

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

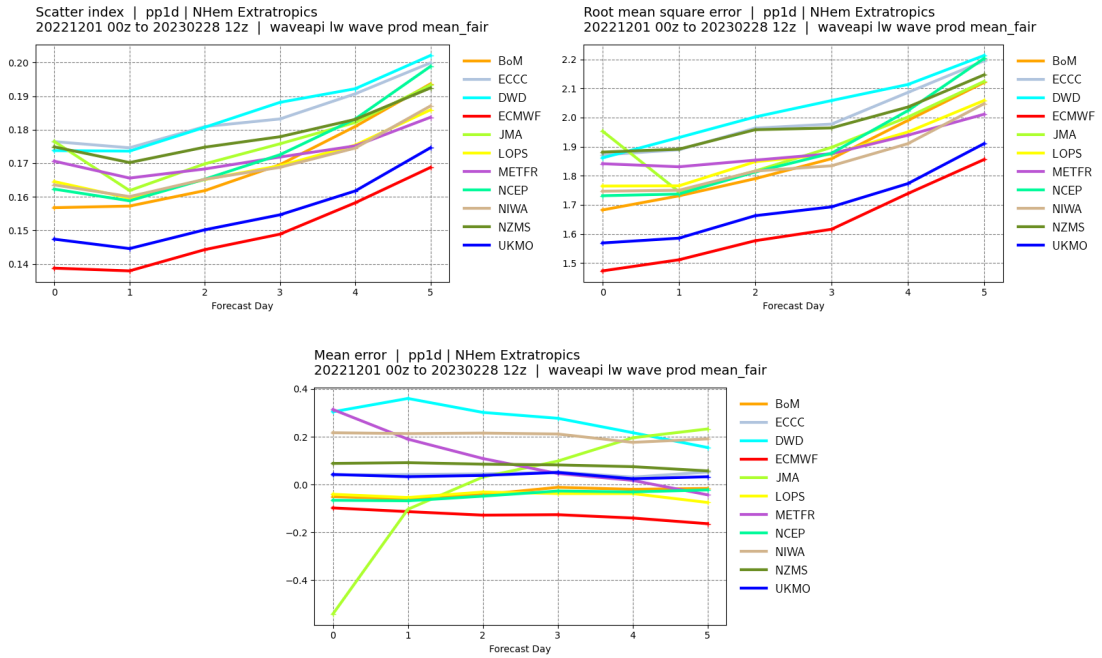
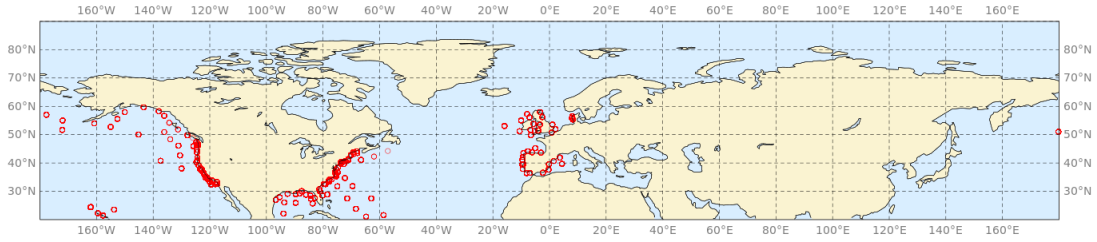
00 and 12 UTC runs

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

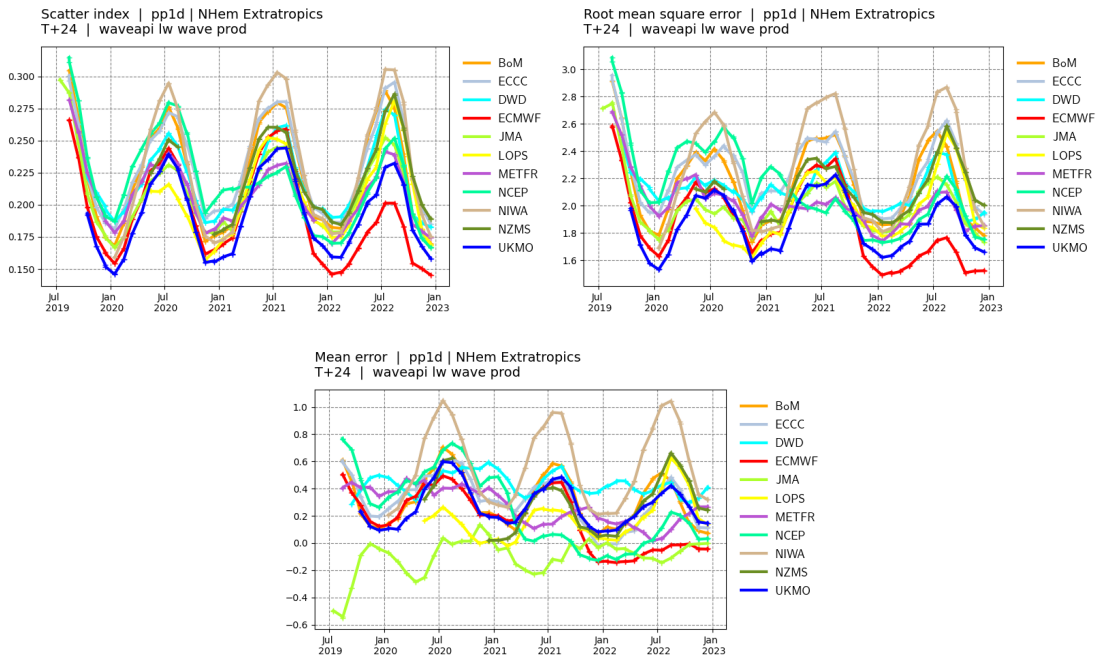
March 28, 2023

PART II: Peak wave period (PP1D)

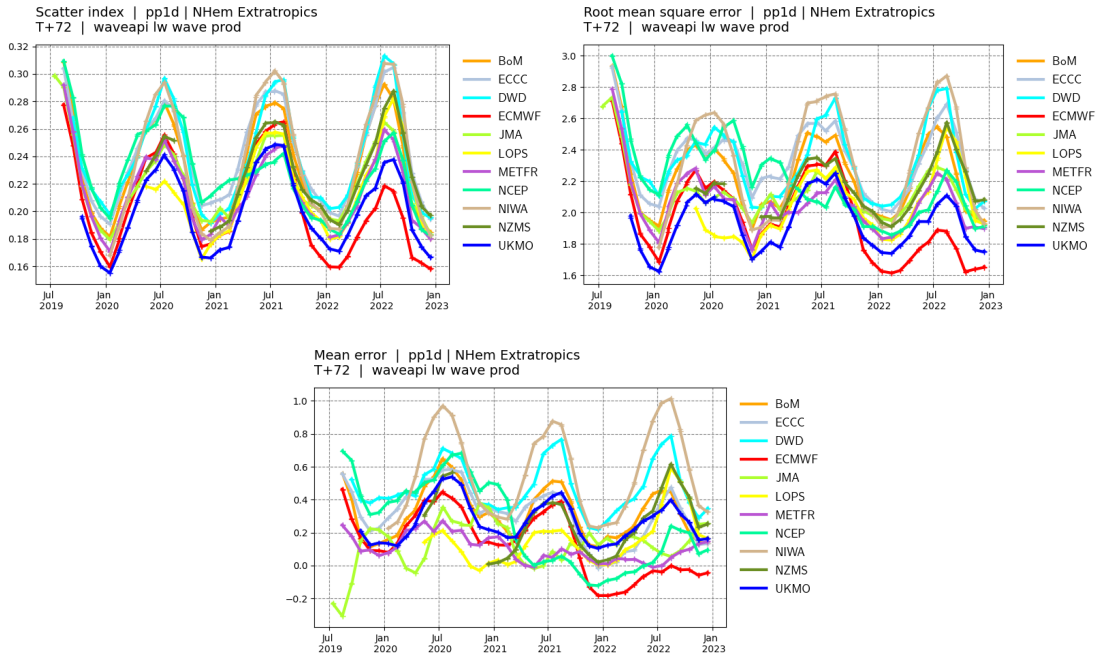
Buoys observations - from 20221201 to 20230228 - (pp1d)



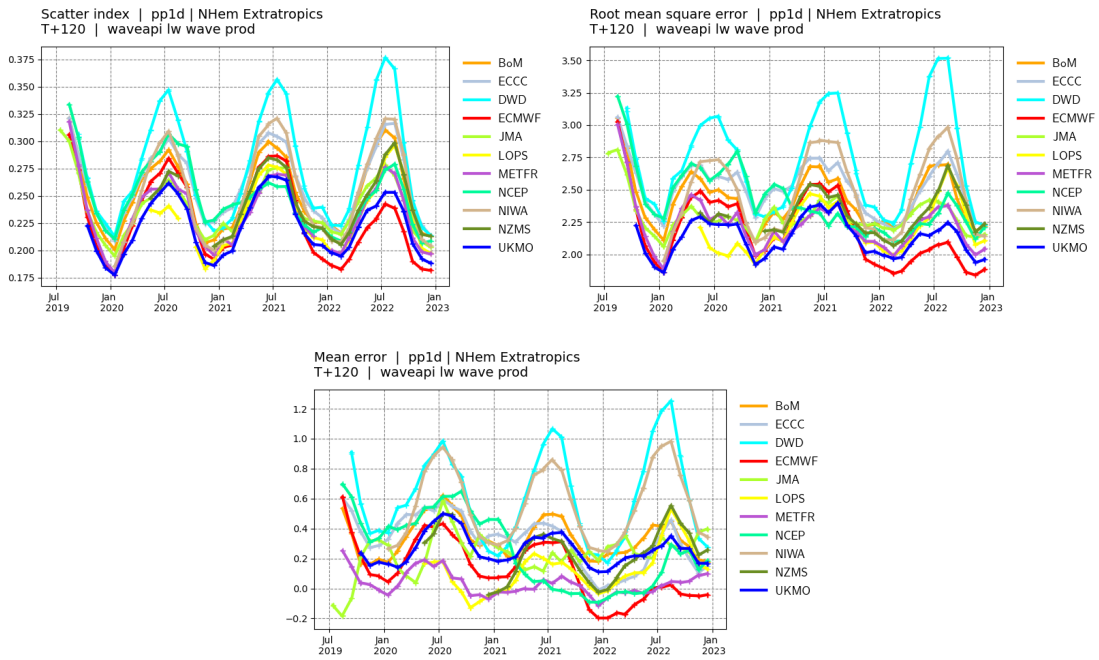
Northern Hemisphere. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

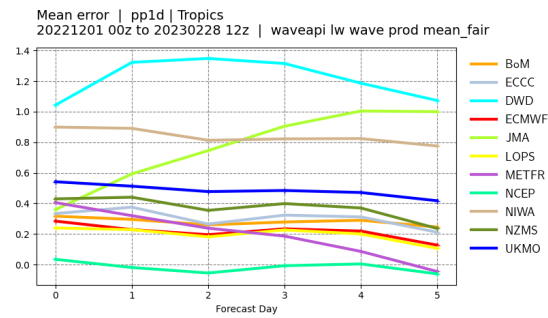
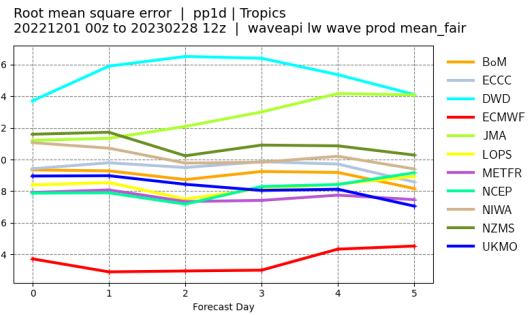
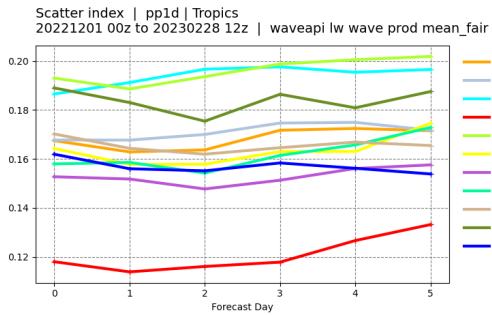
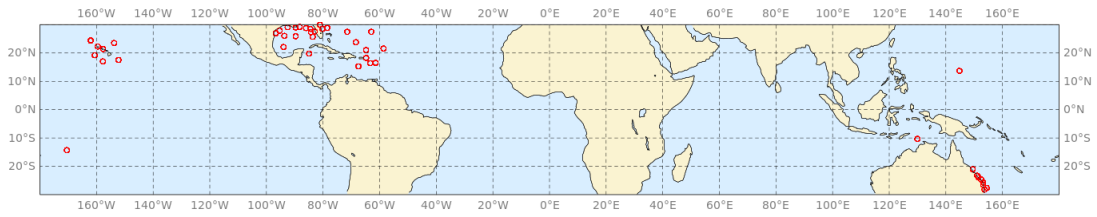


Northern Hemisphere. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

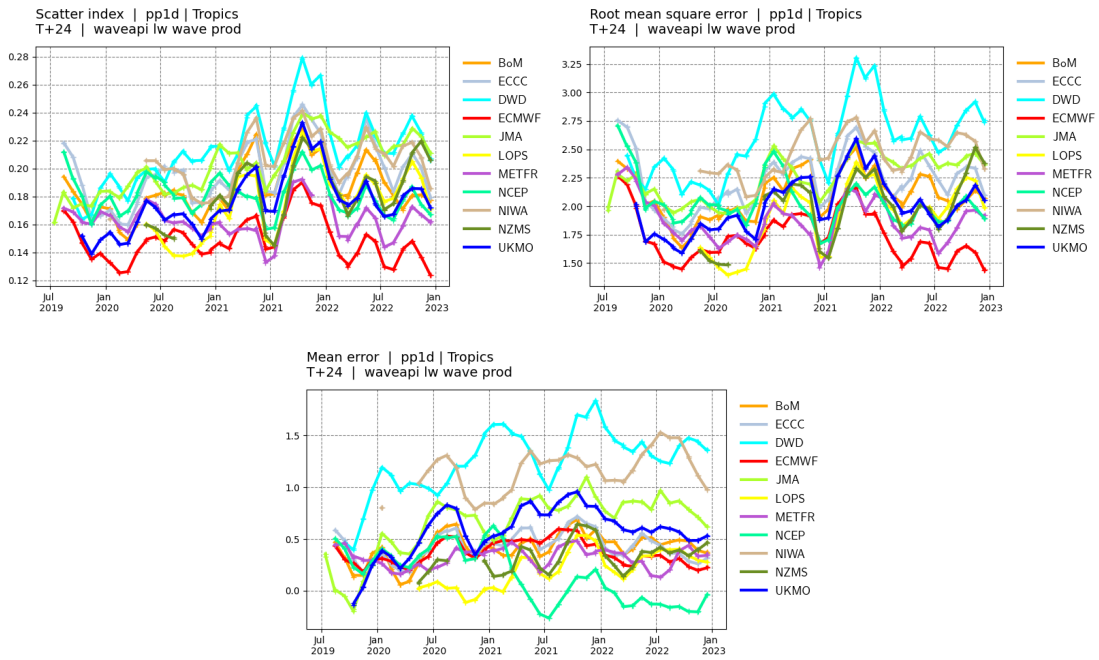


Northern Hemisphere. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

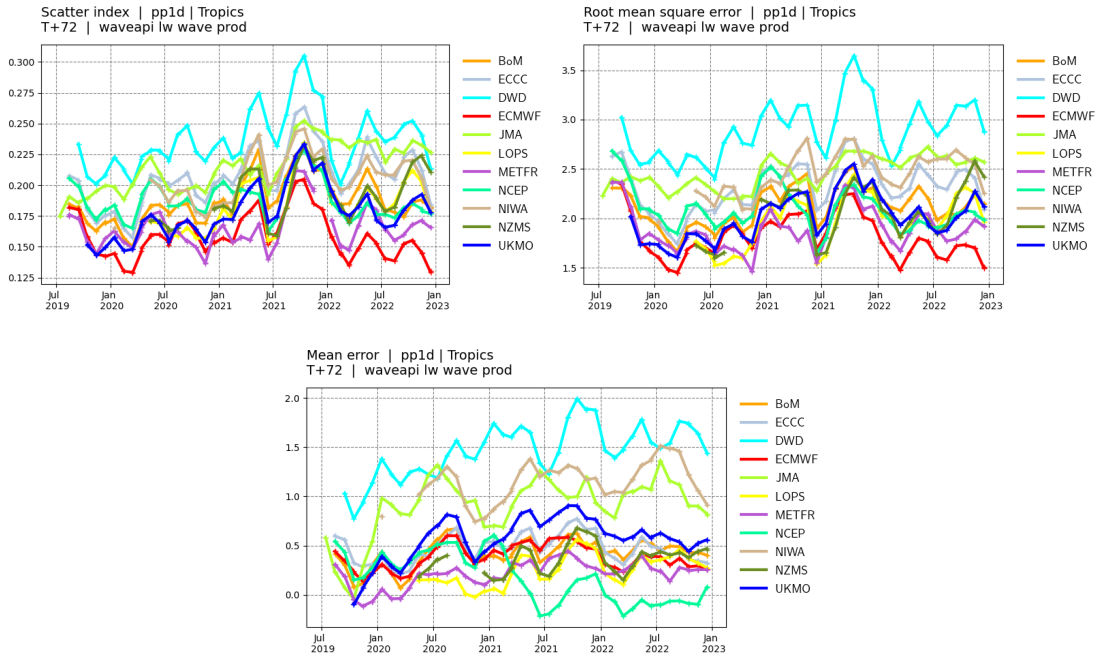
Buoys observations - from 20221201 to 20230228 - (pp1d)



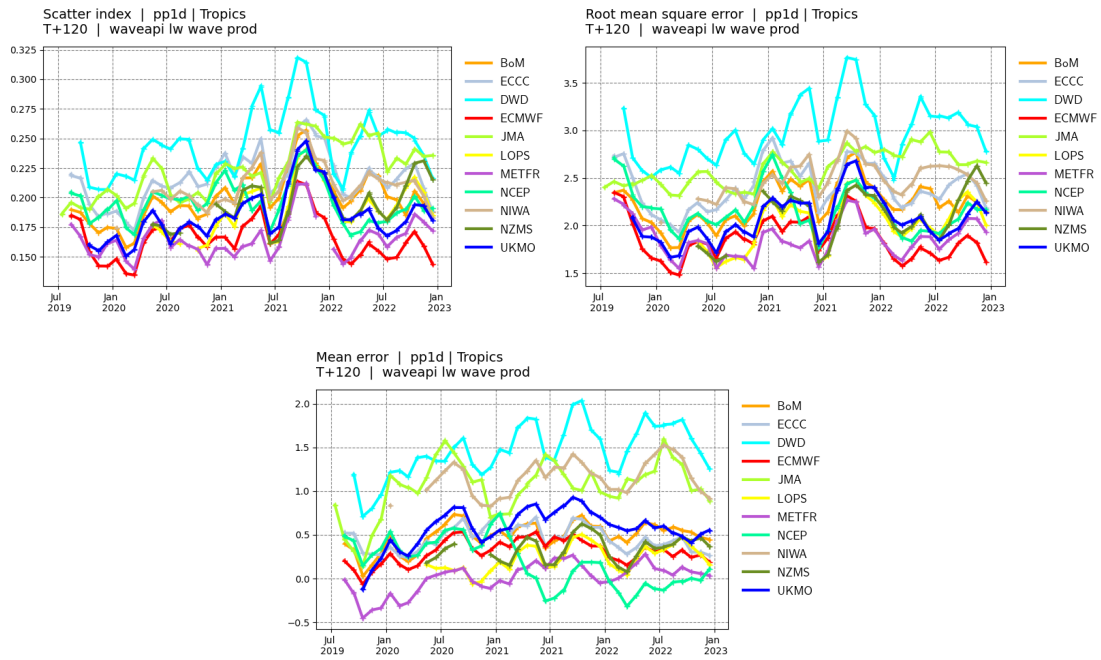
Tropics. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

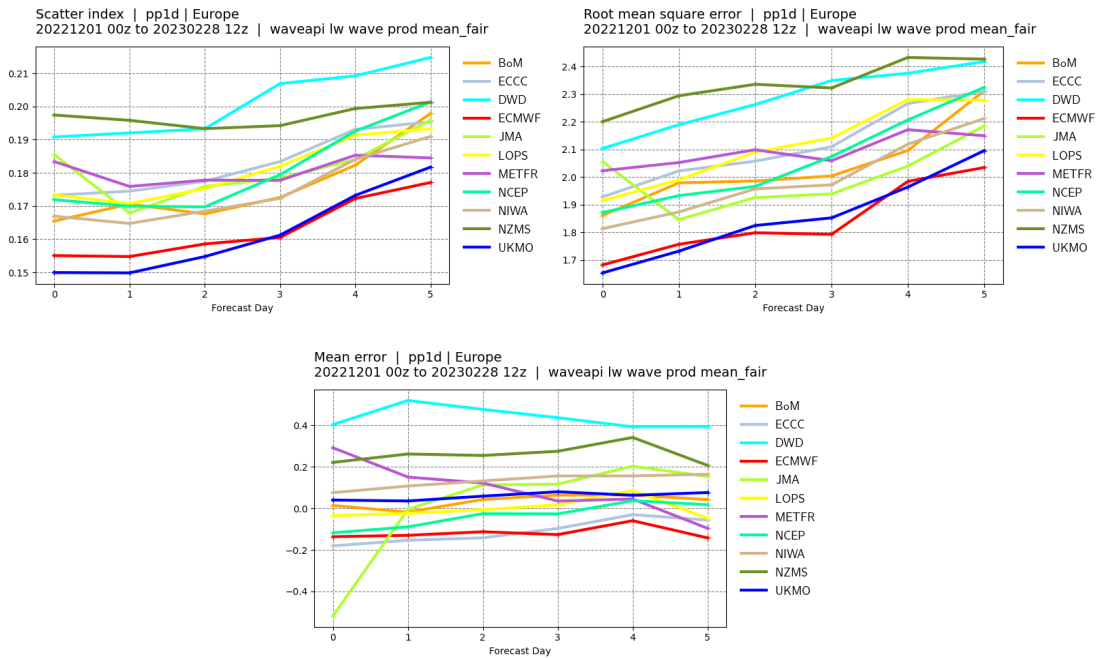
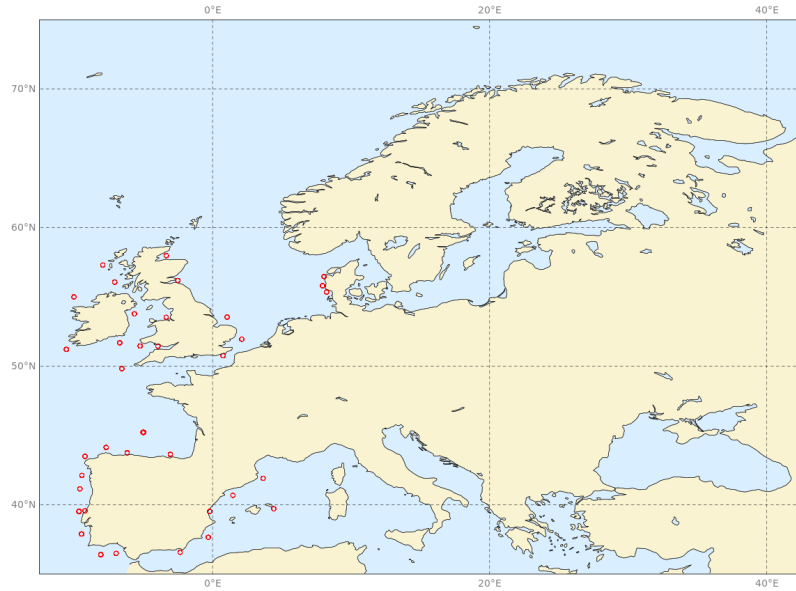


Tropics. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

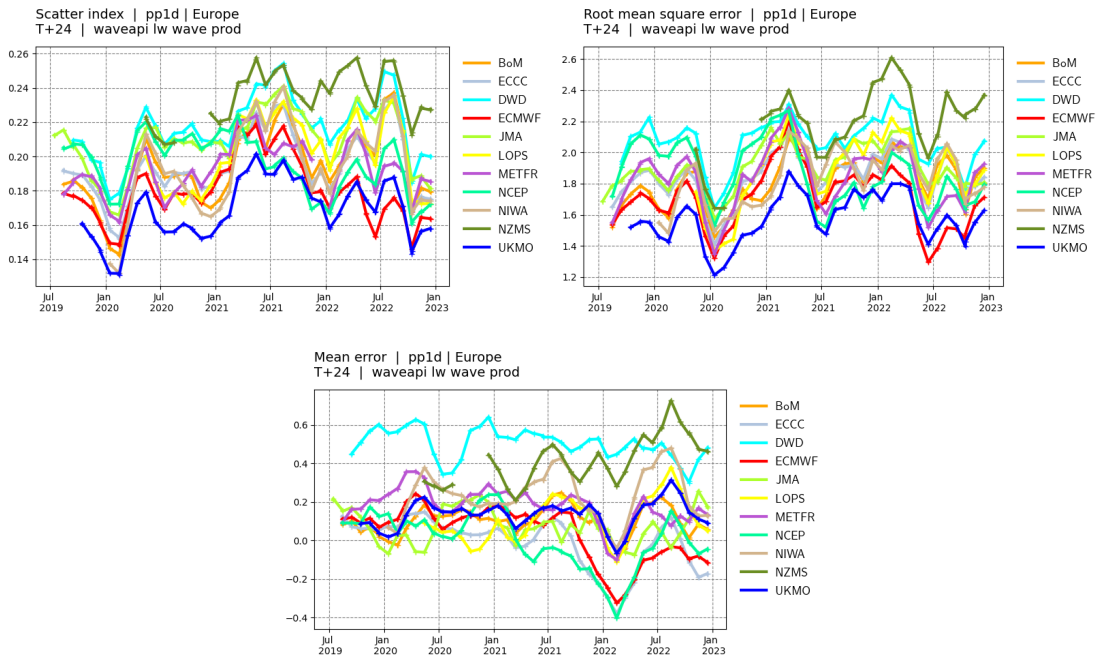


Tropics. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

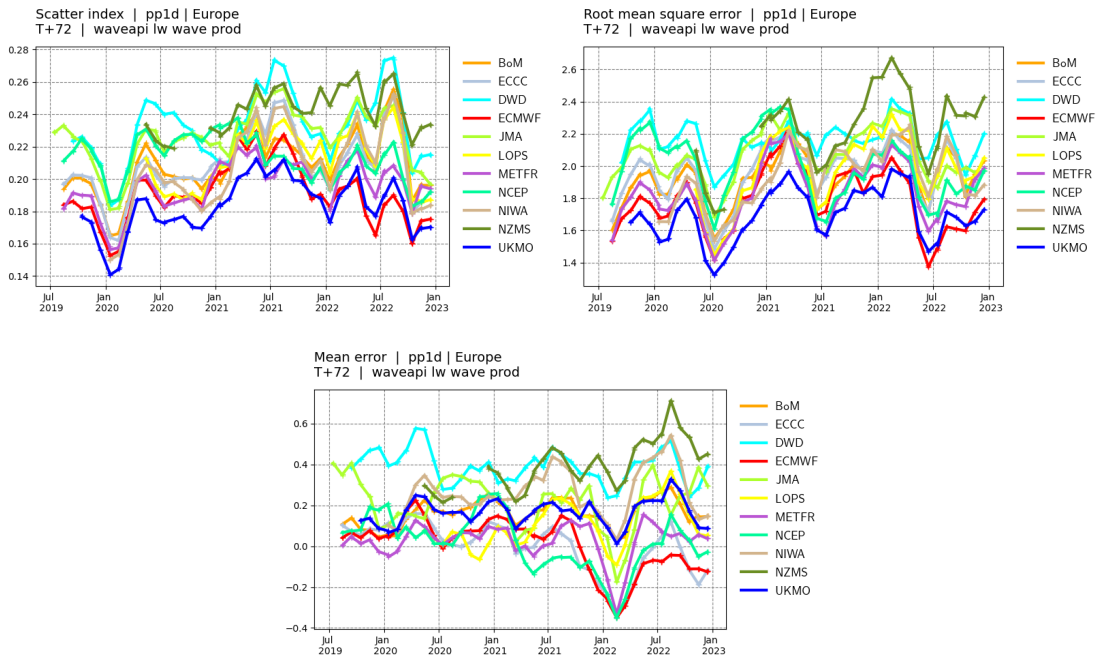
Buoys observations - from 20221201 to 20230228 - (pp1d)



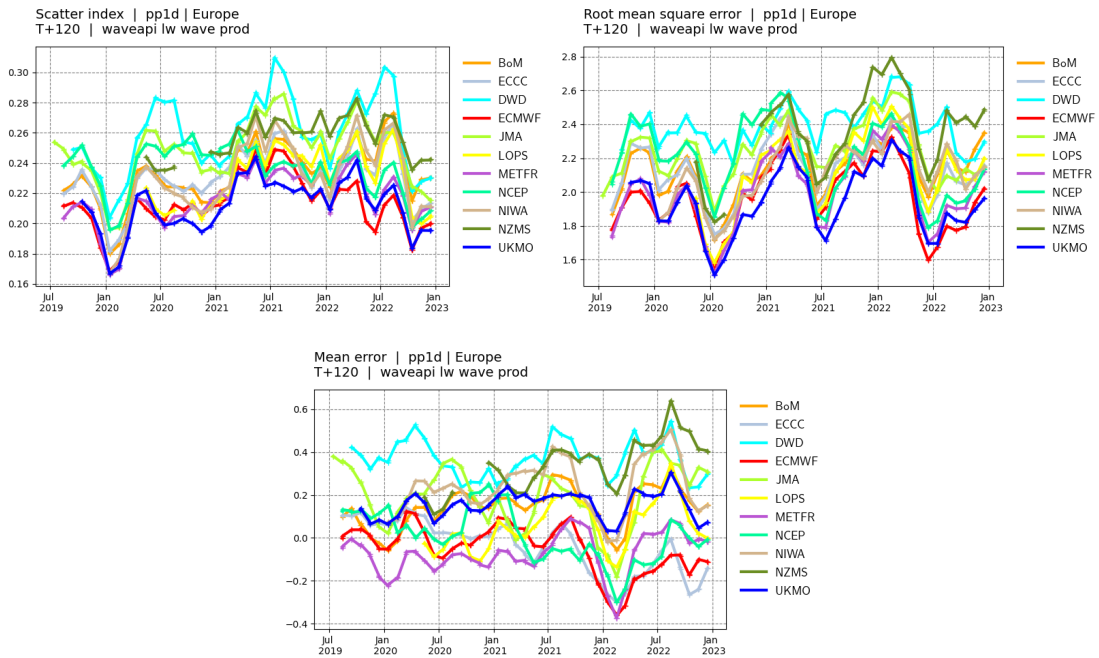
Europe. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

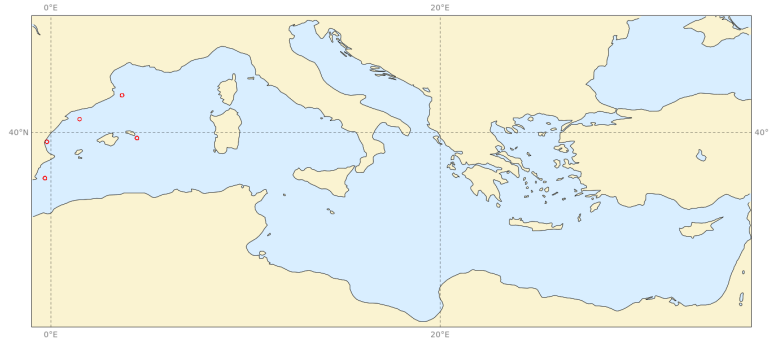


Europe. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

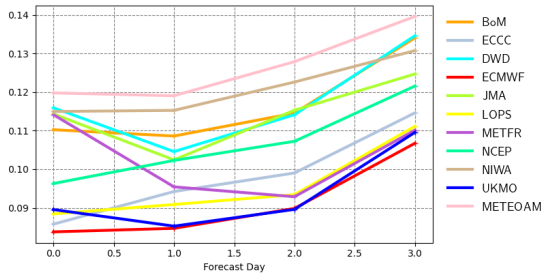


Europe. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

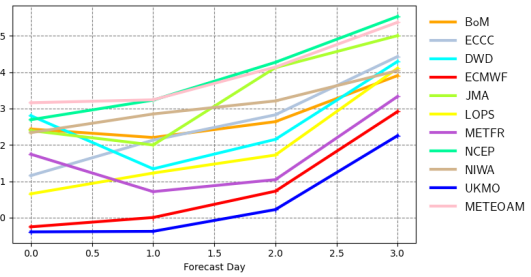
Buoys observations - from 20221201 to 20230228 - (pp1d)



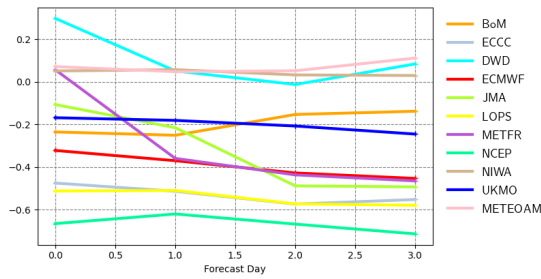
Scatter index | pp1d | Mediterranean
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



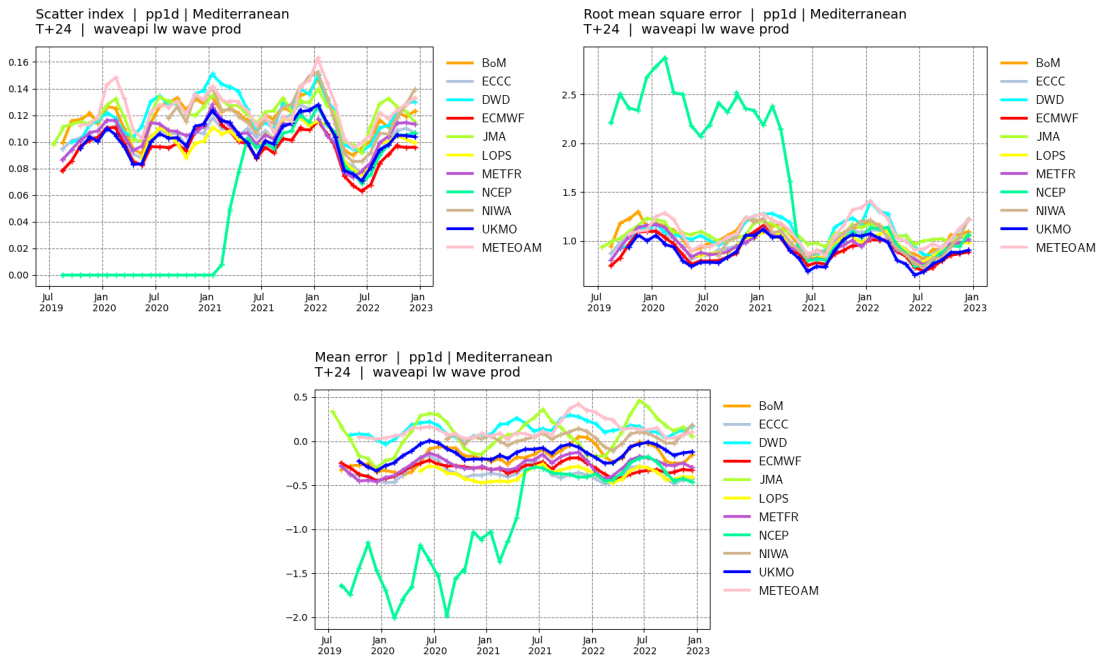
Root mean square error | pp1d | Mediterranean
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



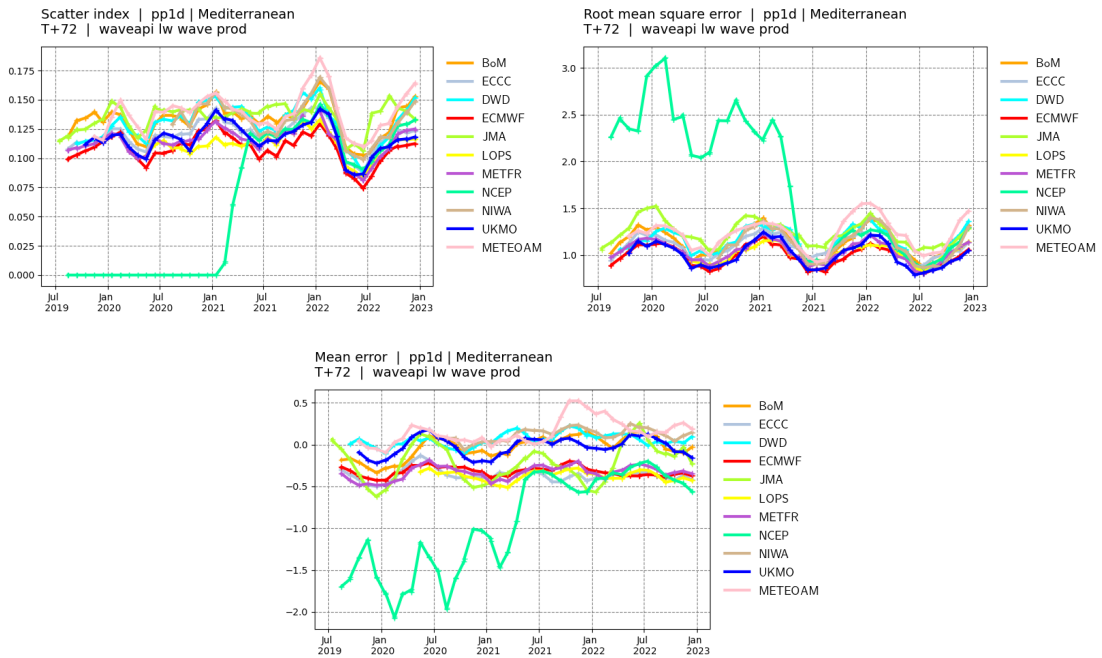
Mean error | pp1d | Mediterranean
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



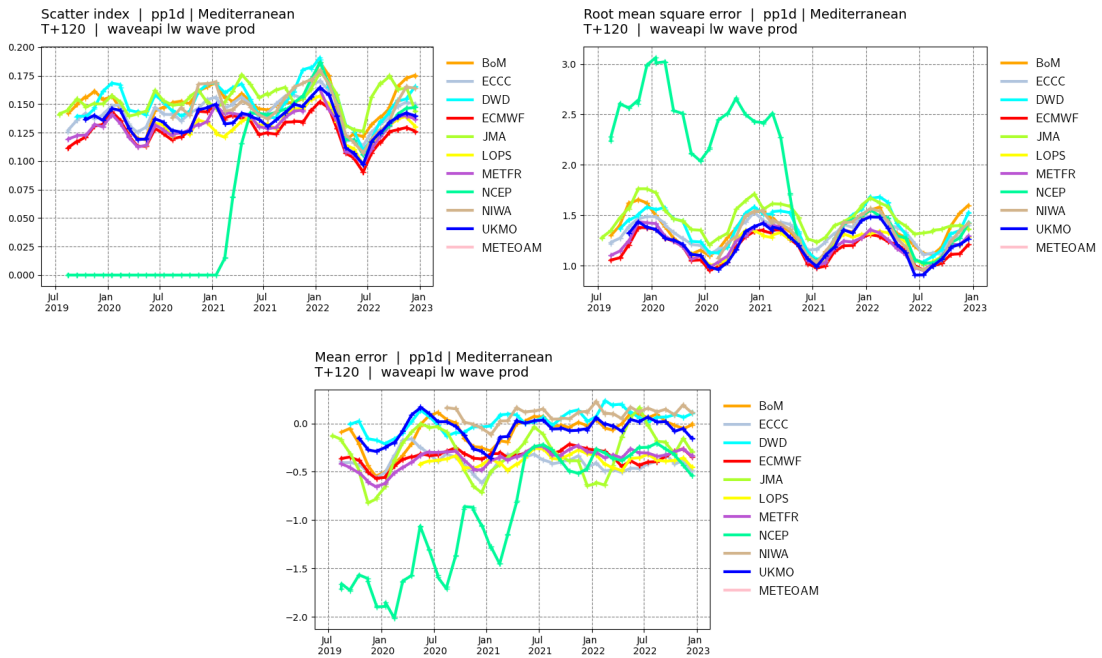
Mediterranean Sea. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

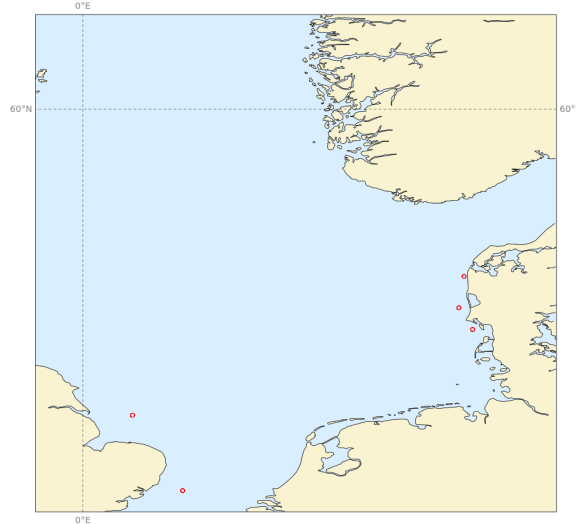


Mediterranean Sea. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

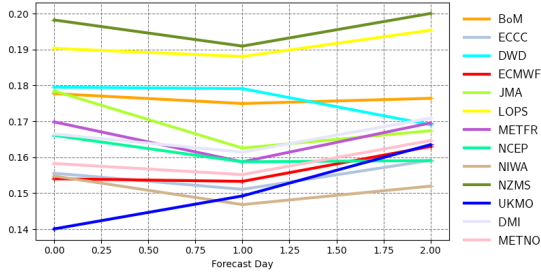


Mediterranean Sea. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

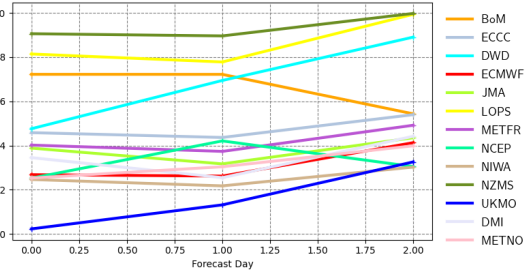
Buoys observations - from 20221201 to 20230228 - (pp1d)



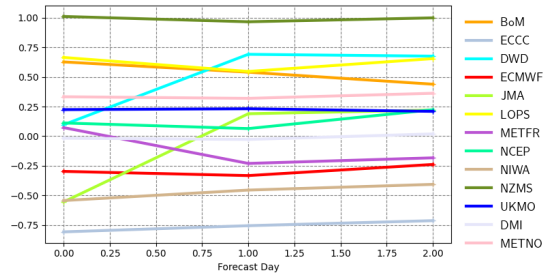
Scatter index | pp1d | North Sea
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



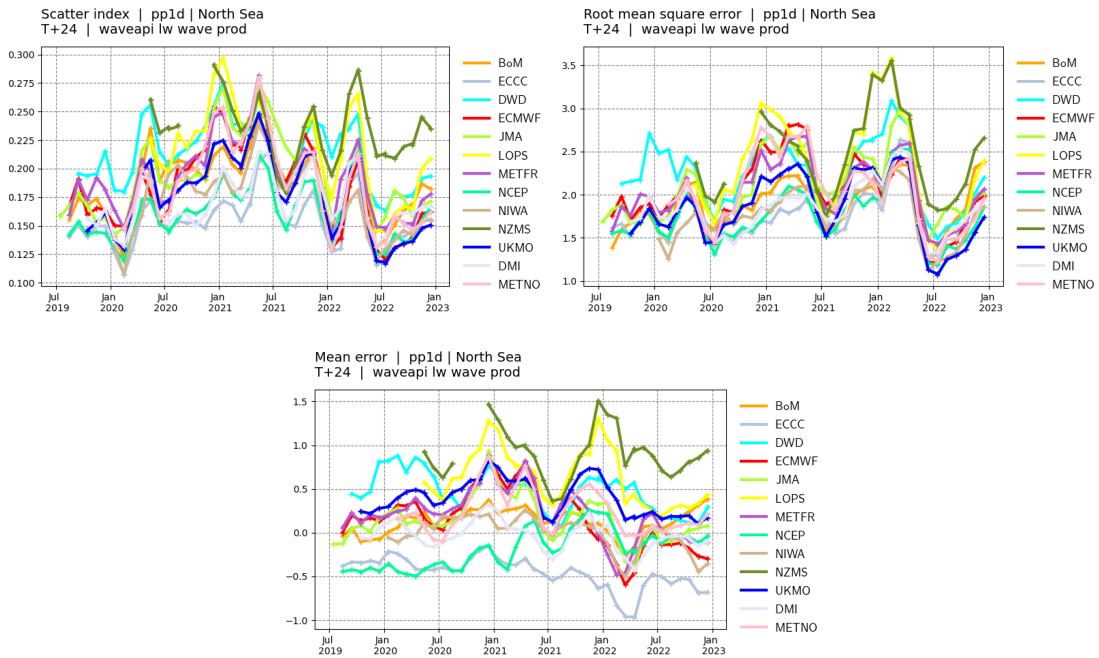
Root mean square error | pp1d | North Sea
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



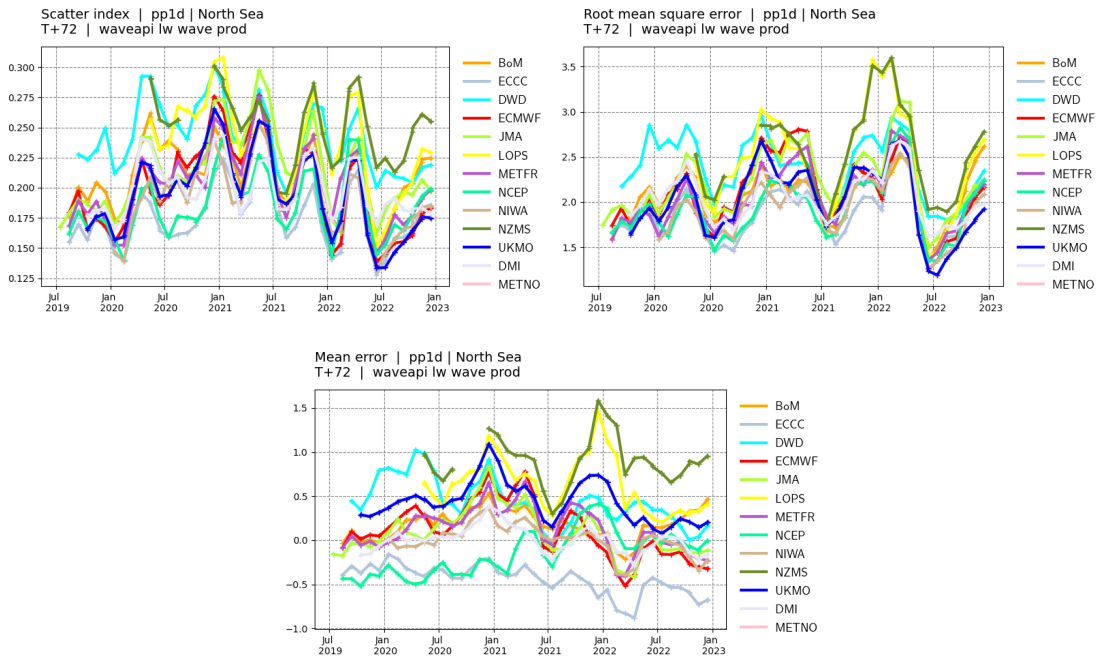
Mean error | pp1d | North Sea
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



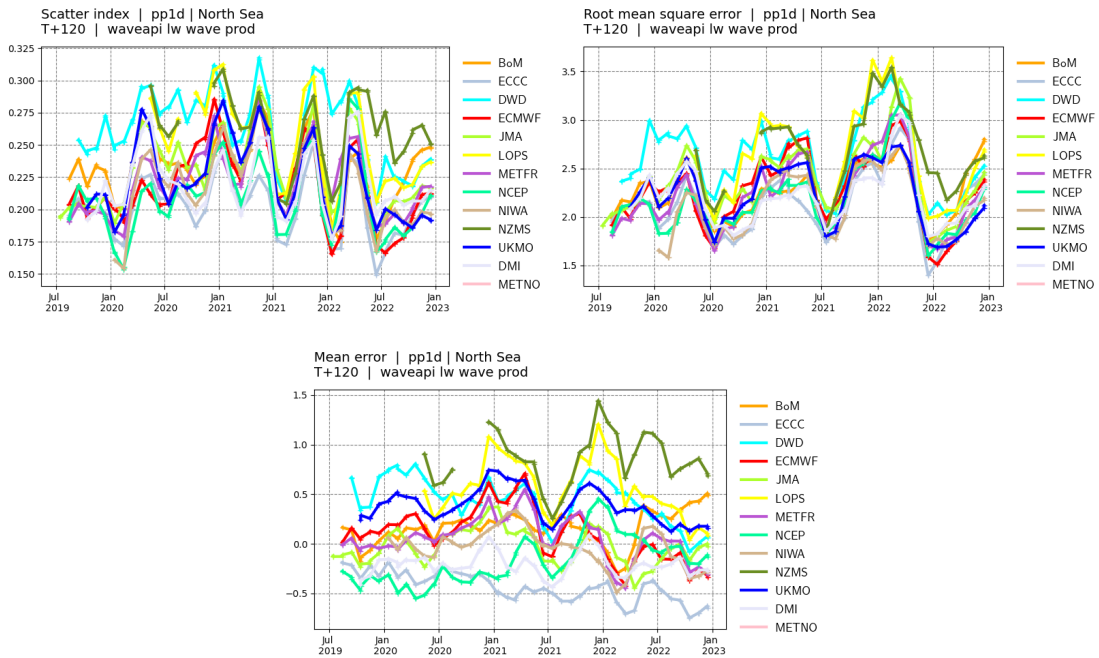
North Sea. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

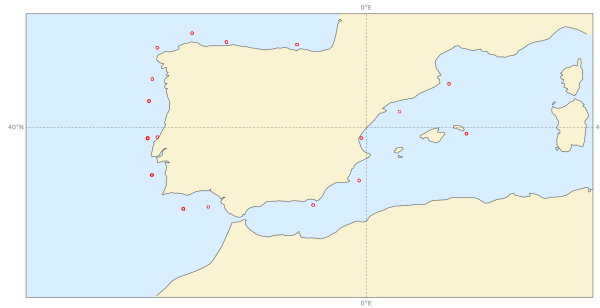


North Sea. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

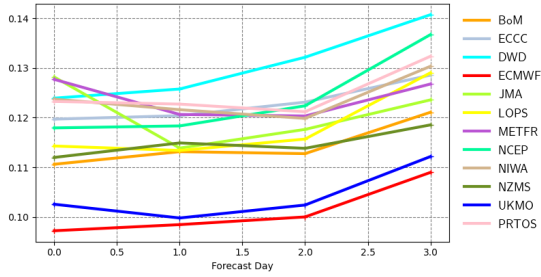


North Sea. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

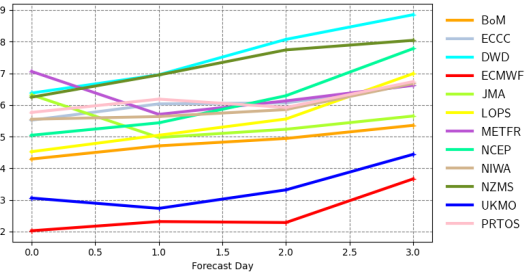
Buoys observations - from 20221201 to 20230228 - (pp1d)



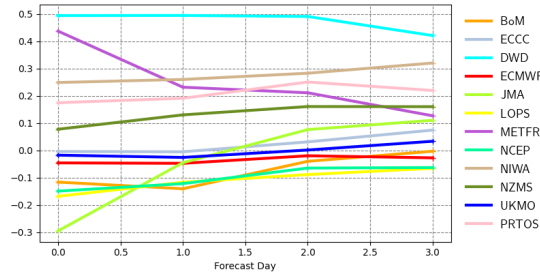
Scatter index | pp1d | SW Europe
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



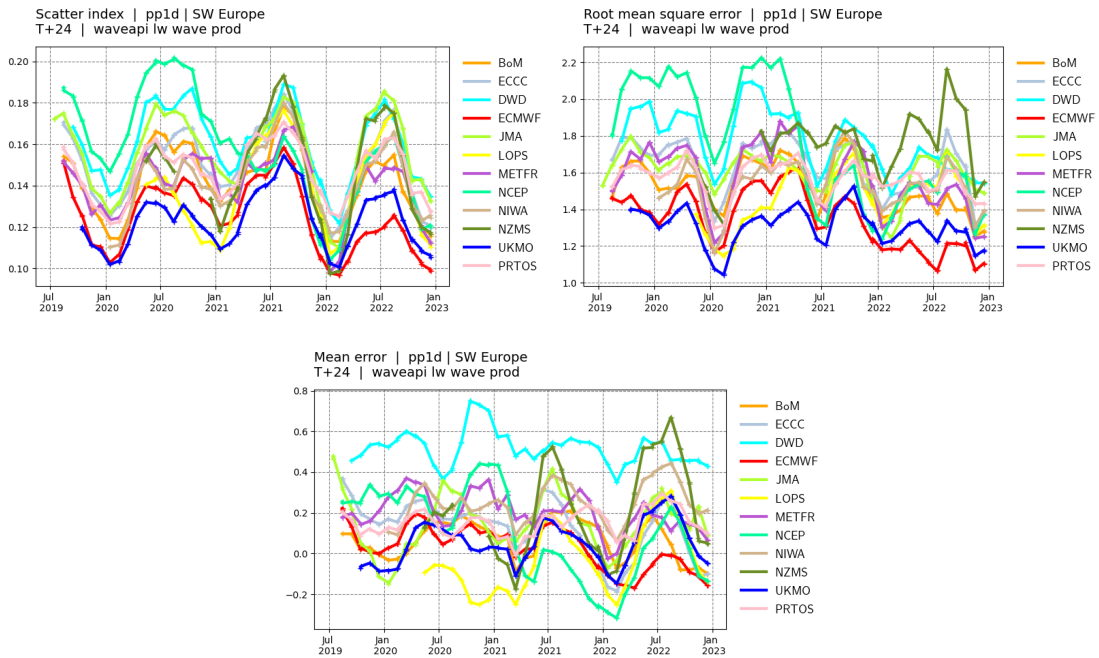
Root mean square error | pp1d | SW Europe
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



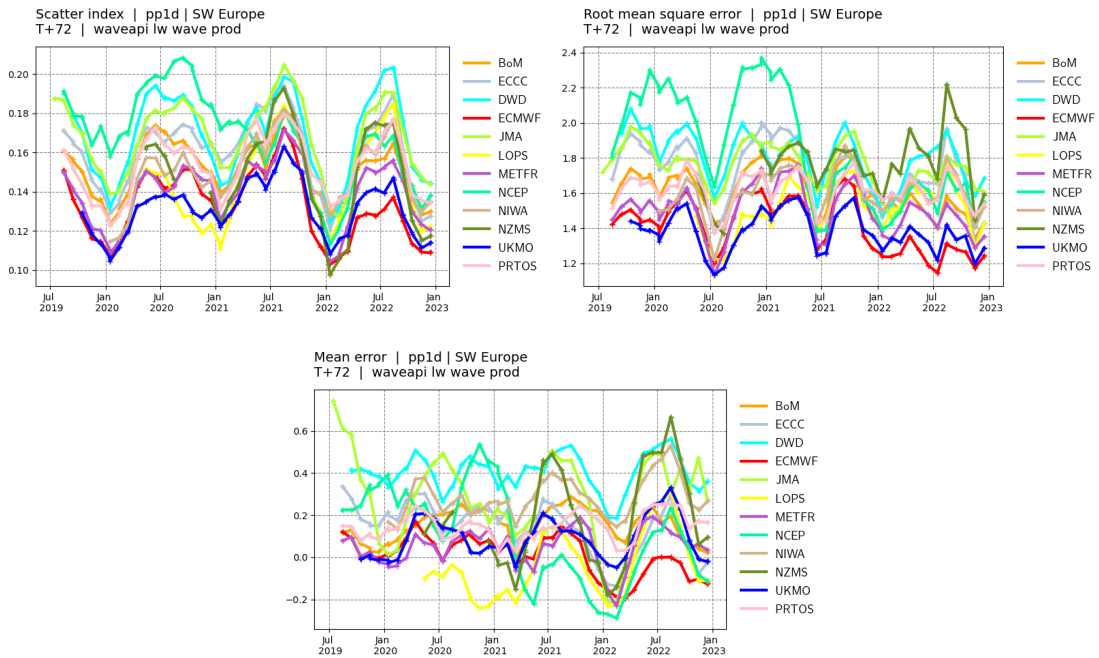
Mean error | pp1d | SW Europe
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



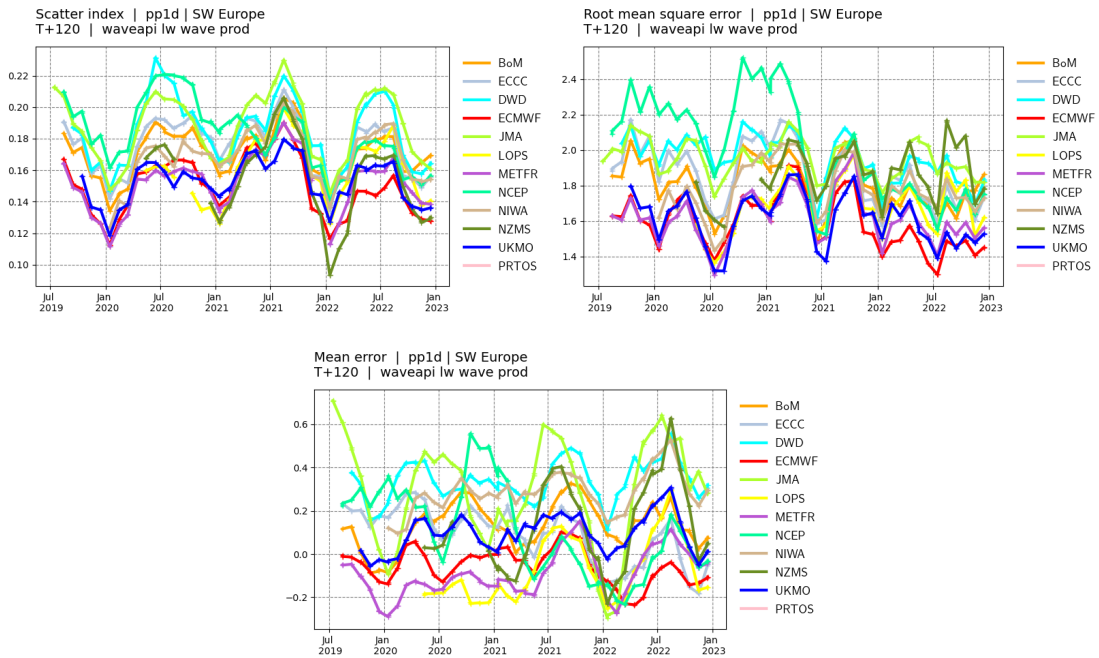
South West Europe. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

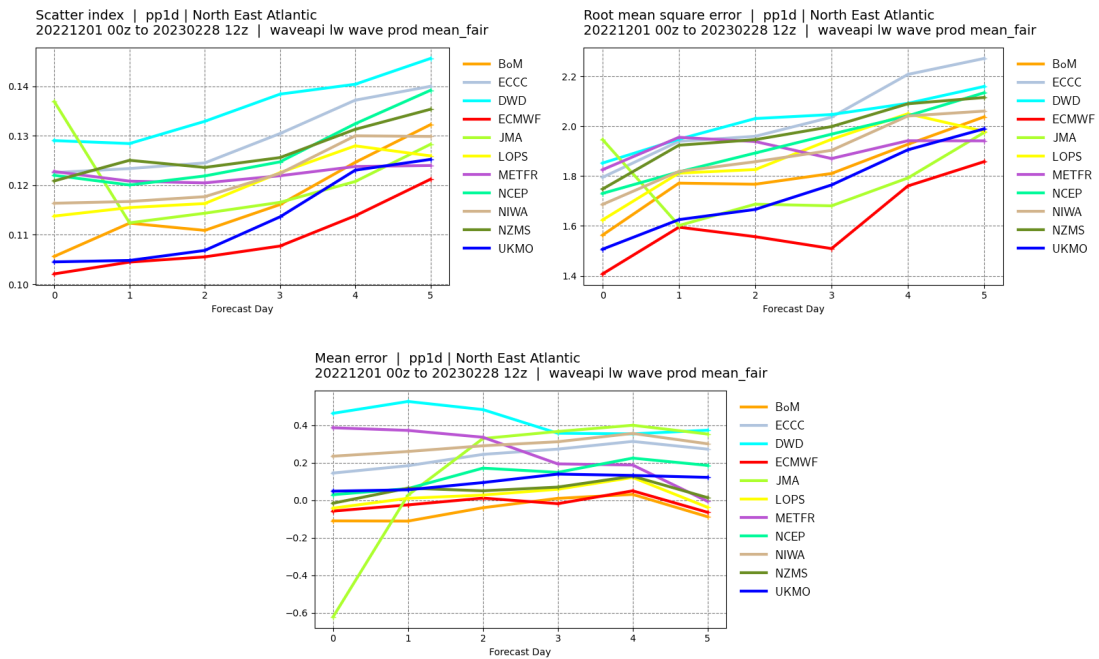
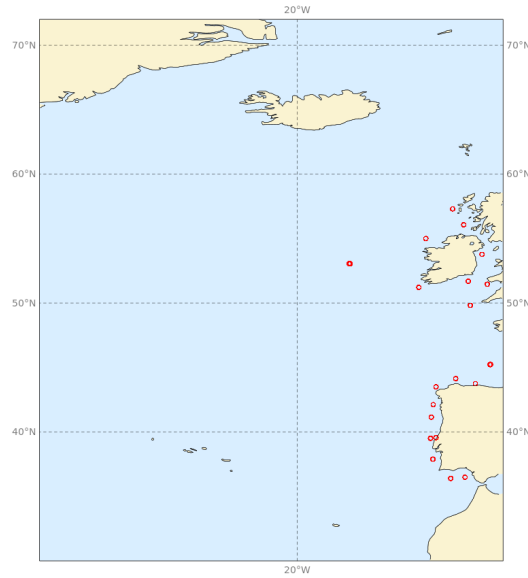


South West Europe. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

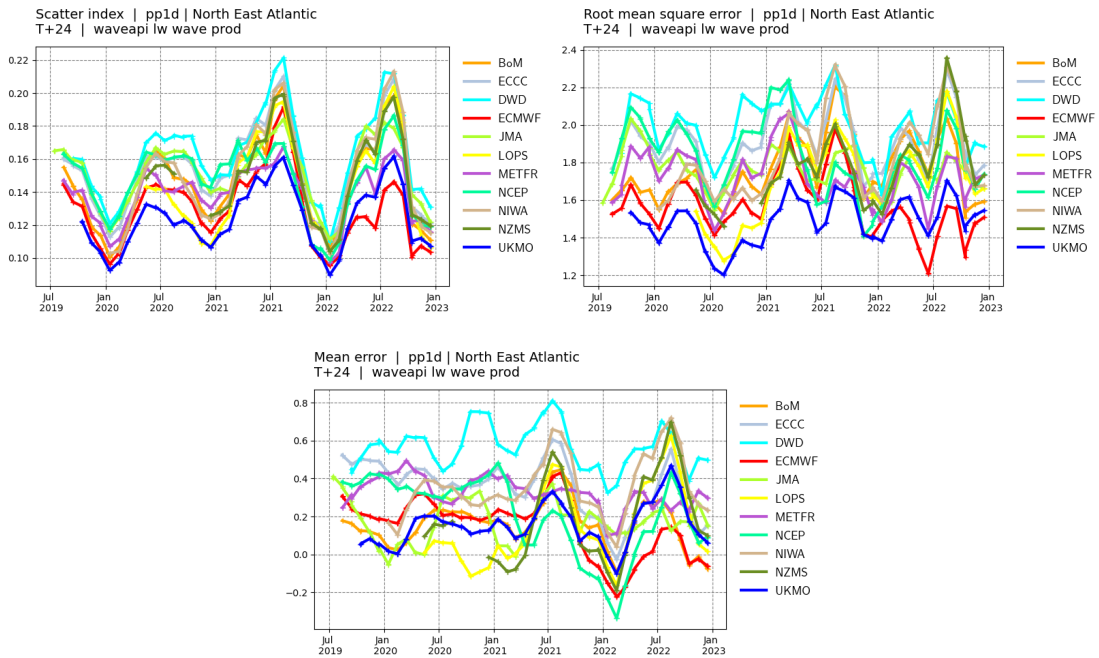


South West Europe. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

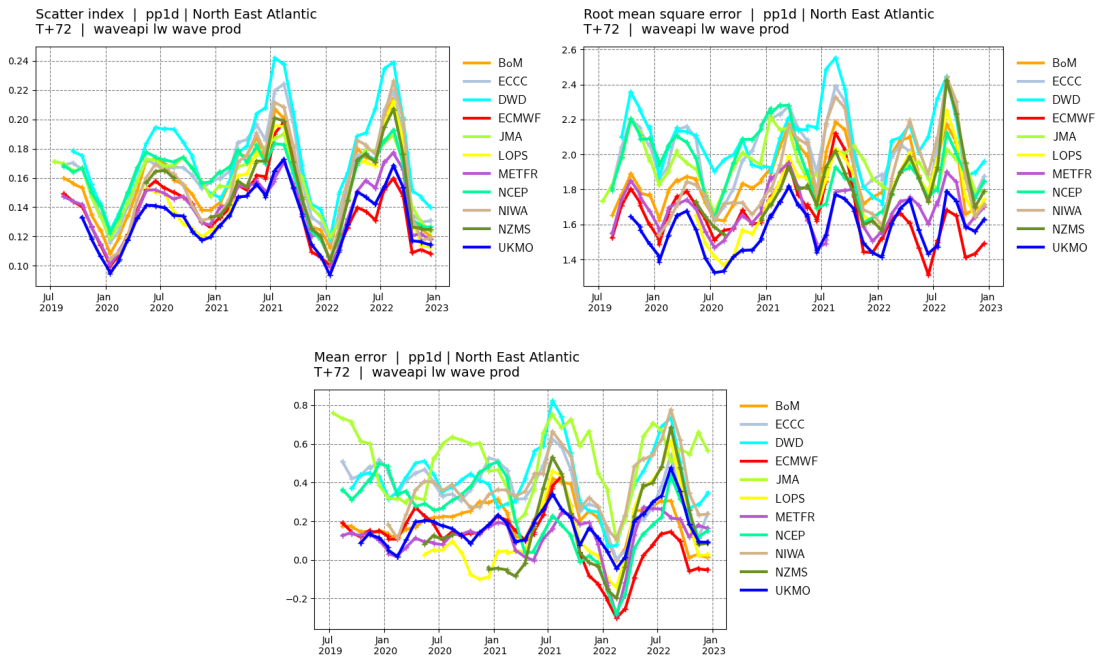
Buoys observations - from 20221201 to 20230228 - (pp1d)



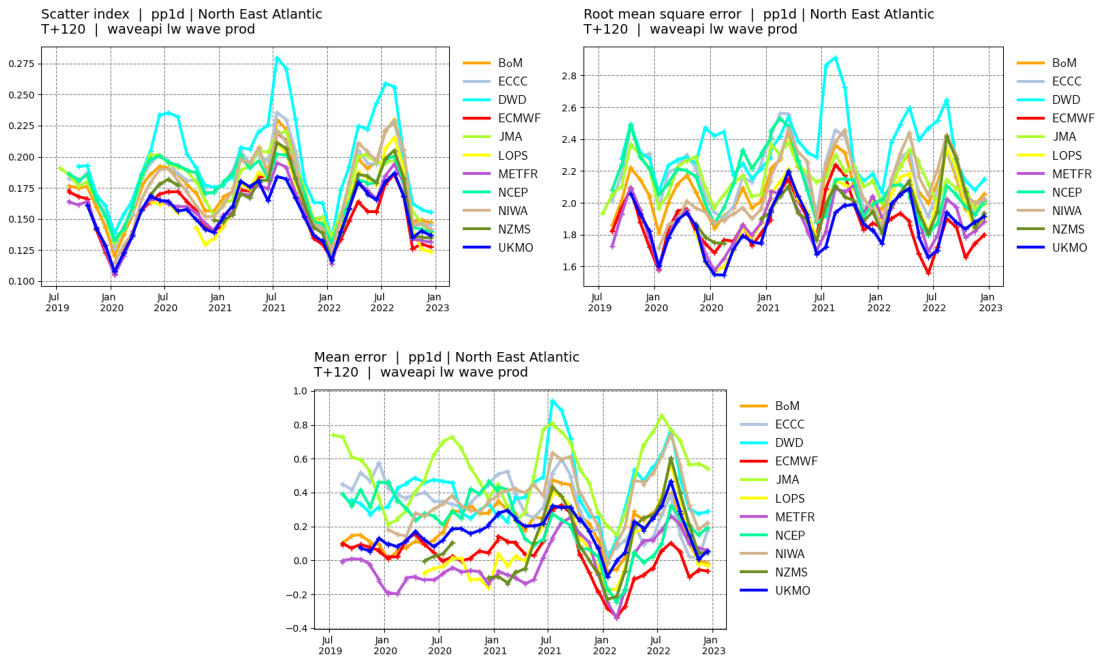
North East Atlantic. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



North East Atlantic. 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).

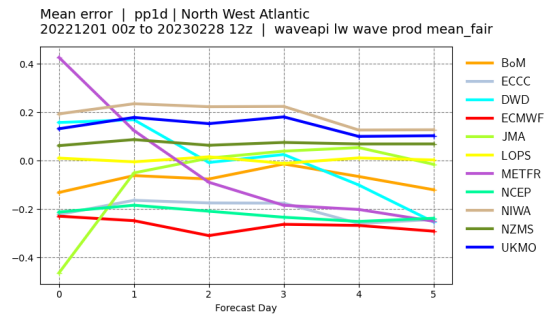
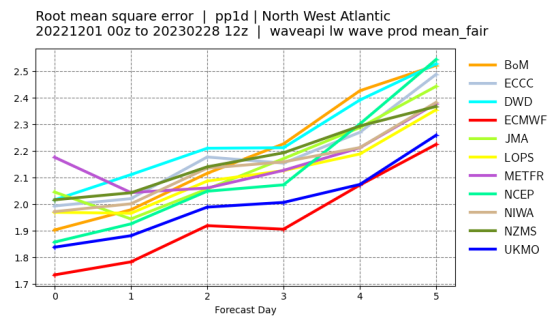
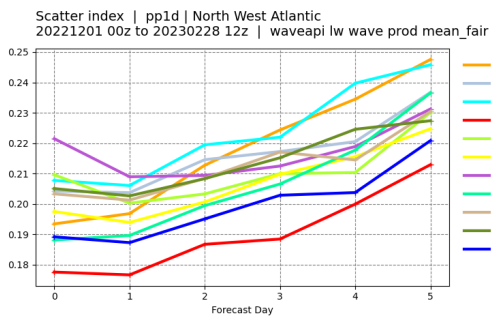
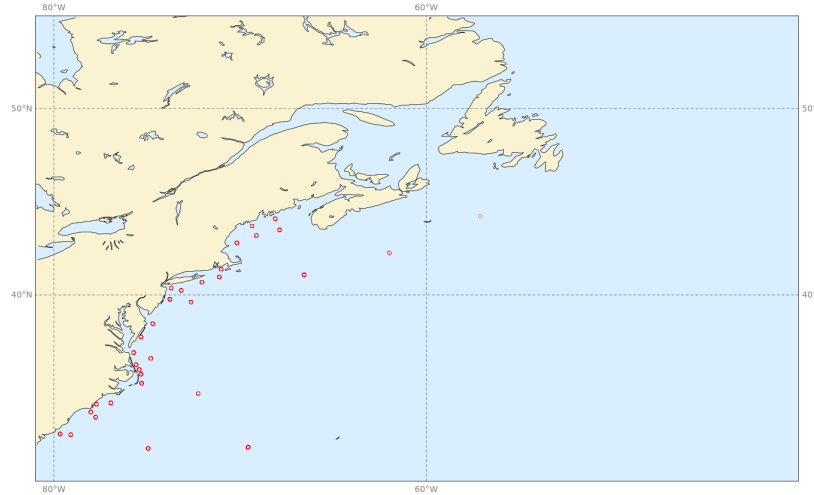


North East Atlantic. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

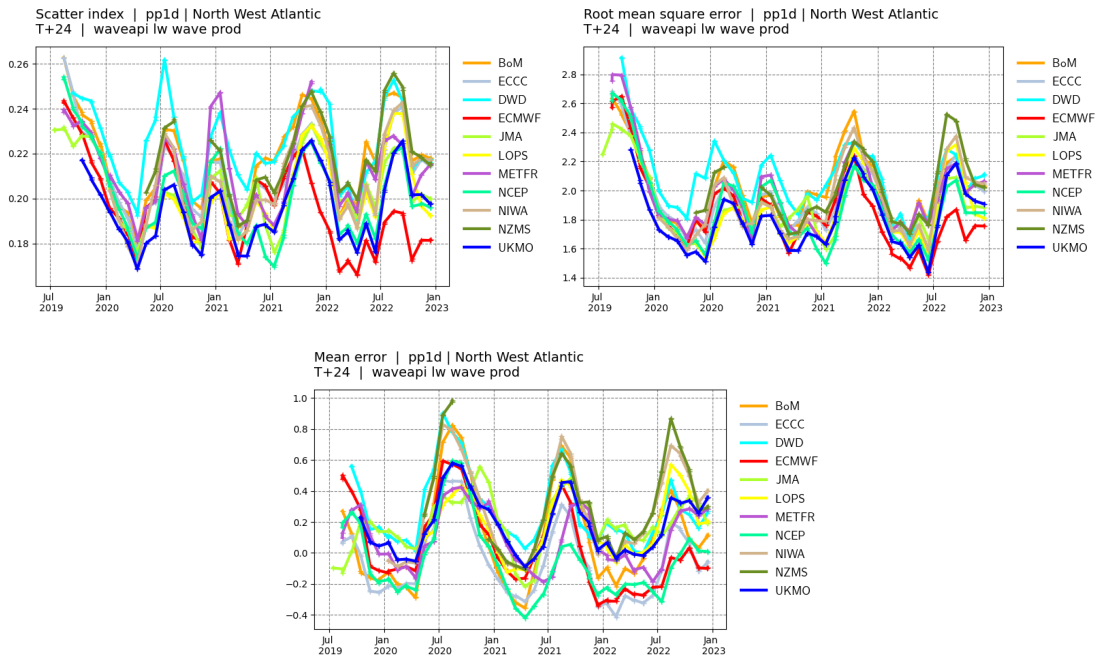


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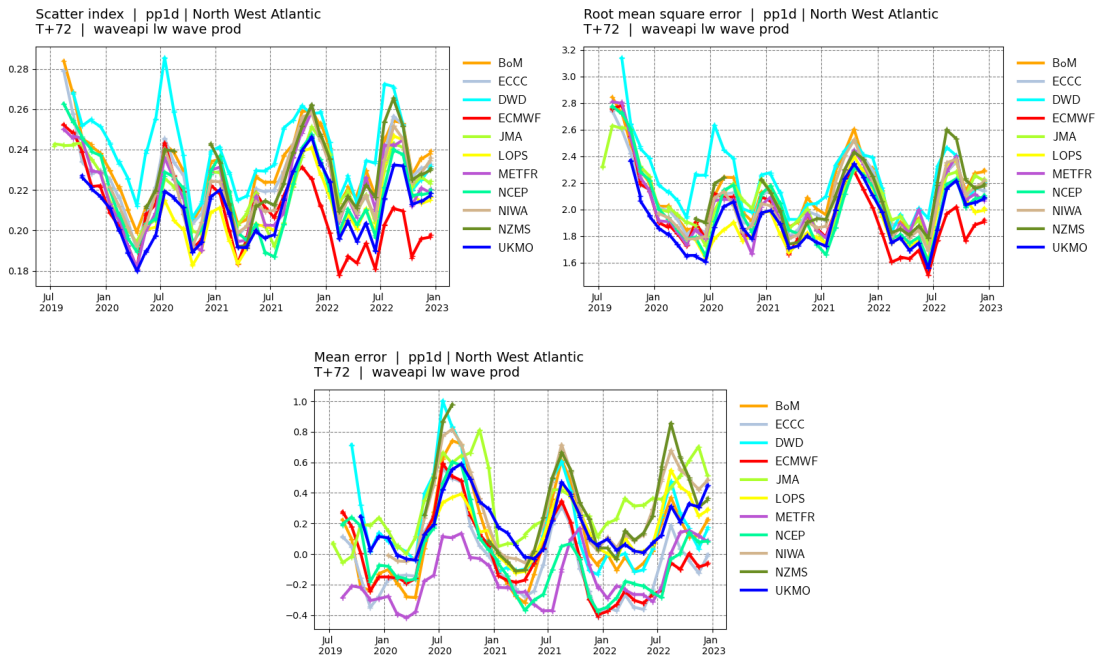
Buoys observations - from 20221201 to 20230228 - (pp1d)



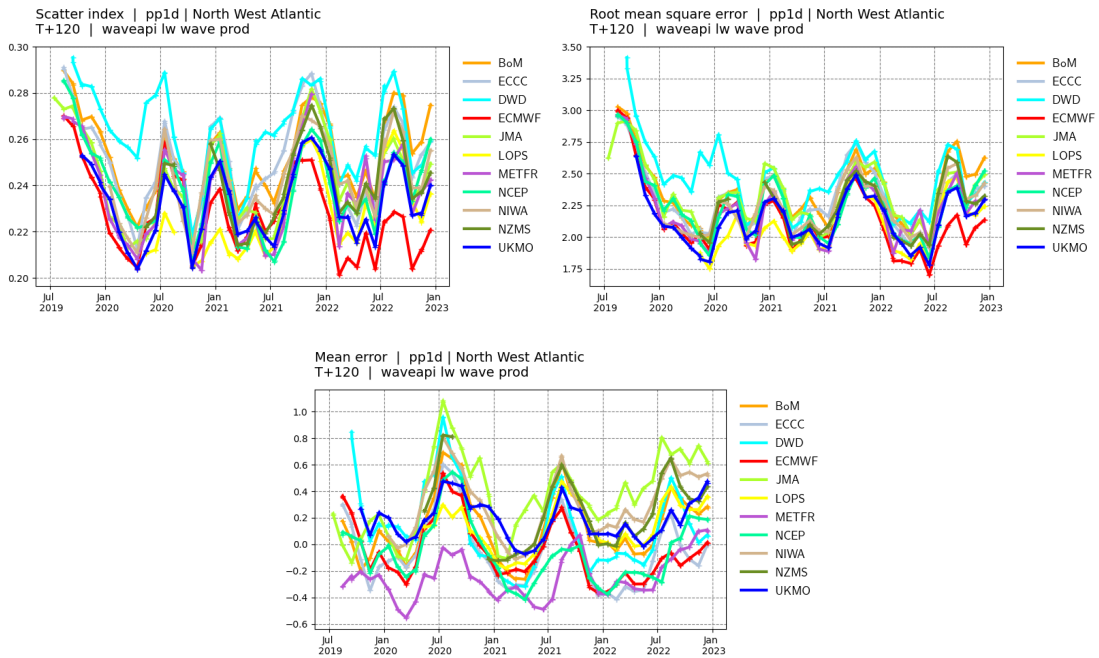
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North West Atlantic. Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast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

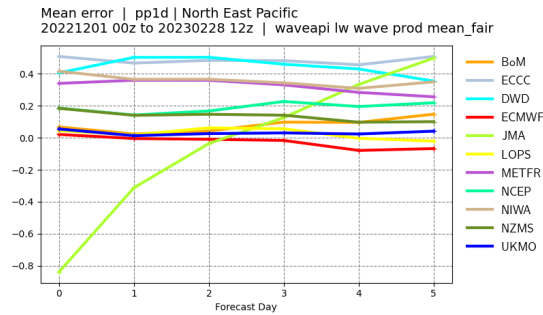
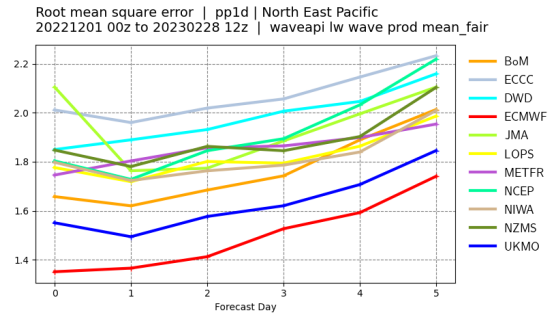
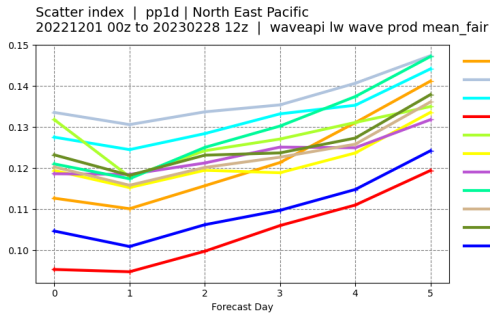
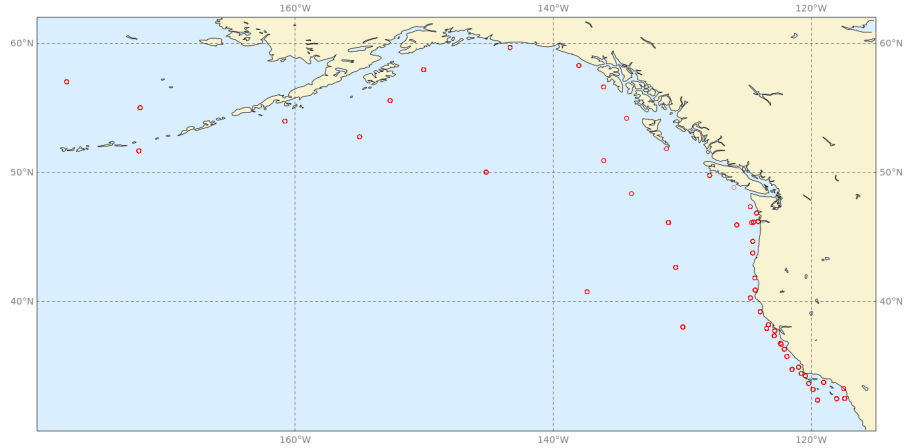


North West Atlantic. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

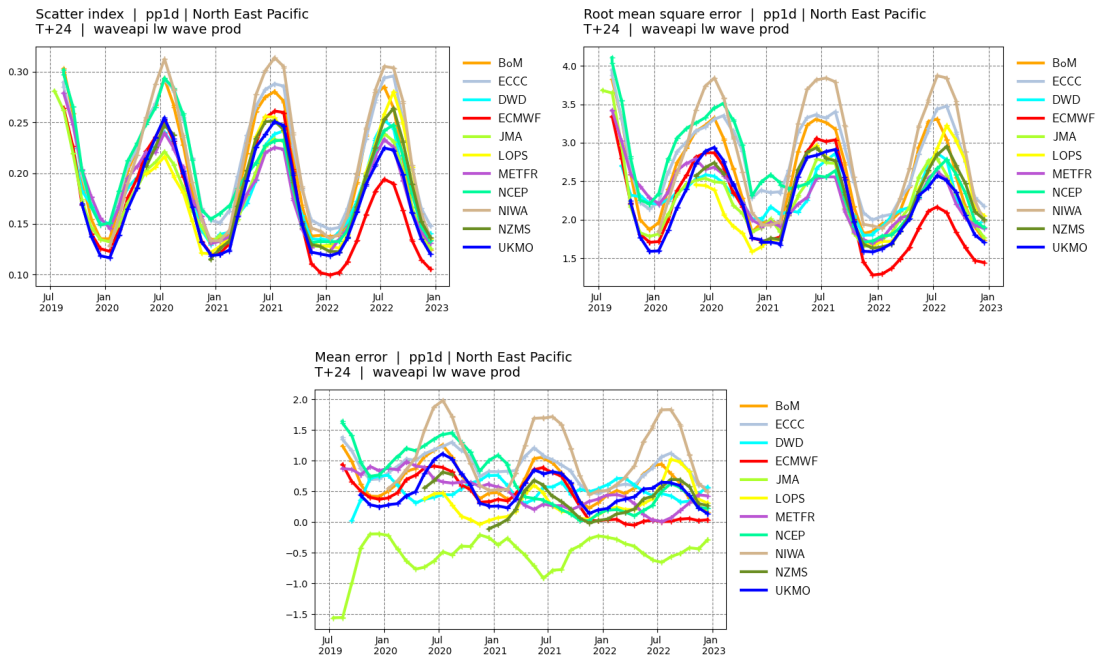


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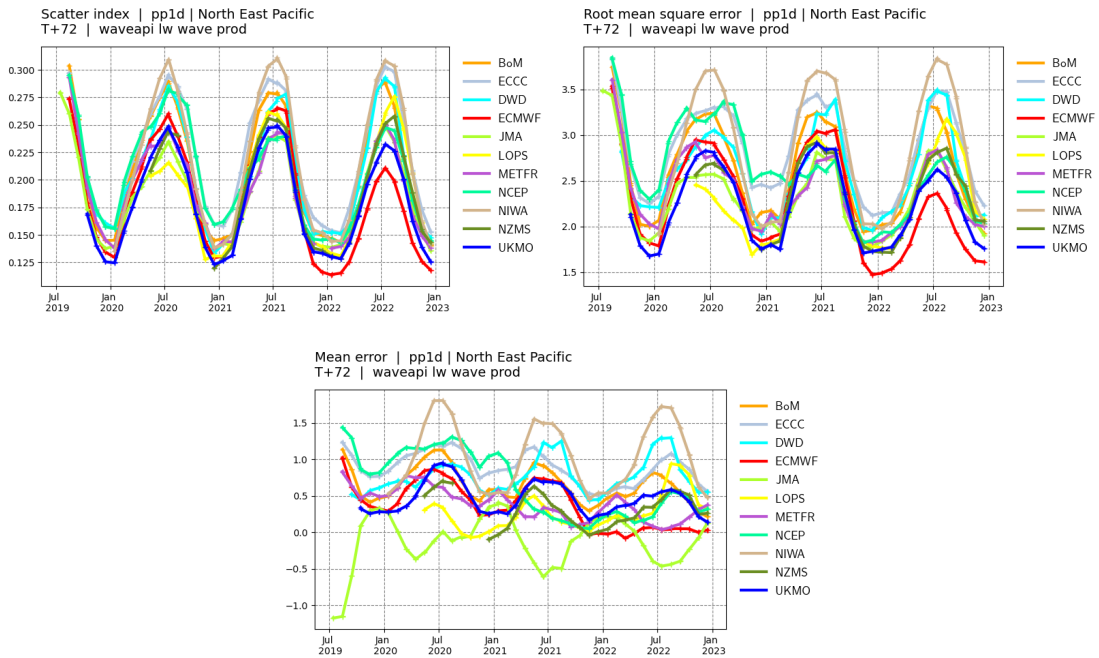
Buoys observations - from 20221201 to 20230228 - (pp1d)



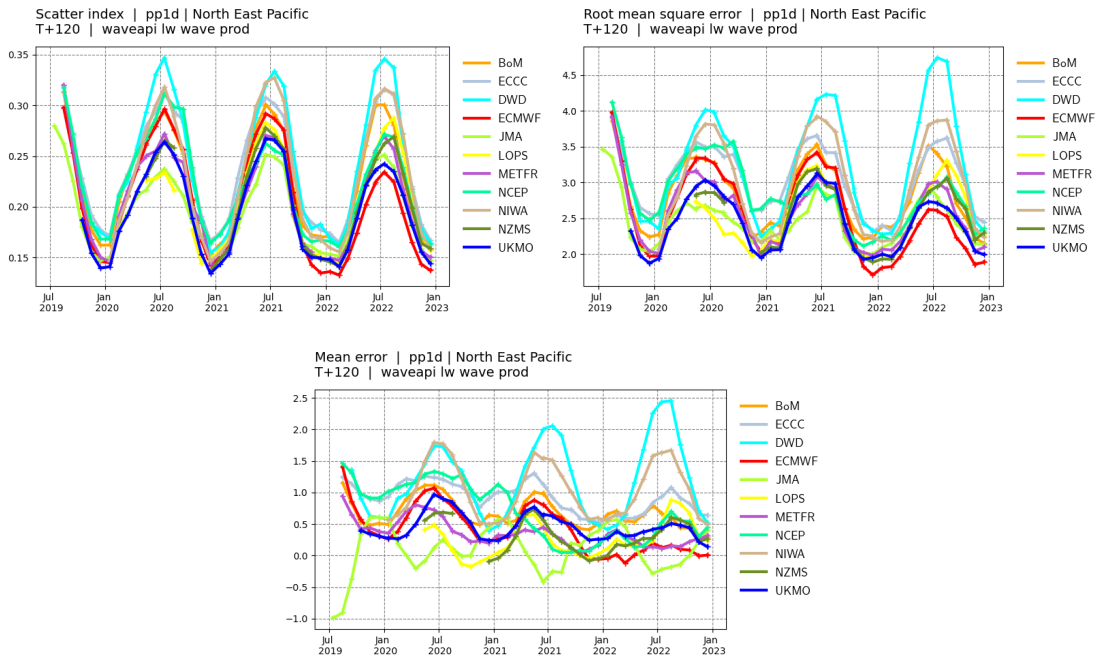
North East Pacific. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

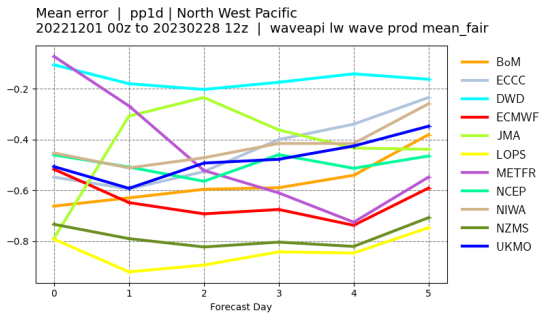
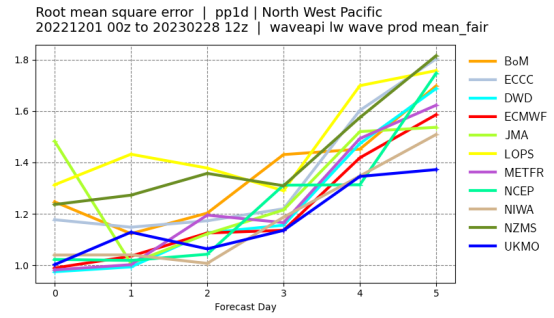
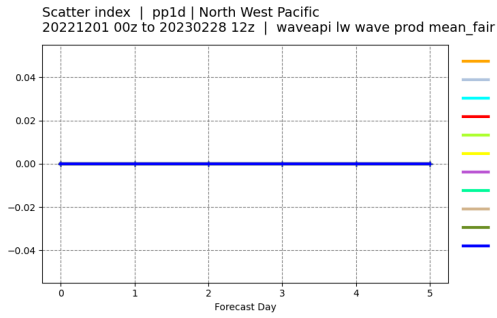
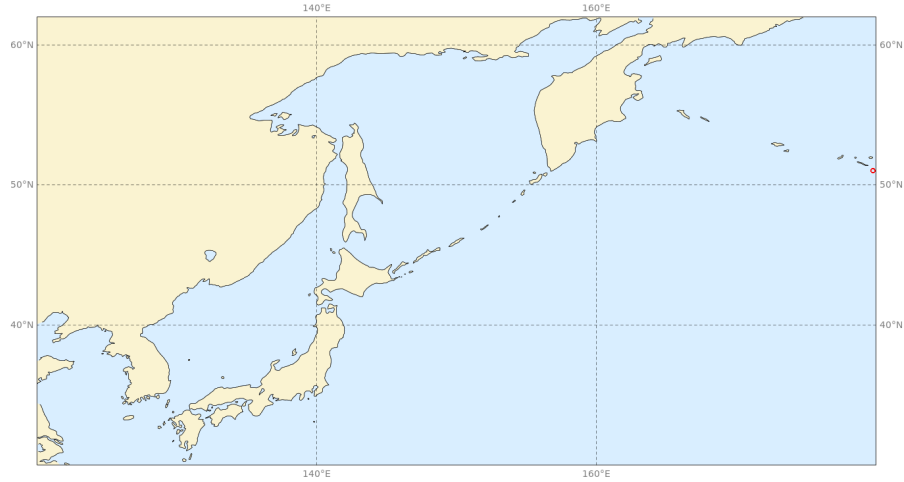


North East Pacific. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

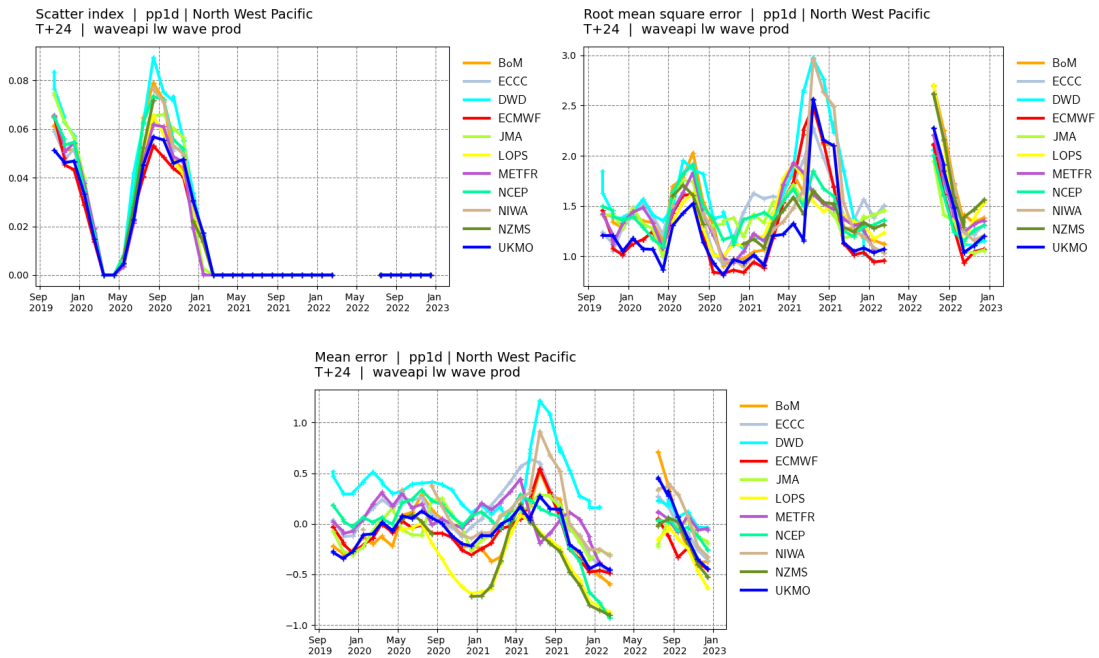


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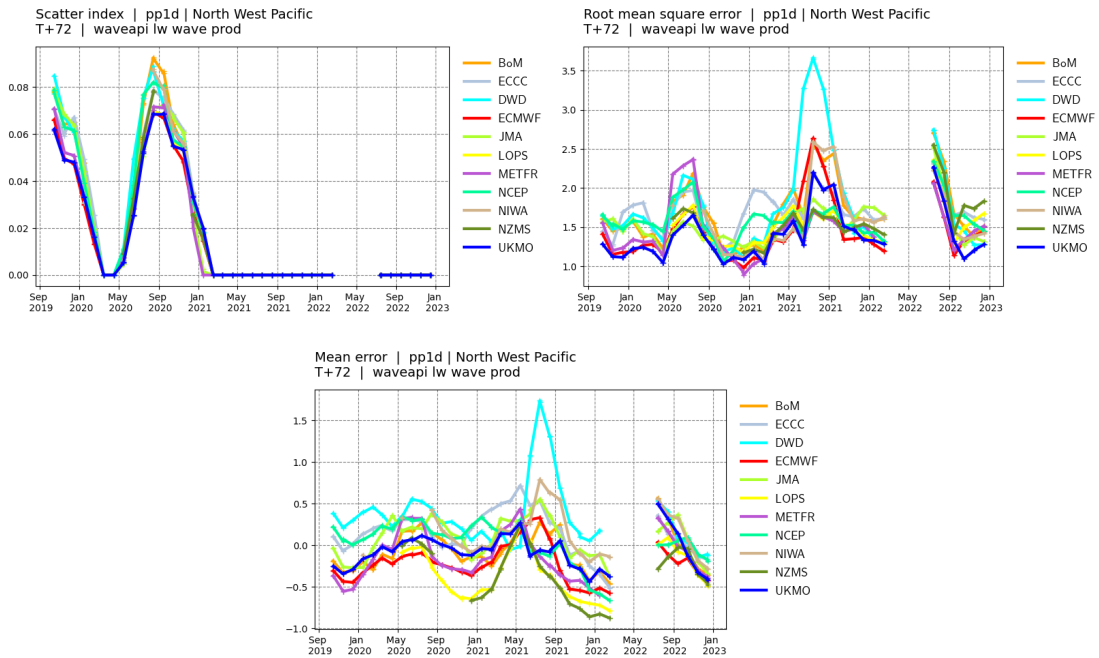
Buoys observations - from 20221201 to 20230228 - (pp1d)



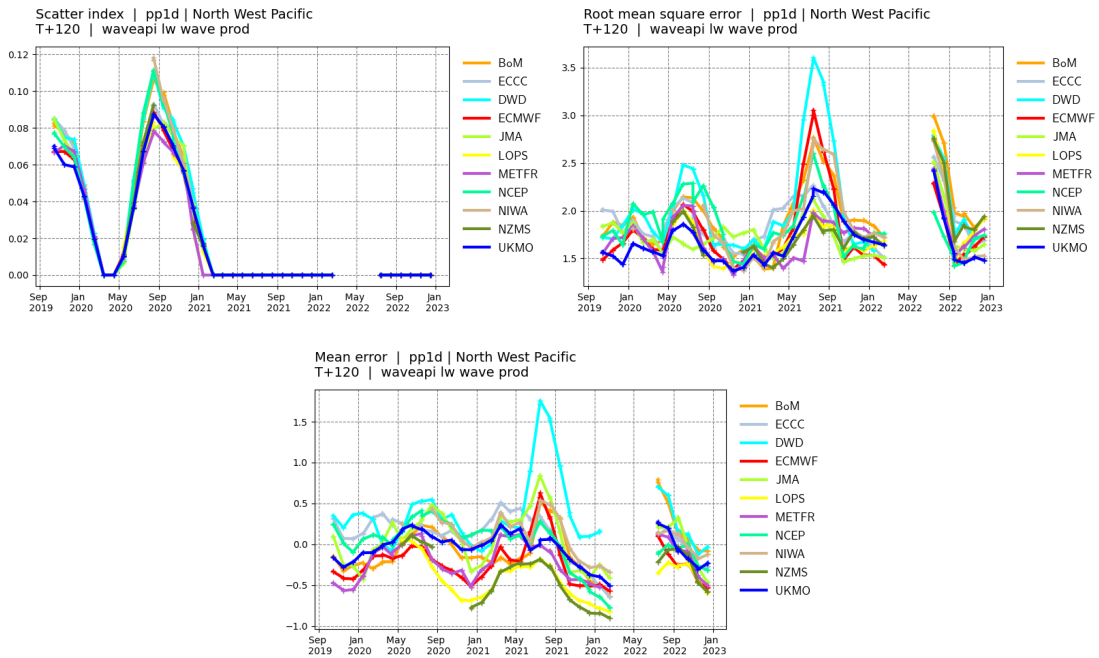
North West Pacific. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



North West 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).

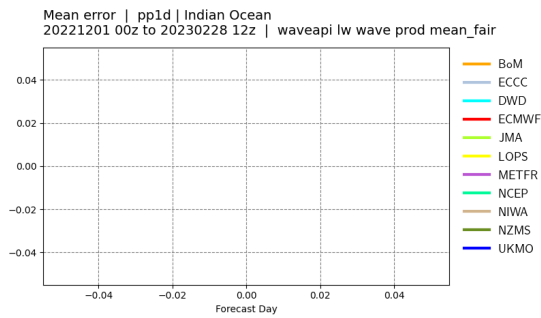
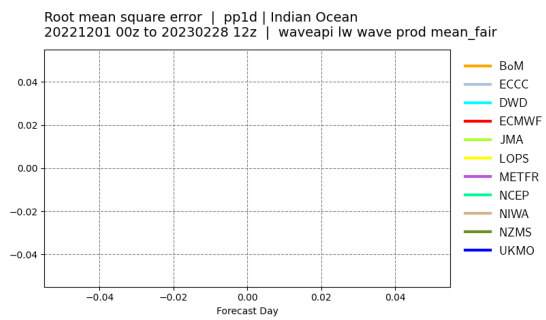
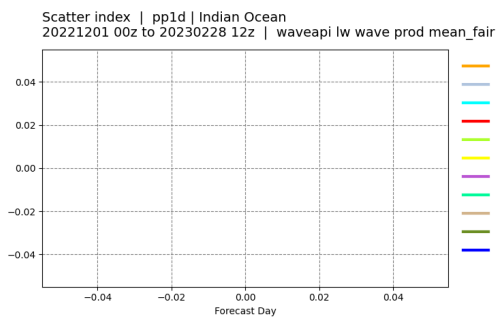
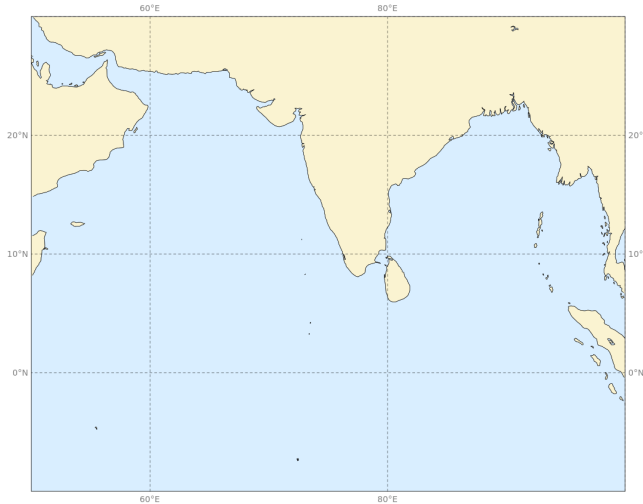


North West Pacific. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

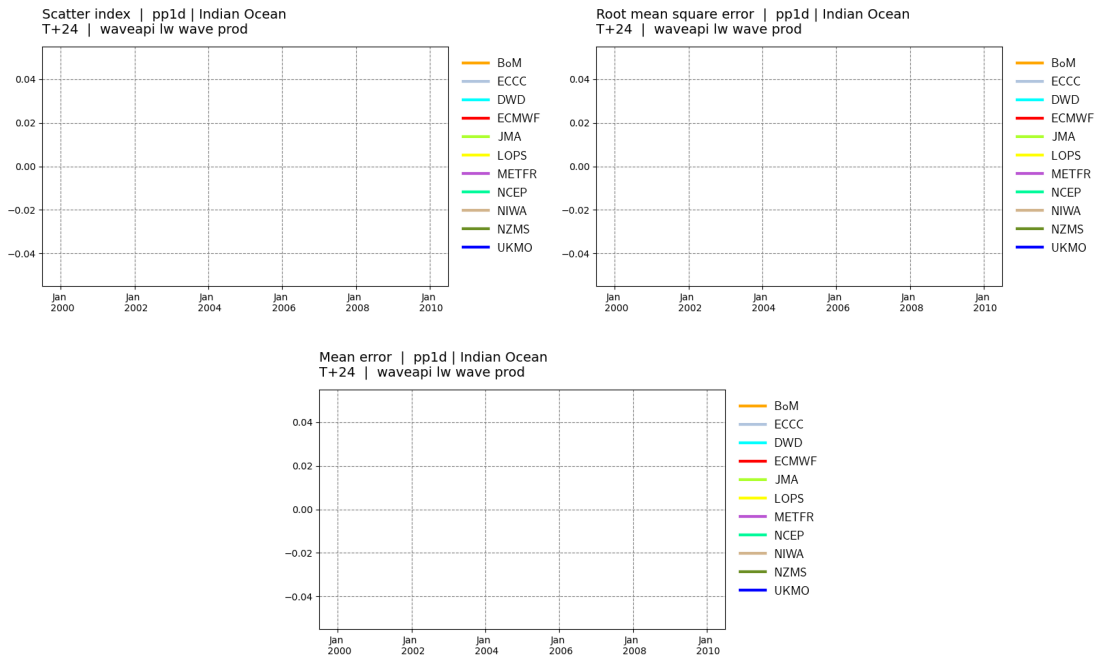


North West Pacific. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

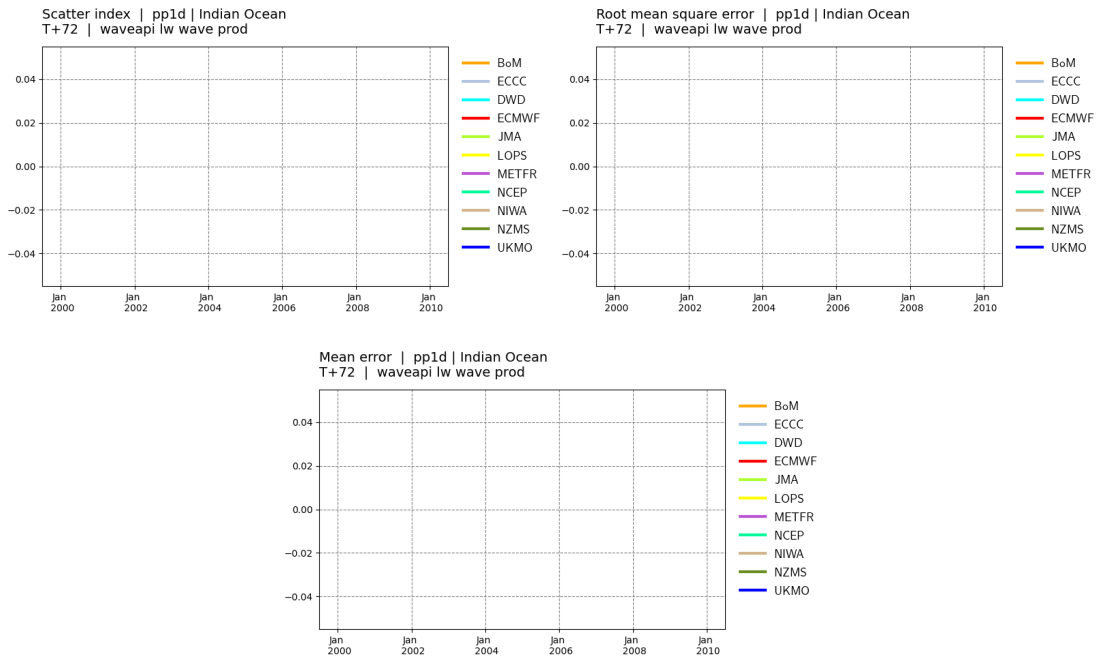
Buoys observations - from 20221201 to 20230228 - (pp1d)



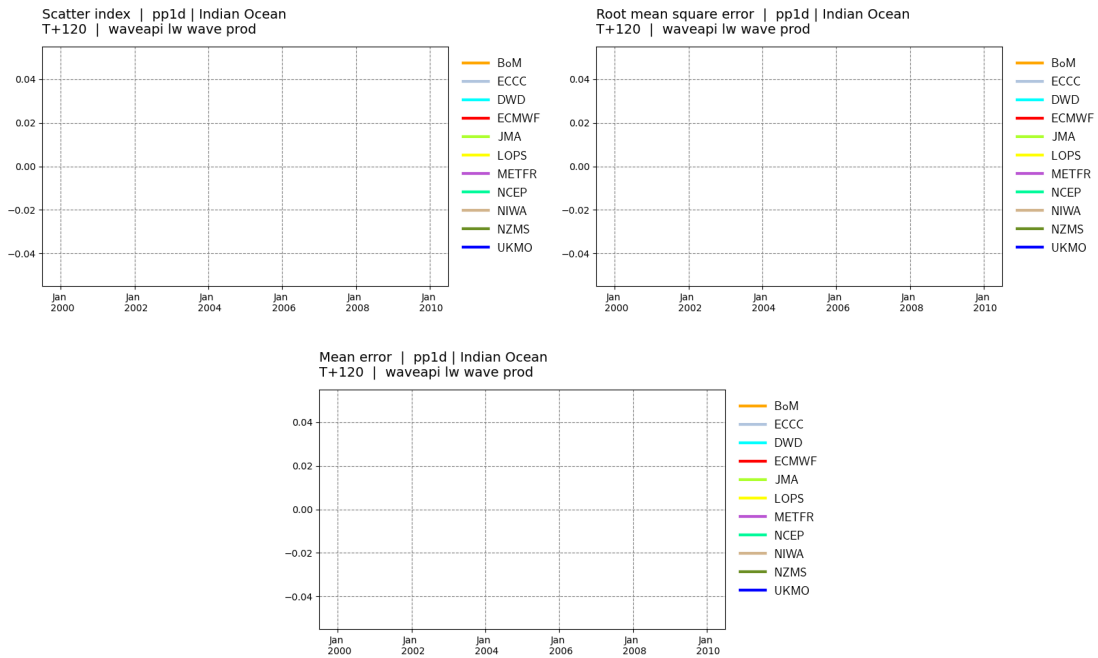
Indian Ocean. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

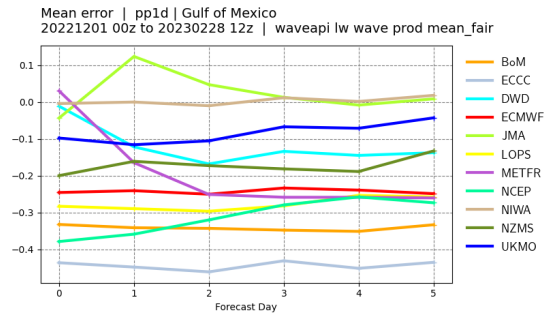
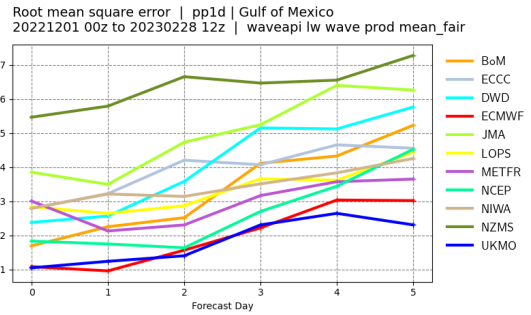
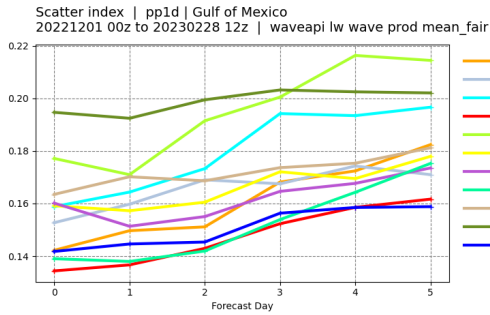
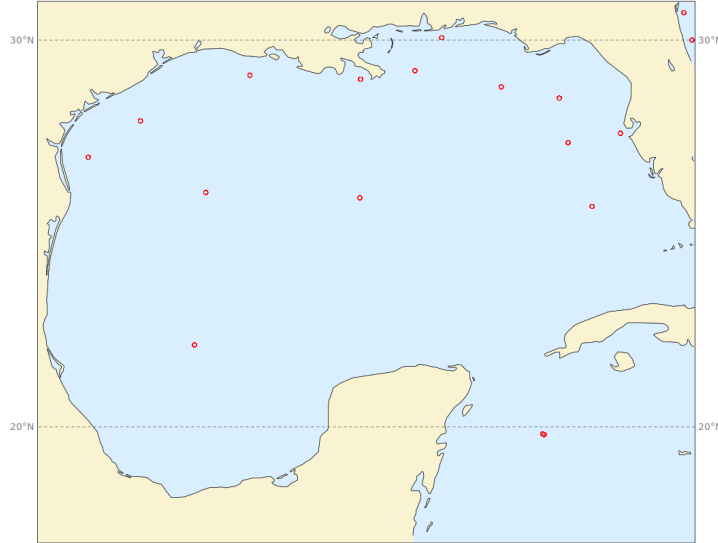


Indian Ocean. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

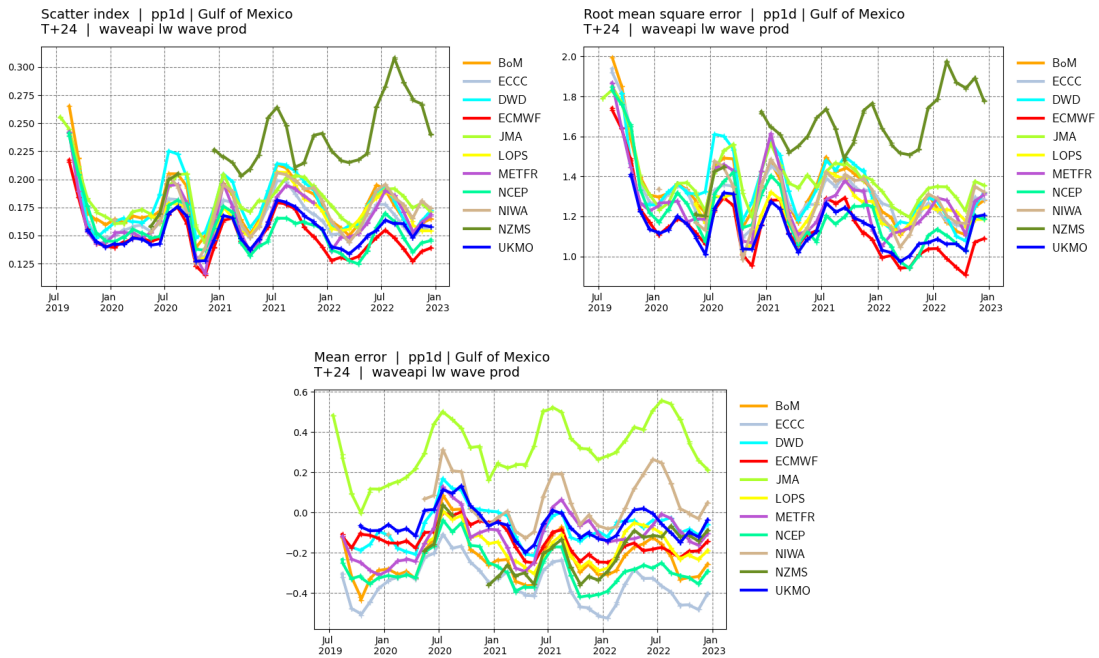


Indian Ocean. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

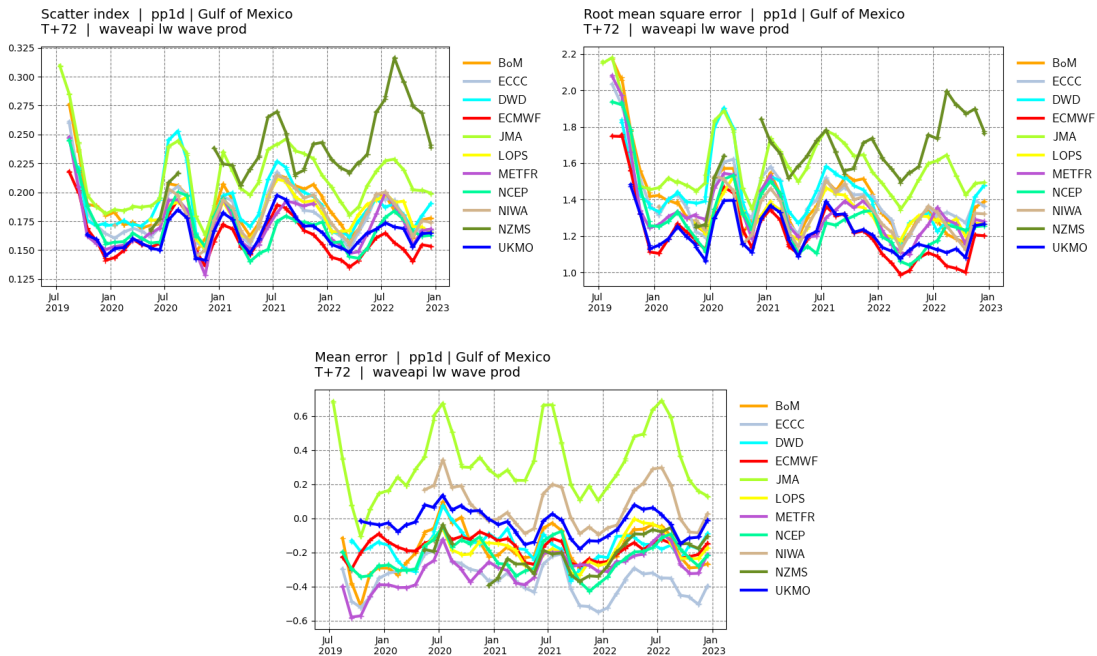
Buoys observations - from 20221201 to 20230228 - (pp1d)



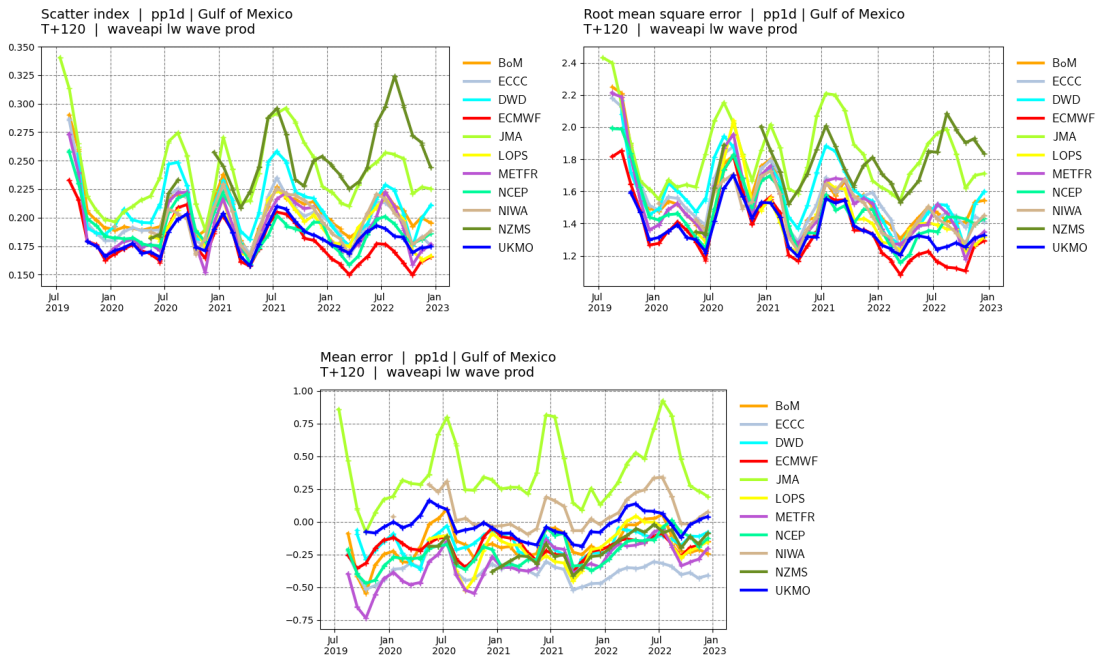
Gulf of Mexico. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

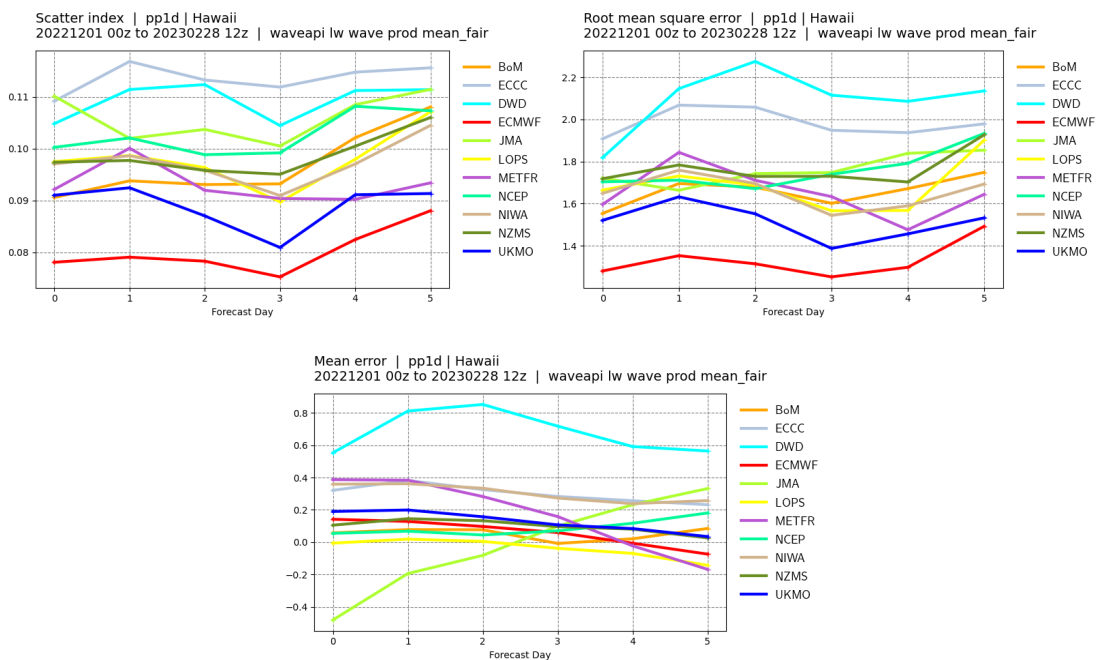
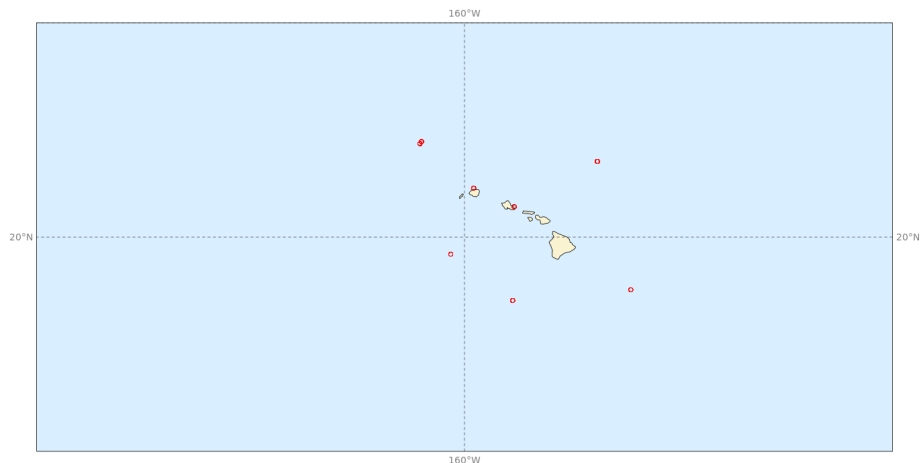


Gulf of Mexico. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

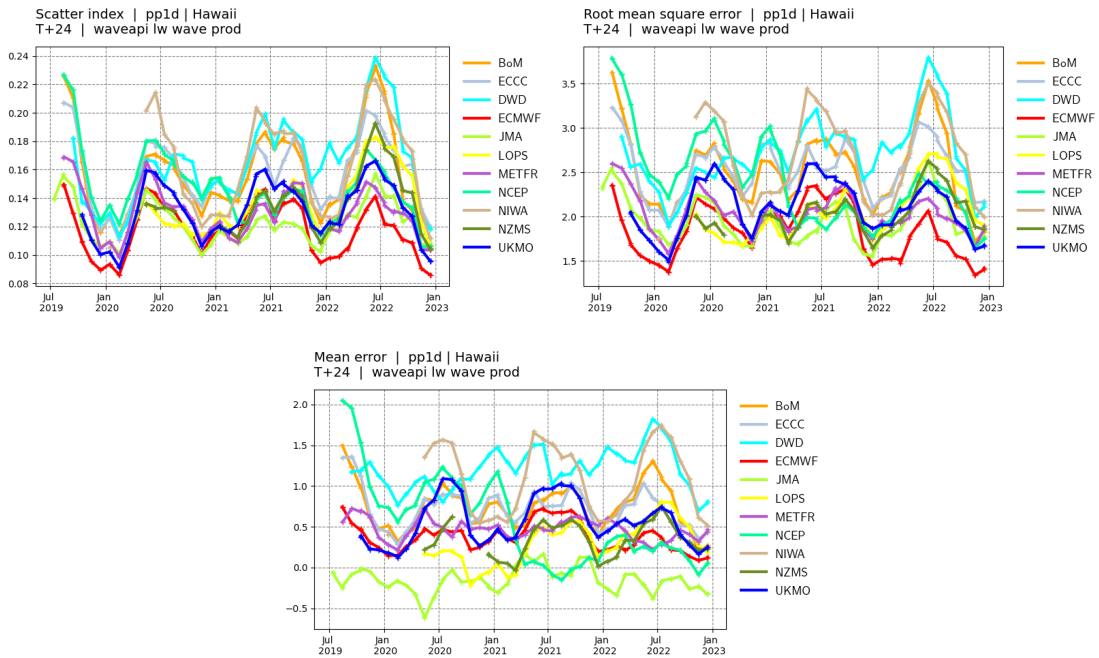


Gulf of Mexico. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

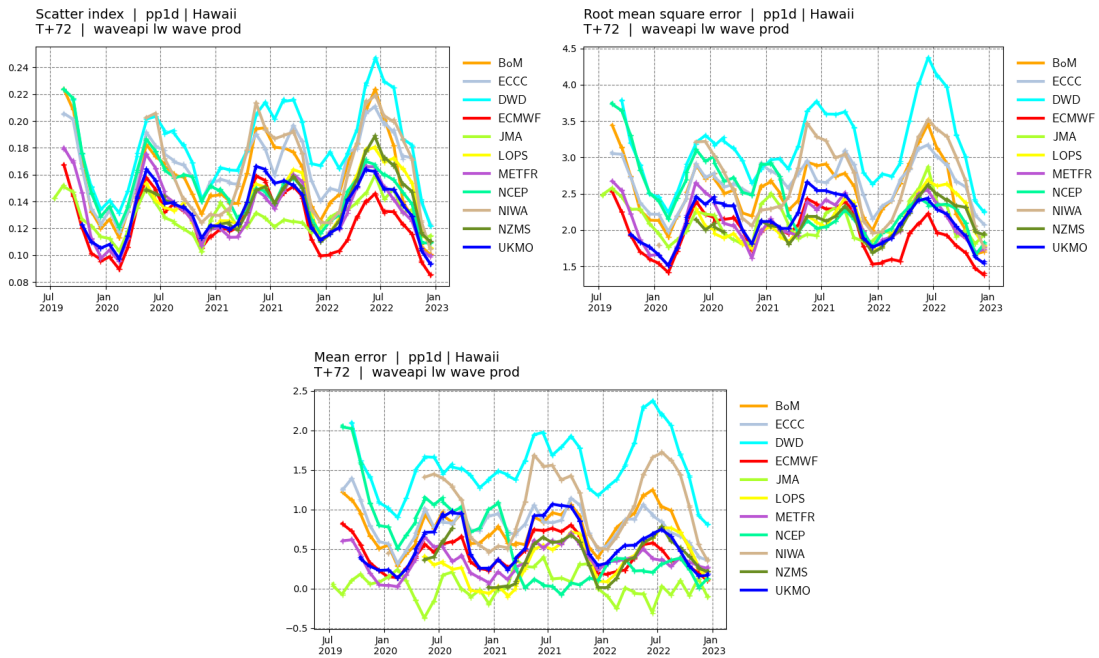
Buoys observations - from 20221201 to 20230228 - (pp1d)



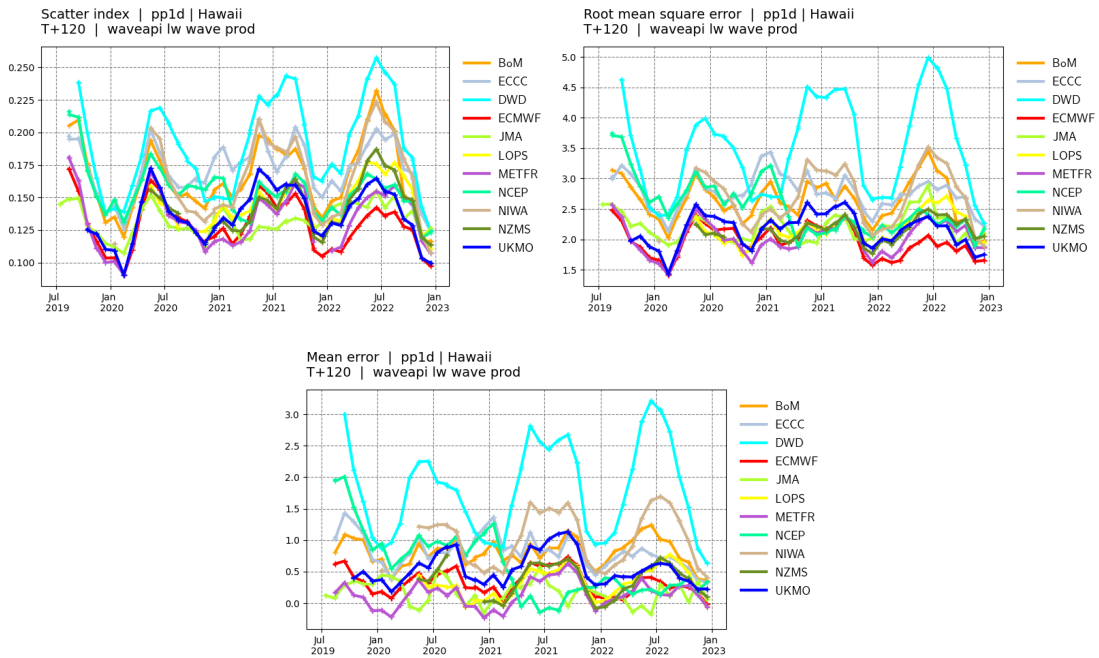
Hawaii. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

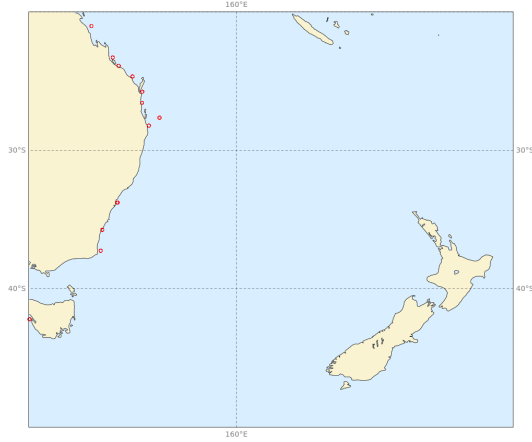


Hawaii. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

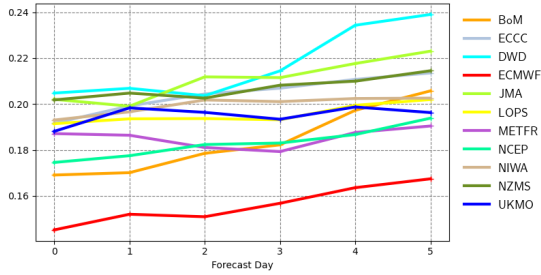


Hawaii. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

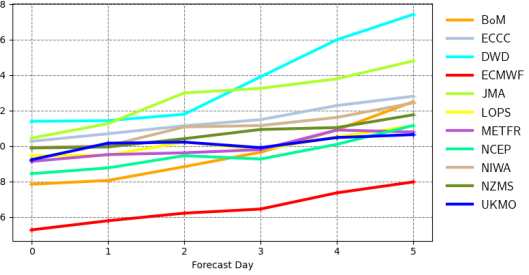
Buoys observations - from 20221201 to 20230228 - (pp1d)



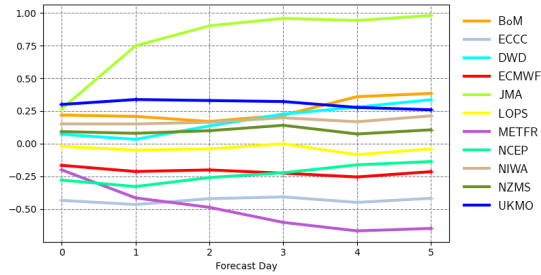
Scatter index | pp1d | Eastern Australia and New Zealand
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



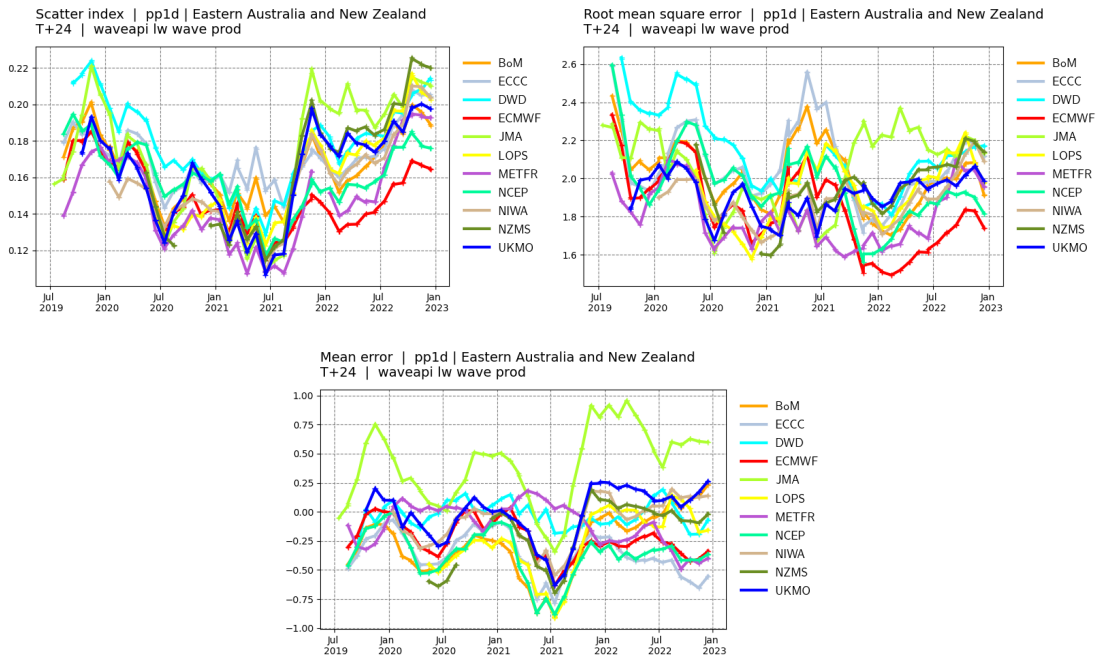
Root mean square error | pp1d | Eastern Australia and New Zealand
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



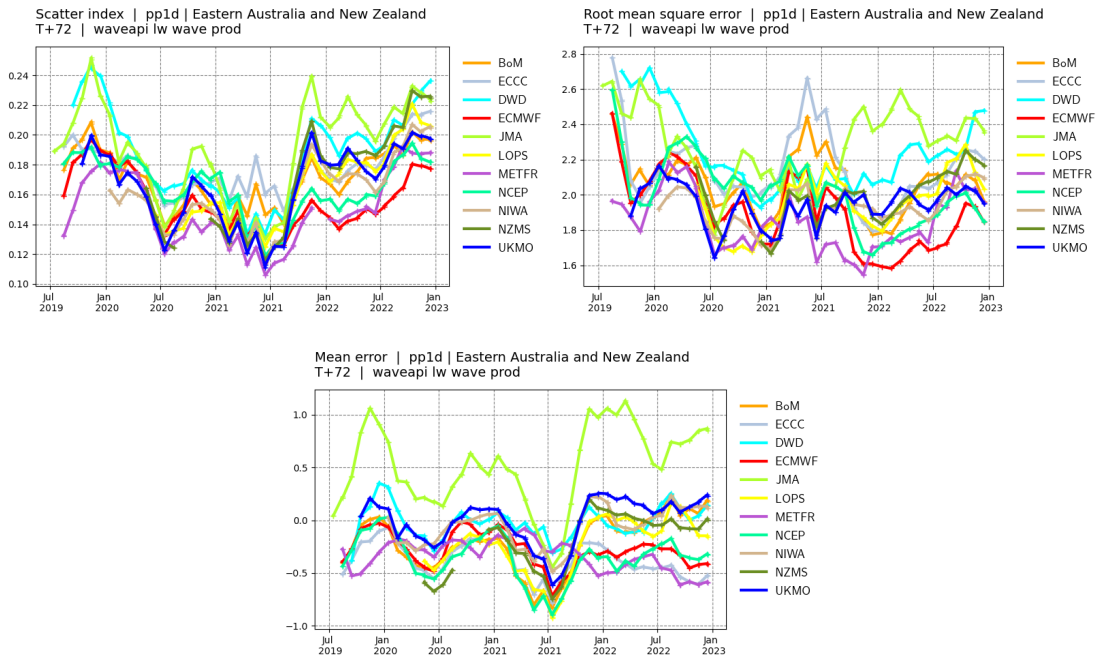
Mean error | pp1d | Eastern Australia and New Zealand
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



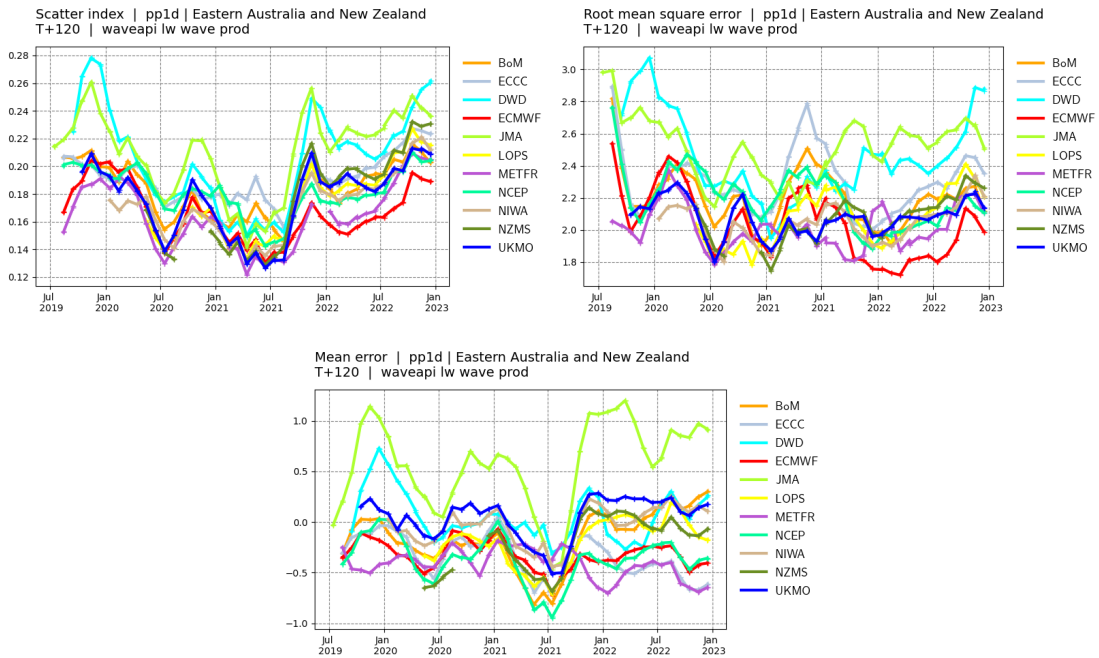
East Australia - New Zealand. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

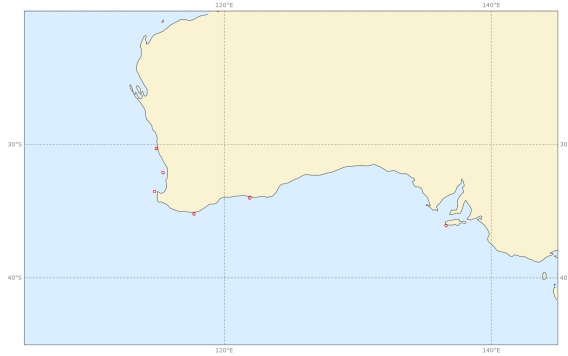


East Australia - New Zealand. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

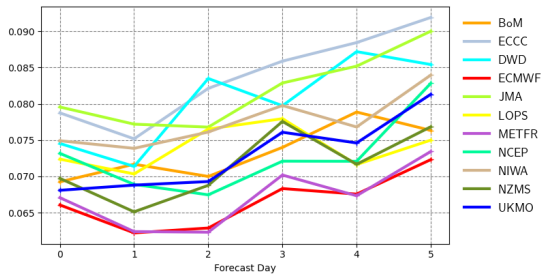


East Australia - New Zealand. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

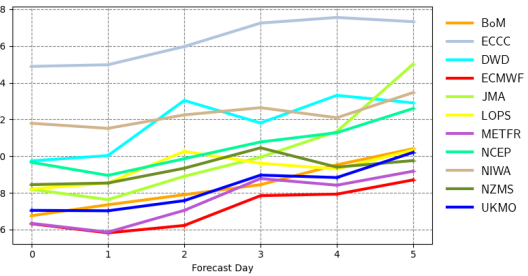
Buoys observations - from 20221201 to 20230228 - (pp1d)



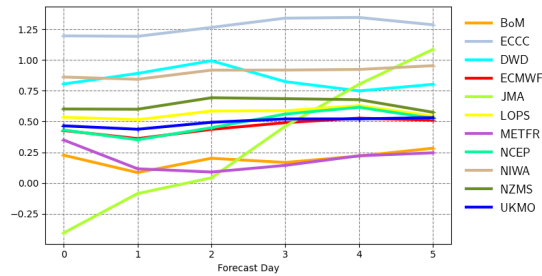
Scatter index | pp1d | South Southwestern Australia
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



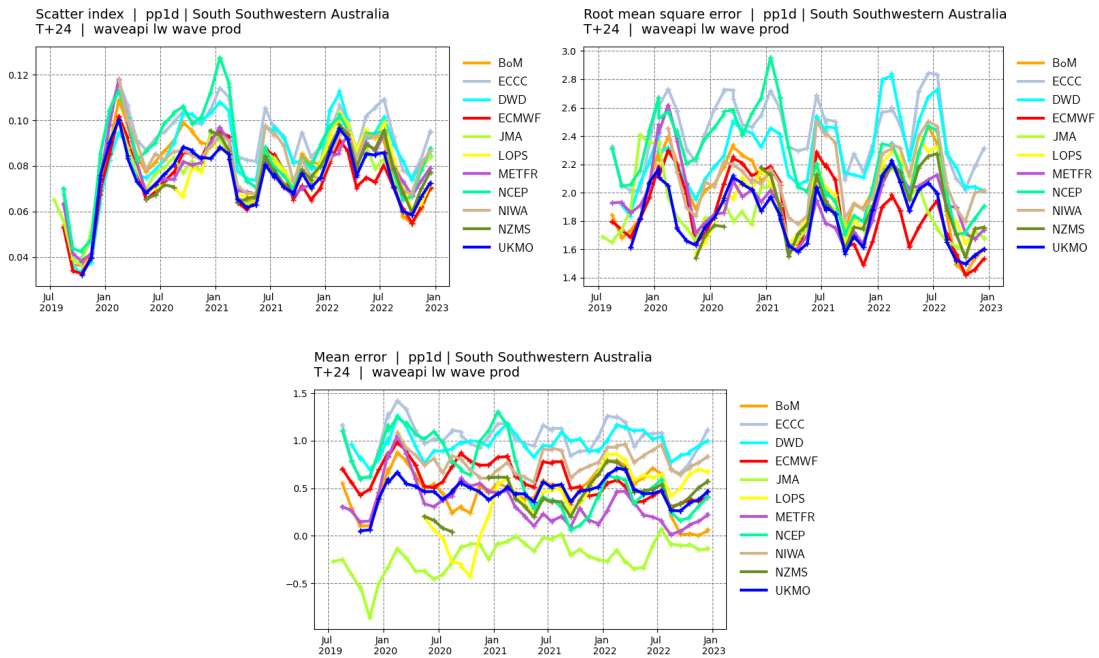
Root mean square error | pp1d | South Southwestern Australia
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



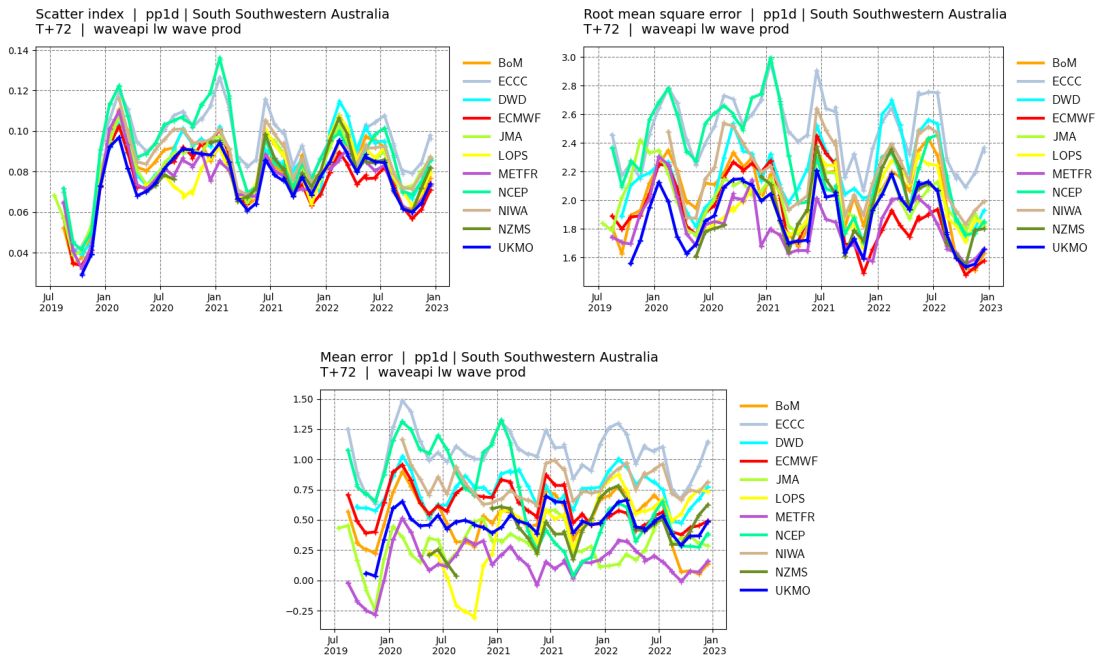
Mean error | pp1d | South Southwestern Australia
20221201 00z to 20230228 12z | waveapi lw wave prod mean_fair



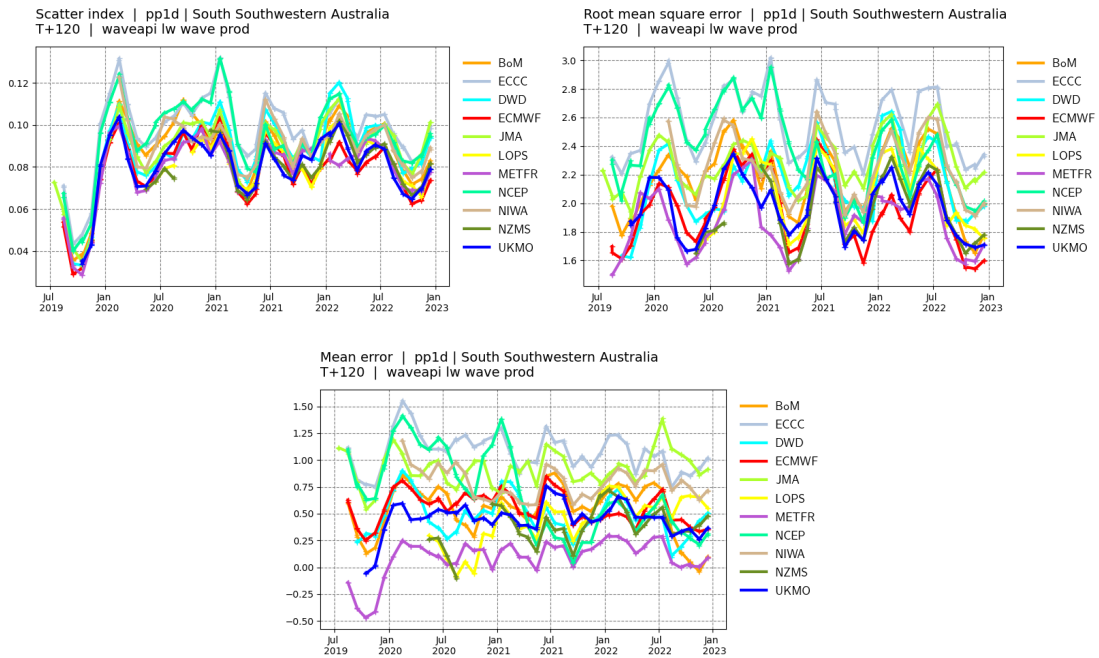
South South West Australia. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).