km-scale regional systems coupled at high frequency for meteotsunamis prediction

Nefeli Makrygianni

Ségolène Berthou

(and co-authors: Flack D.L.A, Lebeaupin Brossier C., Beuvier J., Castillo J.M, Renzi E., O'Neill C., Pelaez-Zapata D., Dias F., Lewis H., and Bruciaferri D.)

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Motivation


Source: https://doi.org/10.21203/rs.3.rs-7020306/v1
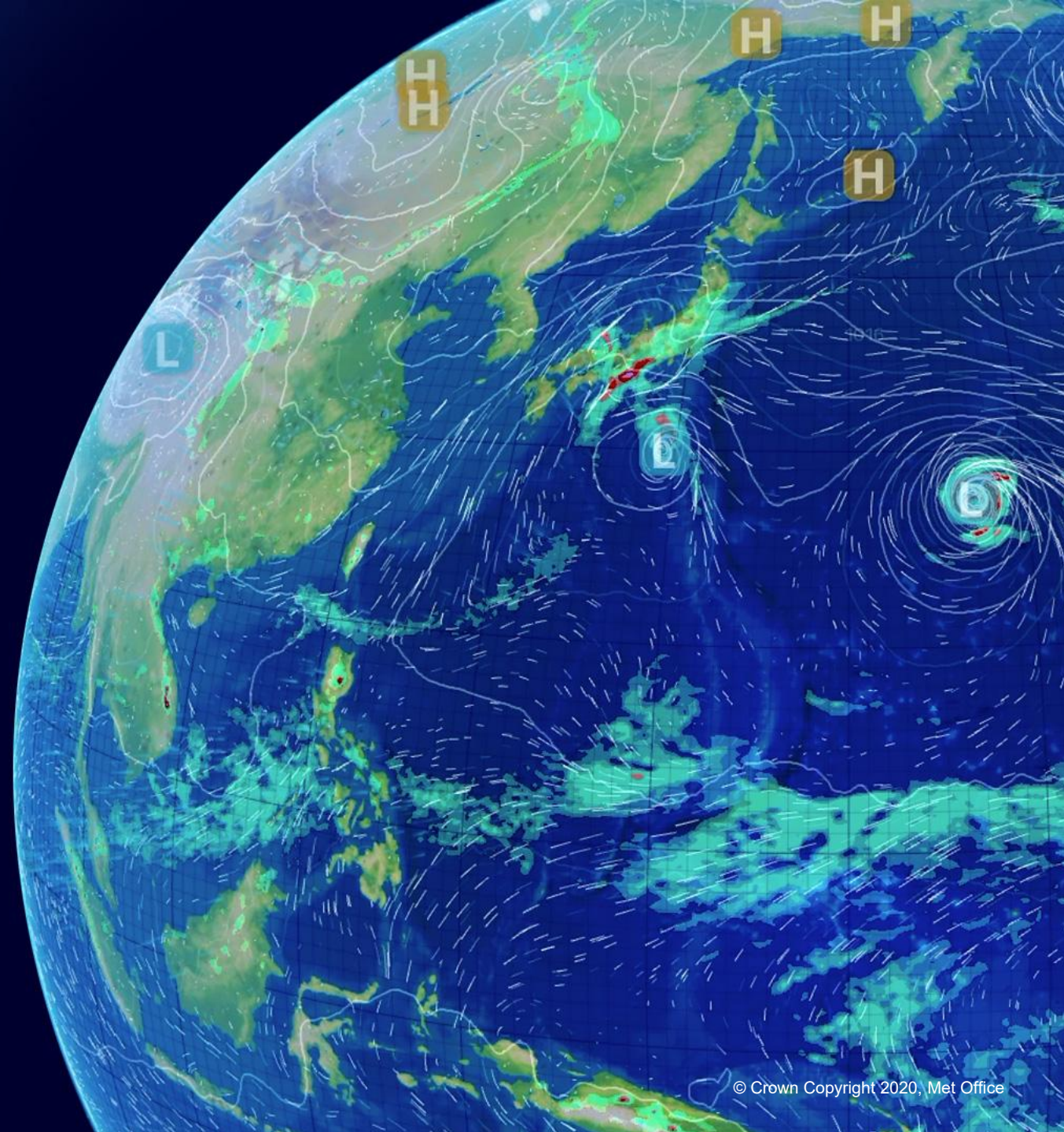
- **Meteotsunamis** are unusual waves triggered by sudden atmospheric disturbances (a few millibars can lead sea levels rising by several centimetres). Signal threshold is usually 0.2 m.

- The main driver is **Proudman resonance**, where water levels rise as disturbance speed matches wave speed ($\approx \sqrt{gh}$).

- **Research in the UK is limited**.
  - _Infrequent tide gauges sampling_ (some meteotsunamis go undetected)
  - _Quality control_ often deletes meteotsunami signal

- In the UK, based on documentary data, **5 per year and one major event every 5 year** (Lewis, 2023).

- Observed impacts include the **sea rushing as far as 50 m** up the beach, along with reported damage in marinas

Models Setup

### MO system [AtmOcnWav]

- **Regional** system integrates the **Unified Model (UM), NEMO, and WaveWatchIII** *(Lewis et al. 2019, Valiente et al., 2021,2023)*.

- **Spatial resolution:** From **4.4 km to 1.5 km**

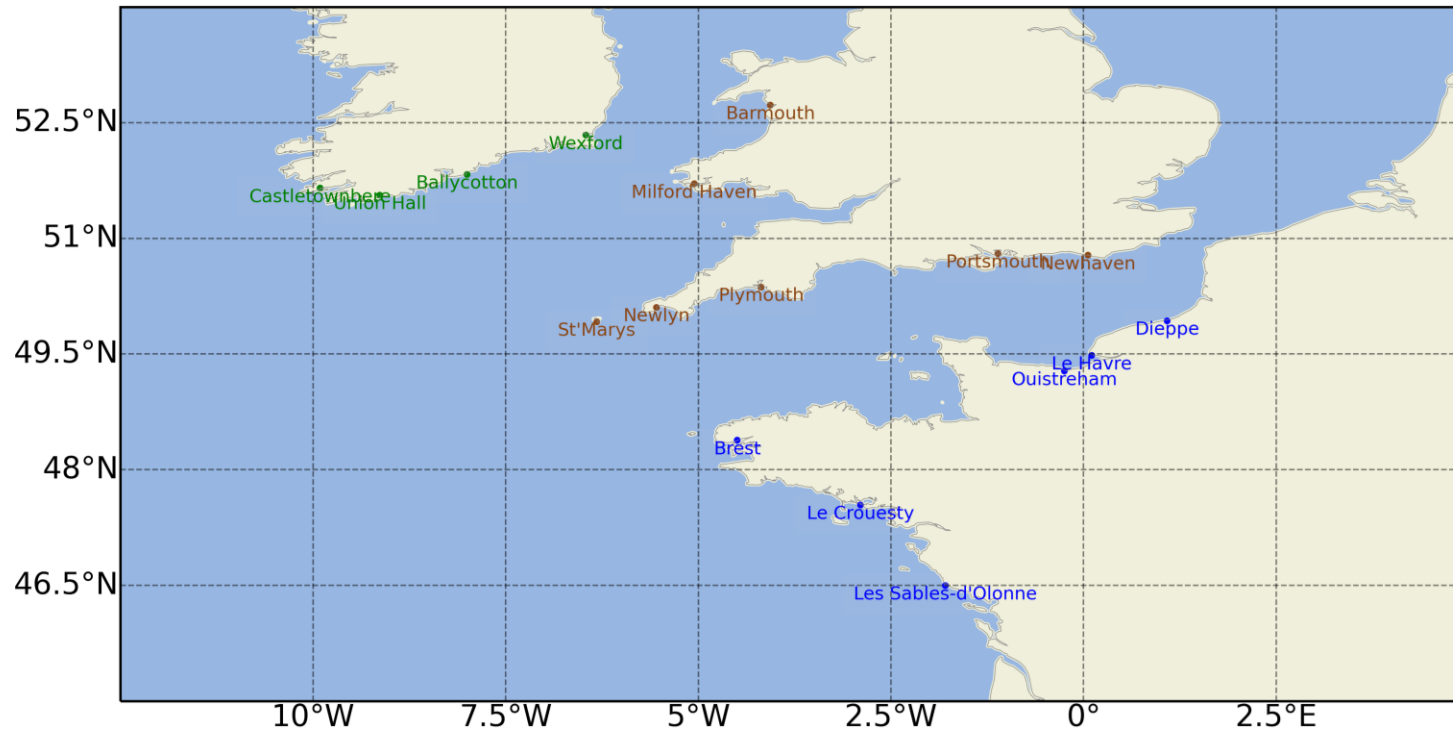- *Coupling Frequency*: **10-minute**
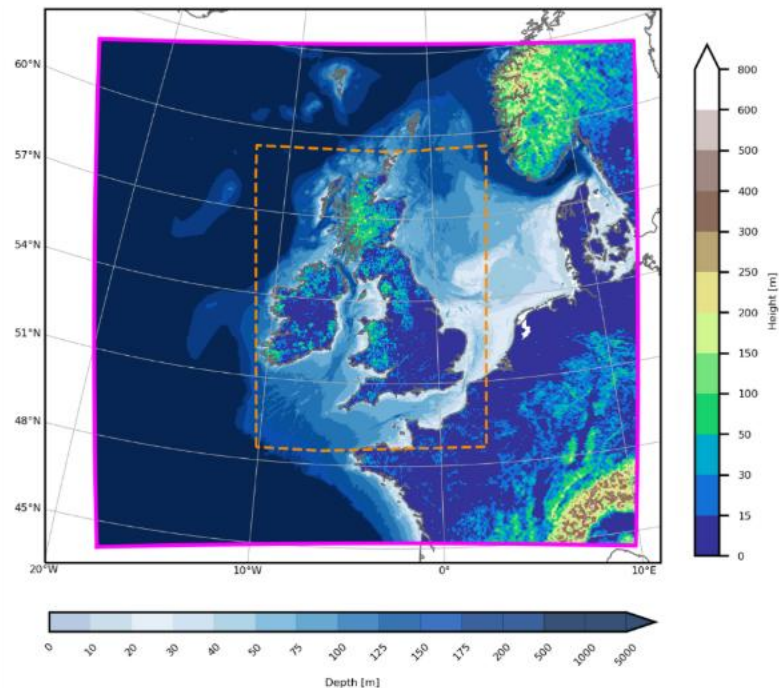
MF system [AtmOcn]

- The Meteo France system integrates **AROME** system and **NEMO** FRA36 *(Beuvier et al., 2024)*.

- **Spatial resolution**: **1.3 km** for AROME and **~2.5 km** (ORCA 1/36°) for NEMO

- **Coupling frequency**: **10-minutes**
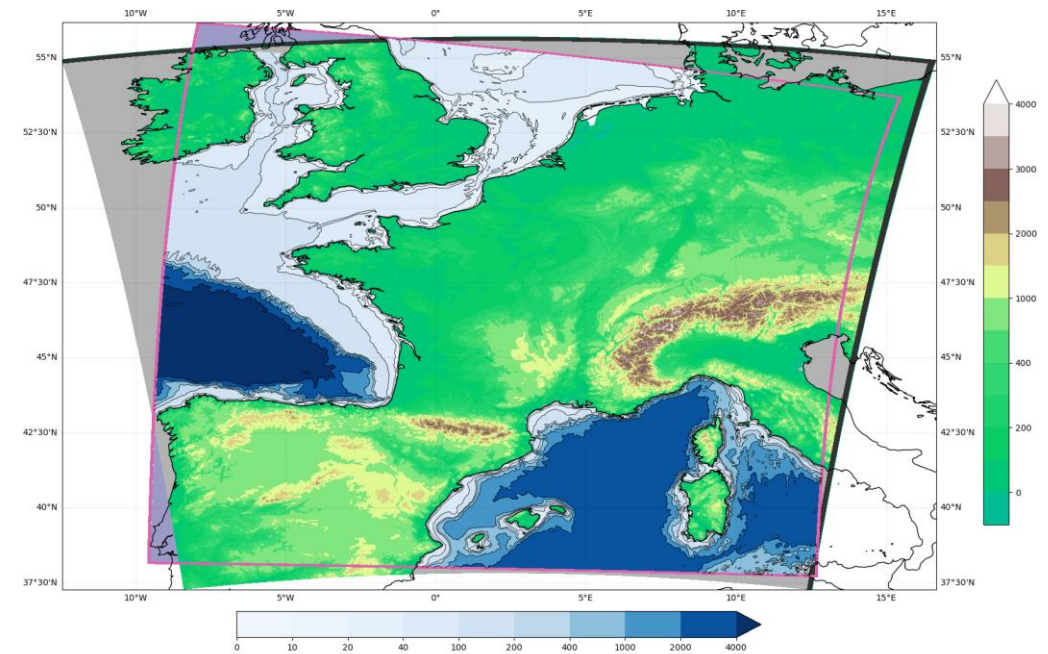
Data and Methods (2/2)

Geographical Coverage
- Analysis conducted for multiple locations in: **UK** (15-minute recording frequency), **Ireland** (5-minute recording frequency), and **France** (5-minute to 1-minute recording frequency)
- Data sources: Renzi et al. (2023), Met Office database for the UK locations.

Data Processing
- **Filter Applied**: Butterworth high-pass 5th-order filter with to remove tidal and subtidal activity.

1-hour coupling and surge models fail to represent such events…
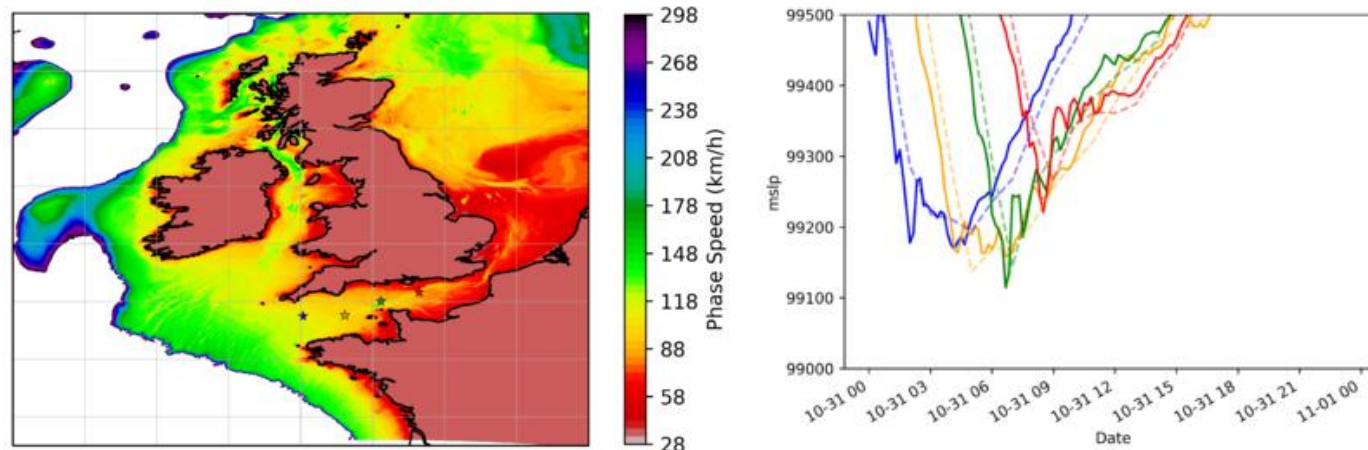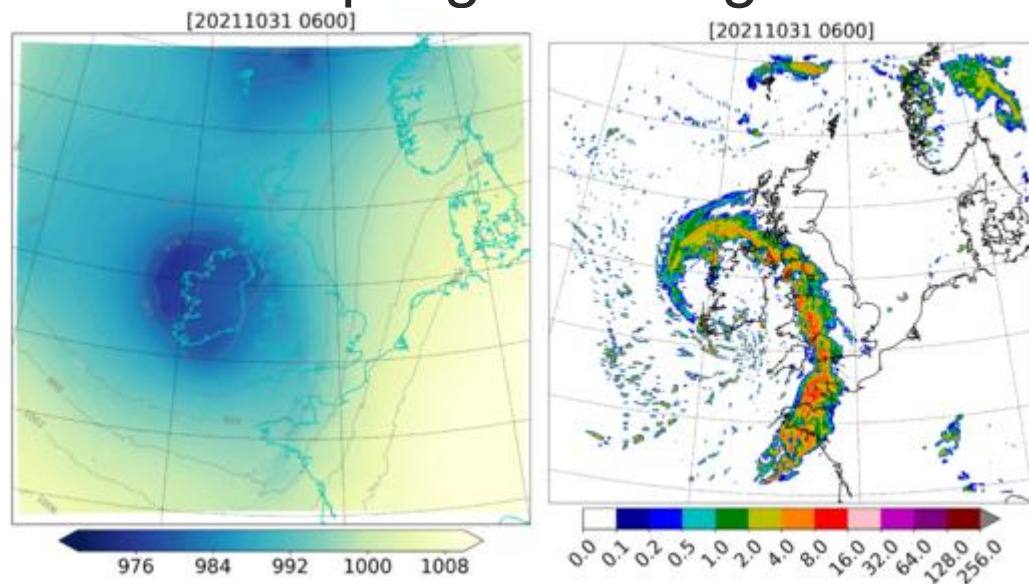
EA feedback

"On Sunday 31st October am tide the observed water levels rose significantly delaying and increasing the peak. This affected locations from Weymouth east to Portsmouth particularly Christchurch (Wessex area) and Lymington (SSD area).

Forecasts on Sunday am showed some response for the additional rise but was under-estimated

Impacts included flooding of quays, missed or late closure of tidal gates at Christchurch and Lymington. A flood warning needed to be issued at Christchurch."
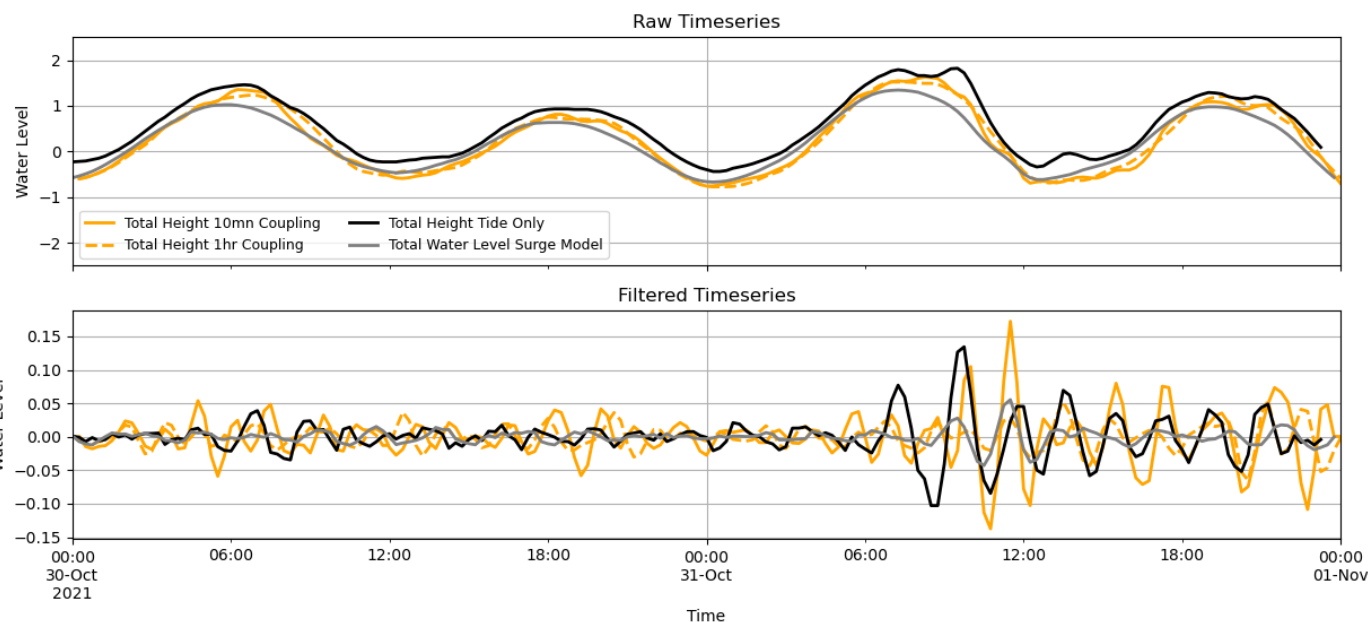
… but 10mn coupling successful!

Met Office   METEO FRANCE

Main Case Study: 18-19 June 2022

- Based on Renzi et al. (2023), which analysed the highest recorded signal (1 m in Ireland).

- Triggered by pressure perturbations within a low-pressure system (Renzi et al., 2023).

- System speed ~51.7 m/s, matching local wave phase speed (~38–54 m/s).

- Météo France analysis highlighted gravity wave representation; event linked to kitesurfer fatality (Mandement, 2025).
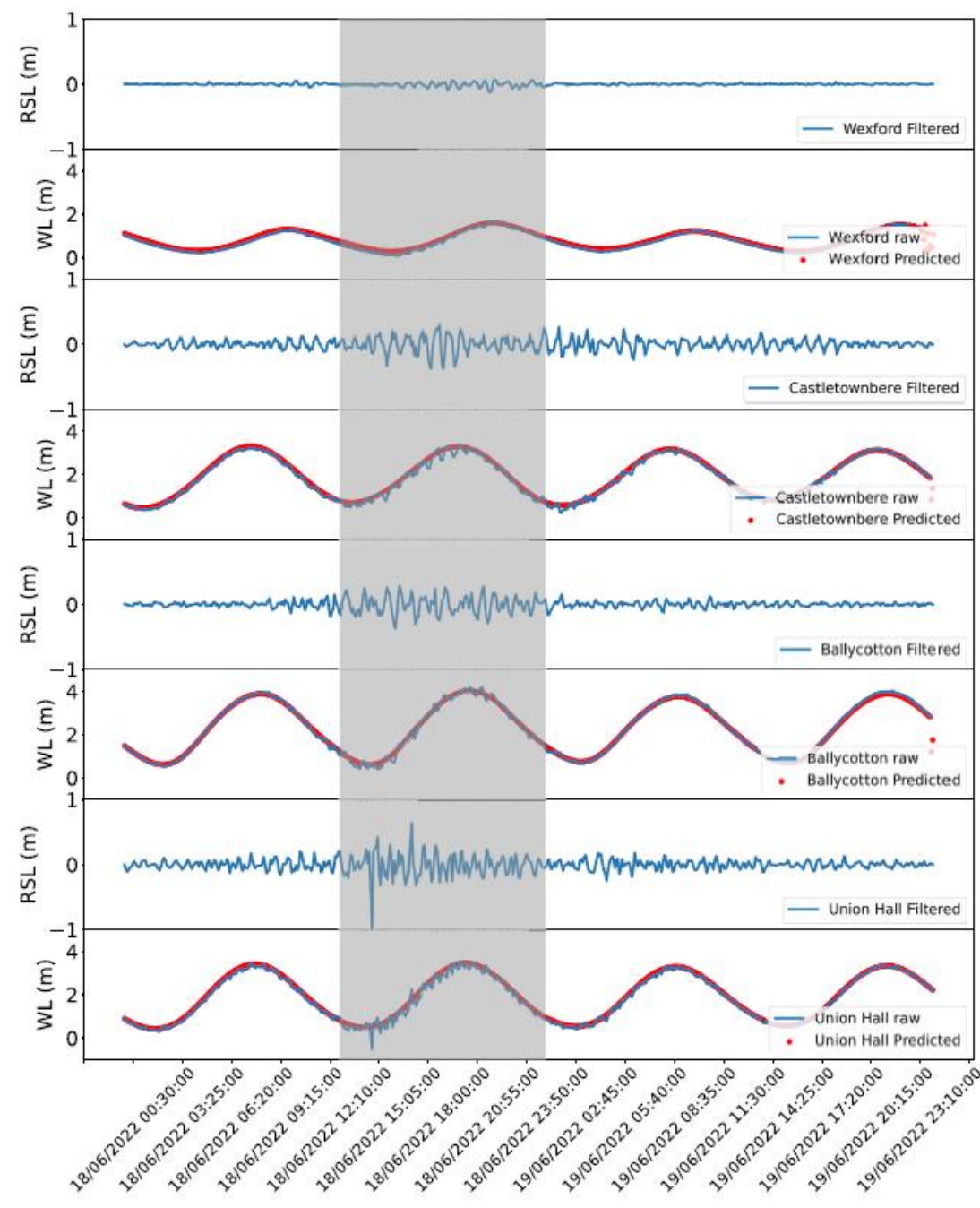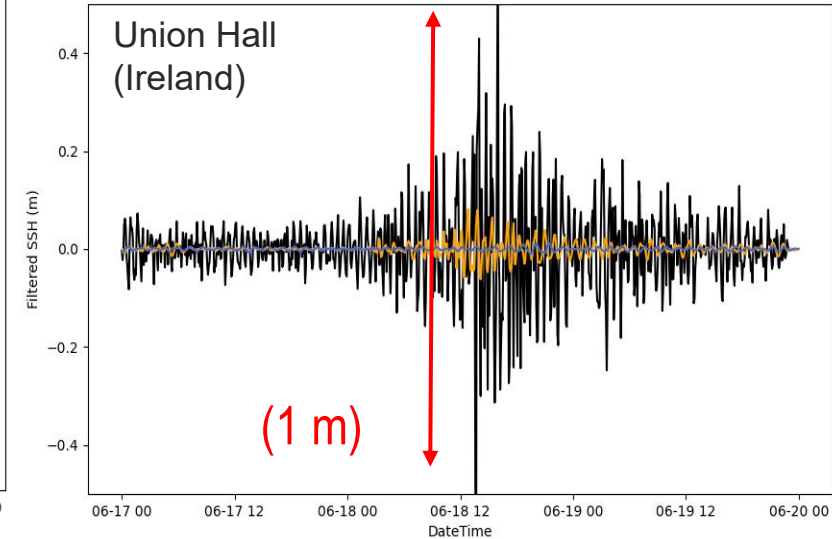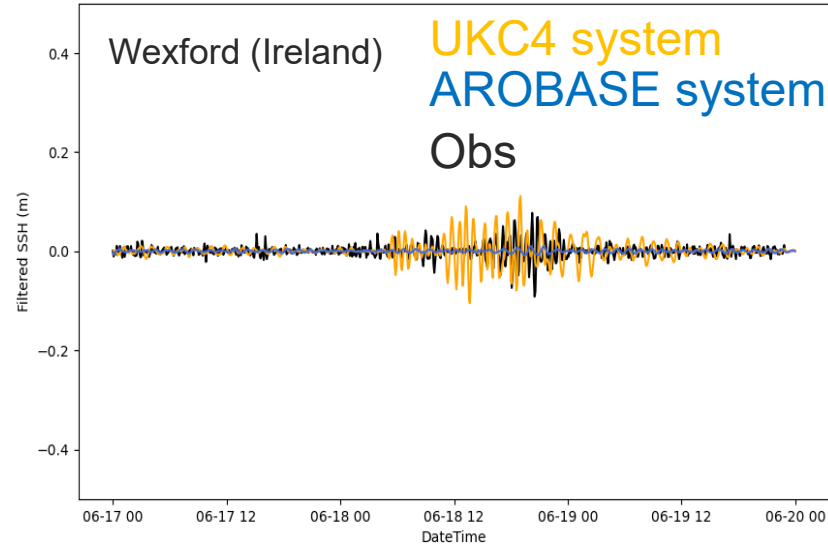

Aims:

1) Are km-scale models able to capture the meteotsunami event when coupled with higher frequency?

2) Can we better understand the atmospheric conditions forcing such events?

3) Are we able to forecast them?

Filtered sea surface height (m)
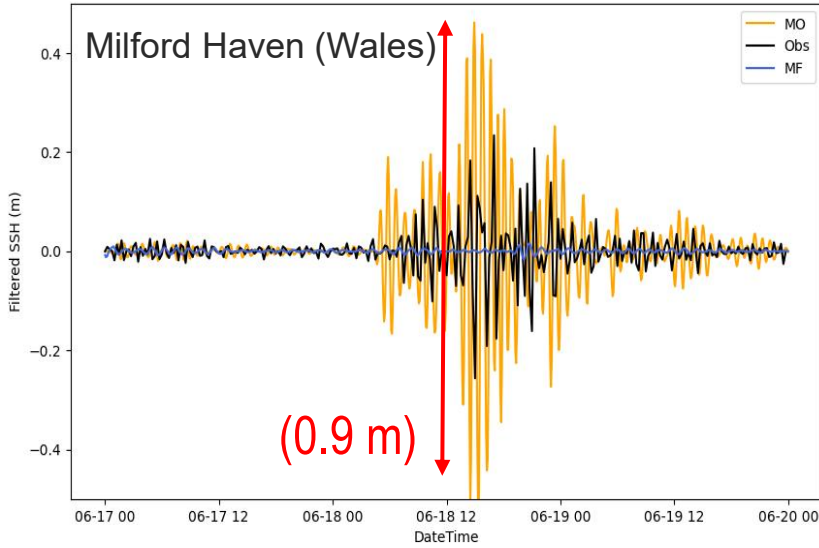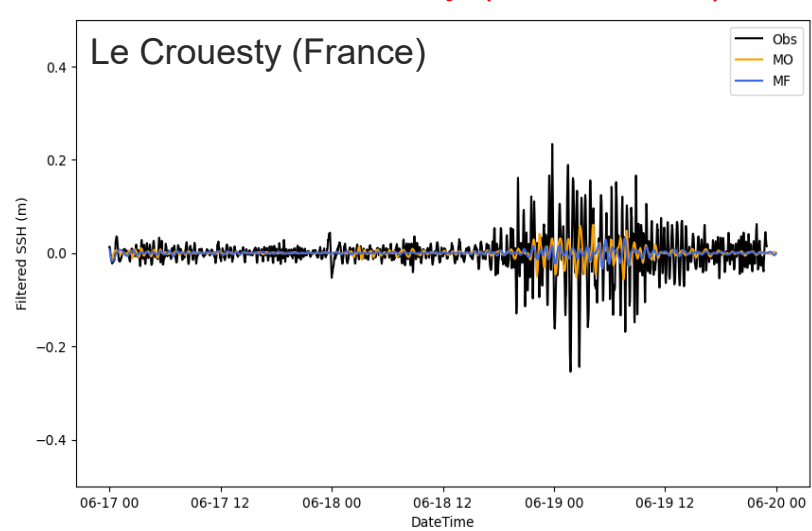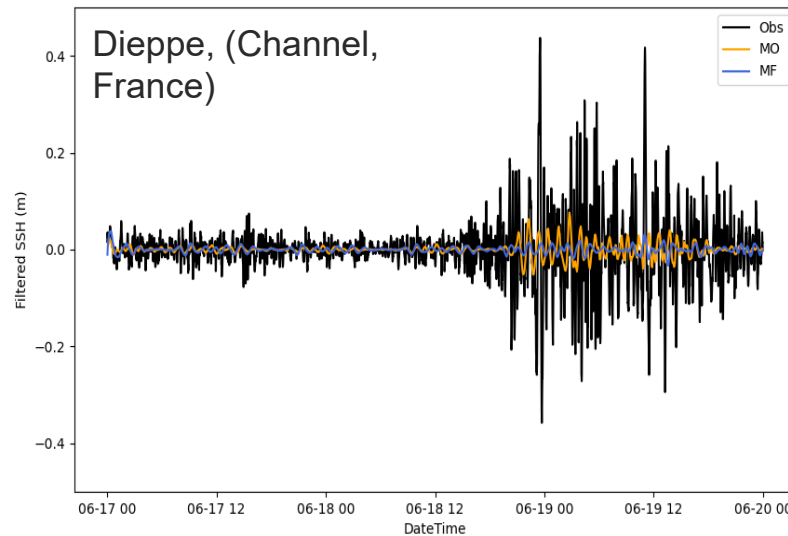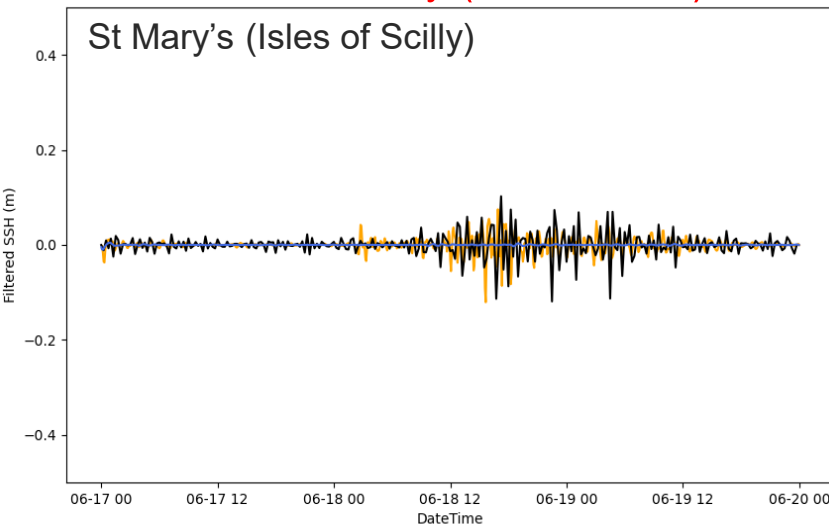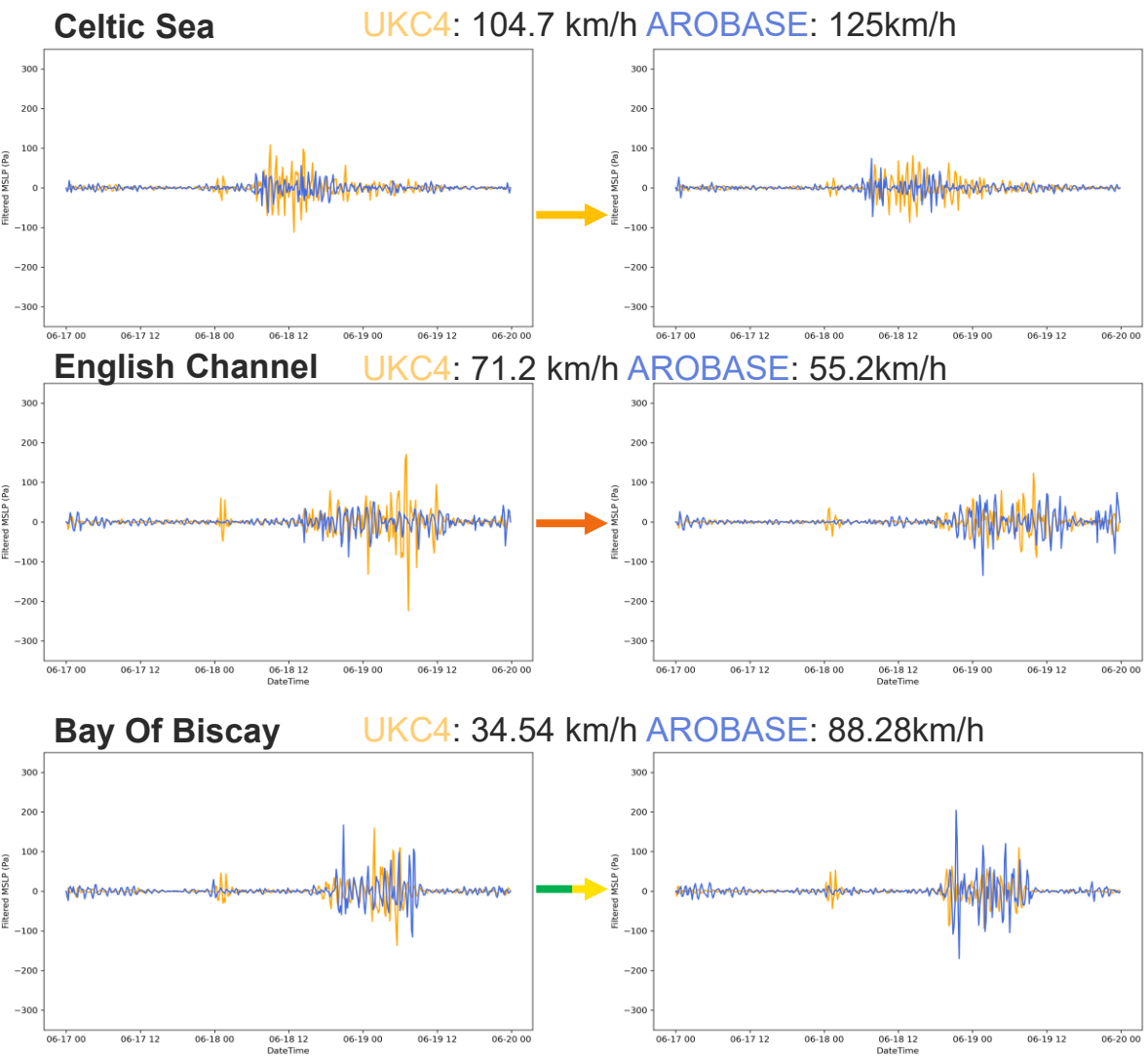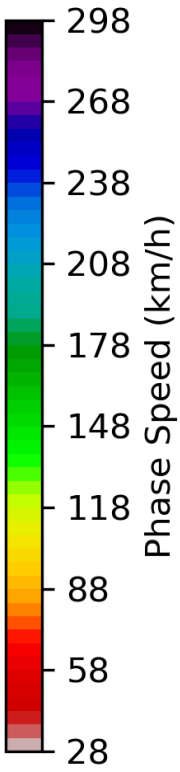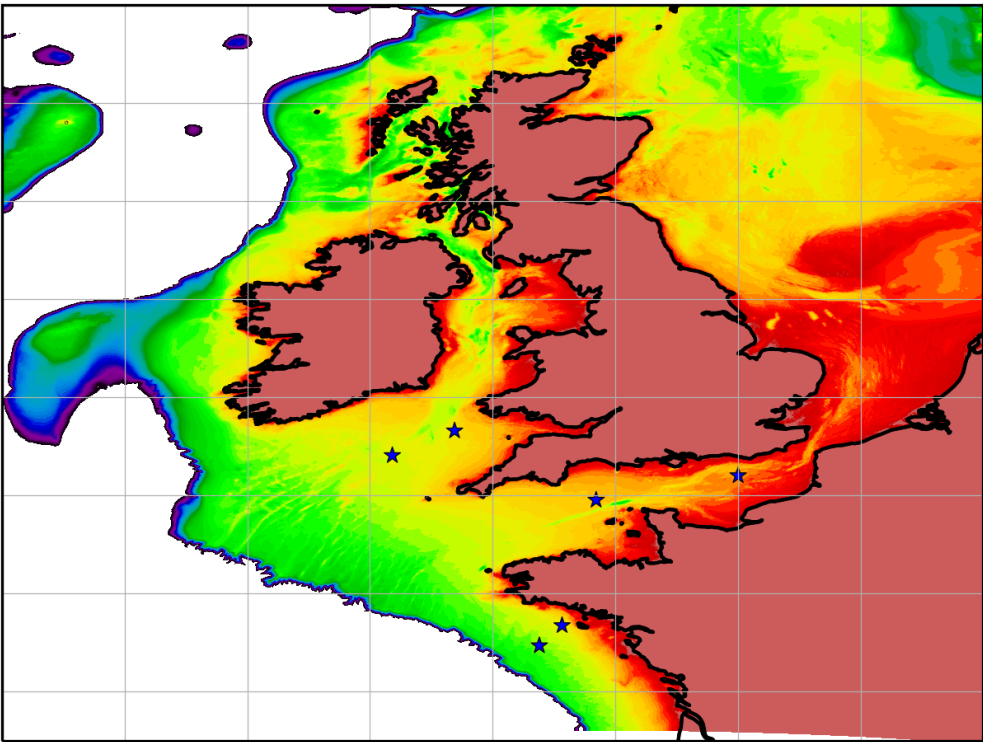
Analysis of the meteotsunami signal
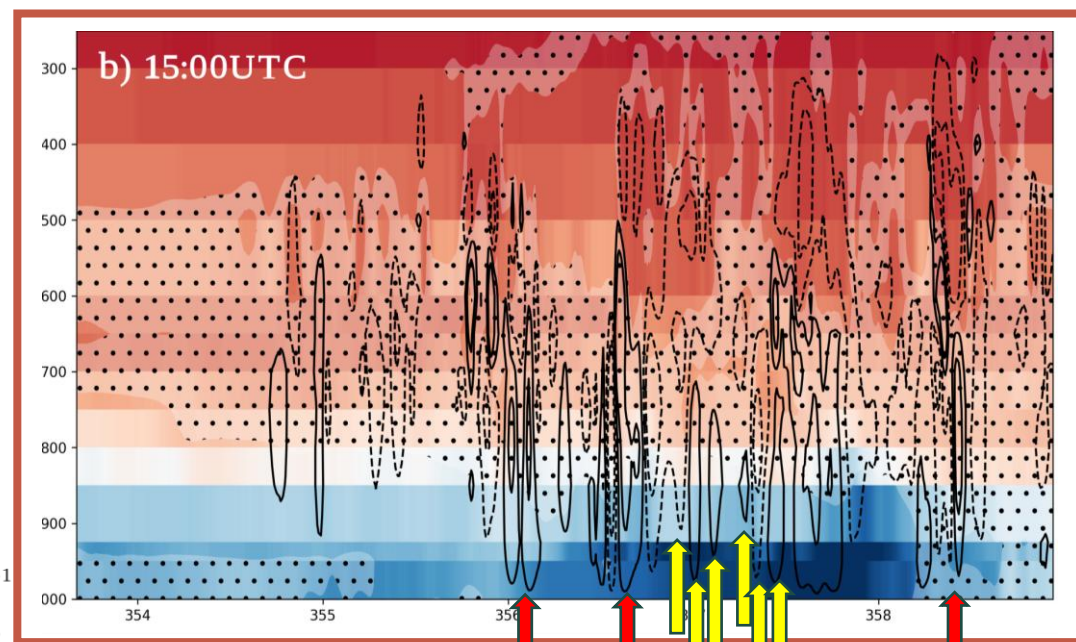
Spatial distribution of meteotsunamis in the UKC4 system

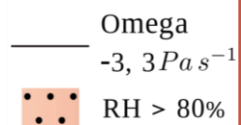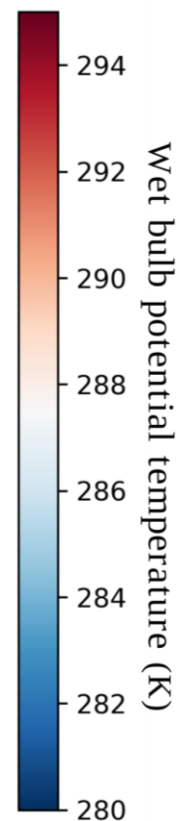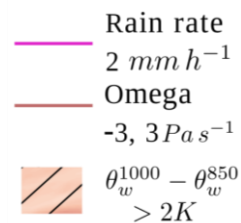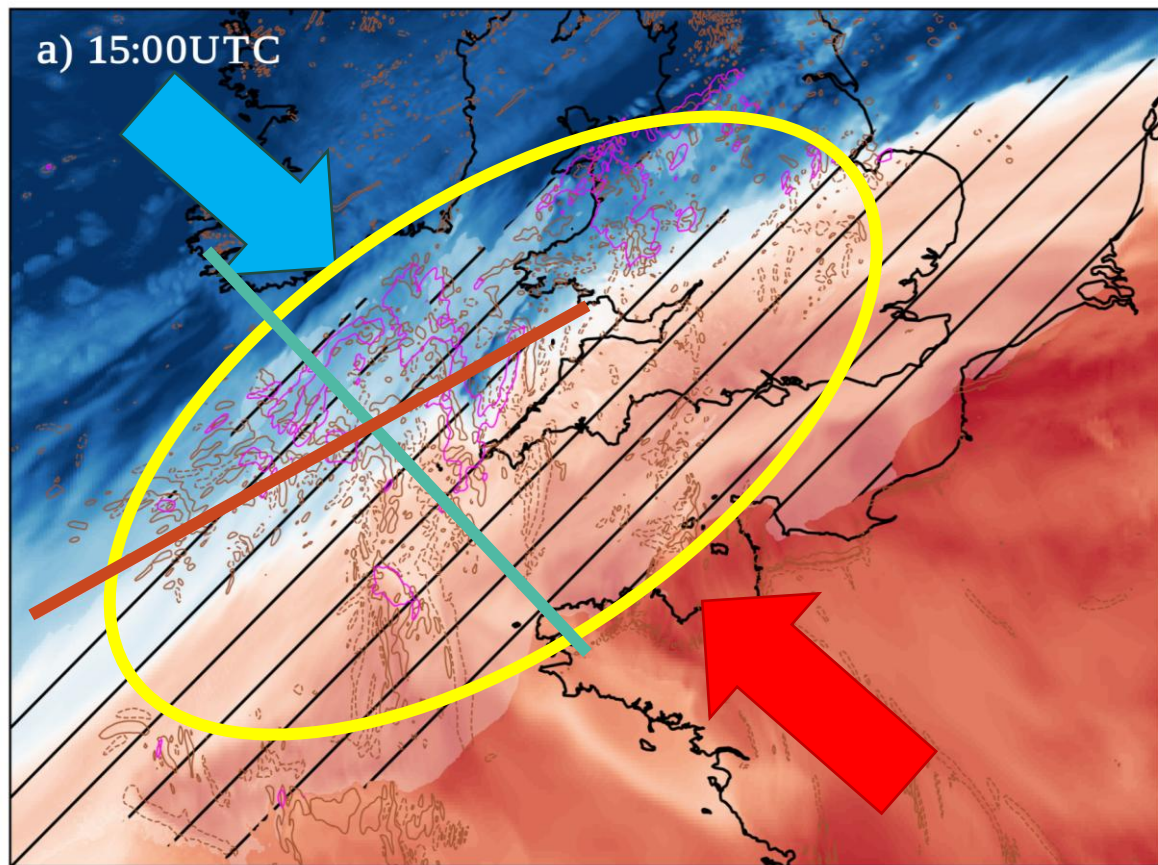Filtered sossheig at 2022-06-18T06:25:00.000000000
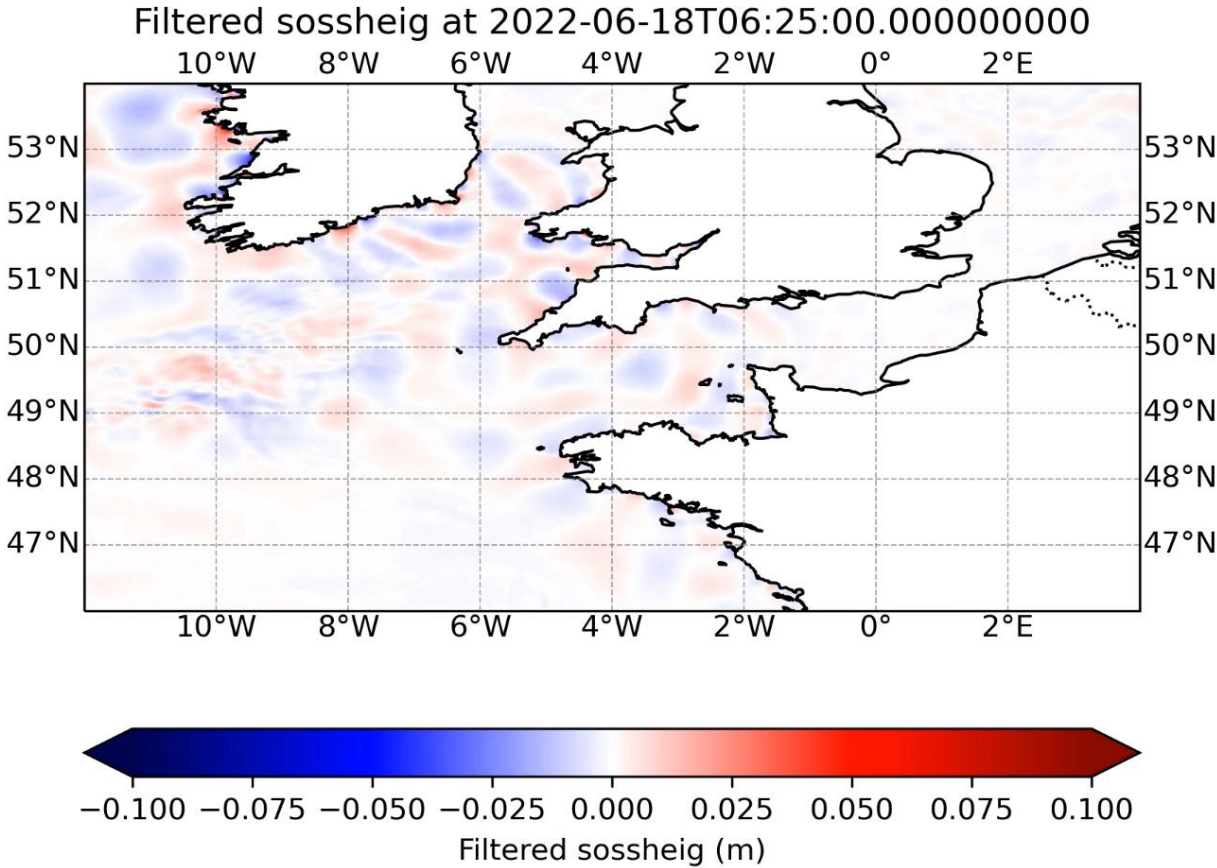
Spatial distribution of meteotsunamis in the UKC4 system
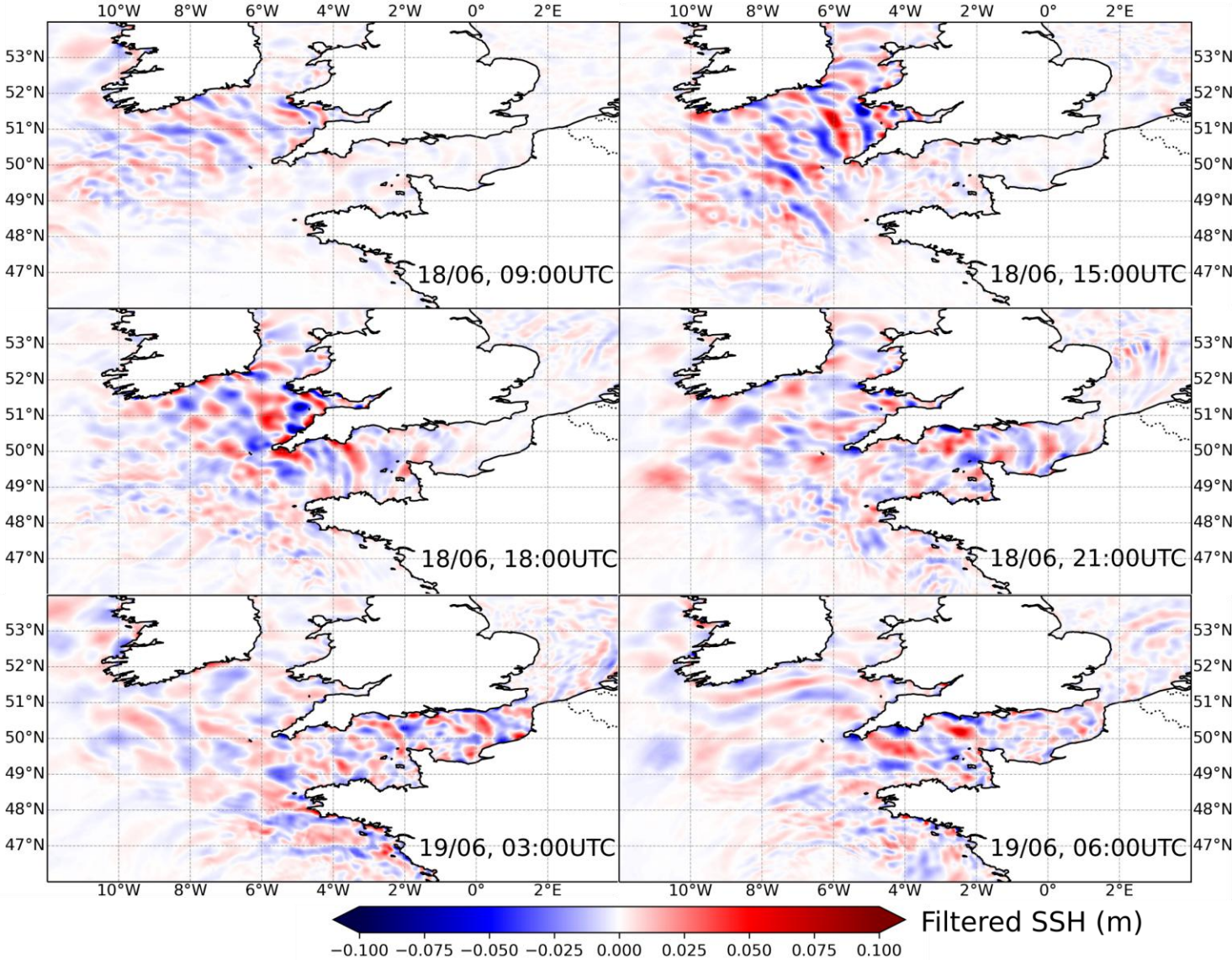
# Signal generation is governed primarily by Proudman resonance, not MSLP alone…

Celtic Sea UKC4: 104.7 km/h AROBASE: 125km/h

English Channel UKC4: 71.2 km/h AROBASE: 55.2km/h

Bay Of Biscay UKC4: 34.54 km/h AROBASE: 88.28km/h

a) 15:00UTC

c) 18:00UTC

Upper-level convection sends downdrafts to lower-level stable layer

b) 15:00UTC

Rain rate
2 $mm\,h^{-1}$

Omega
-3, 3 $Pa\,s^{-1}$

$\theta_w^{1000} - \theta_w^{850} > 2K$

Wet bulb potential temperature (K)

Omega
-3, 3 $Pa\,s^{-1}$

RH > 80%
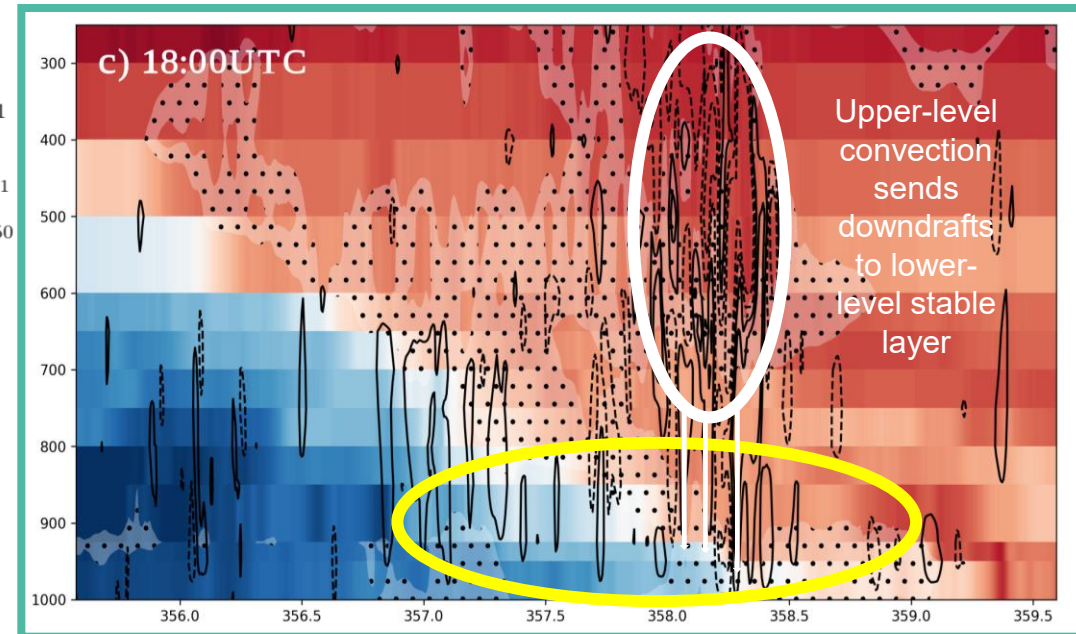
Convective downdrafts

Gravity waves

Met Office

METEO FRANCE

UKC4 Shows Potential for Accurate Forecasting even 3 Days in Advance
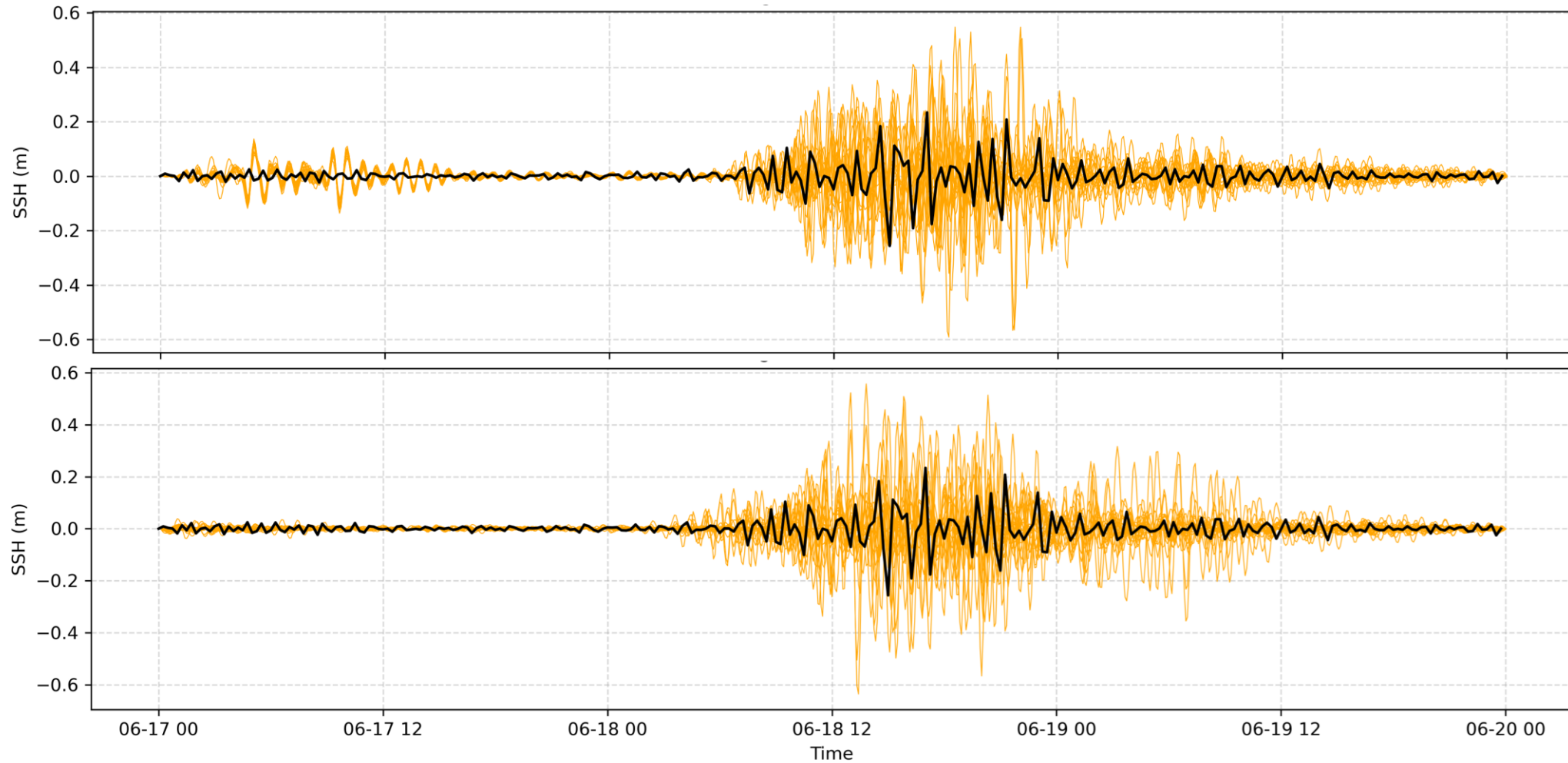
Future work

- Operationalisation
  - Test method on false alarms; initial ensemble results suggest strong potential for future operational forecasting

- Assess meteotsunami risk under climate change.
  - Analyse 20-year time slices (15-min output UKC4 hindcast & projections)
  - Determine if UK meteotsunami risk is likely to increase in the future

NHESS paper – preprint available (**DOI**: https://doi.org/10.5194/egusphere-2025-3555)
Correspondence: **nefeli.makrygianni@metoffice.gov.uk**

Thank you!!