Wave Climate for 12 Locations

11 February 2022

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ECMWF

Introduction

- Wave (and wind) climate at 12 locations is computed.
- The locations are shown in Fig. 1 and their coordinates and depth are listed in Table 1.
- Assumptions:
  - Only wave and wind characteristics that impact the safety of deployed instruments are needed.
  - No minimum or maximum thresholds of wave conditions are required for the operability of any instrument.
  - GEBCO 2021 data set and Google Earth represent the bathymetry well enough.
  - The deployment needs to survive wave conditions for 20 years.
  - ERA5 wave fields are realistic representation of the wave conditions at the 12 locations, and they do not deviate much from what really happened between 1991 and 2020.
- Best effort was dedicated to produce the results shown hereafter. ECMWF and the author are not in any way responsible for any consequences of the use of these results.

Summary (1/2):

- The 12 locations can be classified into 3 groups based on the significant wave height (SWH) and mean wave period (MWP) long-term climate (Fig. 2, 7 & 3, 8): Low wave height (Antikythera, BOUSSOLE, MSEA-N/S, LAMP1/2/3/4), Medioum wave height (MOBY) and high wave height (El-Hierro and Madeira_OPT/SOW).
- A derived parameter was introduced as H2T, which is the square of SWH multiplied by MWP. H2T can be related to the wave energy. The same grouping of emerges in Fig. 5 & 10.
- In terms of wind speed, there is a spectrum of conditions with Madeira_OPT has the calmer conditions (Fig. 4, 9).
- Dominant wave and wind directions are provided in Fig. 11-22 and summarized in Table 2.
- The annual mean SWH (LHS of Fig. 23) and MWP (LHS of Fig. 24) support the 3 groups of wave conditions seen in the PDF's. However, the annual extreme SWH (RHS of Fig. 23) indicates that all locations are subject to comparable extreme conditions except for MOBY which is subject to much lower extremes.
- H2T parameter (Fig. 26) suggest that El-Hierro and both Madeira locations are subject to the highest wave energy both as annual means and extremes.

Summary (2/2):

- Madeira_OPT has the calmest wind speed based on both mean and extreme annual values (Fig. 25).
- Non-excedence statistics show that MOBY locations has the calmest wave conditions (Fig. 27) while Madeira_OPT has the calmest wind conditions (Fig. 28).
- Wind and wave conditions at all locations are rougher from November to February and calmer from June to August except for wind speed at MOBY and El-Hierro (Fig. 29, 30, 31, 32).

Recommendations:

- If **safety due to <u>wind</u> action** is the main concern: *(most probably NOT the case)*
  - Antikythera and BOUSSOLE should be avoided.
  - Madeira_OPT seems to be a good candidate.

- If **safety due to <u>wave</u> action** is of main concern:
  - El-Hierro and Madeira_OPT/SOW should be avoided.
  - MOBY seems to be a good candidate. It is subject to the lowest extreme conditions (although it is not as calm as the others most of the year which may be a concern if calm conditions are needed for maintenance, for example).

Data Sources:

- **ERA5 reanalysis data:**
  - C3S Climate Data Store: https://cds.climate.copernicus.eu
  - Hersbach, H, Bell, B, Berrisford, P, et al. The ERA5 global reanalysis. Q J R Meteorol Soc. 2020; 146: 1999– 2049. https://doi.org/10.1002/qj.3803

- **Bathymetry maps:**
  - https://www.gebco.net/data_and_products/gridded_bathymetry_data/
  - GEBCO Compilation Group (2021) GEBCO 2021 Grid (doi:10.5285/c6612cbe-50b3-0cff-e053-6c86abc09f8f)

- **Water depth in Table 1:**
  - https://earth.google.com/web/

Fig. 1: Geographical locations

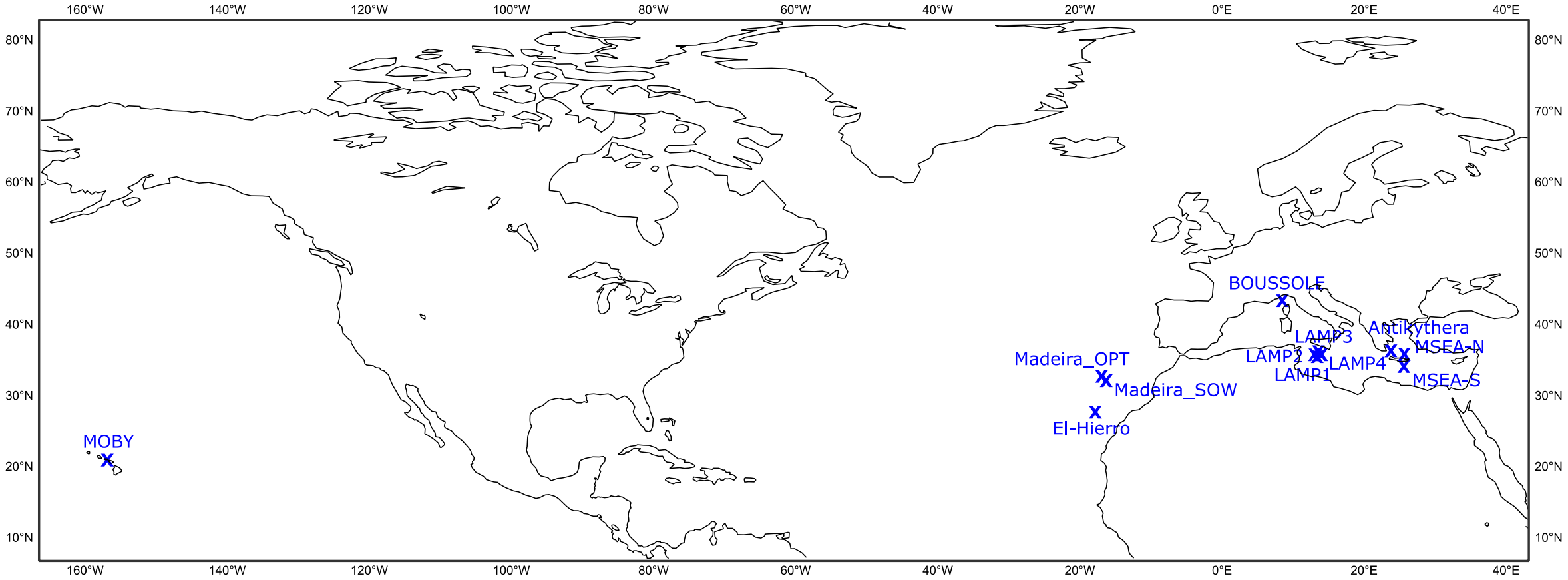


Fig. 1a: Geographical locations (zoom-in)

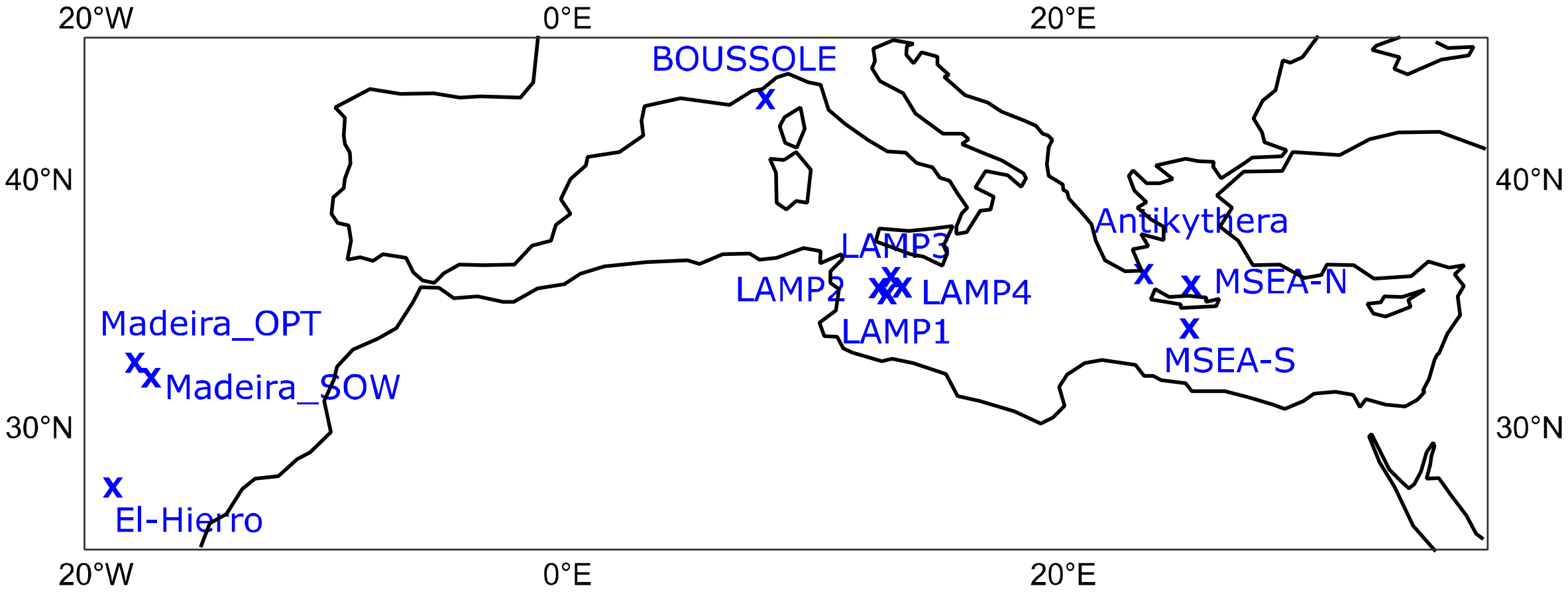


Fig. 1b: Antikythera, MSEA-N, MSEA-S

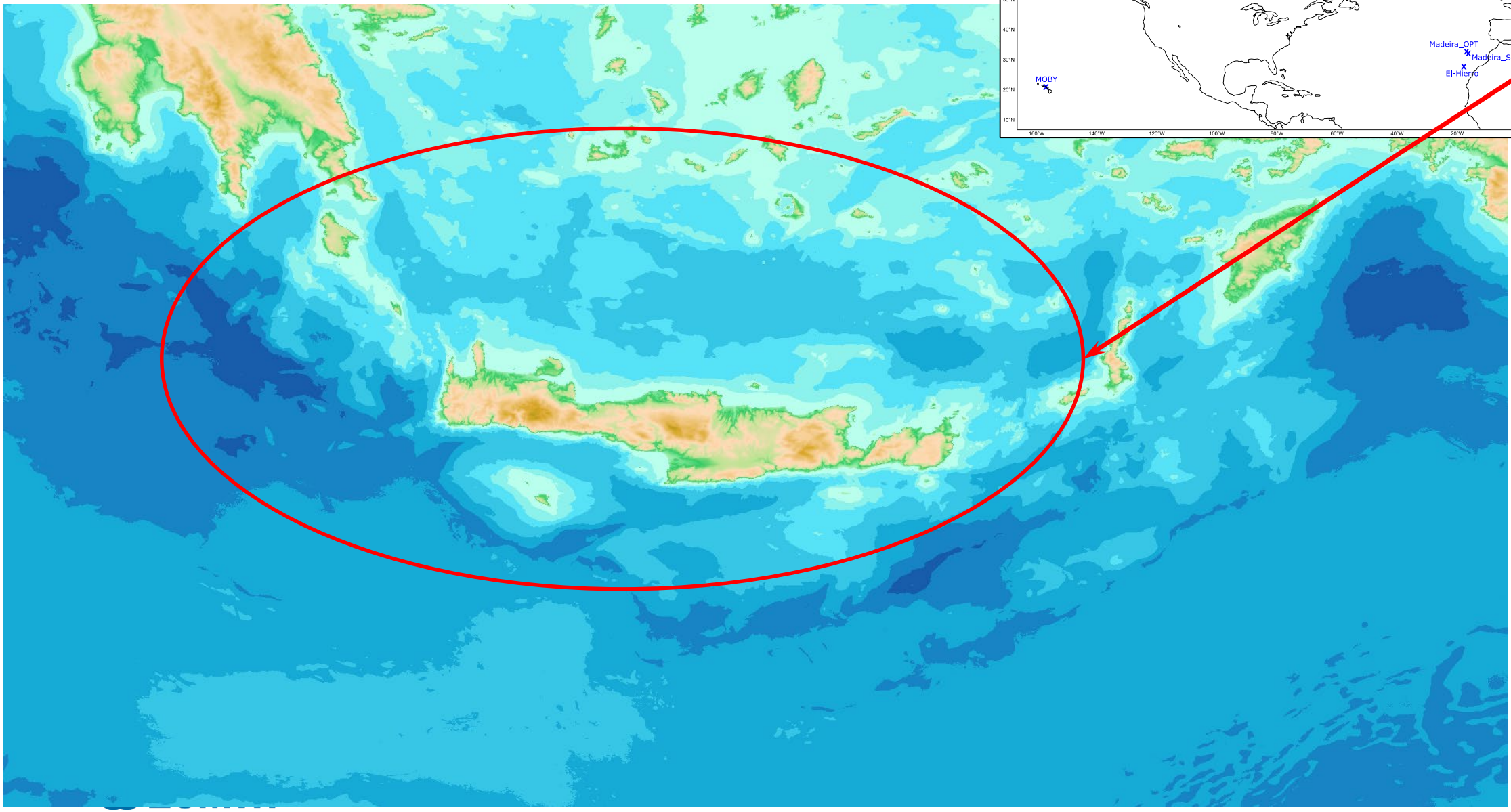
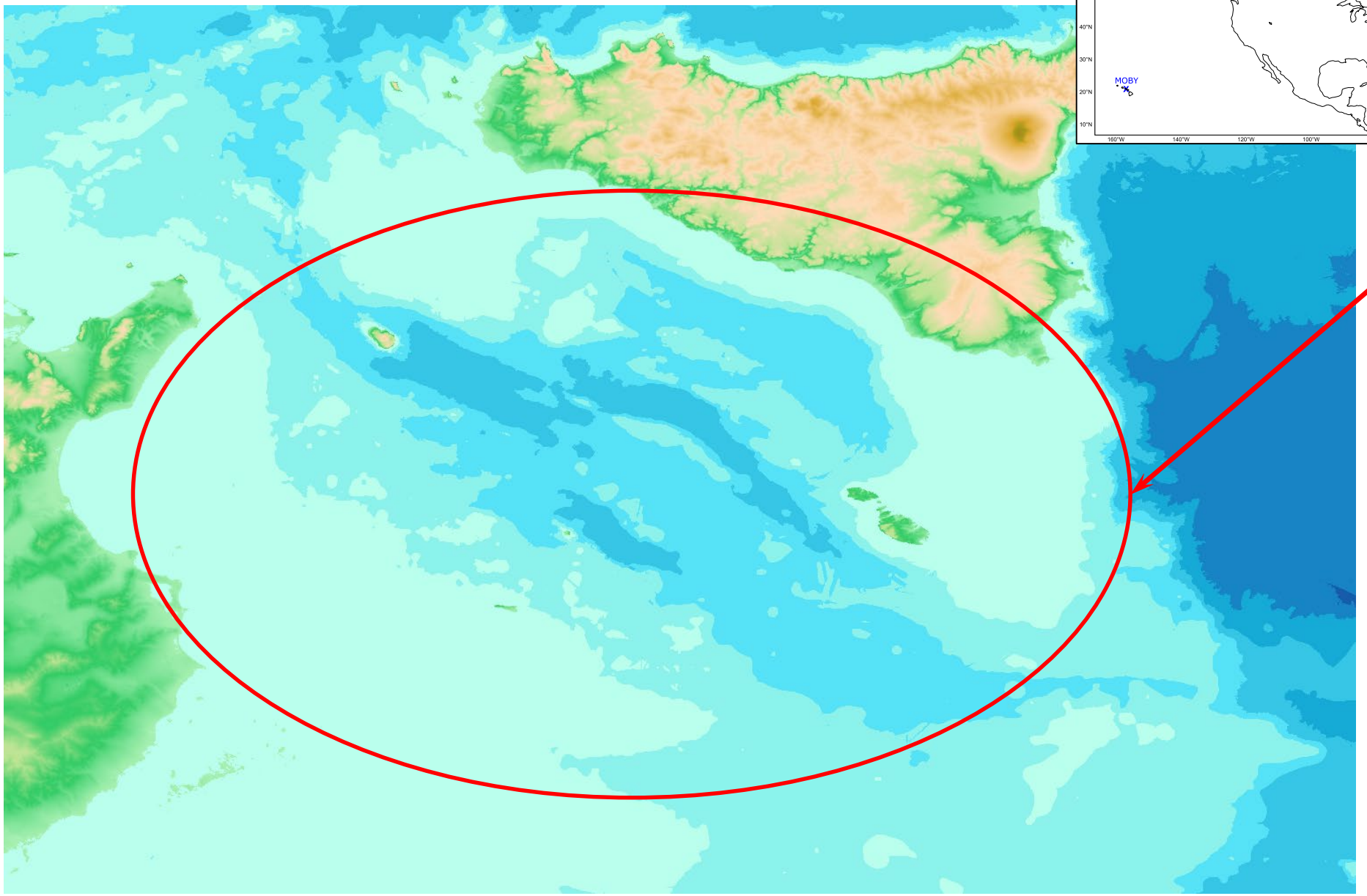


Fig. 1c: LAMP1, LAMP2, LAMP3, LAMP4



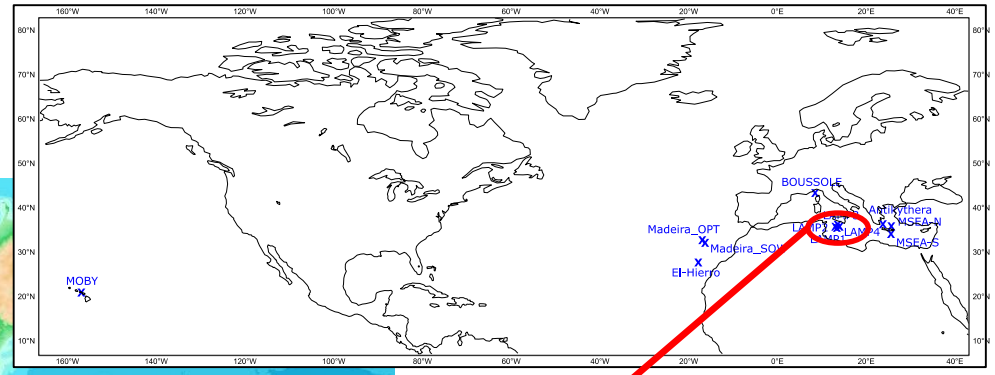
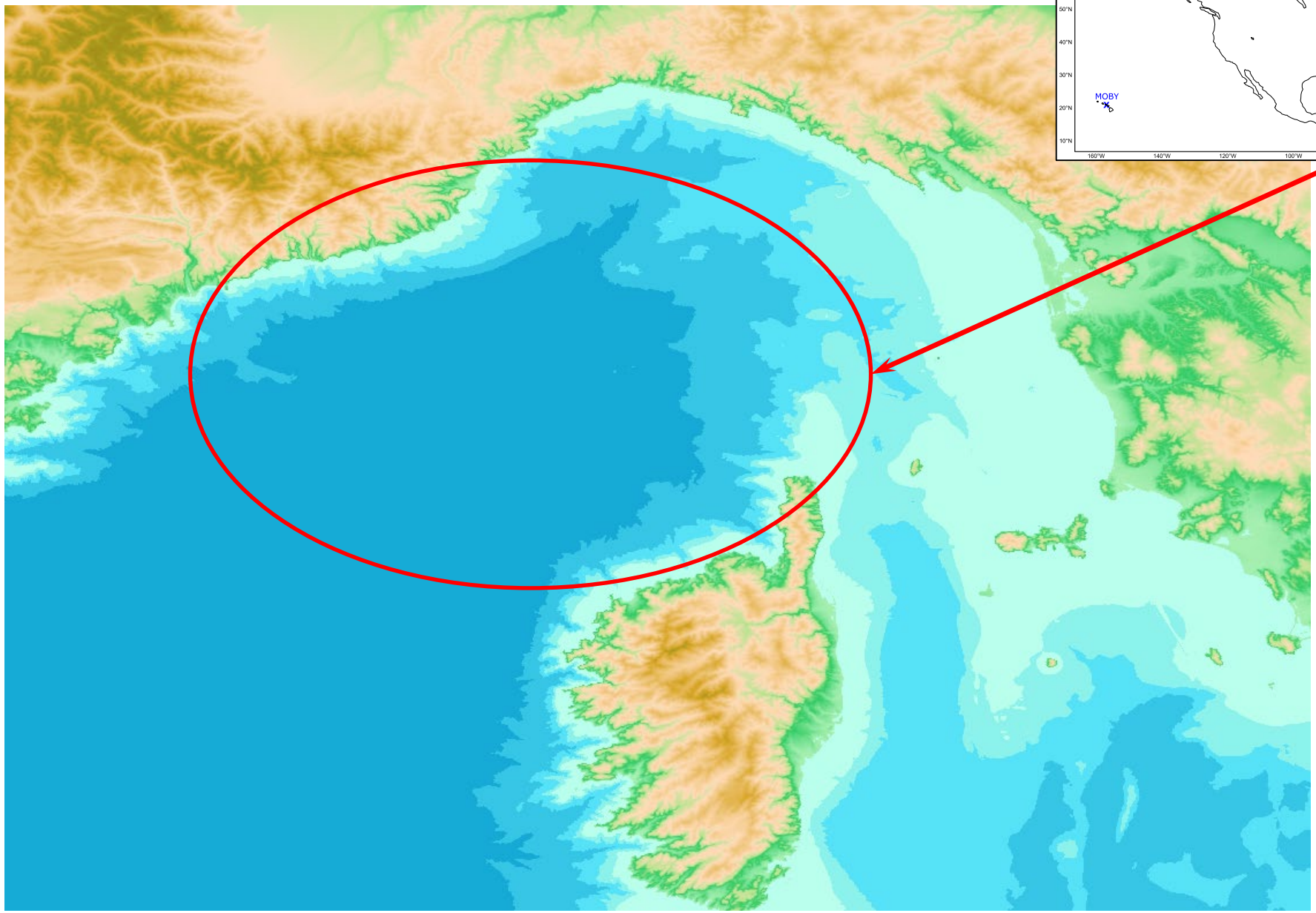


Fig. 1d: BOUSSOLE



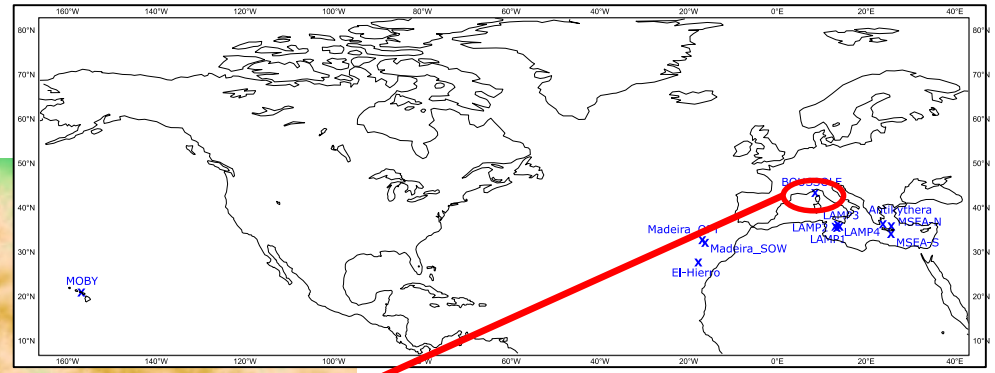
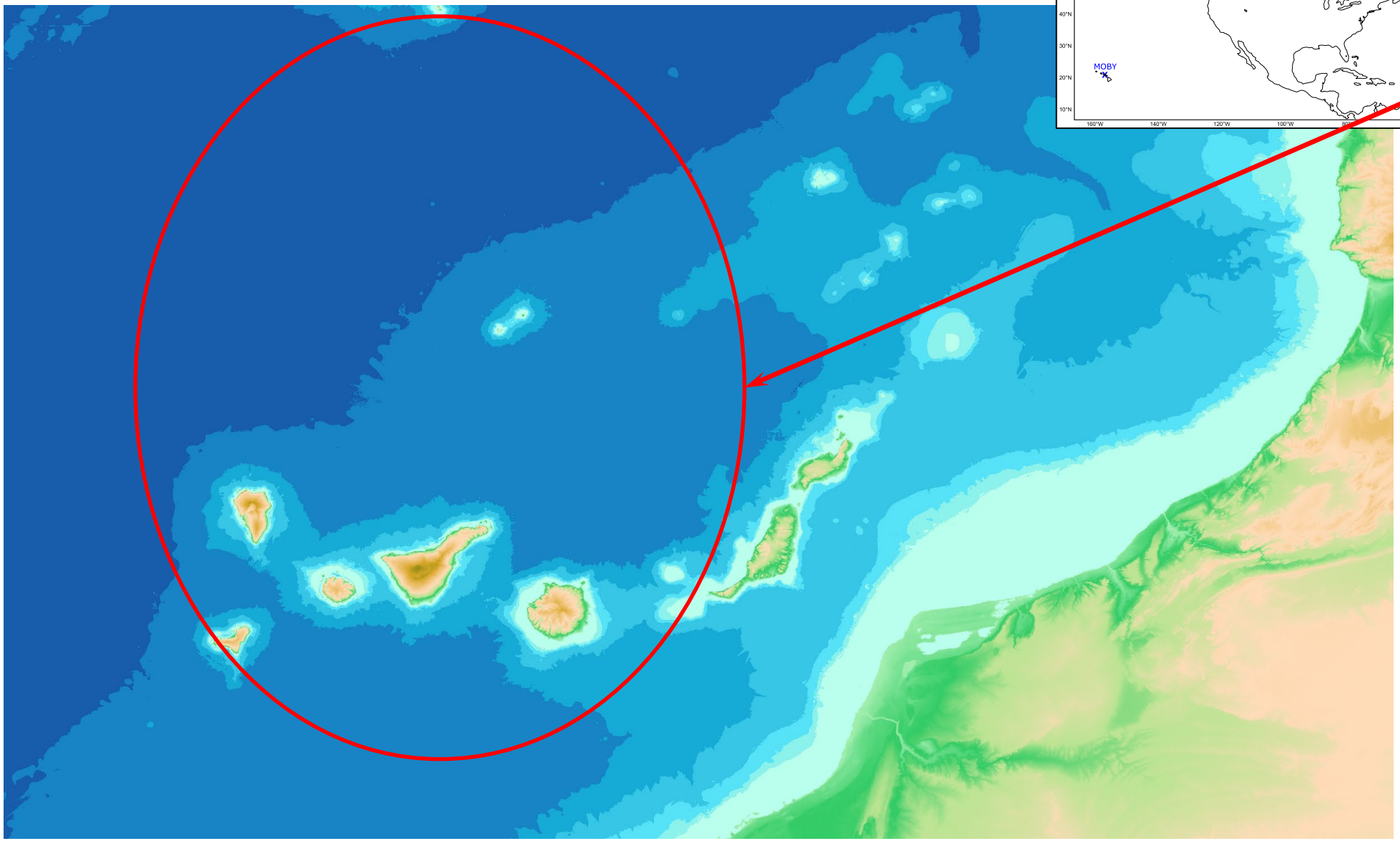


Fig. 1e: El Hierro, Madeira/OPT, Madeira/SOW



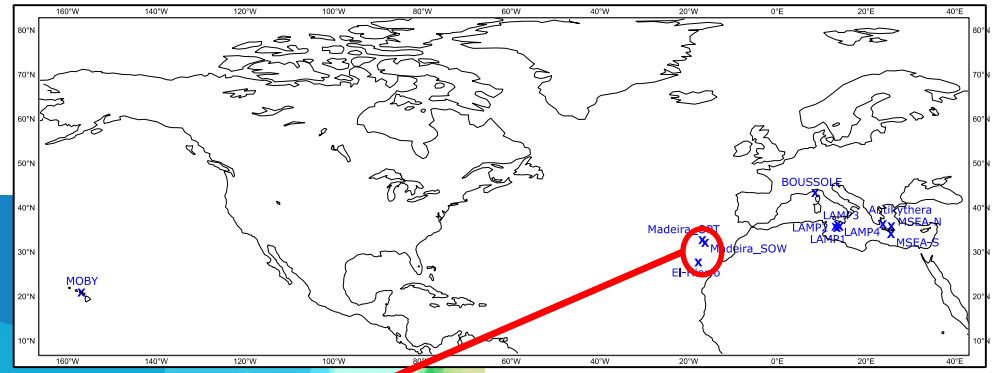
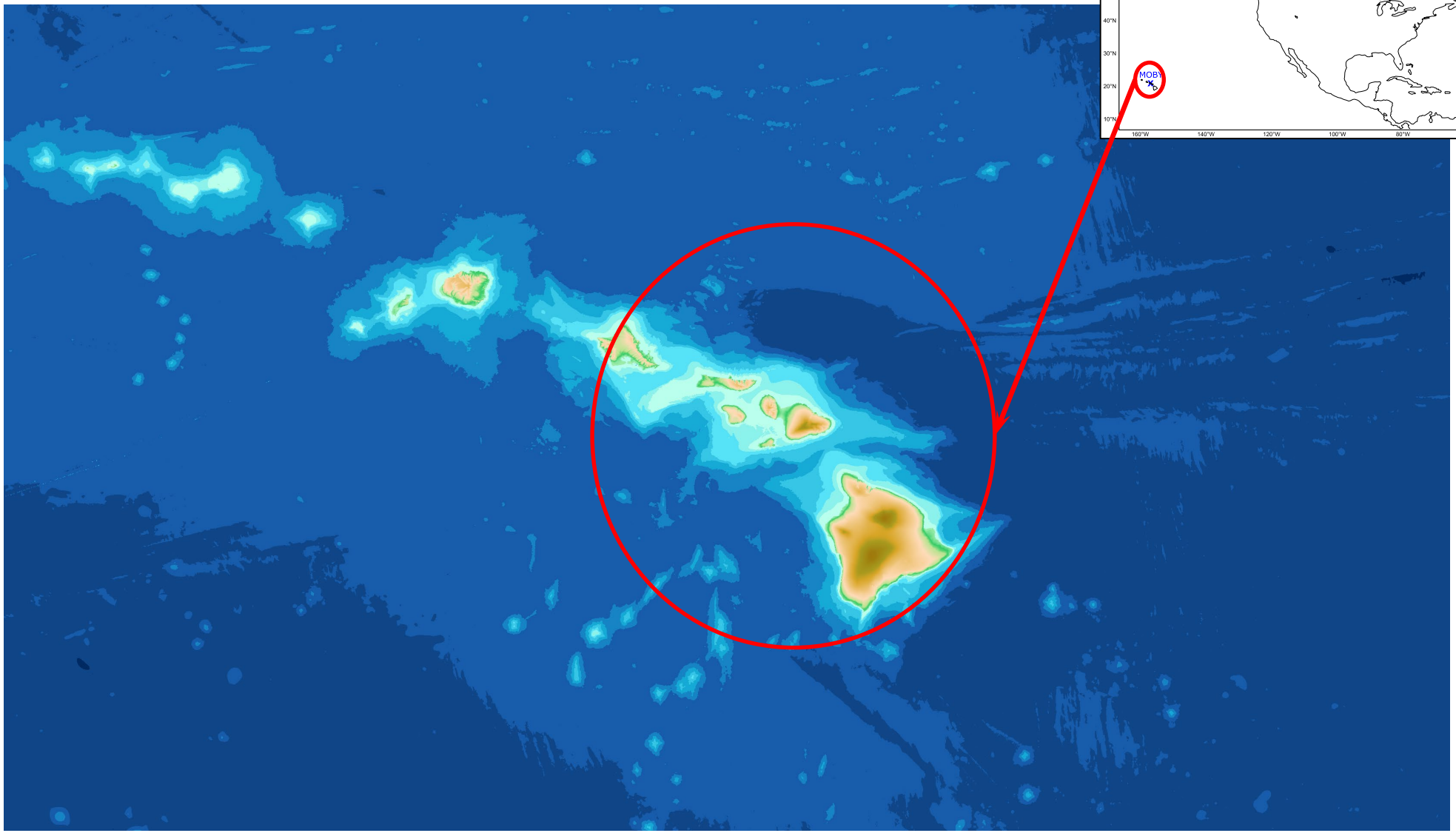


Fig. 1f: MOBY



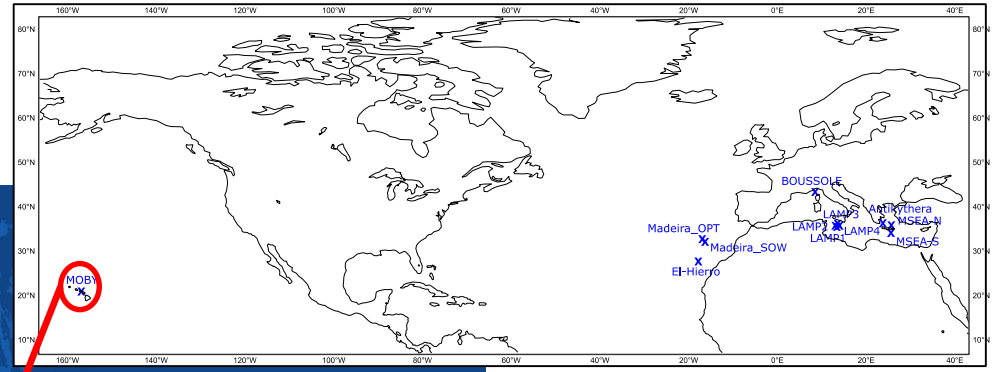

MOBY
BOUSSOLE
LAMP3
LAMP2
LAMP1
LAMP4
Antikythera
MSEA_N
MSEA_S
Madeira_OPT
Madeira_SOW
El-Hierro

Table 1: Actual geographical locations and their ERA5 equivalents

Name	Actual location		Location in ERA5		Depth (m) *(from Google Earth)*
	Latitude	Longitude	Latitude	Longitude	
Antikythera	36.200 N	23.550 E	36.360 N	23.672 E	617
BOUSSOLE	43.366 N	7.900 E	43.200 N	7.890 E	2,545
El Hierro	27.588 N	18.157 W	27.720 N	18.284 W	2,659
LAMP1	35.500 N	12.800 E	35.640 N	12.826 E	312
LAMP2	35.750 N	12.350 E	35.640 N	12.383 E	311
LAMP3	35.850 N	12.730 E	36.000 N	12.889 E	881
LAMP4	35.780 N	13.070 E	35.640 N	13.268 E	1,396
MOBY	20.817 N	157.192 W	20.880 N	157.259 W	1,626
MSEA-N	35.740 N	25.070 E	35.640 N	25.209 E	1,377
MSEA-S	34.000 N	25.000 E	33.840 N	25.096 E	2,650
Madeira/OPT	32.620 N	17.270 W	32.760 N	17.102 E	2,962
Madeira/SOW	32.250 N	17.000 W	32.400 N	17.062 E	3,752

The input data (1/2)

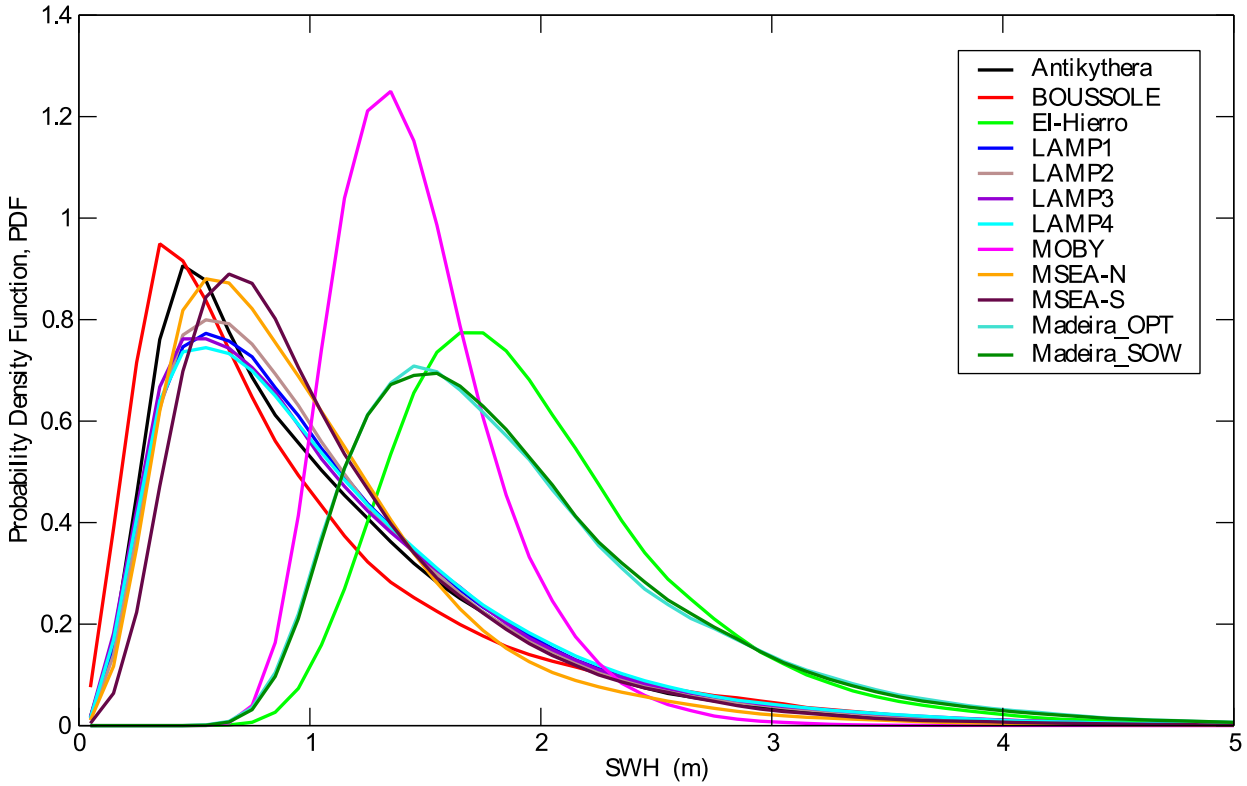
- ERA5 Reanalysis of all years between 1991 and 2020 (both inclusive).
- Hourly analysis fields from the wave model.
- Total: 20 years * 365.25 days/year * 24 hours/day = 175,320 data values at each location
- Parameters are:
  - SWH: Significant wave height
  - MWP: Mean wave height based on the second moment (~zero-crossing wave period)
  - MWD: Mean wave direction
  - U10: Surface wind speed (as seen by the wave model)
  - D10: Surface wind direction.
  - H2T: A derived parameter computed as $SWH^2 * MWP$ which is proportional to the wave energy.

The input data (2/2)

- Notes:
  - Coordinates of locations at which data were produced do not match exactly those of the desired locations. Usually this only matters in case of wave-field discontinuities (e.g. the desired location is on one side of an island while the data are available on the other side).
  - Local features including water depth and shadowing may not be well represented in ERA5.
  - Water depth at each location was read from Google Earth. All locations are in deep water (more that 300-m depth).

Fig. 2-5: Probability density functions

Fig. 2: Probability density functions of **SWH** (1991-2020)



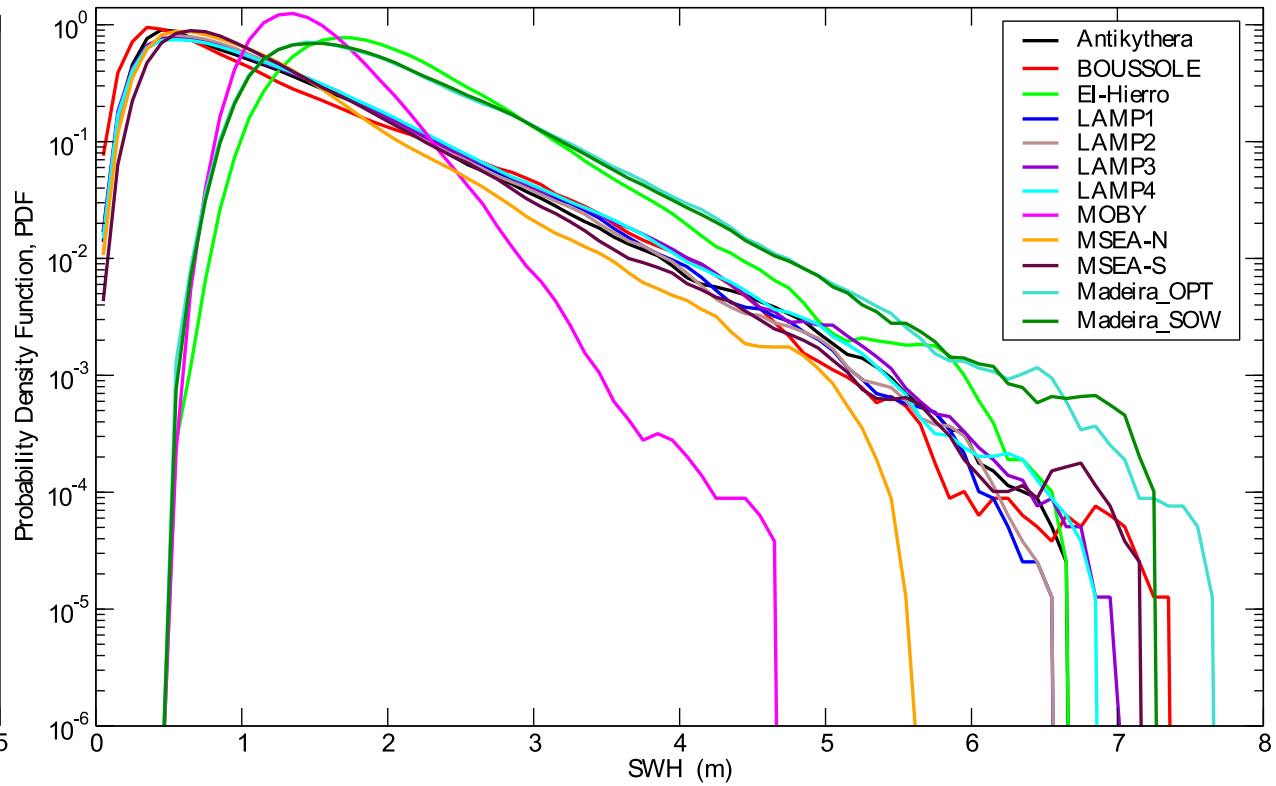
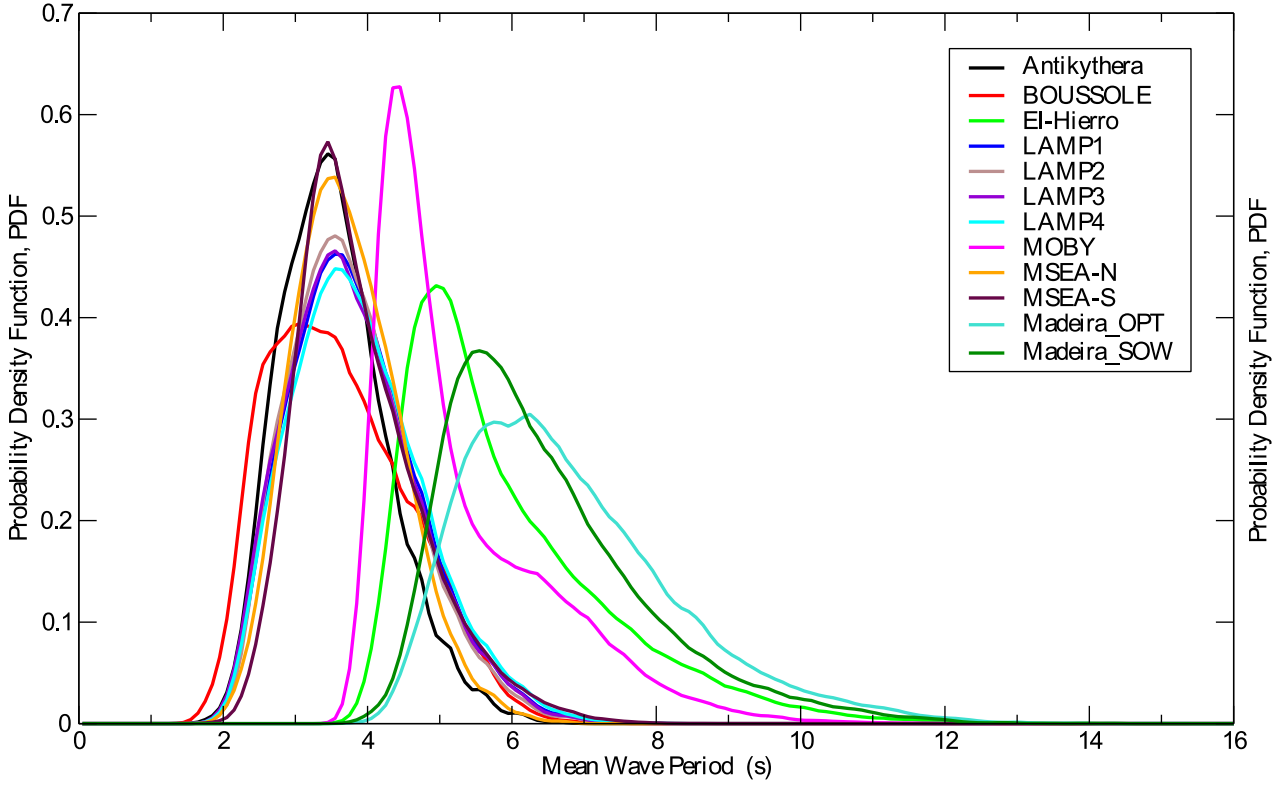


Fig. 3: Probability density functions of **MWP** (1991-2020)



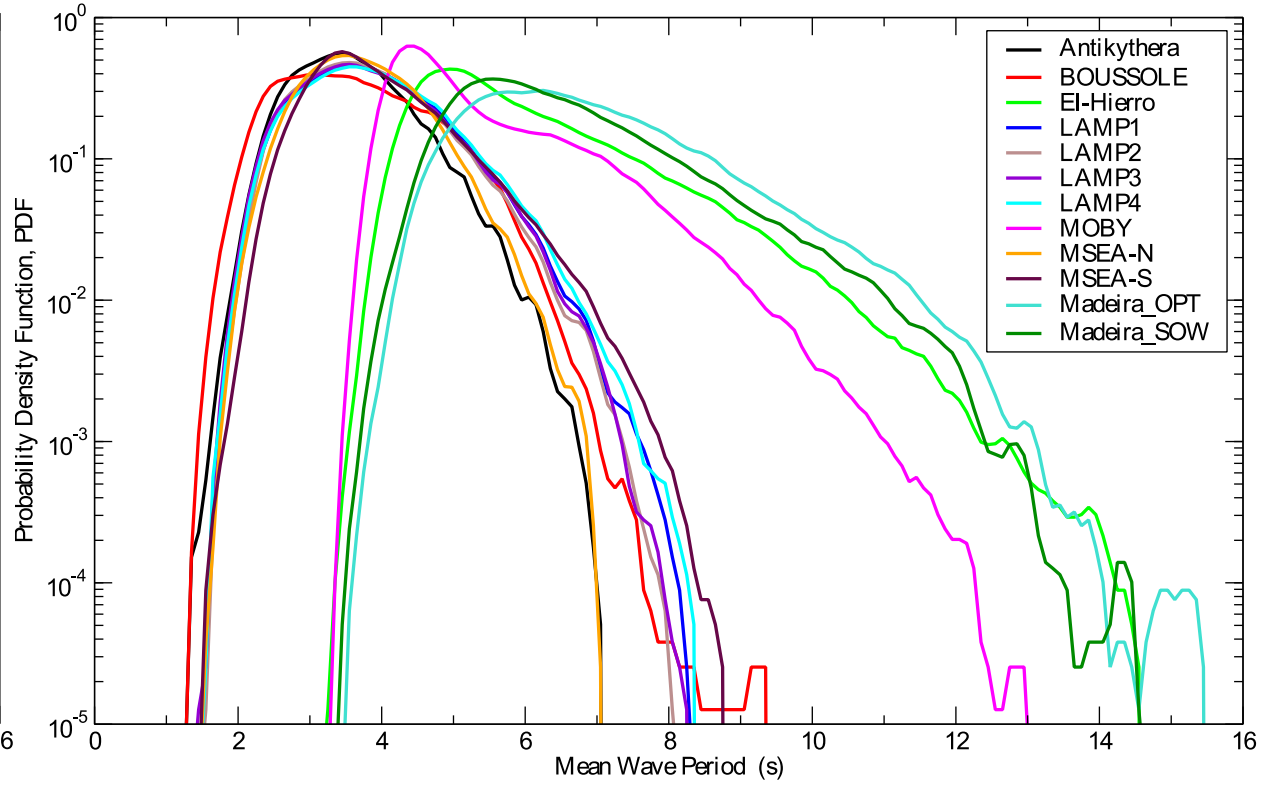


Fig. 4: Probability density functions of **U10** (1991-2020)

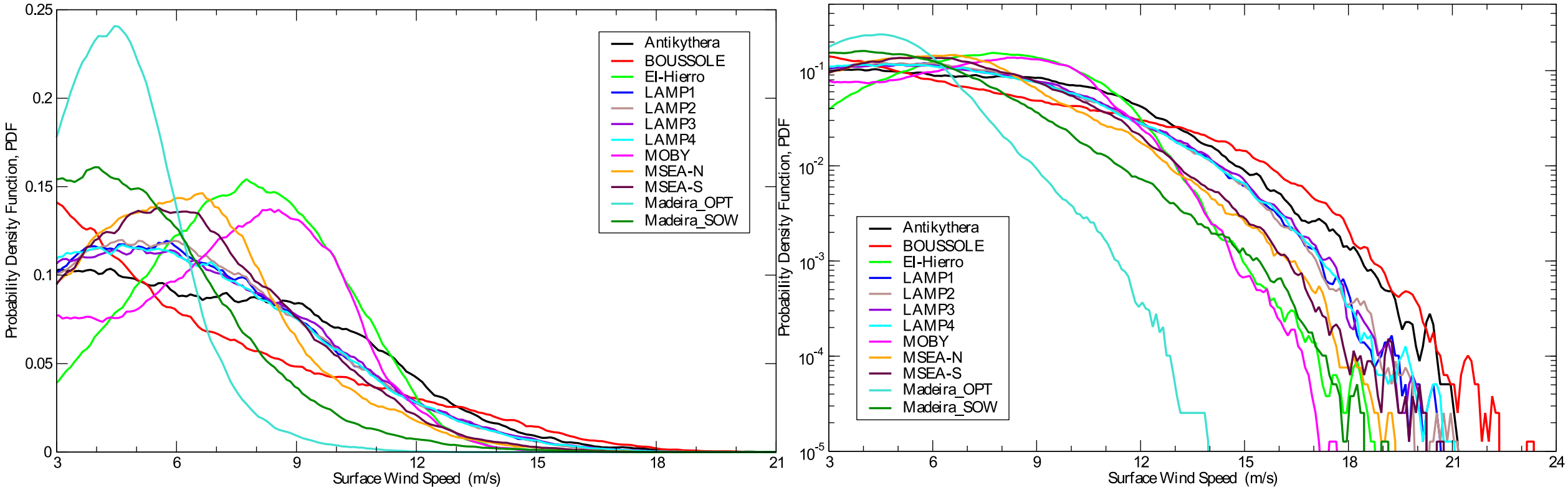
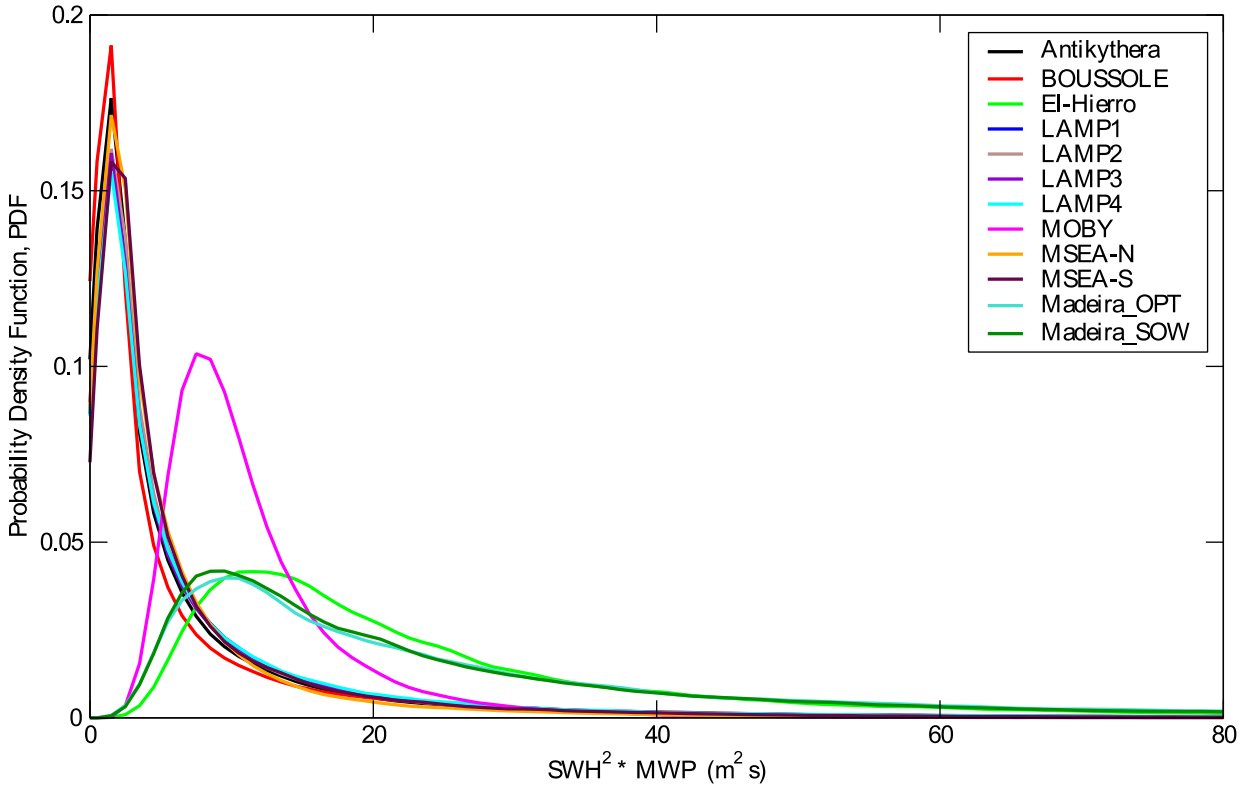


Fig. 5: Probability density functions of **H2T** (1991-2020)



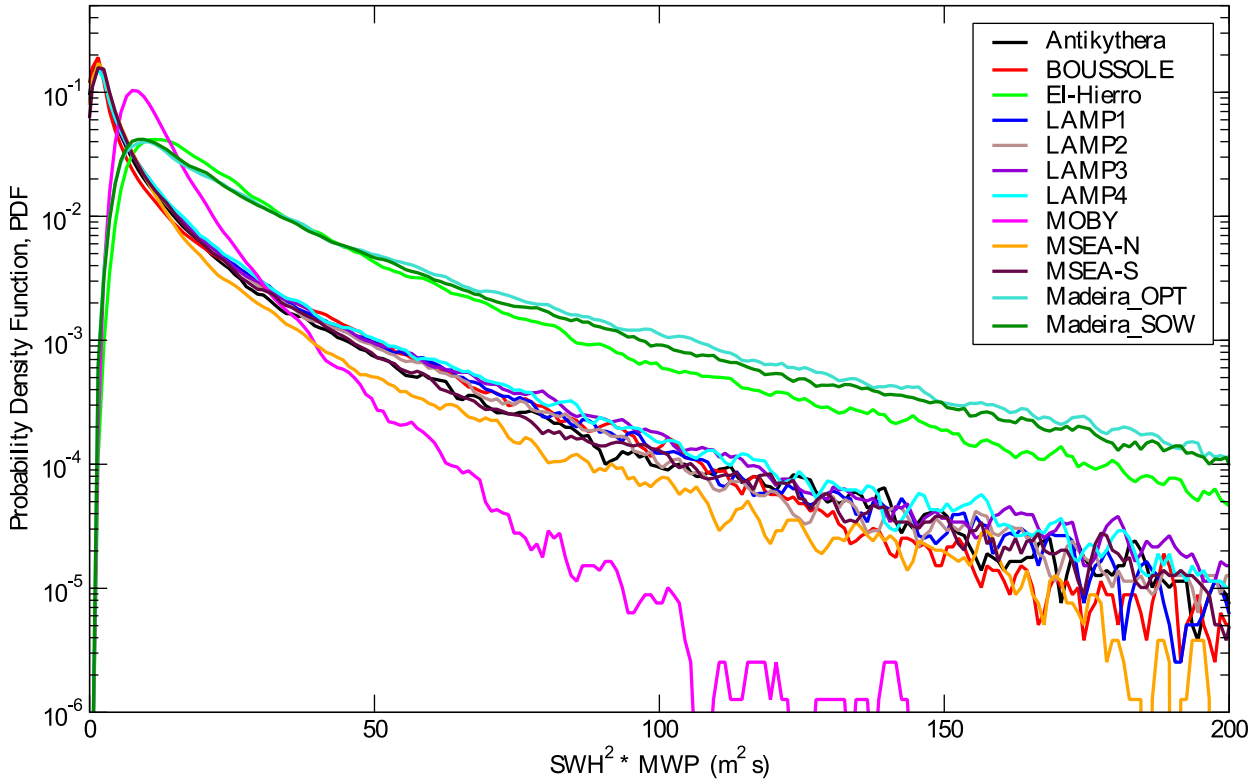


Fig. 7-10: Cumulative distribution functions

Fig. 7: Cumulative distribution functions of **SWH** (1991-2020)

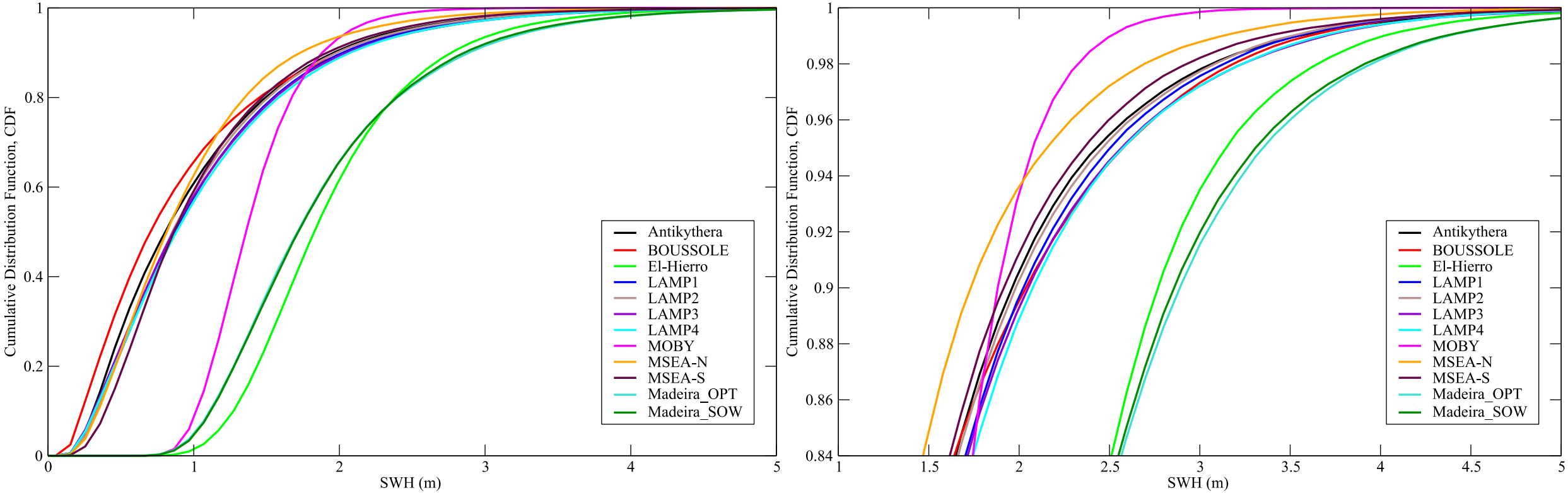
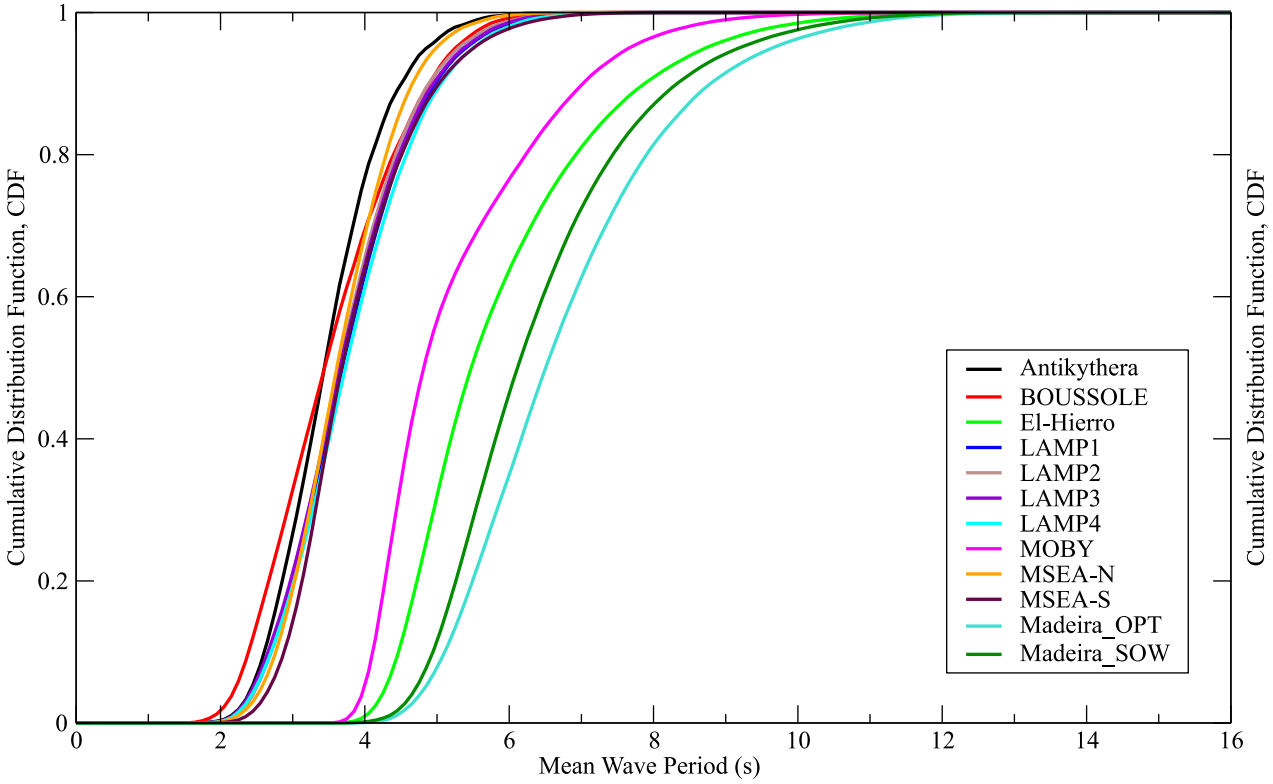


Fig. 8: Cumulative distribution functions of **MWP** (1991-2020)



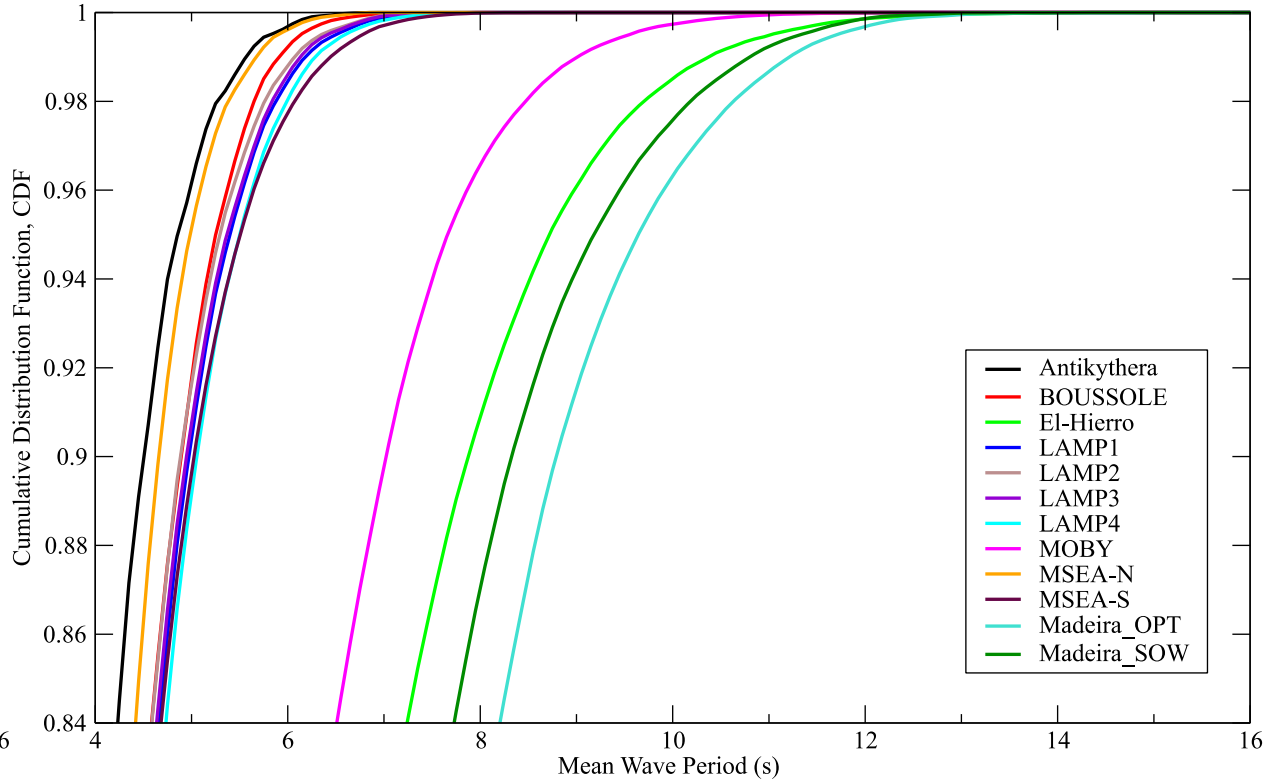
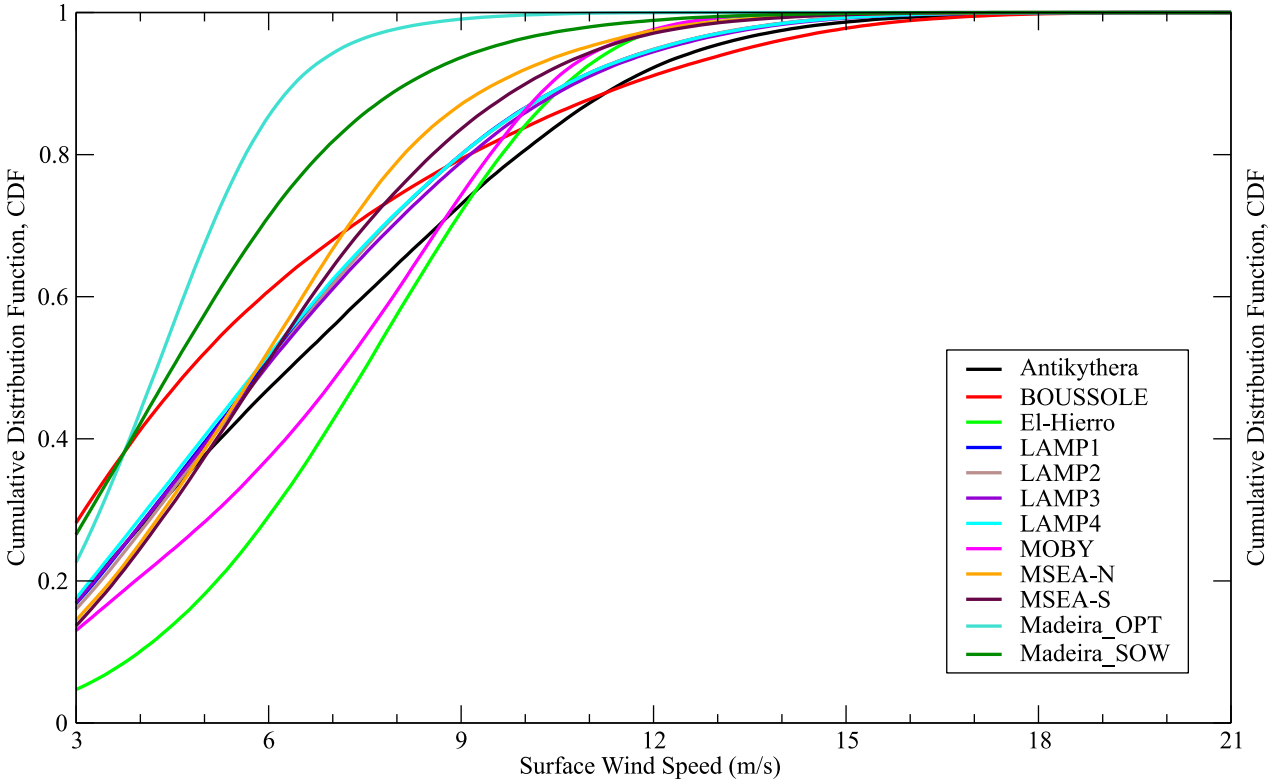


Fig. 9: Cumulative distribution functions of **U10** (1991-2020)



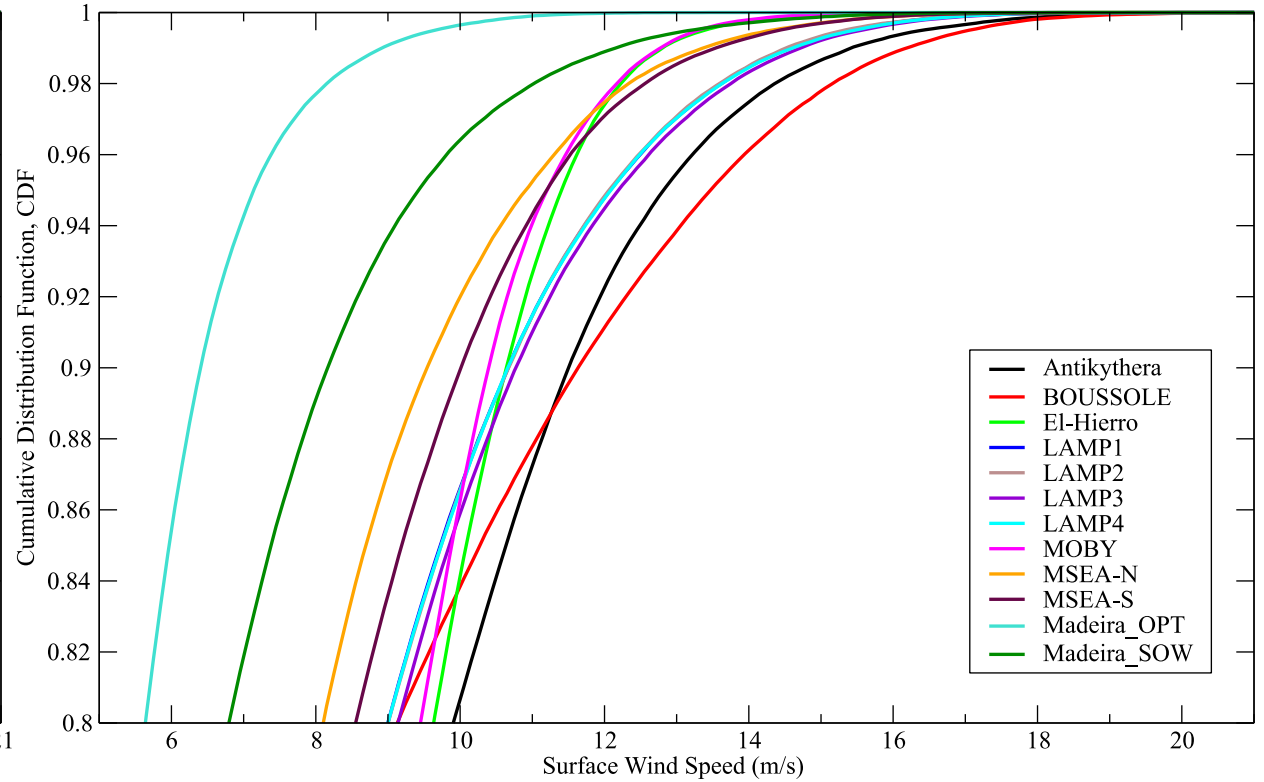
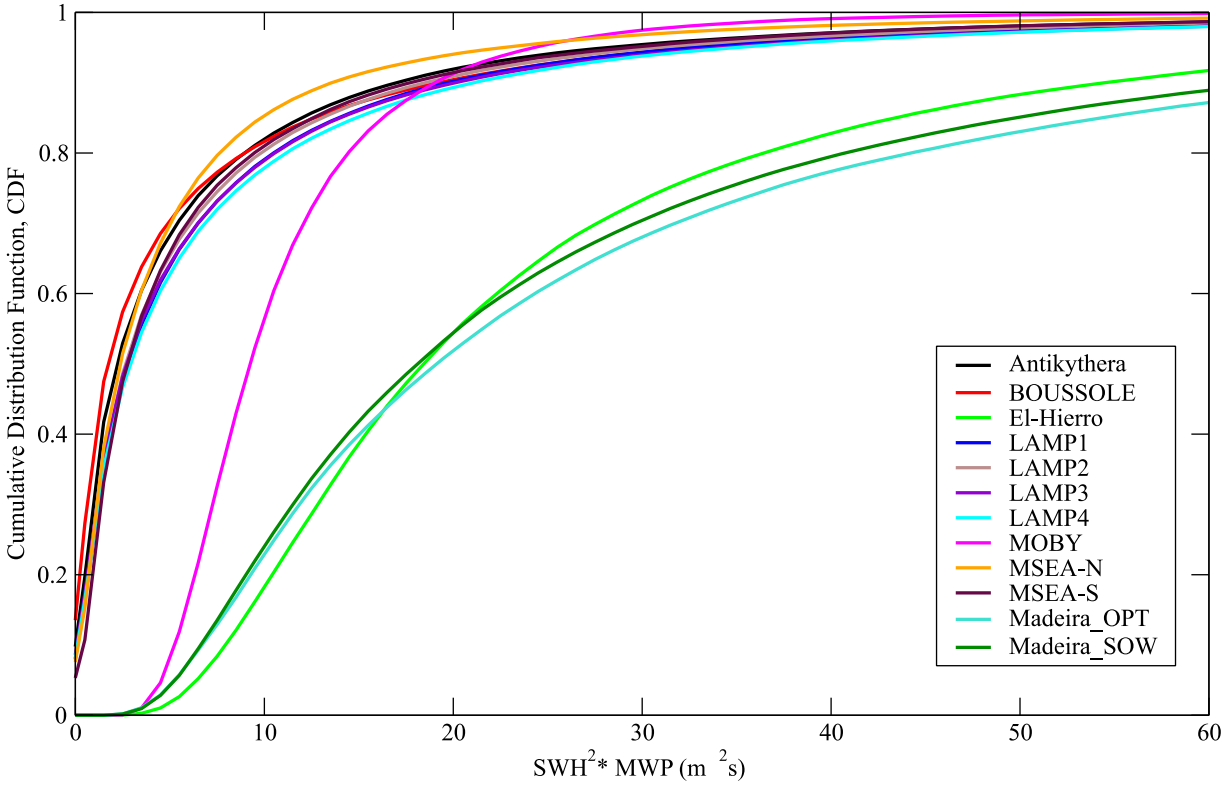


Fig. 10: Cumulative distribution functions of **H2T** (1991-2020)



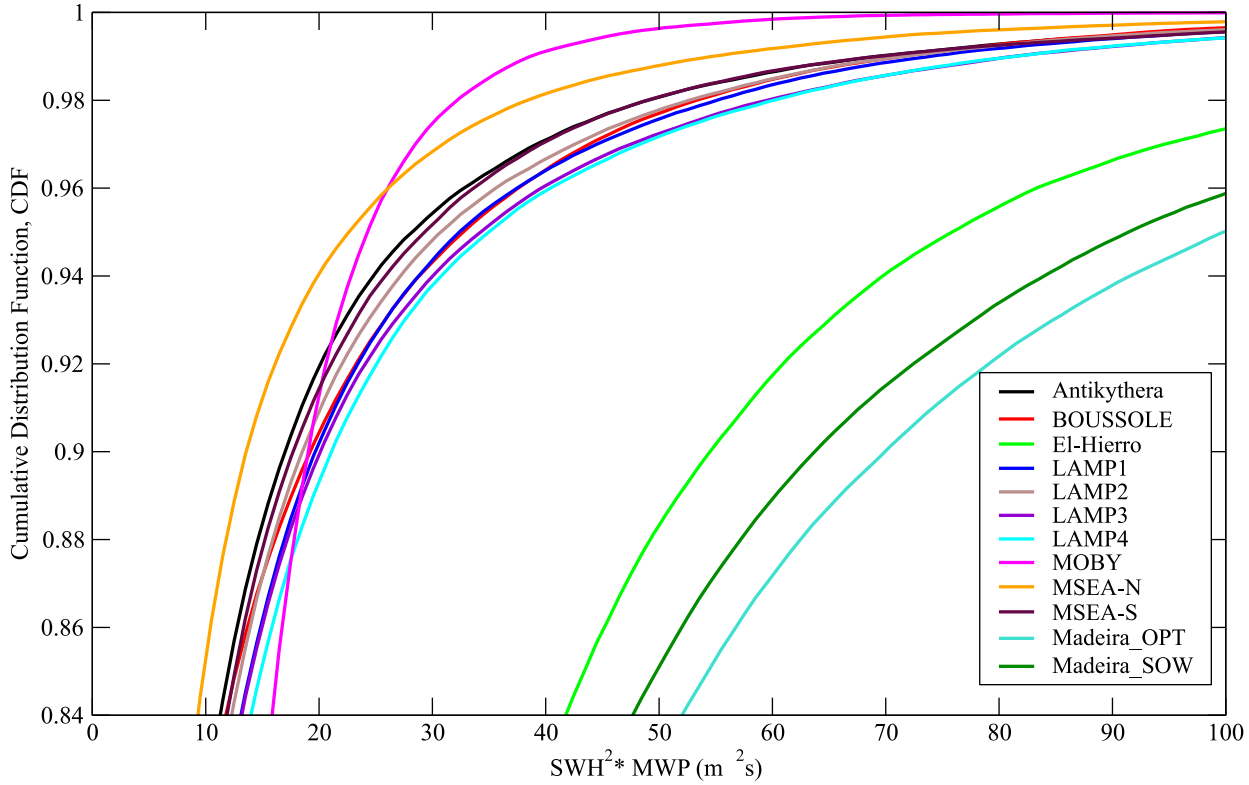
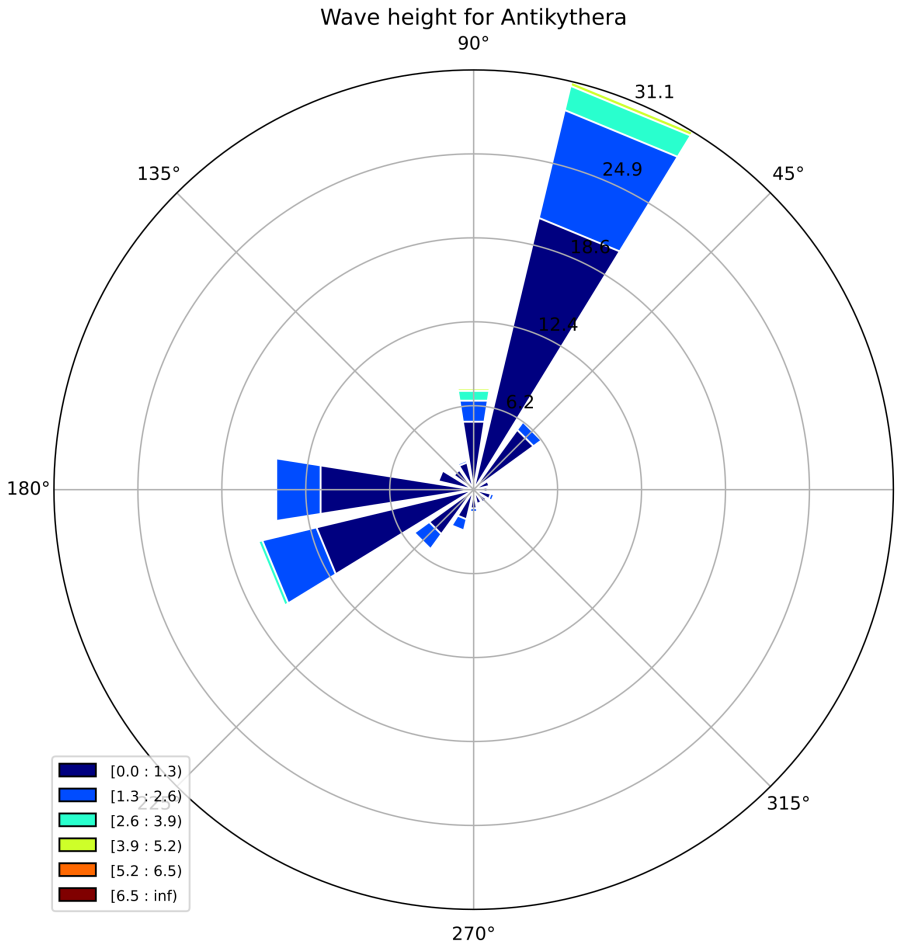
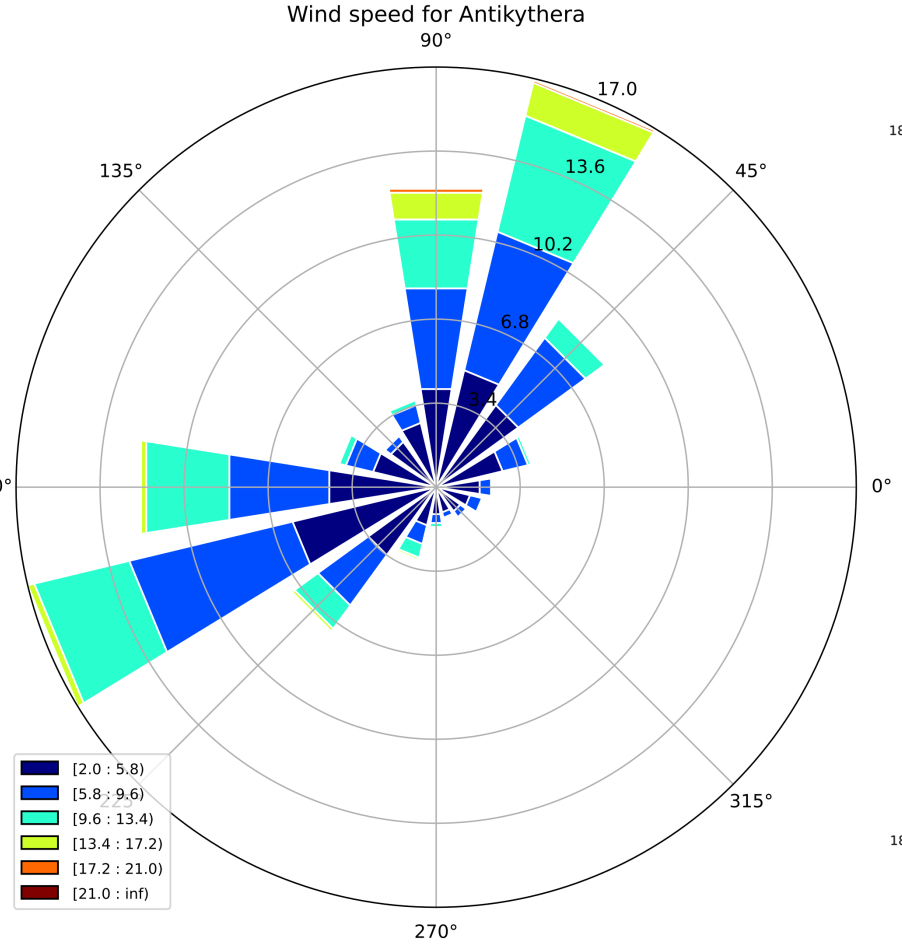
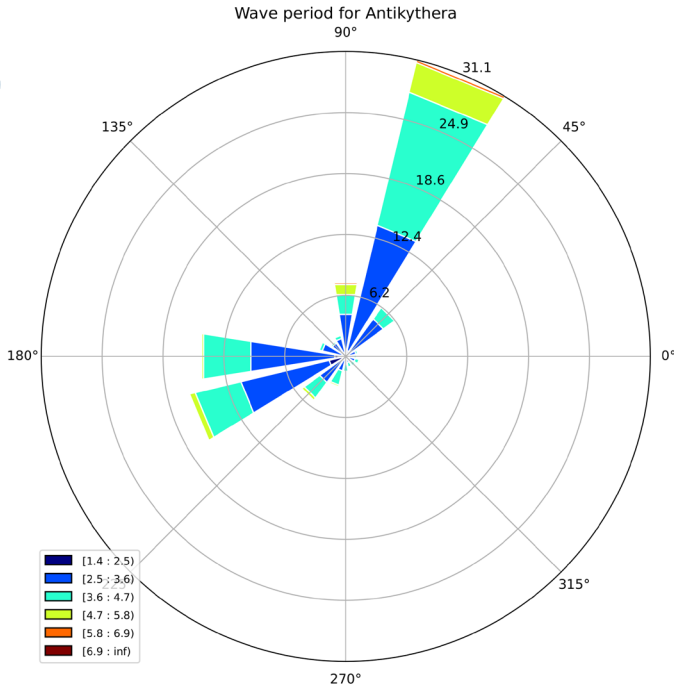


Fig. 11-22: Wave and wind roses

Fig. 11: Wave & wind roses at **Antikythera** (1991-2020







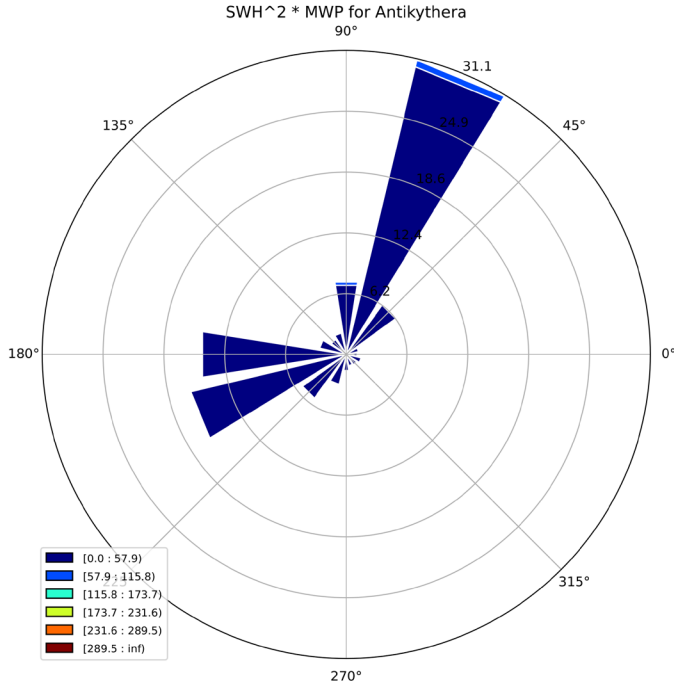
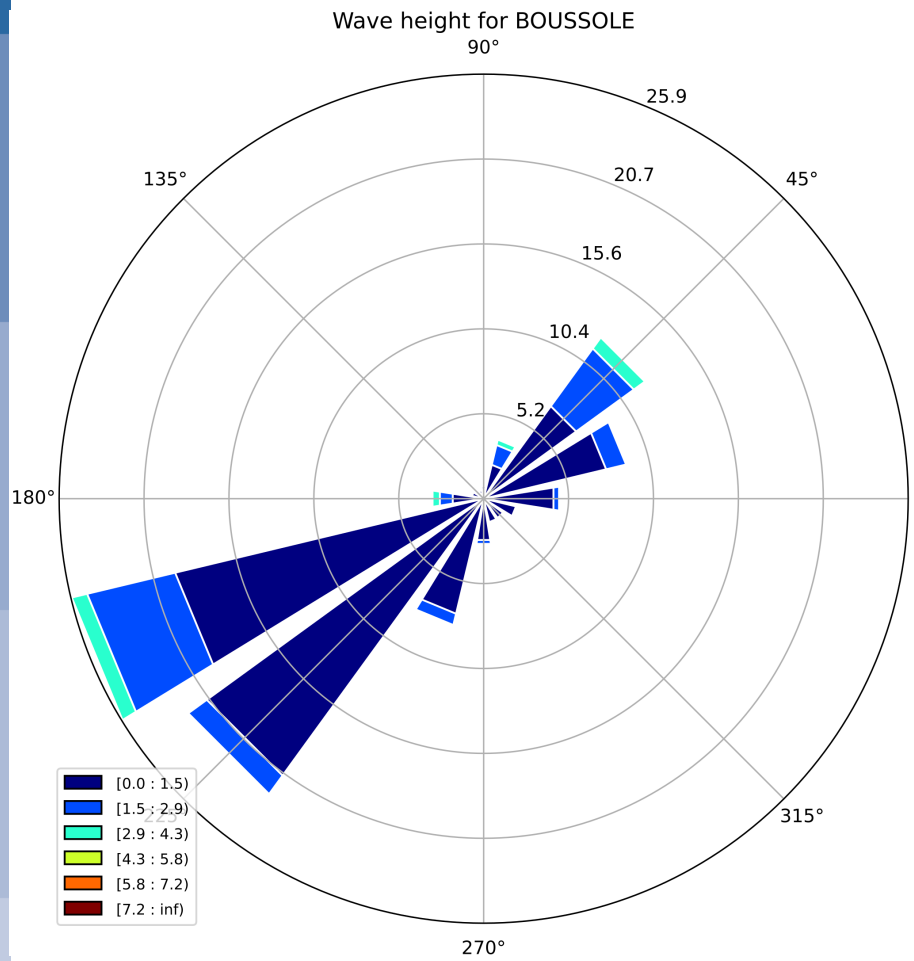
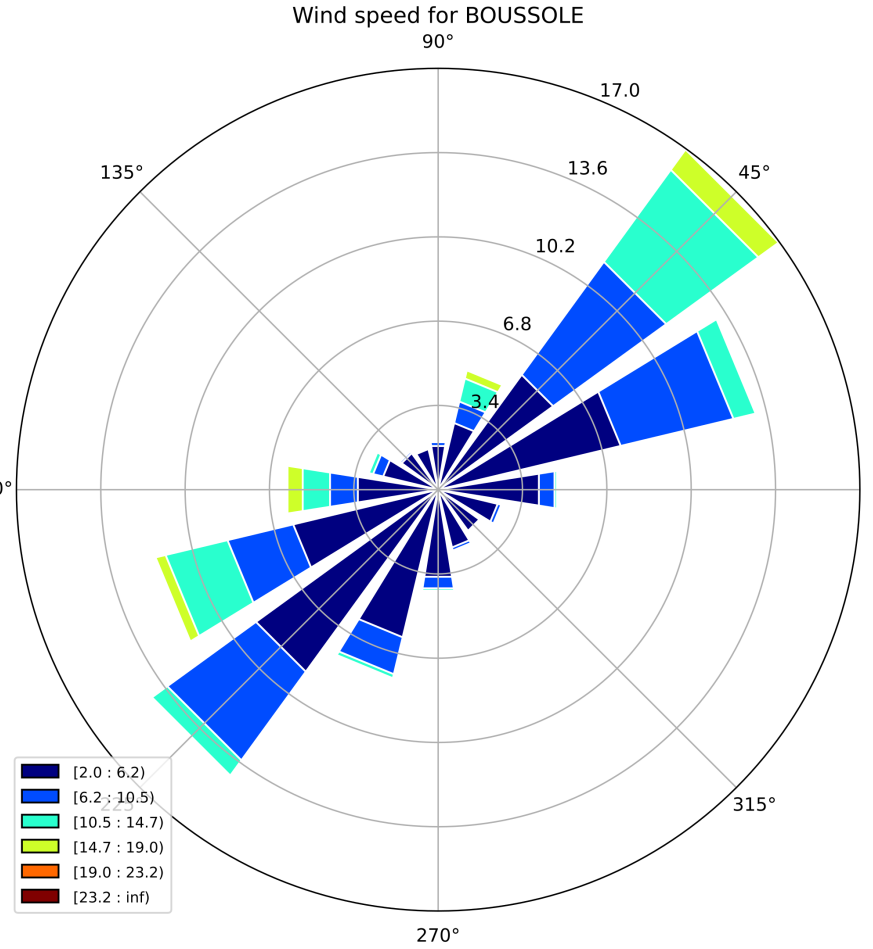
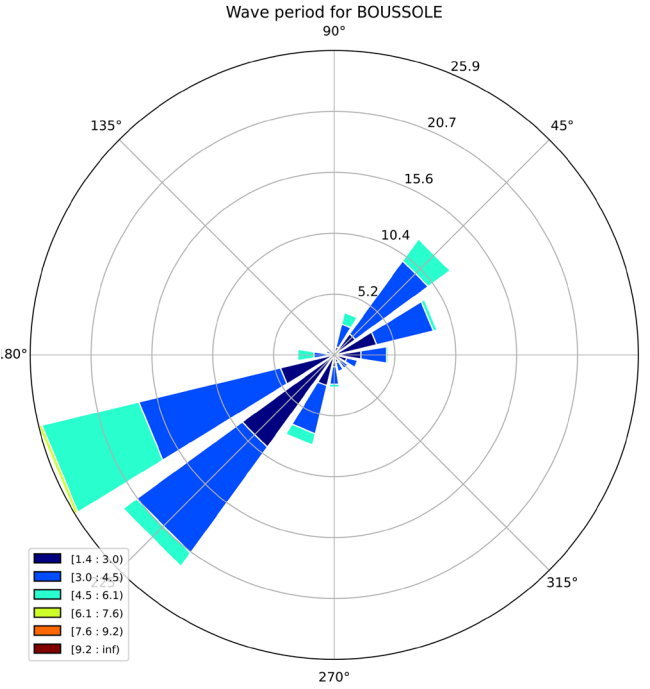


Fig. 12: Wave & wind roses at **BOUSSOLE** (1991-2020







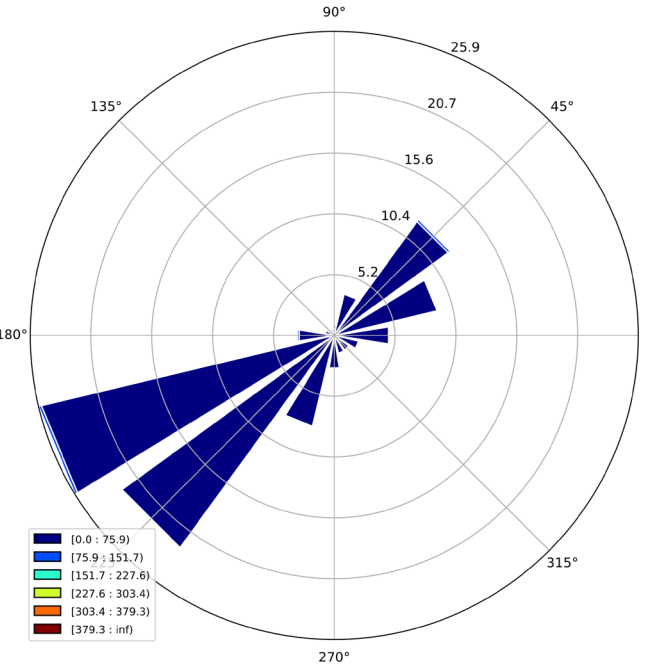
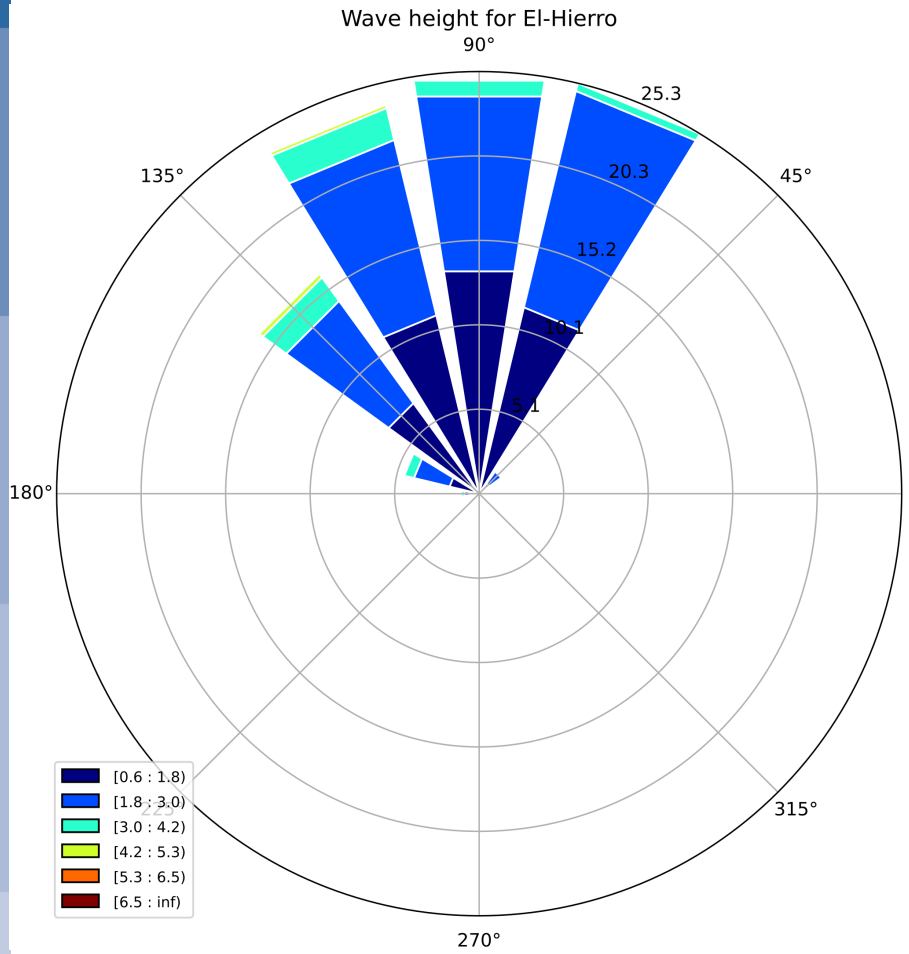
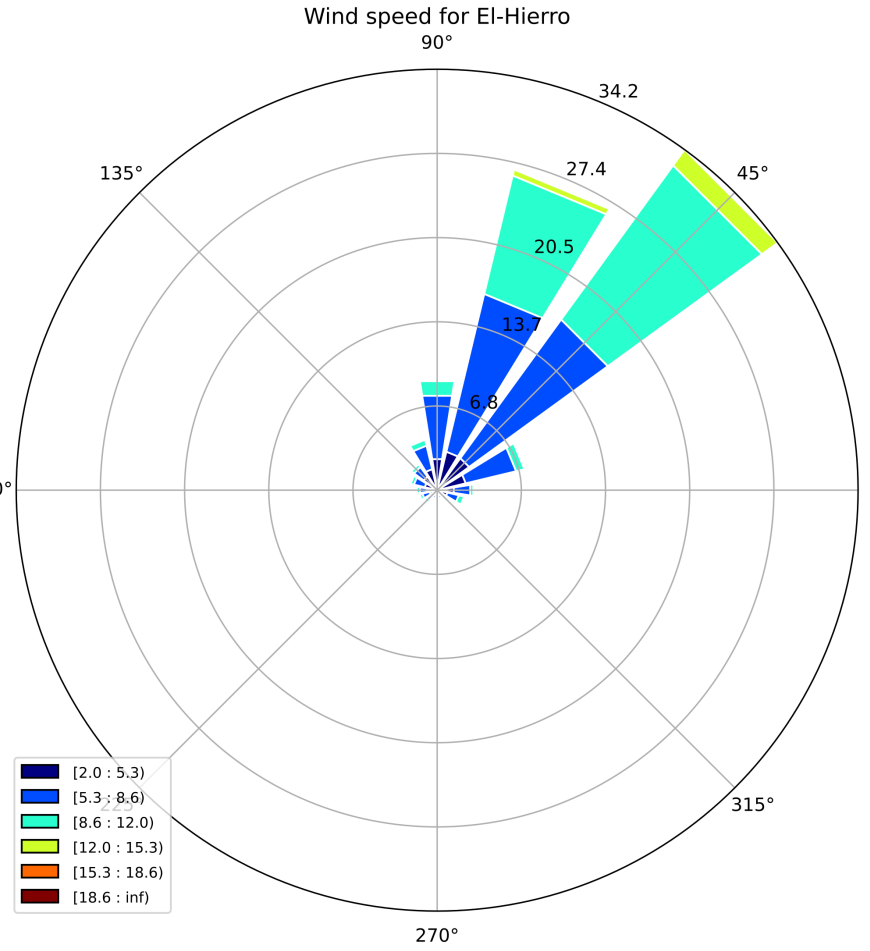
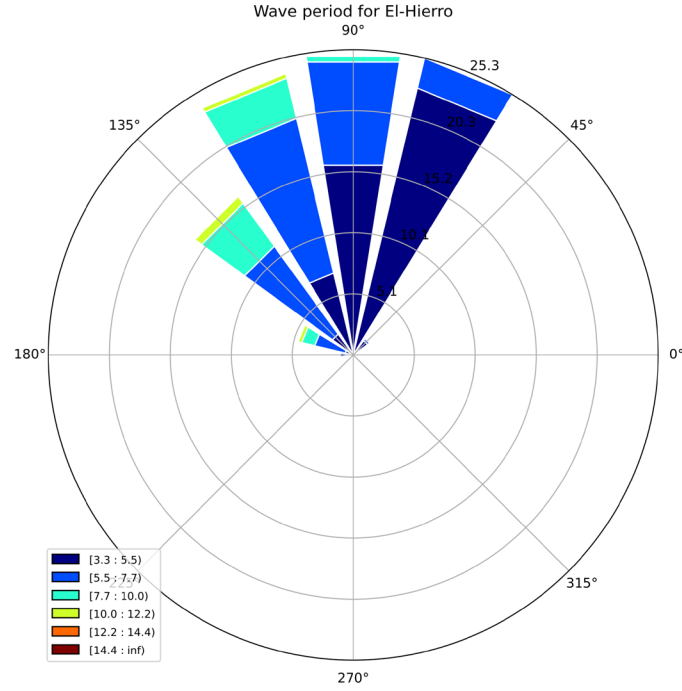


Fig. 13: Wave & wind roses at **El-Hierro** (1991-2020)







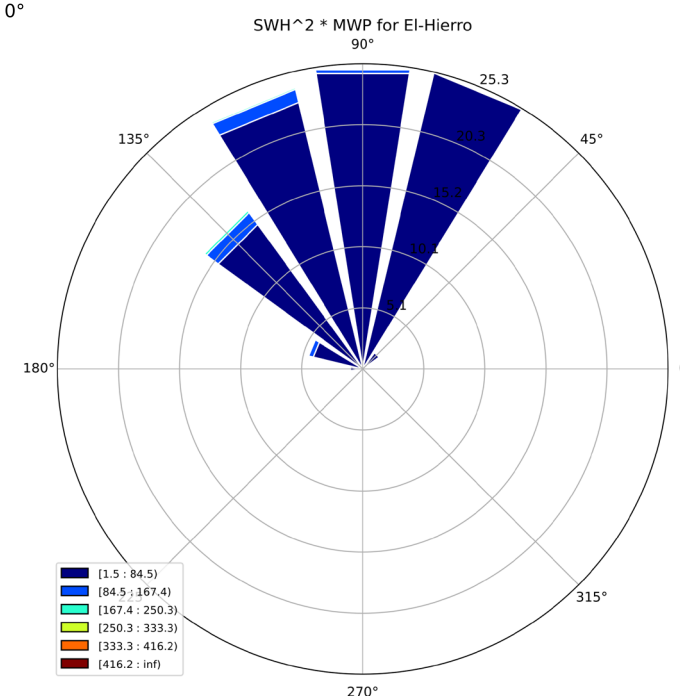
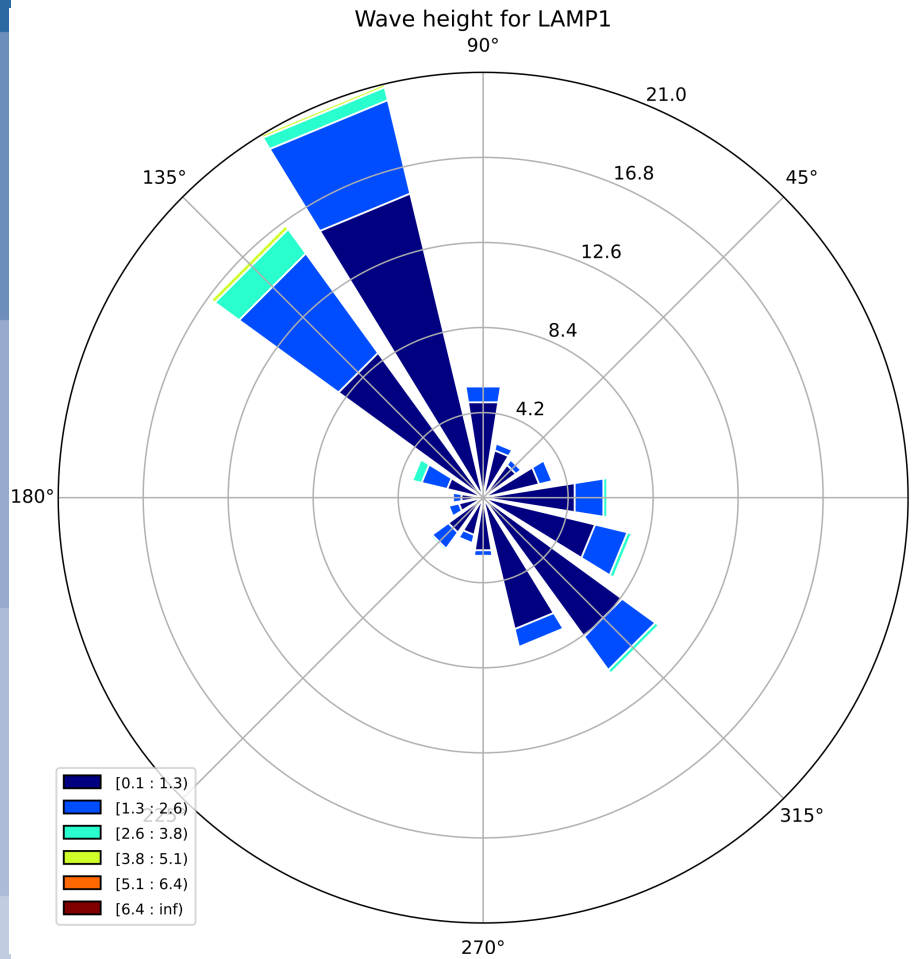
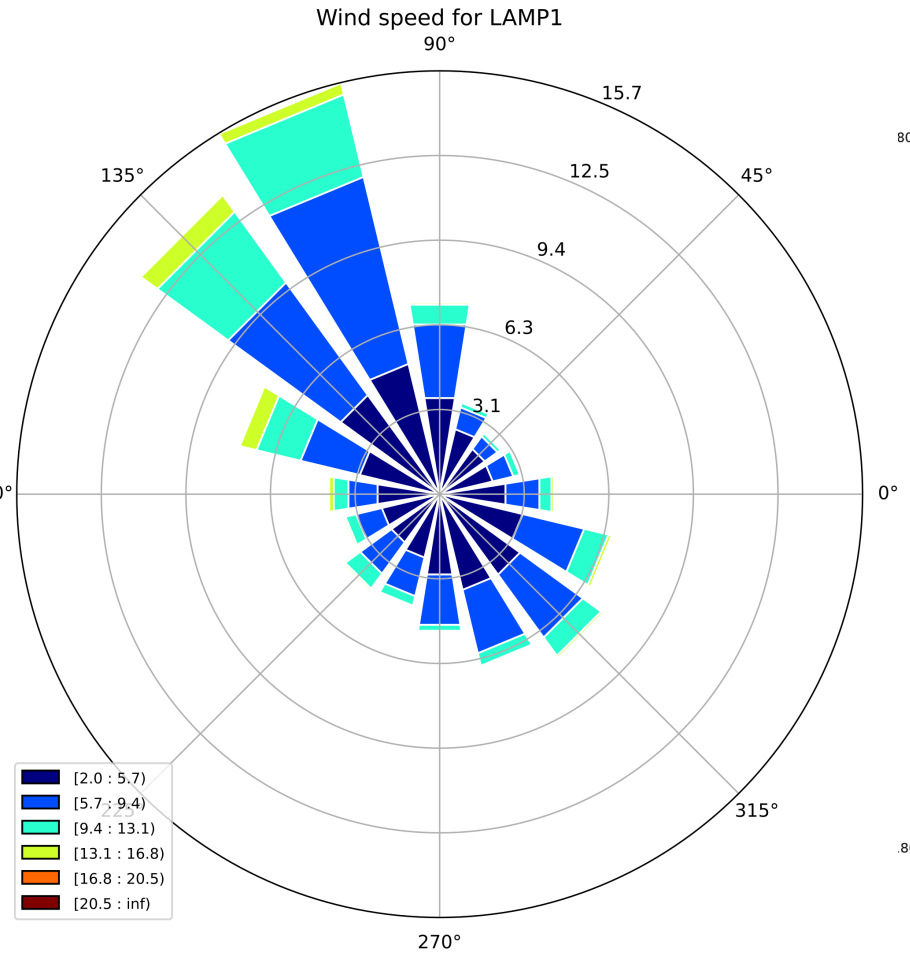
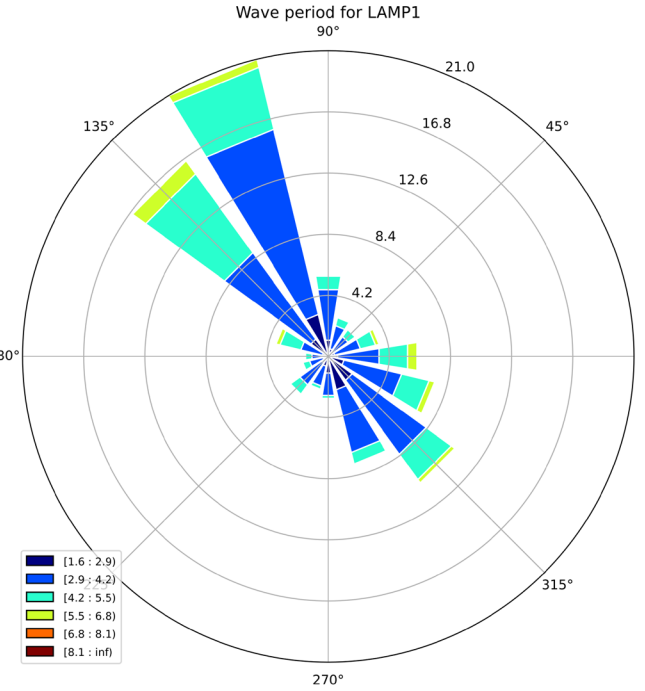


Fig. 14: Wave & wind roses at **LAMP1** (1991-2020)







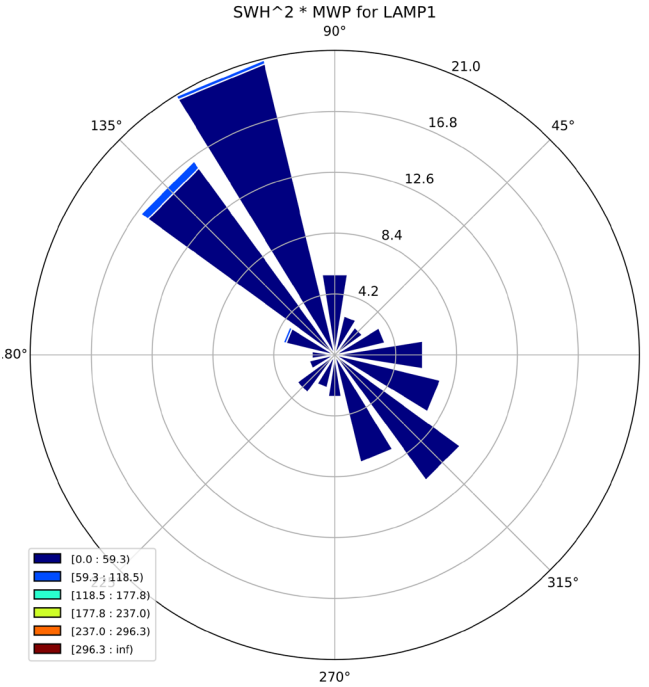
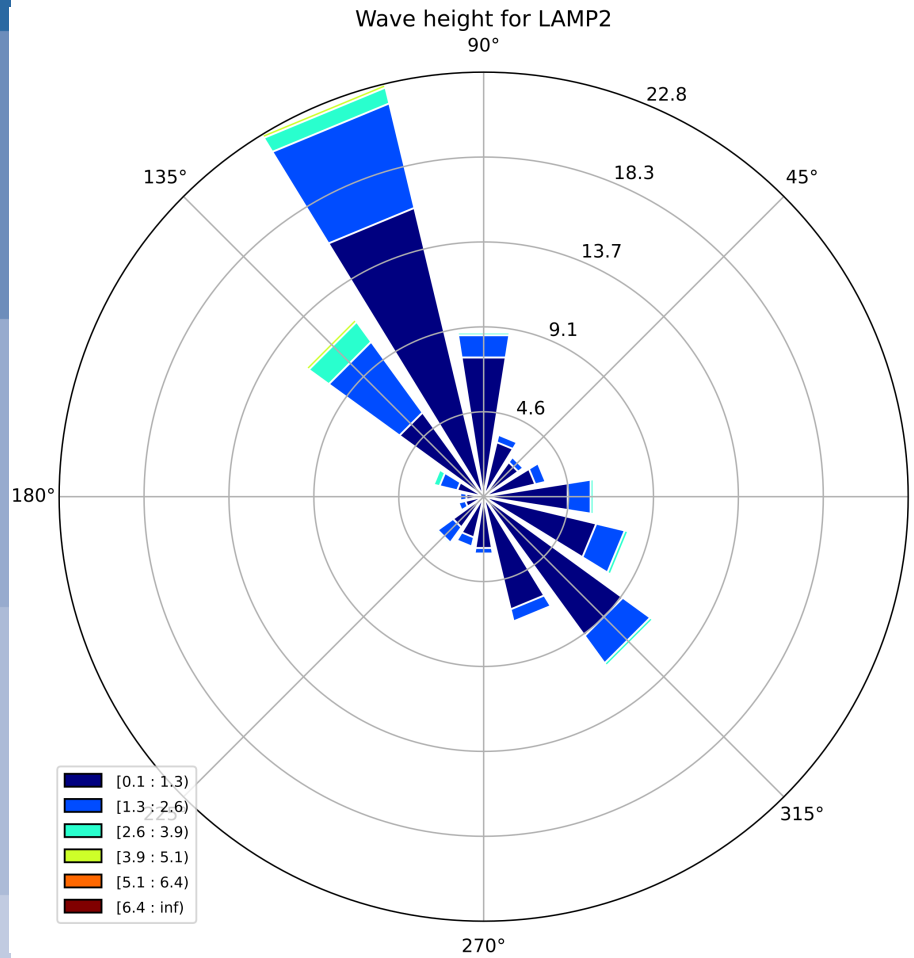
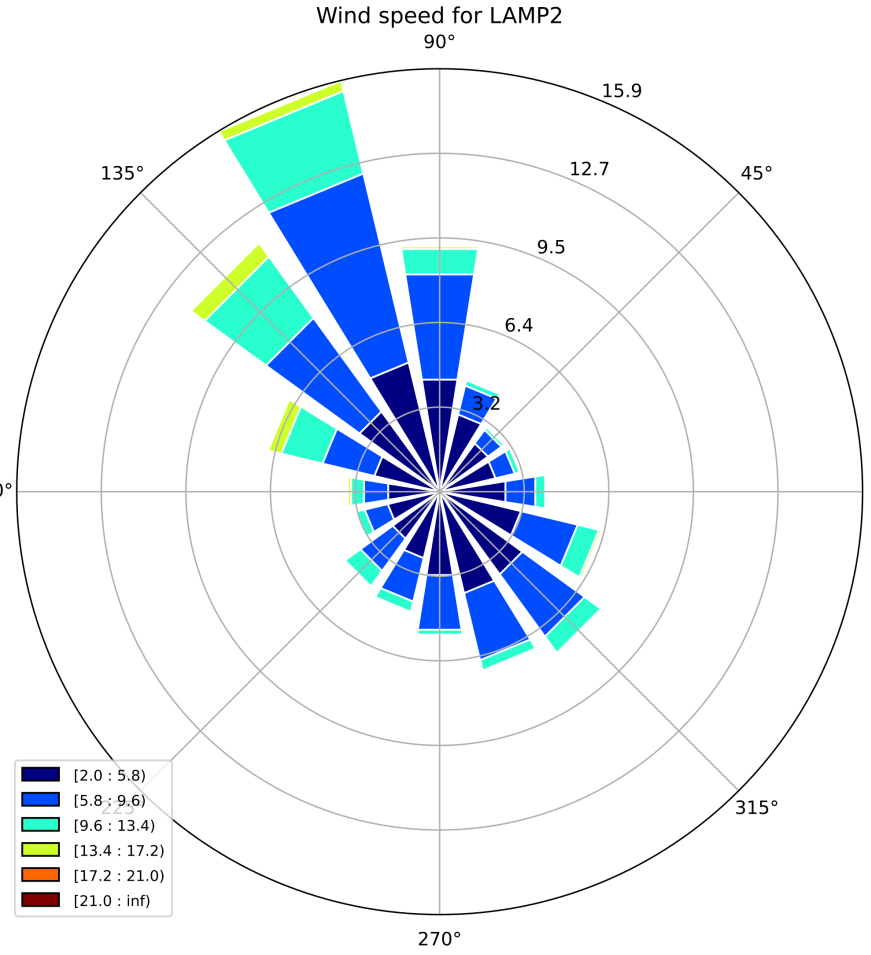
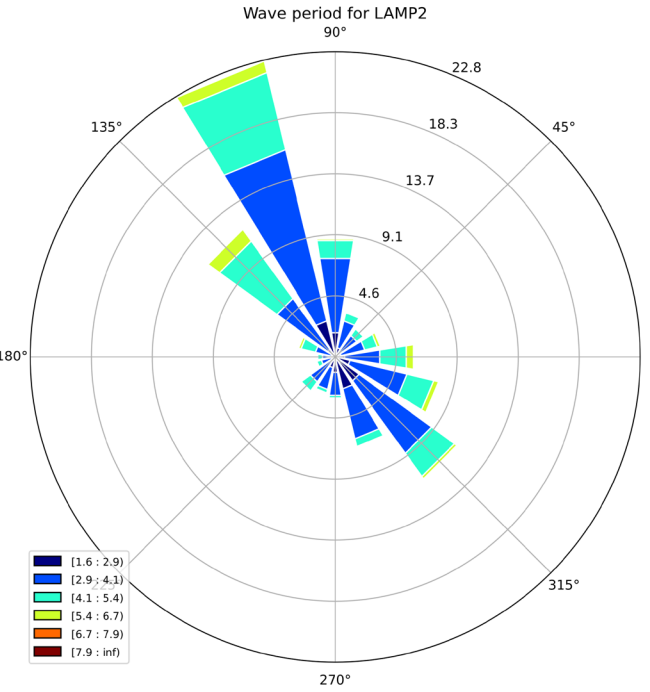


Fig. 15: Wave & wind roses at **LAMP2** (1991-2020)







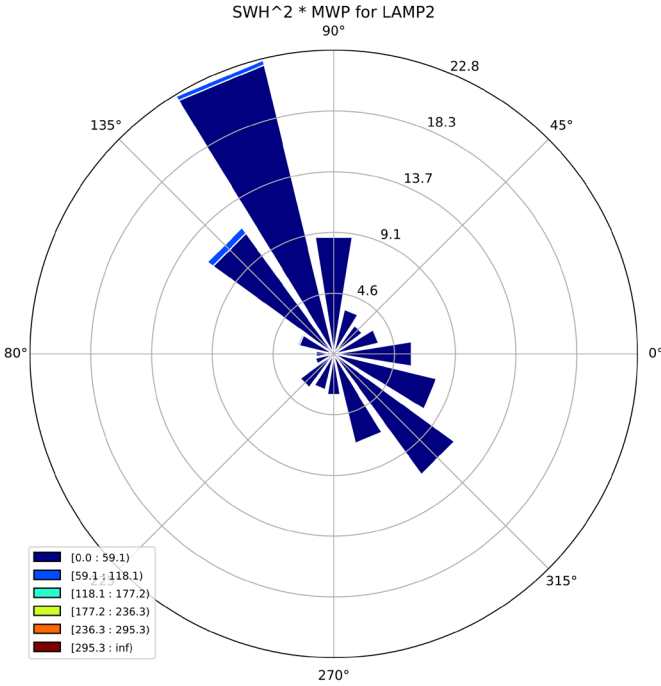
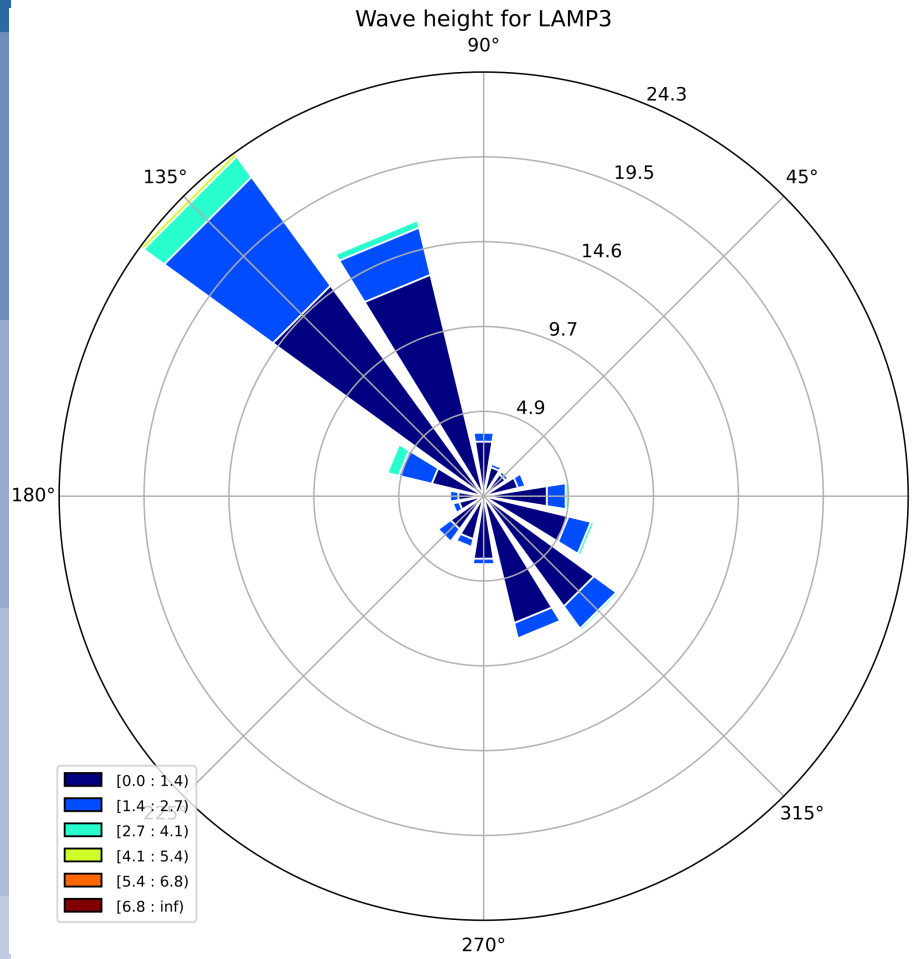
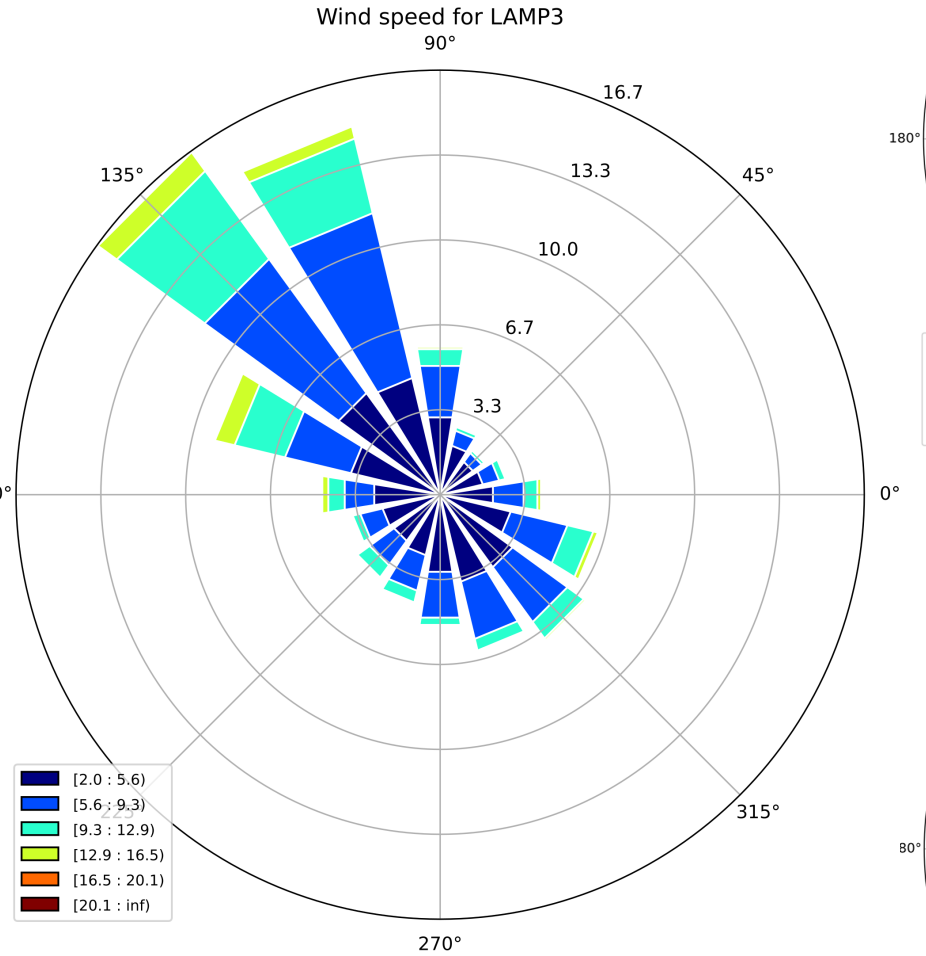
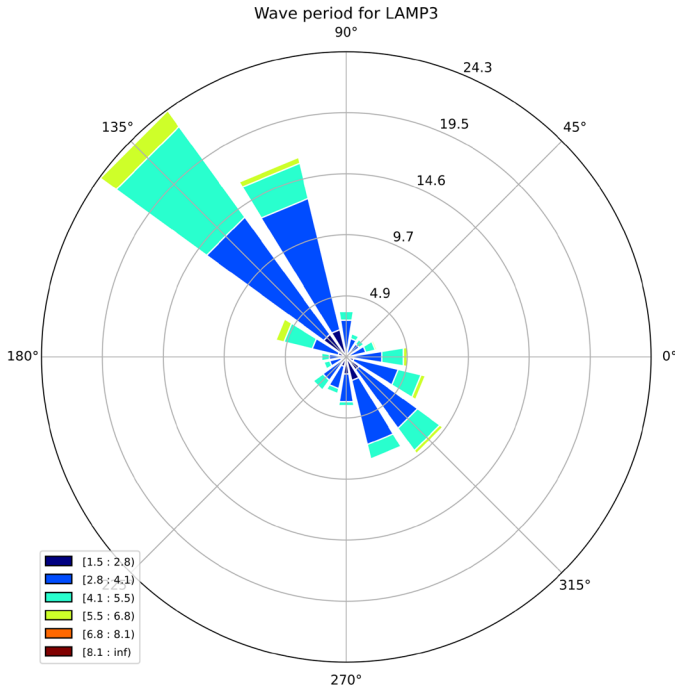


Fig. 16: Wave & wind roses at **LAMP3** (1991-2020)







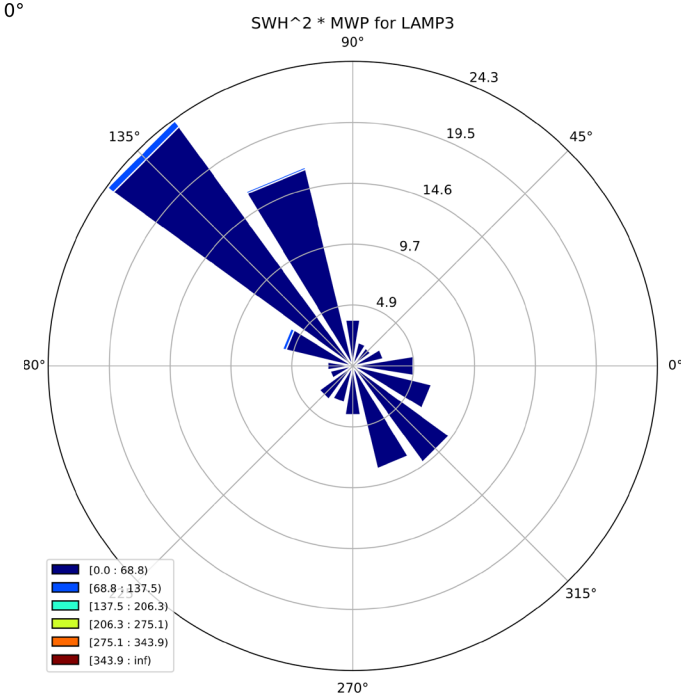
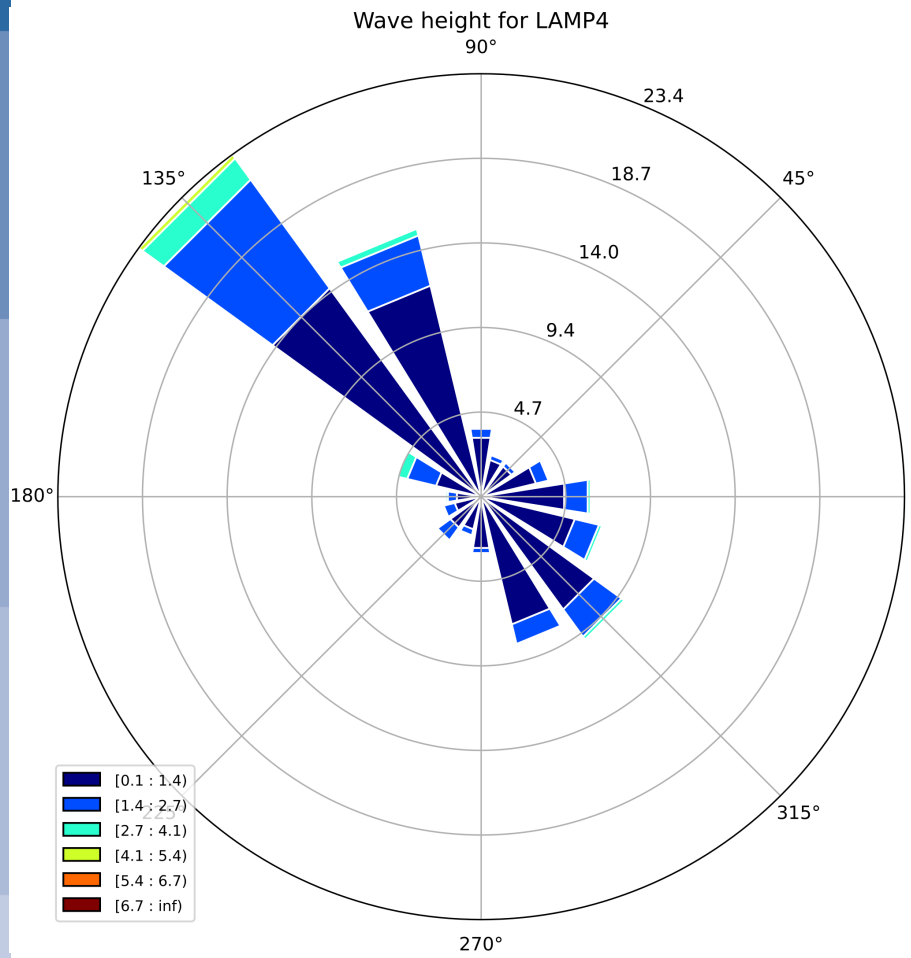
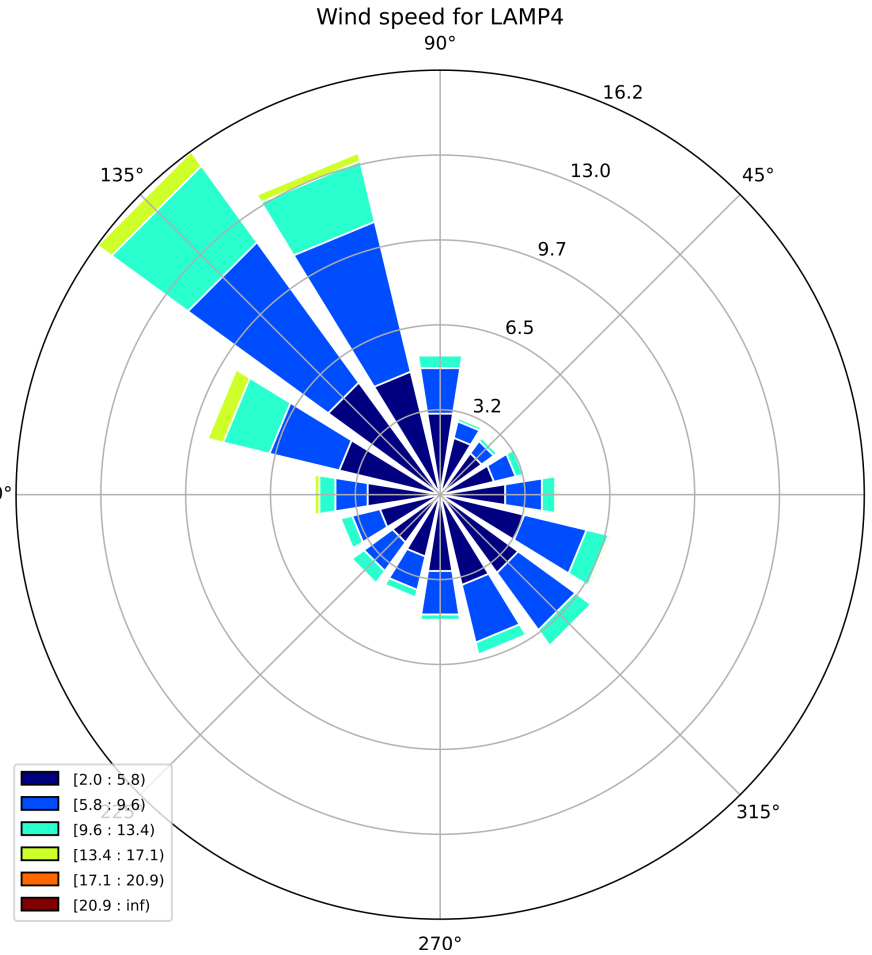
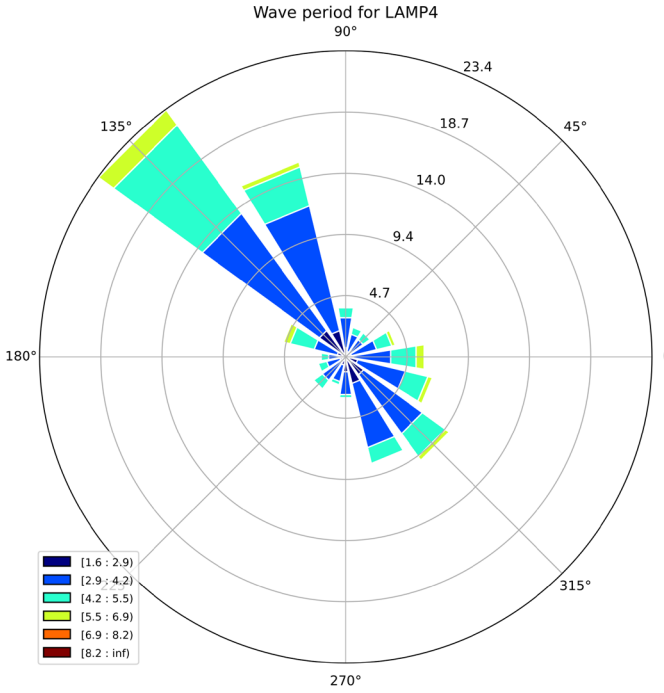


Fig. 17: Wave & wind roses at **LAMP4** (1991-2020)







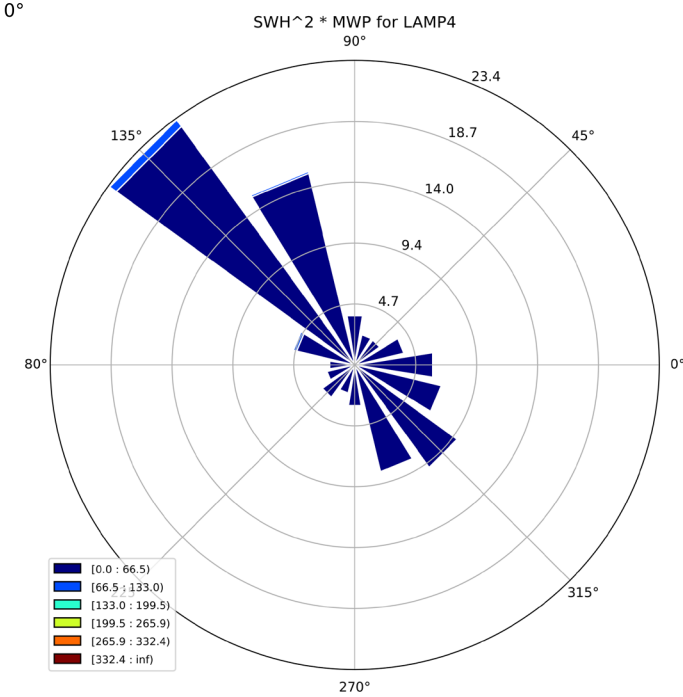
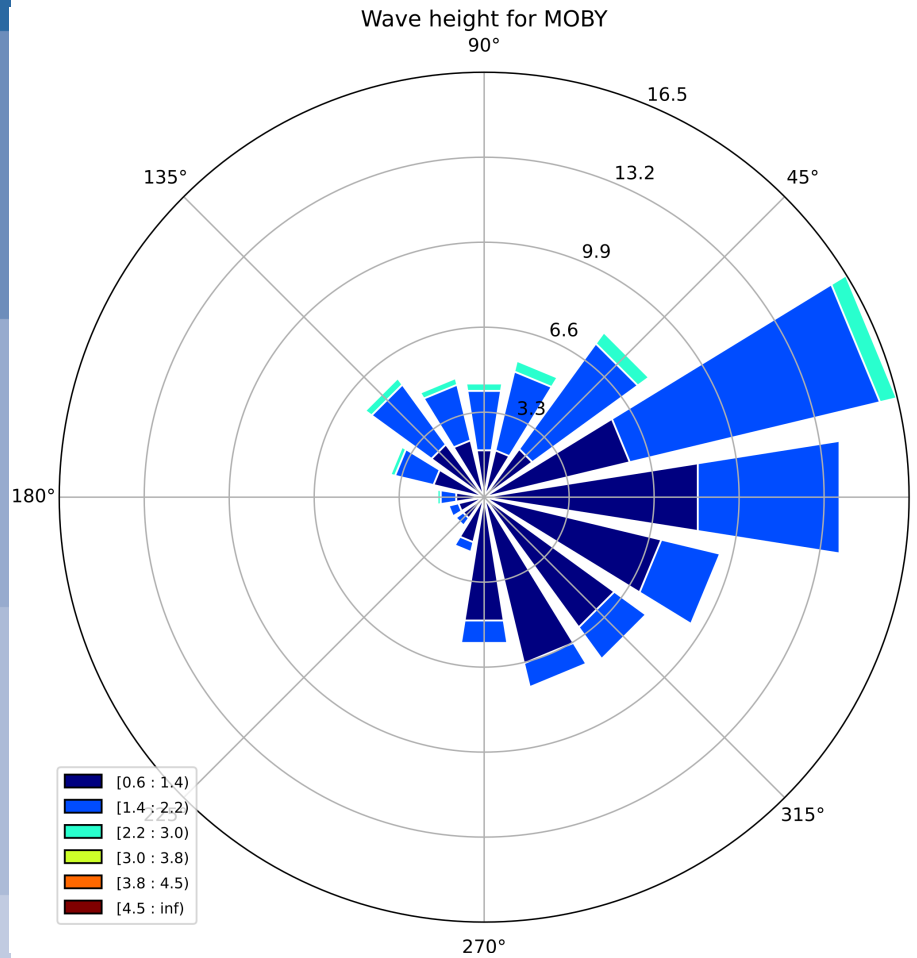
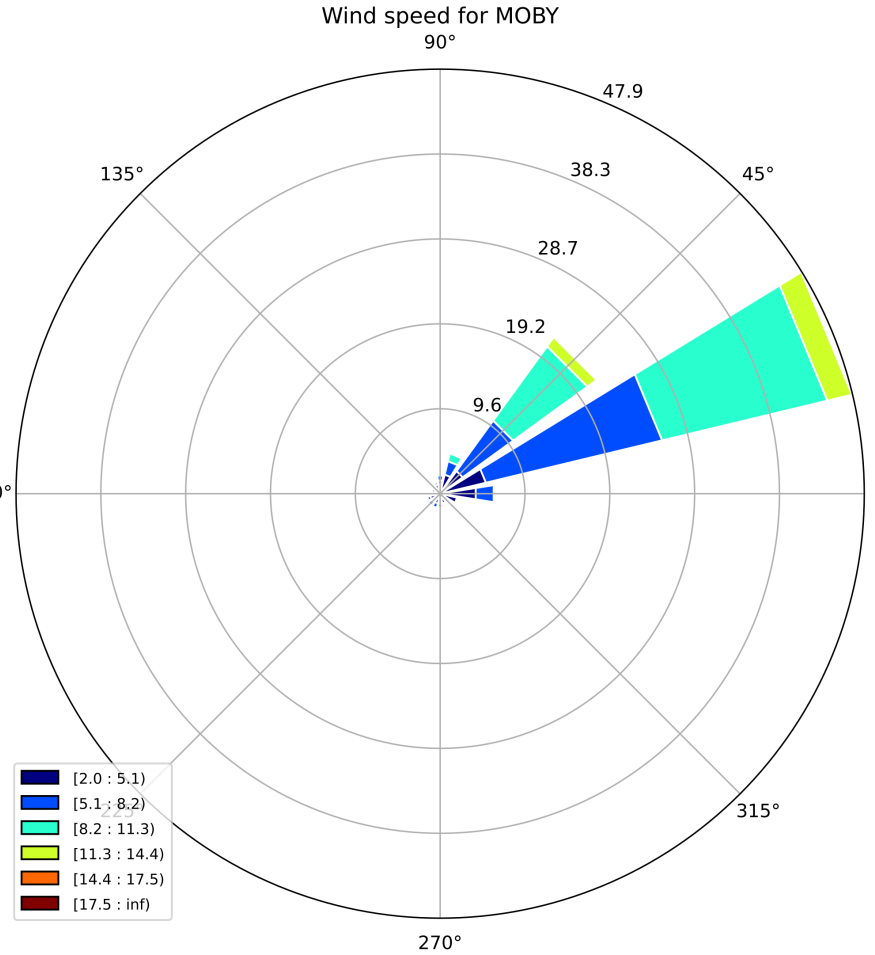
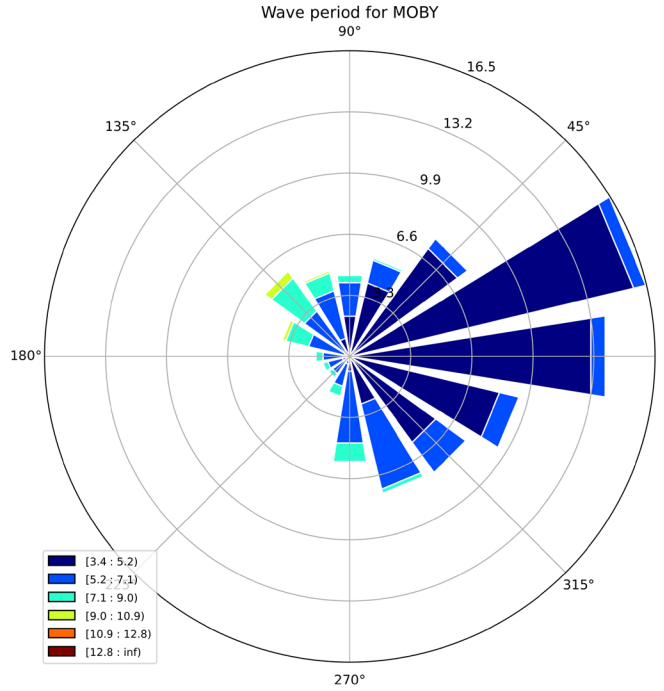


Fig. 18: Wave & wind roses at **MOBY** (1991-2020)







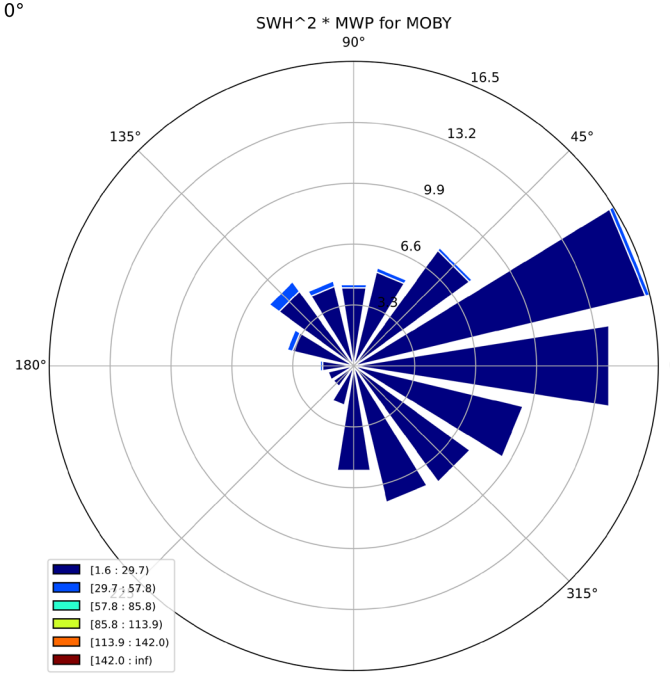
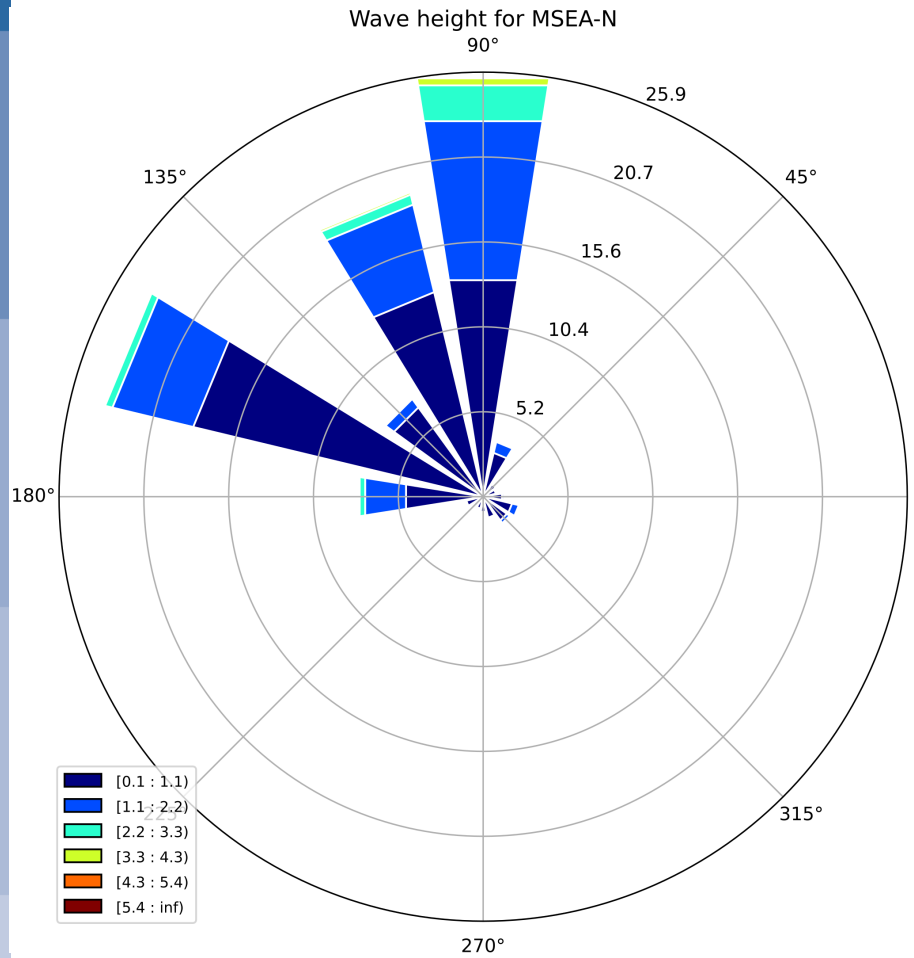
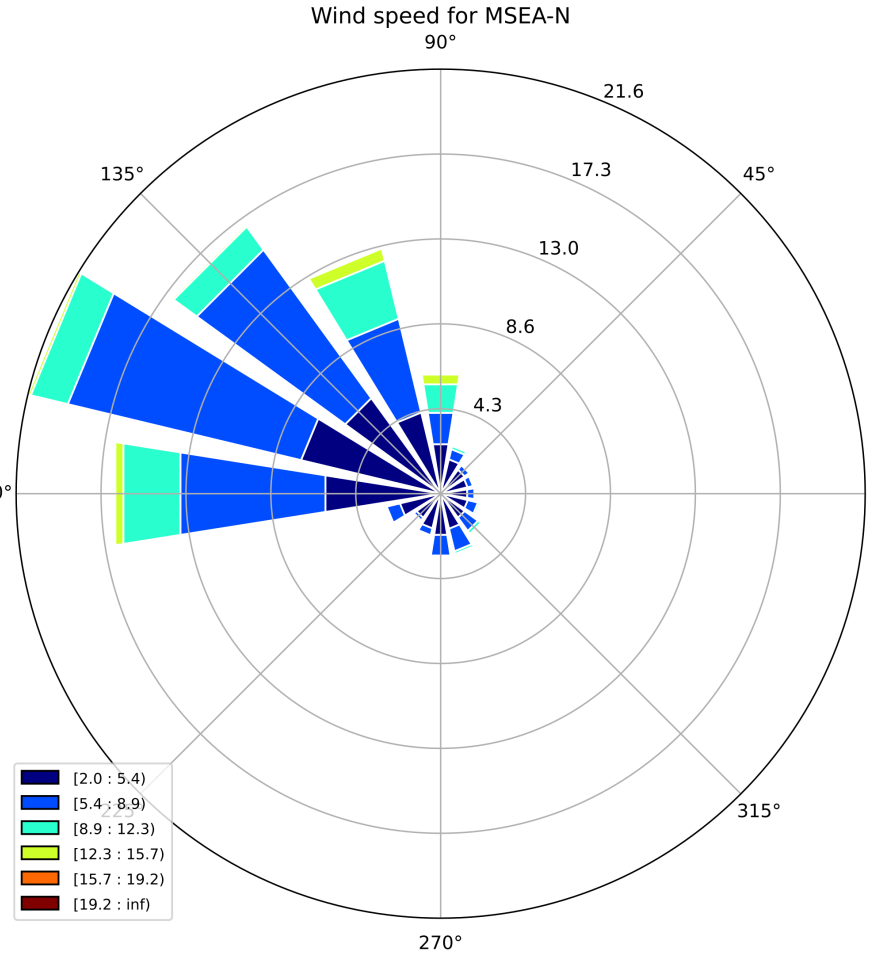
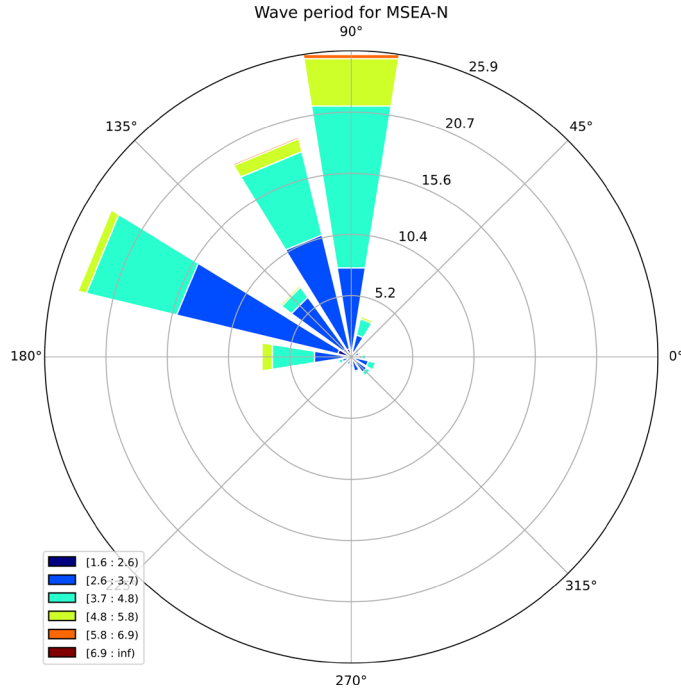


Fig. 19: Wave & wind roses at **MSEA-N** (1991-2020)







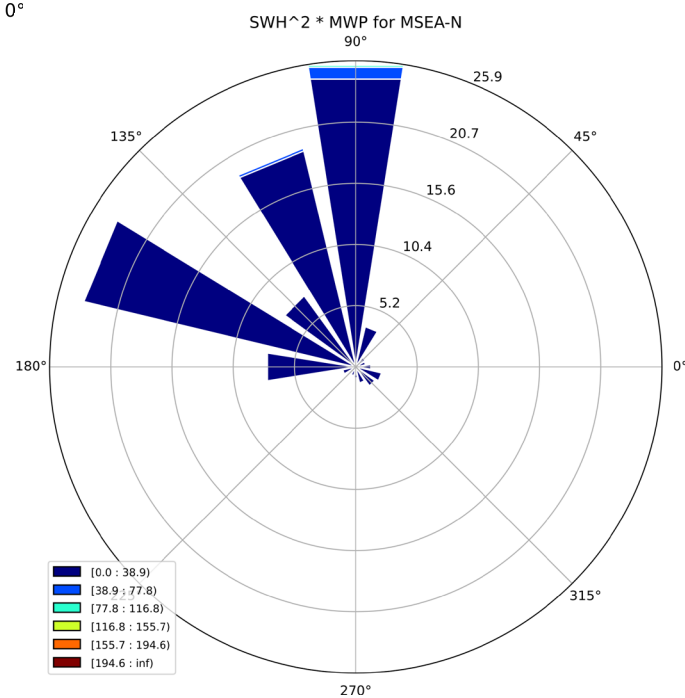
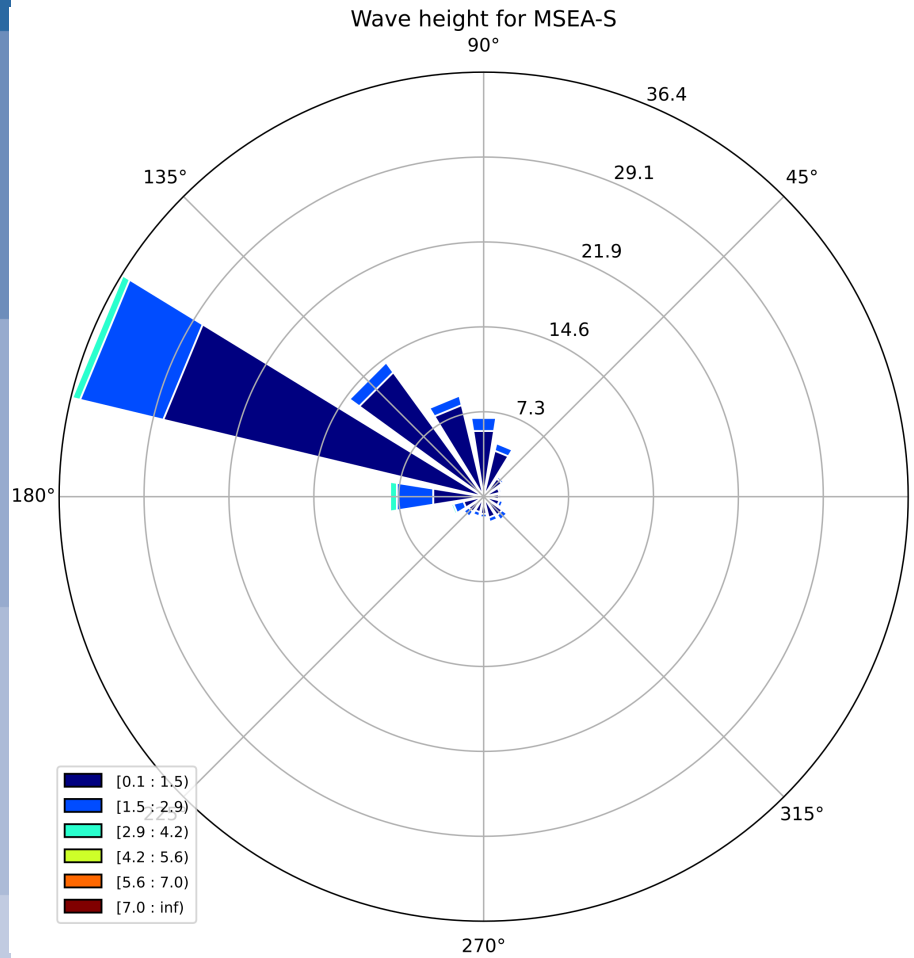
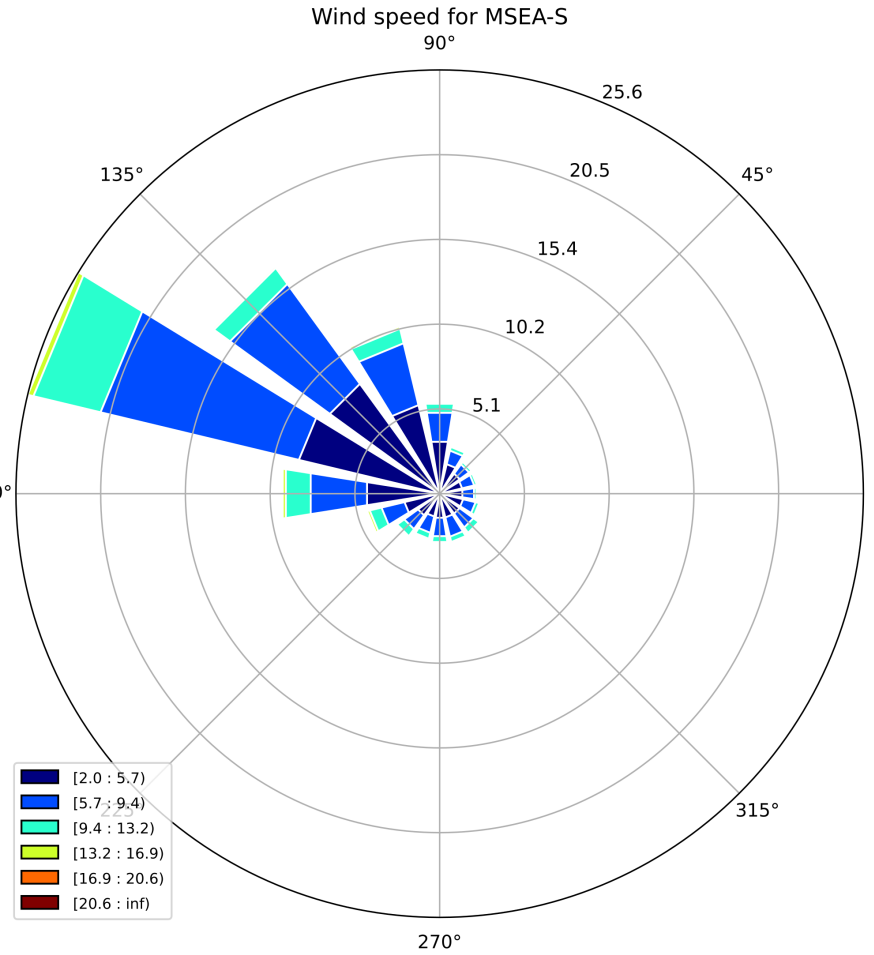
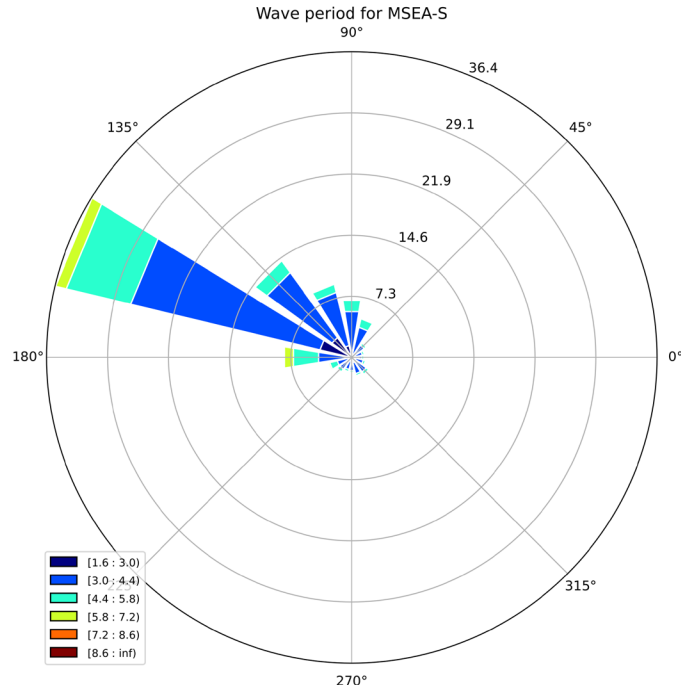


Fig. 20: Wave & wind roses at **MSEA-S** (1991-2020)







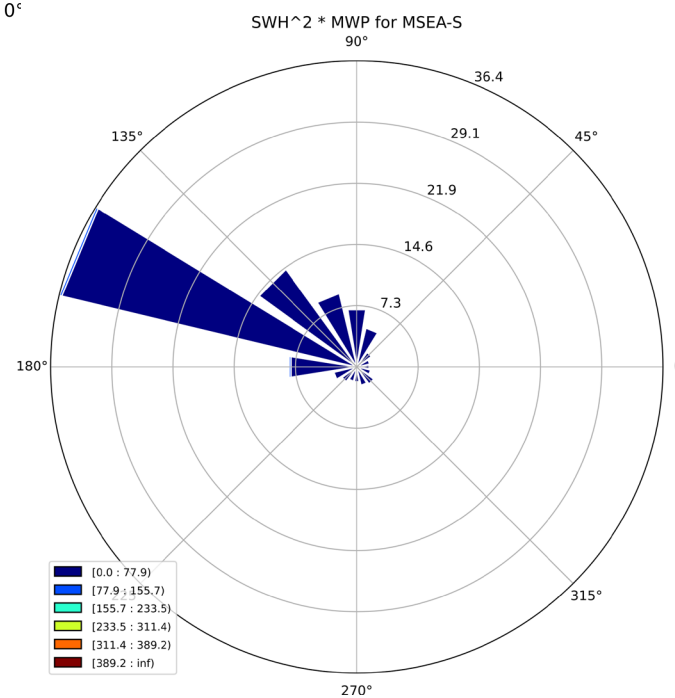
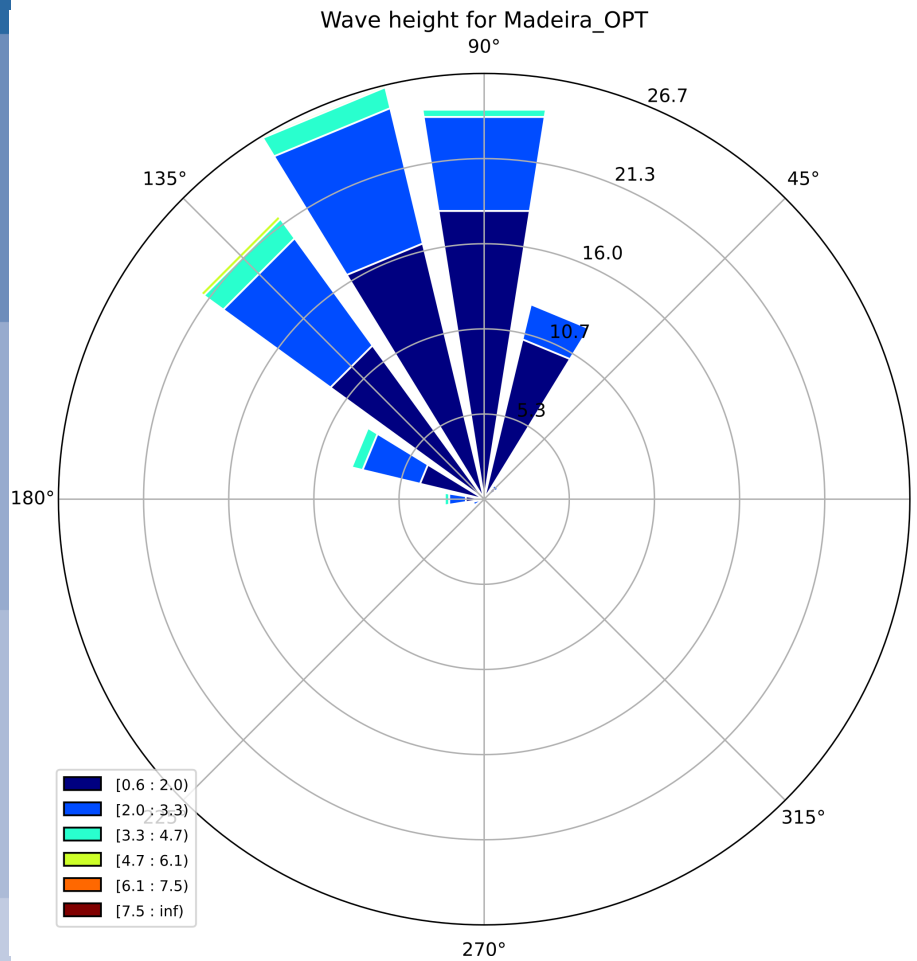
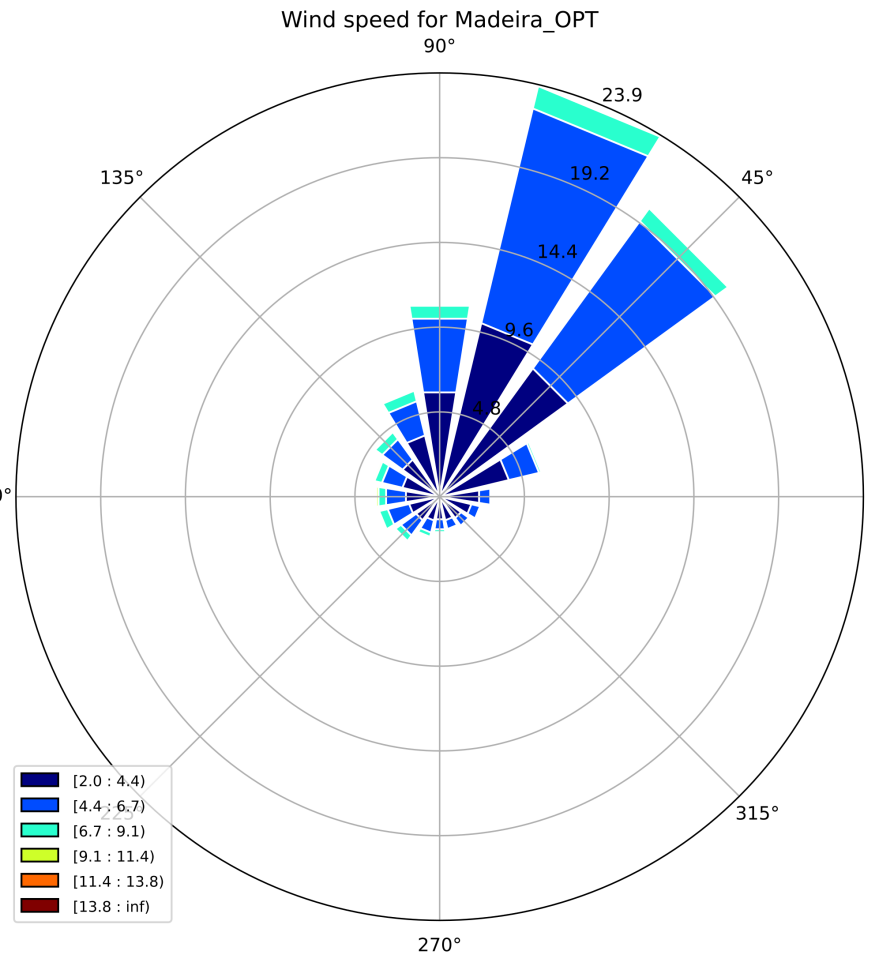
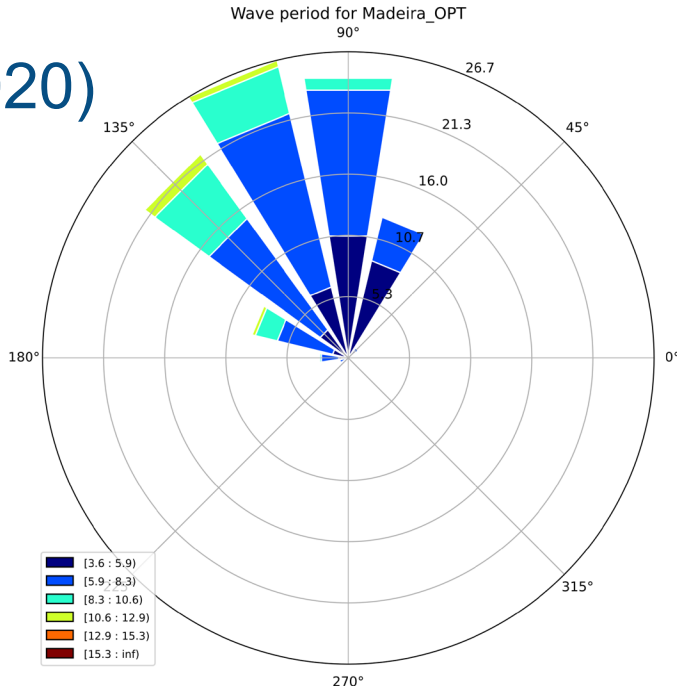


Fig. 21: Wave & wind roses at **Madeira_OPT** (1991-2020)







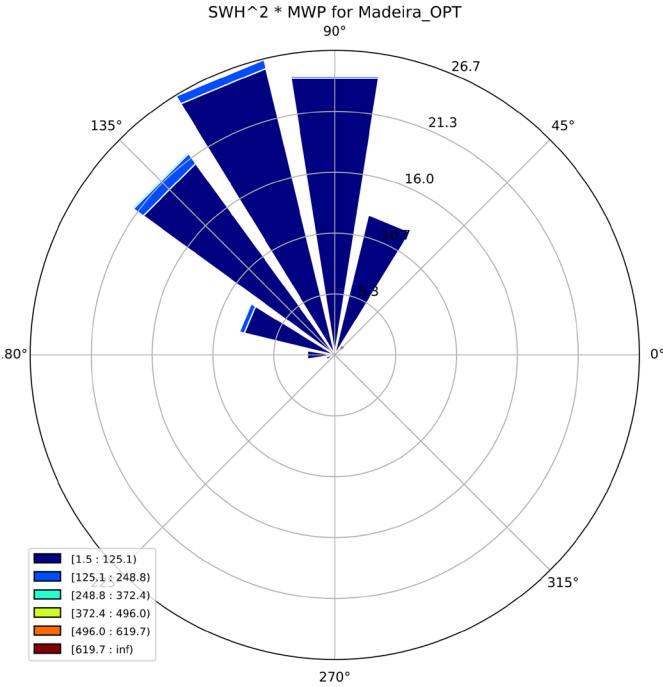
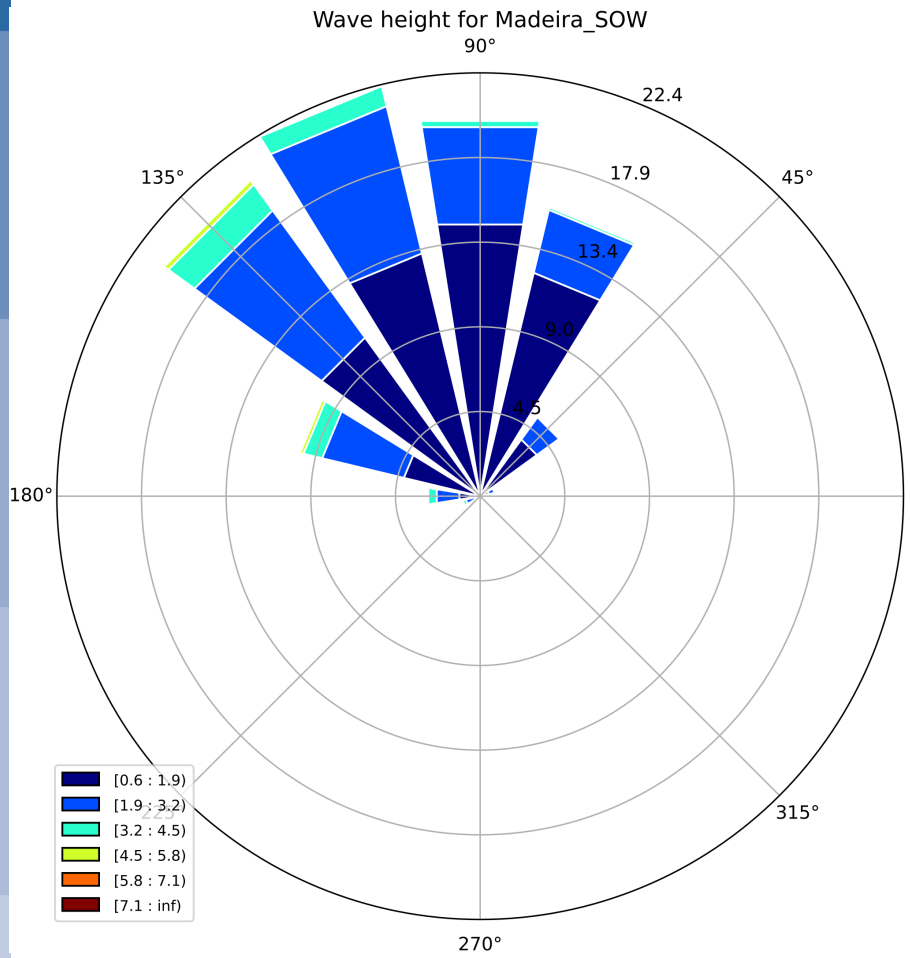
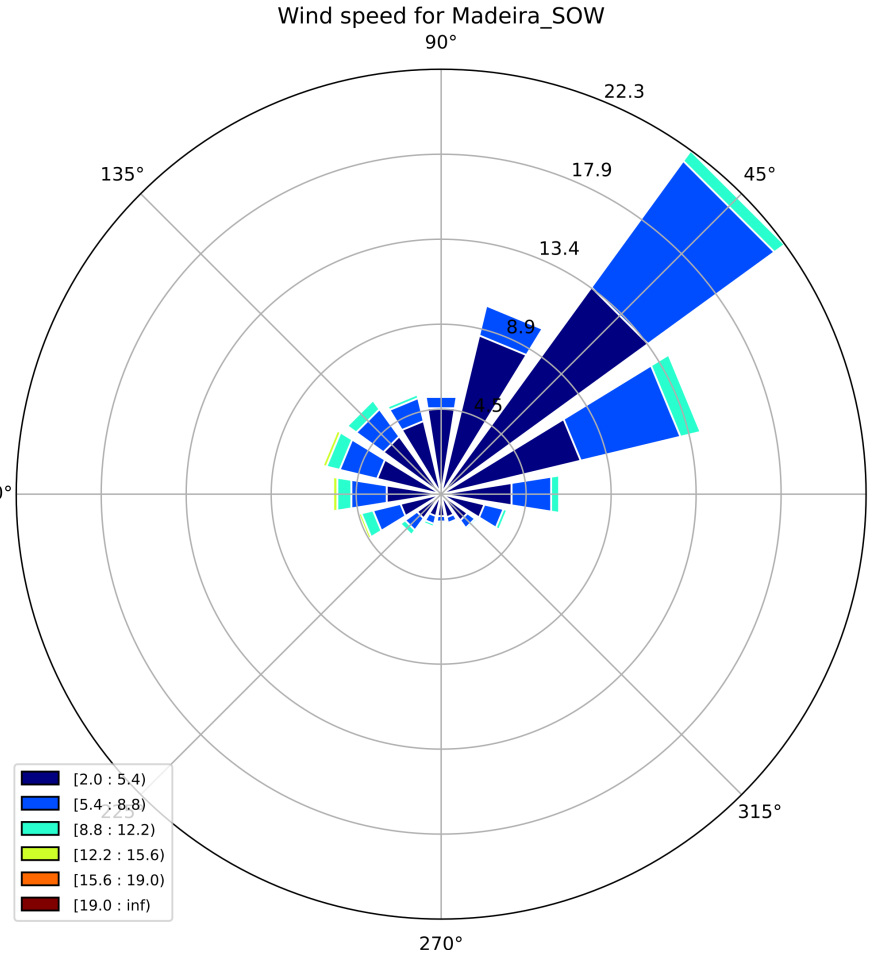
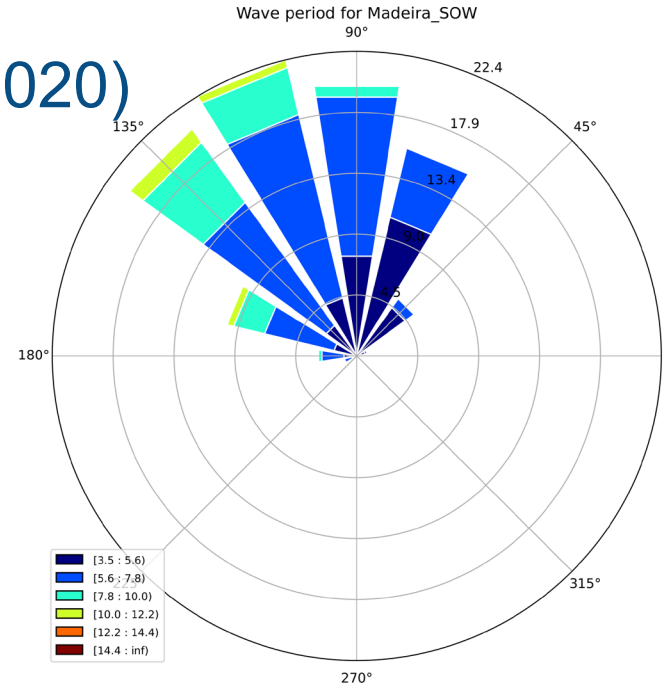


Fig. 22: Wave & wind roses at **Madeira_SOW** (1991-2020)







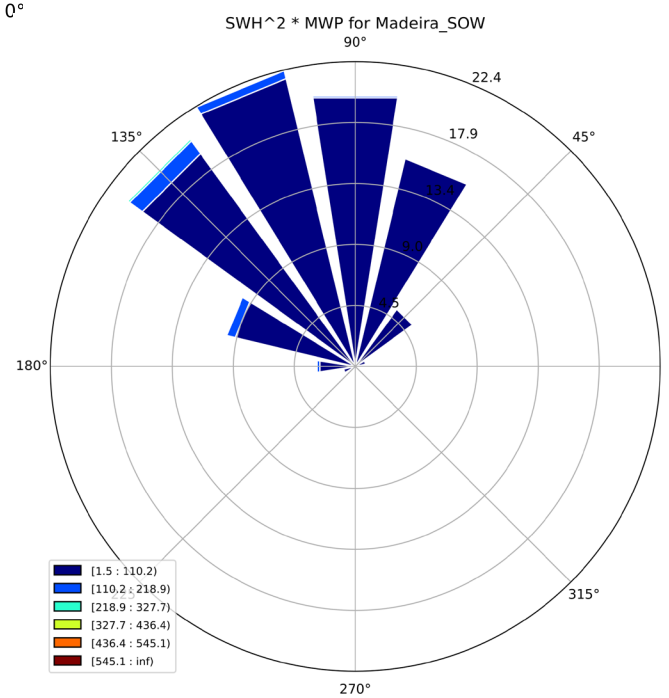
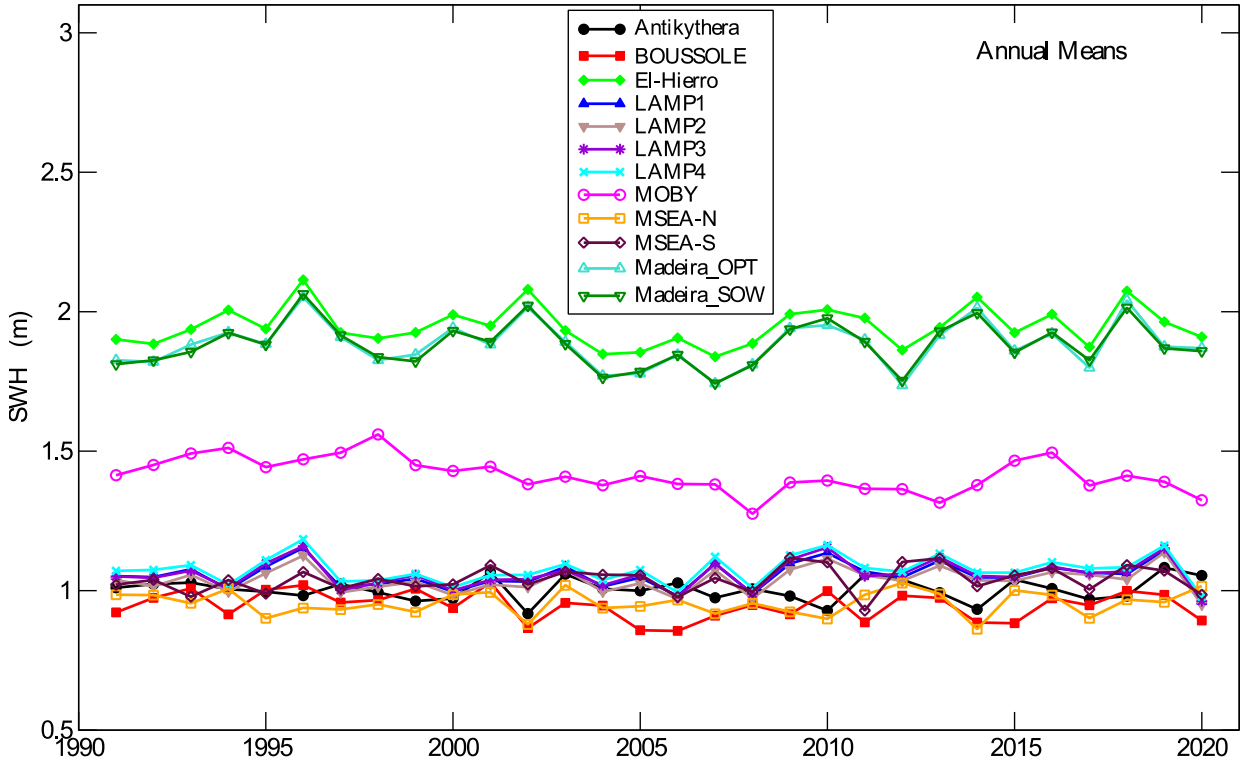


Table 2: Dominant directions of waves and wind (coming from)

Name	Wave conditions	Wind conditions
Antikythera	NNE	N – NNE & W – WSW
BOUSSOLE	WSW – SW	NE – ENE & WSW – SW
El Hierro	NW – NNE	NNE – NE
LAMP1	NW – NNW	NW – NNW
LAMP2	NW – NNW	NW – NNW
LAMP3	NW – NNW	NW – NNW
LAMP4	NW – NNW	NW – NNW
MOBY	ENE – E	ENE
MSEA-N	WNW & NNW – N	W – NW
MSEA-S	WNW	WNW – NW
Madeira/OPT	NW – N	NNE – NE
Madeira/SOW	NW – NNE	NE – ENE

Fig. 23-26: Time series of annual means and extremes

Fig. 23: Time series of annual means and extremes of **SWH**



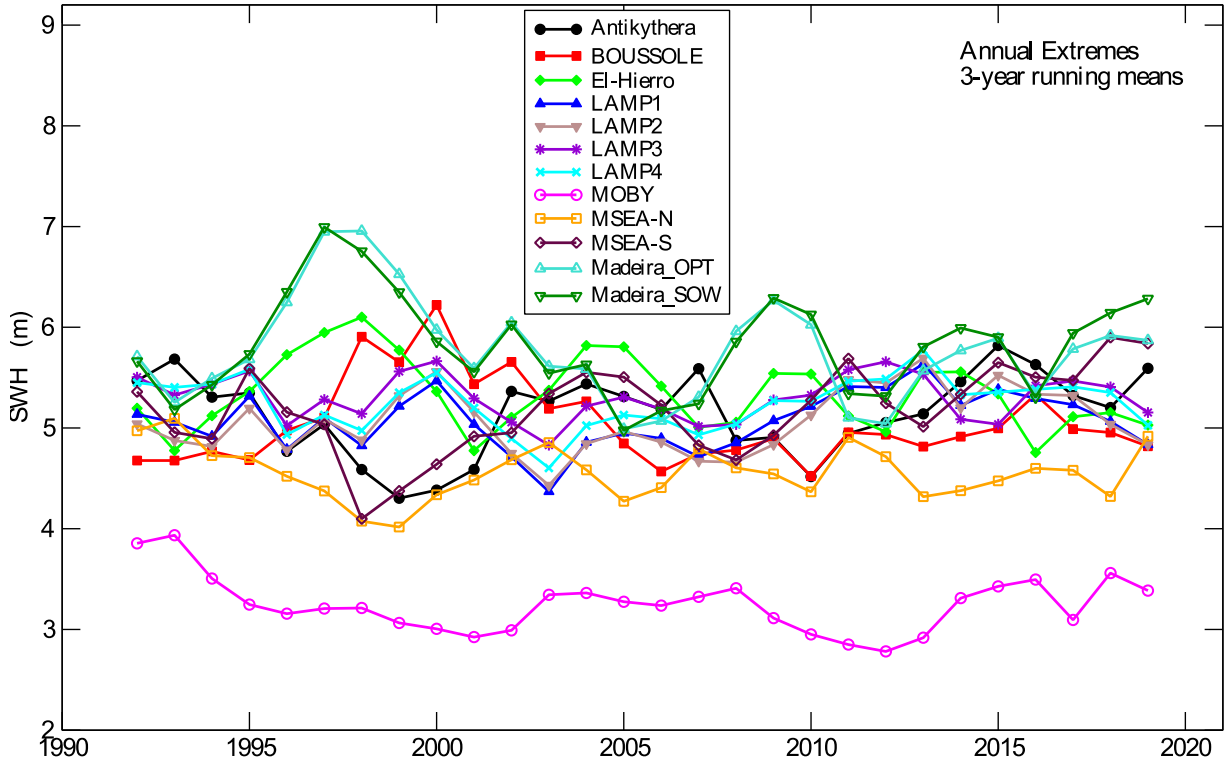
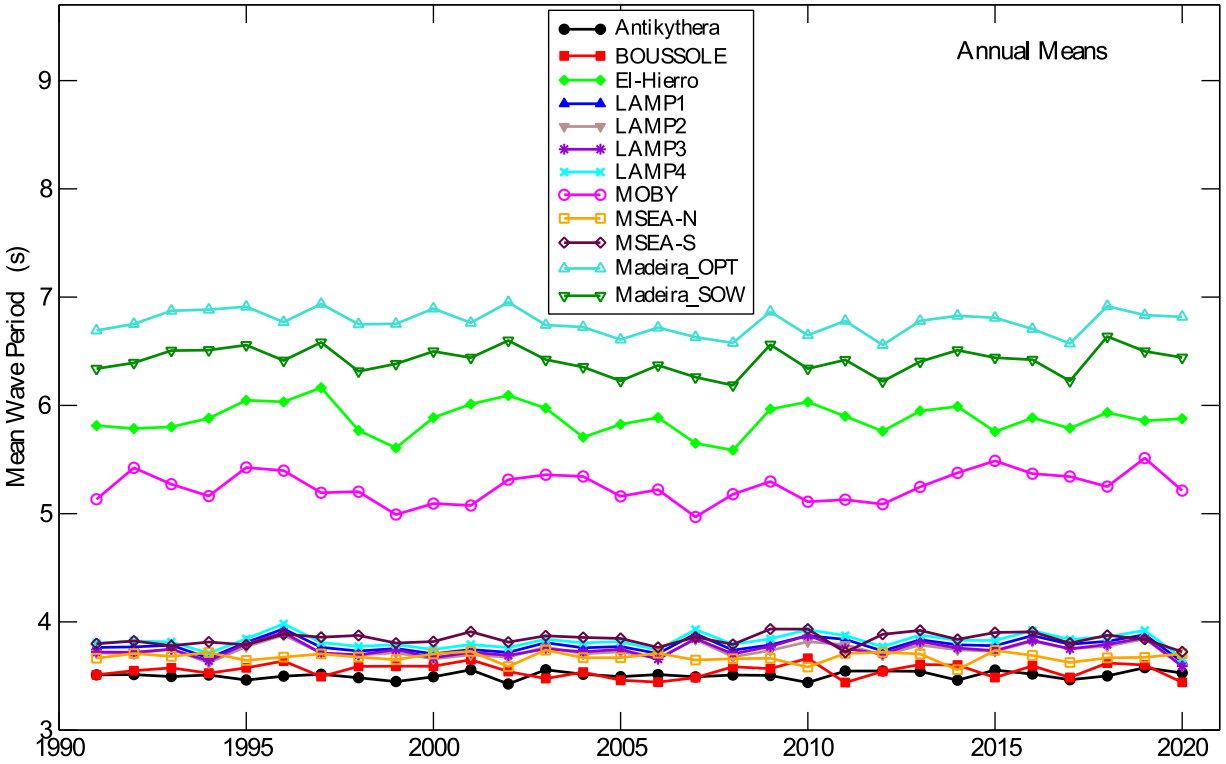


Fig. 24: Time series of annual means and extremes of **MWP**



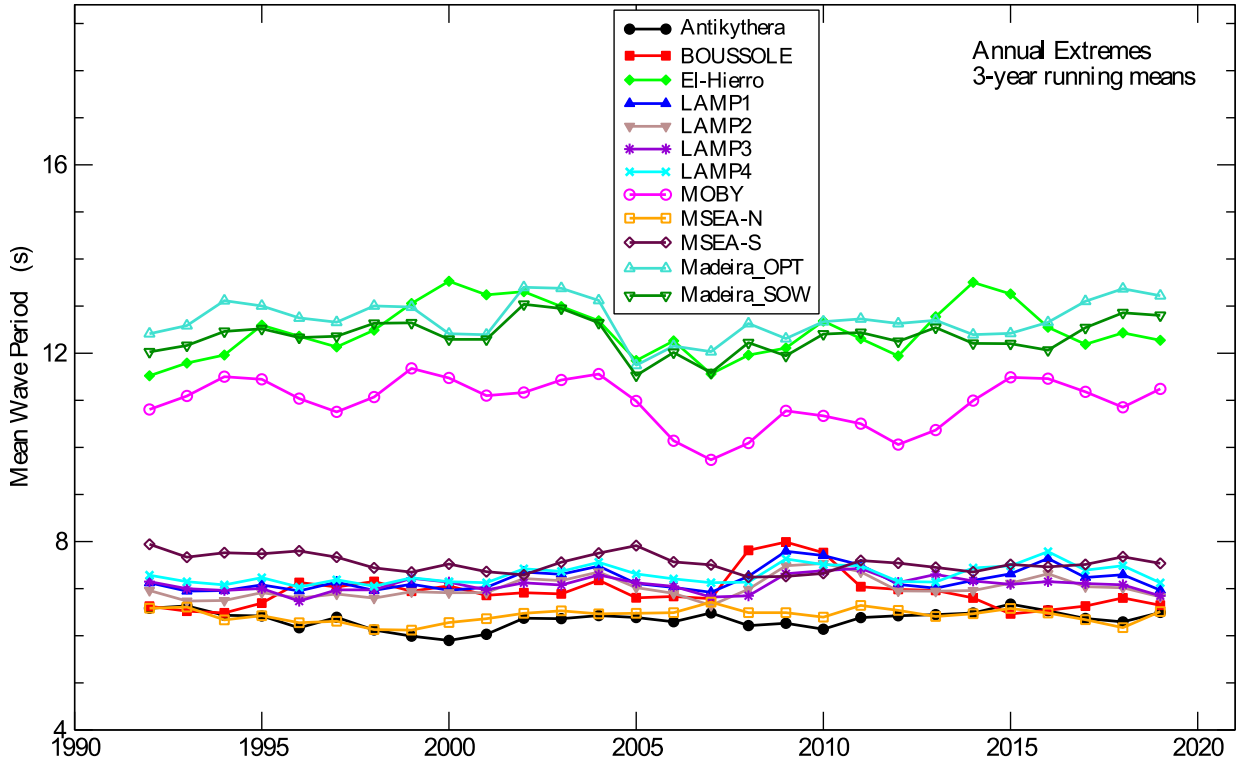
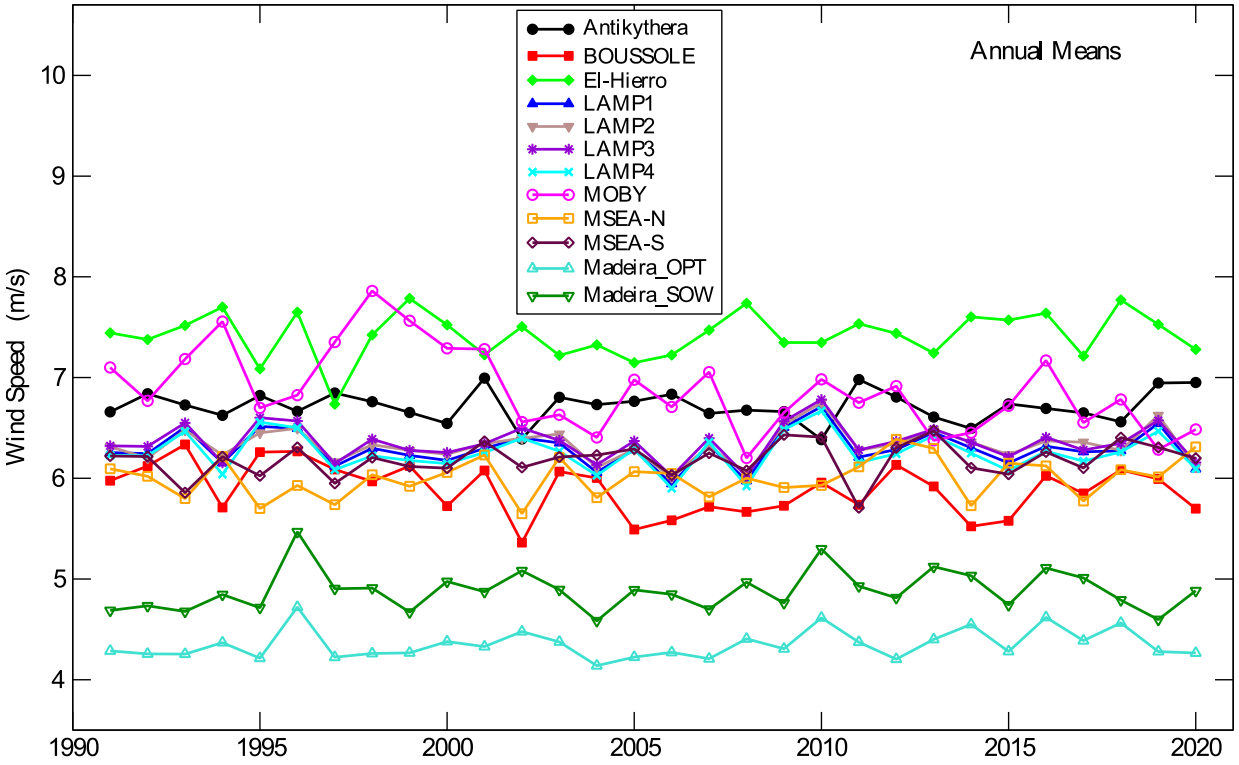


Fig. 25: Time series of annual means and extremes of **U10**



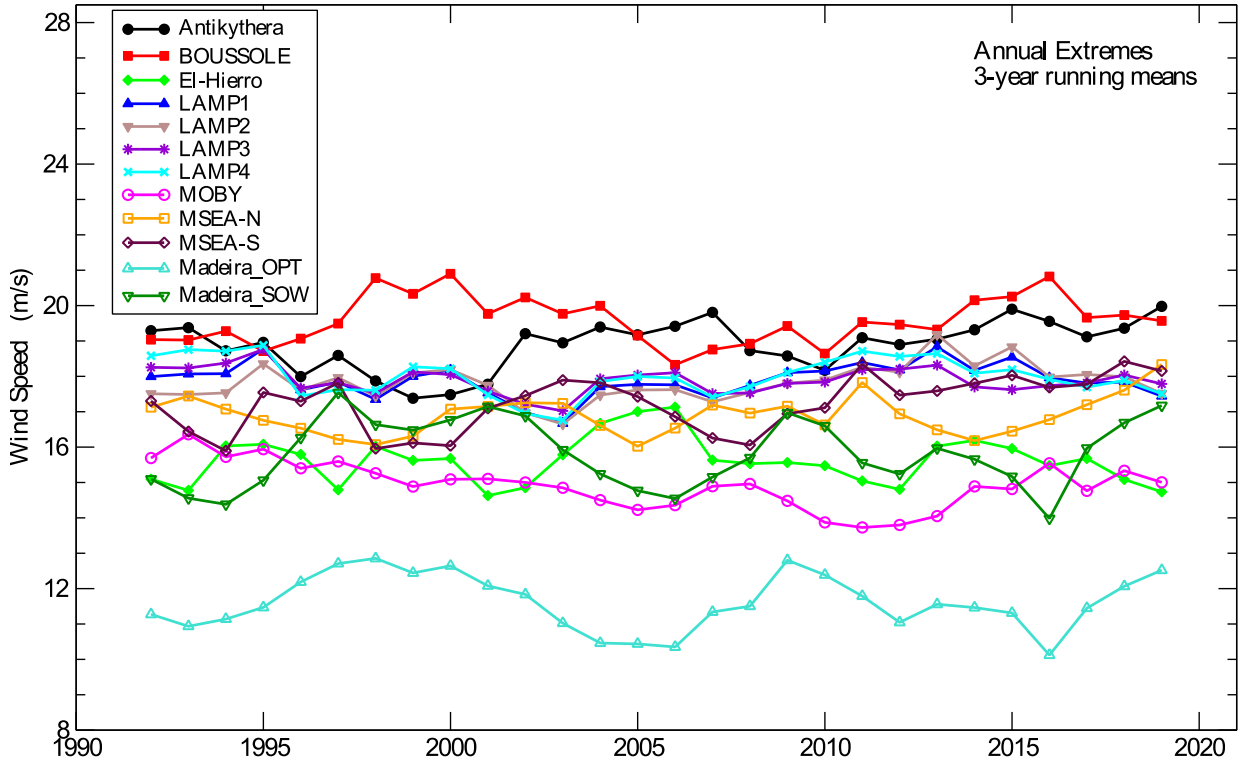
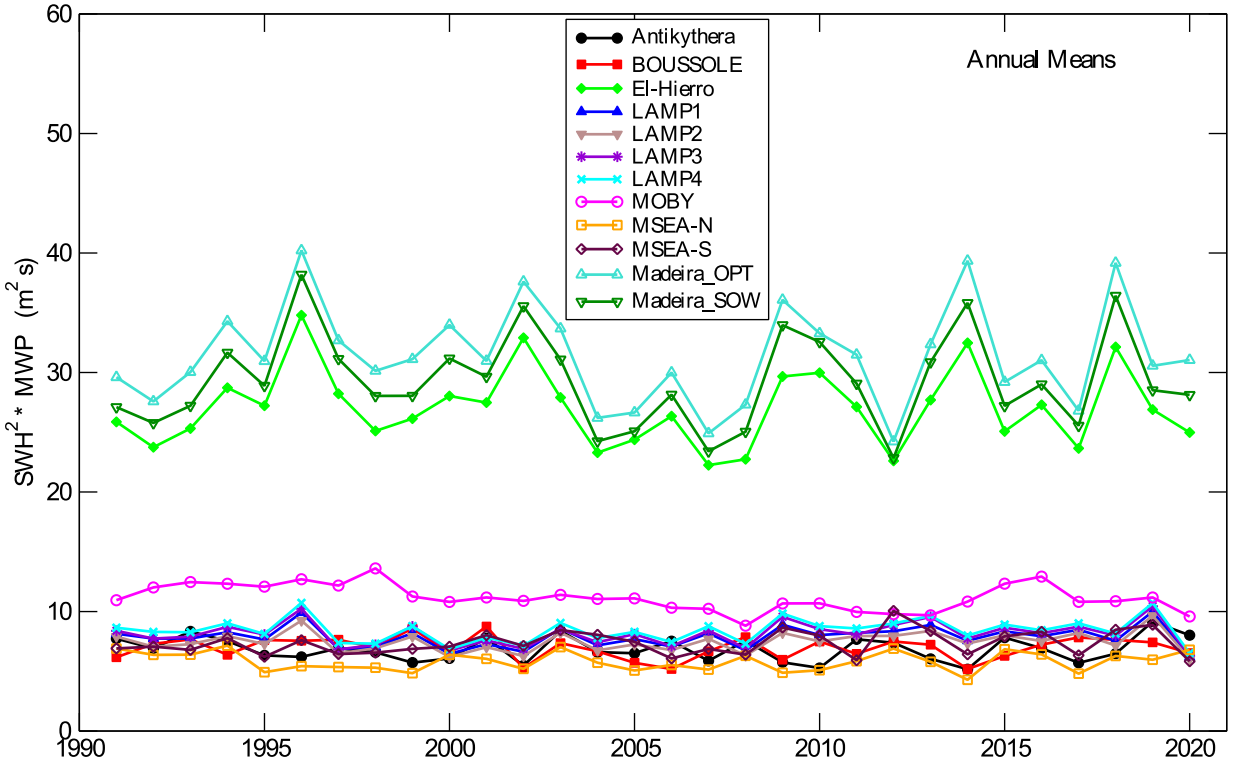


Fig. 26: Time series of annual means and extremes of **H2T**



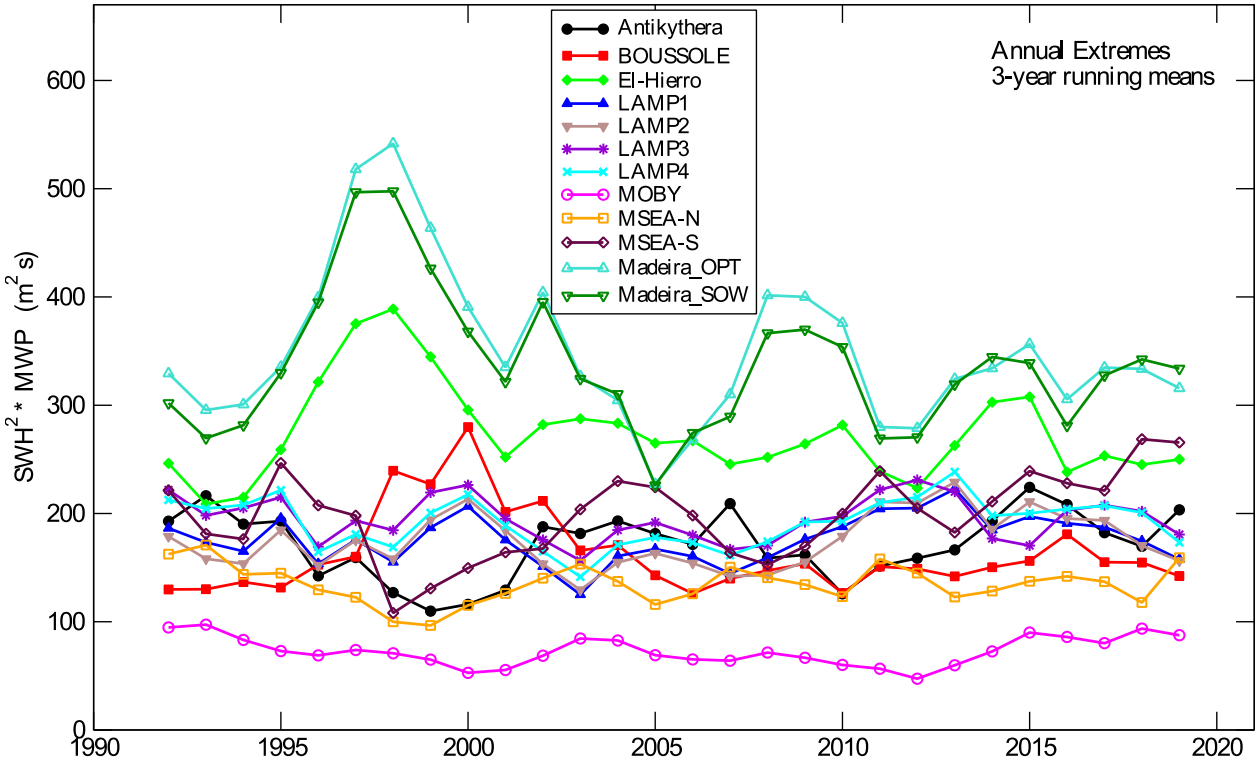


Fig. 27-28: Non-exceedance of annual extremes

Fig. 27: Annual extremes of **SWH** ➔ Non-exceedance

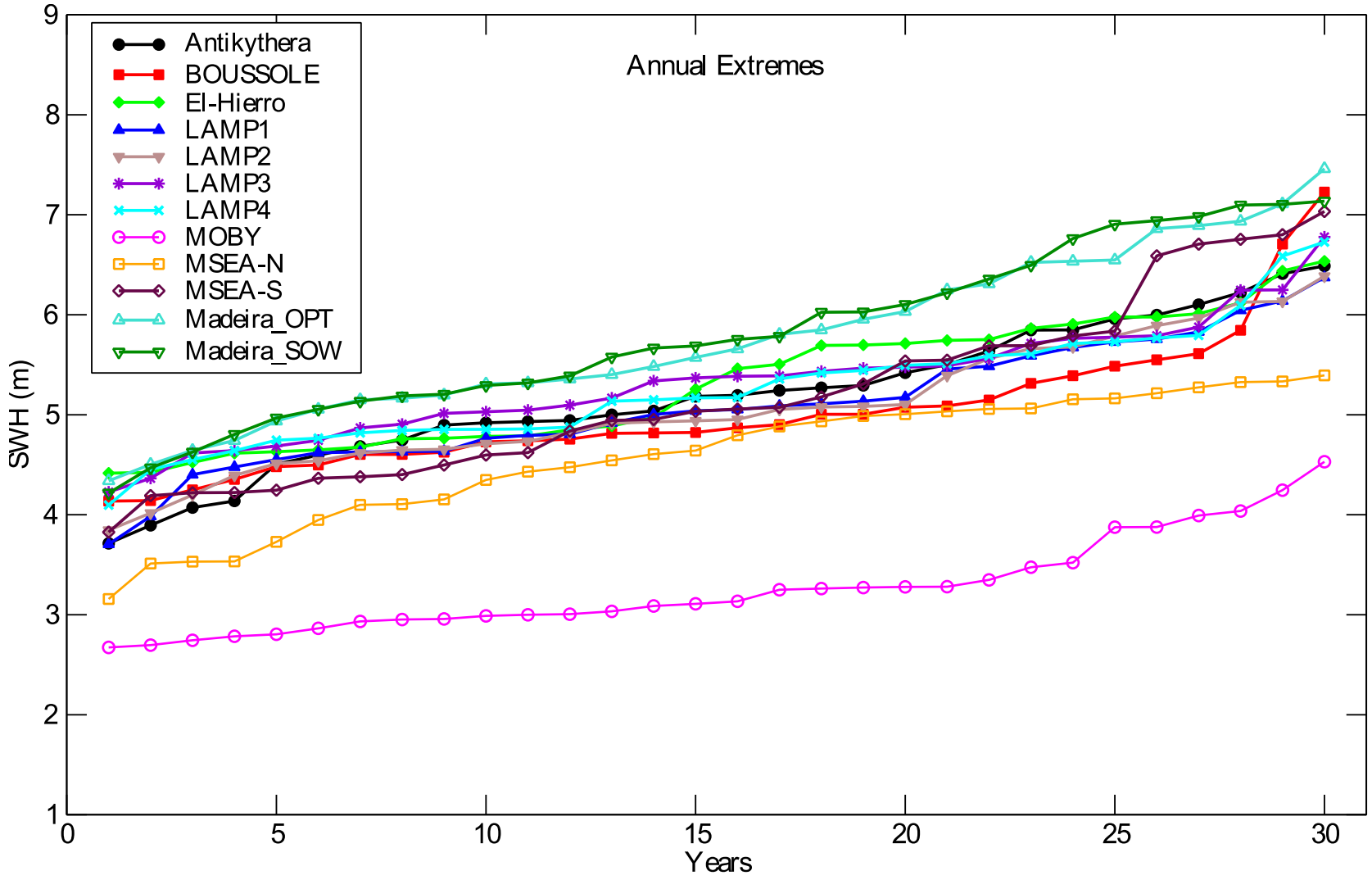


Fig. 28: Annual extremes of **U10** ➔ Non-exceedance

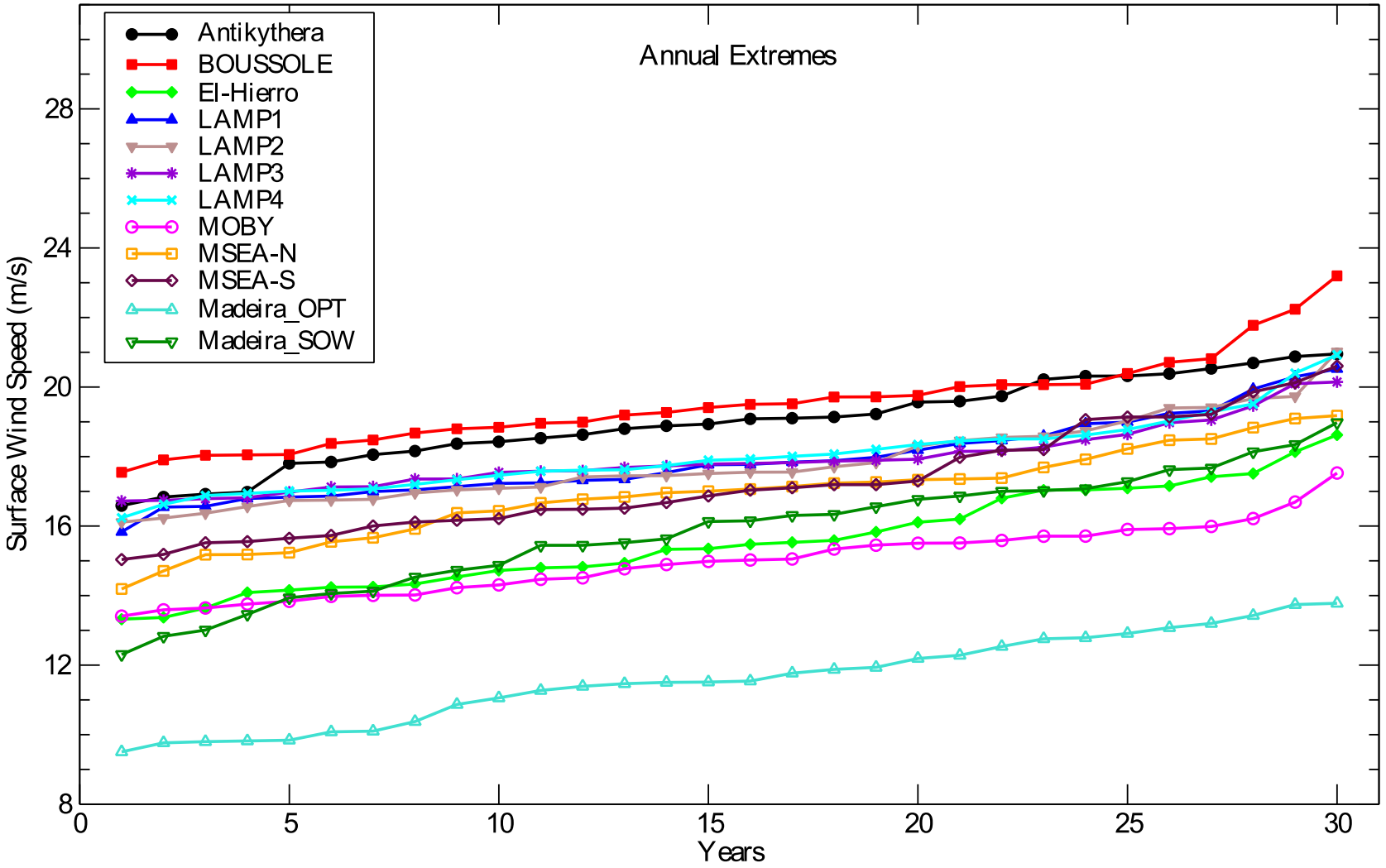
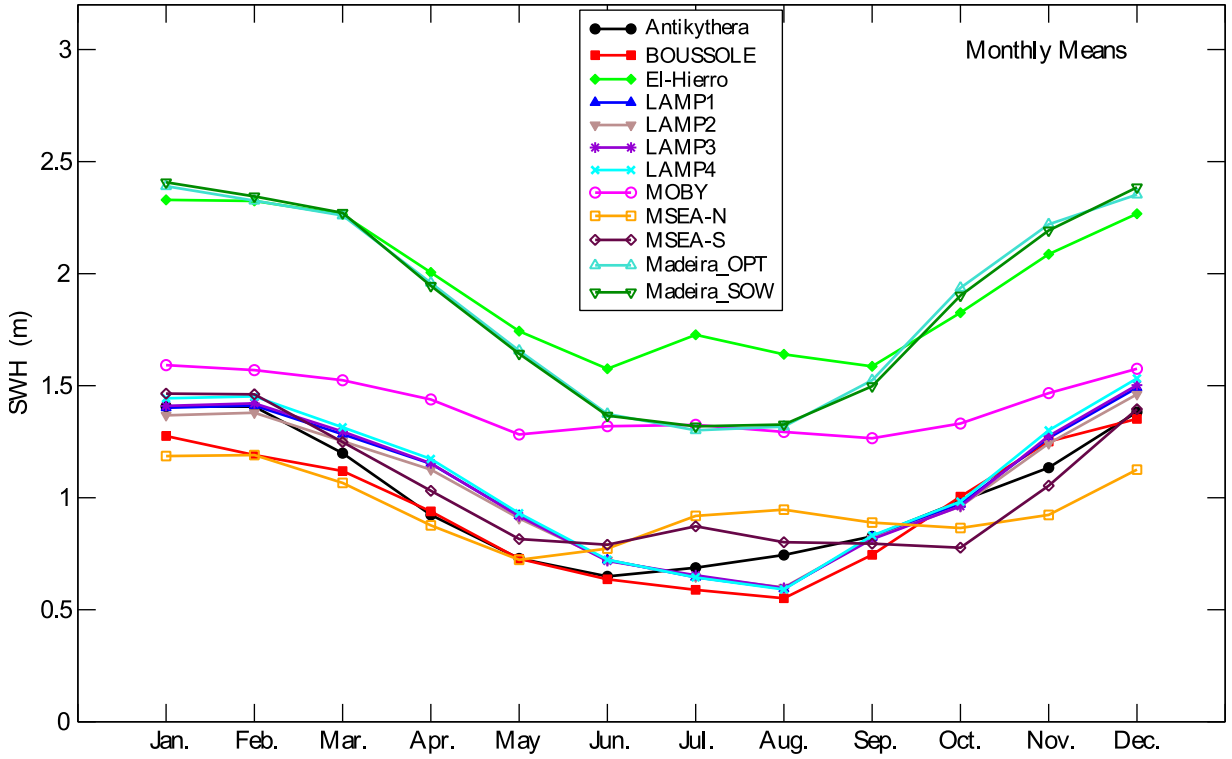


Fig. 29-32: Monthly means and extremes

Fig. 29: Monthly means and extremes of **SWH** over 1991-2020



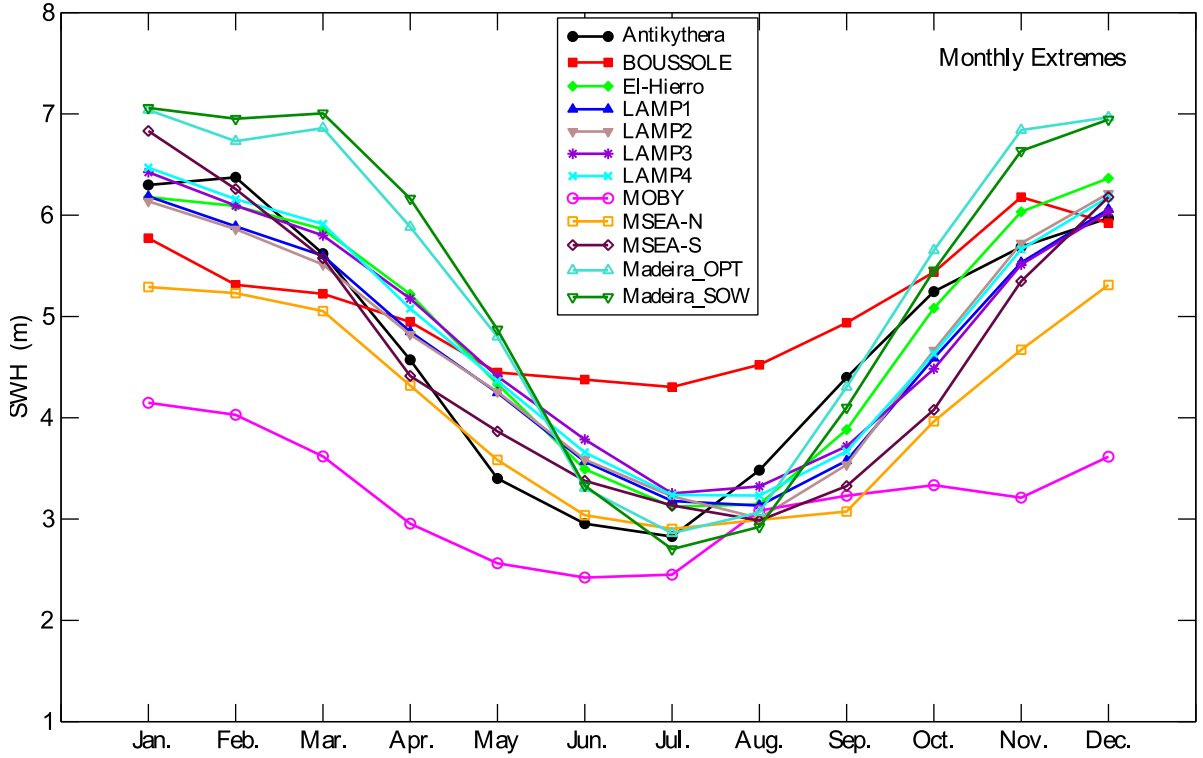


Fig. 30: Monthly means of **MWP** over 1991-2020

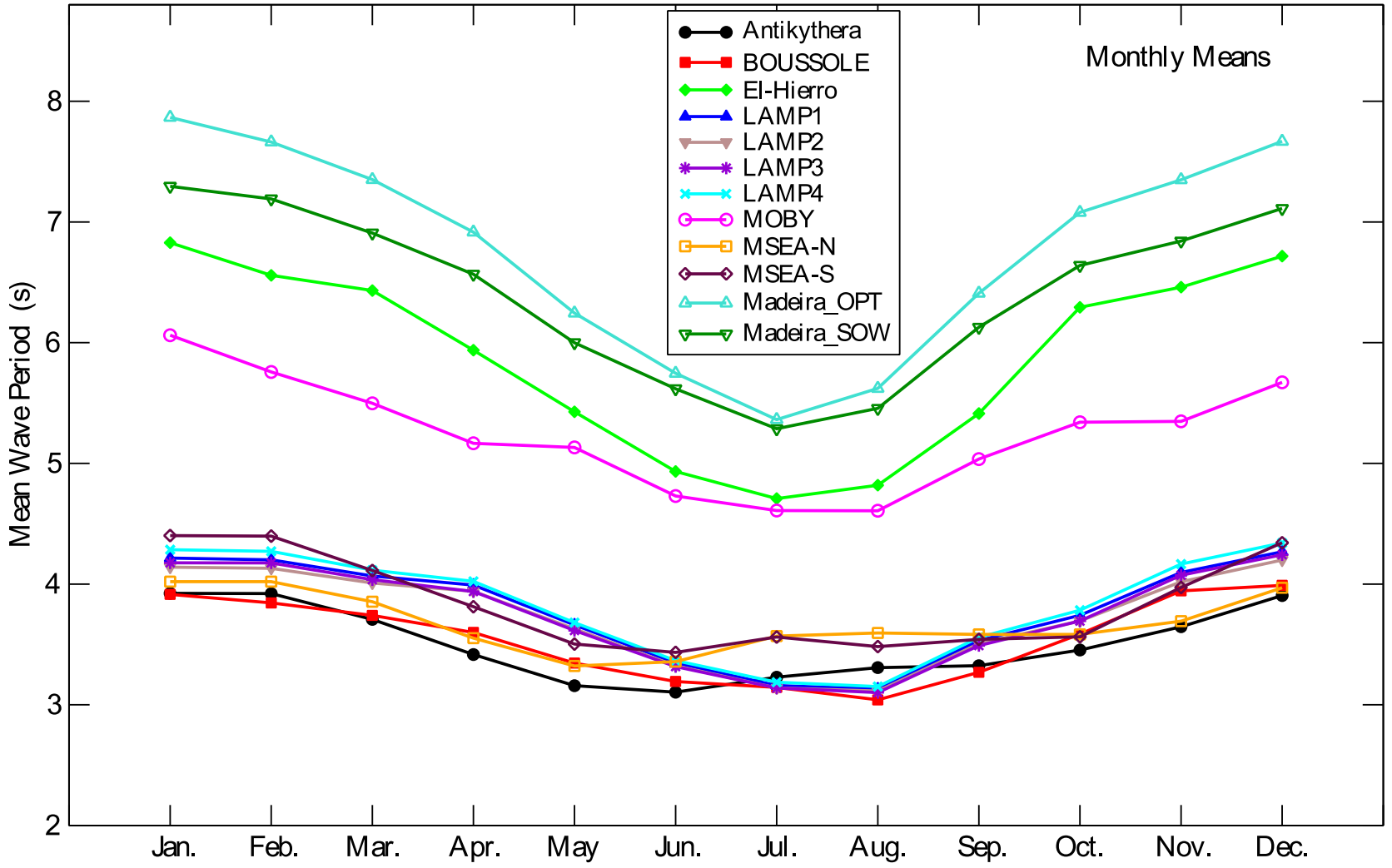
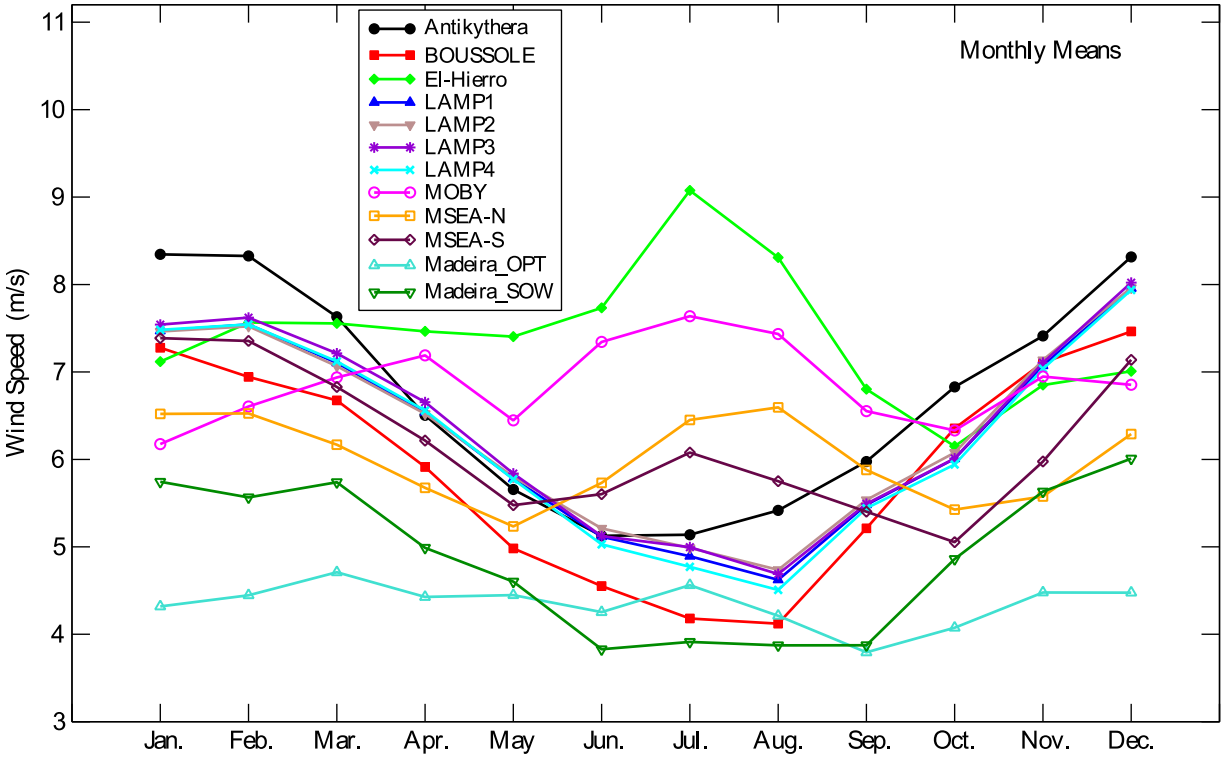


Fig. 31: Monthly means and extremes of **U10** over 1991-2020



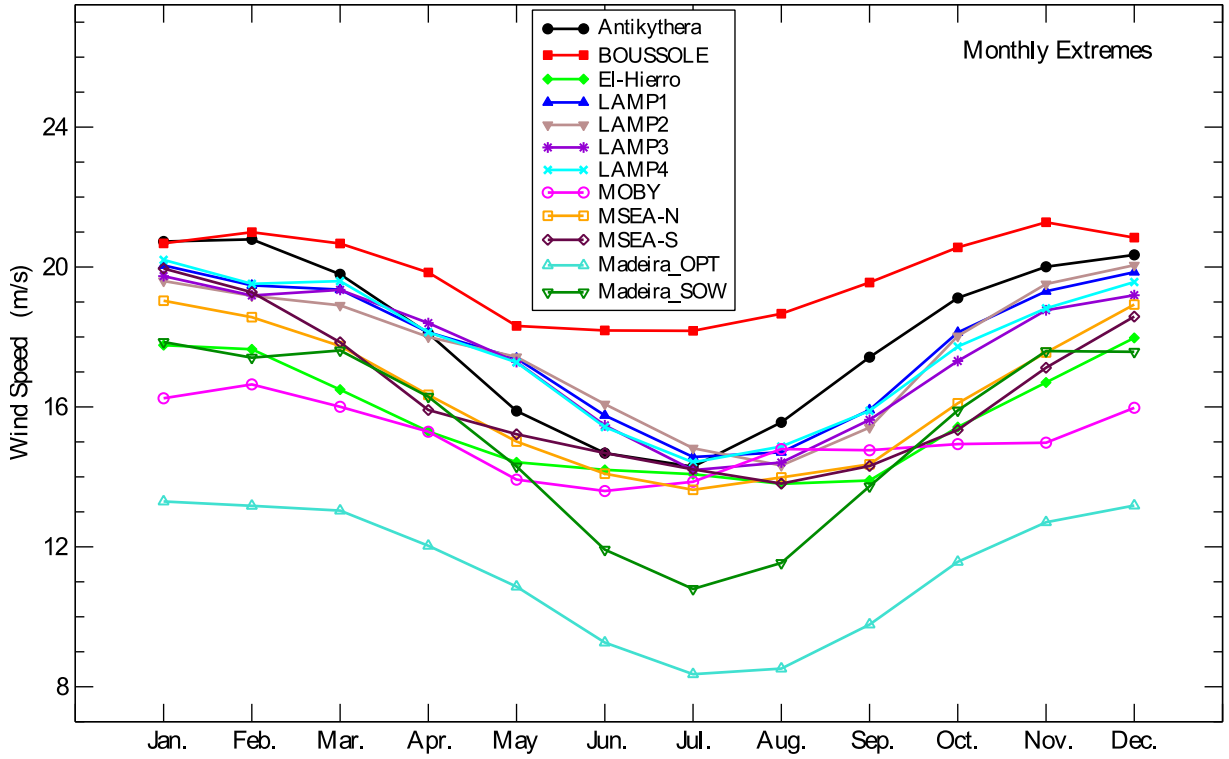


Fig. 32: Monthly means and extremes of **H2T** over 1991-2020