

Intercomparison of operational wave forecasting systems against  
in-situ observations: data from BoM, DMI, DWD, ECCO,  
ECMWF, JMA, LOPS, METEOAM, METFR, METNO, NCEP,  
NZMS, PRTOS, SHNSM, UKMO.

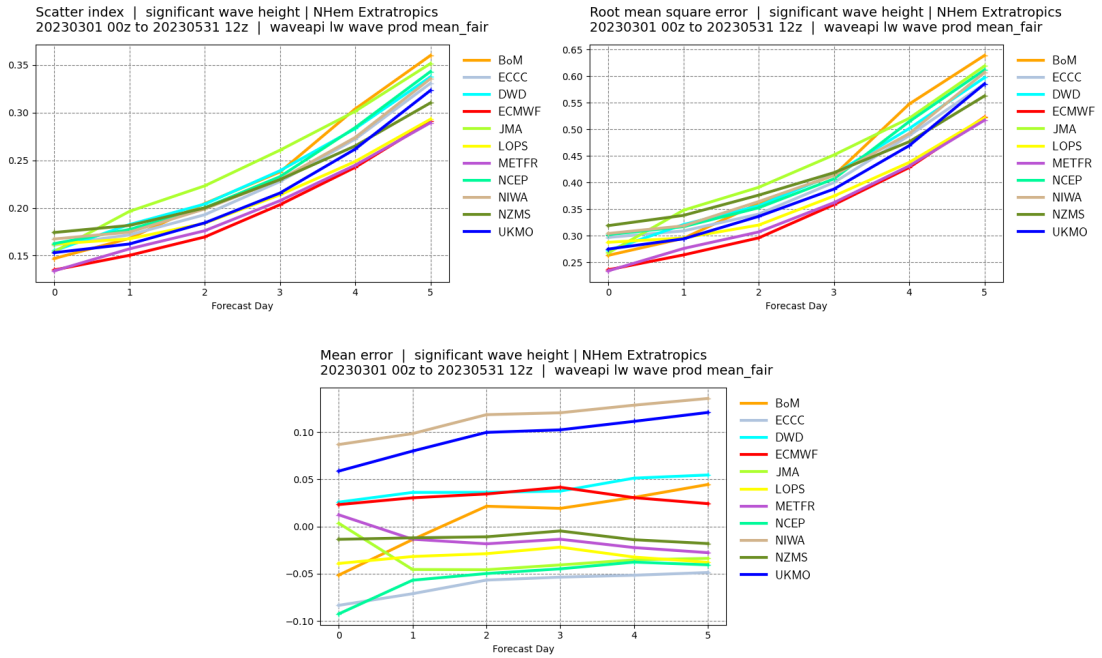
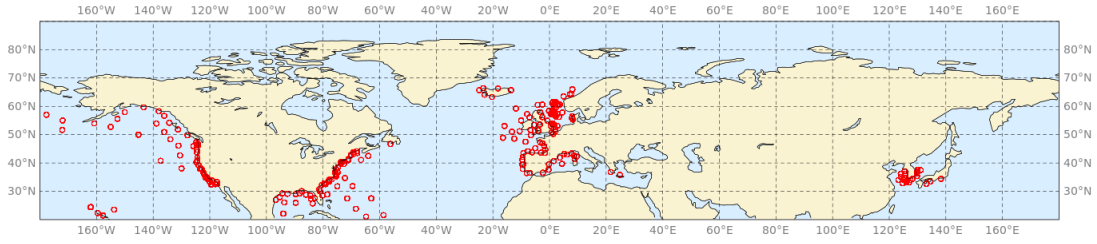
00 and 12 UTC runs

WMO Lead Centre for Wave Forecast Verification LC-WFV,  
European Centre for Medium-Range Weather Forecasts ECMWF

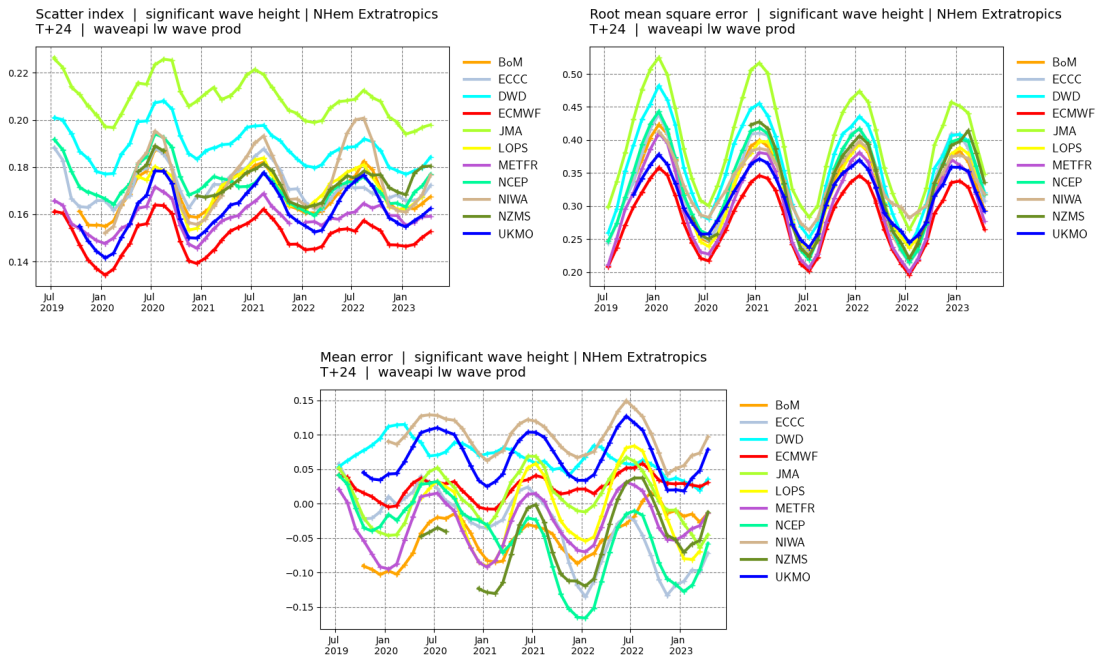
June 14, 2023

**PART I: significant wave height (SWH)**

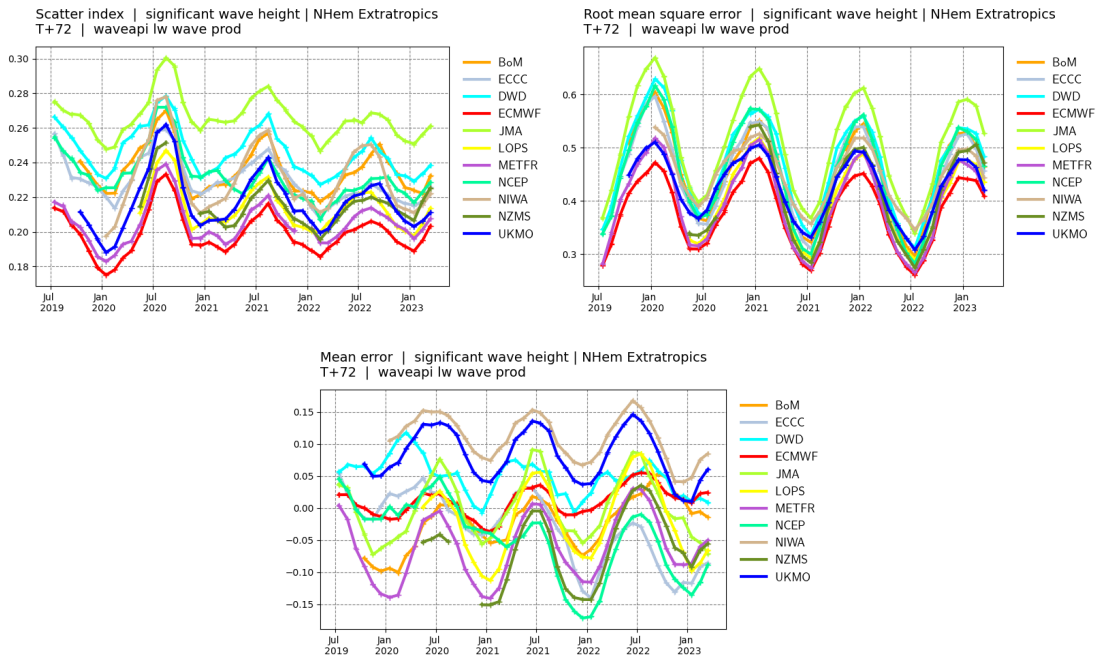
Buoys observations - from 20230301 to 20230531 - (swh)



**Northern Hemisphere.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

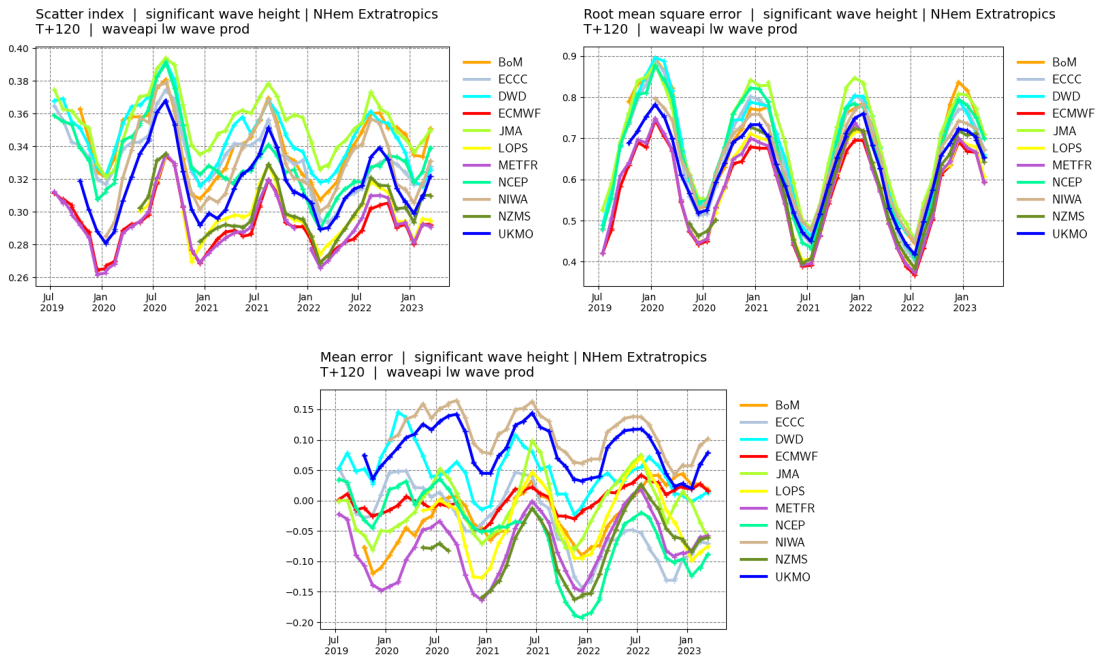


**Northern Hemisphere.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



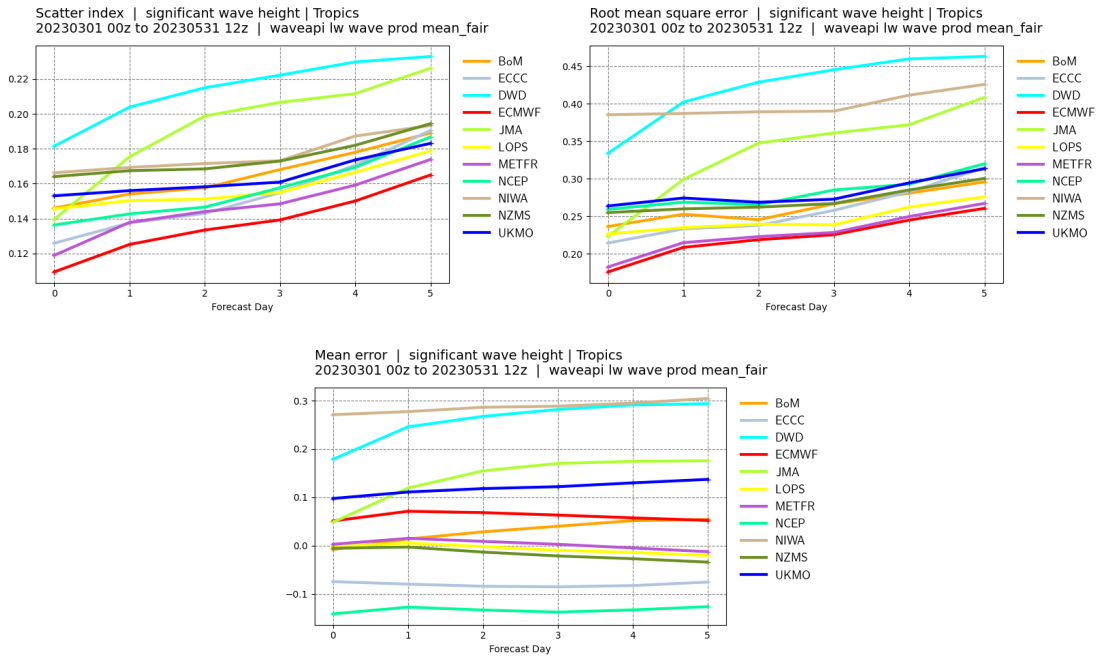
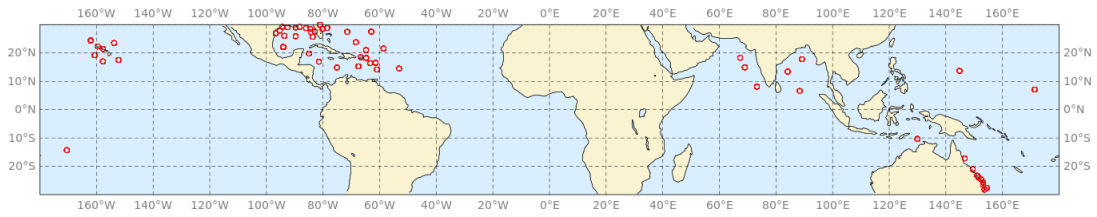
**Northern Hemisphere.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



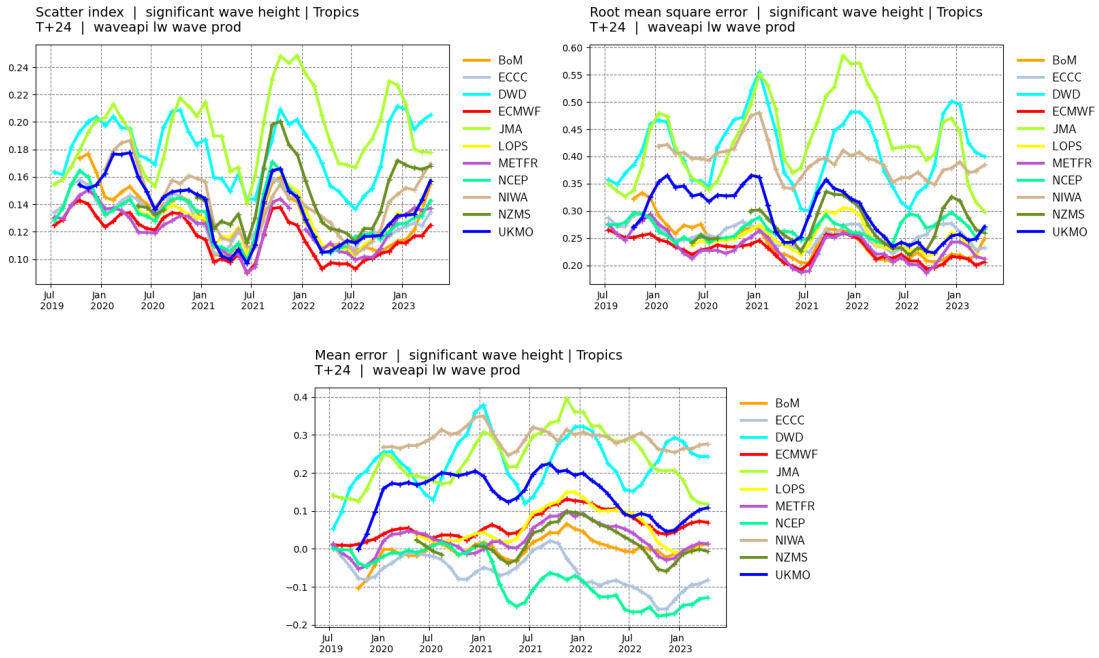


**Northern Hemisphere.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

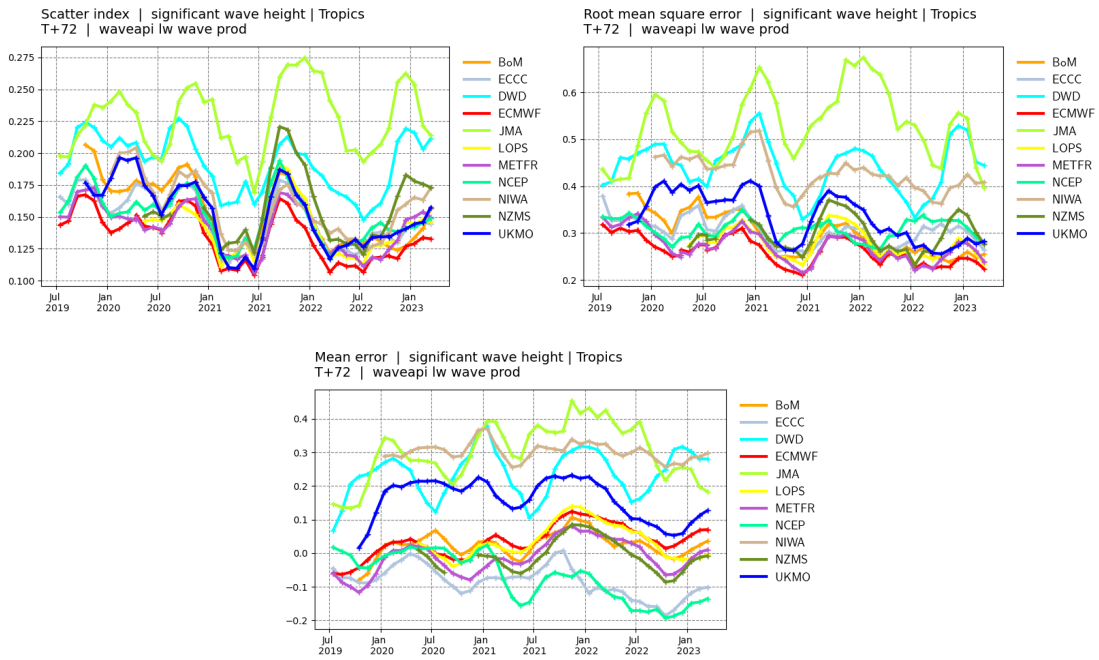
Buoys observations - from 20230301 to 20230531 - (swh)



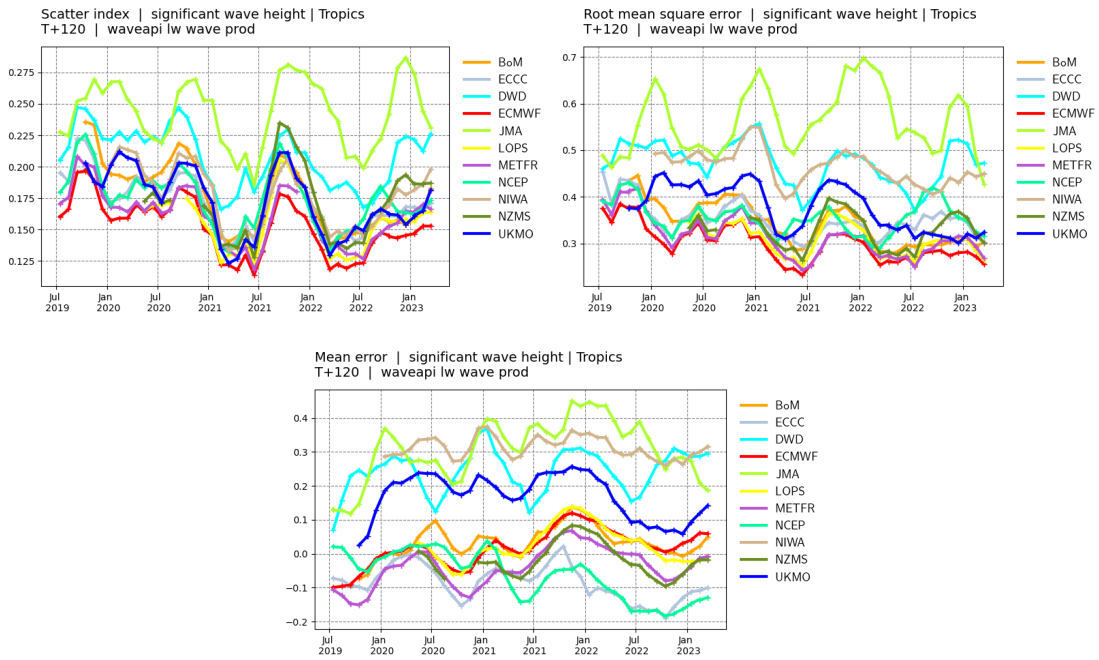
**Tropics.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



**Tropics.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

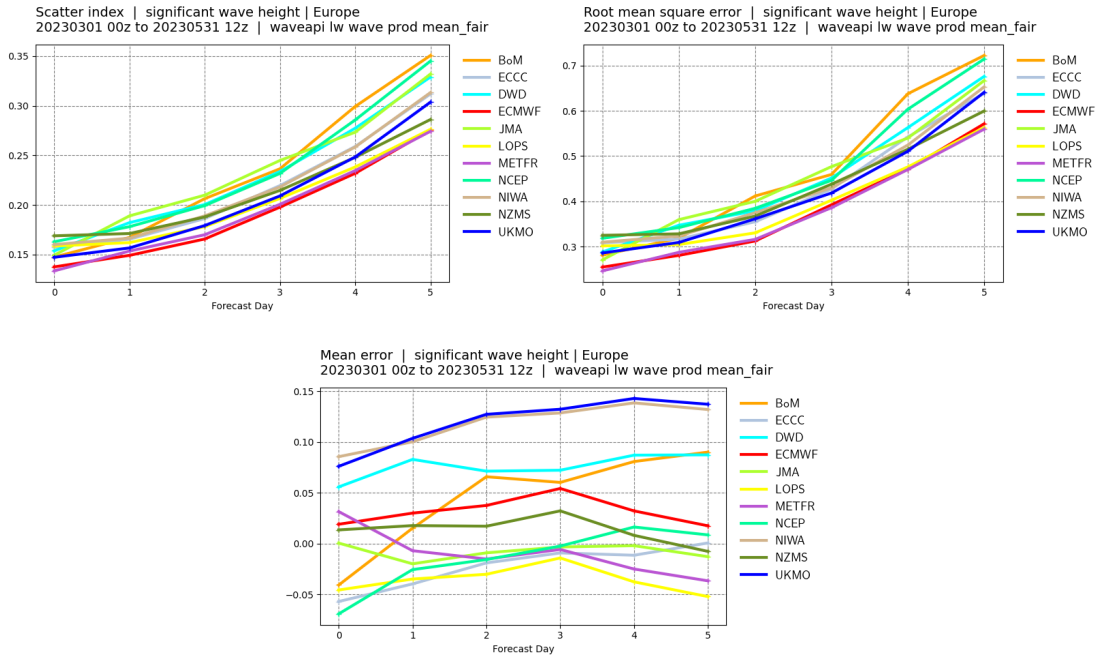
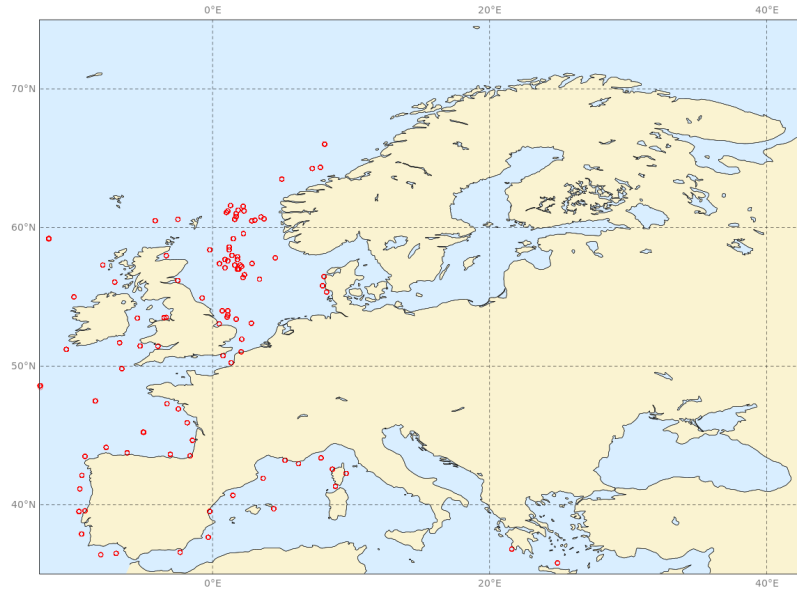


**Tropics.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

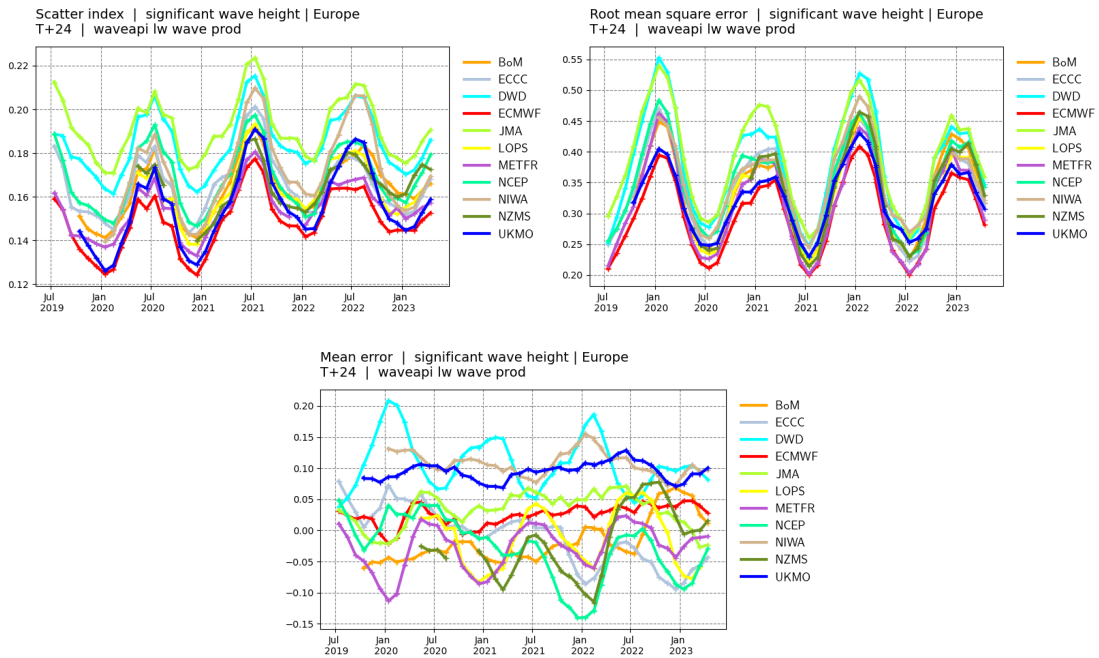


**Tropics.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

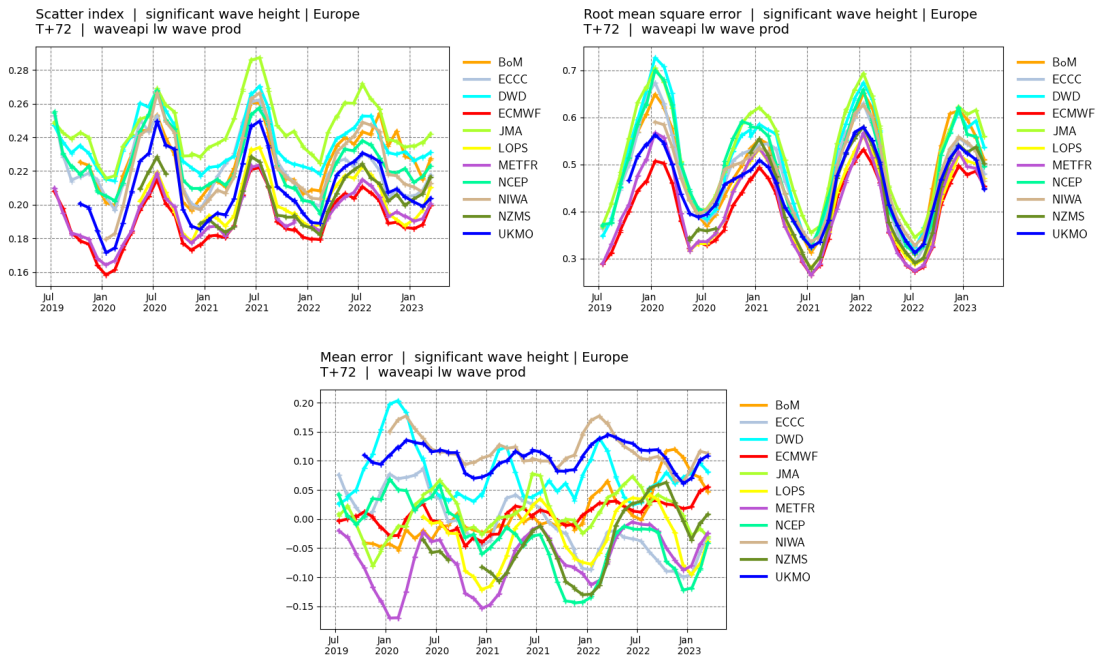
Buoys observations - from 20230301 to 20230531 - (swh)



**Europe.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

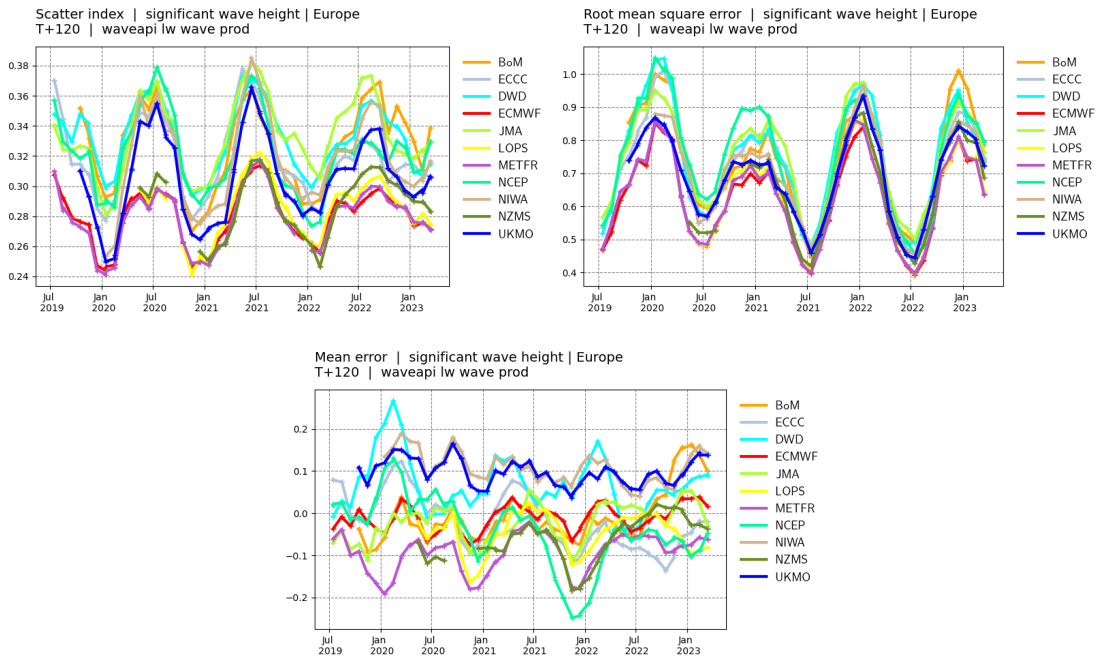


**Europe.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



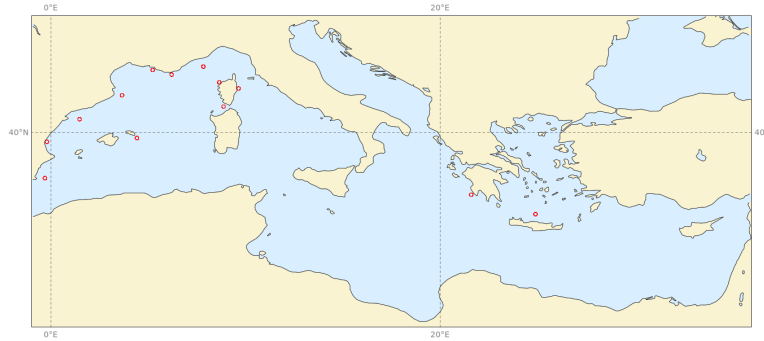
**Europe.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



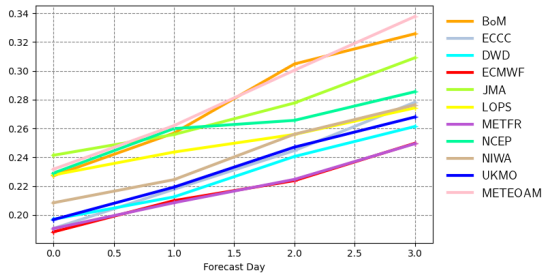


**Europe.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

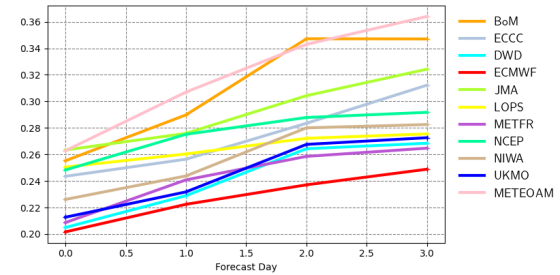
Buoys observations - from 20230301 to 20230531 - (swh)



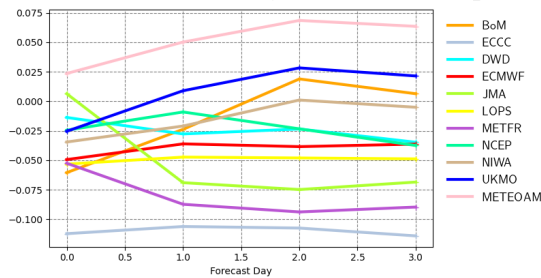
Scatter index | significant wave height | Mediterranean  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



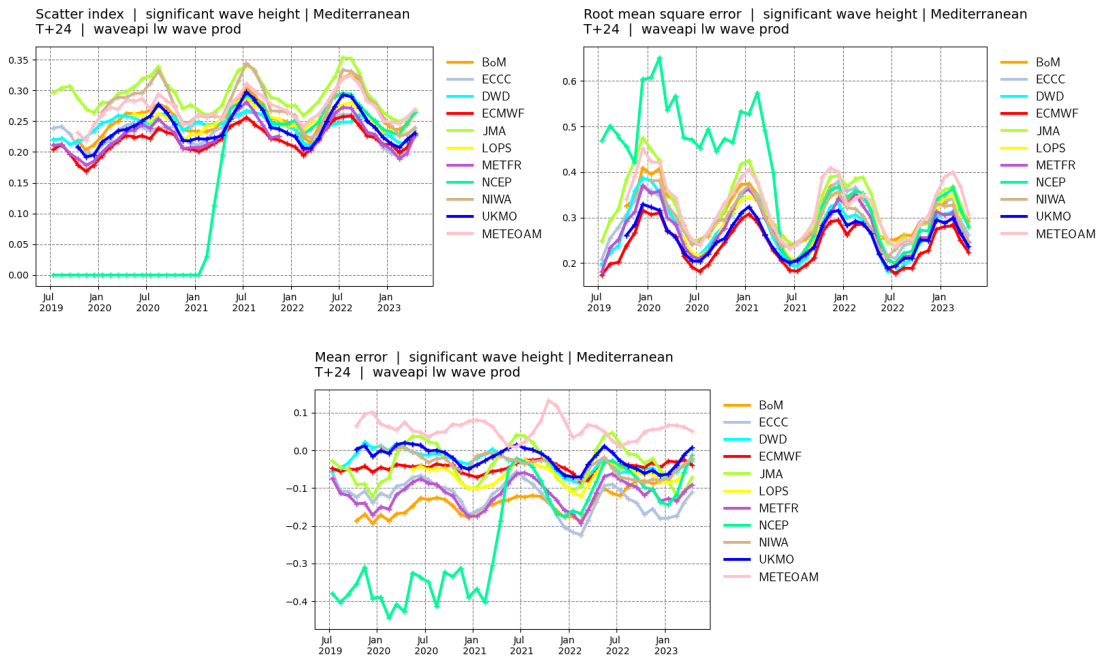
Root mean square error | significant wave height | Mediterranean  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



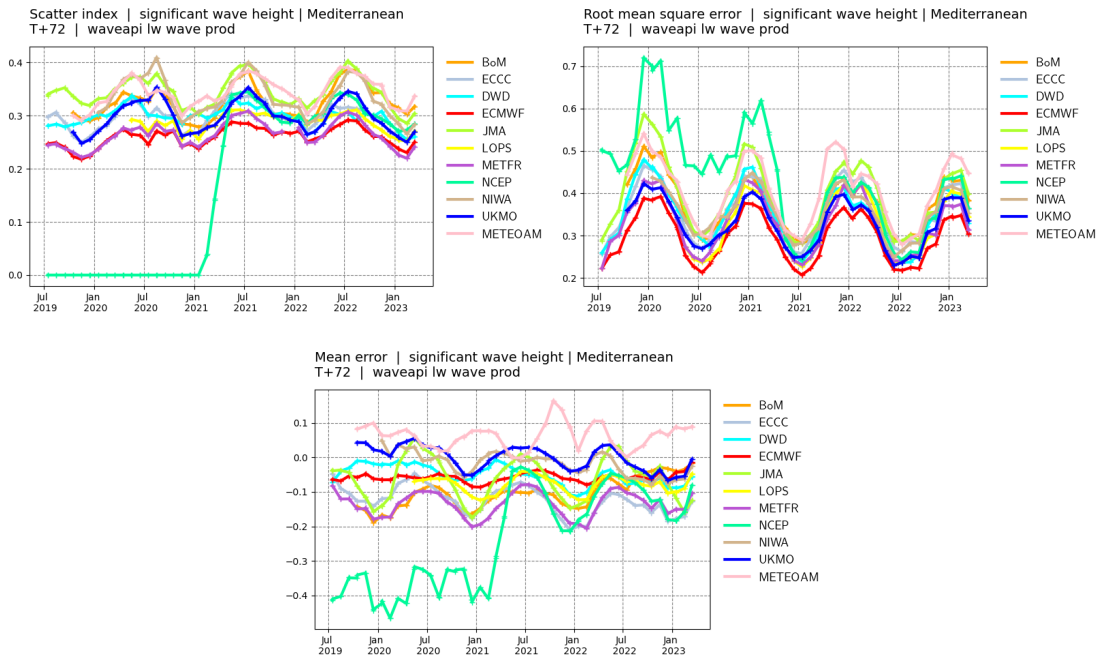
Mean error | significant wave height | Mediterranean  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



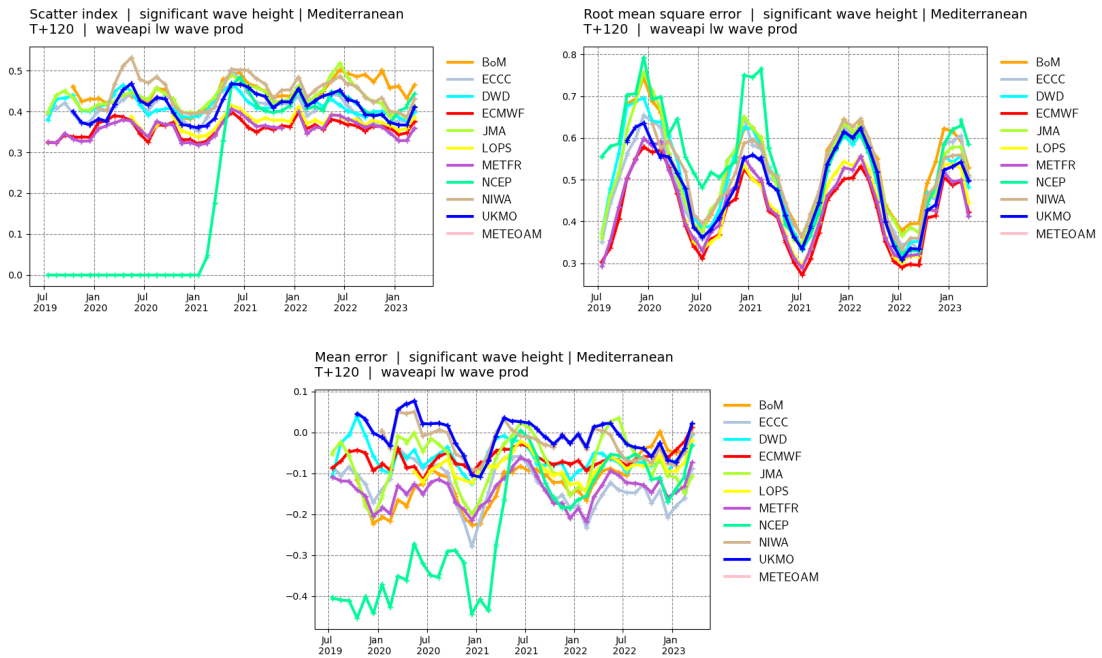
**Mediterranean Sea.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



**Mediterranean Sea.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

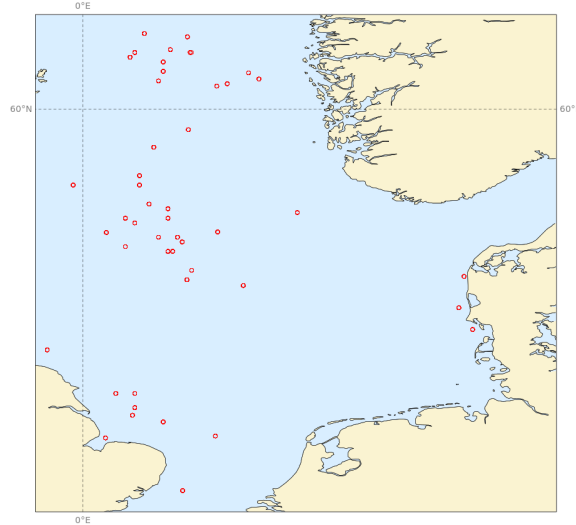


**Mediterranean Sea.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

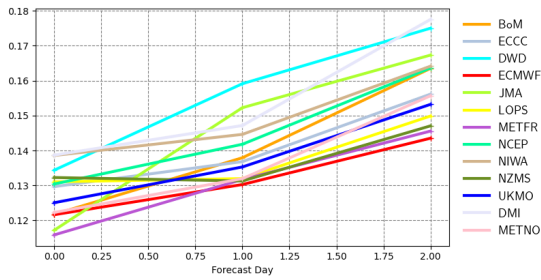


**Mediterranean Sea.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

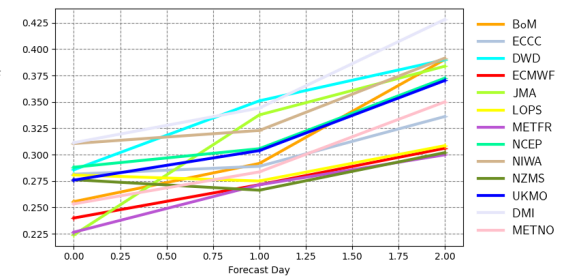
Buoys observations - from 20230301 to 20230531 - (swh)



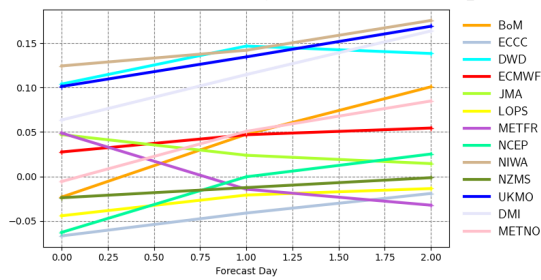
Scatter index | significant wave height | North Sea  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



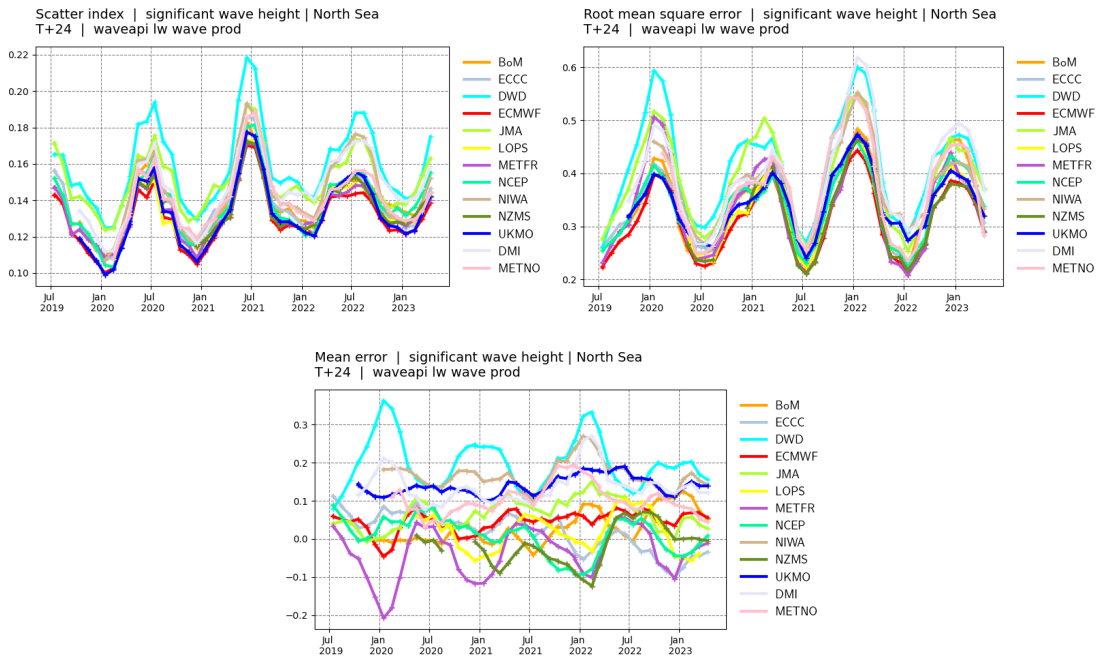
Root mean square error | significant wave height | North Sea  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



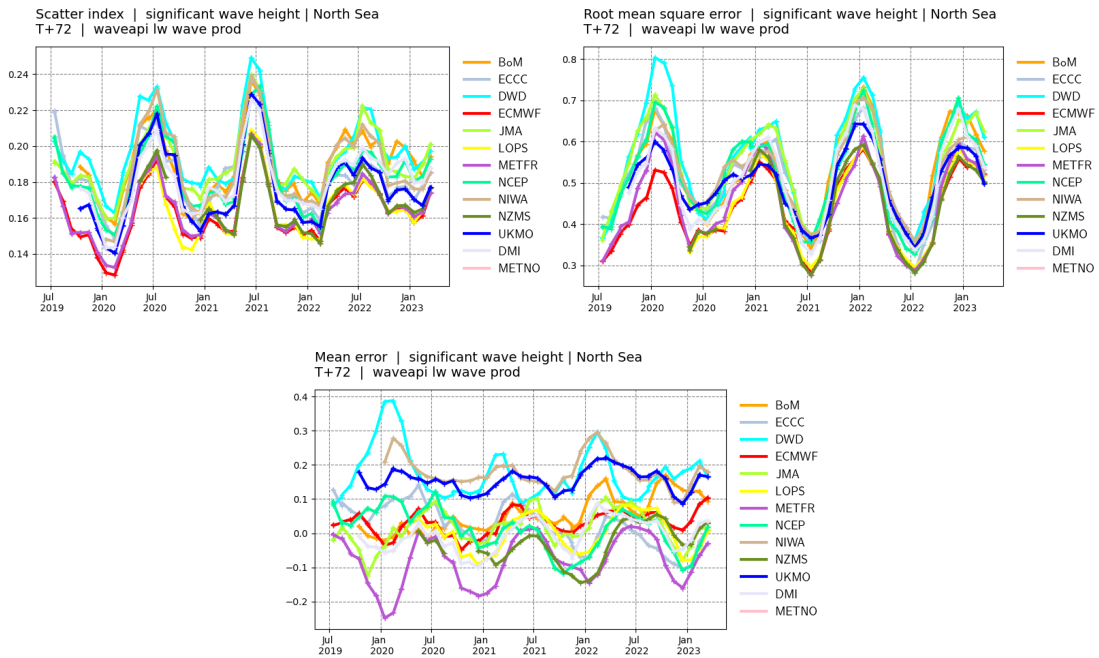
Mean error | significant wave height | North Sea  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



**North Sea.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

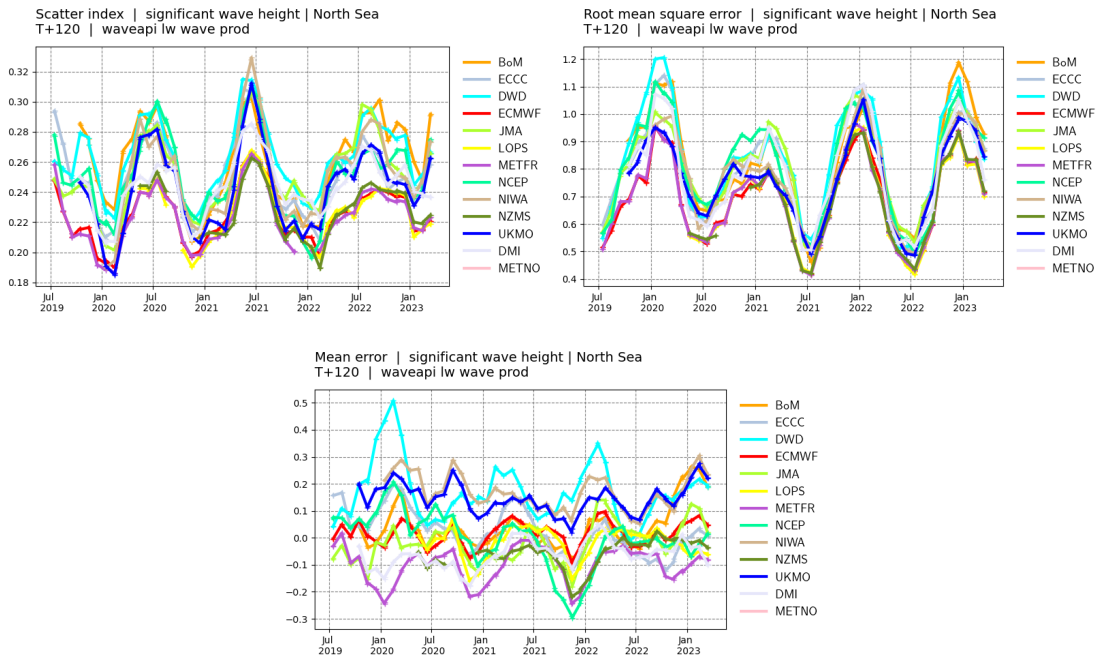


**North Sea.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



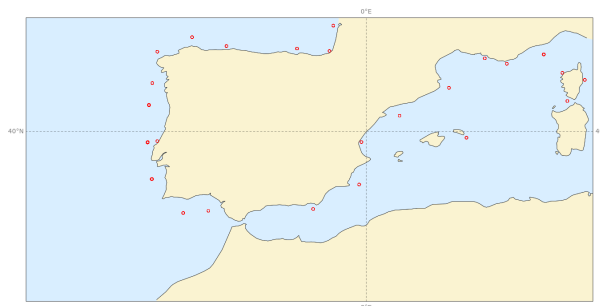
**North Sea.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



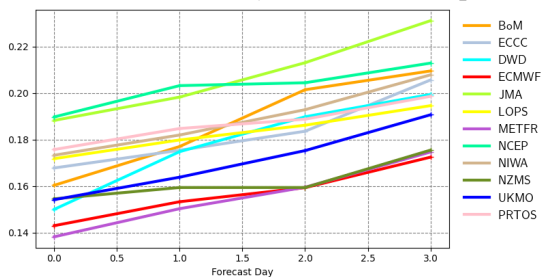


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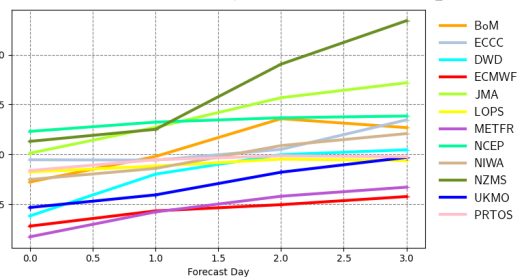
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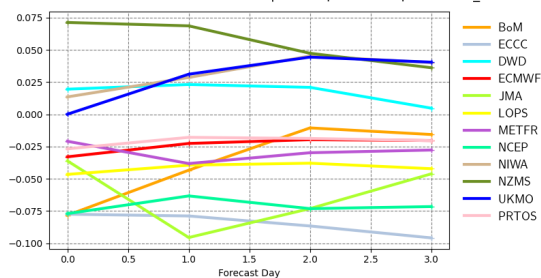
Scatter index | significant wave height | SW Europe  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



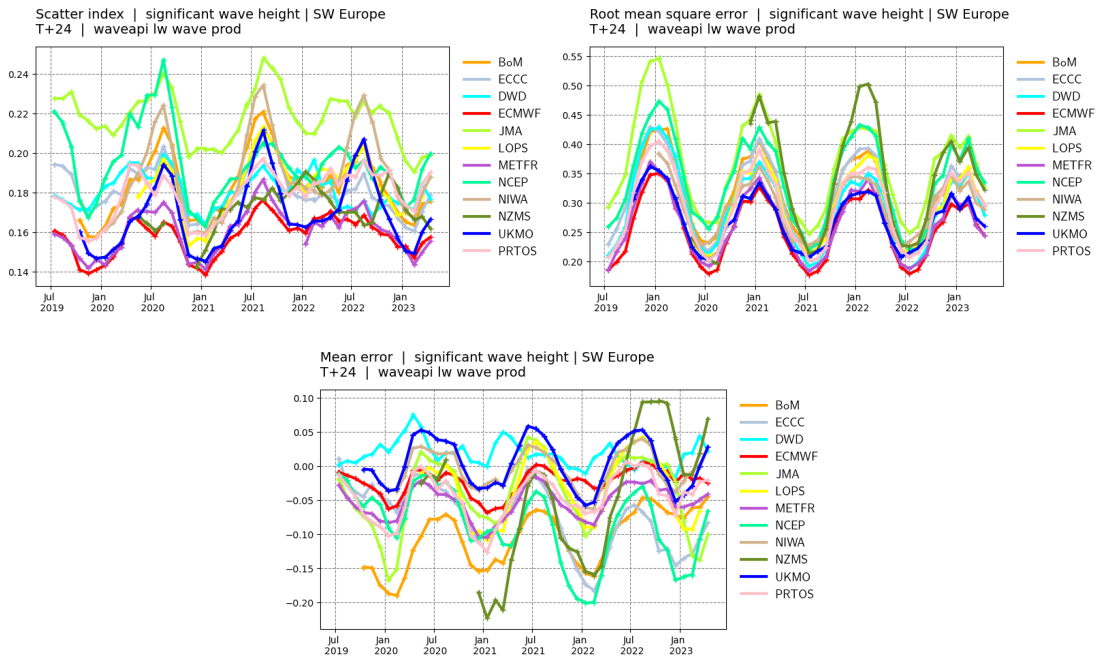
Root mean square error | significant wave height | SW Europe  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



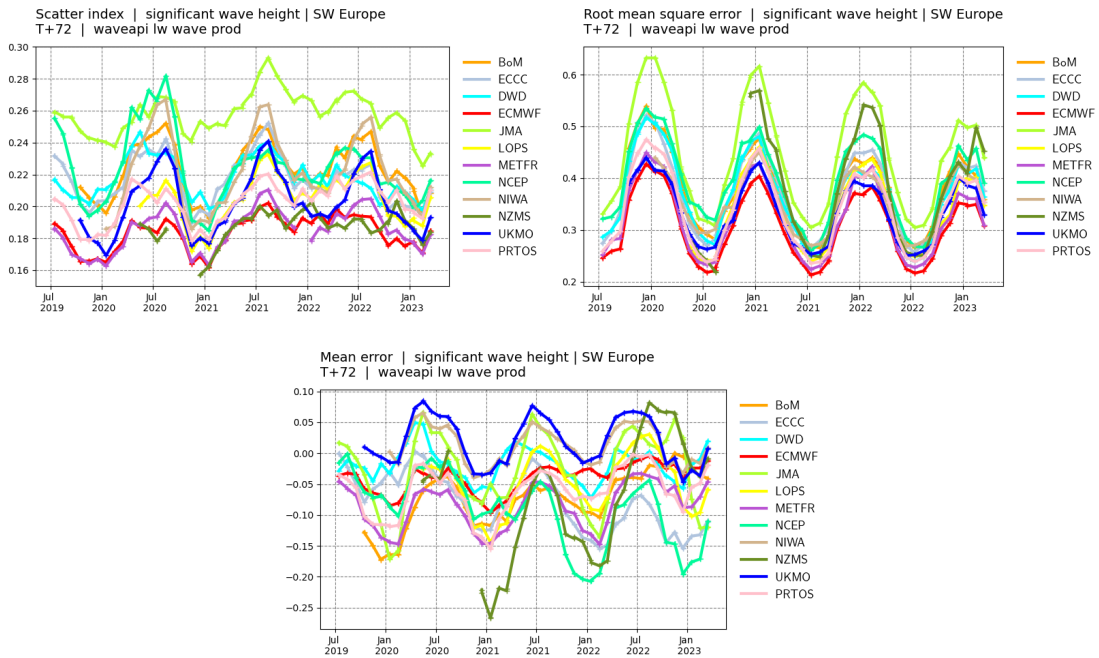
Mean error | significant wave height | SW Europe  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



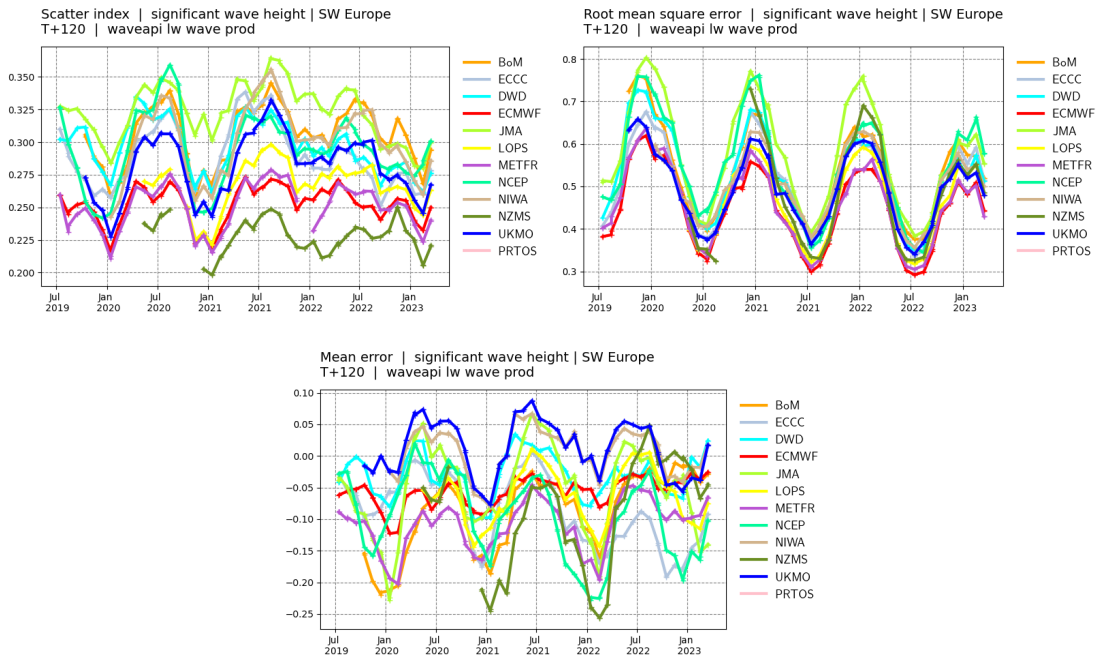
**South West Europe.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



**South West Europe.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

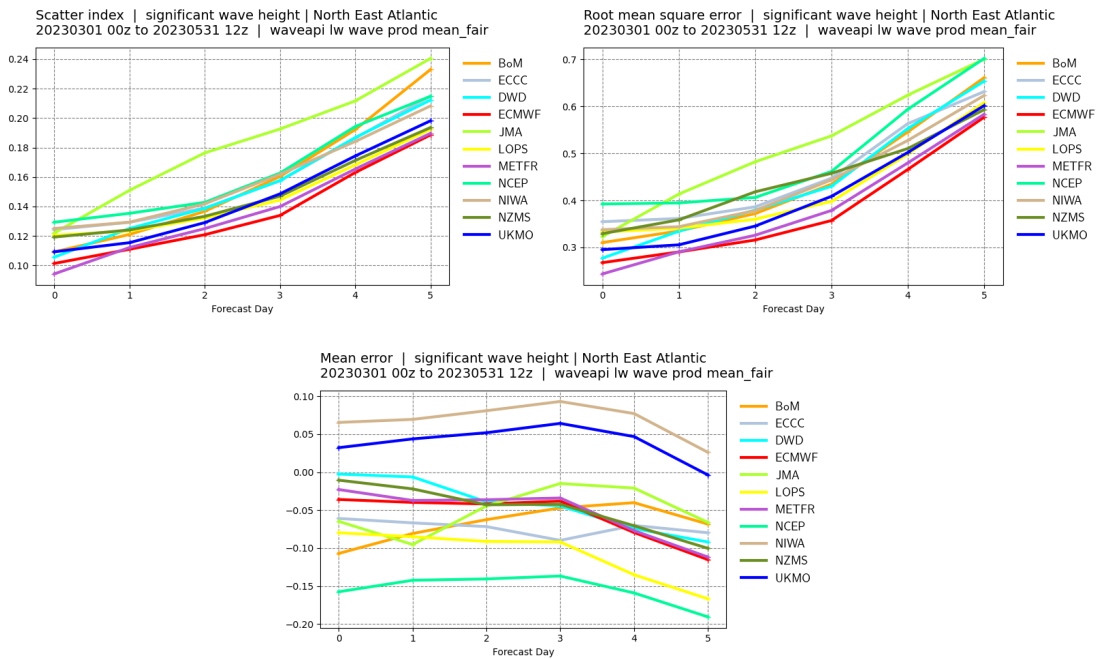
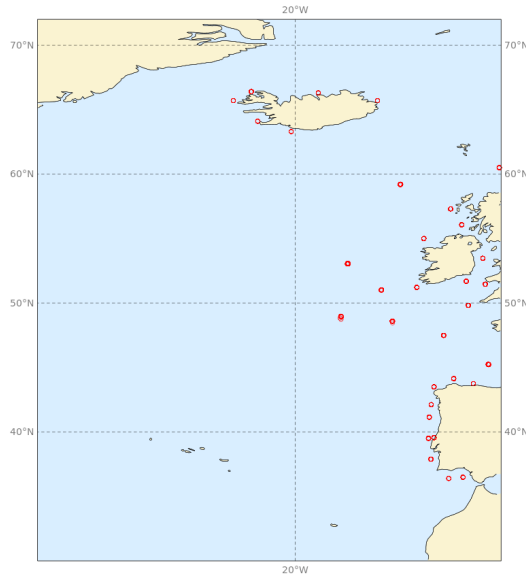


**South West Europe.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

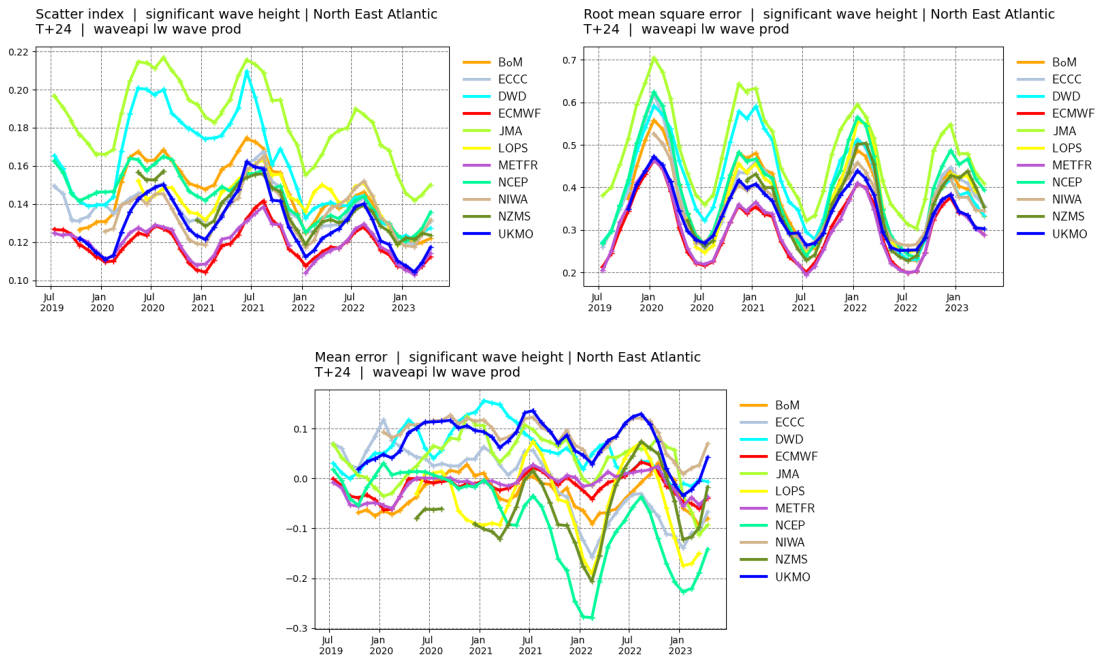


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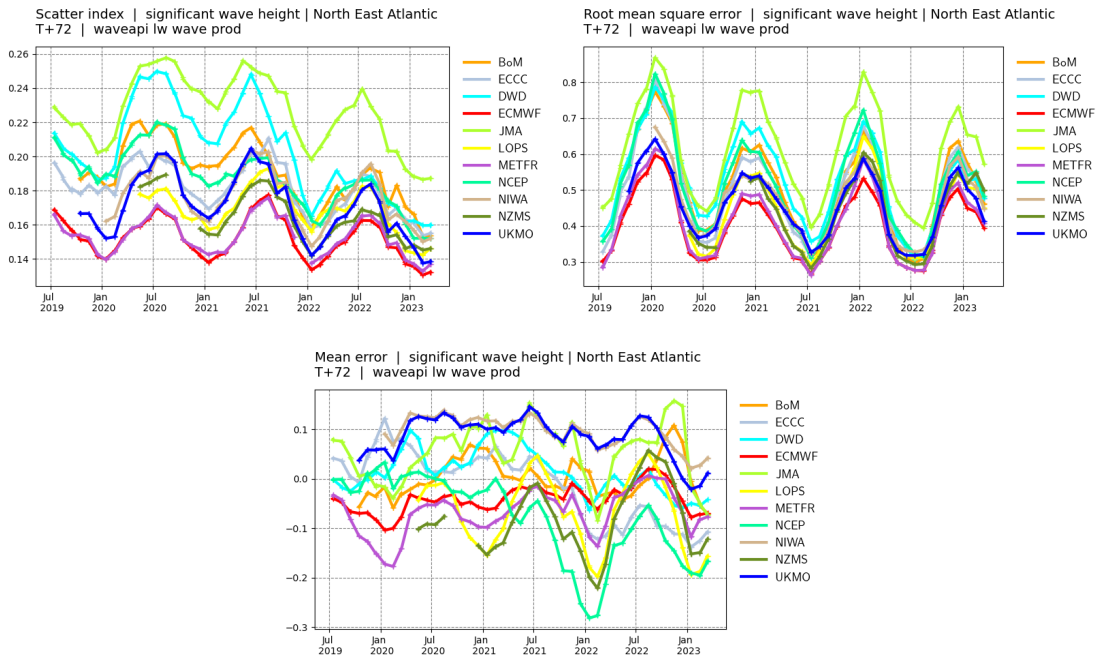
Buoys observations - from 20230301 to 20230531 - (swh)



**North East Atlantic.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

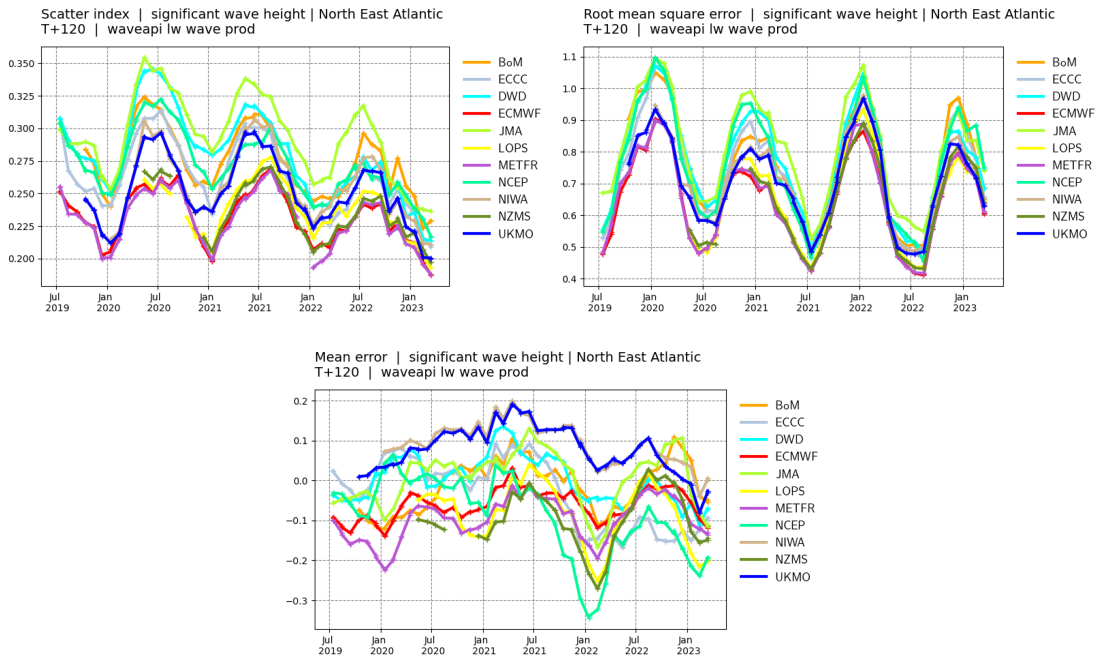


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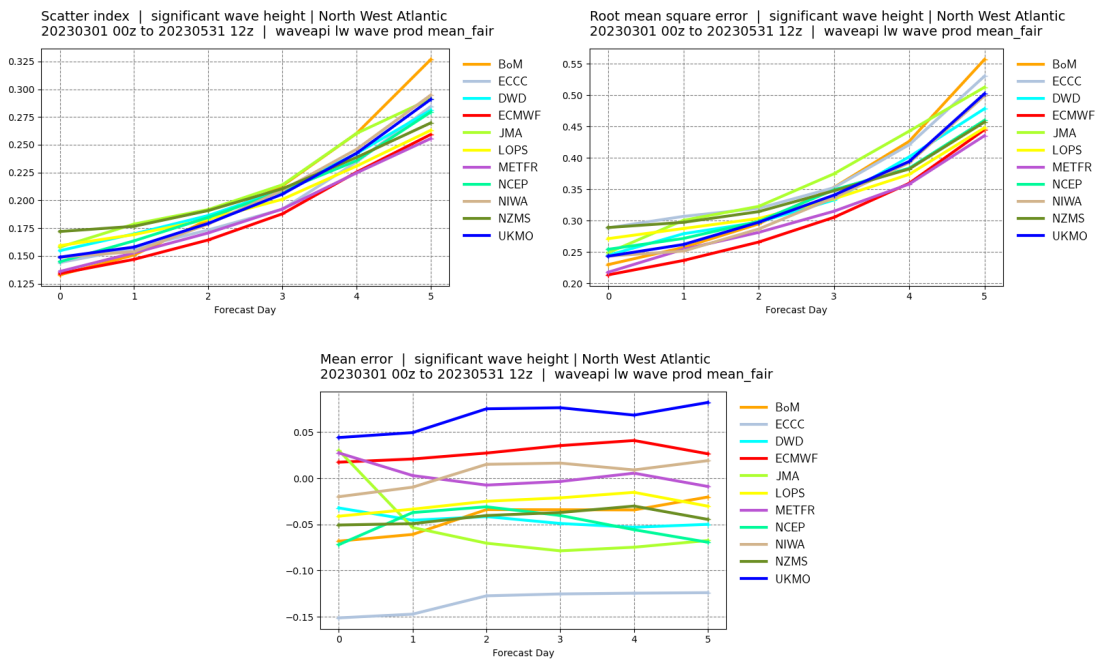
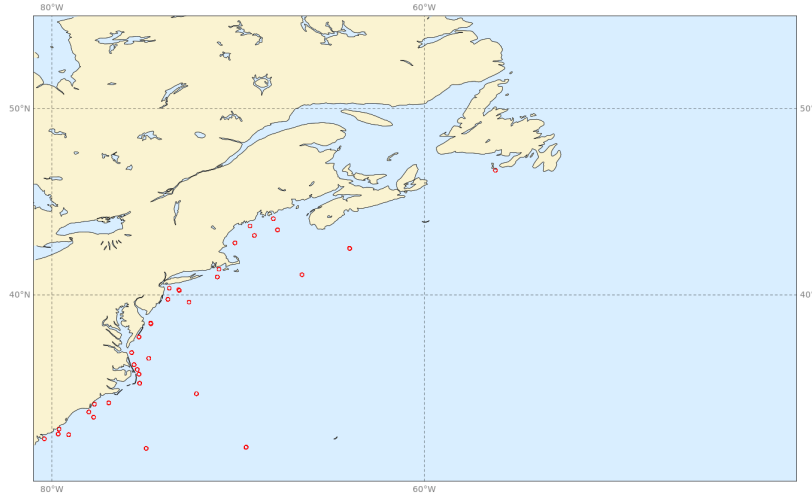
**North East Atlantic.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



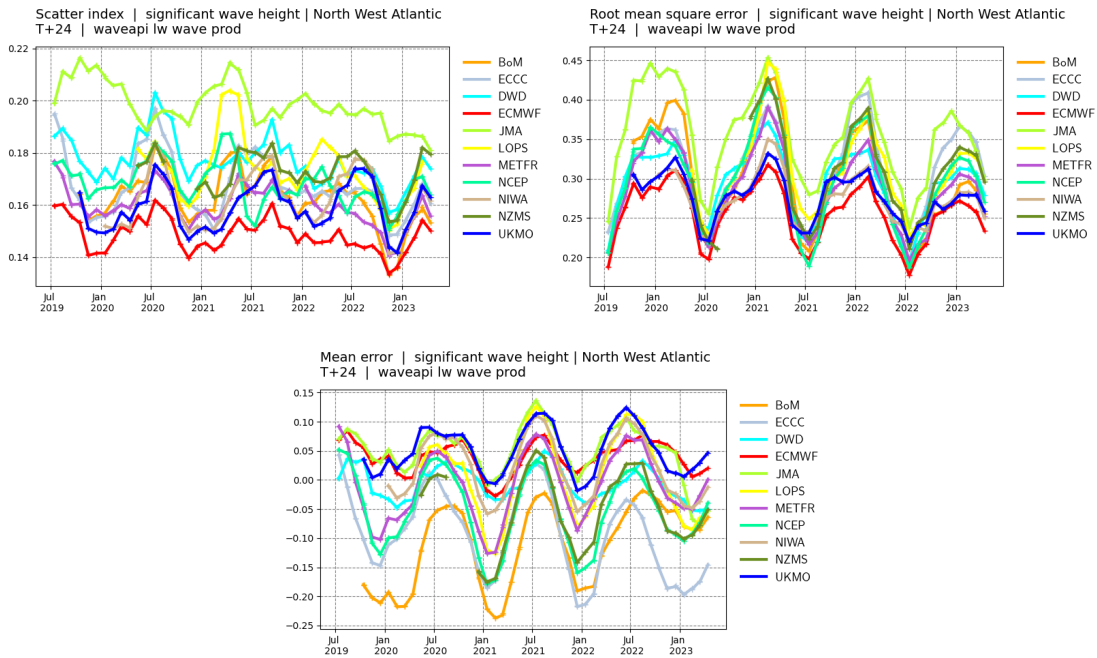


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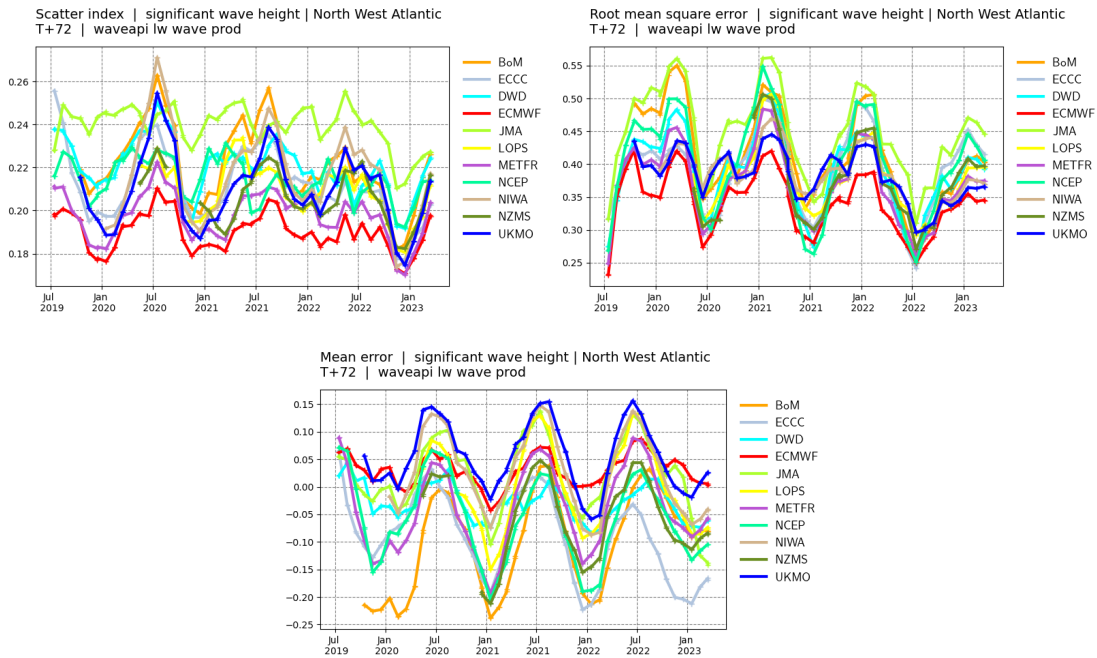
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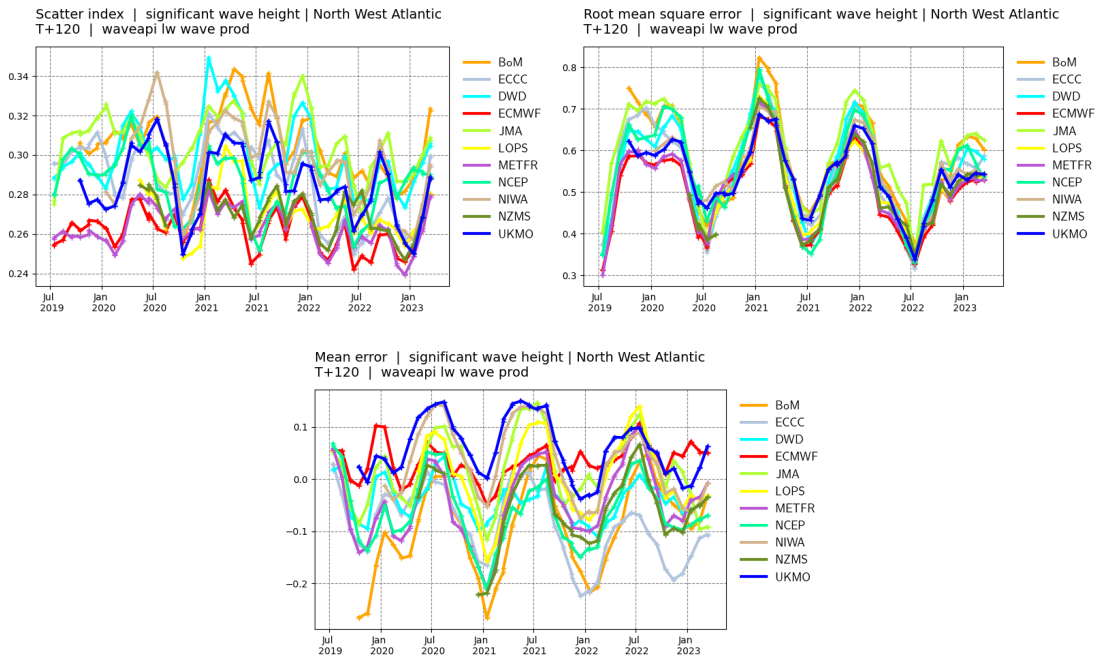
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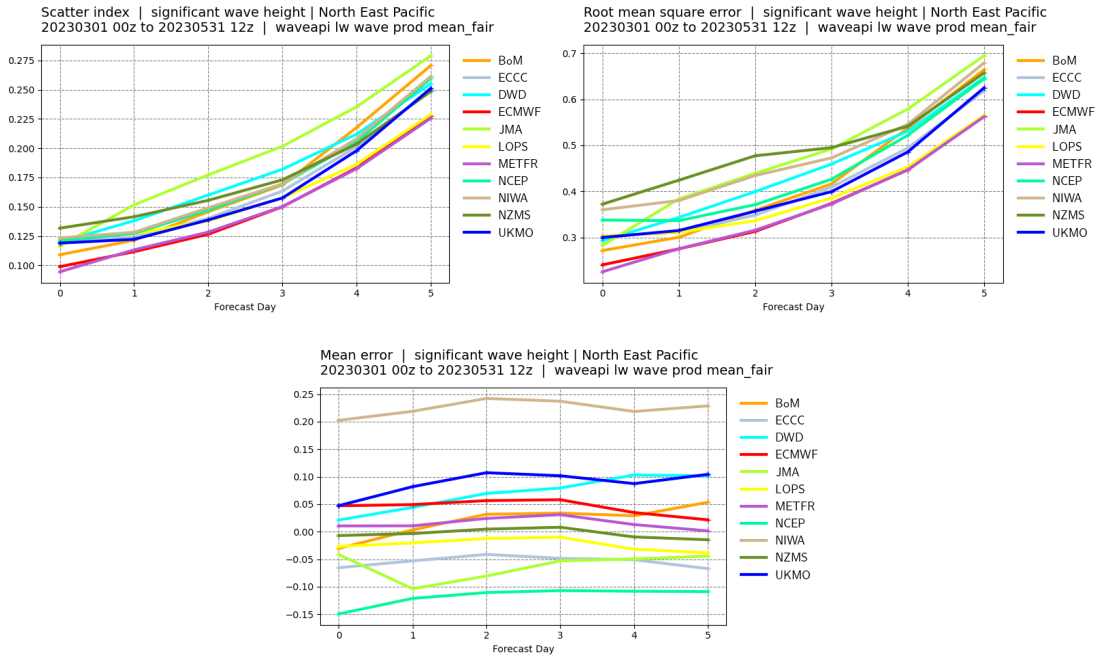
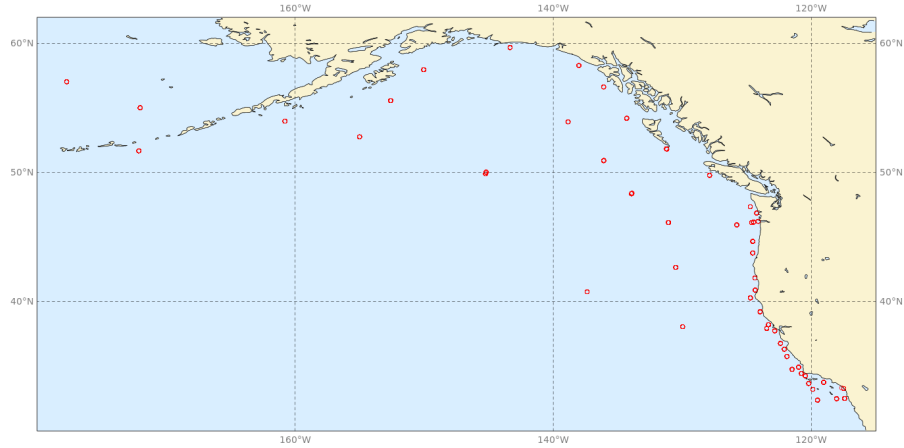


**North West Atlantic.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

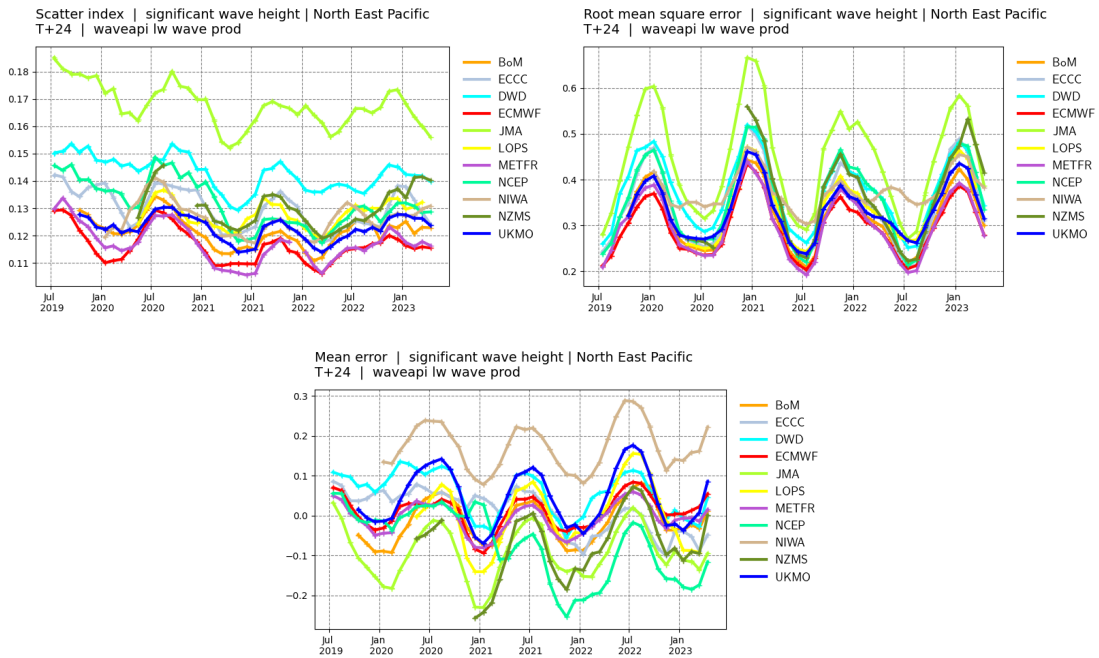


**North West Atlantic.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

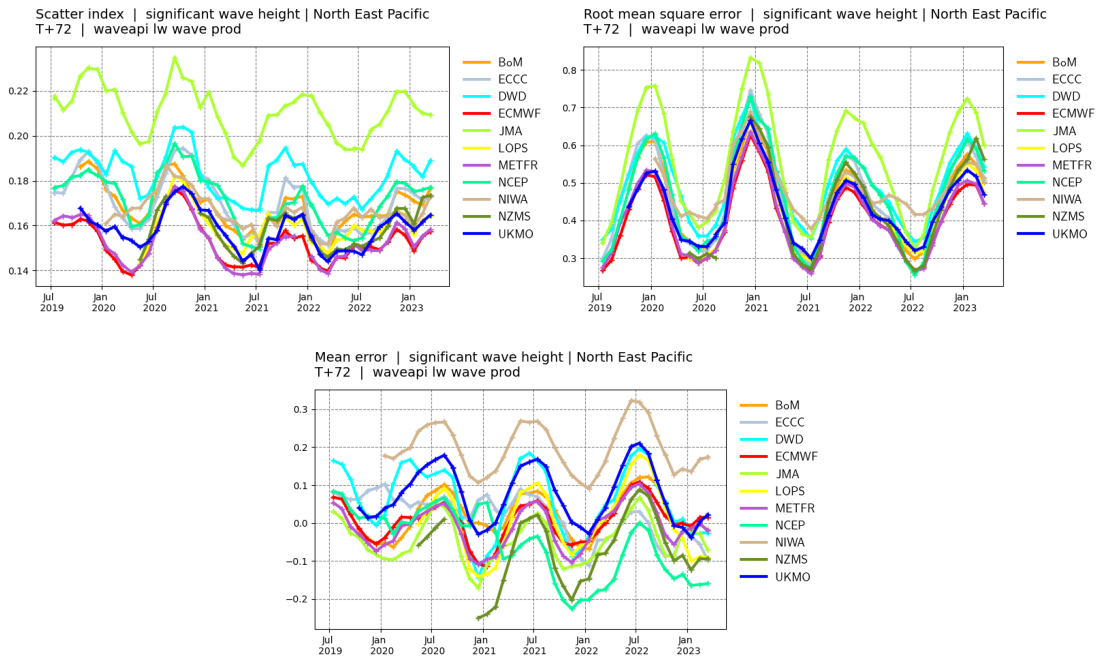
Buoys observations - from 20230301 to 20230531 - (swh)



**North East Pacific.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

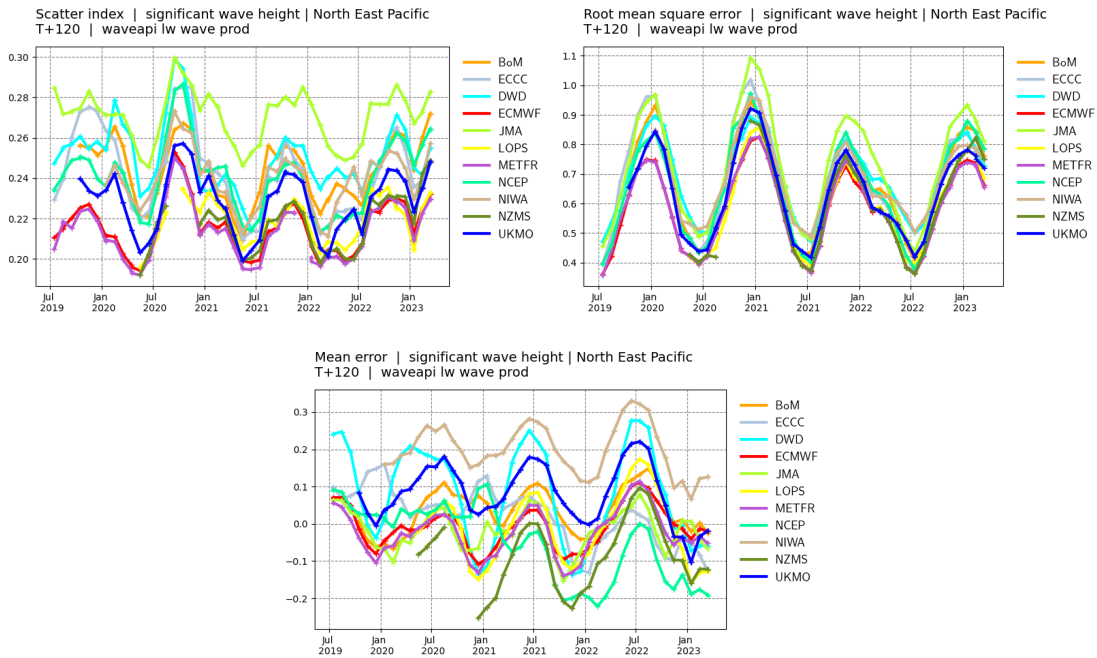


**North East Pacific.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



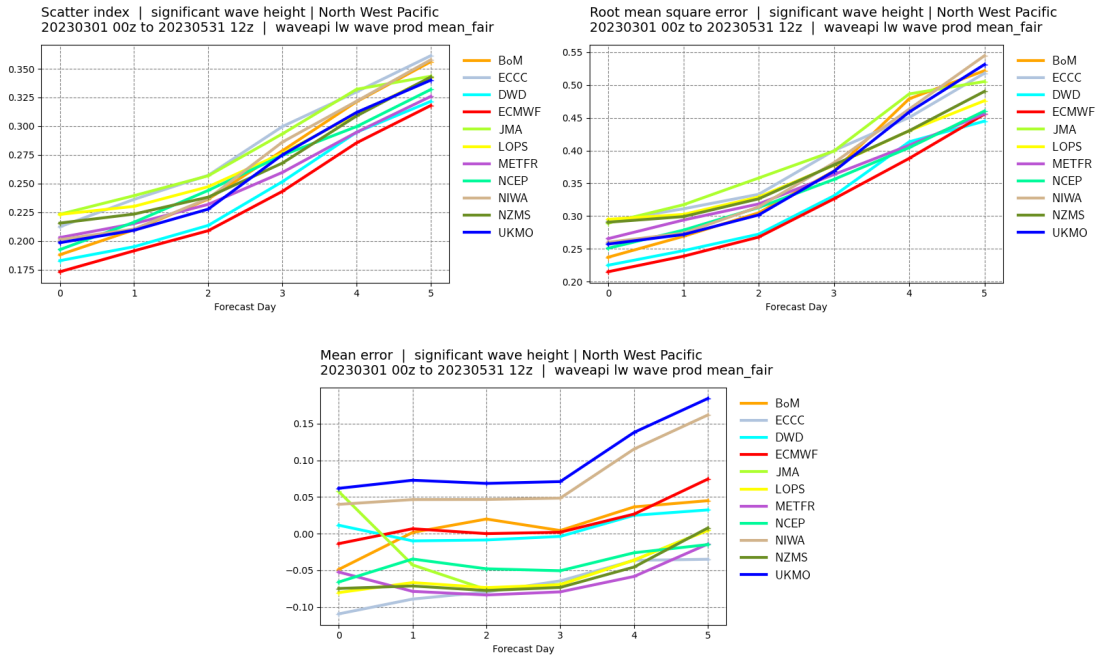
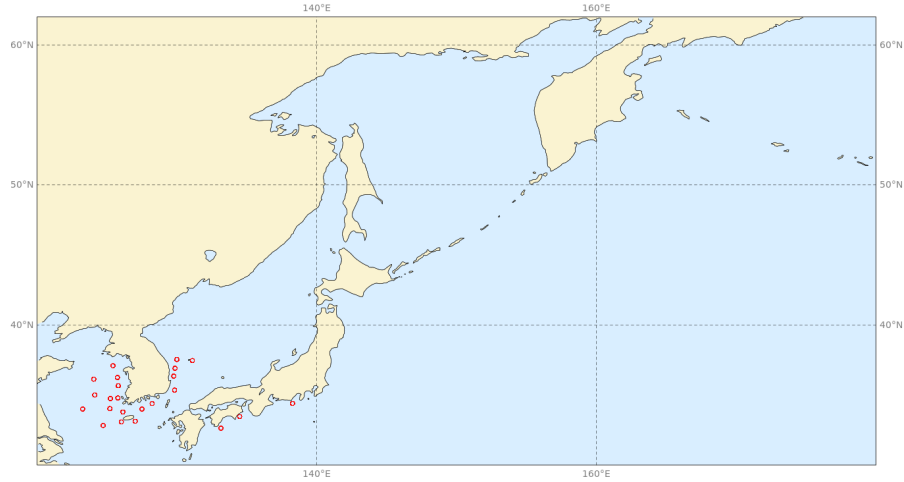
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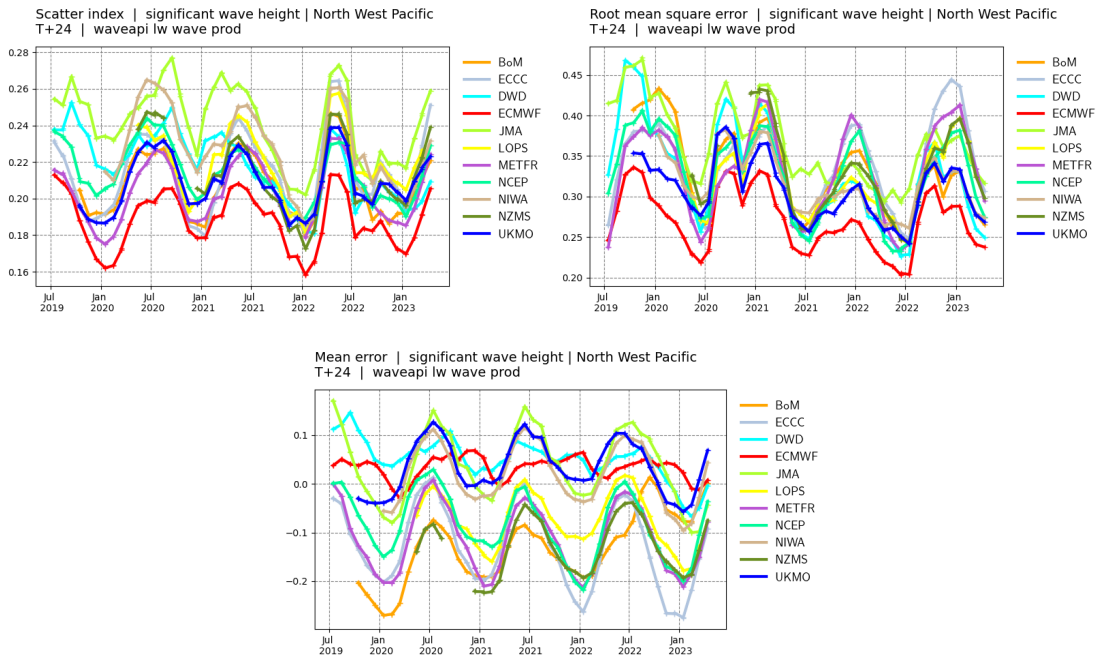


**North East Pacific.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

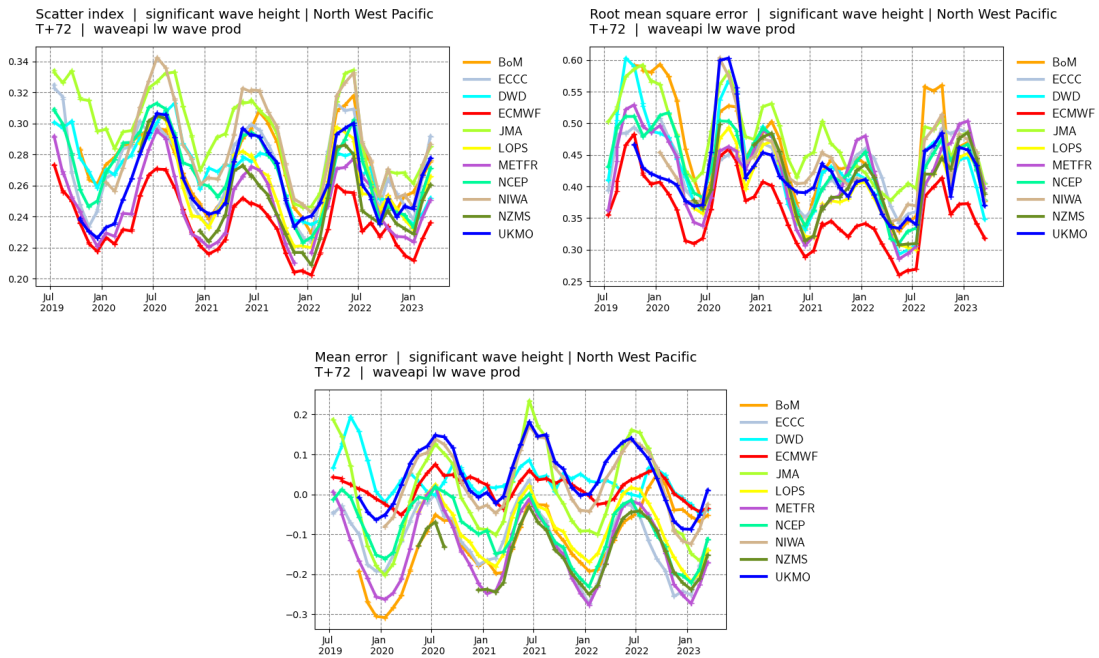
Buoys observations - from 20230301 to 20230531 - (swh)



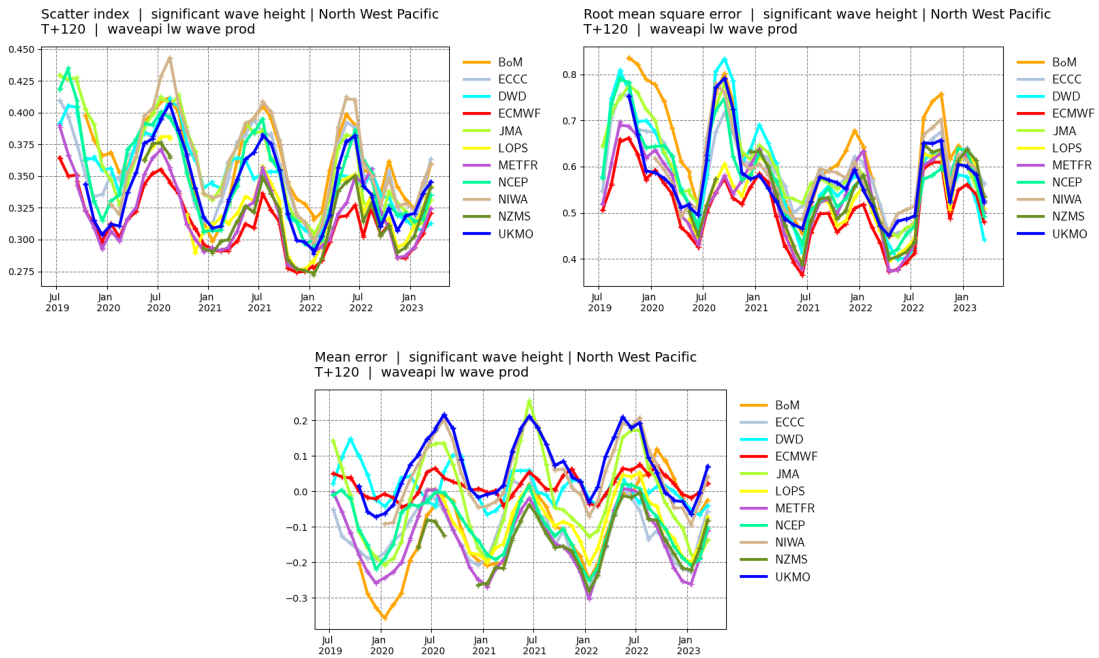
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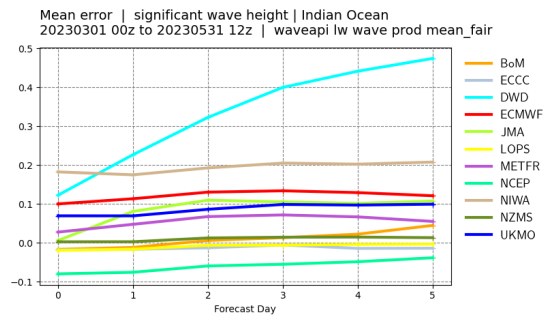
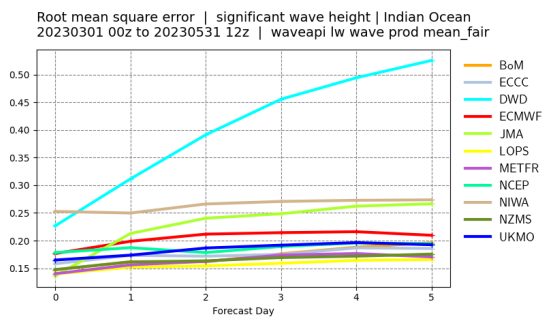
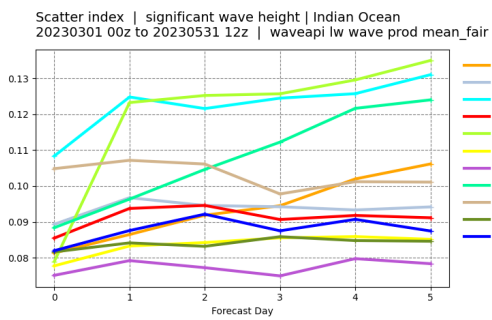
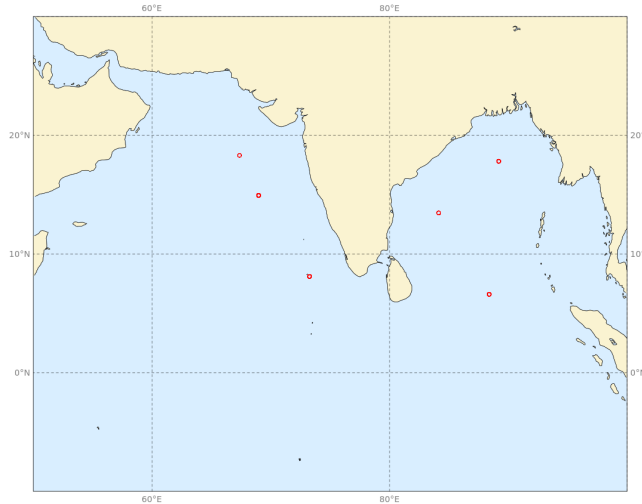


**North West Pacific.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

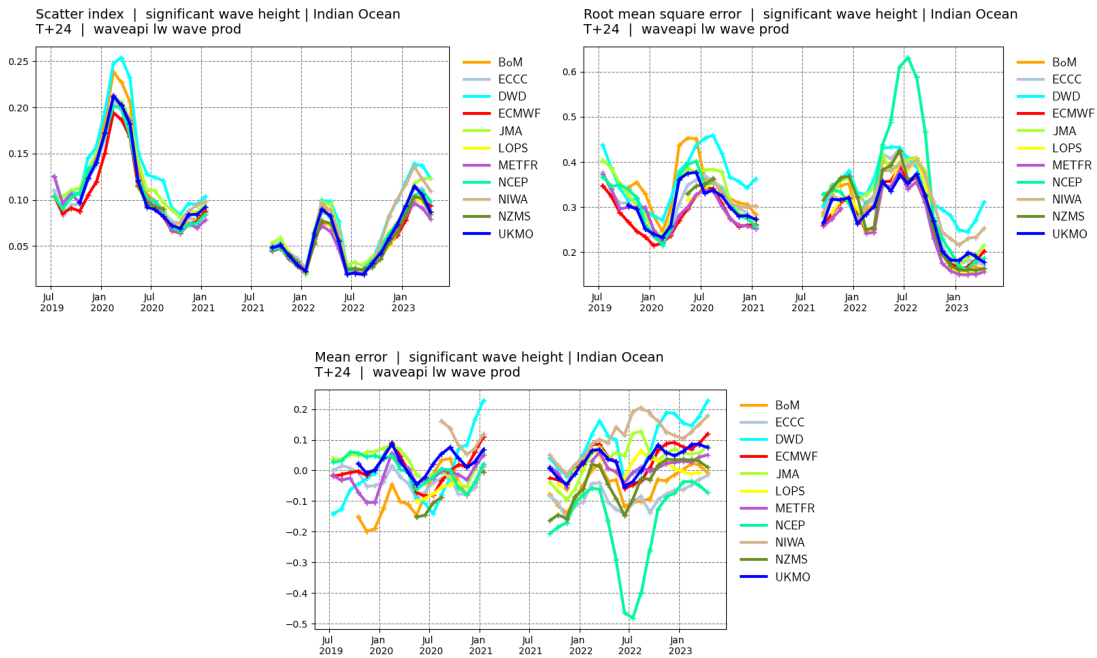


**North West Pacific.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

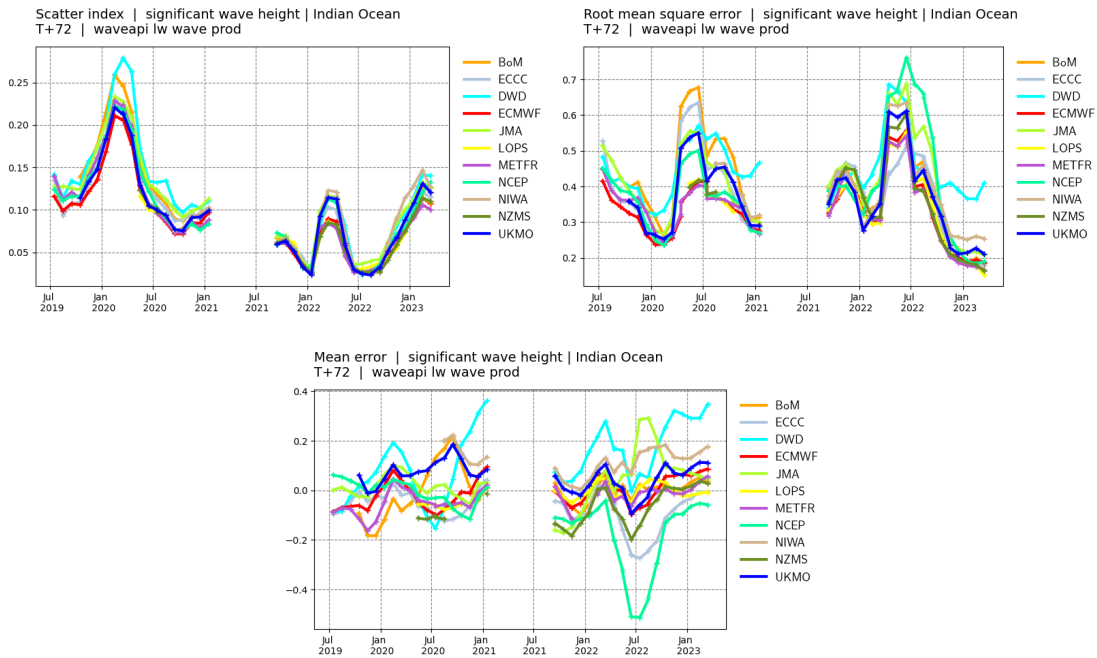
Buoys observations - from 20230301 to 20230531 - (swh)



**Indian Ocean.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

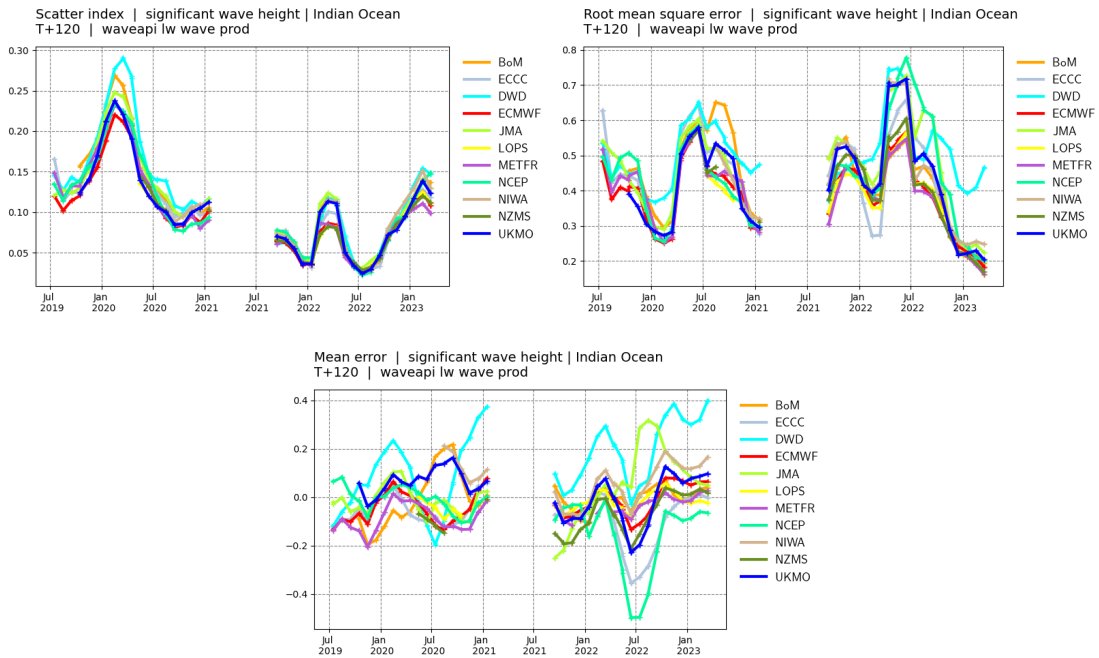


**Indian Ocean.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



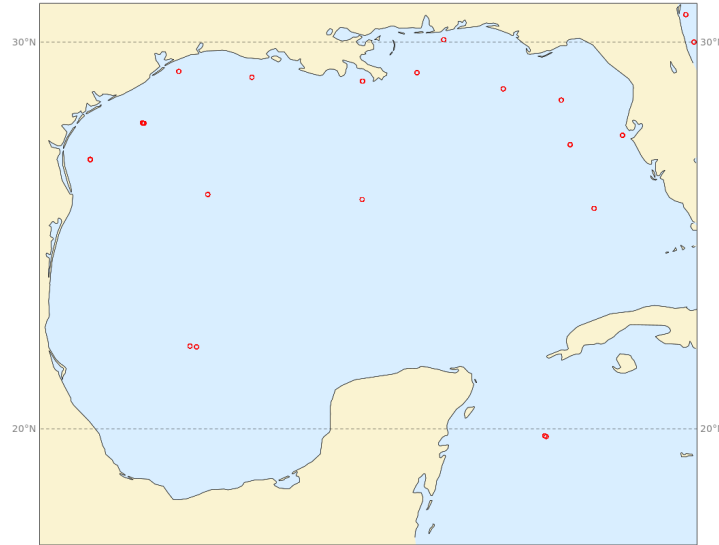
**Indian Ocean.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



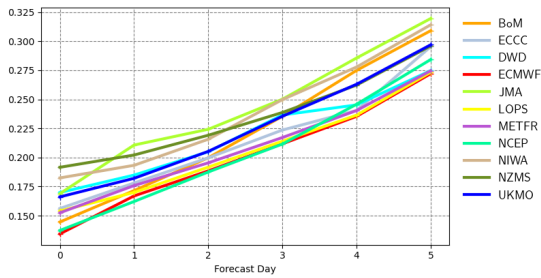


**Indian Ocean.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

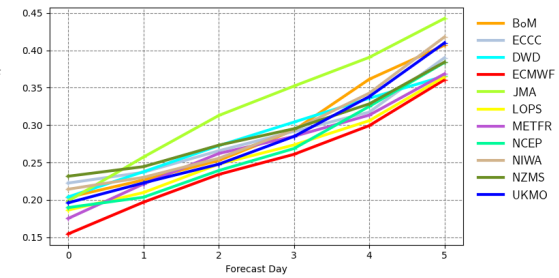
Buoys observations - from 20230301 to 20230531 - (swh)



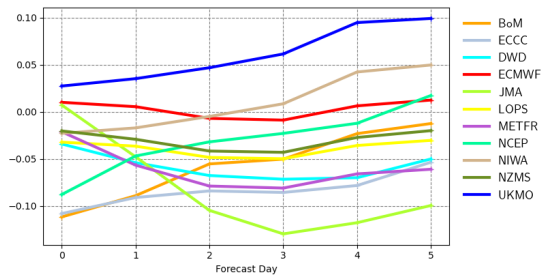
Scatter index | significant wave height | Gulf of Mexico  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



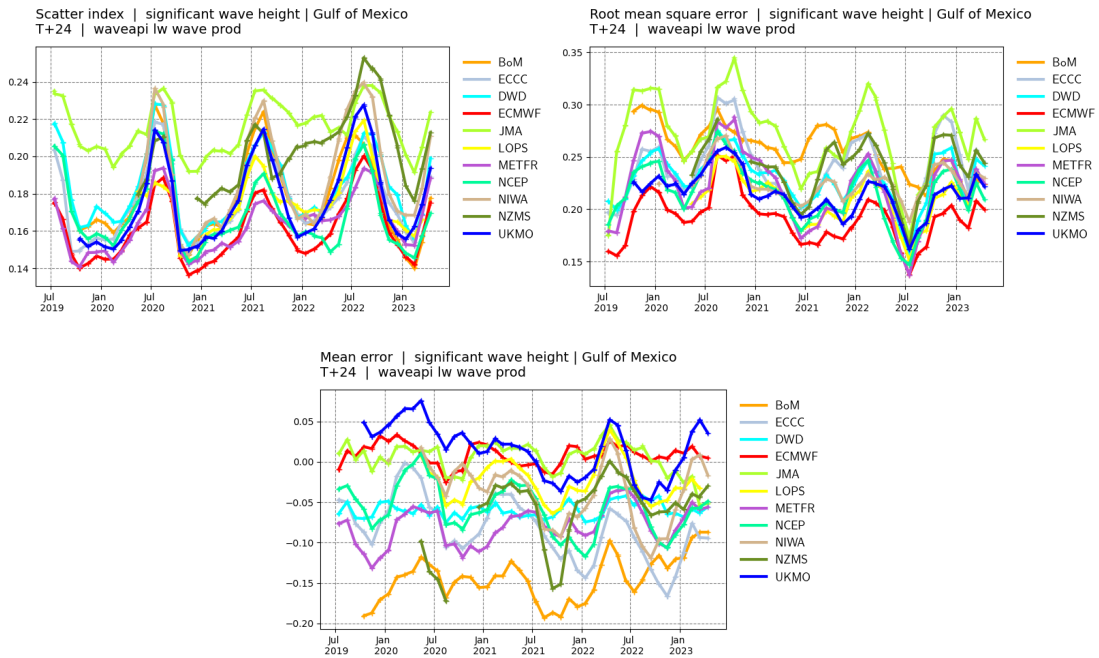
Root mean square error | significant wave height | Gulf of Mexico  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



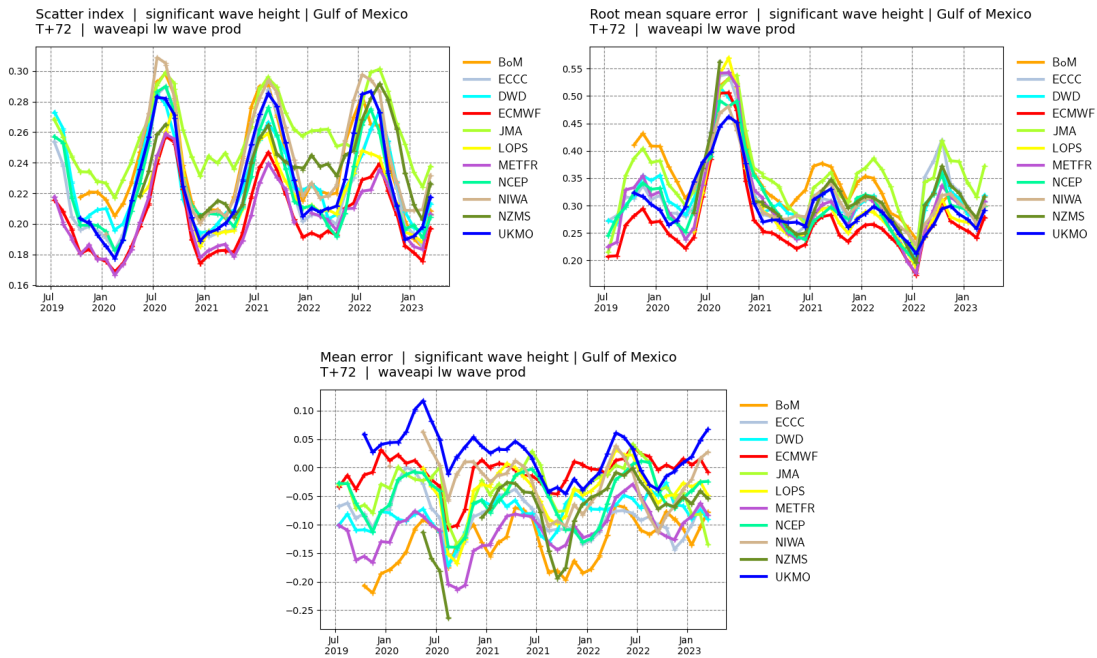
Mean error | significant wave height | Gulf of Mexico  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



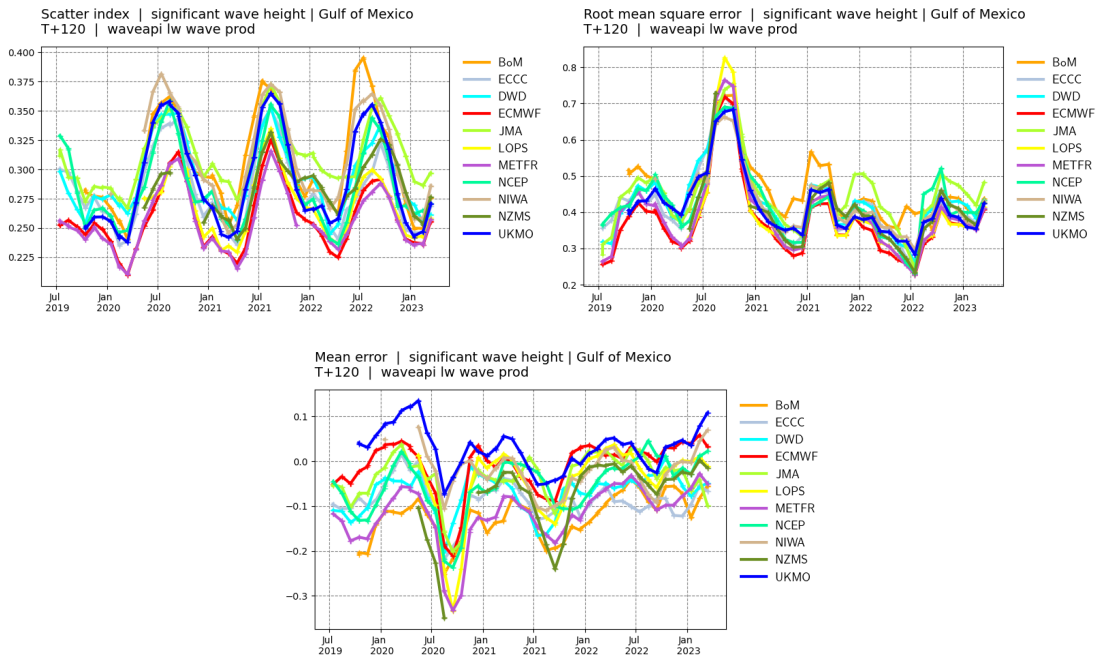
**Gulf of Mexico.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



**Gulf of Mexico.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

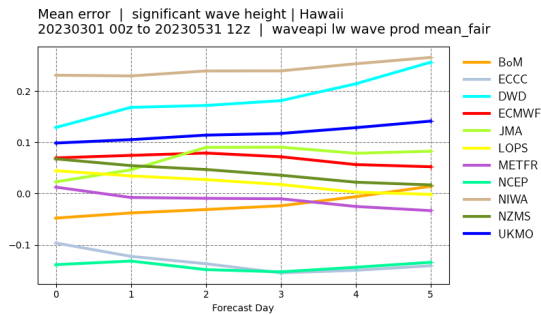
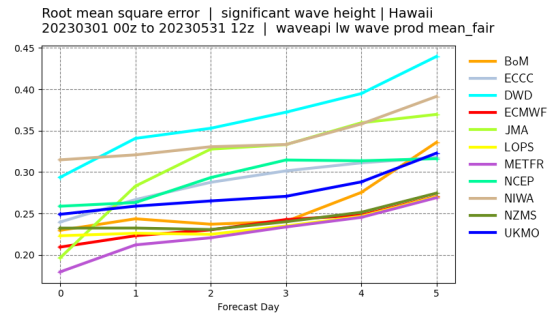
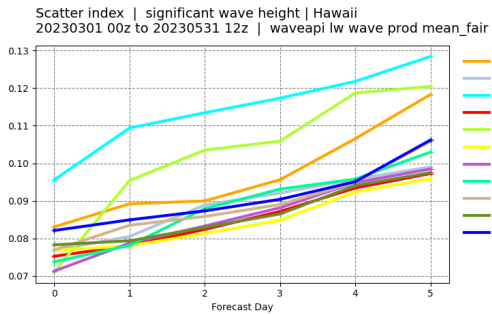
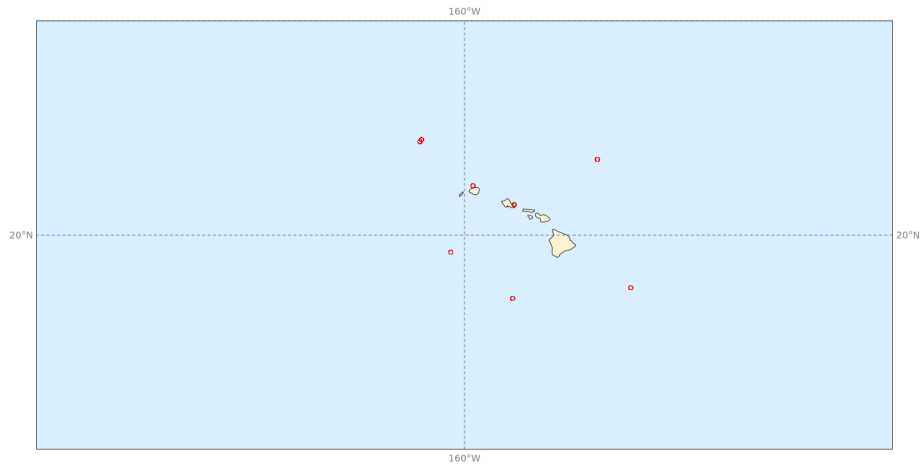


**Gulf of Mexico.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

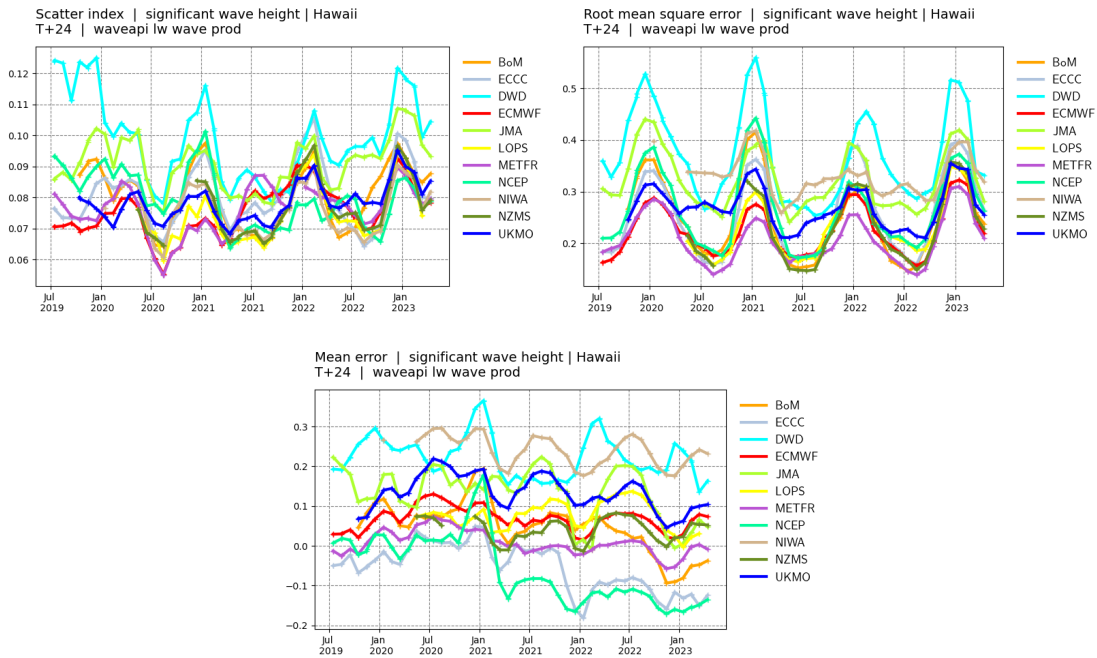


**Gulf of Mexico.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

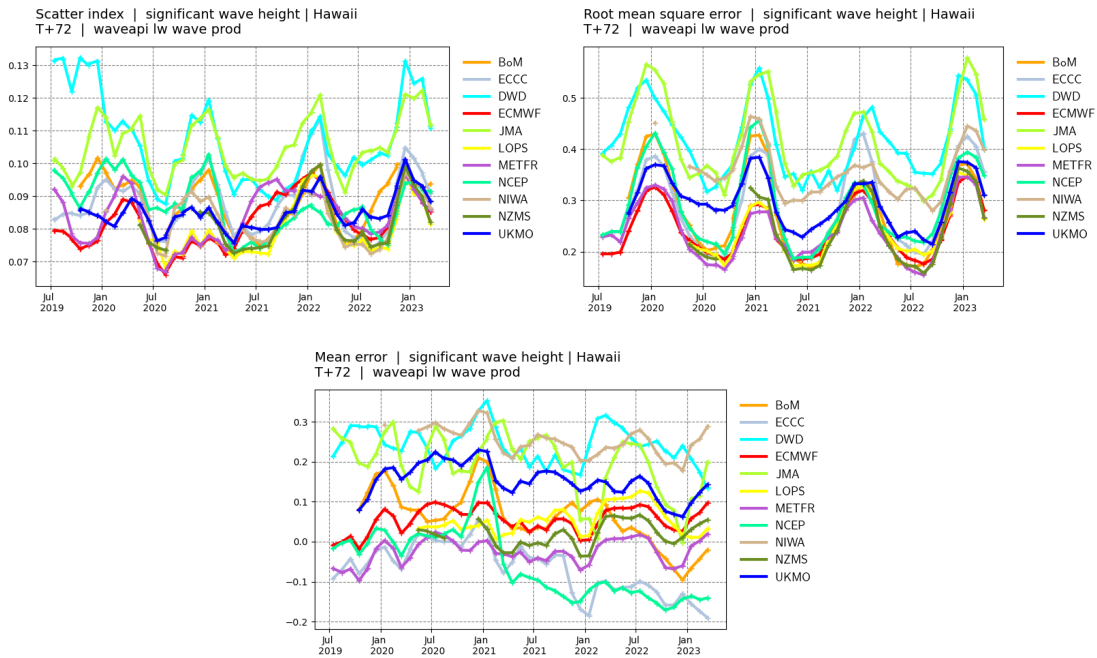
Buoys observations - from 20230301 to 20230531 - (swh)



**Hawaii.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

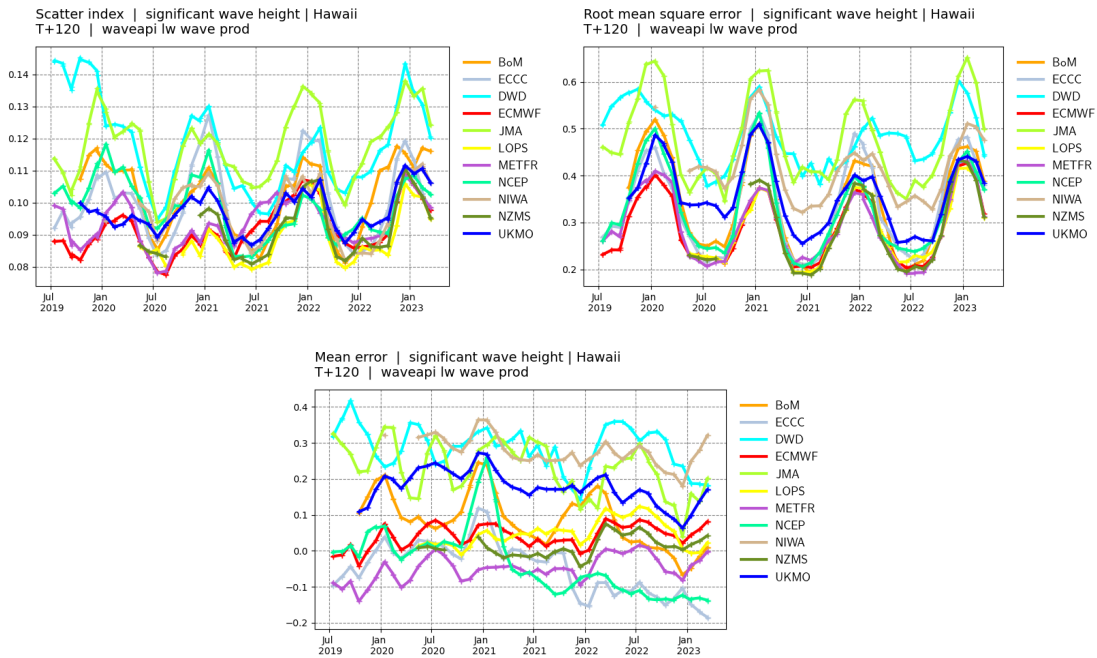


**Hawaii.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



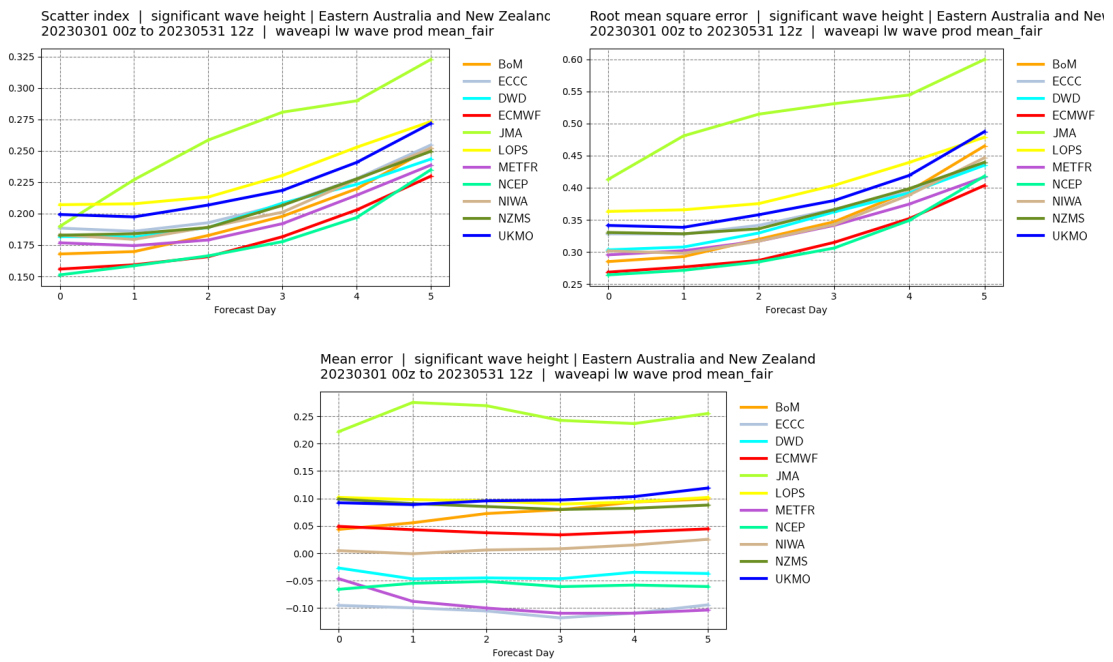
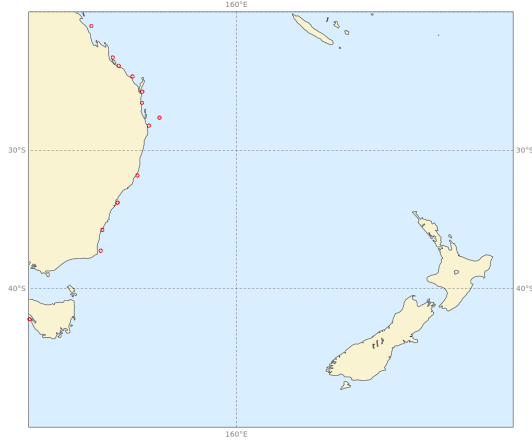
**Hawaii.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



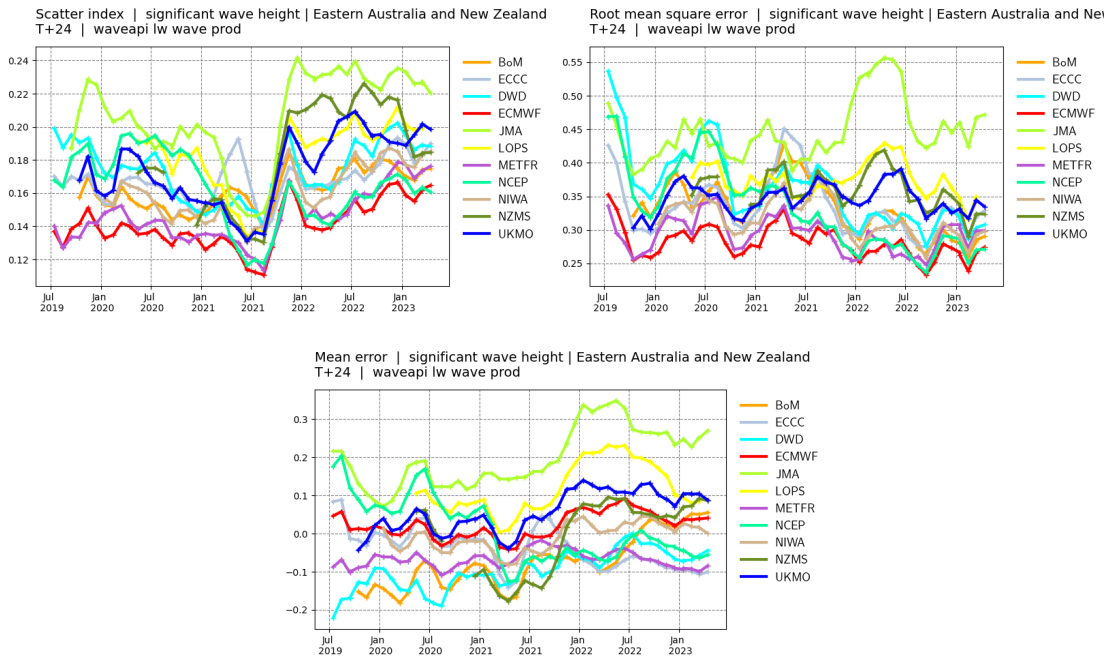


**Hawaii.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

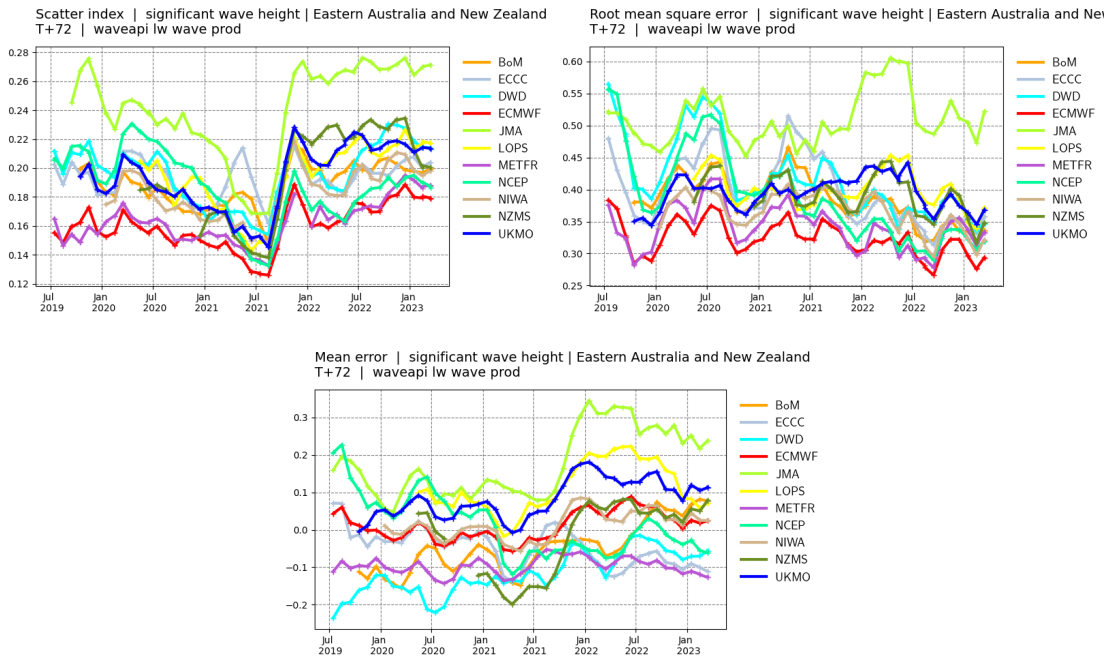
Buoys observations - from 20230301 to 20230531 - (swh)



**East Australia - New Zealand.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



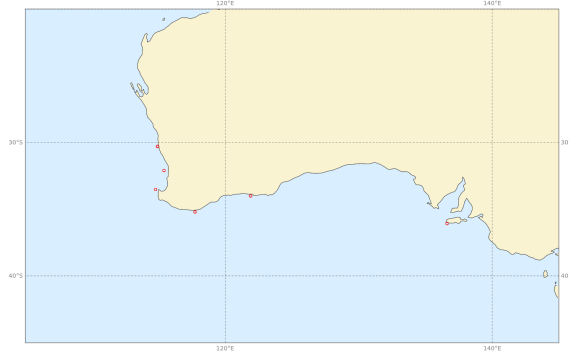
**East Australia - New Zealand.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



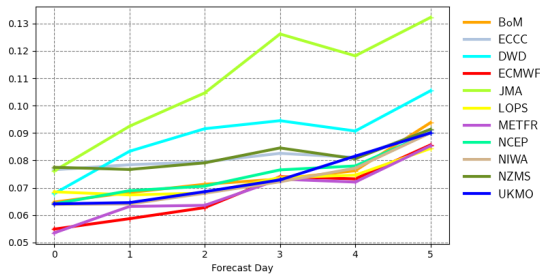
**East Australia - New Zealand.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



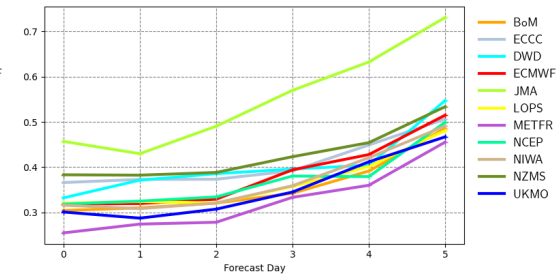
Buoys observations - from 20230301 to 20230531 - (swh)



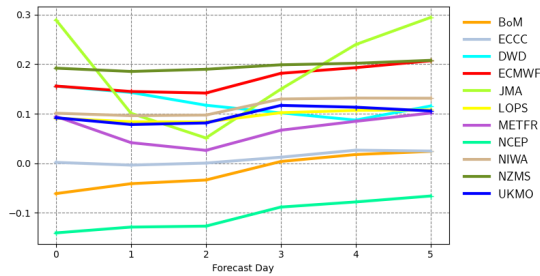
Scatter index | significant wave height | South Southwestern Australia  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



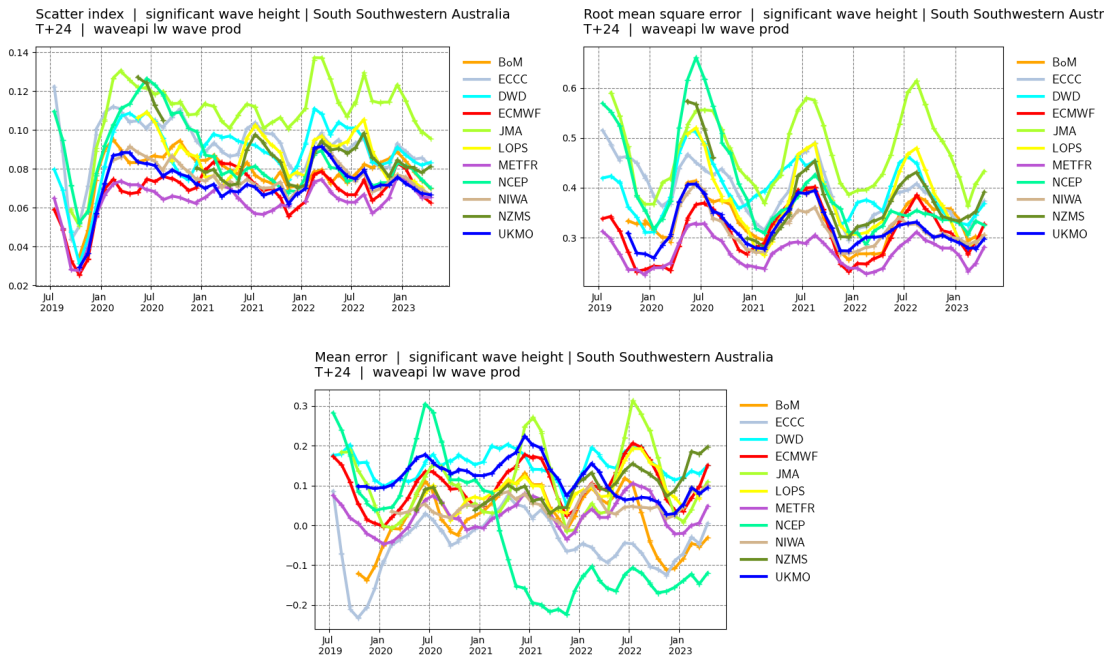
Root mean square error | significant wave height | South Southwestern Austr  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



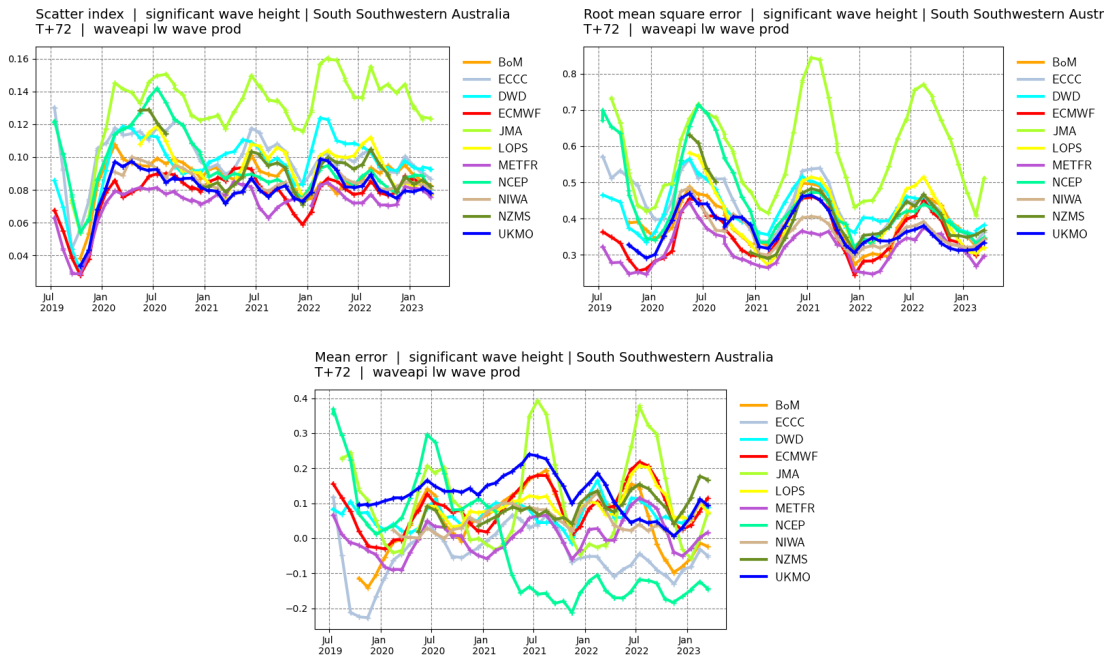
Mean error | significant wave height | South Southwestern Australia  
20230301 00z to 20230531 12z | waveapi lw wave prod mean\_fair



**South South West Australia.** Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

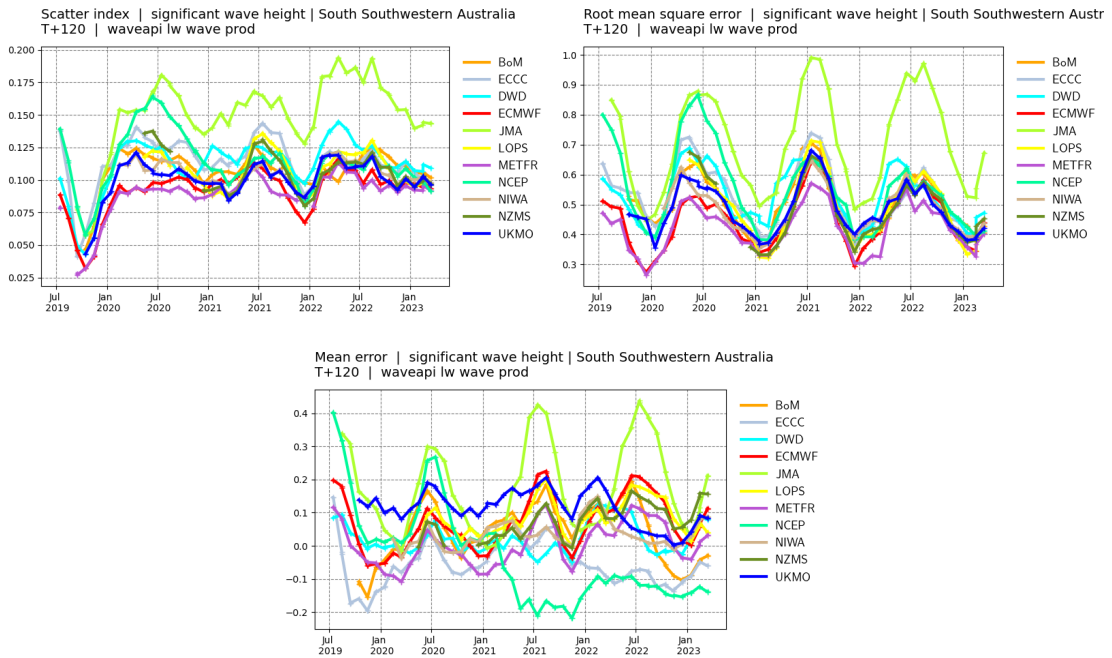


**South South West Australia.** Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



**South South West Australia.** Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).





**South South West Australia.** Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).