THE SOUTHERN SWELL IN THE CANARY ISLANDS

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- **Definition:**
  - Swell originated at latitudes far to the south, during the austral winter. This swell travels 10 000 Kms or more.
  - "Old sea": waves grouped, arriving in very separated series (15-25 min vs 3-5 min of typical northern swell in the islands). The quiet periods between series transmit a dangerous and false perception of calm.
  - Steep slope of the coast and long period swell: a dangerous combination.
  - Unusual direction: intense swell in southern coasts, known for having quiet waters.

The southern swell in the Canary Islands. I.

- *La Provincia*, local newspaper, August 13, 2023 (https://www.laprovincia.es/gran-canaria/2023/08/13/aviso-amarillo-mala-mar-aguas-90922466.html):


LA PROVINCIA
DIARIO DE LAS PALMAS

Aviso amarillo por mala mar en las aguas del sur grancanario

Los fuertes vientos y el mar de fondo de hasta dos metros obligan a extremar la precaución en el litoral y en navegación

- *La Provincia*, July 11, 2018 (https://www.laprovincia.es/gran-canaria/2018/07/11/mar-fondo-inunda-avenida-terrazas-9452046.html):


El mar de fondo inunda la avenida y terrazas de Arinaga

Las olas, de hasta cinco metros de altura, llenan de piedras la avenida de los Pescadores - La fuerte provoca destrozos en el mobiliario urbano

Marcos Álvarez Morice

11·07·18 | 19:19

- And more…

The southern swell in the Canary Islands. I.

- AEMET, episode in June, 2006:
  (https://repositorio.aemet.es/bitstream/20.500.11765/13189/1/Mar_fondo_Canarias_NT.pdf)

MAR DE FONDO EN LAS ISLAS CANARIAS PROCEDENTE DEL ATLÁNTICO SUR. LA IMPORTANCIA DE INCORPORAR LAS CONDICIONES DE CONTORNO DEL MODELO WAM AL ATLÁNTICO SUR.

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(3) Subdirección General de Climatología y Aplicaciones. Unidad de Meteorología Marítima. INM

- AME, *Tiempo y Clima*, January 2024:

ASOCIACIÓN METEOROLÓGICA ESPAÑOLA

METEOROLOGÍA DE LAS ISLAS CANARIAS

Episodio de mar de fondo del sur en Canarias (del 9 al 16 agosto de 2023)

IRENE PEÑATE (AGENCIA ESTATAL DE METEOROLOGÍA-AEMET) Y EDUARDO PORTILLO (INSTITUTO TECNOLÓGICO DE CANARIAS-ITC)

Este caso de estudio está enmarcado en situaciones adversas de oleaje debidas a mar de fondo que afecta a las islas Canarias procedentes del Atlántico Sur

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- **A very important event: August 2023.** Deep lows in the southern hemisphere:

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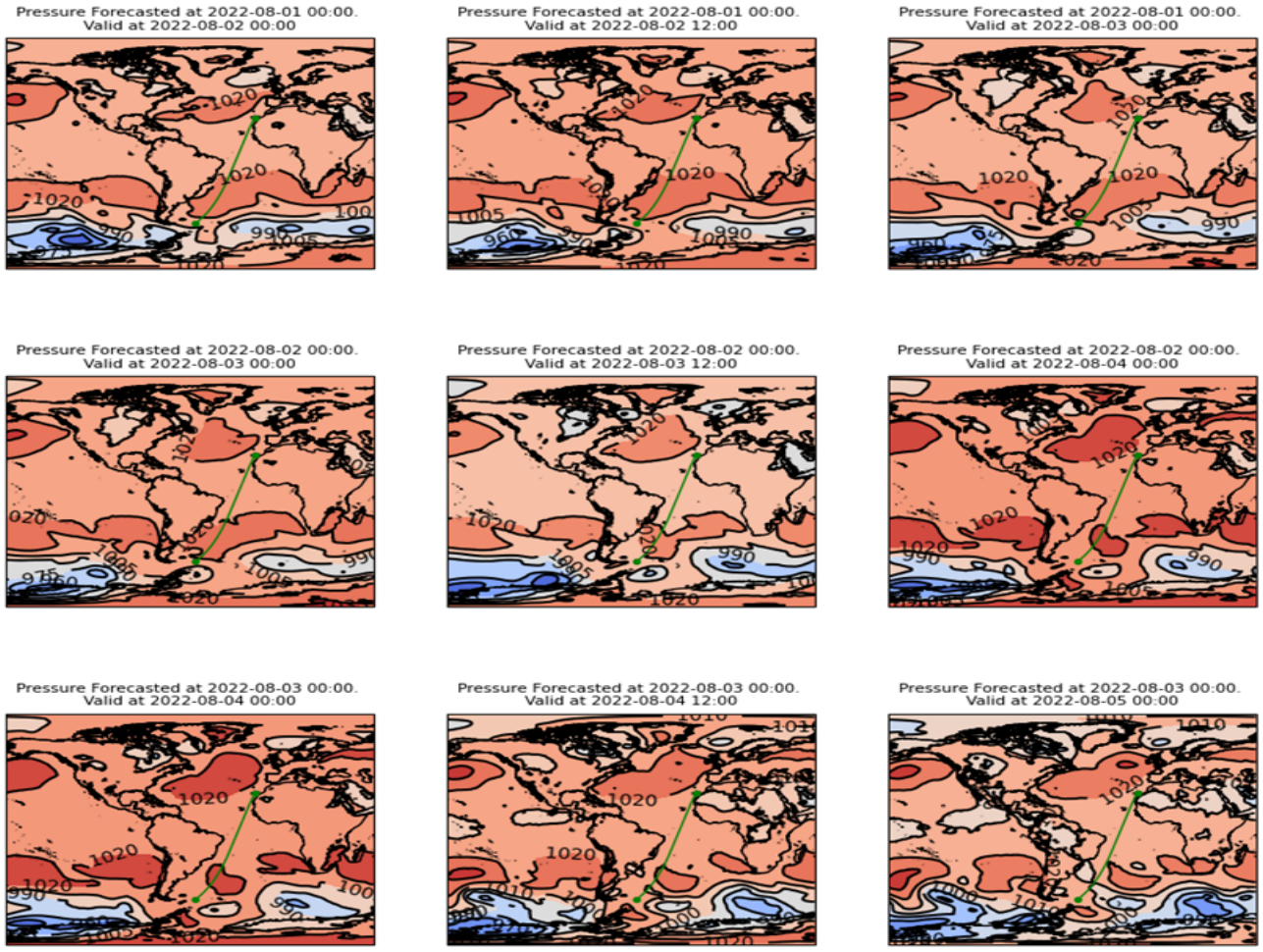
- **A very different situation:** August, 2022 (one year before).



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- **A connection with ENSO?**

- The 2 most intense episodes coincide with an El Niño.
  - August 2023: SOI = -0.8
  - August 2014: SOI = -0.7

- The episode of June, 2016, SOI = -0.4.

- And August 2022, when “nothing” happened, La Niña (SOI=1.0).

- But a strong El Niño in the summer of 2015, and nothing. And episodes with La Niña (August 2016 and August 2021).

- More factors involved:
  - Right direction between South America and Africa.
  - A belt of lows is not needed: 1 low with the right routing is probably enough.

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- **"Tenerife Sur", buoy owned by Puertos del Estado,** moored in the south of Tenerife.

Source: Puertos del Estado.

- Studying southern directions as [135º, 250º] (generous interval). Since 2003-05-06. Months [May, September], to include only austral events.

- **We do not have the full spectrum of the buoy.**
- **The direction problem:** what is the direction of the swell? The buoy offers a mean direction and the direction of the peak.
- **Models offer "wefxd":** an integration of the 2D spectrum to get the mean direction.
- **Can they be compared?**

- **The period problem:** in the previous power equation, T is the period associated with the transmission of the energy, $T_{m-1,0}$, but buoys typically measure the period as the time between two positions at level 0, T_{m02}.

- Let *S* be the spectral energy density (also called elevation variance). Define m_n:

$$m_n = \int_0^{2\pi} \int_0^{\infty} f^n S(\theta, f) df d\theta$$

- Then, for the periods we have

$$T_{m02} = \sqrt{\frac{m_0}{m_2}}$$

$$T_{m-10} = \frac{m_{-1}}{m_0}$$

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- **The significant height of a wave:** many times defined the average of the superior third part of the spectrum, $H_s = \hat{H}_{1/3}$.

- **Another definition (recommended by the WMO):** four times the standard deviation of the sea surface elevation.

$$H_s = H_{m0} = 4\sqrt{E} = 4\sqrt{\int_0^{2\pi}\int_0^{\infty} S(f,\theta)\,df\,d\theta}$$

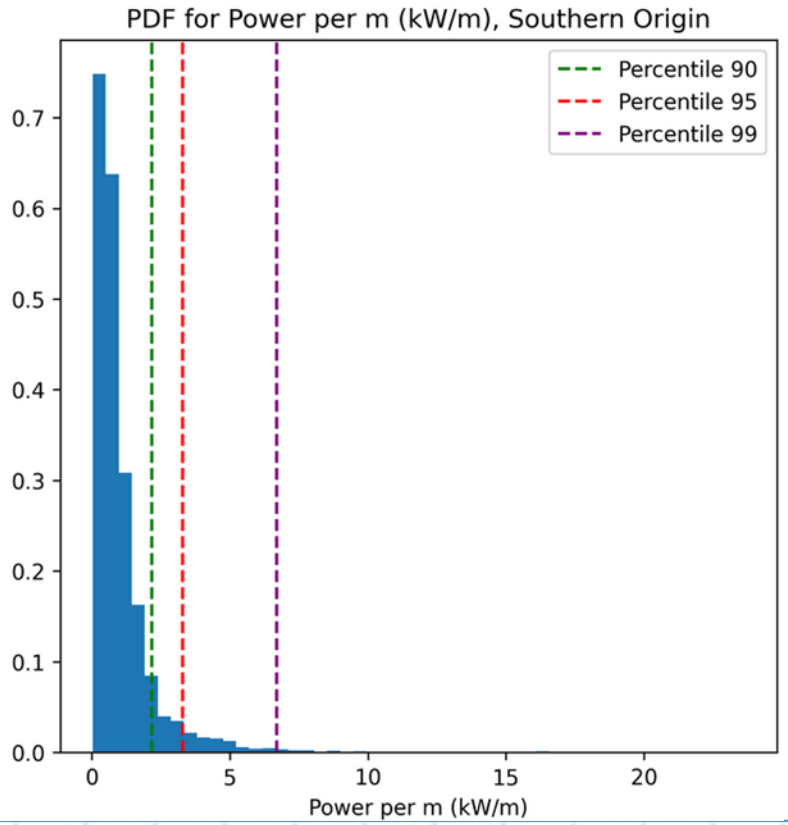
(Not equal to $\hat{H}_{1/3}$ but very close).

- **Equation** for the power of the waves (linear theory). Typically in kW/m:

$$P = \frac{\rho g^2}{64\pi} H^2 T$$

- **As stated, the buoy is measuring** T_{m02} and significant height (among others)

Power per m from Sig. Height & Mean Period (T_{m02})



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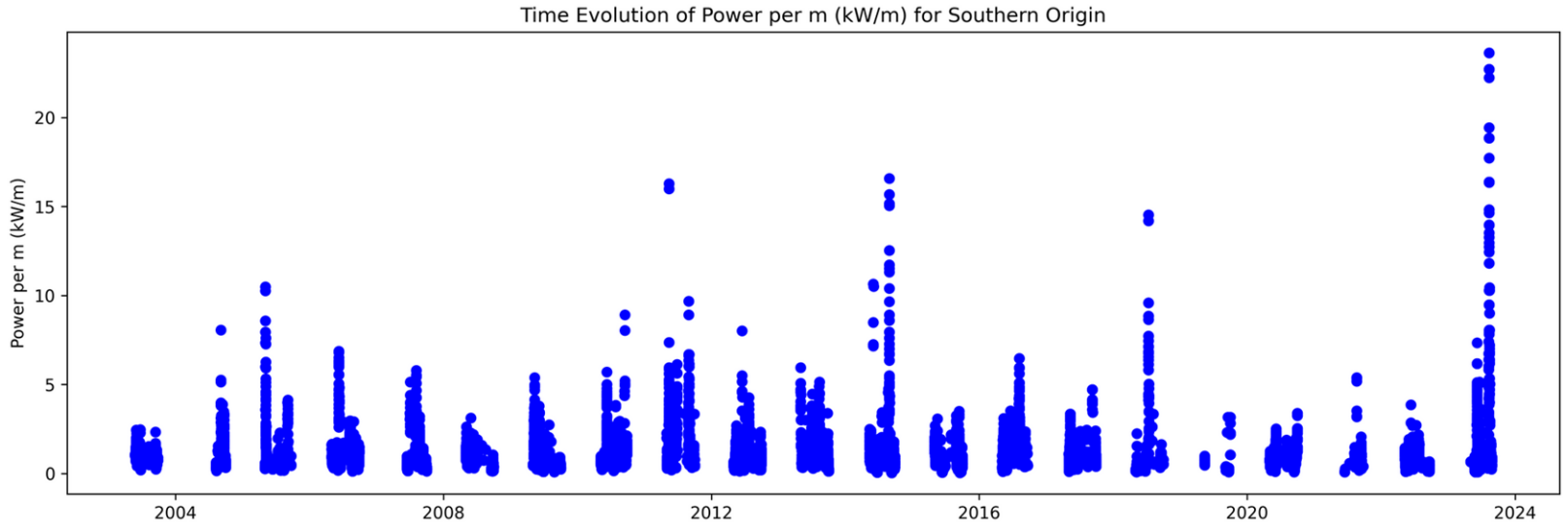
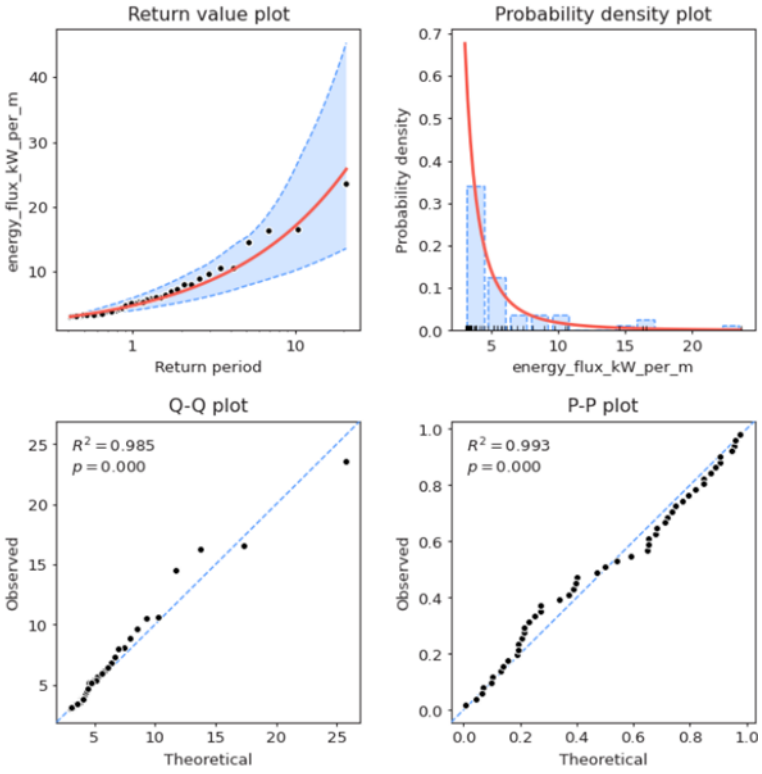
- **Time evolution.**



- **Extreme Value Theory (EVA):** for power per m. Scheme used: POT (Peak Over Threshold) with a declustering of 4 days to avoid correlations.

- Fitted to a Generalized Extreme Value (GEV) distribution that is very close to the Gumbel (shape parameter near 0).



The southern swell in the Canary Islands. II.

- Table with dates, P, exceedance probability in 1 year and return period:

Fecha (GMT)	energy_flux_kW_per_m	exceedance probability	return period
2023-08-13 06:00:00	23.630177	0.019608	20.665955
2014-08-27 15:00:00	16.575699	0.039216	10.332977
2011-05-14 06:00:00	16.280893	0.058824	6.888652
2018-07-11 16:00:00	14.530084	0.078431	5.166489
2014-06-02 07:00:00	10.644357	0.098039	4.133191
2005-05-05 05:00:00	10.493654	0.117647	3.444326
2011-08-29 04:00:00	9.672132	0.137255	2.952279
2010-09-15 14:00:00	8.910491	0.156863	2.583244
2004-09-03 21:00:00	8.069300	0.176471	2.296217
2012-06-15 21:00:00	8.024217	0.196078	2.066595

- "Lower" values:

2019-09-30 21:00:00	3.157838	0.901961	0.449260
2008-05-27 14:00:00	3.109343	0.921569	0.439701
2016-05-12 00:00:00	3.098143	0.941176	0.430541
2015-05-17 23:00:00	3.067879	0.960784	0.421754
2013-05-28 02:00:00	3.007397	0.980392	0.413319

- But few data (20 years) and very fat tailed, so caution is needed.

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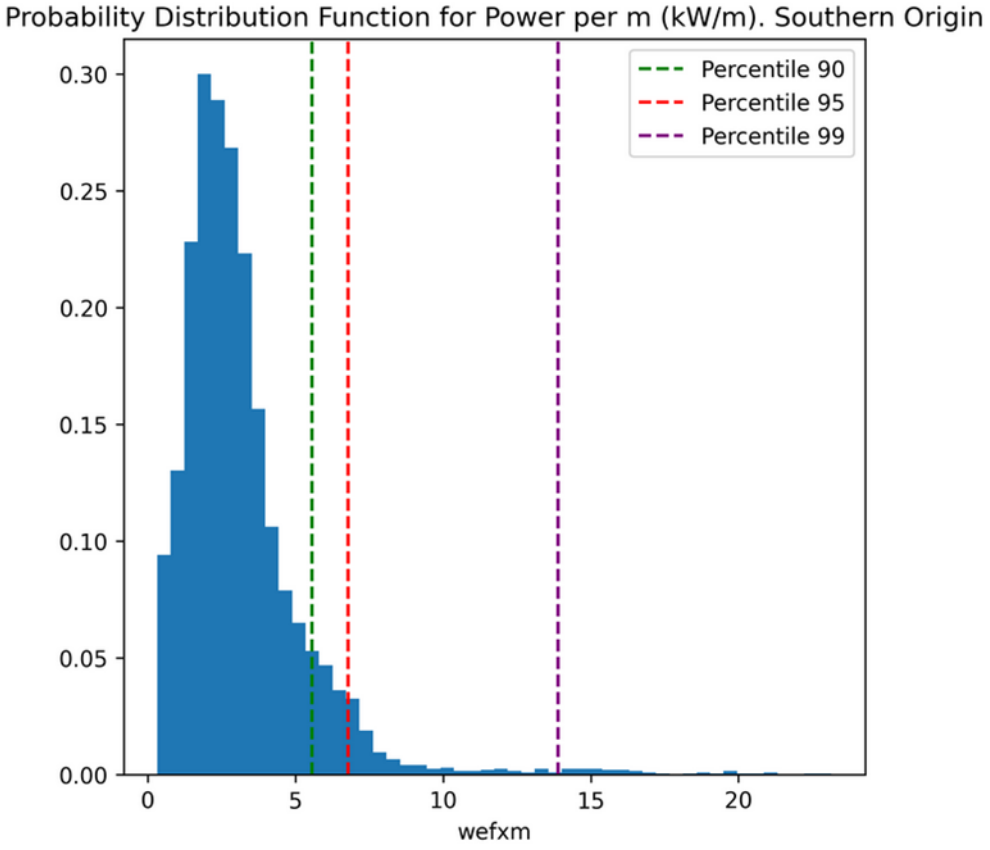
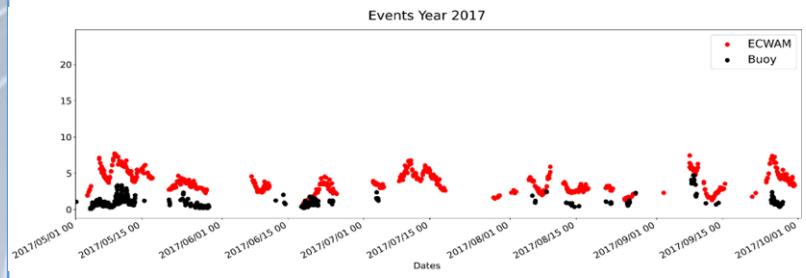
- **ECWAM:** wave model of the ECMWF. Resolution: 0.125º since 2016-03-08, global. 36 frequencies and 36 directions.
- **AEWAM:** wave model by AEMET. Spatial resolution: 4 Km (aprox. 0.04º), 36 directions, 30 frequencies.
- **"wefxm":** integrated (in 2D) wave energy spectrum (*P* in the previous equation). In kW/m.
- **"wefxd":** integrated direction.
- **Also other magnitudes: mp2, swh**, pp1d, mwp…

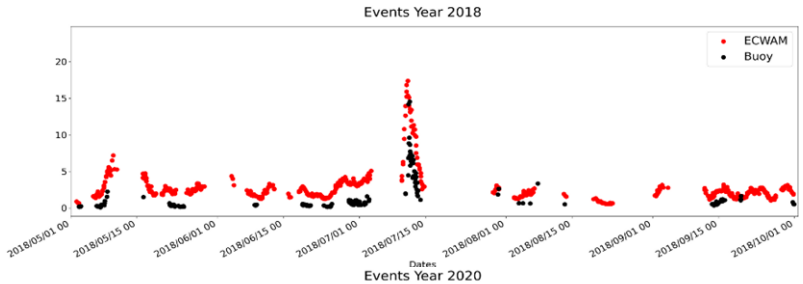
- **ECWAM, southern origin, histogram, *wefxm*. (Leadtimes 24 to 72 by 6).**

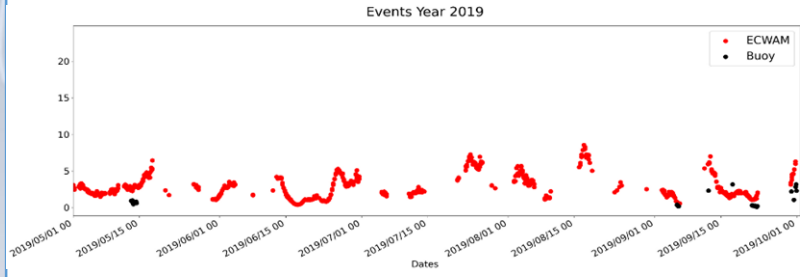


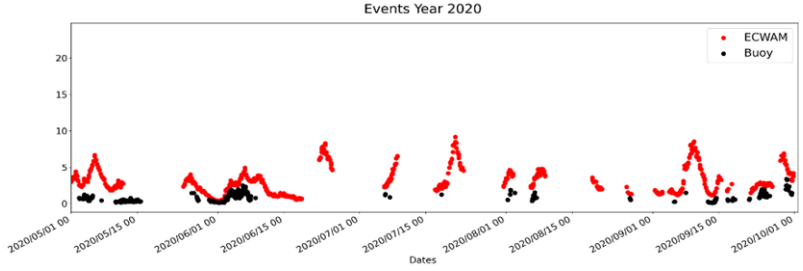
The southern swell in the Canary Islands. III.

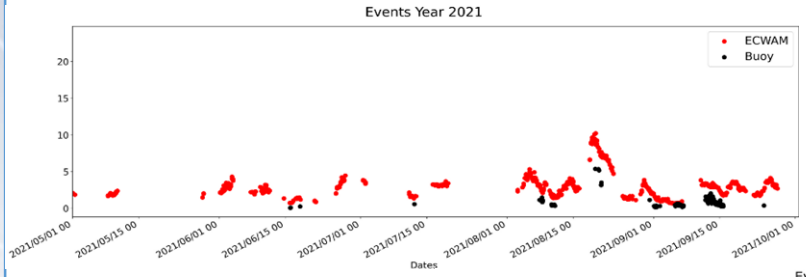
- **ECWAM, time evolution.**

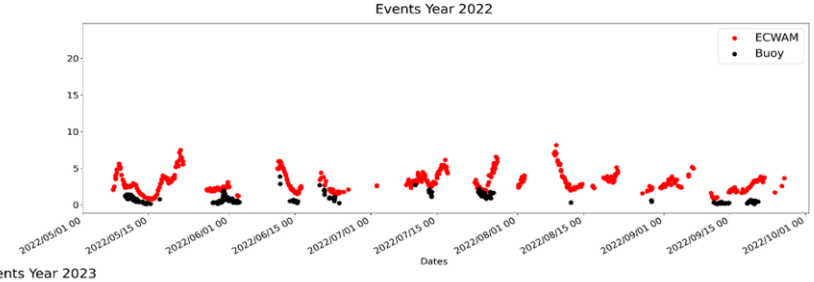


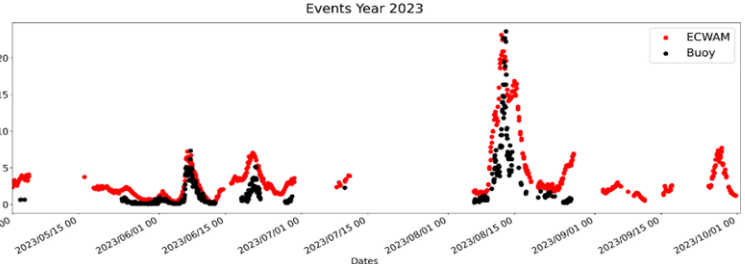






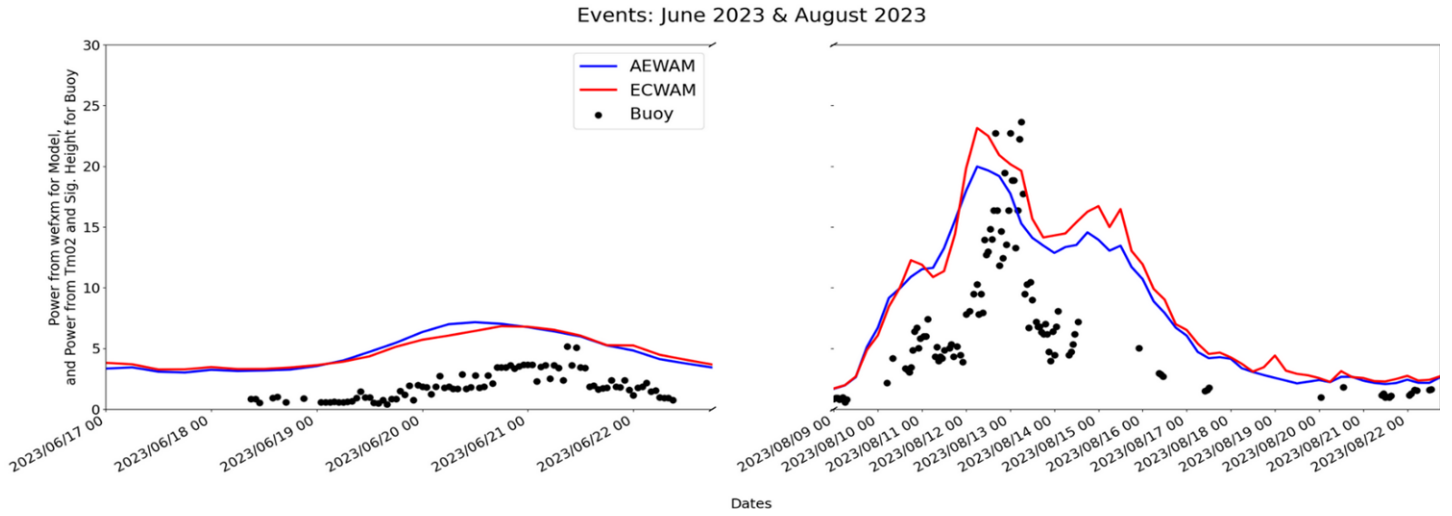


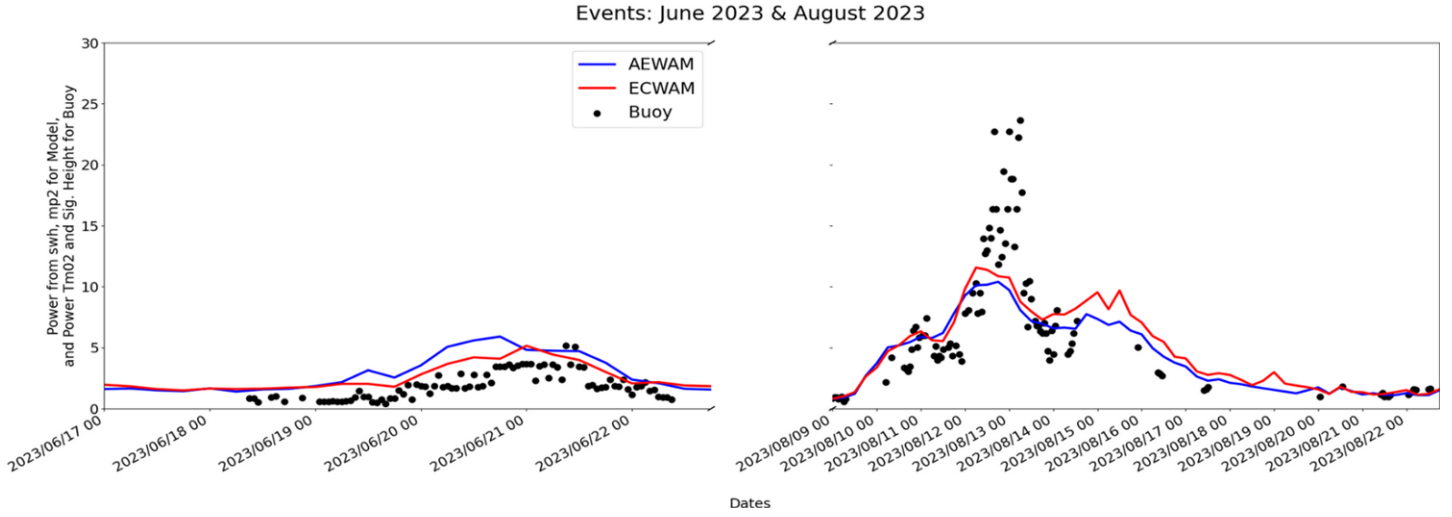




The southern swell in the Canary Islands. III.

- **Events June & August, 2023.** Leadtimes 24, 30, 36, 42.





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- **Southern swell affecting coasts of the Canary Islands.** Probably Cape Verde, too, rest of Macaronesia?
- **Important impacts:** enough energy, especially when breaking (due to height increase), unusual direction, false and dangerous perception of calm between series.
- **Origin** in lows in the austral winter. Possible intensification with ENSO.
- **AEWAM and ECWAM** seem to forecast well the phenomenon.