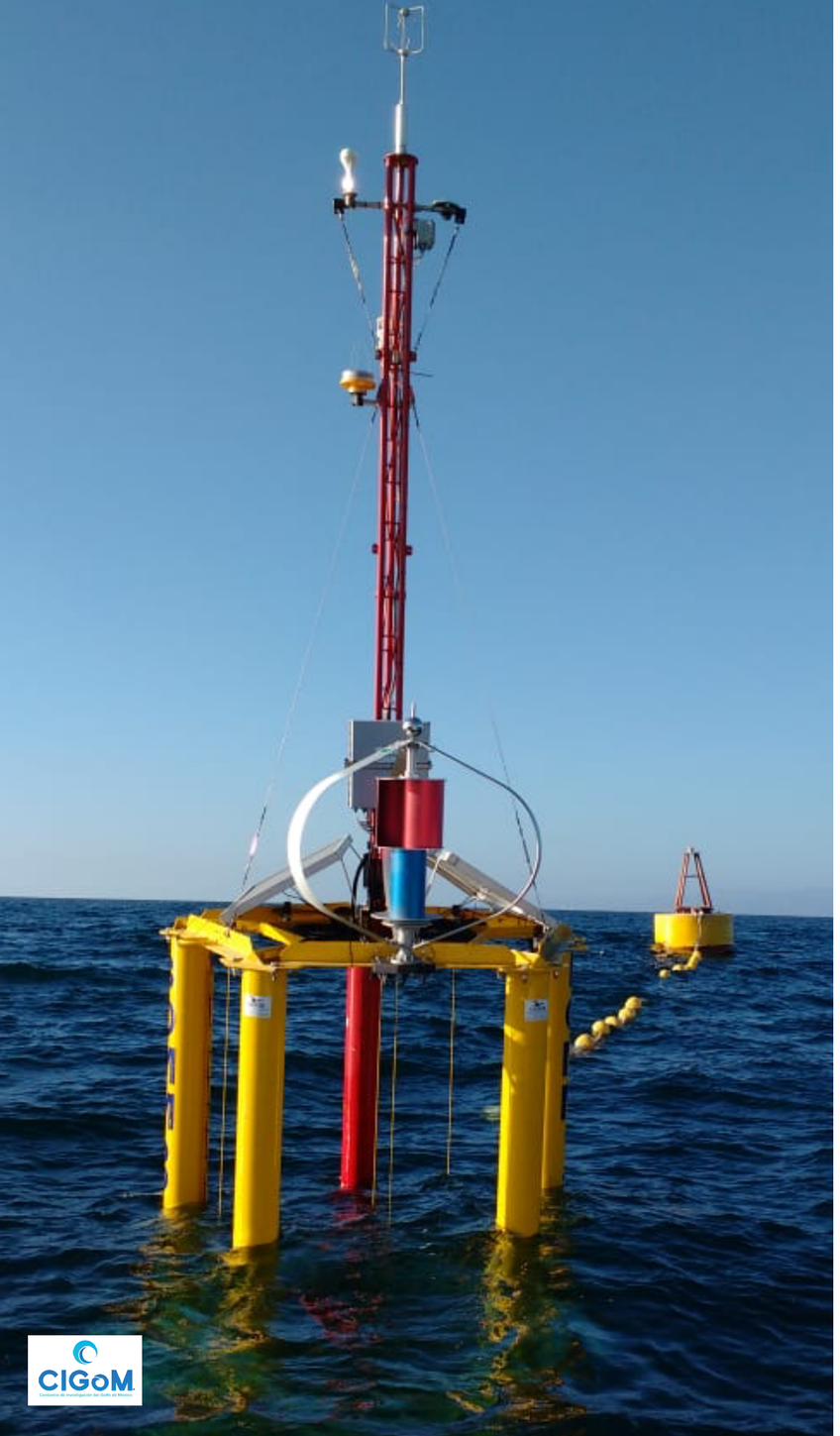
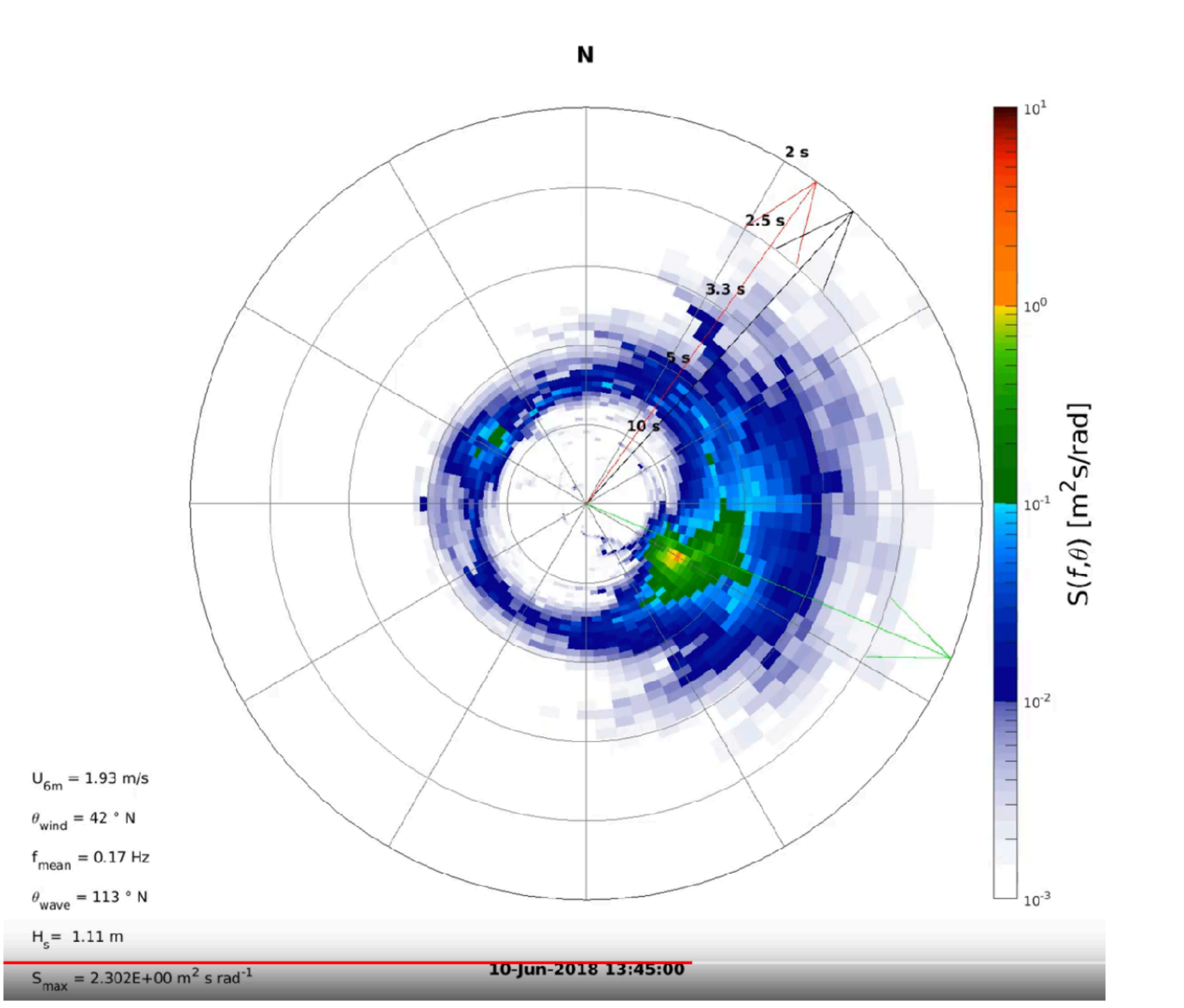
[restore zoom] [close]
Display data
more
SAR roughness Sentinel-1 (ESA, ODL)
80%
A B IW EW SM WV VV HH
False Color Sentinel-2 (ESA, Sinergise)
100%
Gain
5
Selection Info
Info
ID:
s1a-iw-grd-vv-20180610t134434-20180610t134459-022295-0269b5-001-1D84
Product:
SAR roughness Sentinel-1 (ESA, ODL)
From: 2018-06-10 13:44:34 UTC
Till: 2018-06-10 13:44:59 UTC
Metadata
Download: link
Products
31.85° N
31.8° N
31.75° N
*Estimate wave directional spectrum (SAR, sunglint)
2 km
1 NM
2018-06-10
12:00:00 UTC
Google
Map data ©2024 INEGI Imagery ©2024 TerraMetrics
Terms
Report a map error
1-Hour
12-Hour
Daily
3-Day
Weekly
Bi-weekly
2 datasets
s1a-iw-grd-vv-20180610t134434-20180610t134459-022295-0269b5-001-1D84 from SAR roughness Sentinel-1 (ESA, ODL)
31.80°N 116.84°W
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024
January February March April May June July August September October November December
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Sentinel-1A IW 20180610T134434h UTC [VV-pol, Az = 191.2°; Δx = Δy = 20.0 m]
Latitud [grados]
32.4
32.2
32
31.8
31.6
31.4
Longitud [grados]
-117.6
-117.4
-117.2
-117
-116.8
-116.6
-116.4
-116.2
-116
-115.8
p1
p2
σ0 [dB]
0
-5
-10
-15
-20
-25
-30


1. S1A-IW 20180610T134434h UTC; VV-pol [31.820° N, -116.838° E], θ_i = 42.1°
Subimagen de 5120 m por lado (256 x 256 pix. $\Delta_x = \Delta_y$ = 20 m)
Latitud [grados]
Longitud [grados]
31.84
31.835
31.83
31.825
31.82
31.815
31.81
31.805
31.8
-116.86
-116.85
-116.84
-116.83
-116.82
0
-5
-10
-15
-20
-25
-30
σ_0 [dB]


1. Sentinel-1 IW, VV-pol - 20180610T134434 UTC [31.820° N, -116.838° E]
L_p = 151m (T_p = 8.8s)
α_p = 294° (114°)
N
L = 50 m
75
100
150
200
300
500
U_{10} = 1.5 ms^{-1} (279°)
Az
$(u_{10} / c_p) \cos(\alpha_p - \phi)$ = 0.08
L_{OML} = 250m
k_y [rad m^{-1}]
k_x [rad m^{-1}]
0.1
0.05
0
-0.05
-0.1
densidad de σ_0 [dB^2 m^{-2}] normalizado
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2




N
2 s
2.5 s
3.3 s
5 s
10 s
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
S(f,θ) [m²s/rad]
U_{6m} = 1.93 m/s
θ_{wind} = 42 ° N
f_{mean} = 0.17 Hz
θ_{wave} = 113 ° N
H_s = 1.11 m
S_{max} = 2.302E+00 m^2 s rad^{-1}
10-Jun-2018 13:45:00

Multi-angle Imaging Spectro Radiometer (MISR). Sunglint, mss.

Remote Sensing of Environment 216 (2018) 786–797

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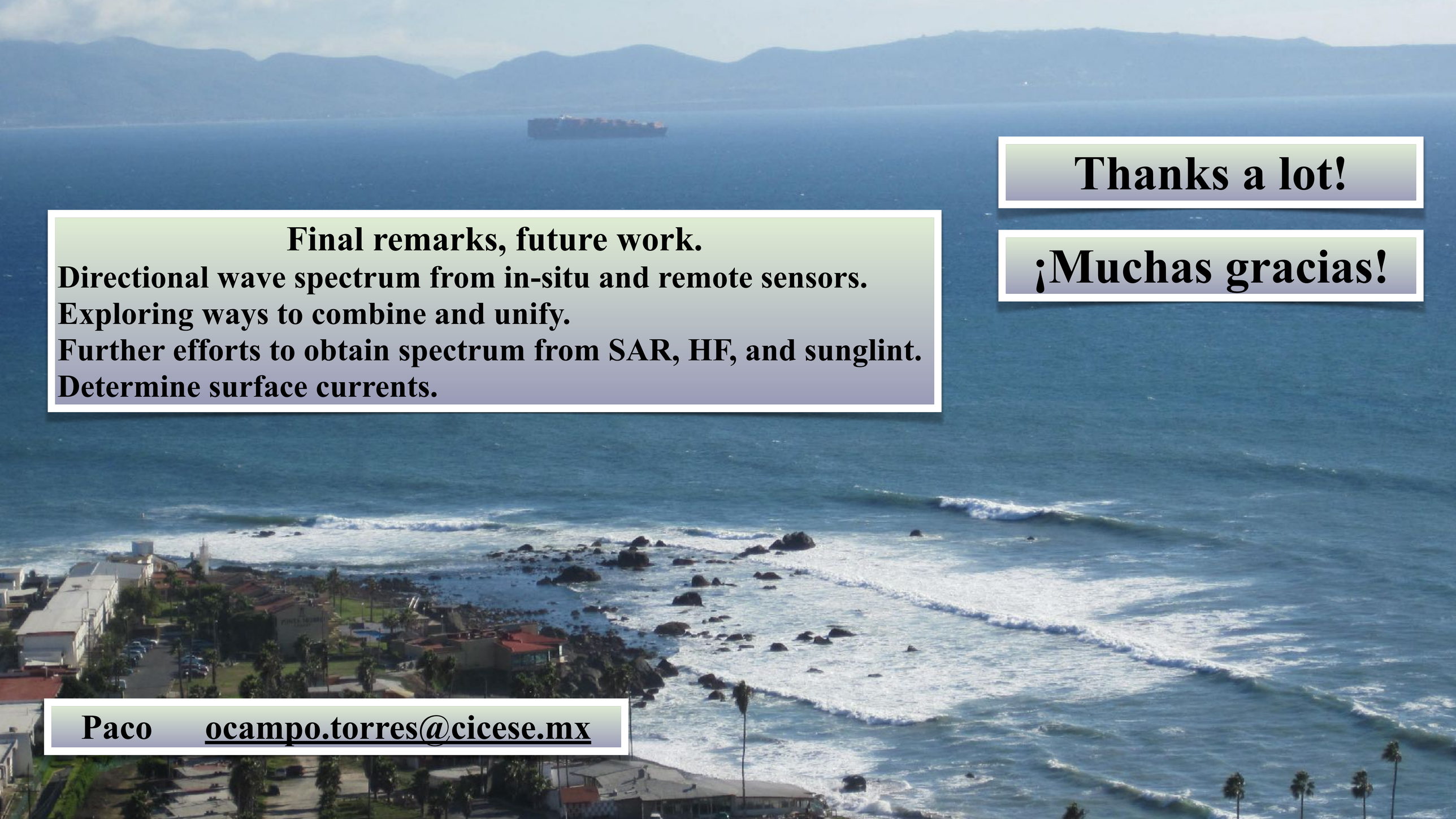
journal homepage: www.elsevier.com/locate/rse

Sunglint images of current gradients at high resolution: Critical angle and directional observing strategy

Nicolas Rascle[a,b,*], Frédéric Nouguier[a,c], Bertrand Chapron[a], Francisco J. Ocampo-Torres[b]

[a] Univ. Brest, CNRS, IRD, Ifremer, Laboratoire d'Océanographie Physique et Spatiale (LOPS), IUEM, Brest, France
[b] Departamento de Oceanografía Física, Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California, México
[c] Université de Toulon, CNRS/INSU, IRD, Mediterranean Institute of Oceanography (MIO), UM 110, La Garde 83957, France

Optical sensors.
Sunglint is related to directional roughness and to statistical wave properties (mss wave mean square slope parameter).



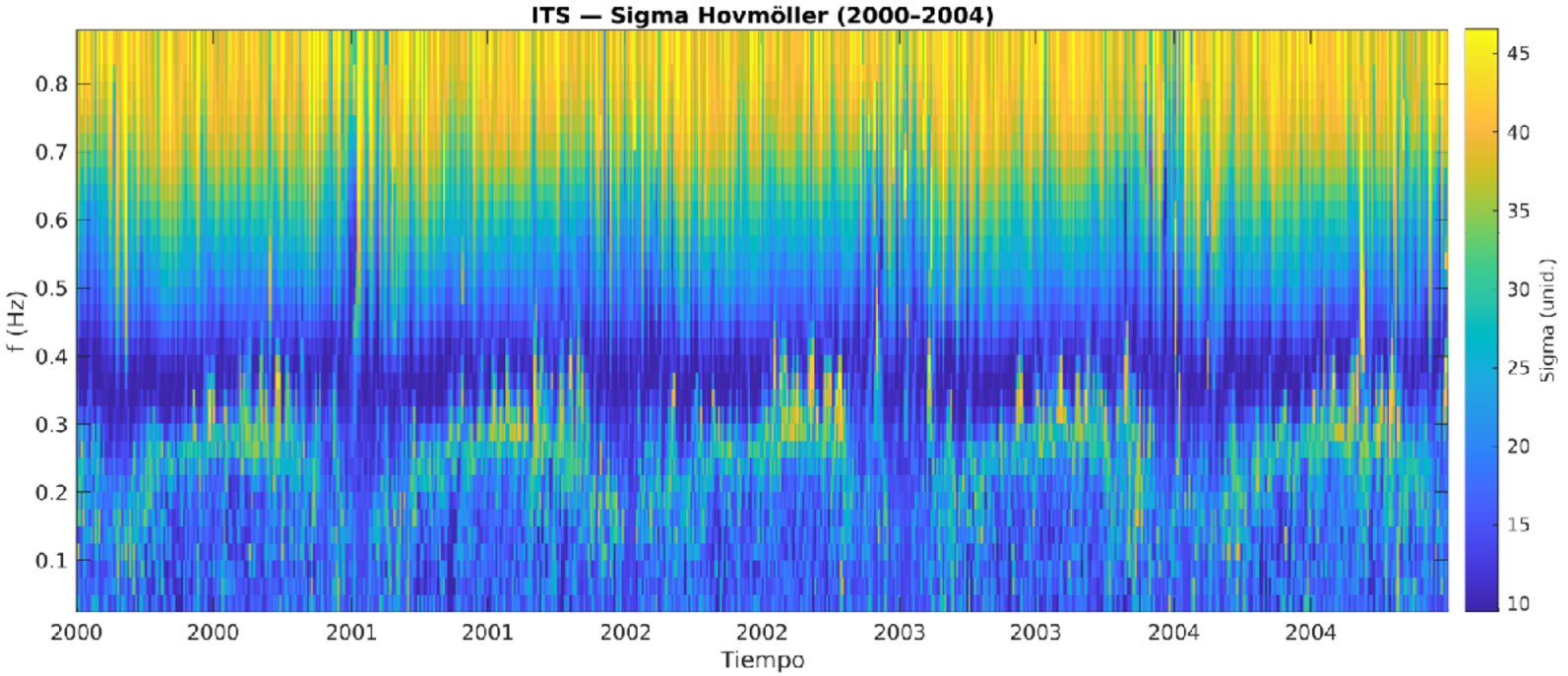
Thanks a lot!

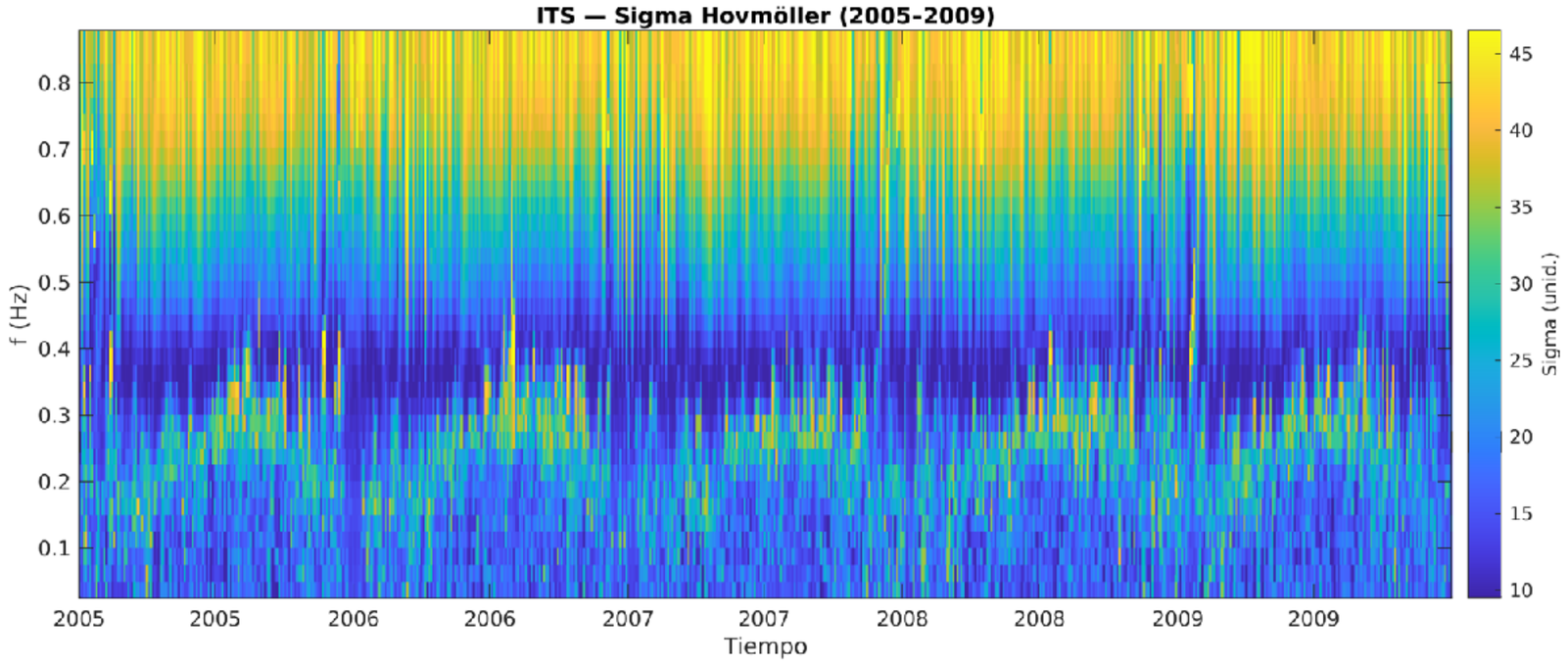
¡Muchas gracias!

Final remarks, future work.

Directional wave spectrum from in-situ and remote sensors.
Exploring ways to combine and unify.
Further efforts to obtain spectrum from SAR, HF, and sunglint.
Determine surface currents.

Paco **ocampo.torres@cicese.mx**





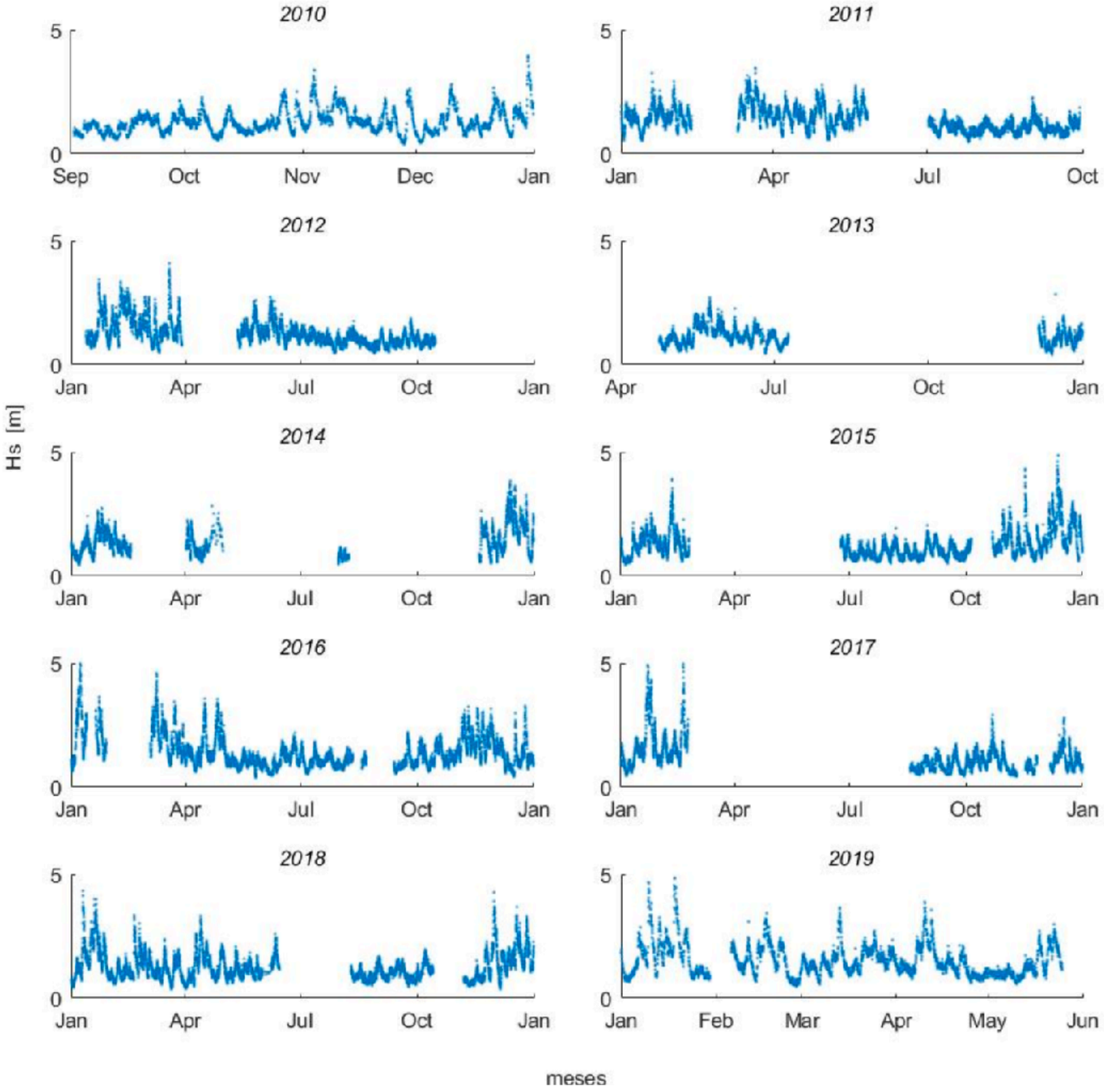
Relevance of the directional spectrum shape.
Directional spread (*f*) time variaton.

Open questions: Natural variability and possible effect in near shore processes.

Effect in breaking waves nearshore. Possible association with climate?

Numerical simulations.
Direct measurements.

Acosta Solís, G. (2020) Caracterización del oleaje en la Isla Todos Santos, Baja California, durante el periodo 2010-2020.
B.Sc. Thesis. Oceanology, FCM, UABC



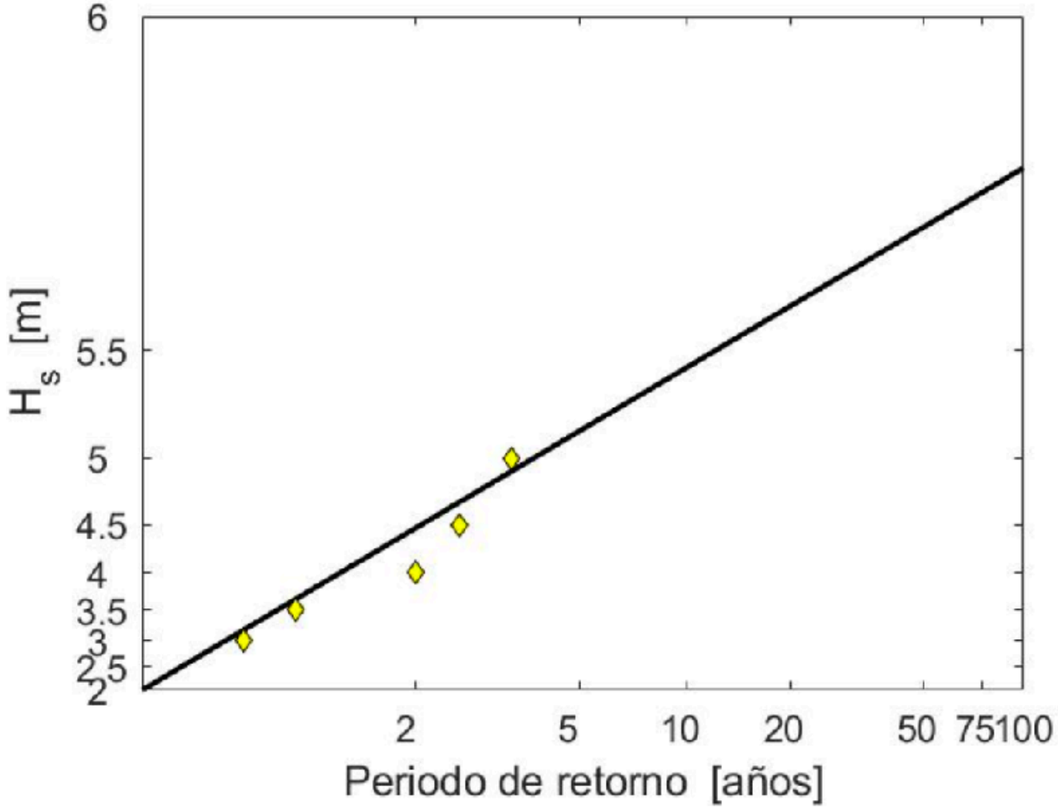
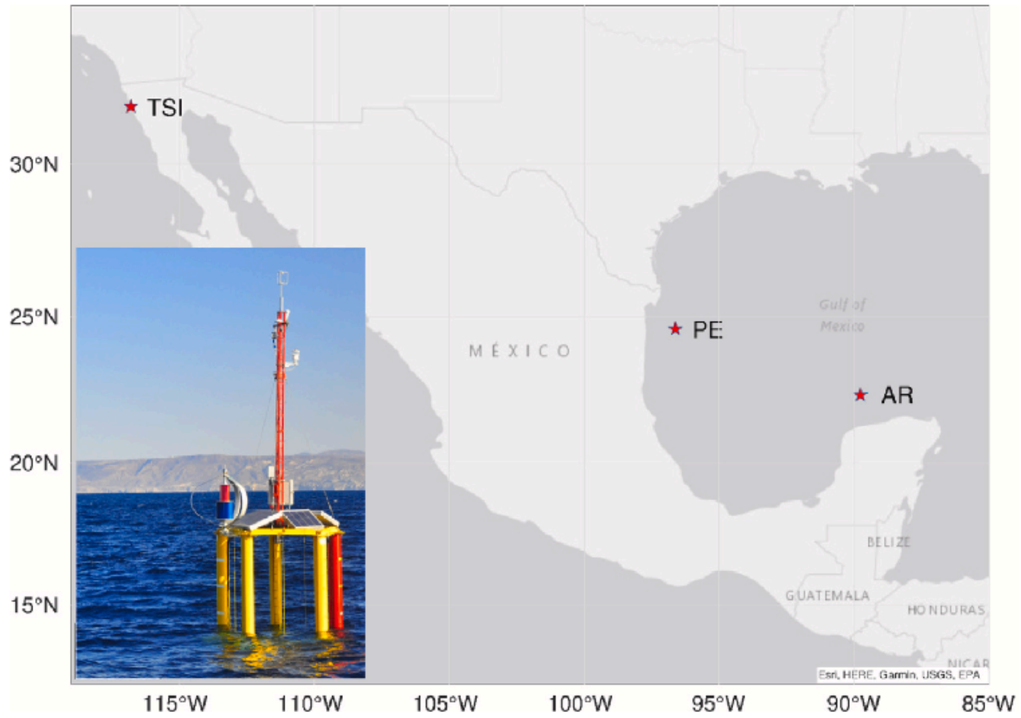
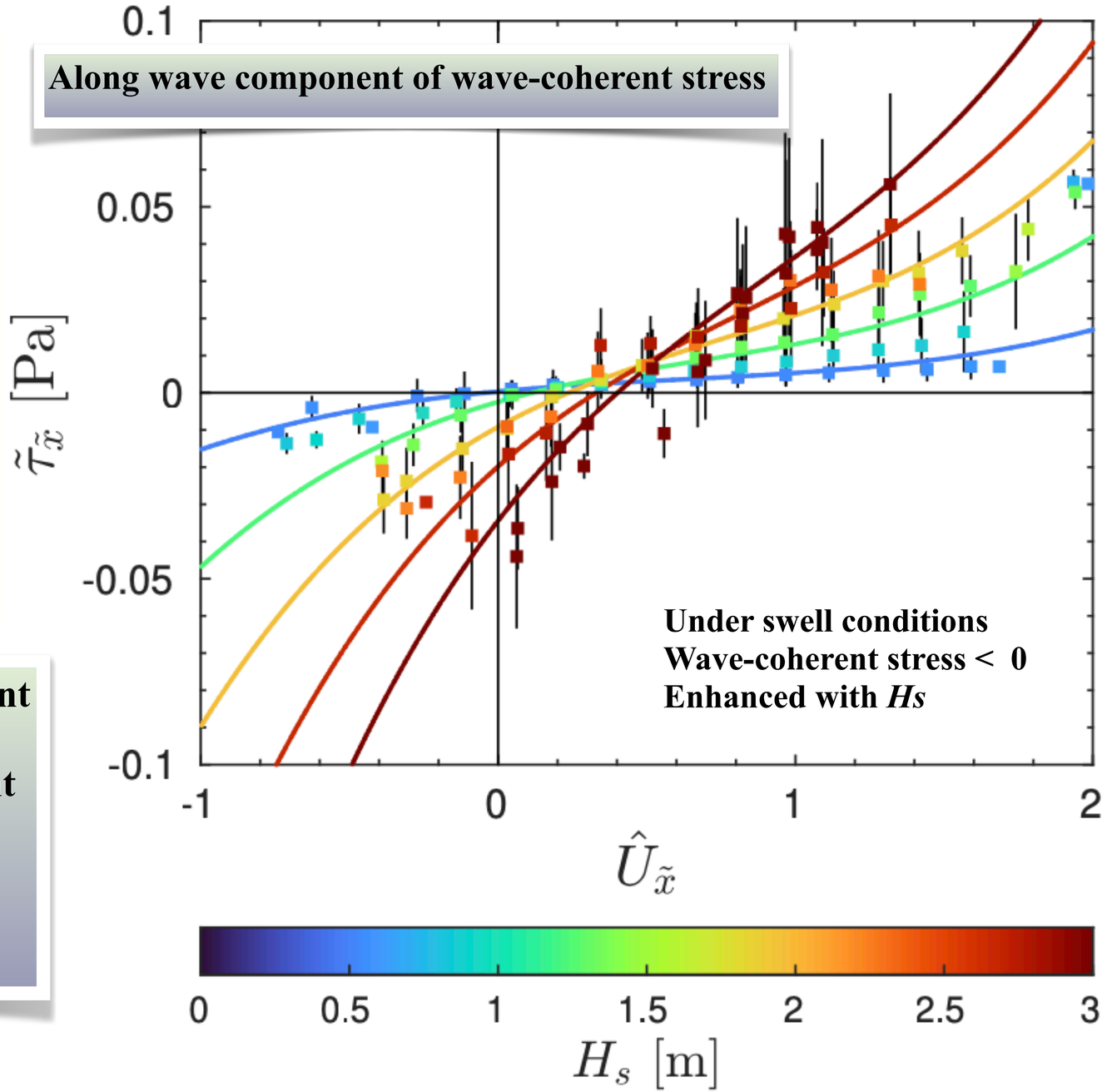


Figura 17. Extrapolación de la distribución de probabilidad del valor extremo



Significant wave height influence on wave coherent wind stress component in the wave propagation direction as a function of relative wind component (in the wave propagation direction).
Typical single peak spectrum or unimodal ocean wave field.
****Consider bimodal spectrum cases.**



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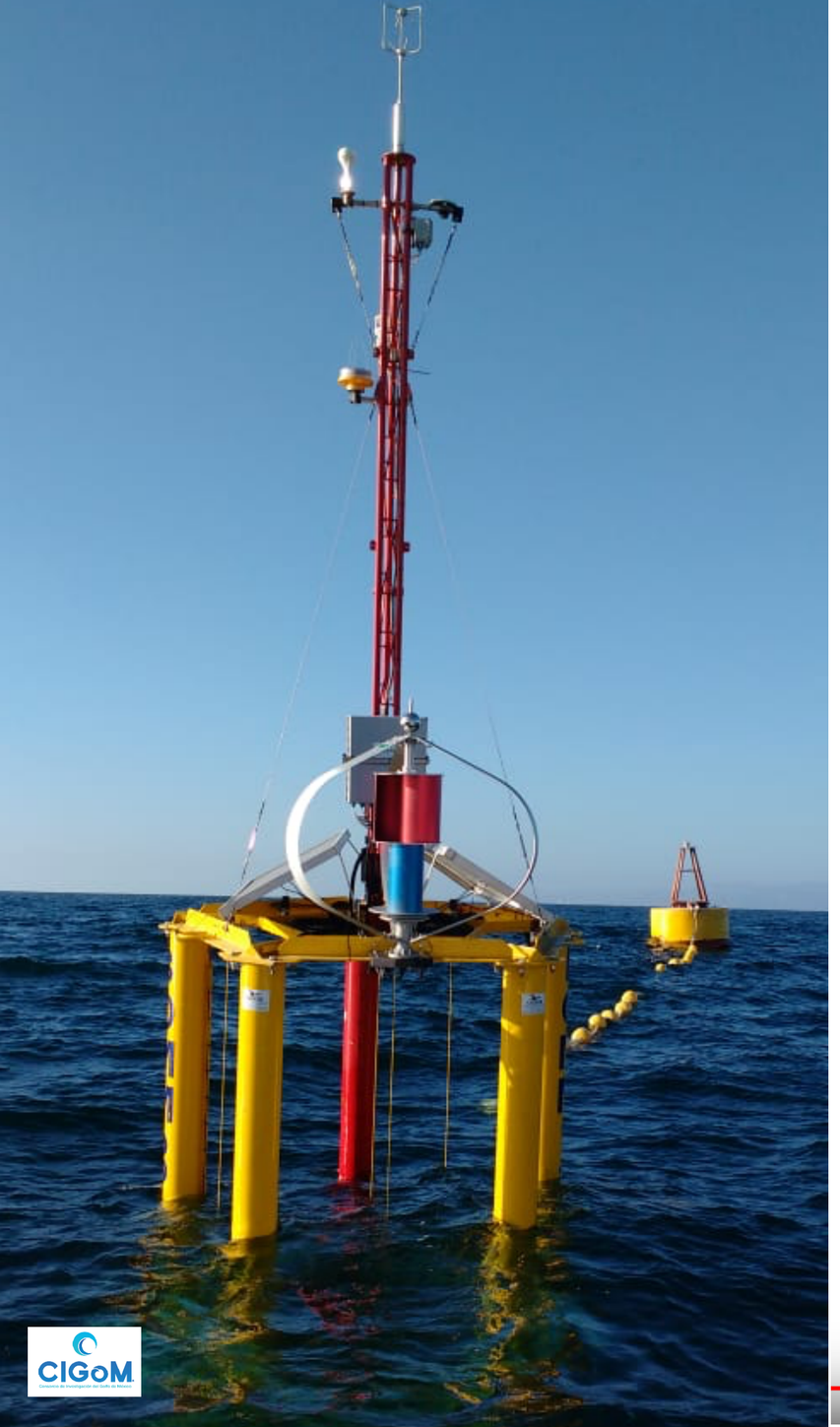
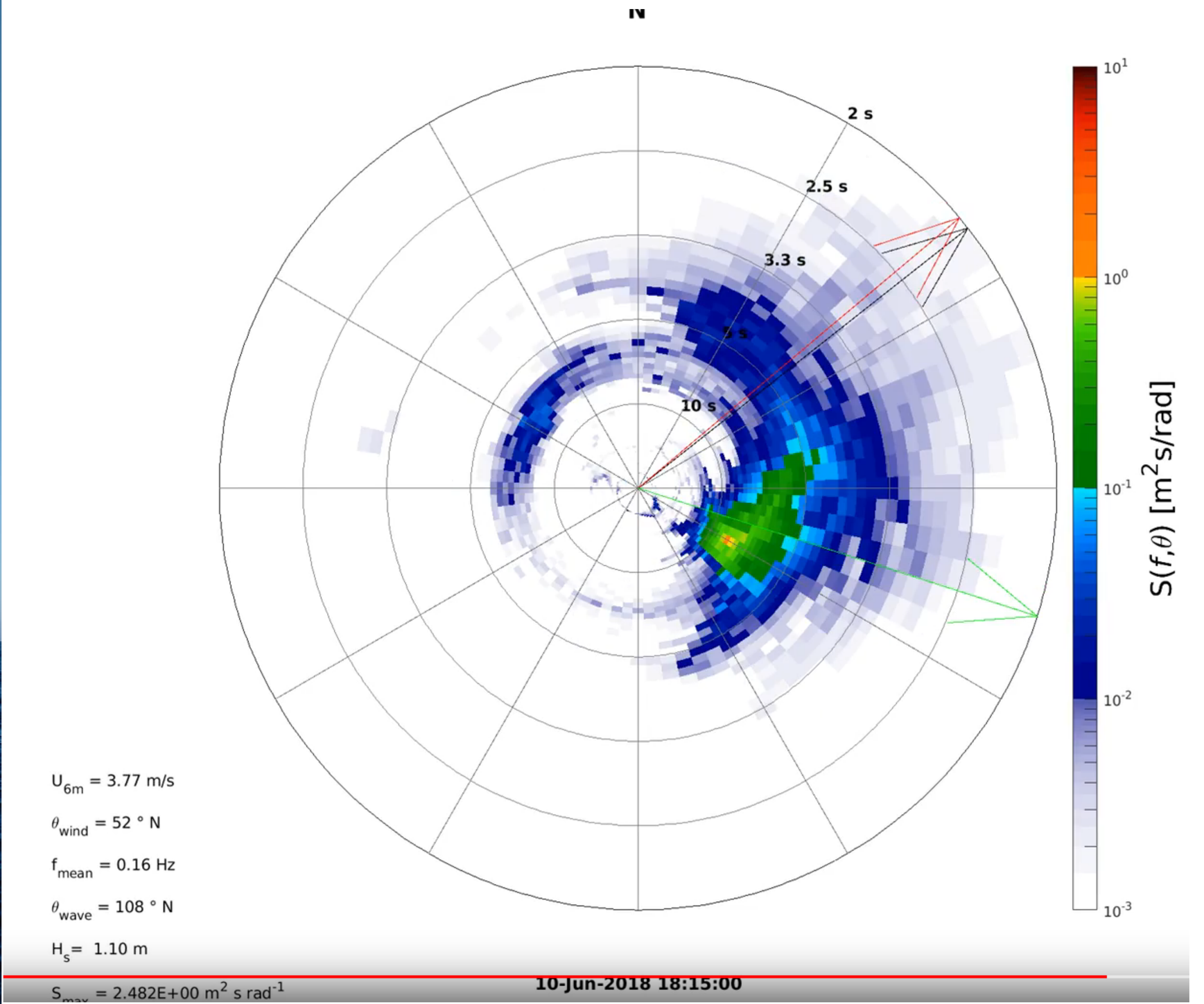
Villarreal-Olavarrieta, C. E., F. J. Ocampo-Torres, P. Osuna, R. E. Mora-Escalante (2024). Effect of waves on the magnitude and direction of wind stress over the Ocean, Ocean Modelling, 191, 102420, ISSN 1463-5003, https://doi.org/10.1016/j.ocemod.2024.102420.




N
2 s
2.5 s
3.3 s
5 s
10 s
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
S(f,θ) [m²s/rad]
U_{6m} = 3.77 m/s
θ_{wind} = 52 ° N
f_{mean} = 0.16 Hz
θ_{wave} = 108 ° N
H_s = 1.10 m
S_{max} = 2.482E+00 m^2 s rad^{-1}
10-Jun-2018 18:15:00