The October 29, 2018 storm in Northern Italy – an exceptional event with meteorological and oceanographic strong implications

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Disastrous wind and waves on both sides of Italy

on its West side wave heights never seen before
(but the memory is short)

high waves in front of, and flooding of, Venice

record wind speeds in the mountains
(11 millions trees fell to the floor)


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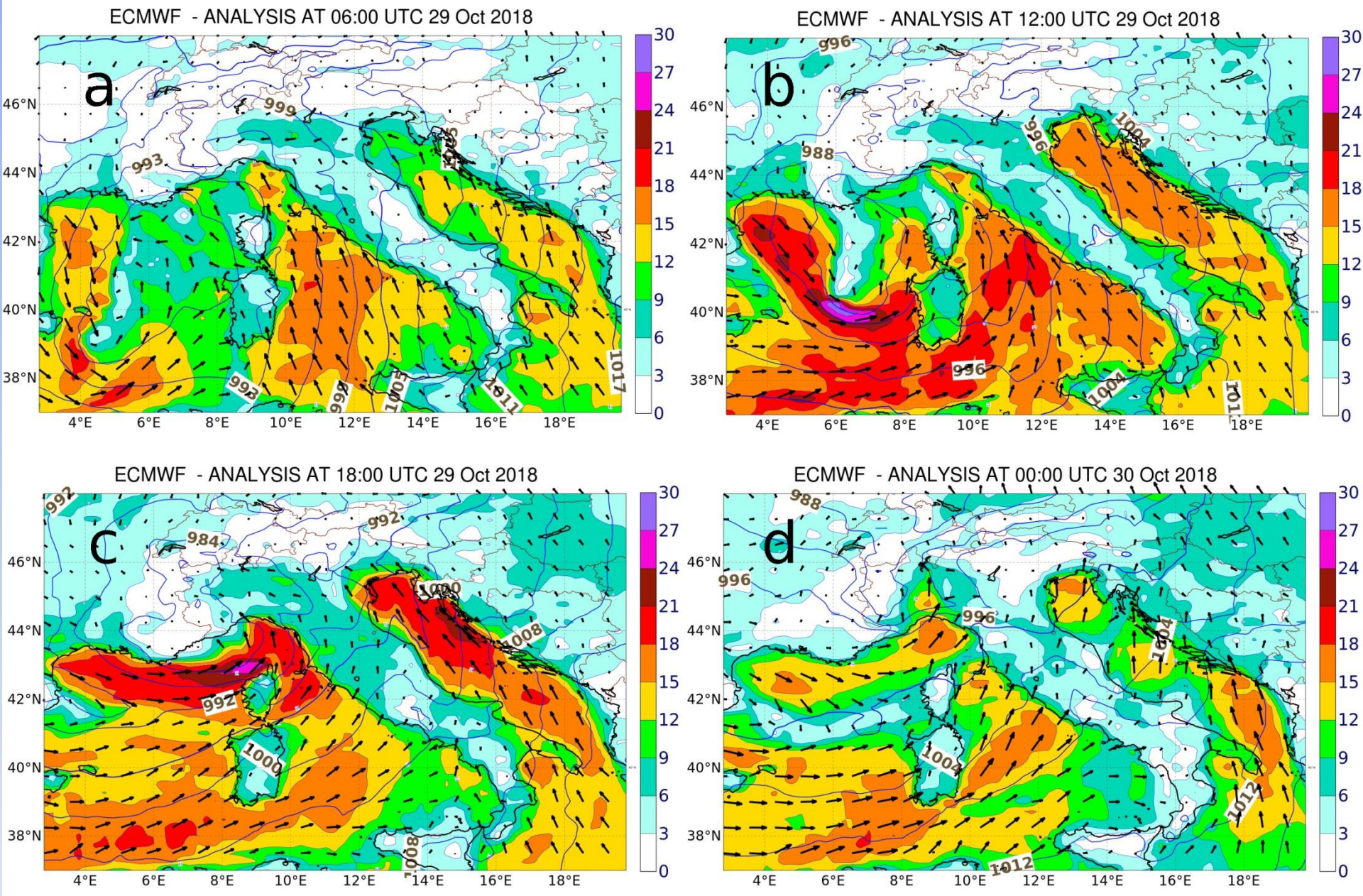
EUROPE
Atlantic Ocean
France
Slovenia
Croatia
Bosnia & Herzegovina
Monaco
Ligurian Sea
Adriatic Sea
Italy
Montenegro
Albania
Black Sea
Bosporus Strait
Sea of Marmara
Corsica
Balearic Sea
Spain
Tyrrhenian Sea
Greece
Aegean Sea
Dardanelles Strait
ASIA
Strait of Gibraltar
Balearic Islands
Sardinia
Ionian Sea
Turkey
Syria
Sicily
Malta
Sea of Crete
Cyprus
Crete
Alboran Sea
Algeria
Mediterranean Sea
Lebanon
Morocco
AFRICA
Tunisia
Israel
Libya
300 mi
300 km
Suez Canal
Egypt
N
Countries that border the Mediterranean Sea


Dolomites
Alps
Venice
Genoa
Balkans
Ligurian
Sea
Apennines
18:00
Gulf of
Lion
Adriatic
Sea
C
D
16:00
Corsica
Italy
B
Western
Mediterranean
Sea
14:00
Sardinia
Tyrrhenian
Sea
12:00
10:00
A
Sicily
Tunisia


ECMWF - ANALYSIS AT 06:00 UTC 29 Oct 2018
a
ECMWF - ANALYSIS AT 12:00 UTC 29 Oct 2018
b
ECMWF - ANALYSIS AT 18:00 UTC 29 Oct 2018
c
ECMWF - ANALYSIS AT 00:00 UTC 30 Oct 2018
d
46°N
44°N
42°N
40°N
38°N
4°E
6°E
8°E
10°E
12°E
14°E
16°E
18°E
30
27
24
21
18
15
12
9
6
3
0

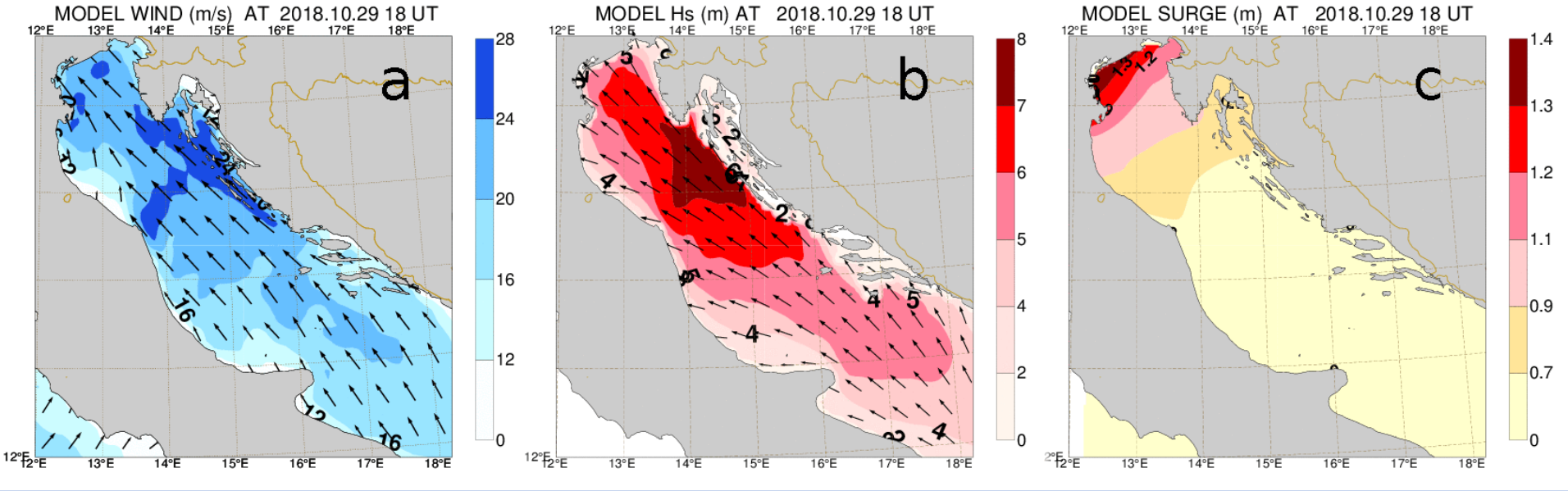

Dolomites
Alps
Venice
Genoa
Balkans
Ligurian
Sea
Apennines
18:00
Gulf of
Lion
Adriatic
Sea
C
D
16:00
Corsica
Italy
B
Western
Mediterranean
Sea
14:00
Sardinia
Tyrrhenian
Sea
12:00
10:00
A
Sicily
Tunisia


Venice
Lido
lagoon
Malamocco
Acqua Alta
tower
Chioggia
0
10 km

WIND

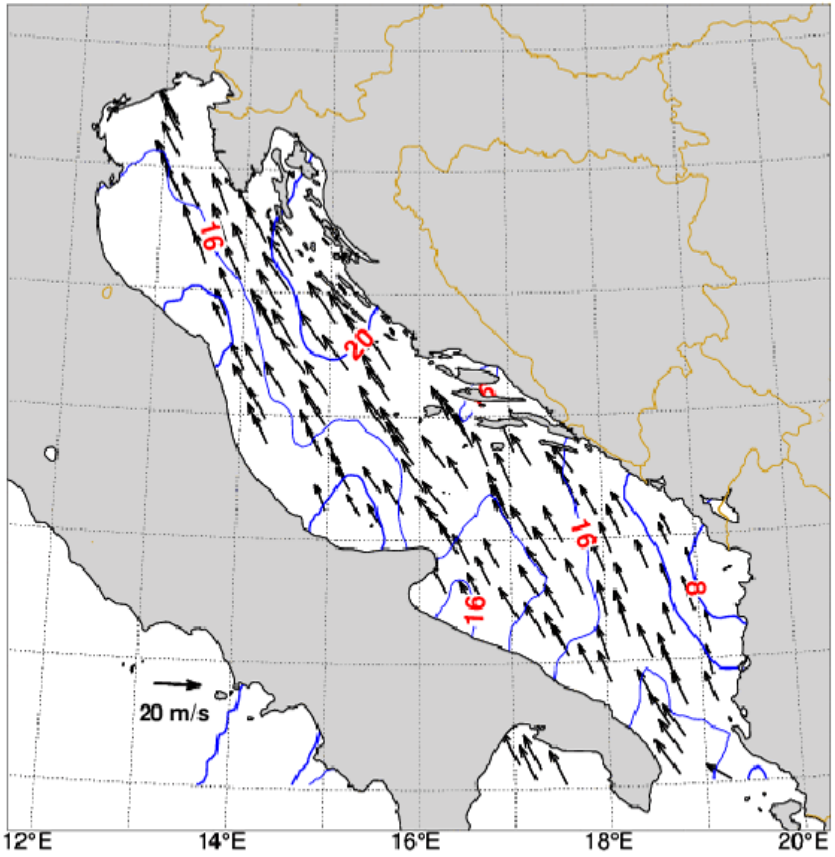
WAVES

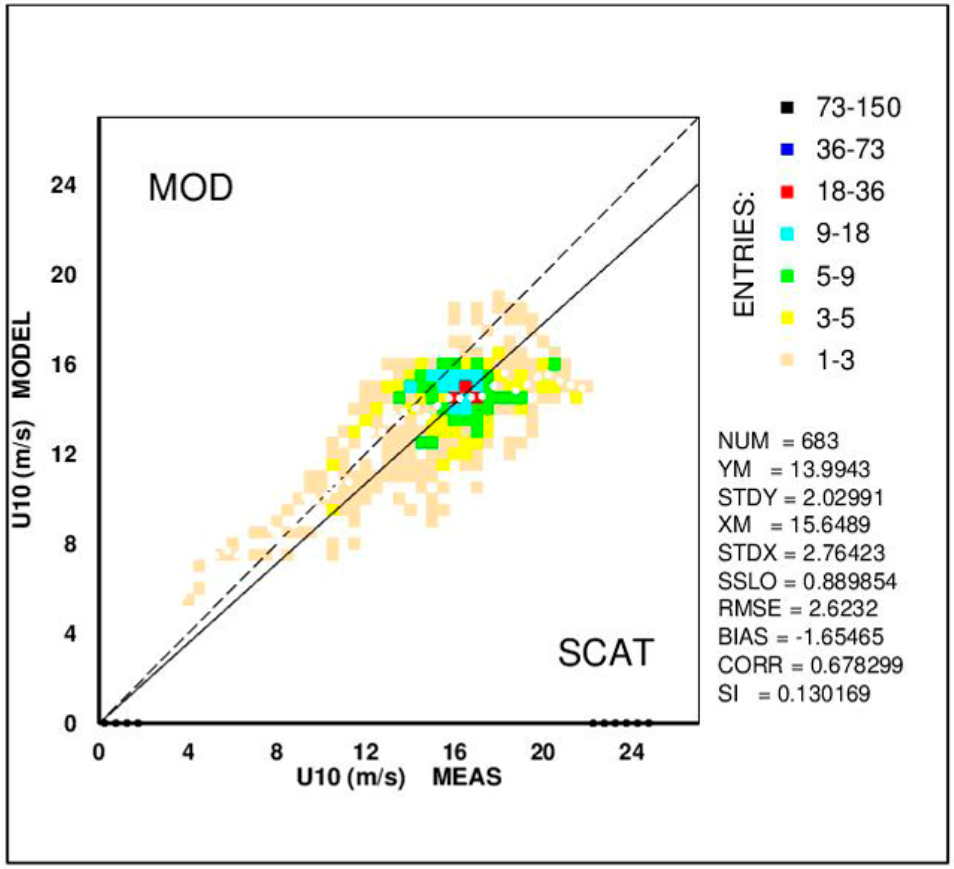
SURGE



SCATTEROMETER DATA

BEST-FIT ECMWF WIND vs SCAT DATA





Modelling:

- Meteorological : ECMWF Tco1279 24 hour forecasts - 9 km resolution - hourly fields

- Wind waves : WAM, 9 km resolution, 30 frequencies, 24 directions

- Surge : unstructured grid, non-linear surge equations - model covers the whole Mediterranean Sea and also the Venice lagoon

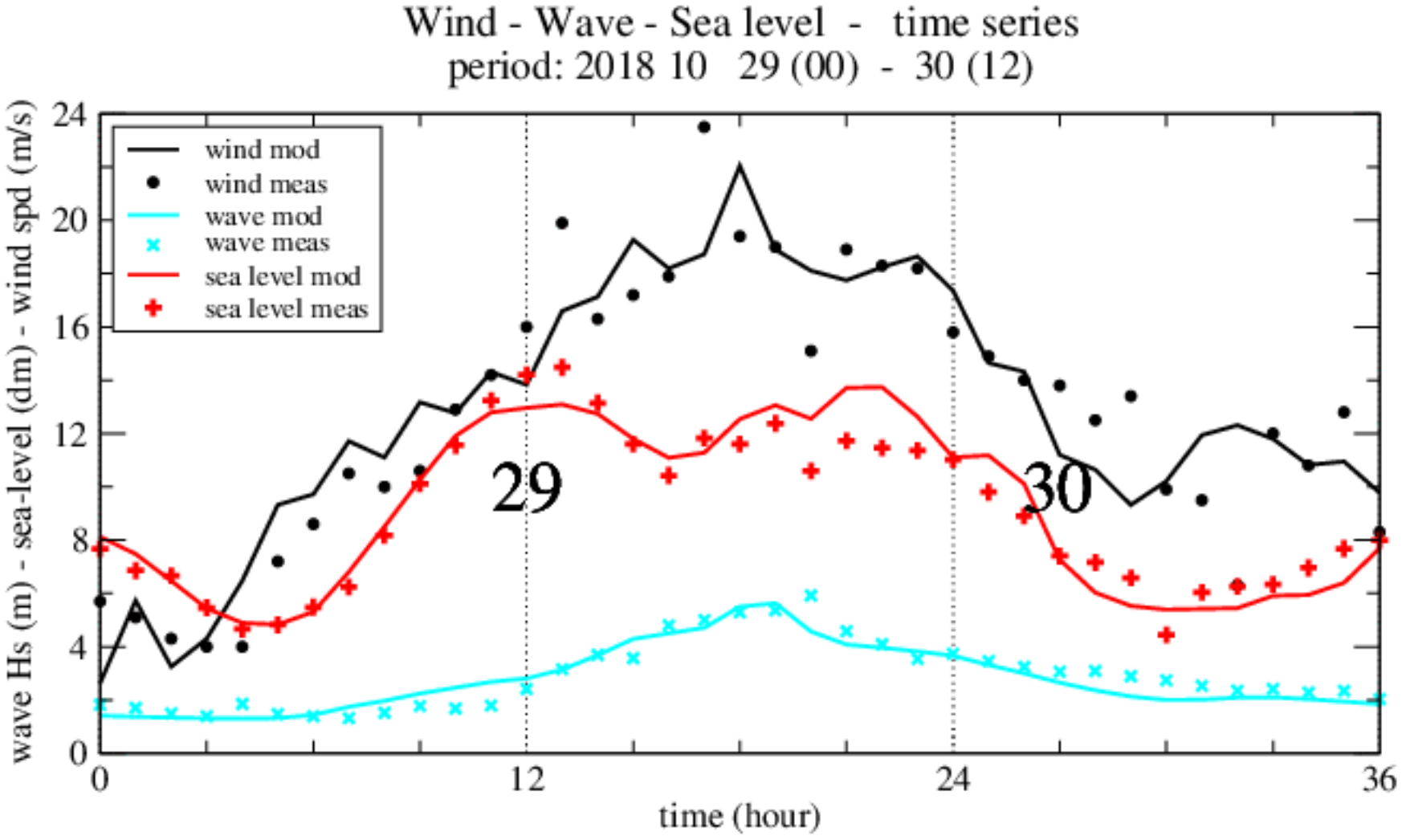
Extensive measurements available both at the ISMAR oceanographic tower and at the coast

tower : wind,
waves (radar gauge, AWAC system, echo-sounder, pressure transducer, stereo-video system)
sea level (standard tide well, radar gauge, pressure transducer)

at the coast:
sea level (standard tide well – two positions)

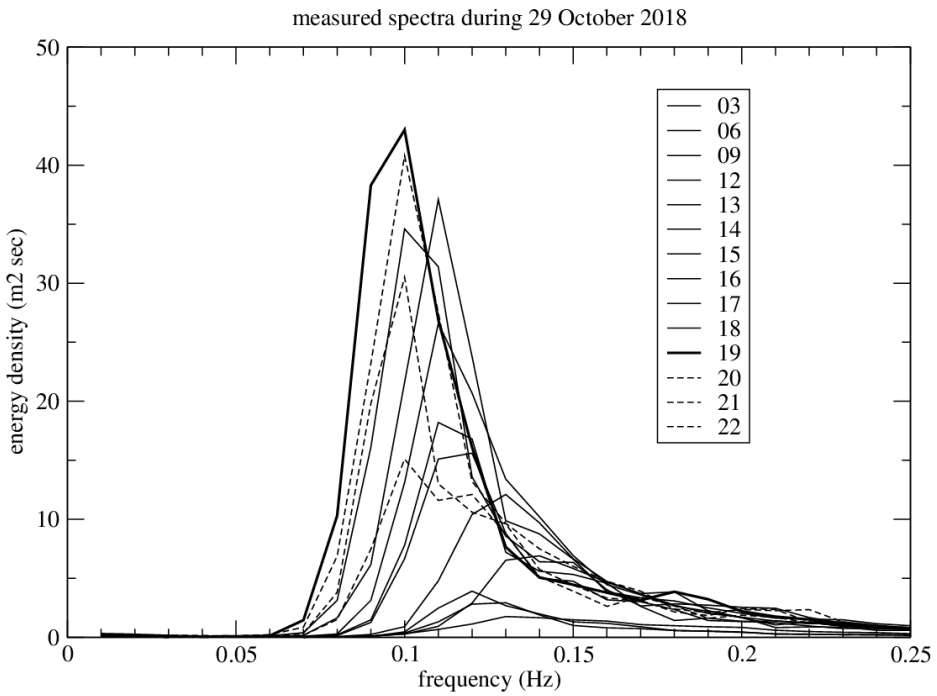
in Venice:
sea level (standard tide well – several positions)

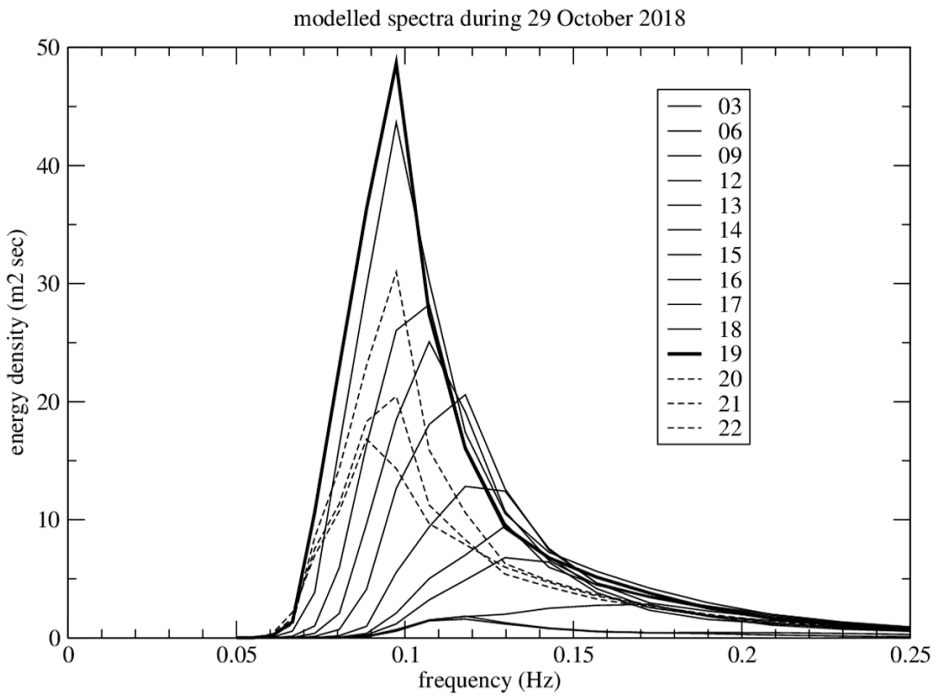

Venice
Lido
lagoon
Malamocco
Acqua Alta
tower
Chioggia
0
10 km

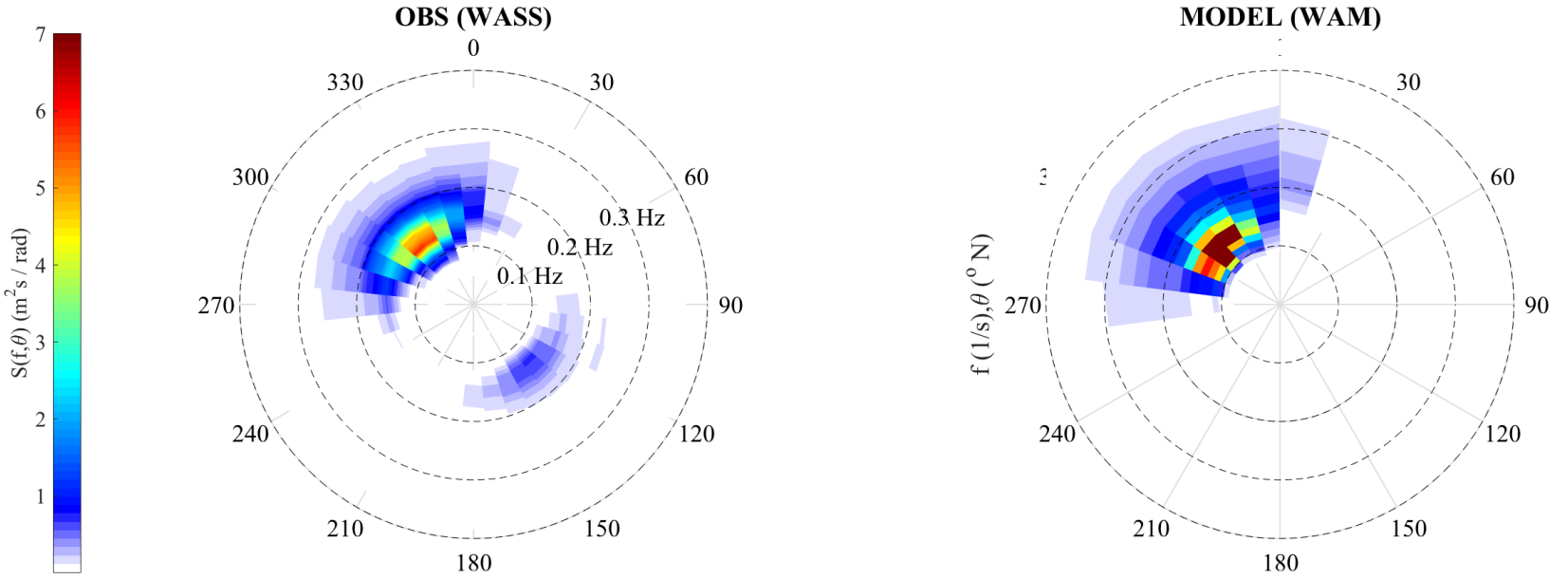

Wind - Wave - Sea level - time series
period: 2018 10 29 (00) - 30 (12)
wind mod
wind meas
wave mod
wave meas
sea level mod
sea level meas
29
30
wave Hs (m) - sea-level (dm) - wind spd (m/s)
time (hour)
0
4
8
12
16
20
24
0
12
24
36

measured

modelled

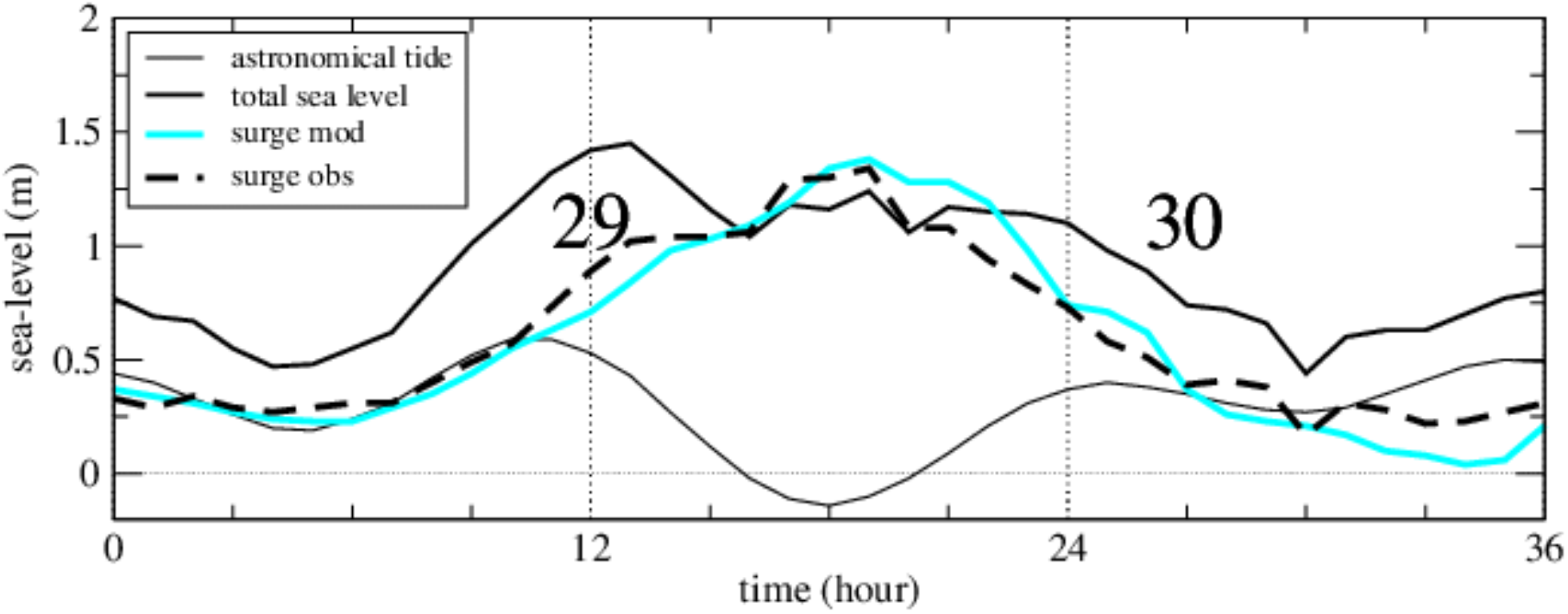


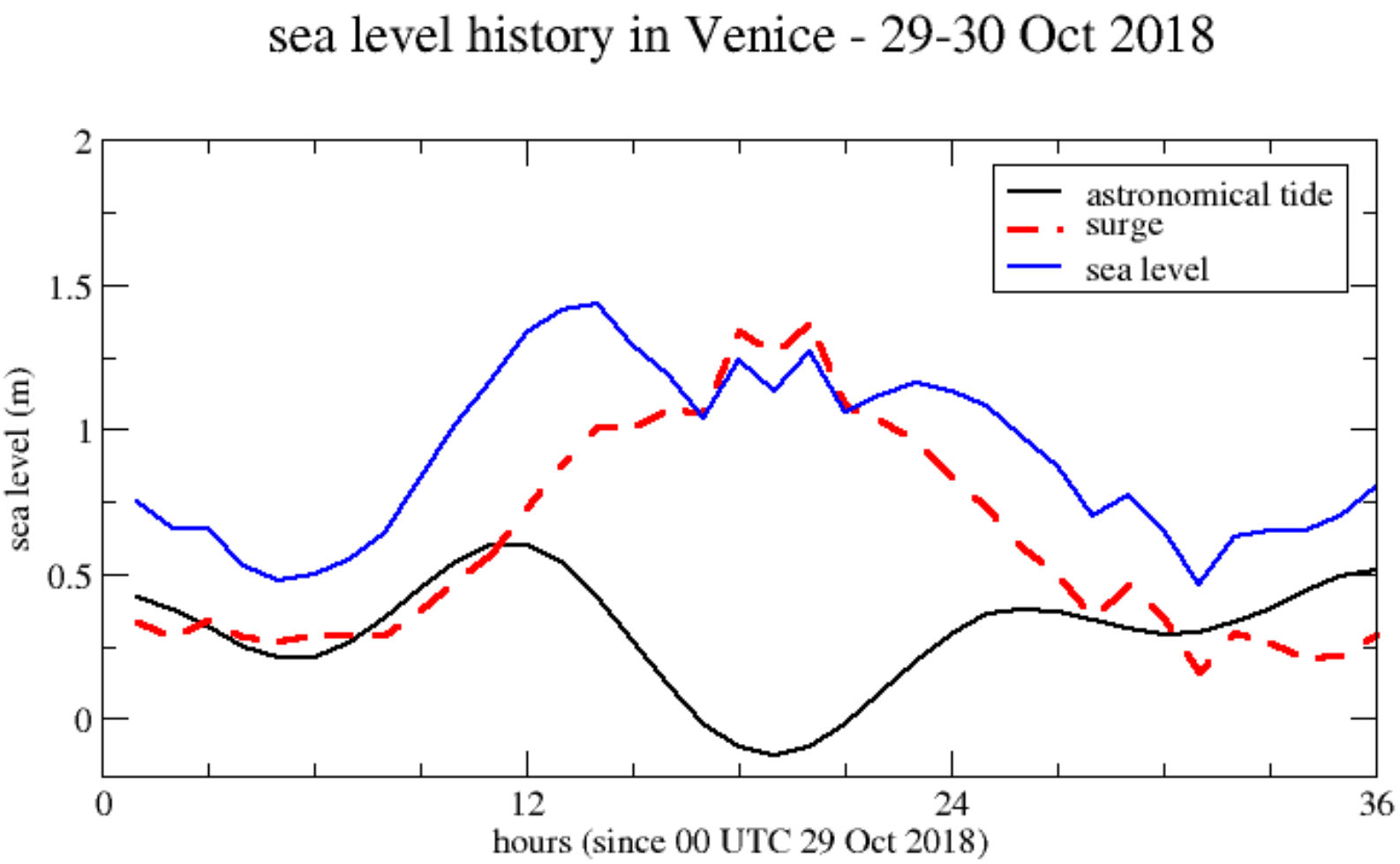


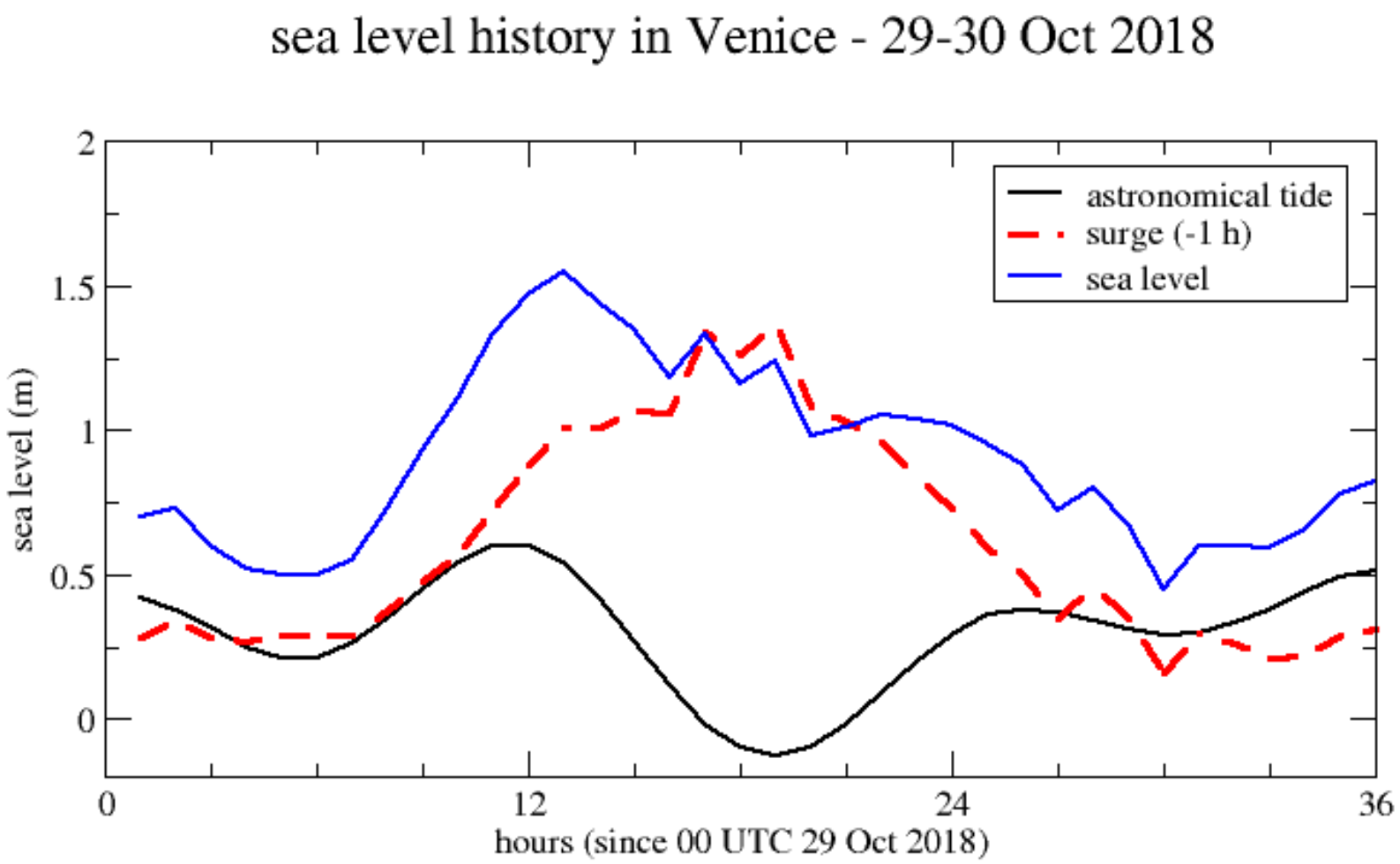

OBS (WASS)
MODEL (WAM)
S(f,θ) (m²s / rad)
f (1/s),θ (° N)
0.1 Hz
0.2 Hz
0.3 Hz
0
30
60
90
120
150
180
210
240
270
300
330
1
2
3
4
5
6
7

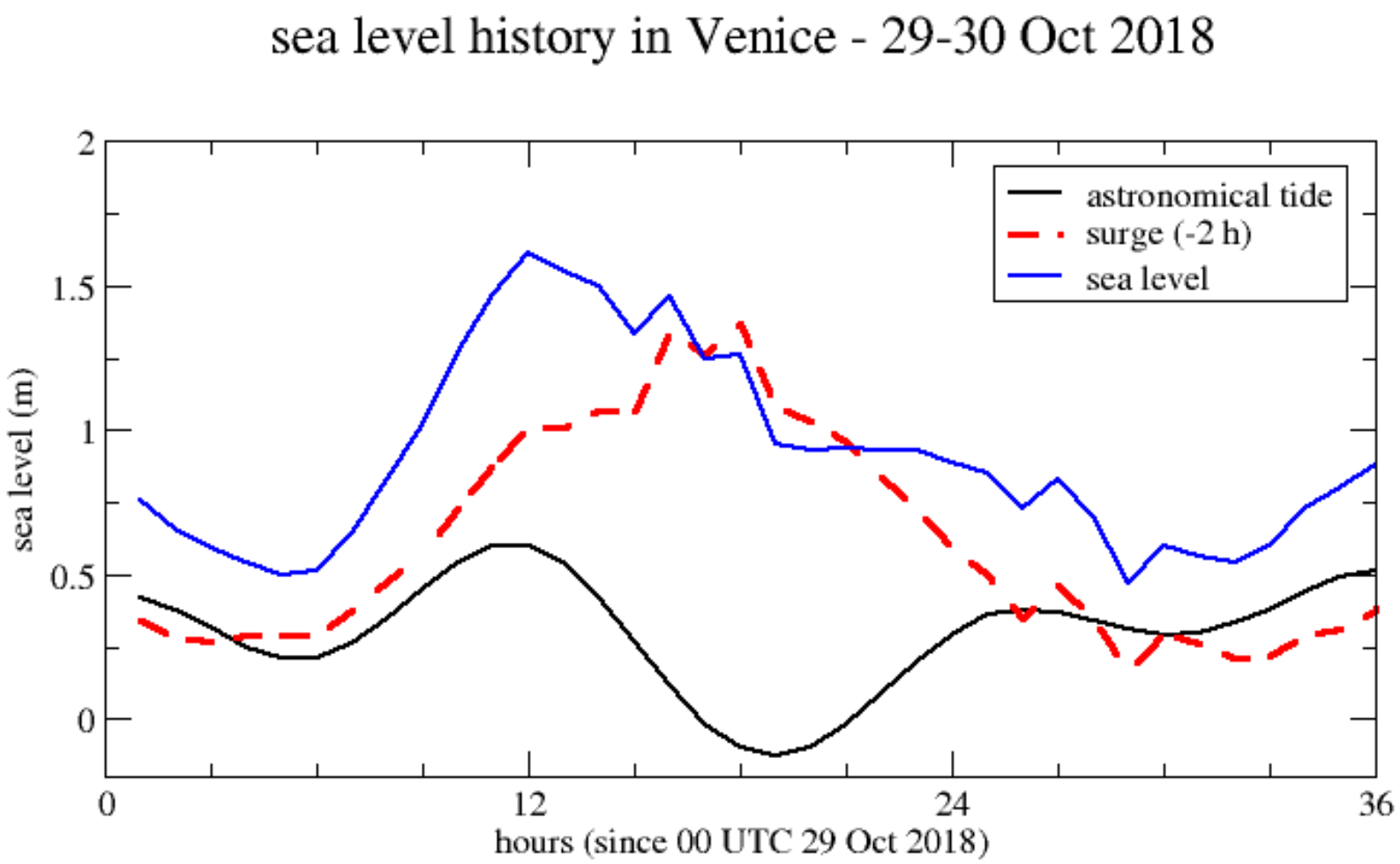
look carefully at this plot -

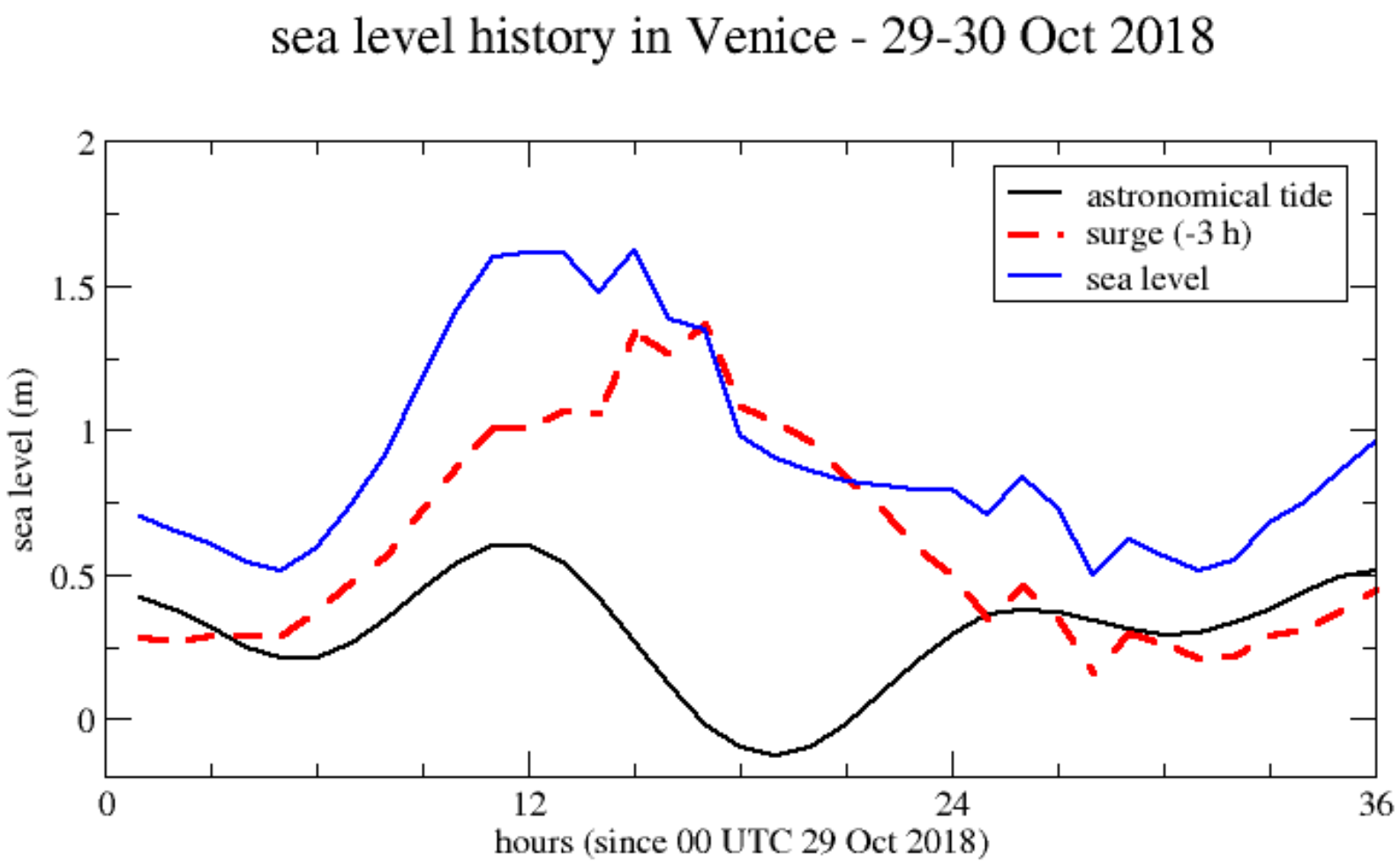
"the implications for Venice"

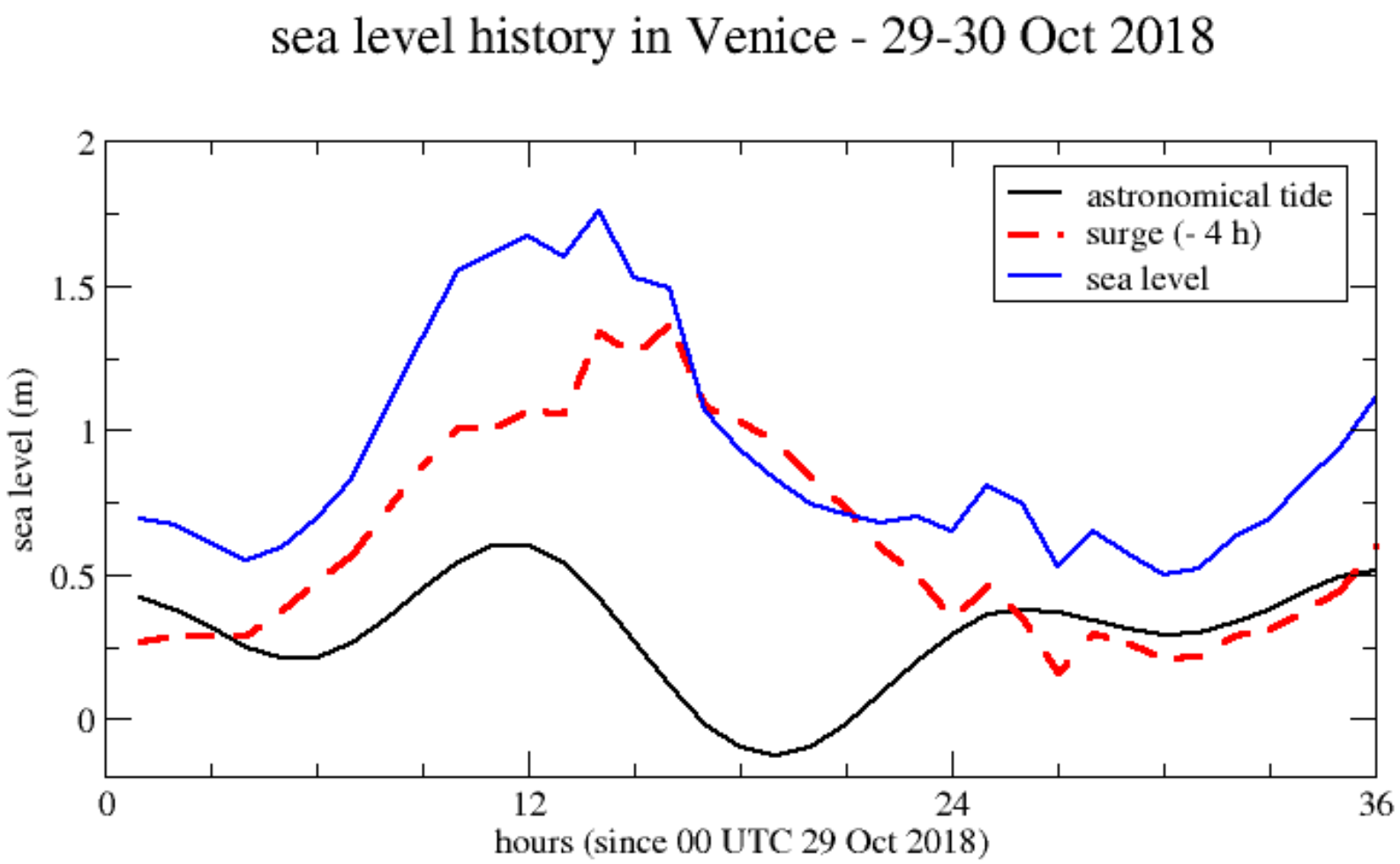


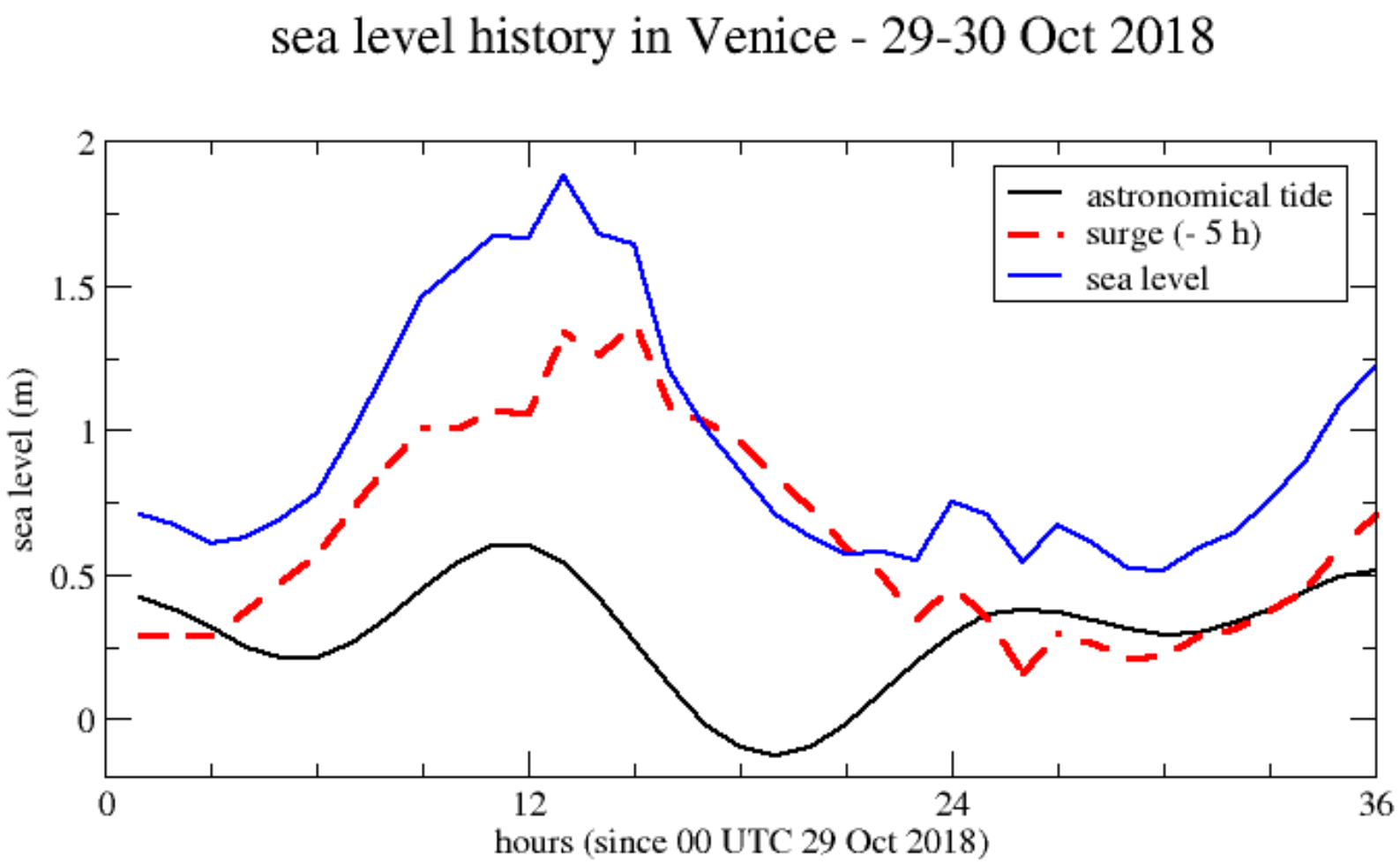

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

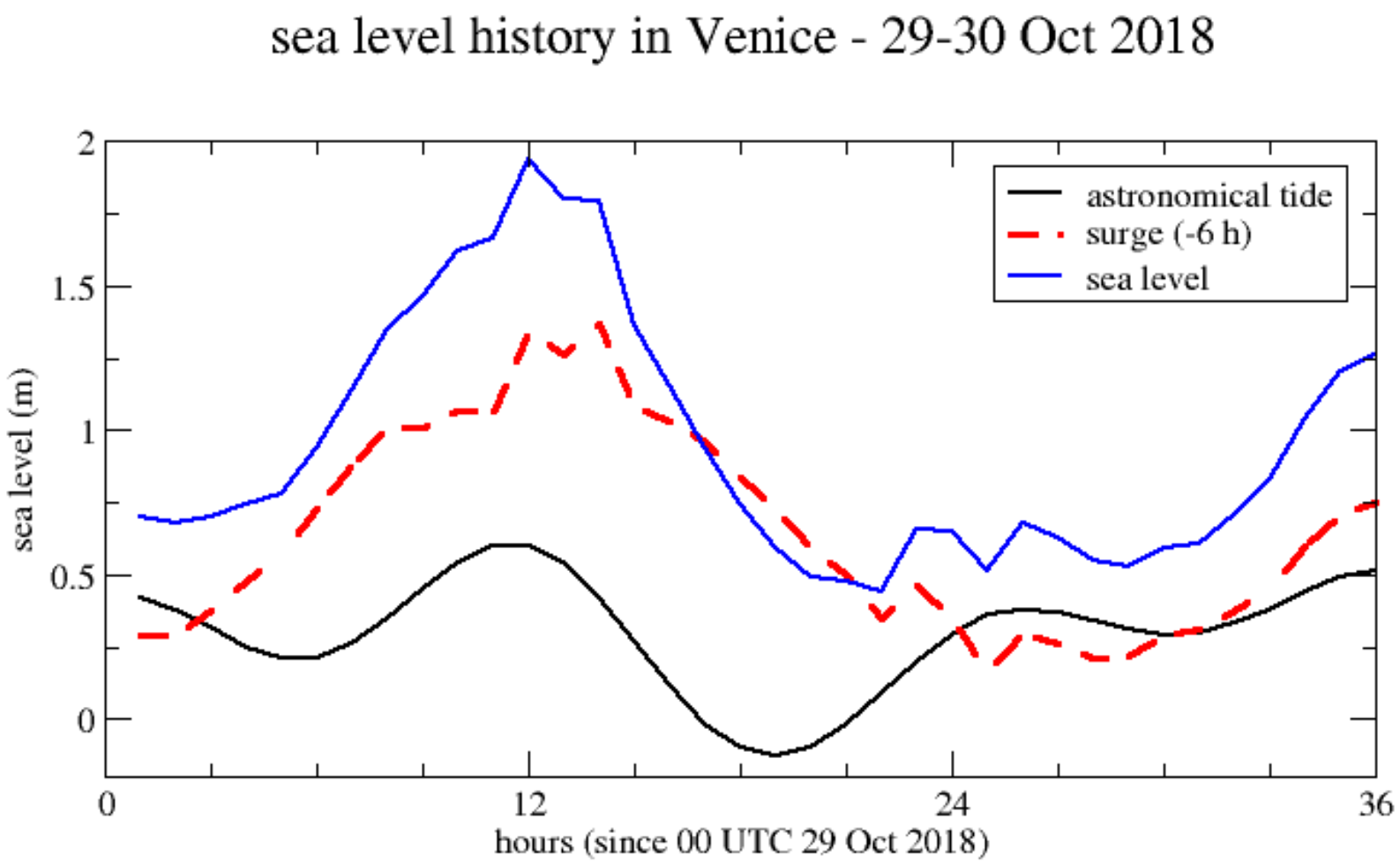

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-1 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

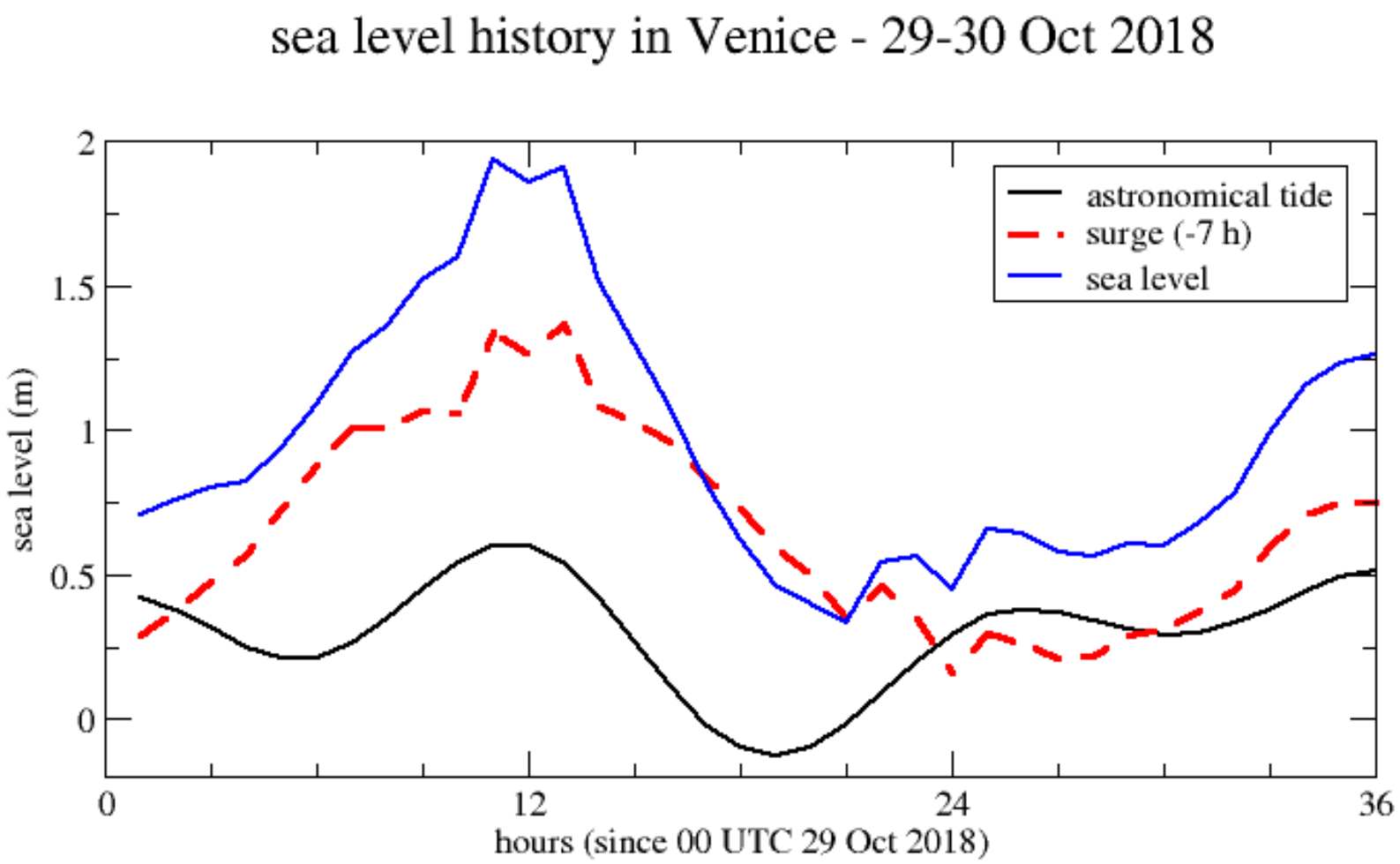

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-2 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

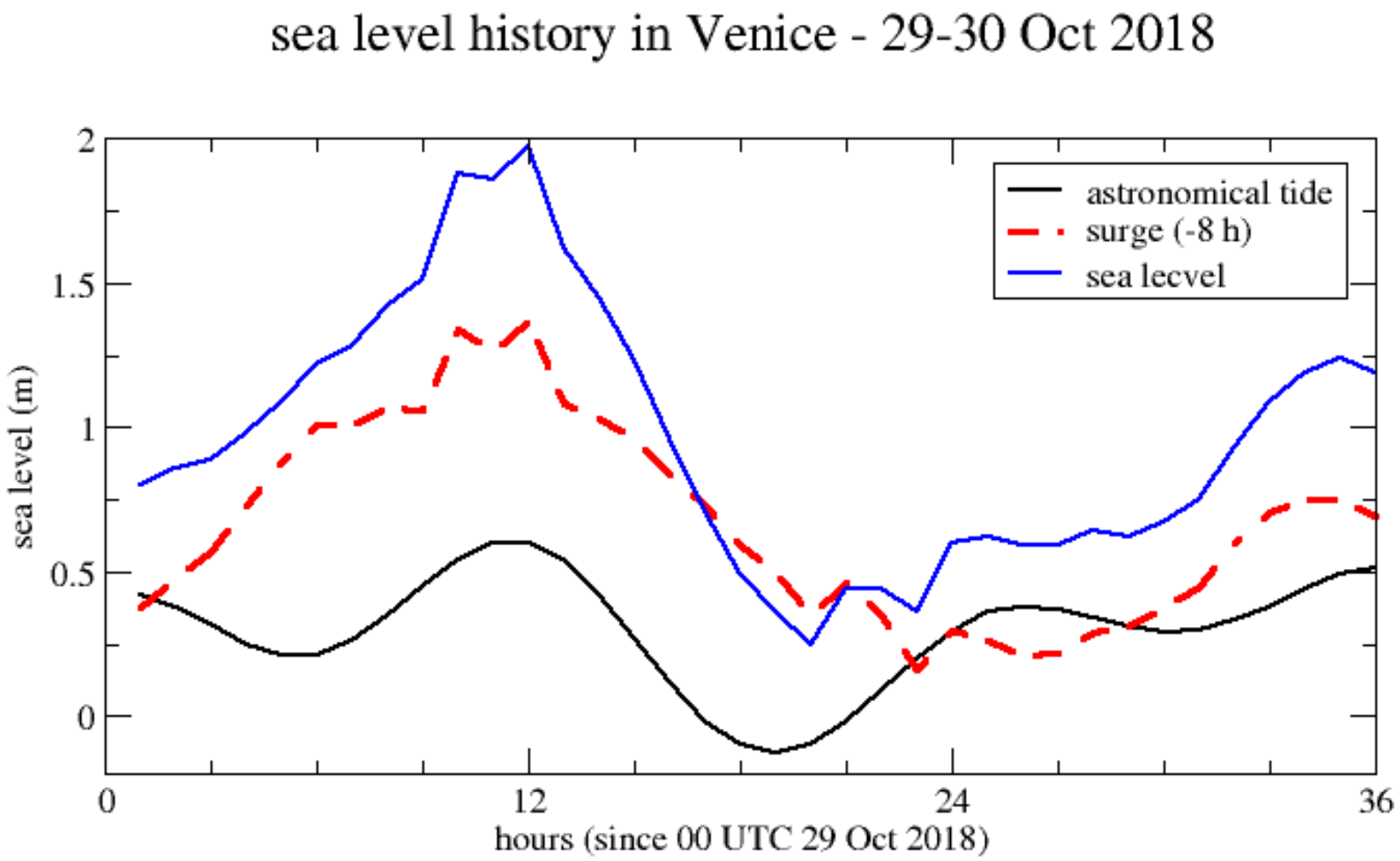

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-3 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

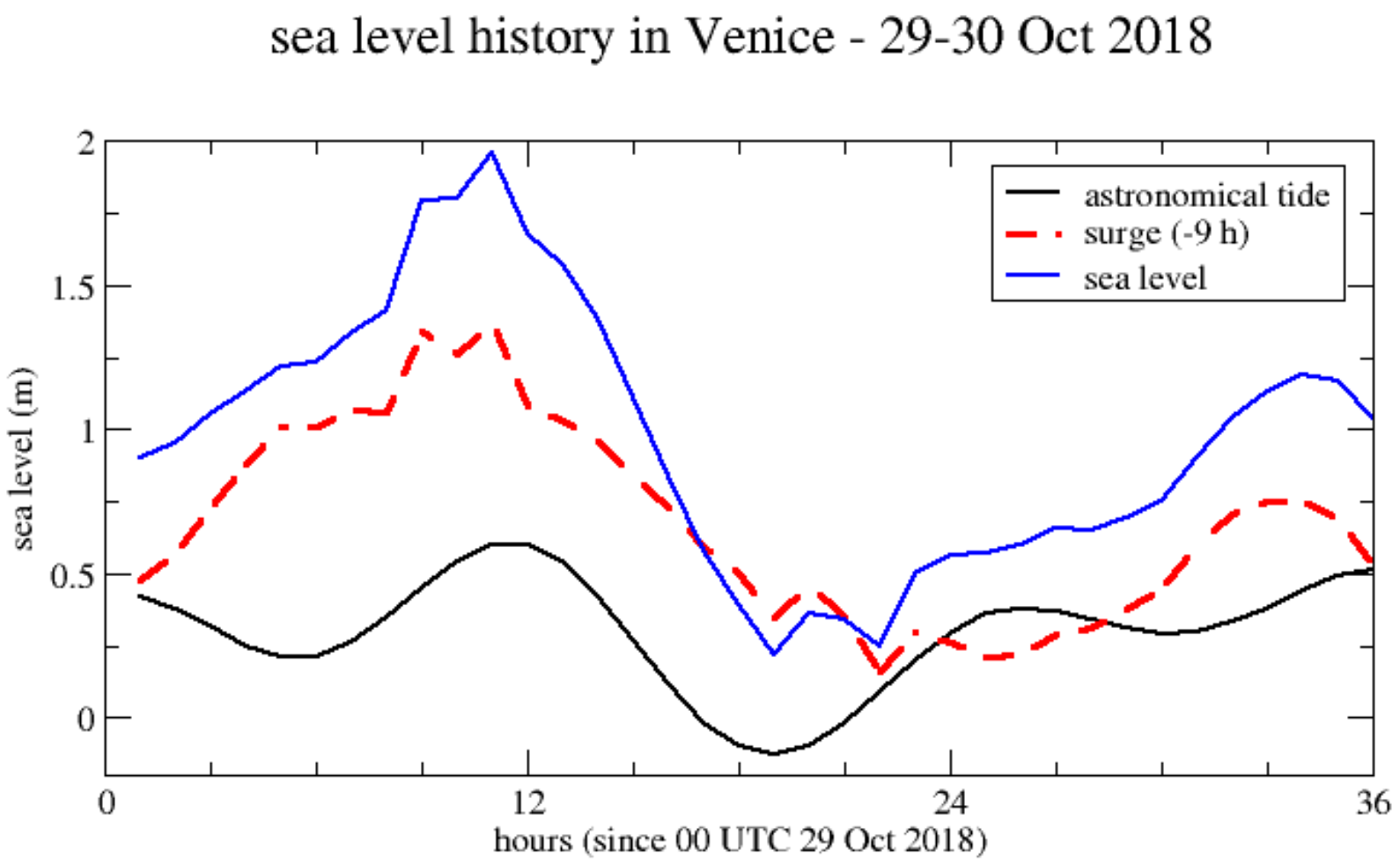

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (- 4 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

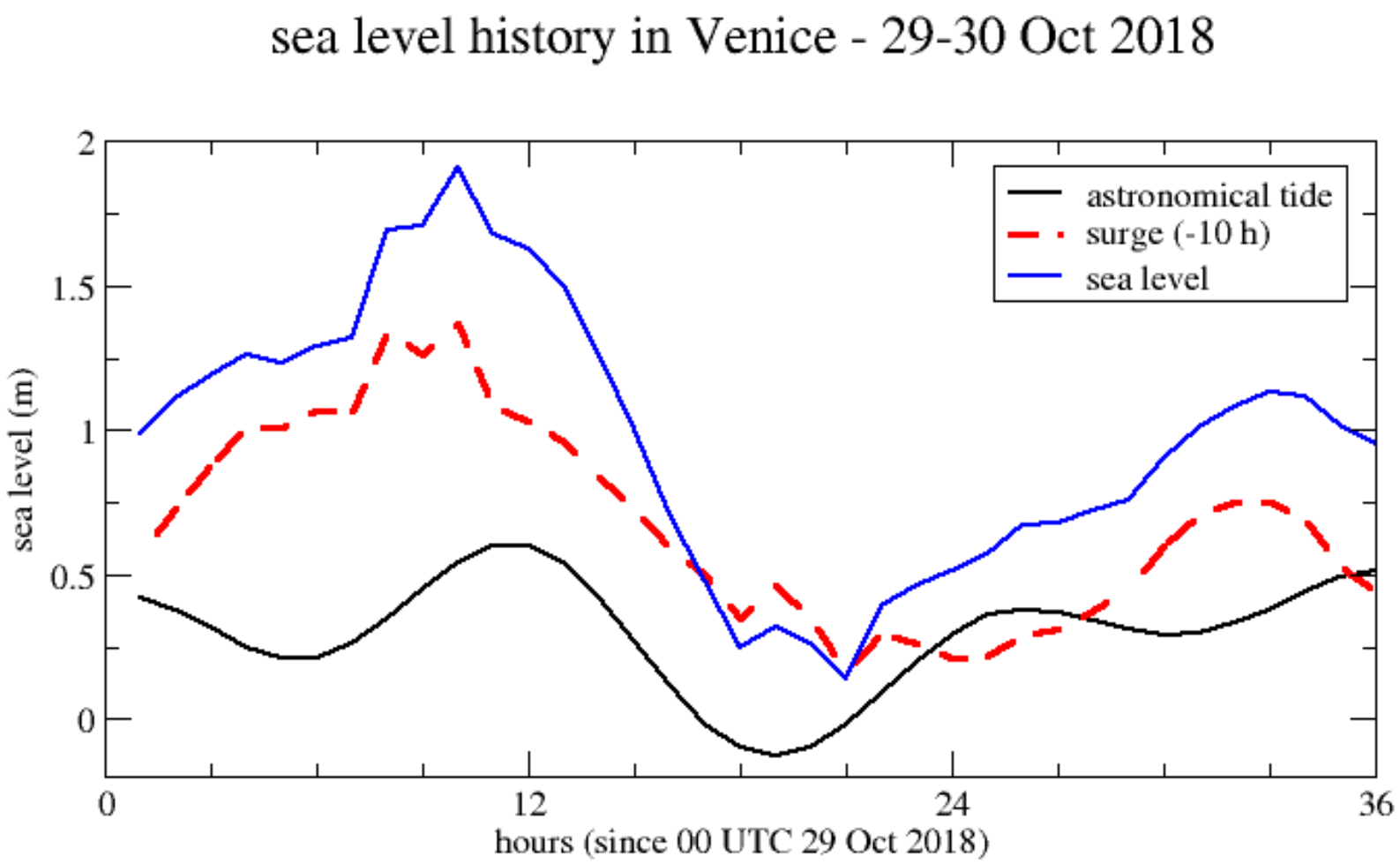

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (- 5 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)


sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-6 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)


sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-7 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)


sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-8 h)
sea lecvel
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

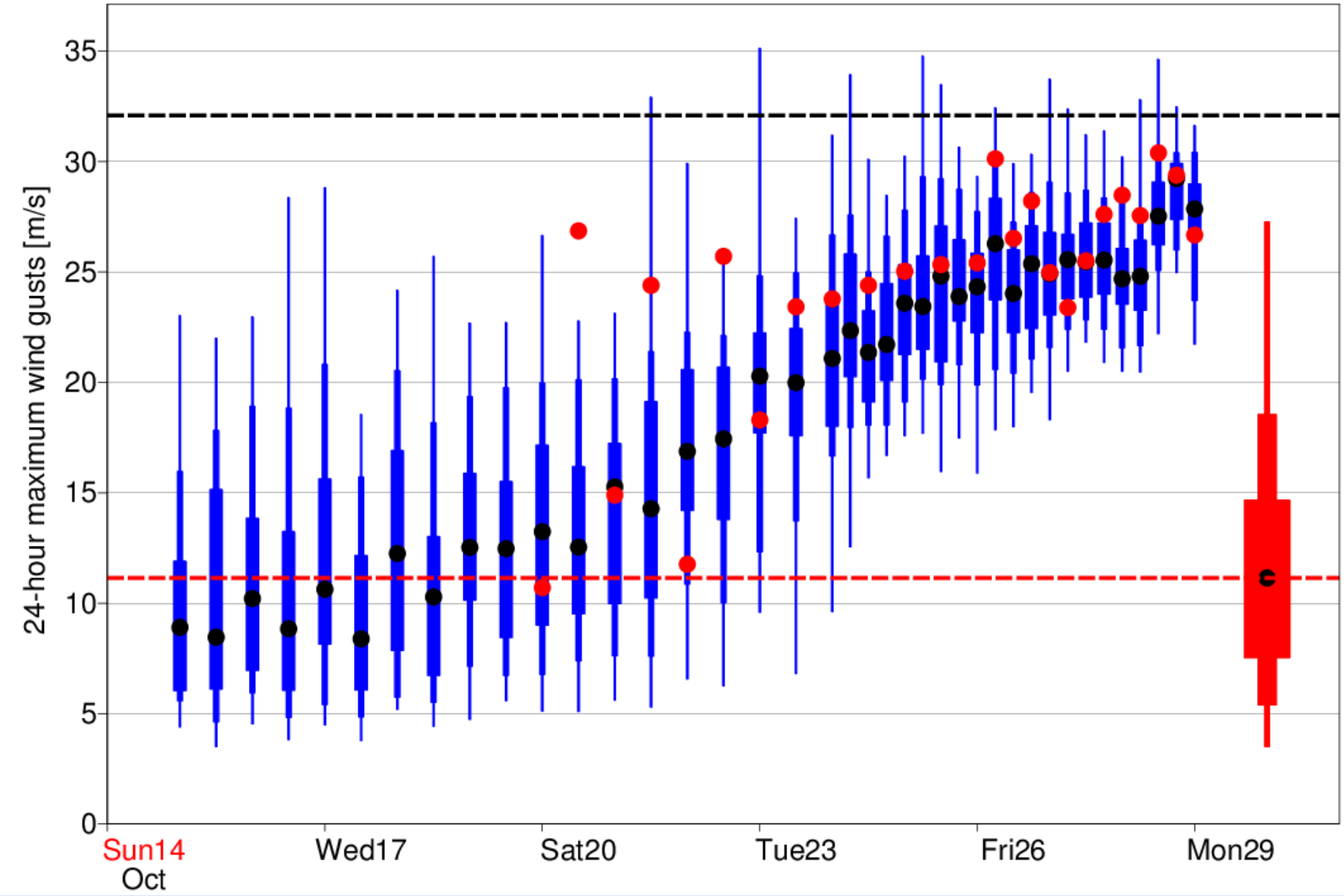

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-9 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

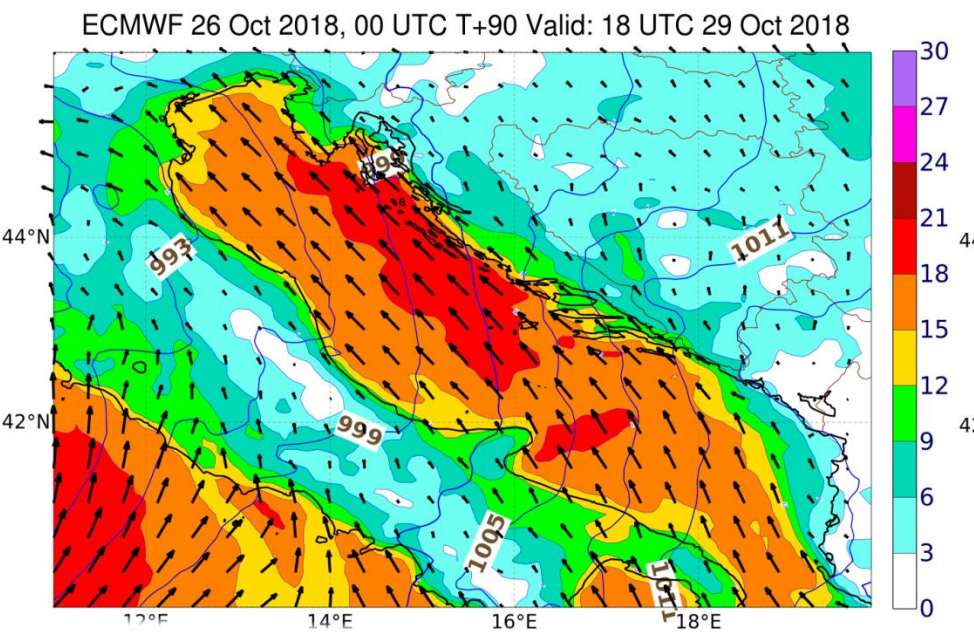

sea level history in Venice - 29-30 Oct 2018
astronomical tide
surge (-10 h)
sea level
sea level (m)
2
1.5
1
0.5
0
0
12
24
36
hours (since 00 UTC 29 Oct 2018)

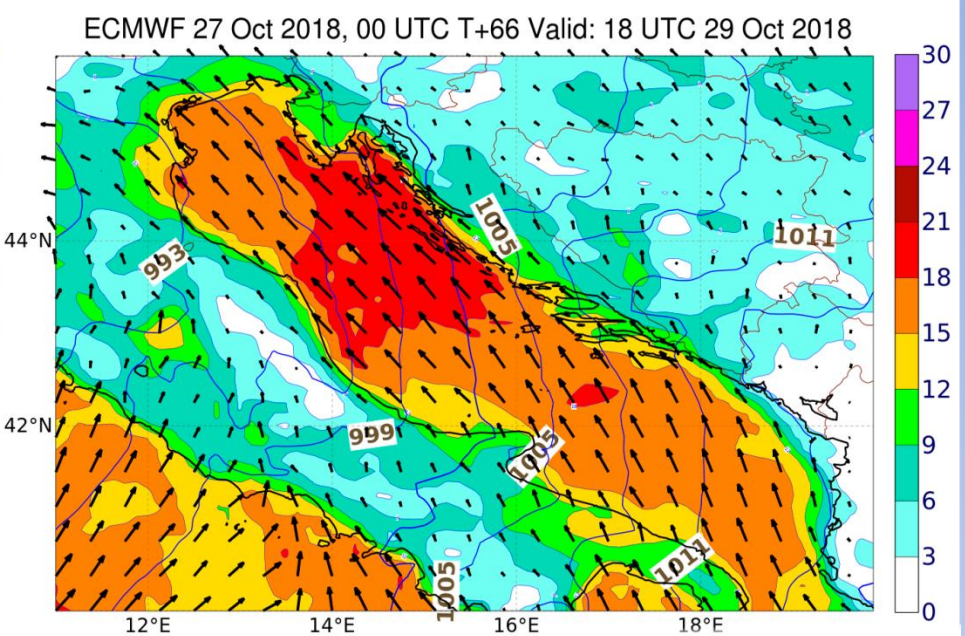
what about predictability ?

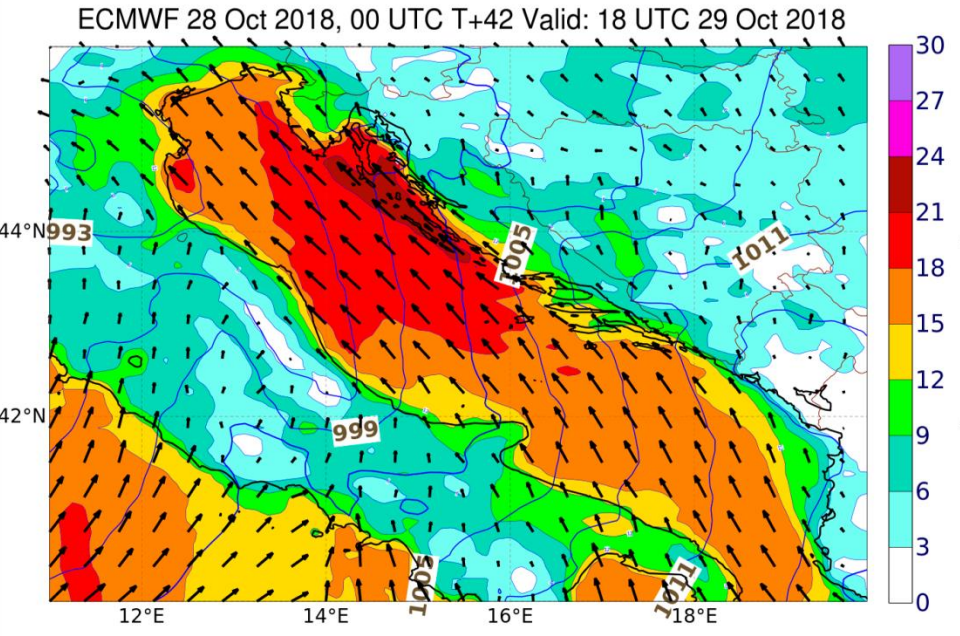
we can do various things:

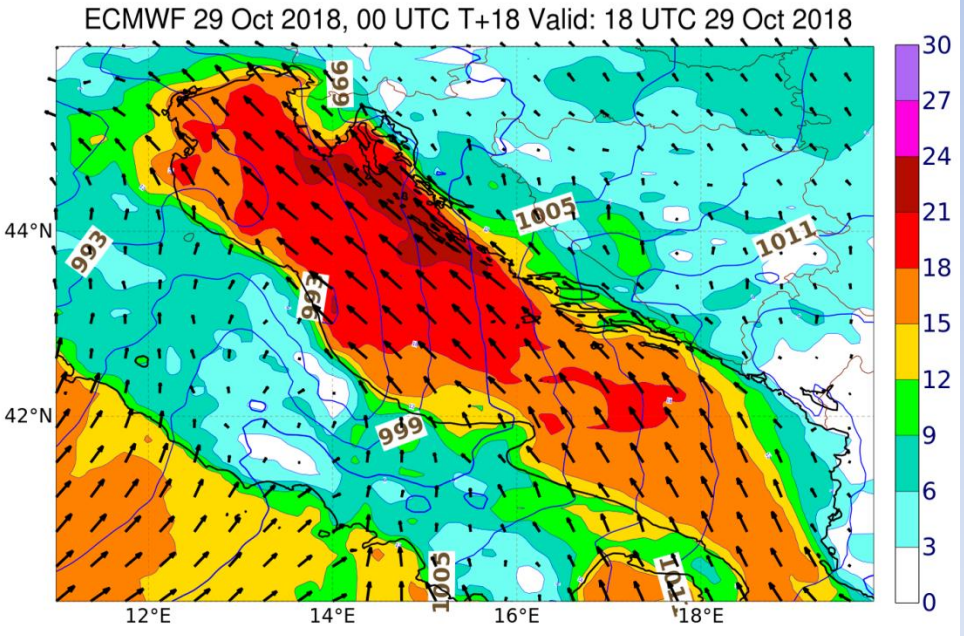
- check the forecasts of ECMWF (e.g. gustiness)
- explore the forecasts of ECMWF (wind fields)
- see, using these forecasts, how was the one of waves and surge


24-hour maximum wind gusts [m/s]
35
30
25
20
15
10
5
0
Sun14
Oct
Wed17
Sat20
Tue23
Fri26
Mon29
c

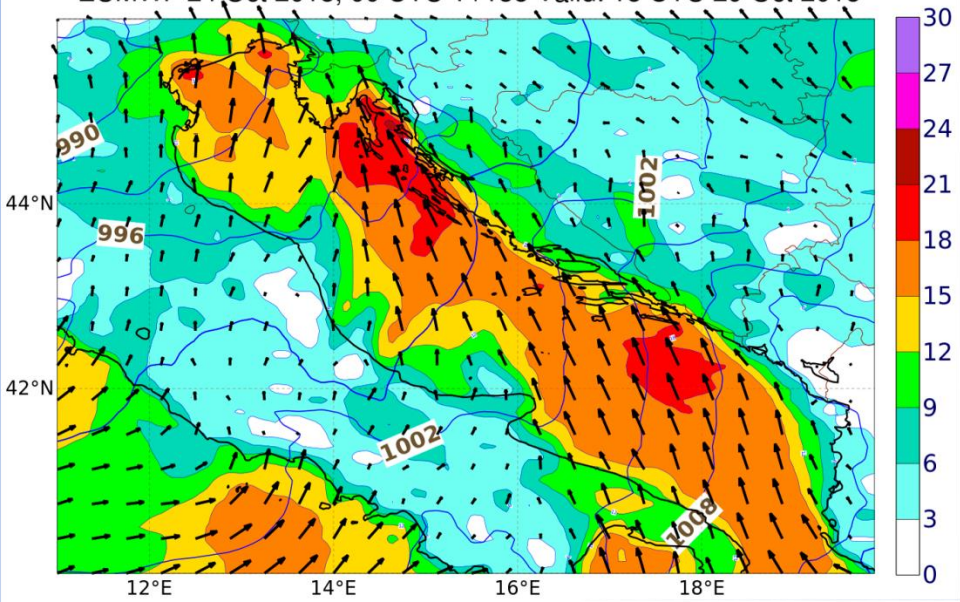

ECMWF 26 Oct 2018, 00 UTC T+90 Valid: 18 UTC 29 Oct 2018
44°N
42°N
12°E
14°E
16°E
18°E
993
999
1005
1011
30
27
24
21
18
15
12
9
6
3
0


ECMWF 27 Oct 2018, 00 UTC T+66 Valid: 18 UTC 29 Oct 2018
44°N
42°N
12°E
14°E
16°E
18°E
993
999
1005
1011
30
27
24
21
18
15
12
9
6
3
0

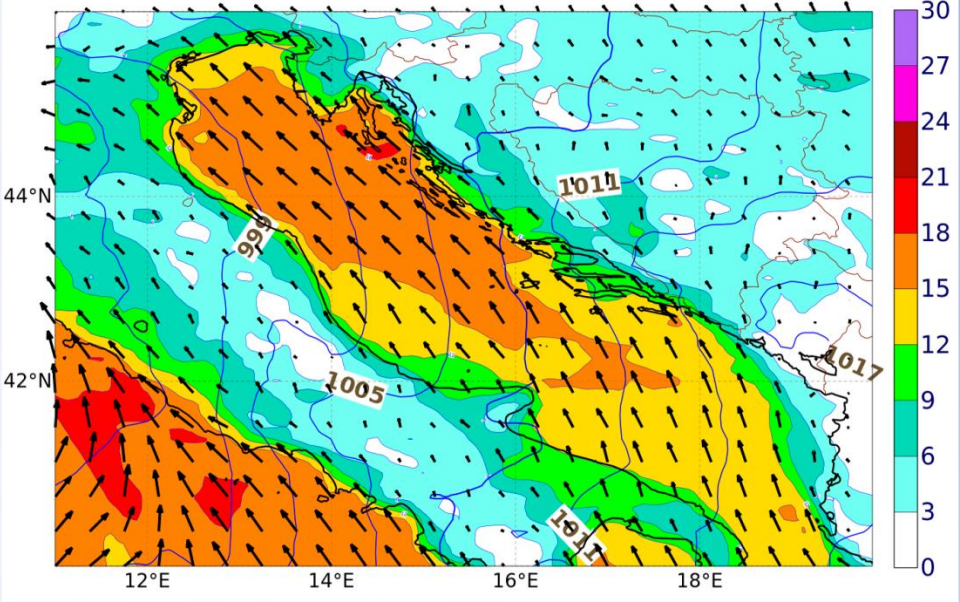

ECMWF 28 Oct 2018, 00 UTC T+42 Valid: 18 UTC 29 Oct 2018
44°N
42°N
12°E
14°E
16°E
18°E
993
999
1005
1011
30
27
24
21
18
15
12
9
6
3
0


ECMWF 29 Oct 2018, 00 UTC T+18 Valid: 18 UTC 29 Oct 2018
44°N
42°N
12°E
14°E
16°E
18°E
993
999
1005
1011
30
27
24
21
18
15
12
9
6
3
0

ECMWF 24 Oct 2018, 00 UTC T+138 Valid: 18 UTC 29 Oct 2018



ECMWF 25 Oct 2018, 00 UTC T+114 Valid: 18 UTC 29 Oct 2018



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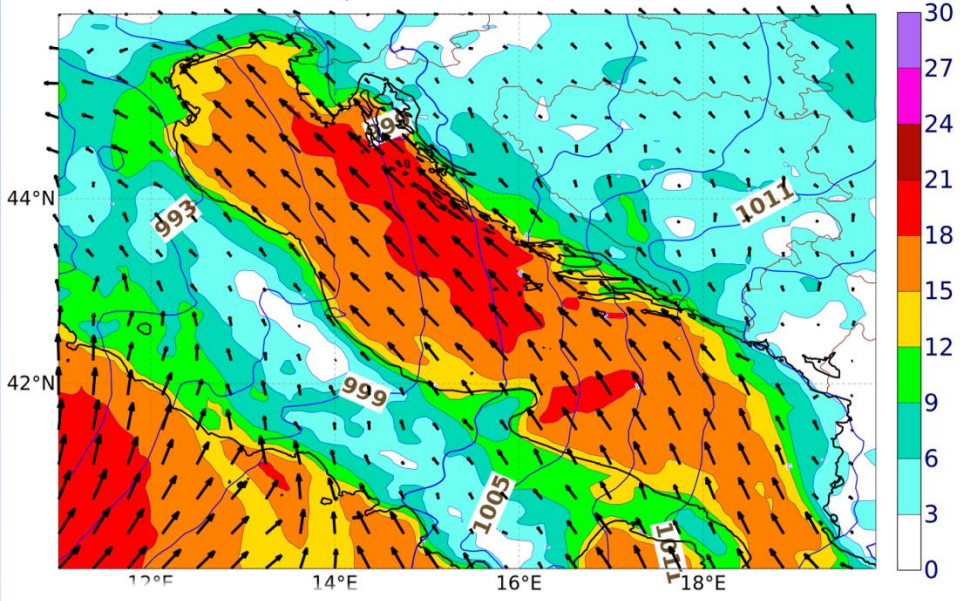
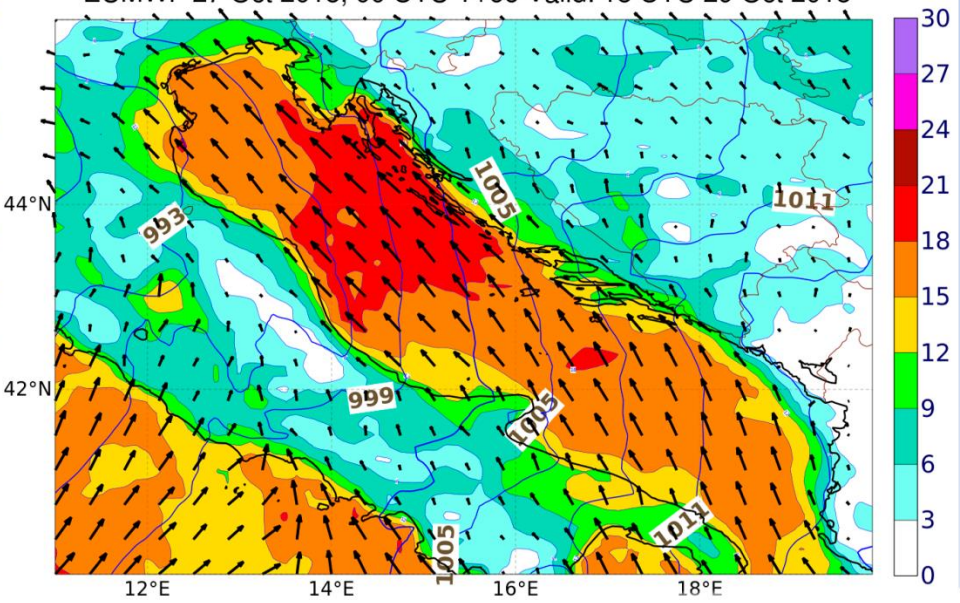
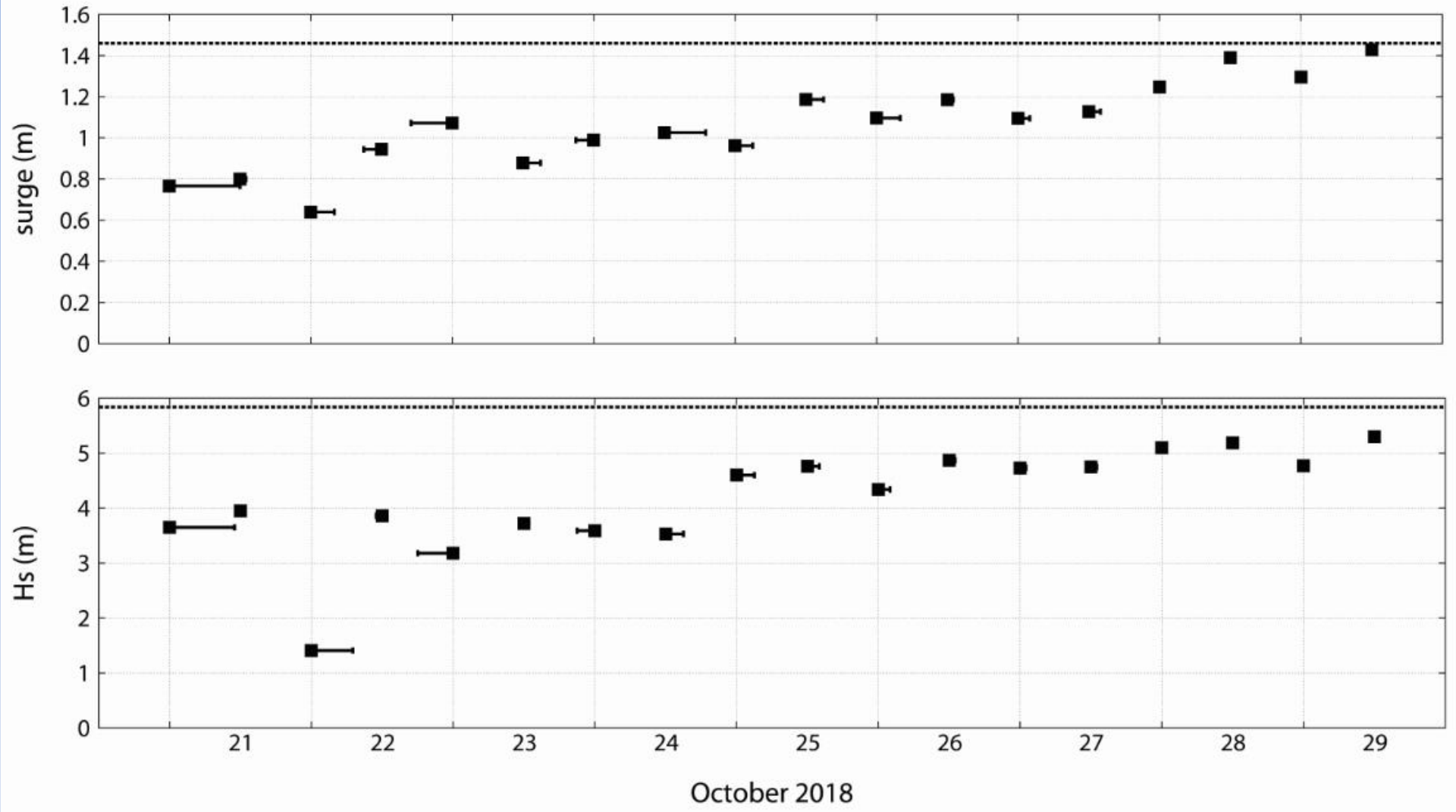


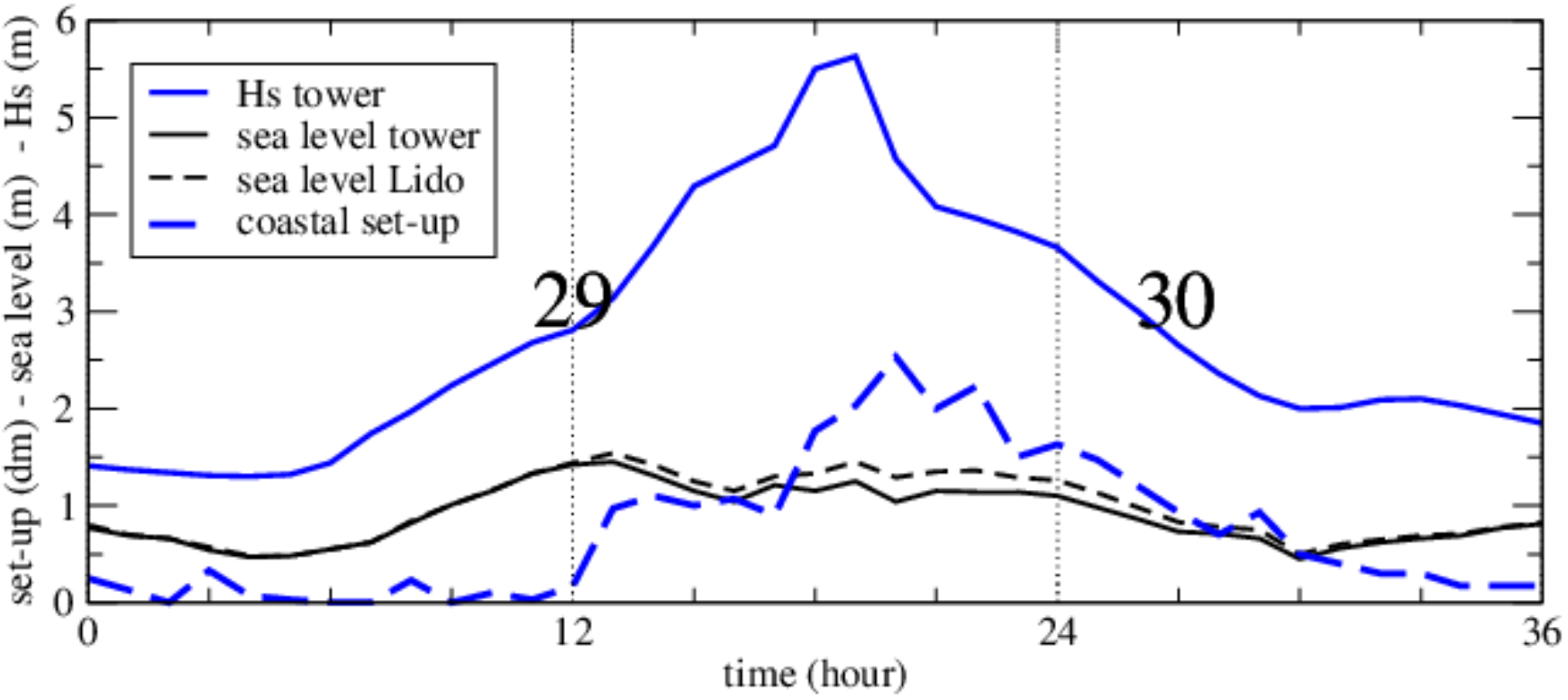
ECMWF 27 Oct 2018, 00 UTC T+66 Valid: 18 UTC 29 Oct 2018

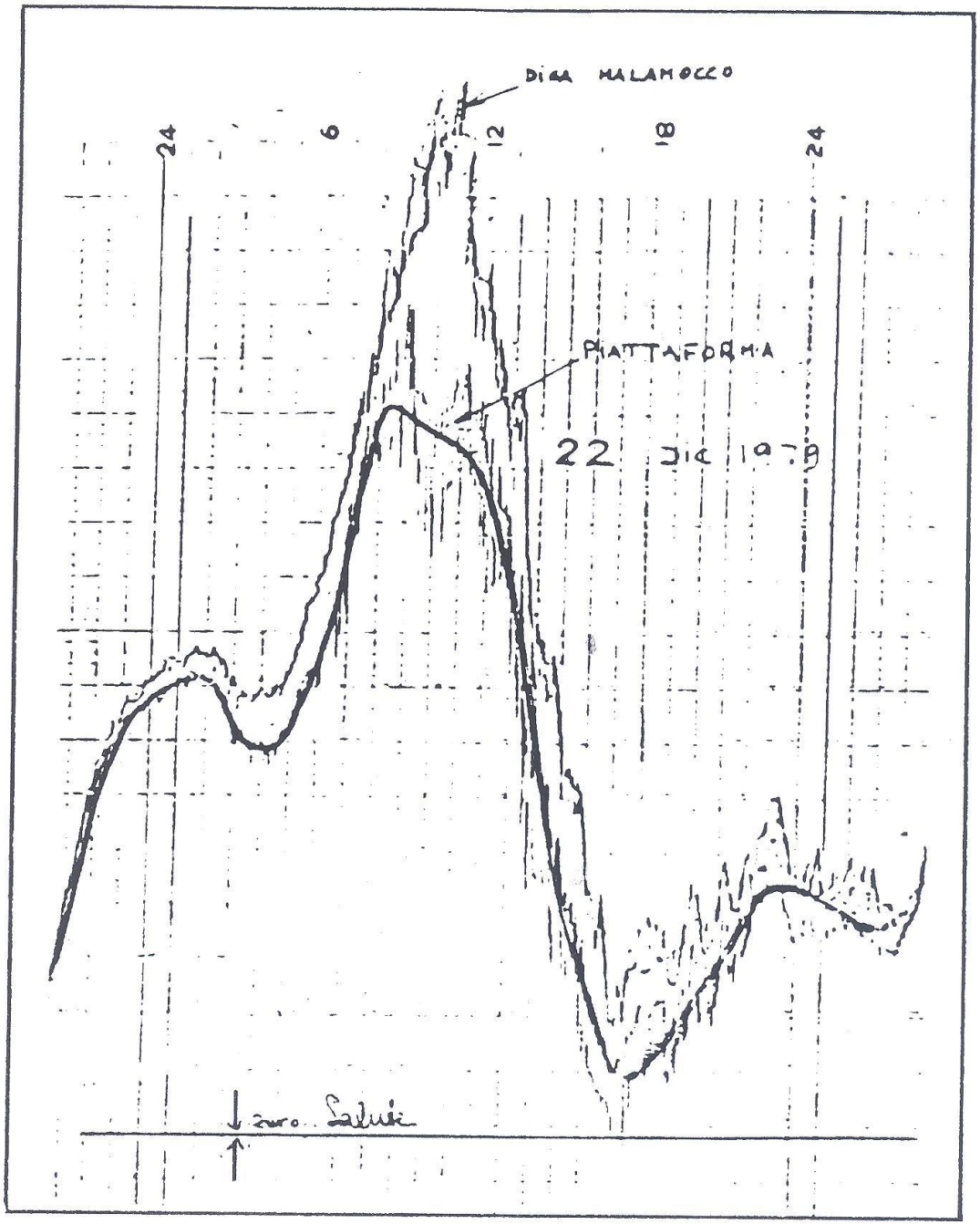


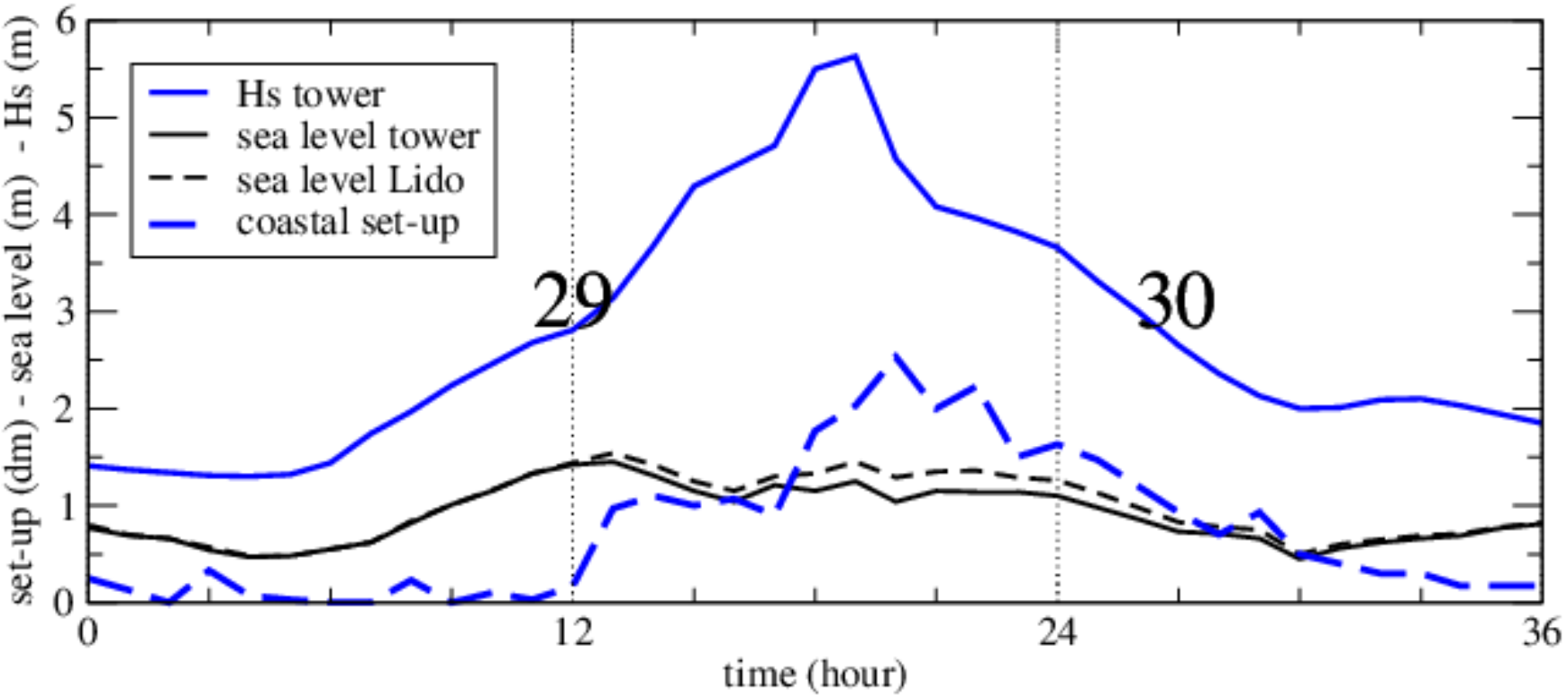
ECMWF 28 Oct 2018, 00 UTC T+42 Valid: 18 UTC 29 Oct 2018

ECMWF 29 Oct 2018, 00 UTC T+18 Valid: 18 UTC 29 Oct 2018


surge (m)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Hs (m)
6
5
4
3
2
1
0
21
22
23
24
25
26
27
28
29
October 2018

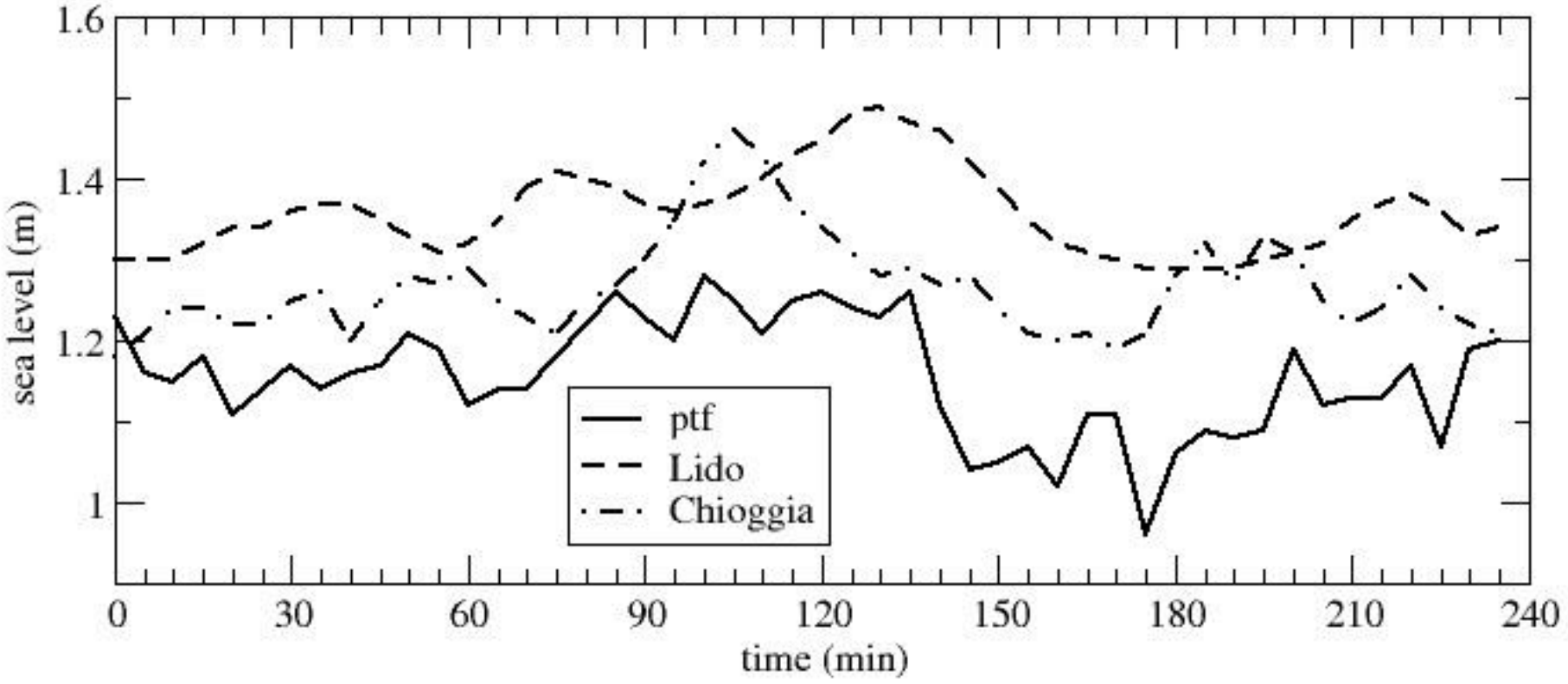

Hs tower
sea level tower
sea level Lido
coastal set-up
29
30
set-up (dm) - sea level (m) - Hs (m)
time (hour)
0
1
2
3
4
5
6
0
12
24
36


DIGA MALAMOCCO
24
6
12
18
24
PIATTAFORMA
22 DIC 1979
zero Salute


Hs tower
sea level tower
sea level Lido
coastal set-up
29
30
set-up (dm) - sea level (m) - Hs (m)
time (hour)
0
1
2
3
4
5
6
0
12
24
36


Venice
Lido
lagoon
Malamocco
Acqua Alta
tower
Chioggia
0
10 km

sea level variation in time at the tower (ptf) and at the coastal inlets tide gauges (Lido and Chioggia)



did all this trigger anything in particular ?

think a bit:

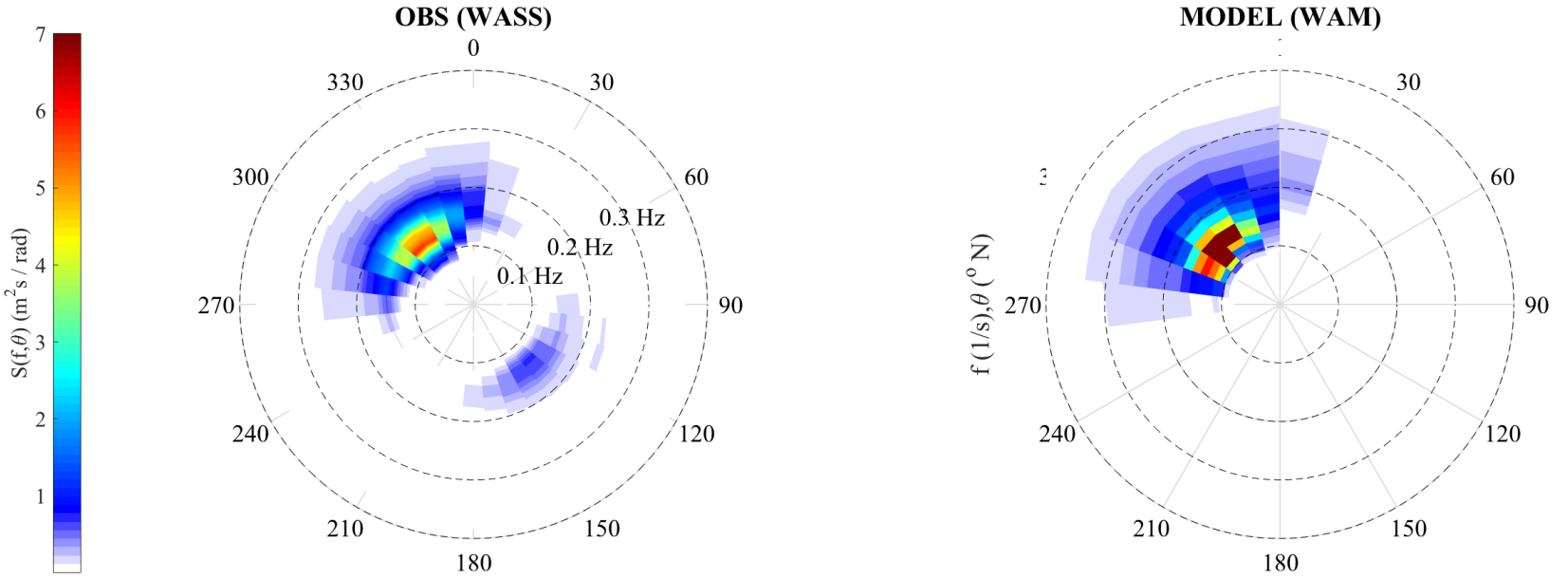
1 – we have a coastal set-up due to wind pile up and wave set-up

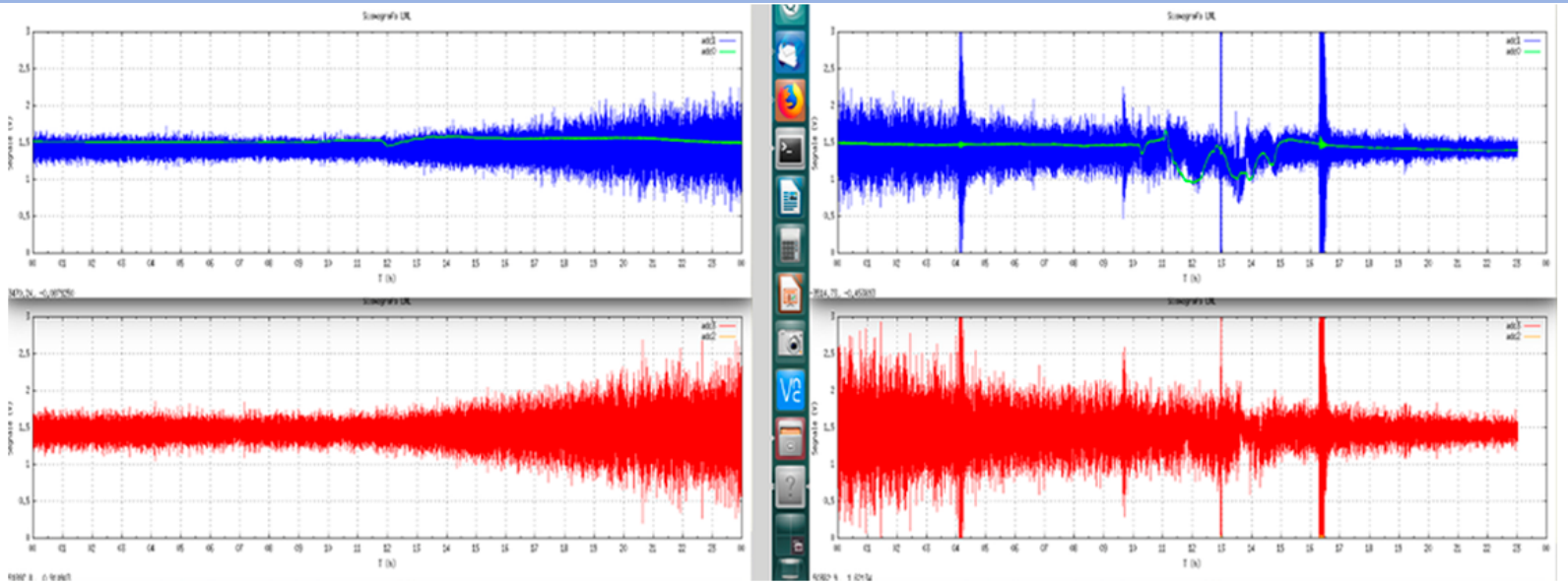
2 – wind pile up is due to the atmospheric surface stress

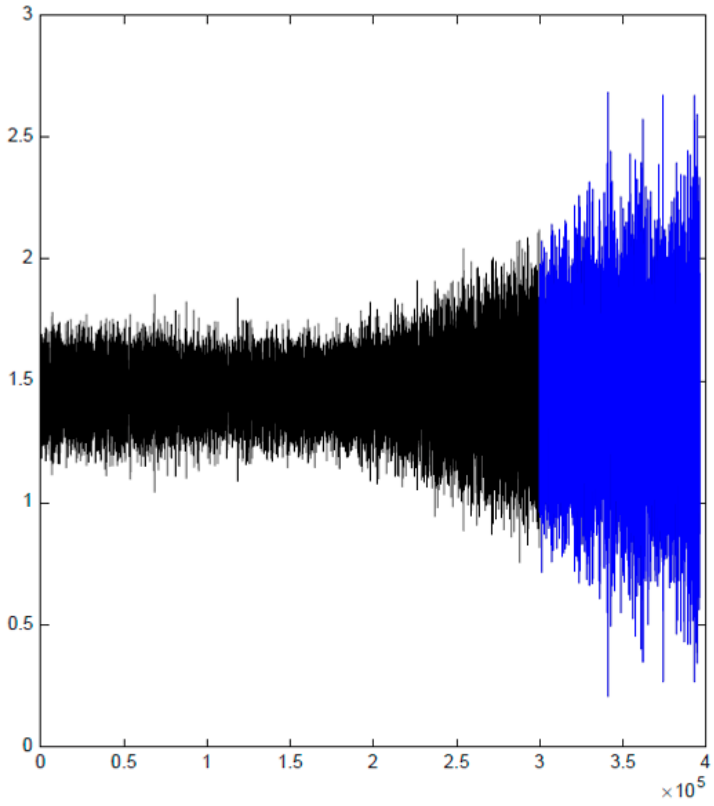
3 – suddenly we shut off, or change direction of, wind

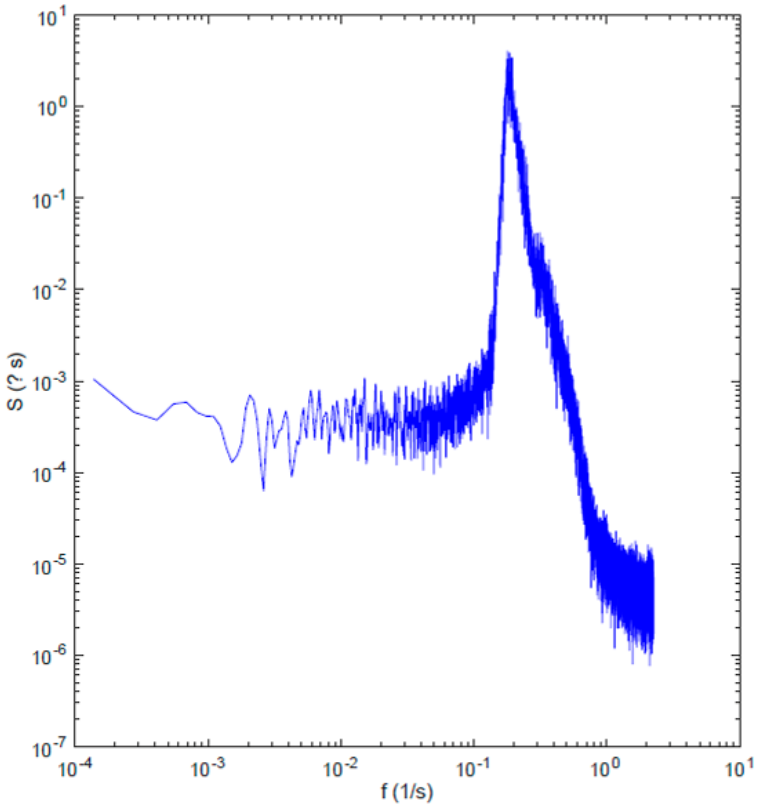
4 – in a few minutes the slope towards the coast (partly) collapses

5 – for the first time (?) we have a direct measurement of the effect of surface wind stress


OBS (WASS)
MODEL (WAM)
S(f,θ) (m²s / rad)
f (1/s),θ (° N)
0.1 Hz
0.2 Hz
0.3 Hz
0
30
60
90
120
150
180
210
240
270
300
330
1
2
3
4
5
6
7

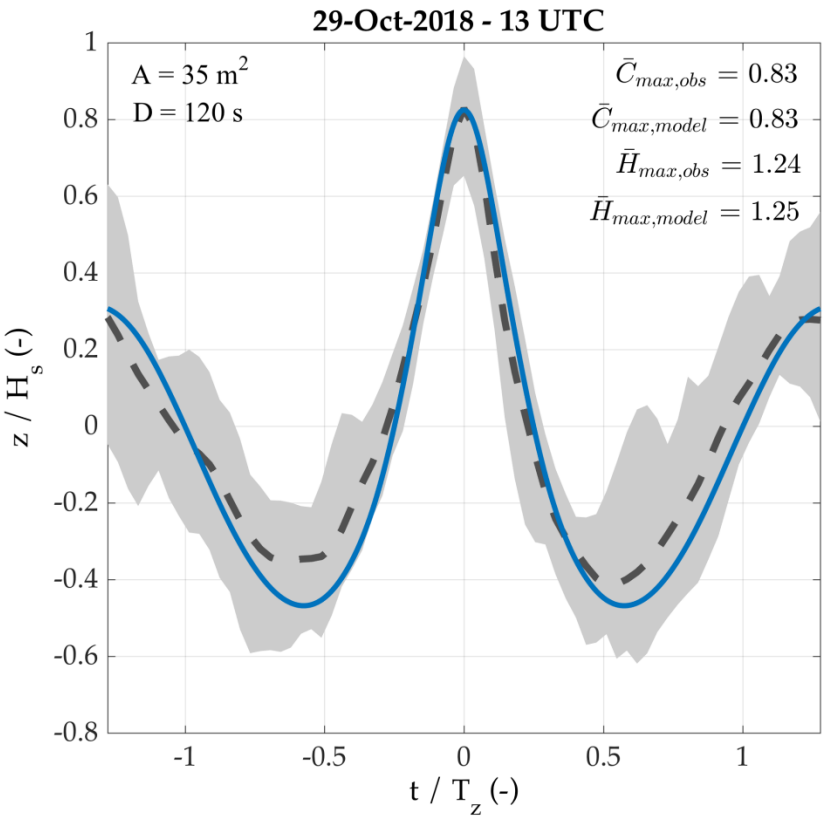


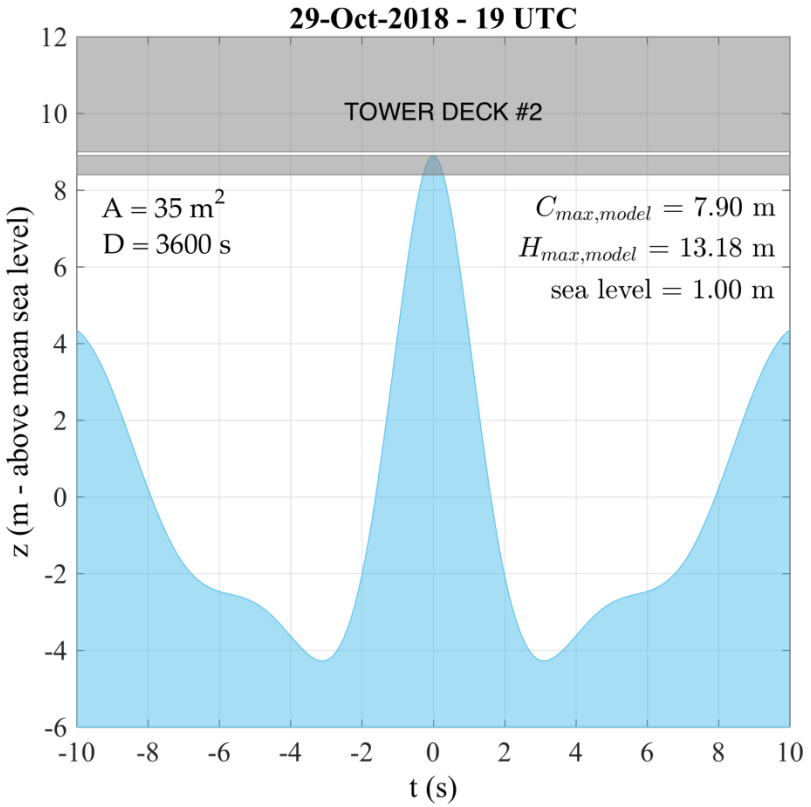

3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
×10^5


10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
S (? s)
10^-4
10^-3
10^-2
10^-1
10^0
10^1
f (1/s)

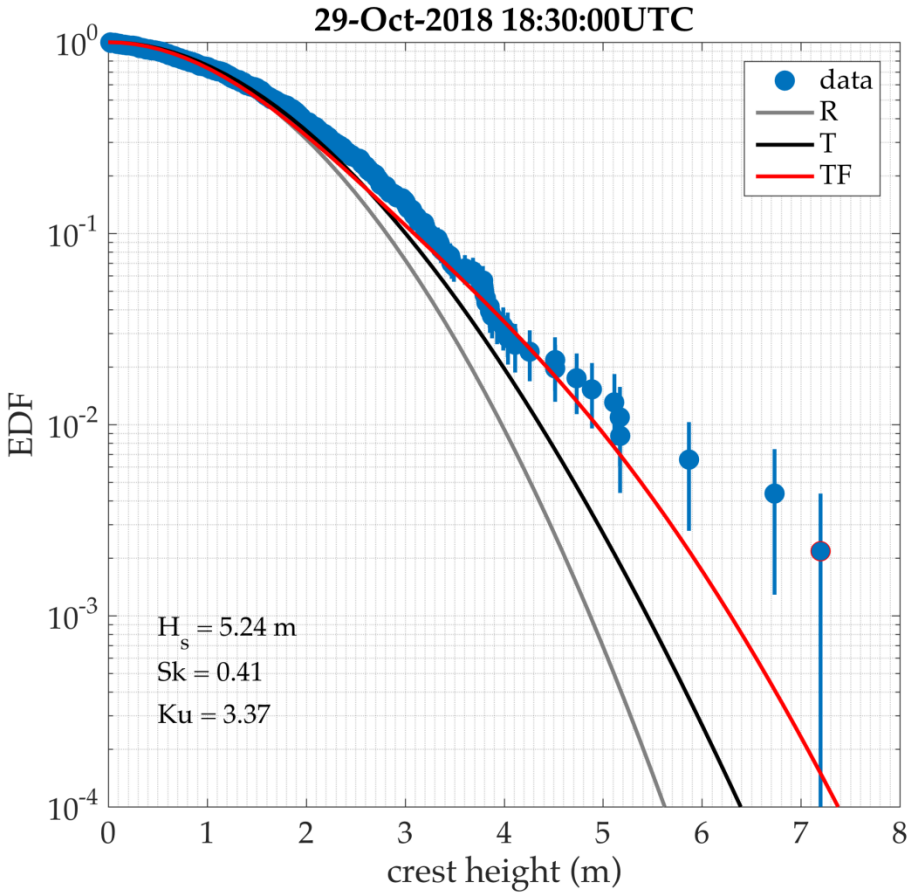
let us talk a bit about what we measured – just because we are here, wave heights

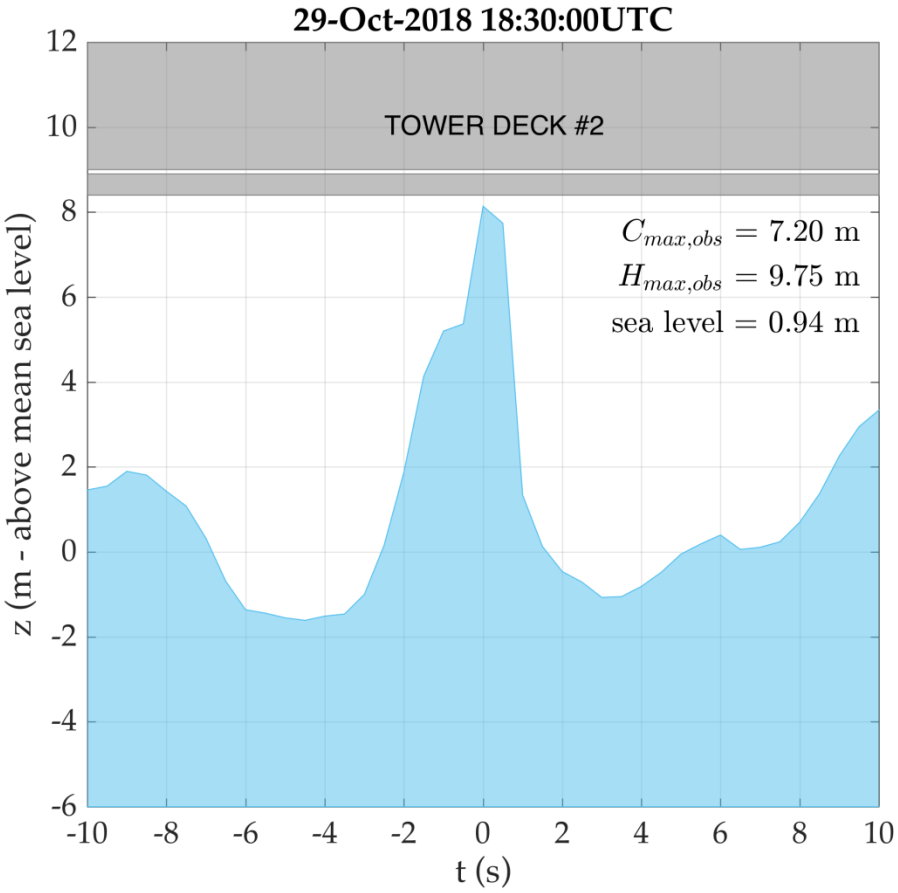
in particular, given a spectrum, which are the shape and height of the highest expected wave?





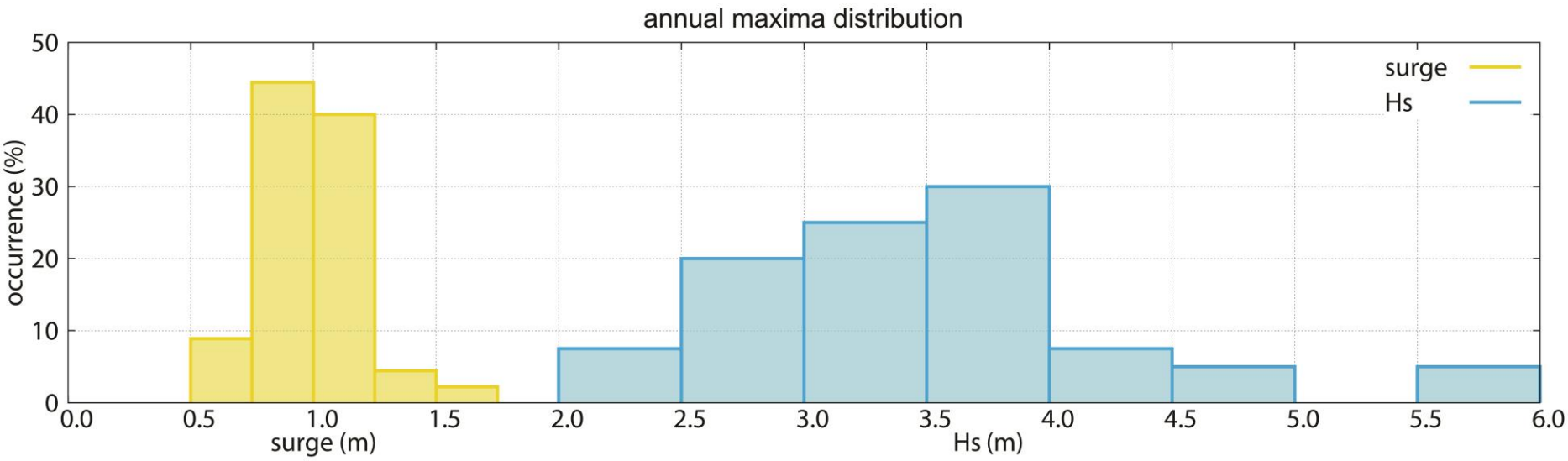
we have continuous recording at 2 Hz – what about the crest height distribution ?





last piece of information (but a big question) :

We have 40 years of measured wave heights (that we have also hindcast of course) : we plot the yearly peak values



Focus your attention on the significant wave heights :

basically we have a continuous distribution (e.g., …, 3.9, 4.1, 4.3, 4.4 m, then the void till two storms (three with the historical 1966) whose values are at 6 m Hs (8 m estimated for 1966, also supported by the damages)

My question: are we dealing with a single or two families of events?

Questions

(and possibly suggestions please)

Thanks