Met Office

Km-scale regional systems coupled at high frequency for meteotsunami prediction

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Introduction

Meteotsunamis are **anomalous tidal waves** that occur at frequencies similar to tsunamis, triggered by **atmospheric disturbances** such as thunderstorms, gravity waves, squalls, and cyclones. Rapid changes in atmospheric pressure (a few millibars) can cause **sea level oscillations** of several centimetres.

The primary mechanism behind meteotsunamis is **Proudman resonance**, which **amplifies water levels** when the speed of atmospheric disturbances aligns with the wave speed ($\approx \sqrt{gh}$).

While meteotsunamis have been studied in regions like the **Mediterranean** and the **U.S.**, research **in the UK** remains limited. Due to **low frequency of tide gauge sampling**, meteotsunamis often go **undetected**, posing potential risks to **infrastructure** and **safety**.

Data and Methods

Models Setup
The **Met Office regional A-O-W** system integrates the **Unified Model (UM), NEMO, and WaveWatchIII** with **10-minute** coupling and spatial resolution from 4.4 km to 1.5 km.

The **AROME** system has a 1.3 km resolution and is coupled with the in-house high-resolution **NEMO** FRA36 (~2.5 km, ORCA 1/36°), also with a **10-min coupling** frequency.

Study Period
Simulation runs from **17th June 2022 to 19th June 2022**, with a focus on capturing the event on **18th June 2022**.

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 Processing
Filter Applied: Butterworth high-pass 5th-order filter with a **1.5-hour cutoff** to remove tidal and subtidal activity.

Synoptic conditions

Convective activity: Embedded within the front, driving distinct circulation.

Downdraft interaction: Enhances meteotsunami formation.

Stable layer displacement: Warmer downdrafts generate gravity waves.

Wave propagation: Gravity waves spread toward Cornish, Welsh, Irish, and French coasts.

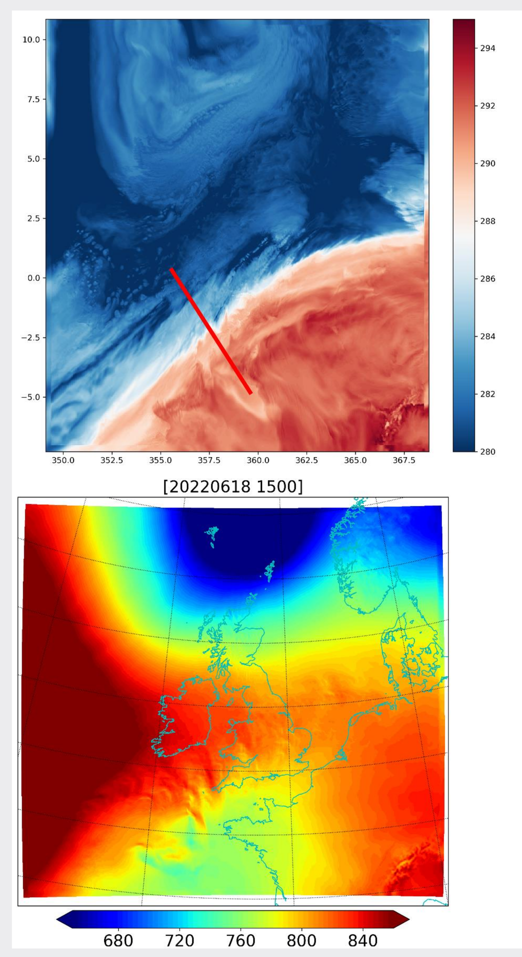

Fig. 1 Location of the cross-section shown on wet-bulb temperature at 850hPa (top) and geopotential height at 925hPa (bottom)

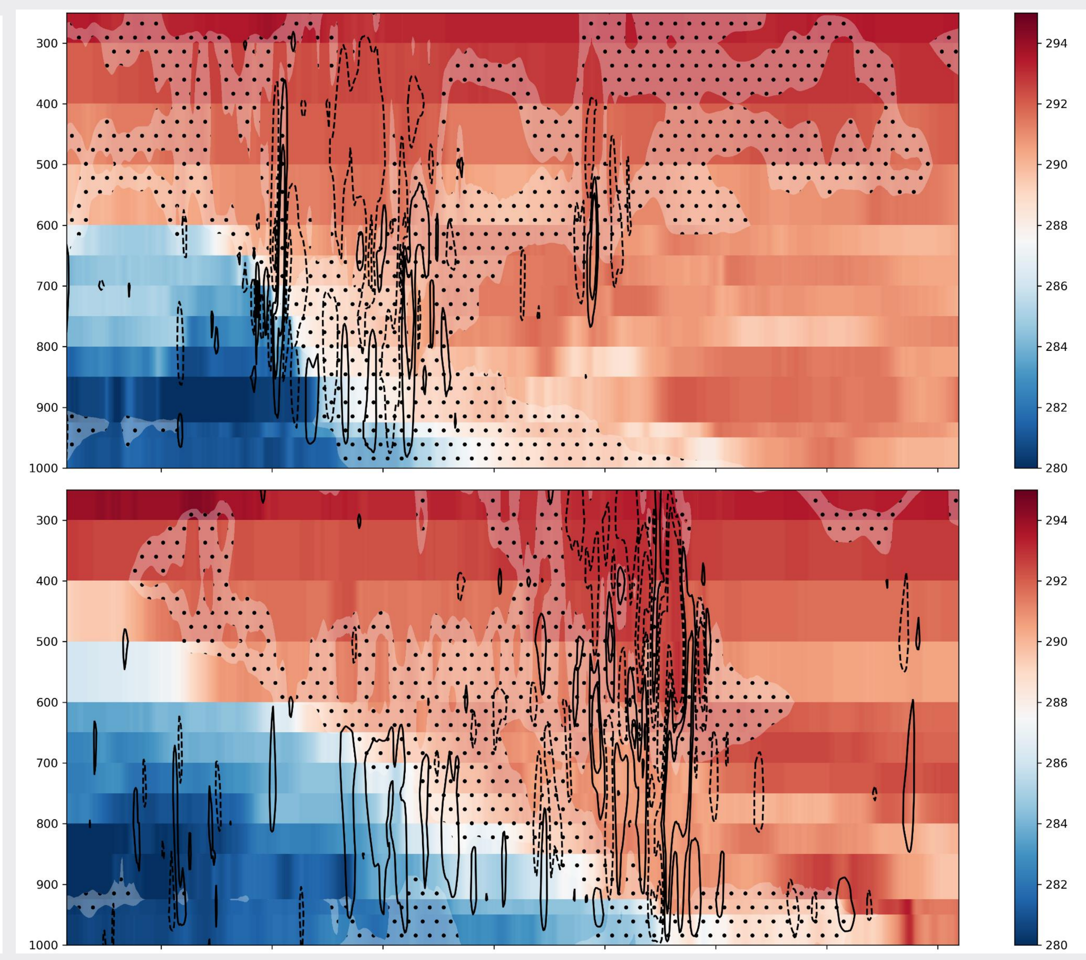

Fig. 2 Cross-front cross sections for the 18/06/2022 09:00 (top) and 18:00 (bottom).

Analysis of the meteotsunami signal

Results demonstrate that the **higher coupling frequency** captures **meteotsunamis** more effectively than the **one-hour coupling** and **surge model**. Signal analysis shows **excellent representation** for **Wales** and **Ireland**, and **relatively good** for locations in **France.** The **Meteo France** model does not capture meteotsunamis as effectively in Wales and Ireland but provides some indication for locations in France.

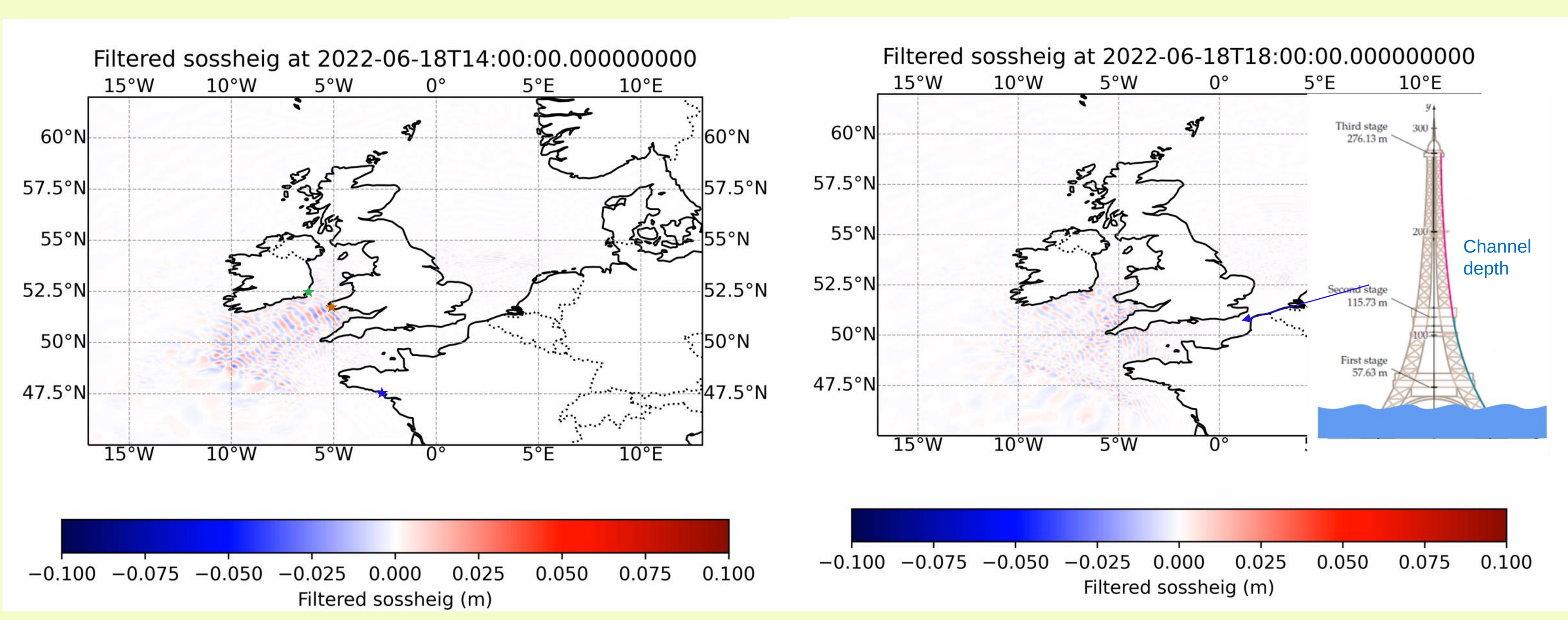

Fig.3 Spatially filtered SSH (meteotsunami signal) at a peak time (14:00, left) and upon reaching France and the English Channel (18:00, right). The Eiffel Tower illustrates the depth of the Channel for scale.

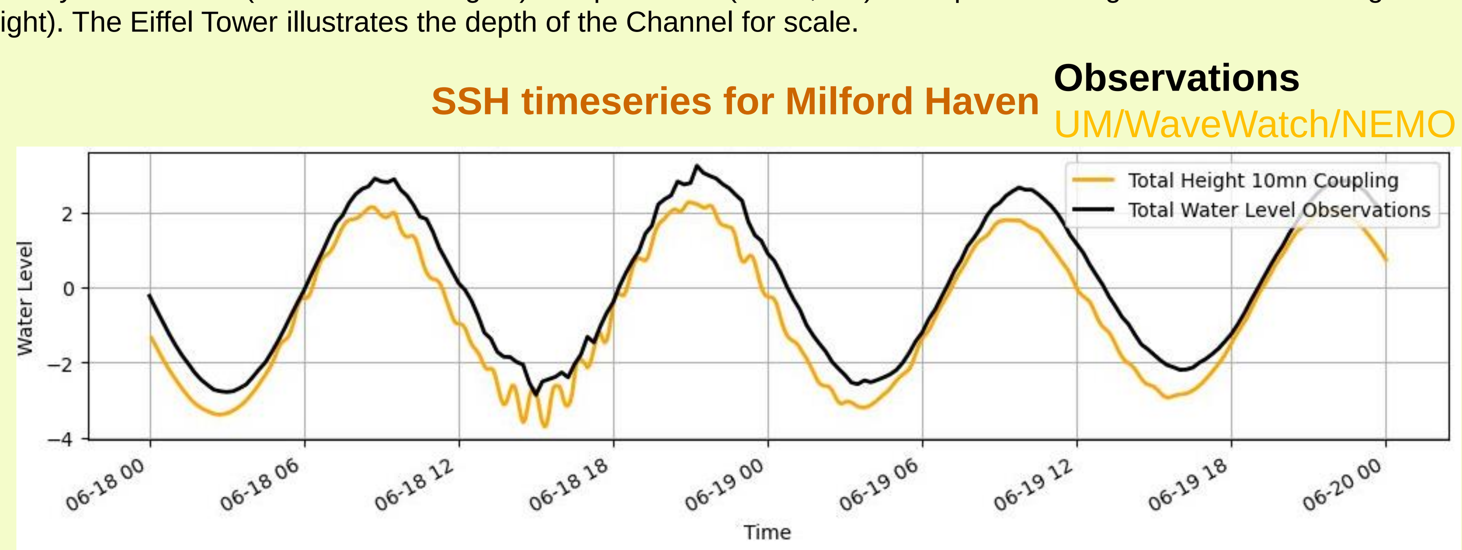

Fig.4 SSH timeseries from the observations (black) and the UM/WaveWatch/NEMO system (orange)

Running the model to assess its **forecasting skill** for this type of event shows promising potential, **with six members indicating** a high-frequency disturbance one day in advance.

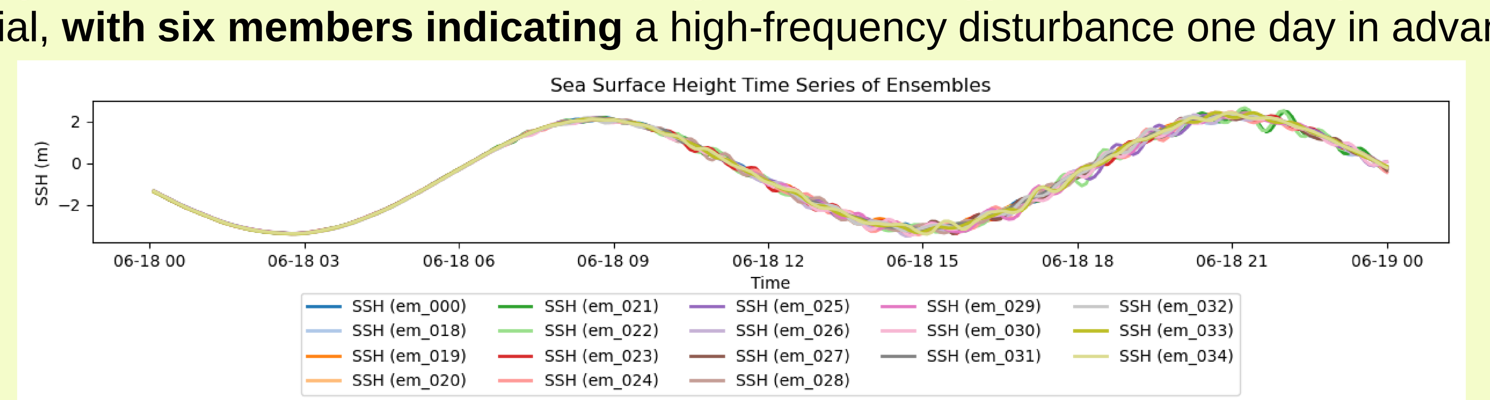

Fig.6 Ensemble forecast generated one day before the event.

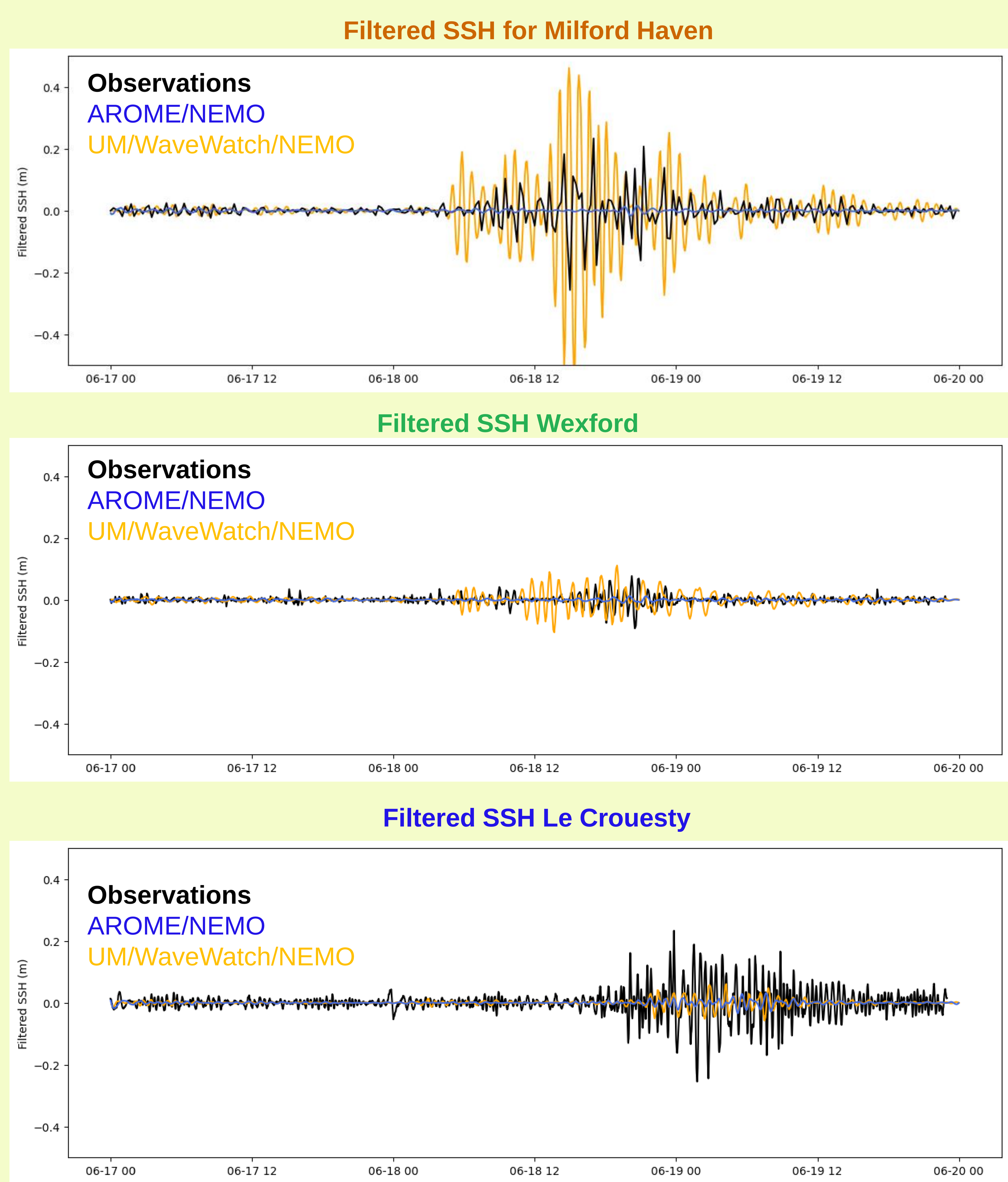

Fig. 5 Time series of filtered SSH (meteotsunami signal) for Milford Haven (top), Wexford (middle), and Le Crouesty (bottom). Observations are shown in black, UM/Wavewatch/NEMO in orange, and ARMOME/NEMO in blue.

Future Steps

Examine **Additional Case Studies**
Evaluate **Forecasting Skill**
Gain a **deeper understanding** of the **synoptic conditions** that trigger meteotsunamis
Is the frequency and intensity of meteotsunamis likely to **change in the future**?

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