

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

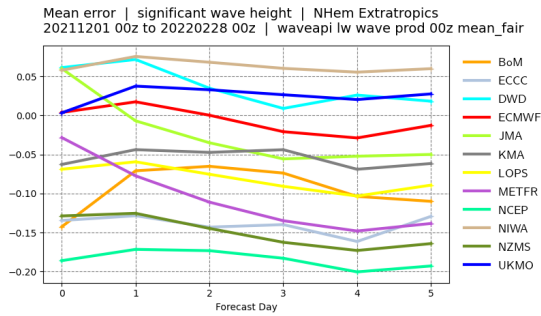
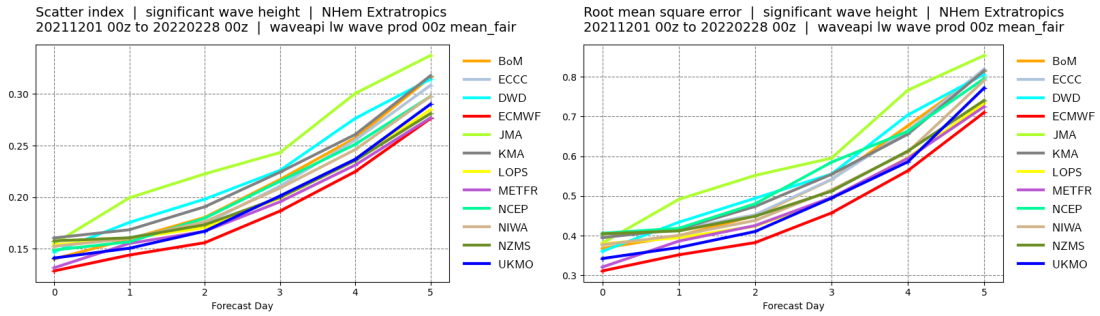
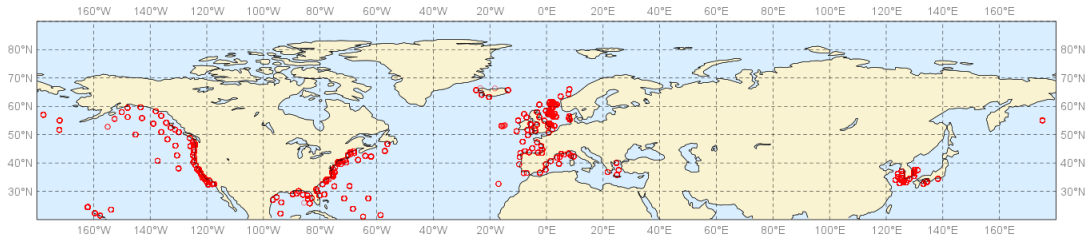
00 UTC runs only

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

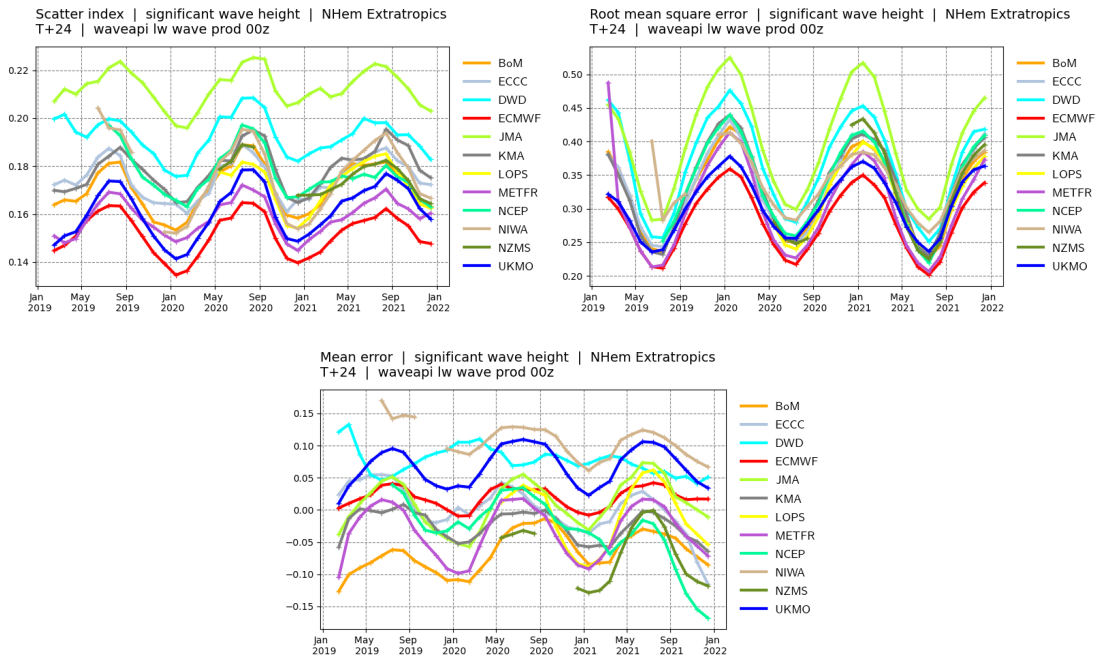
March 23, 2022

PART I: significant wave height (SWH)

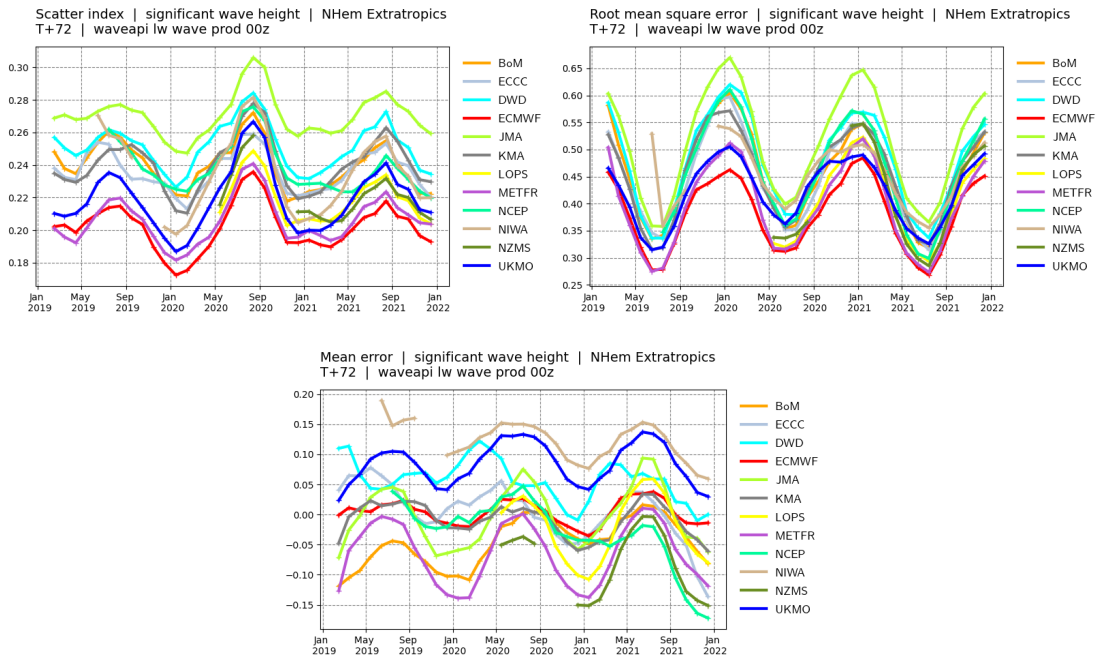
Buoys observations - from 20211201 to 20220228 - (swh)



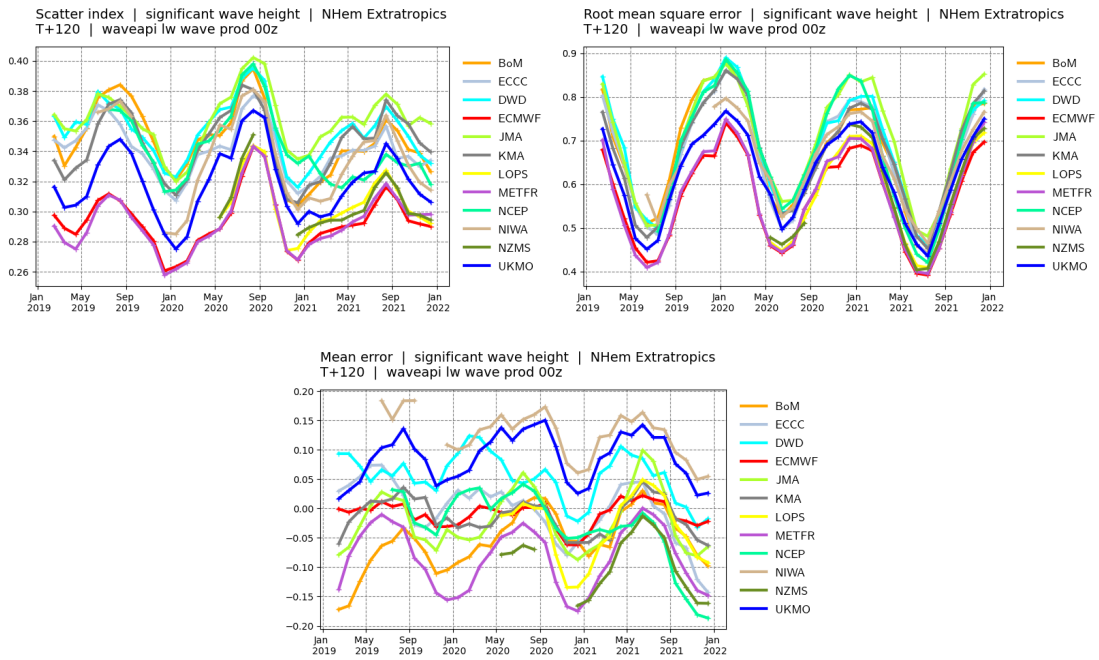
Northern Hemisphere. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

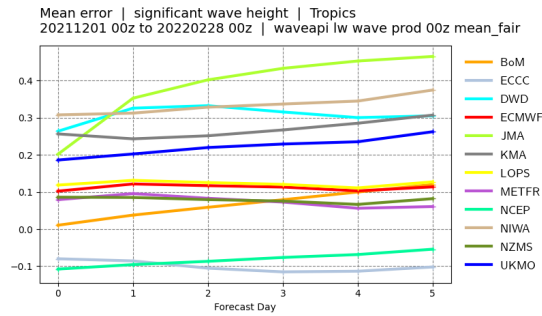
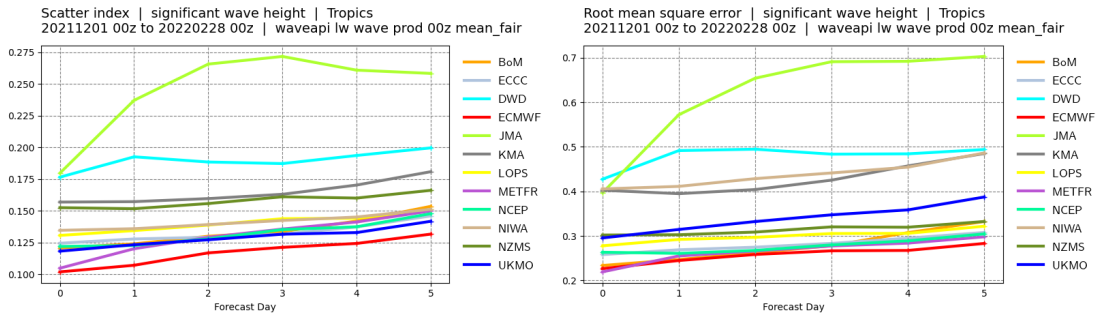
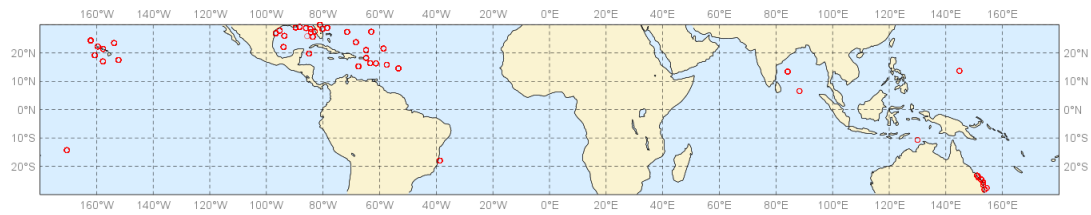


Northern Hemisphere. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

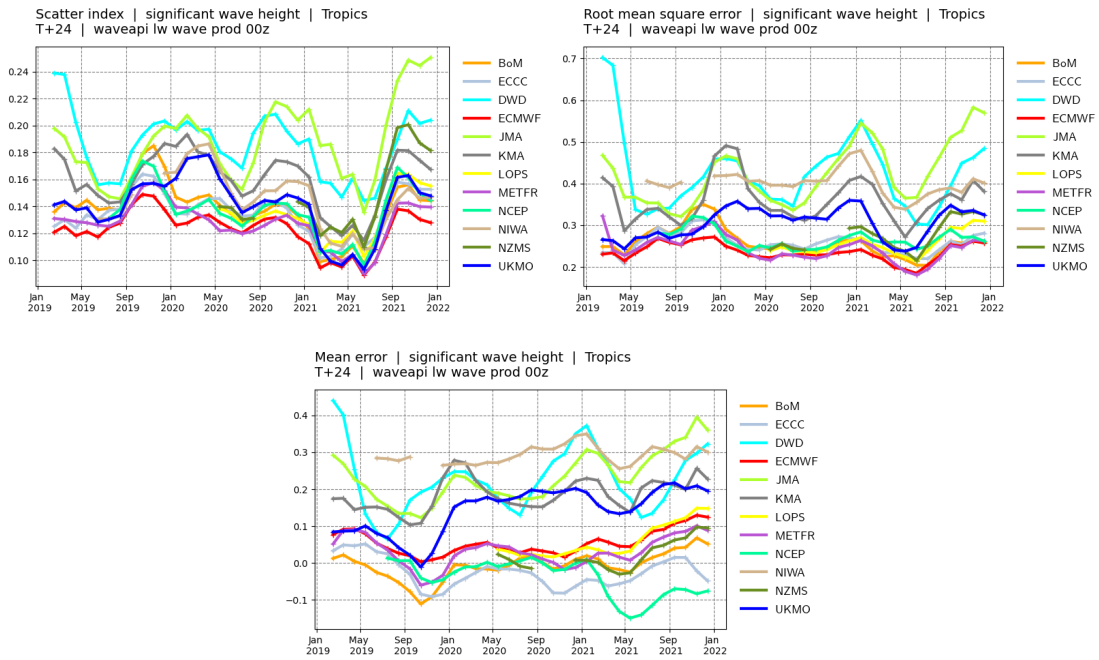


Northern Hemisphere. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

Buoys observations - from 20211201 to 20220228 - (swh)

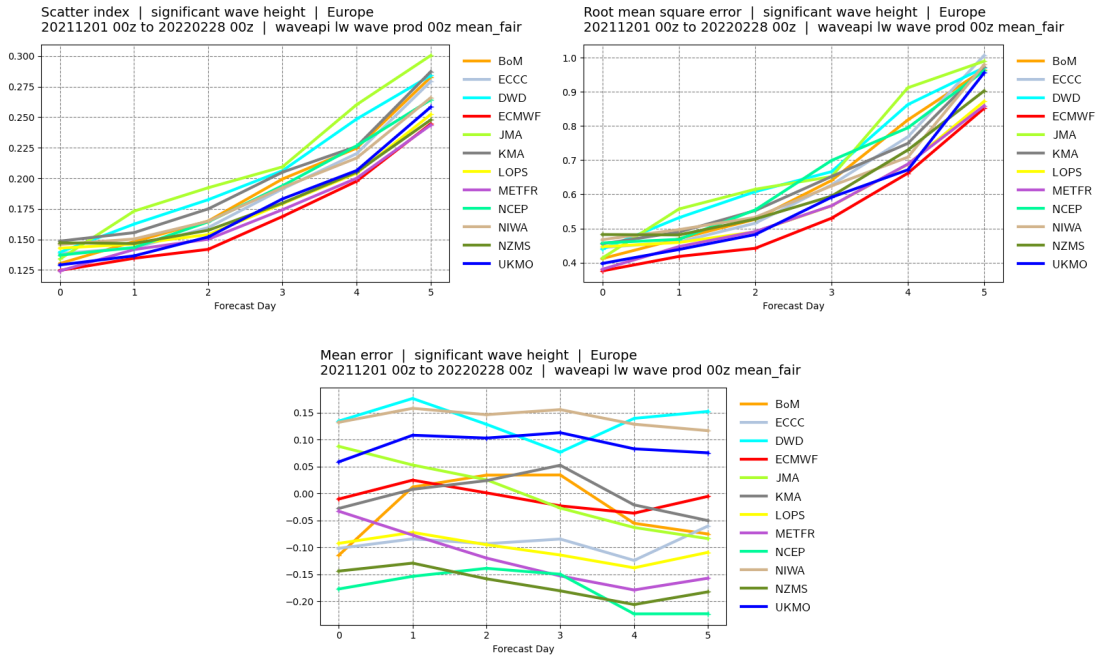
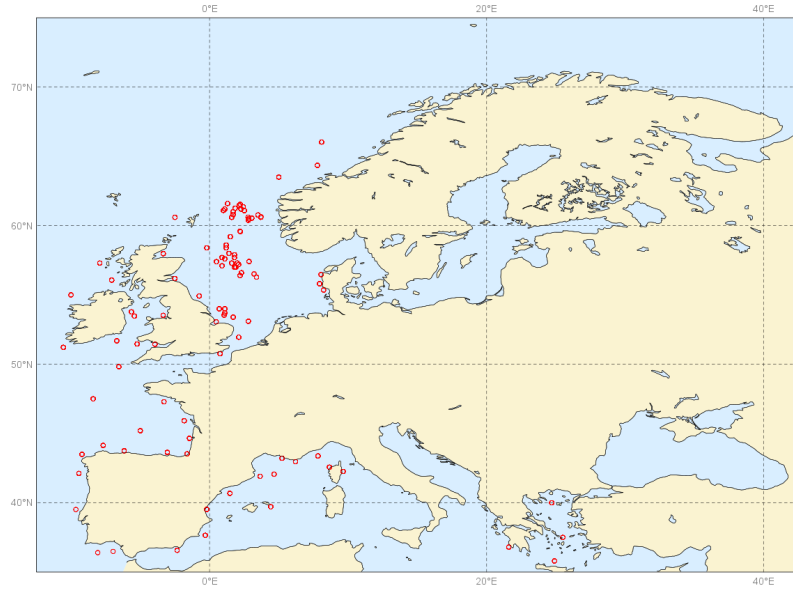


Tropics. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

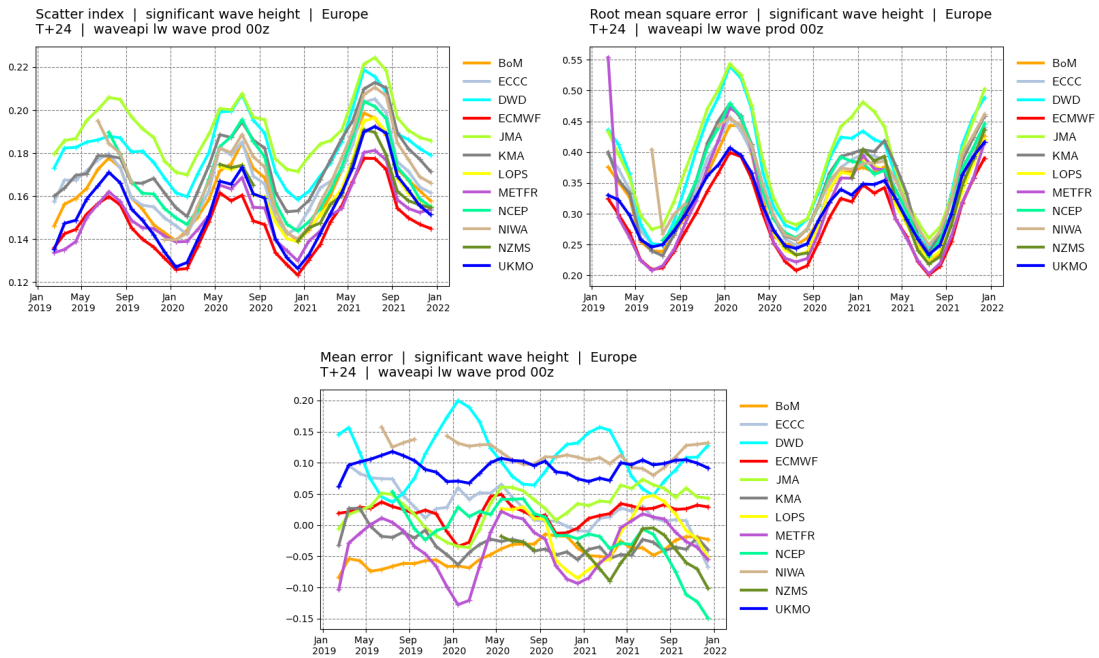


Tropics. Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

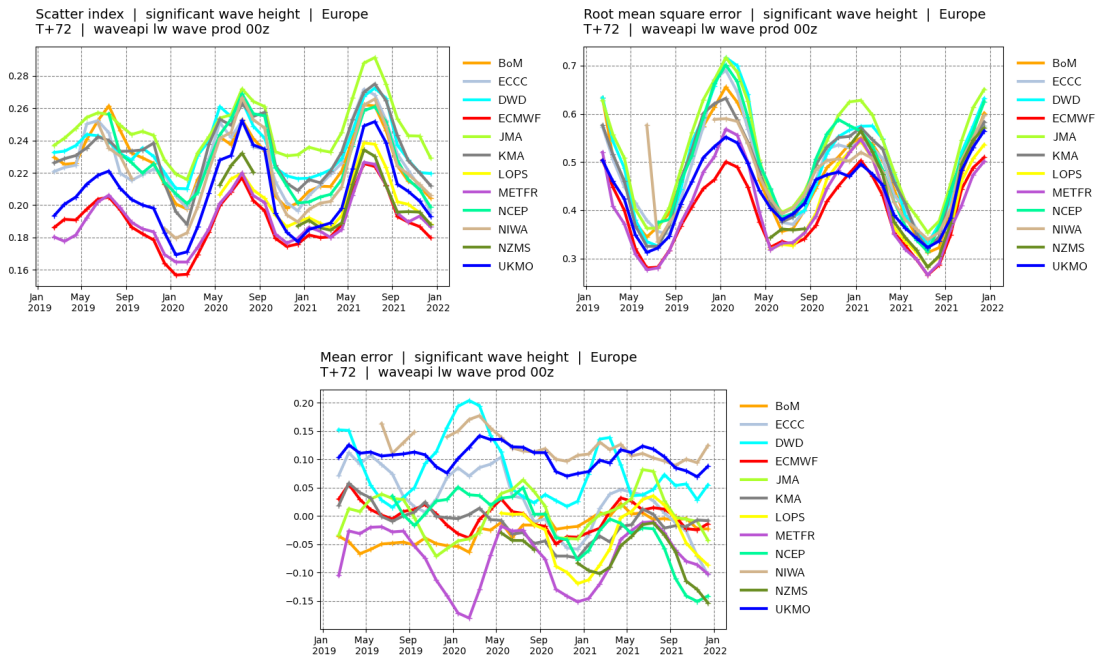
Buoys observations - from 20211201 to 20220228 - (swh)



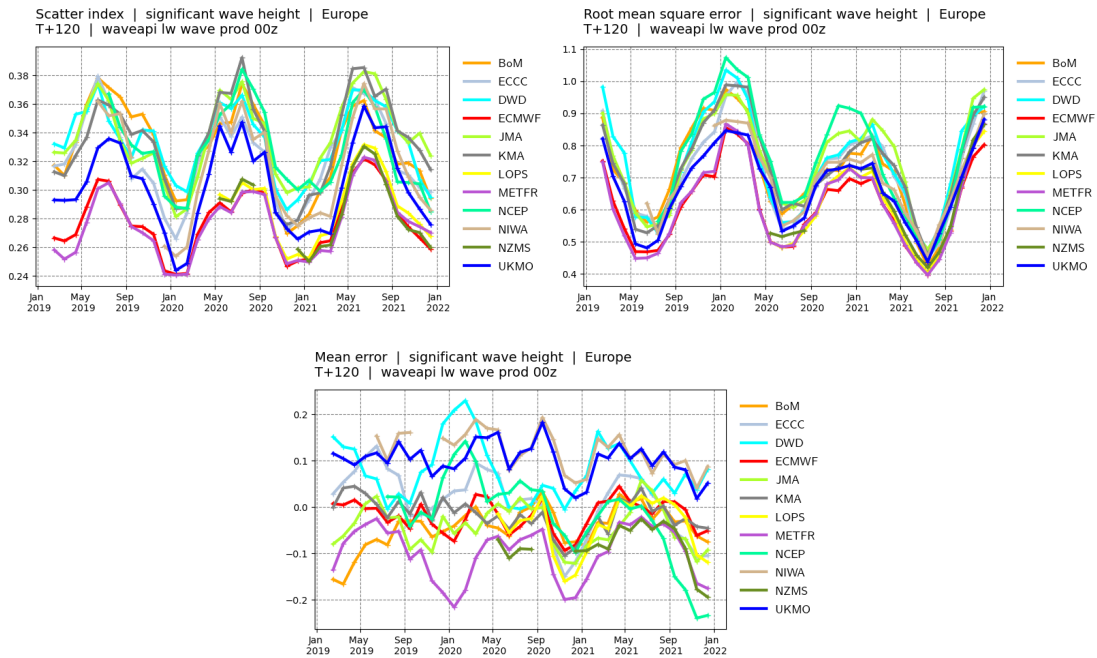
Europe. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

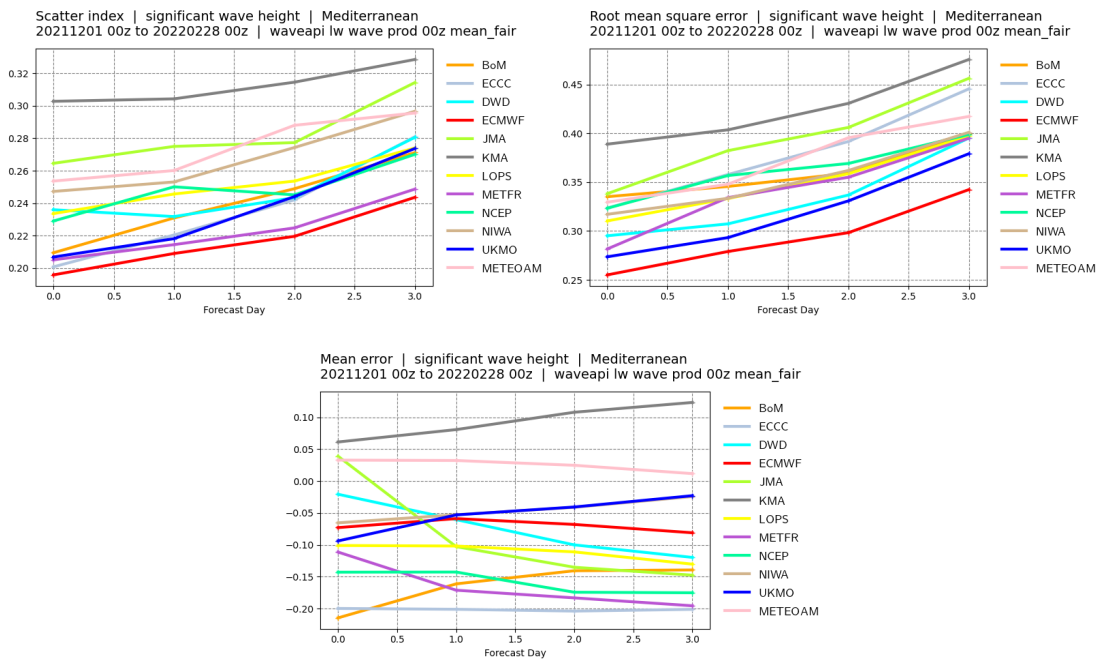
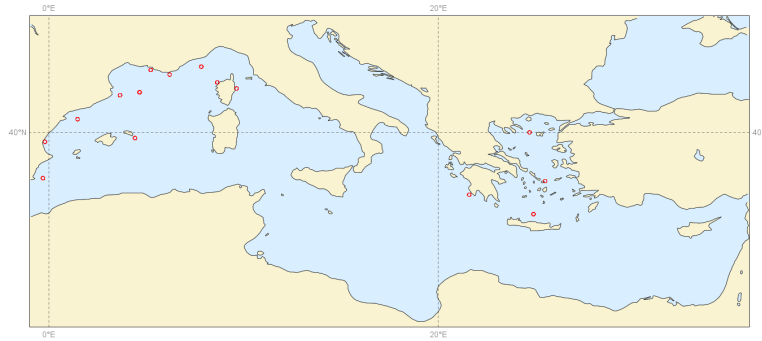


Europe. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

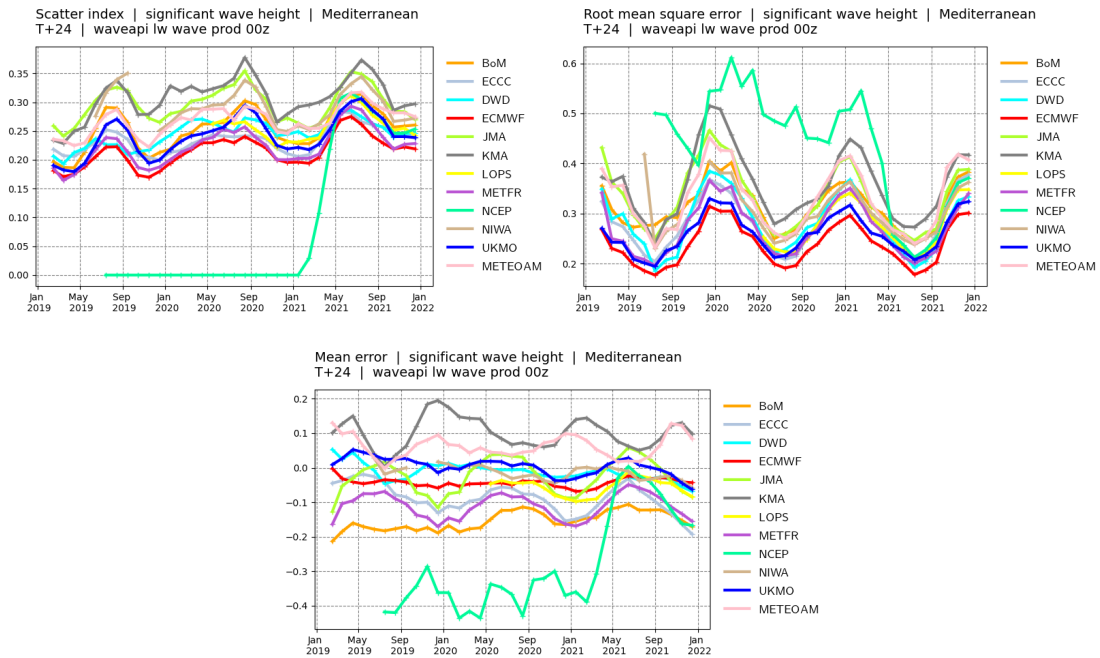


Europe. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

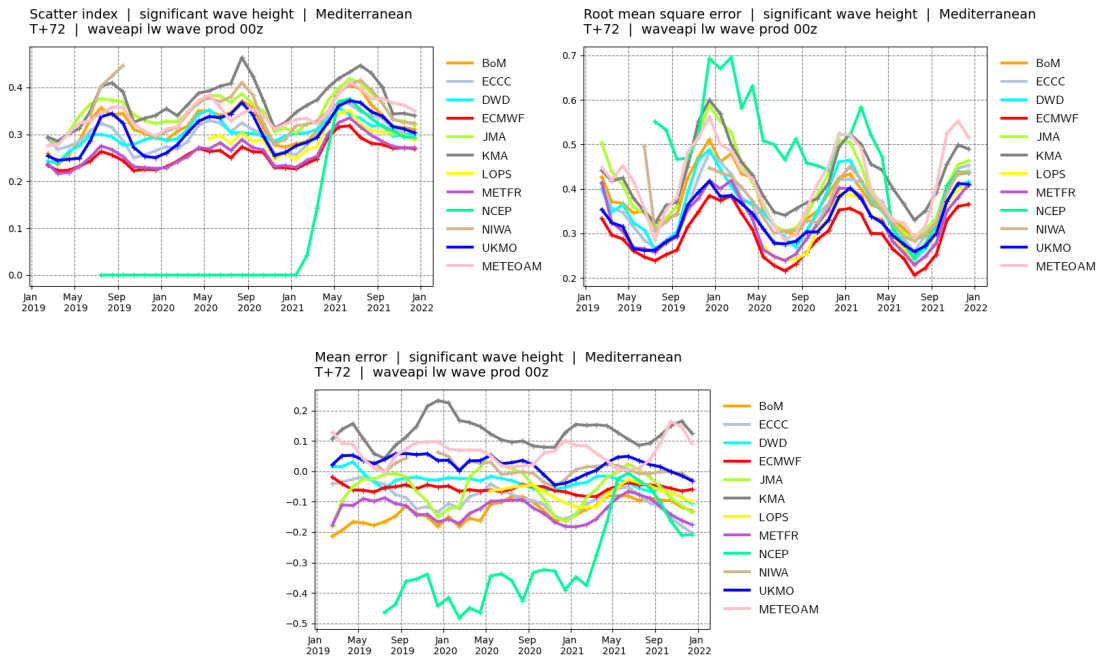
Buoys observations - from 20211201 to 20220228 - (swh)



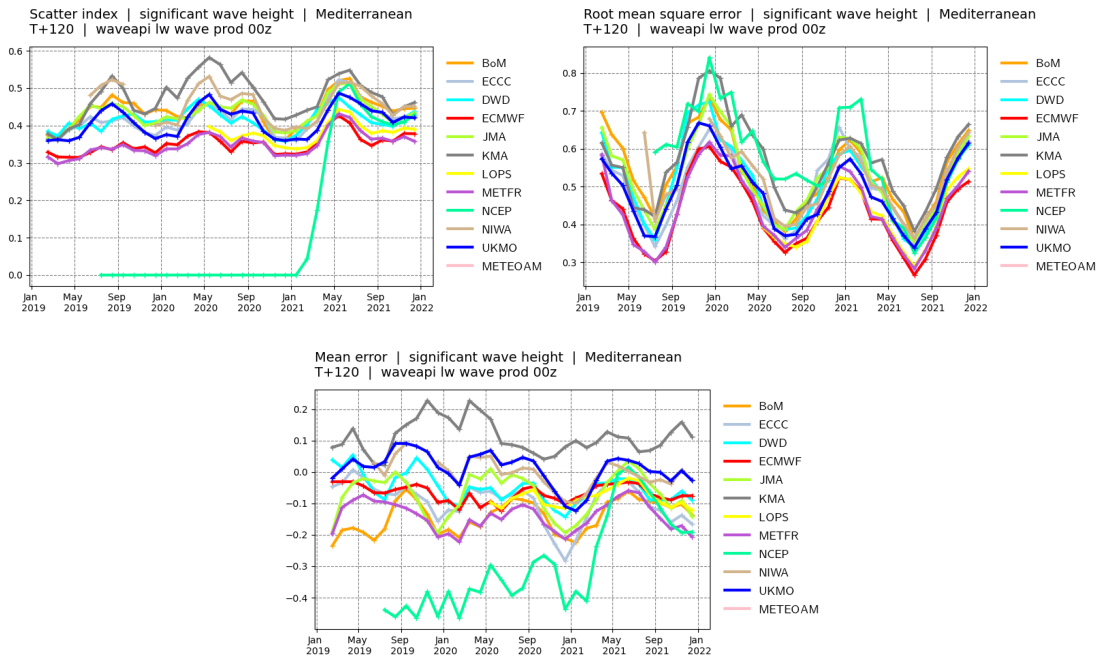
Mediterranean Sea. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

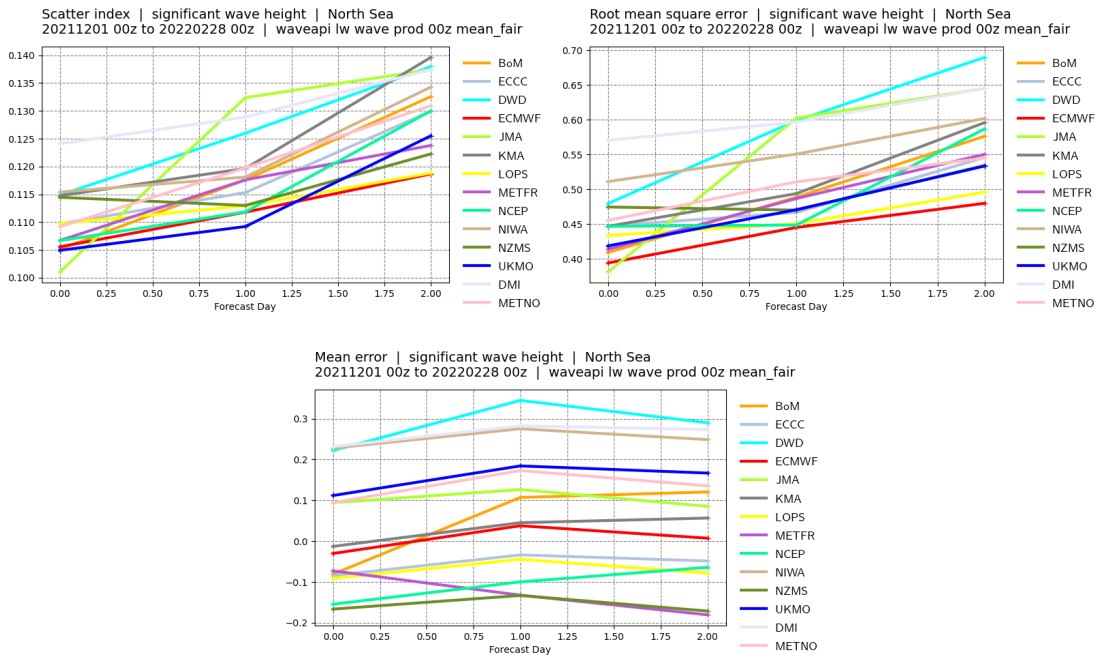
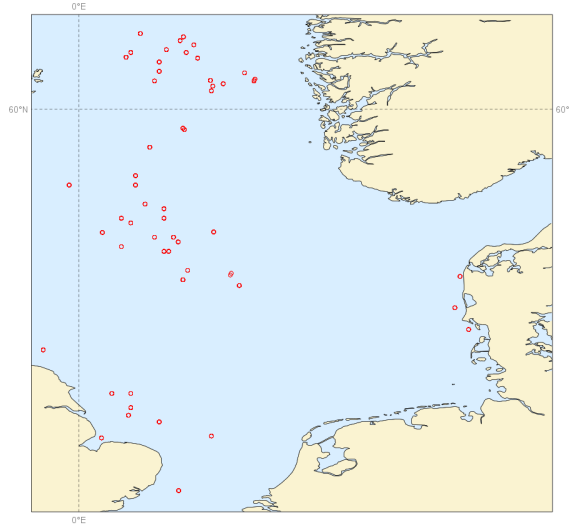


Mediterranean Sea. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

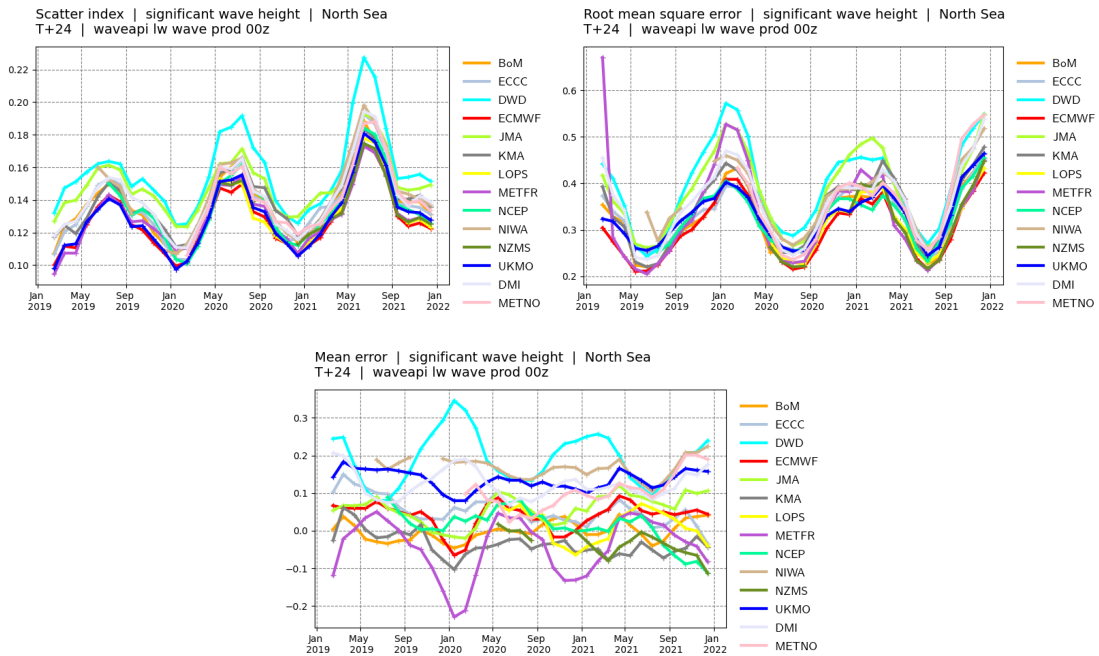


Mediterranean Sea. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

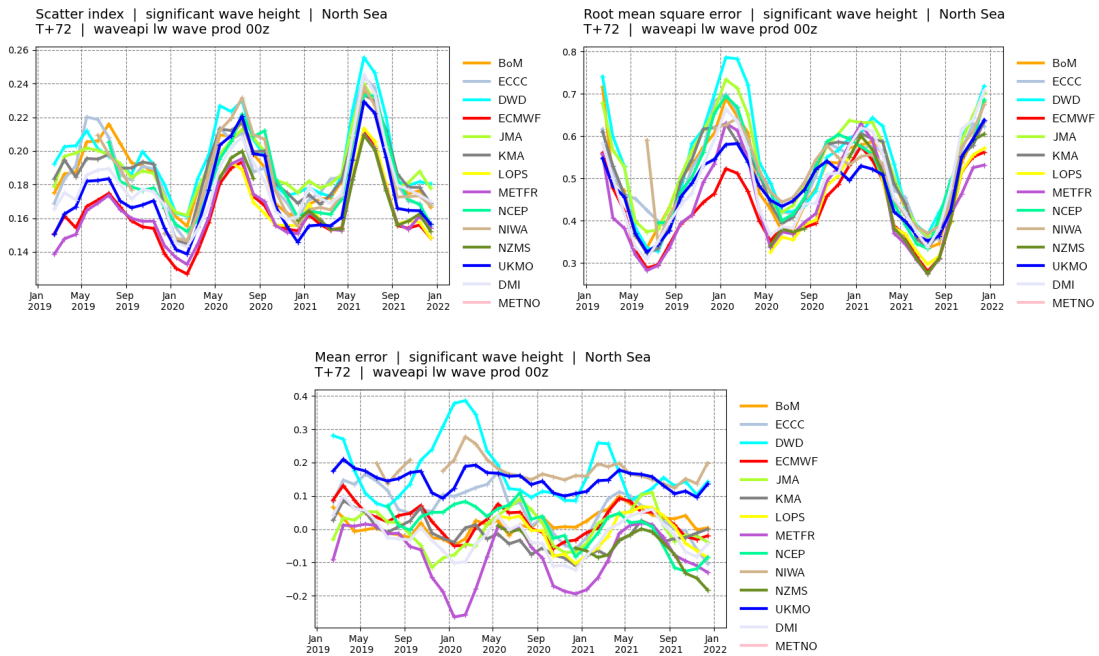
Buoys observations - from 20211201 to 20220228 - (swh)



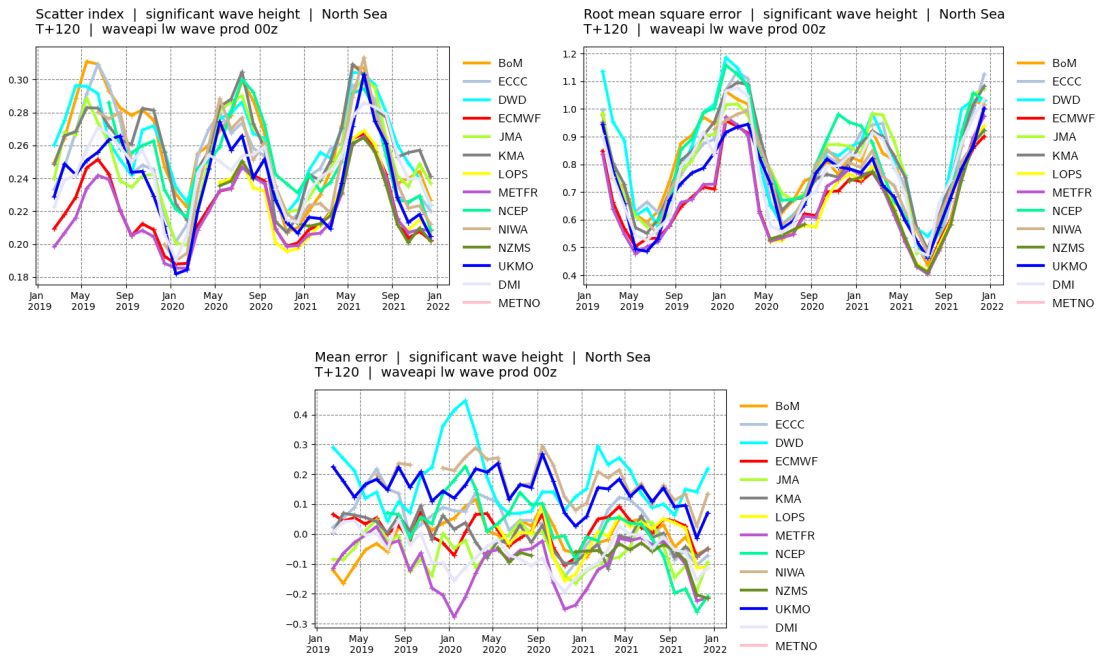
North Sea. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

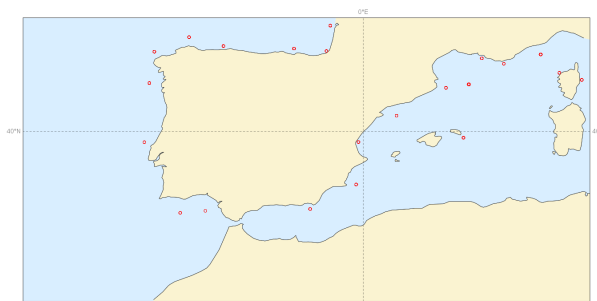


North Sea. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

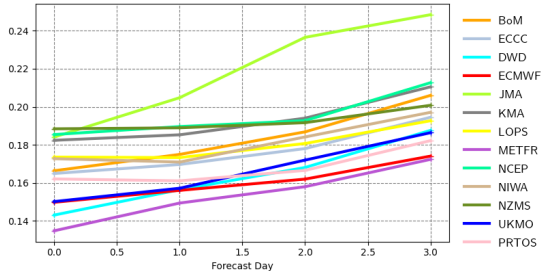


North Sea. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

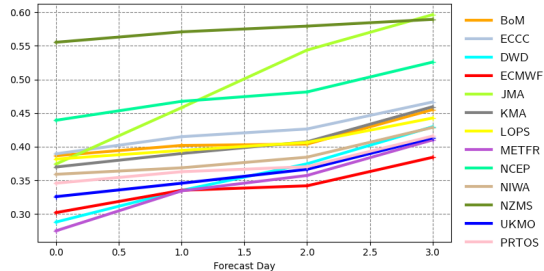
Buoys observations - from 20211201 to 20220228 - (swh)



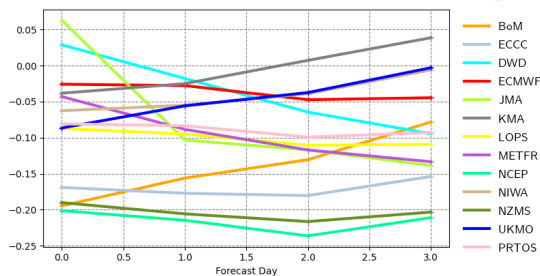
Scatter index | significant wave height | SW Europe
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



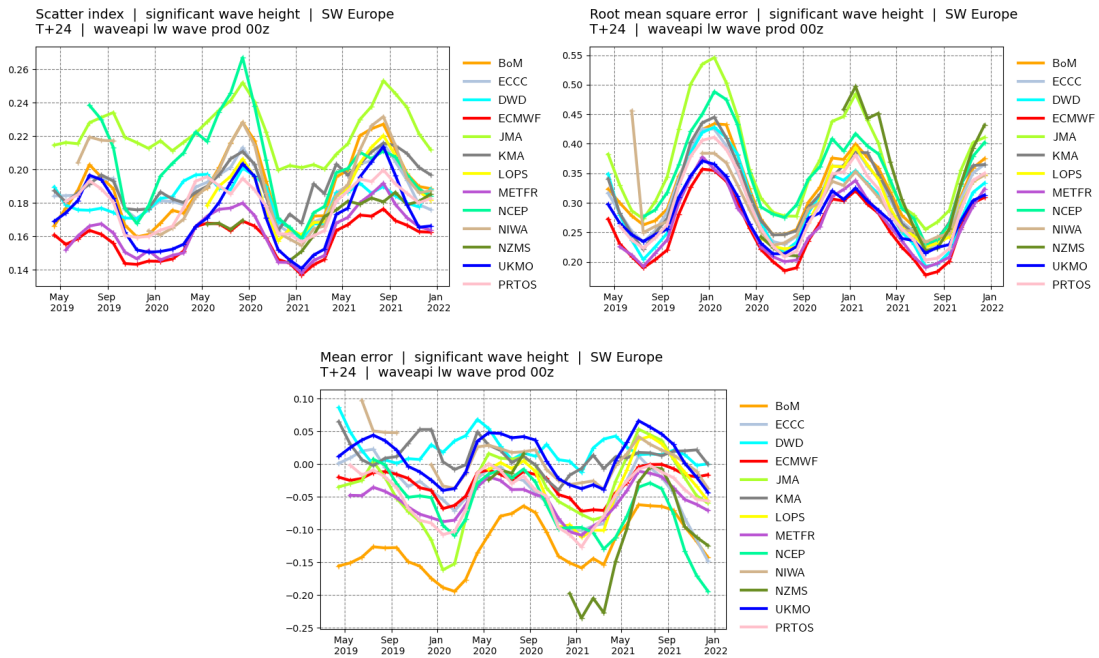
Root mean square error | significant wave height | SW Europe
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



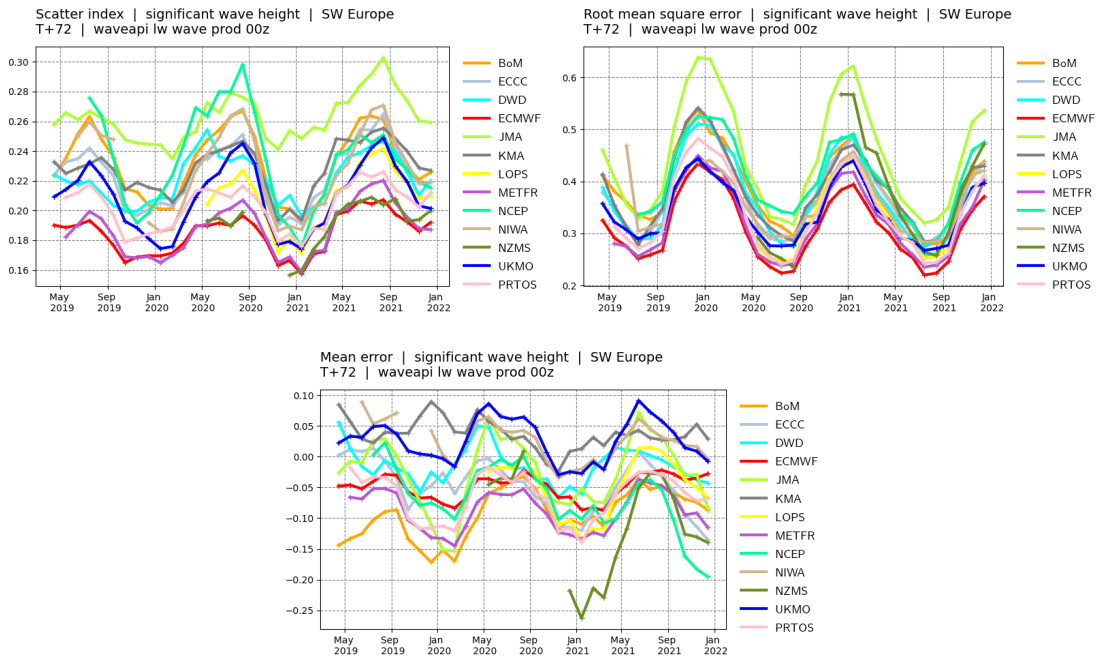
Mean error | significant wave height | SW Europe
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



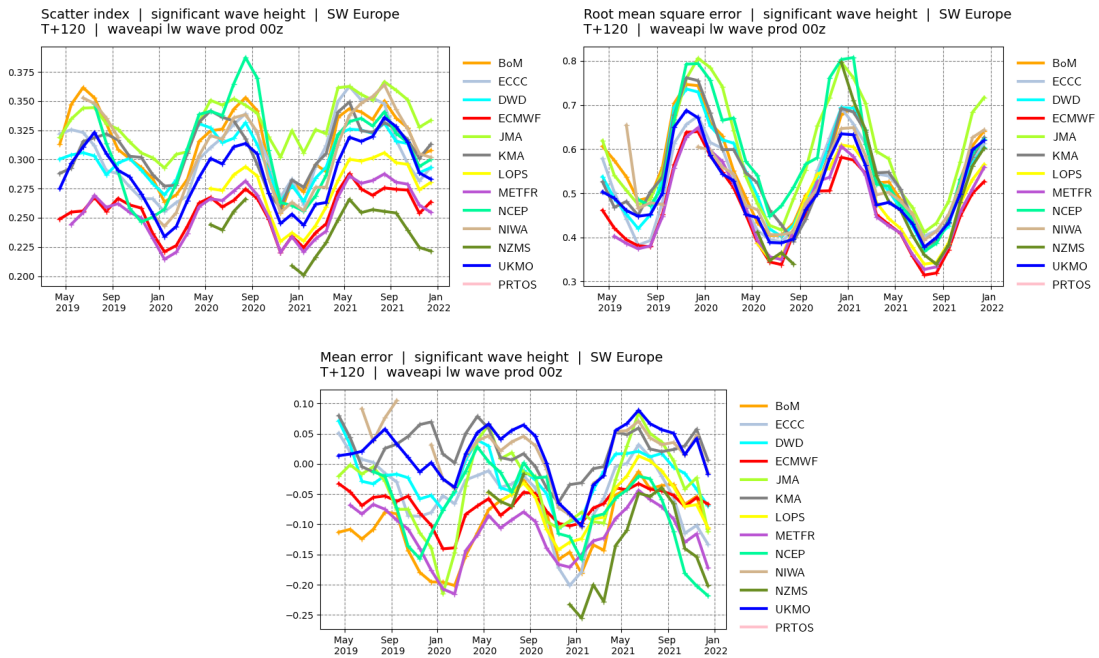
South West Europe. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

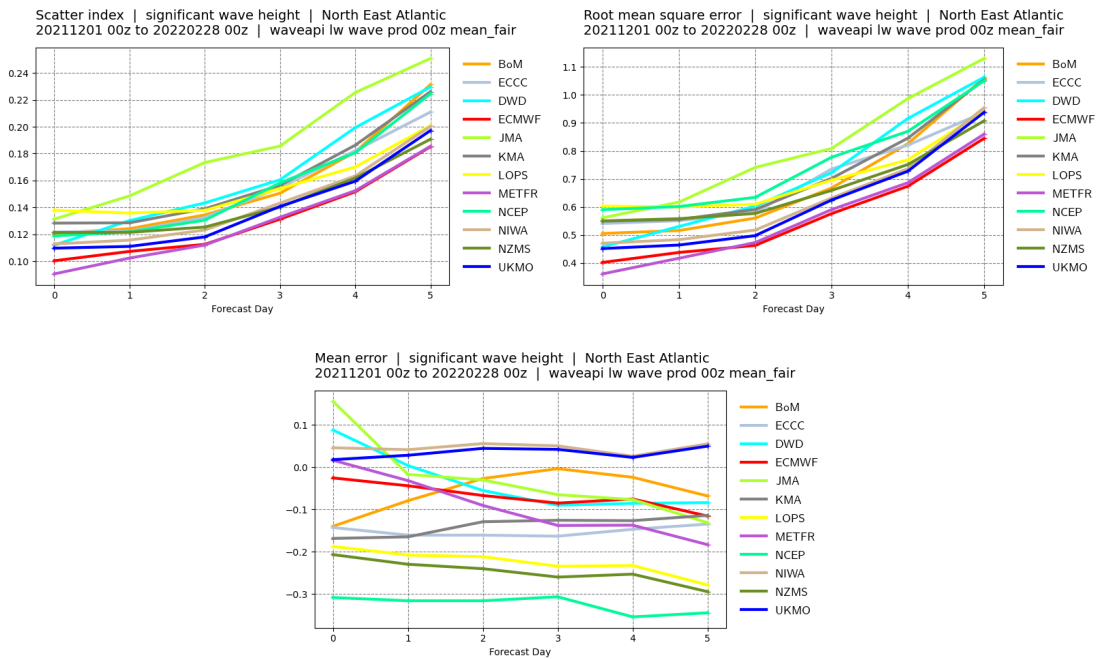
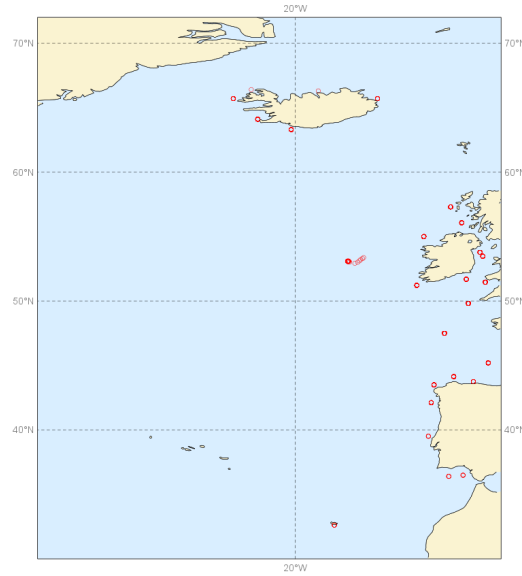


South West Europe. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

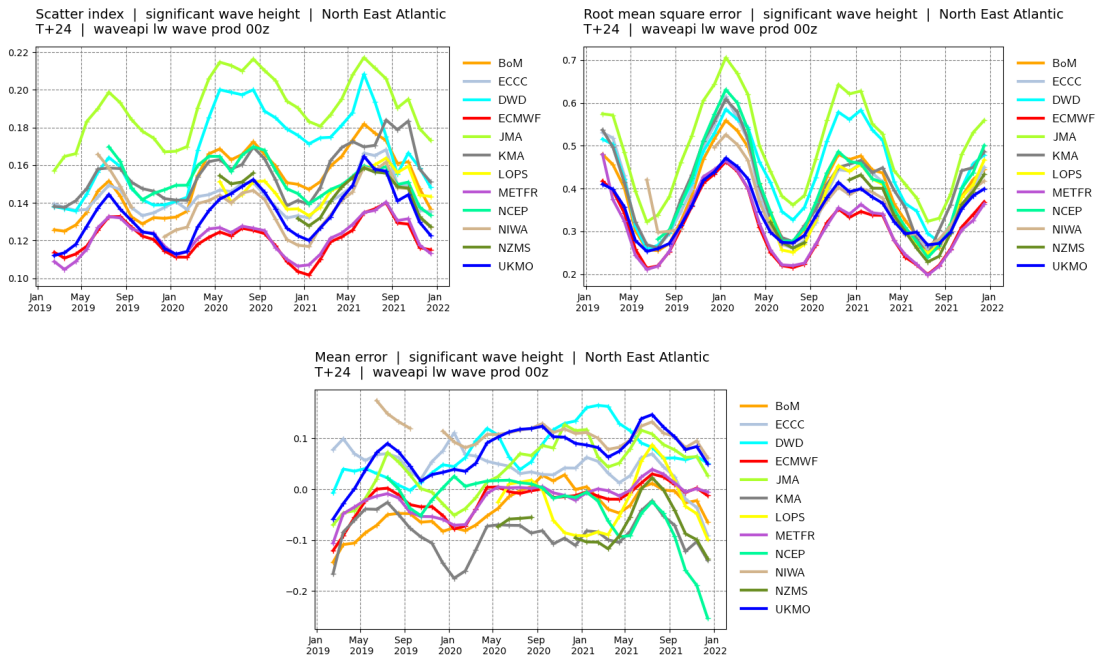


South West Europe. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

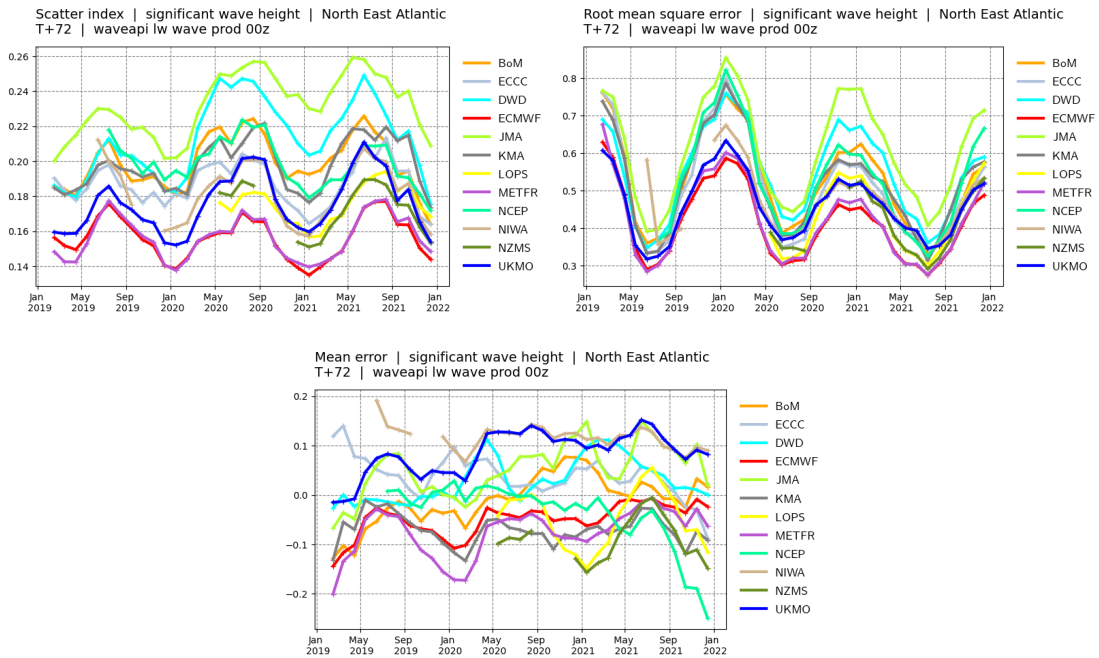
Buoys observations - from 20211201 to 20220228 - (swH)



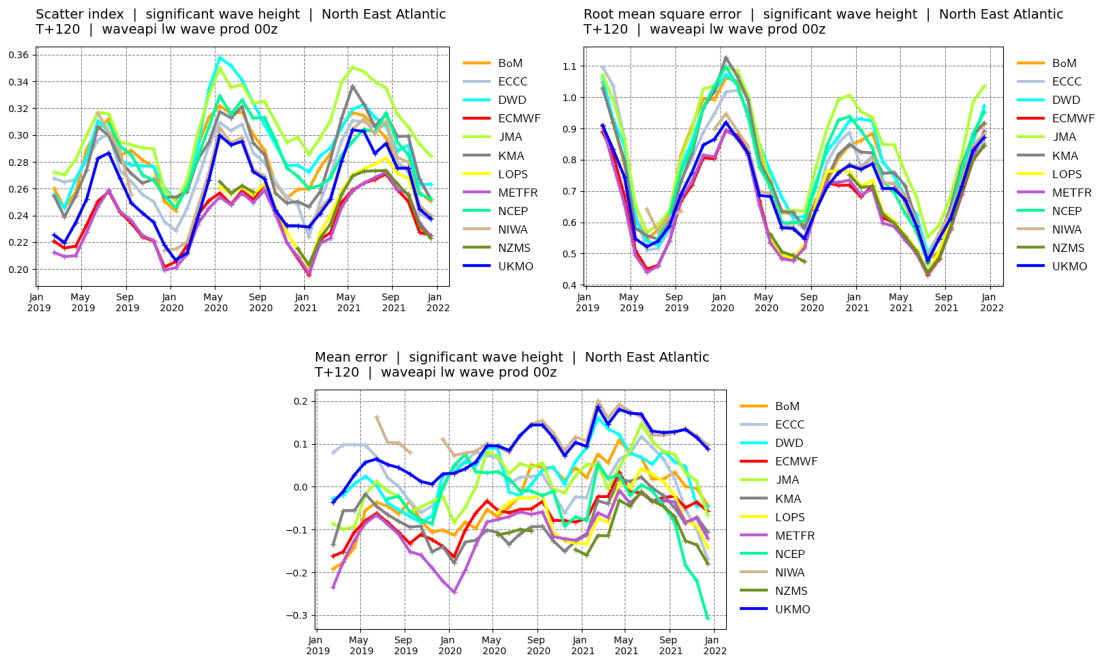
North East Atlantic. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

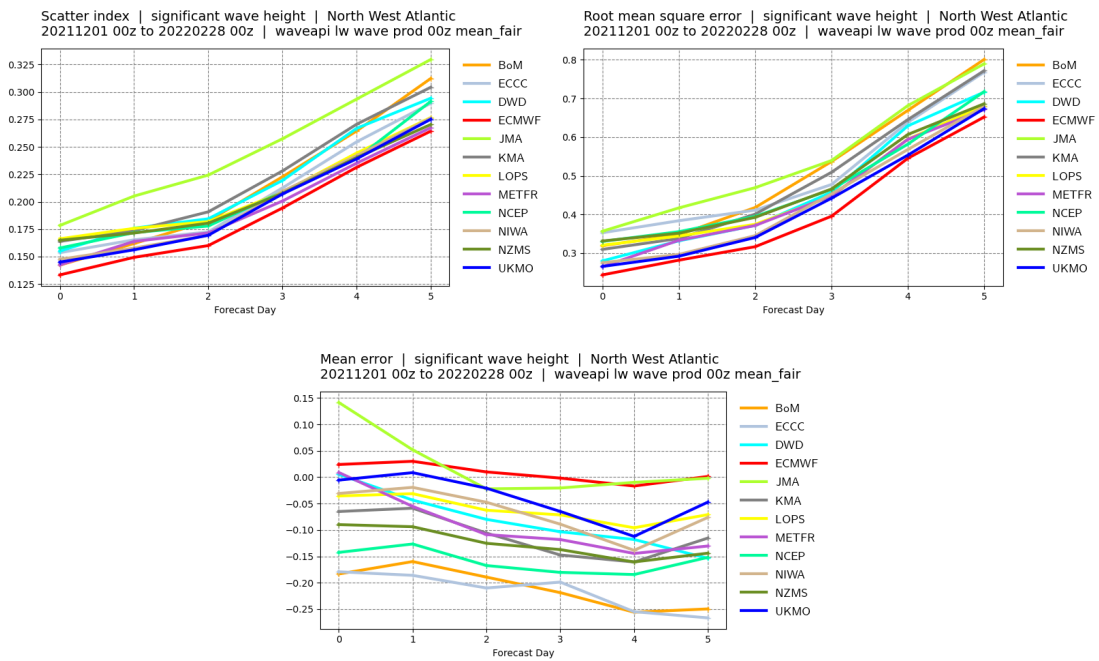
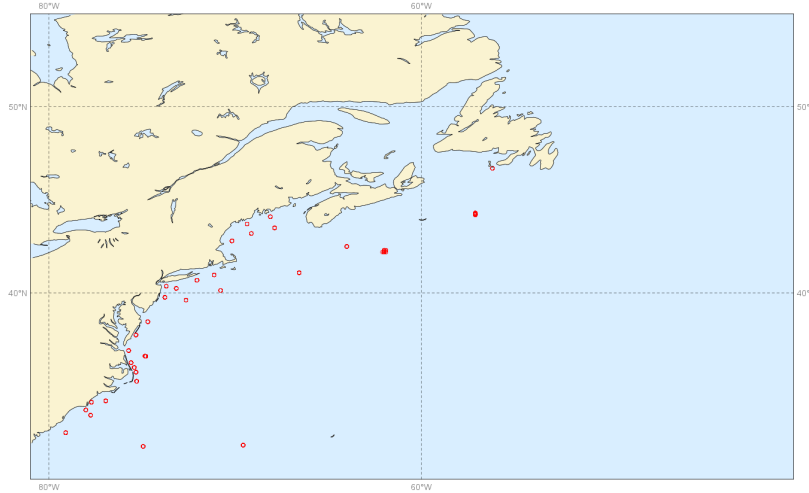


North East Atlantic. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

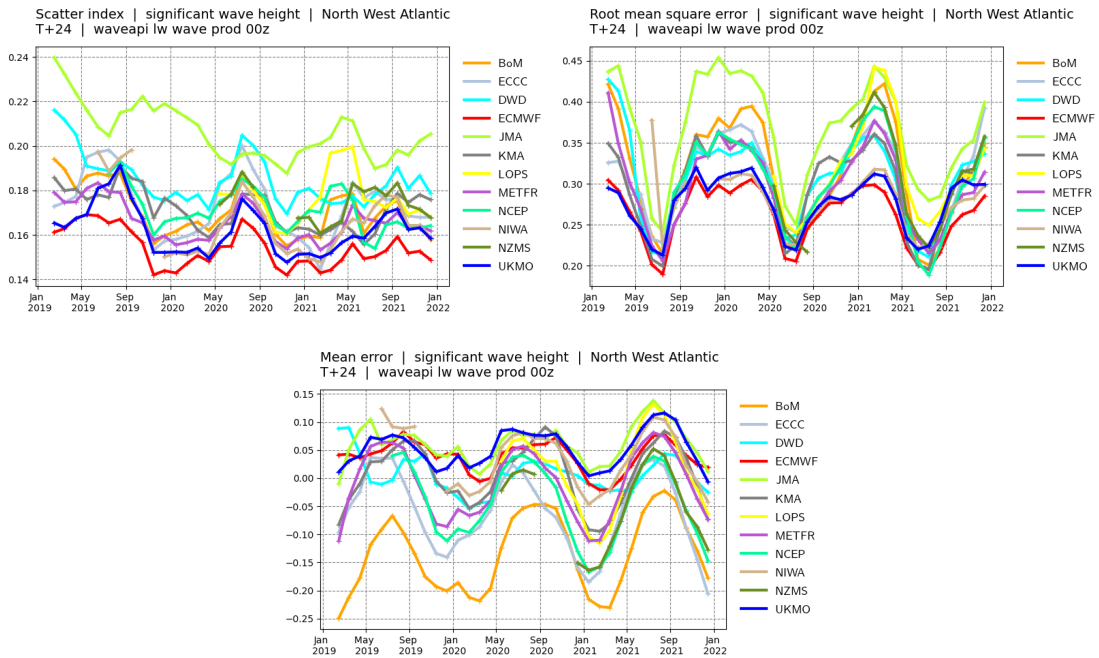


North East Atlantic. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

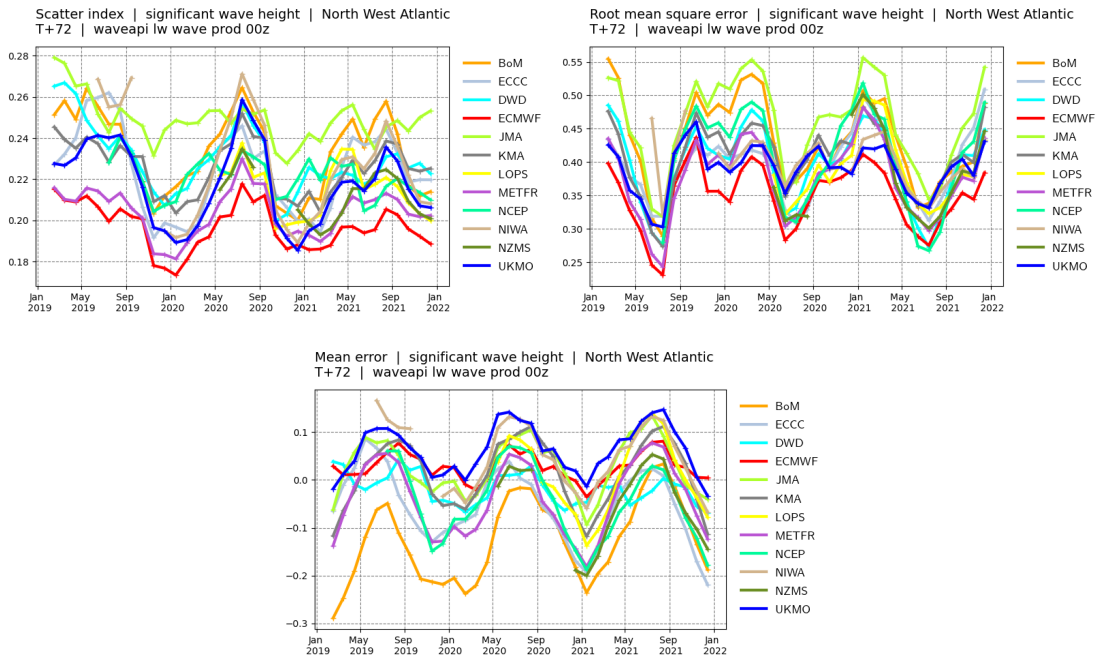
Buoys observations - from 20211201 to 20220228 - (swh)



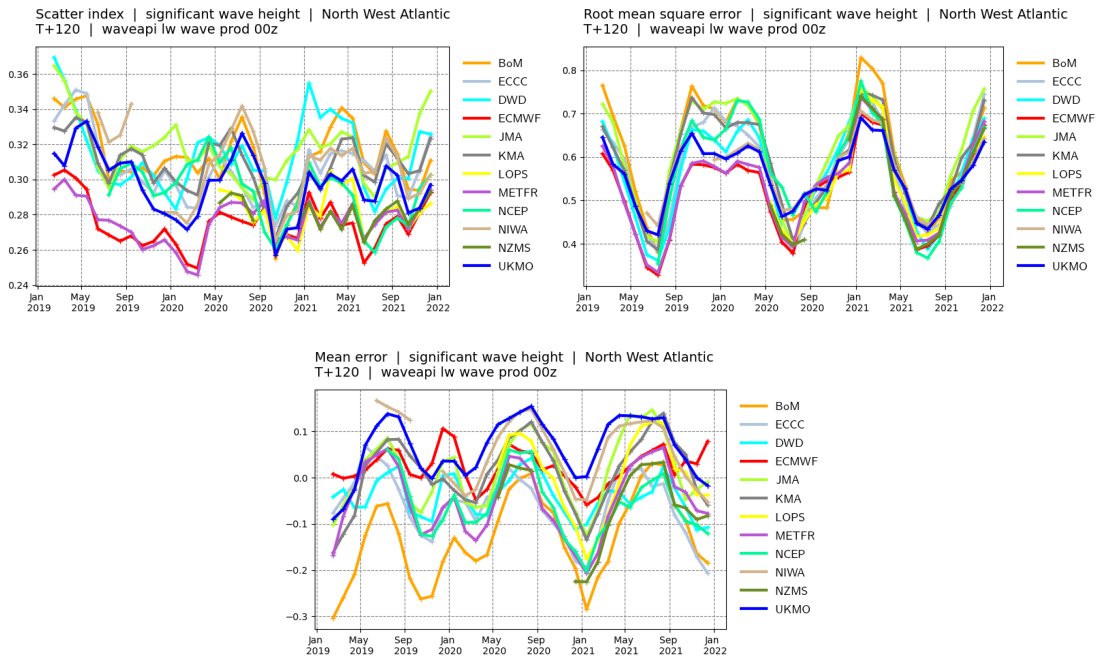
North West Atlantic. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



North 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).

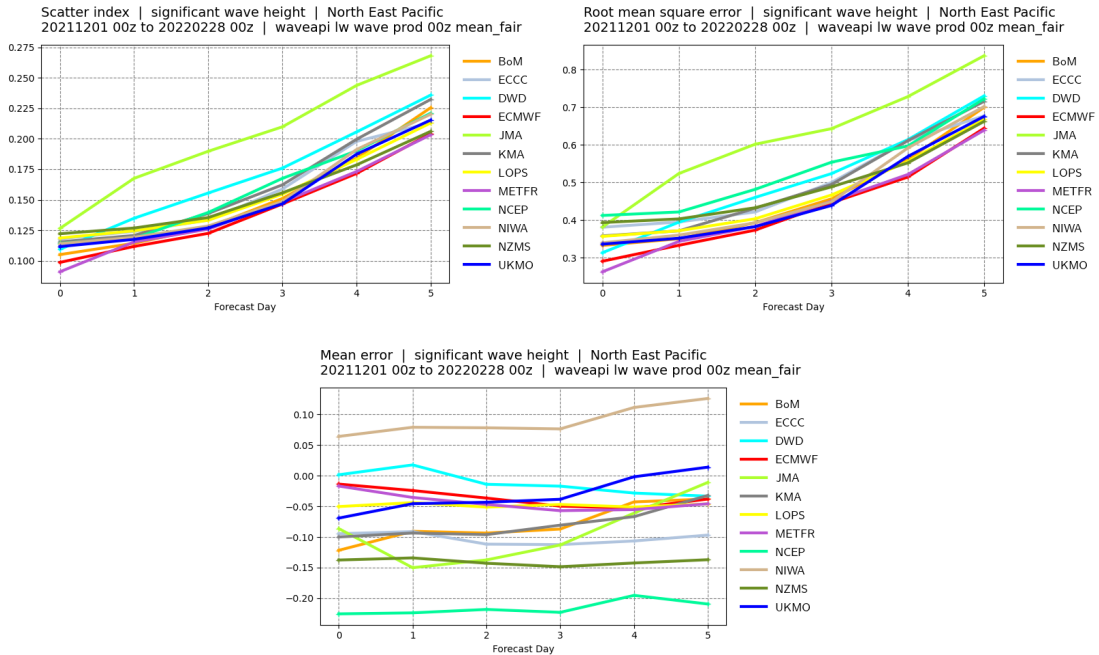
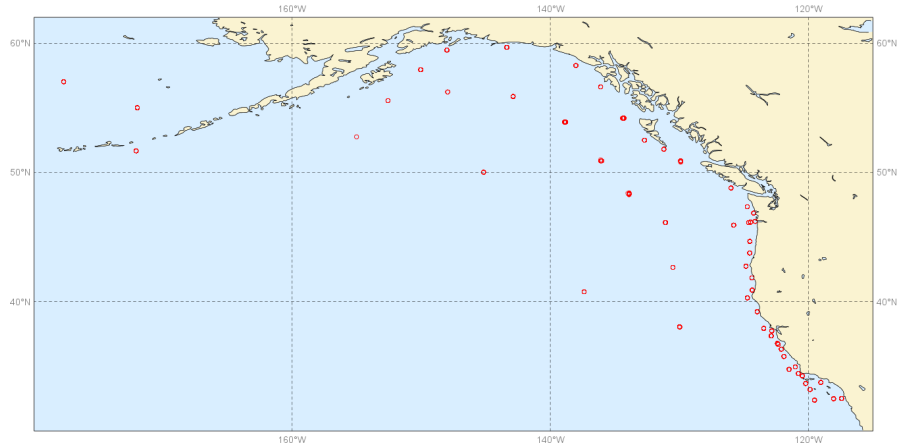


North West Atlantic. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

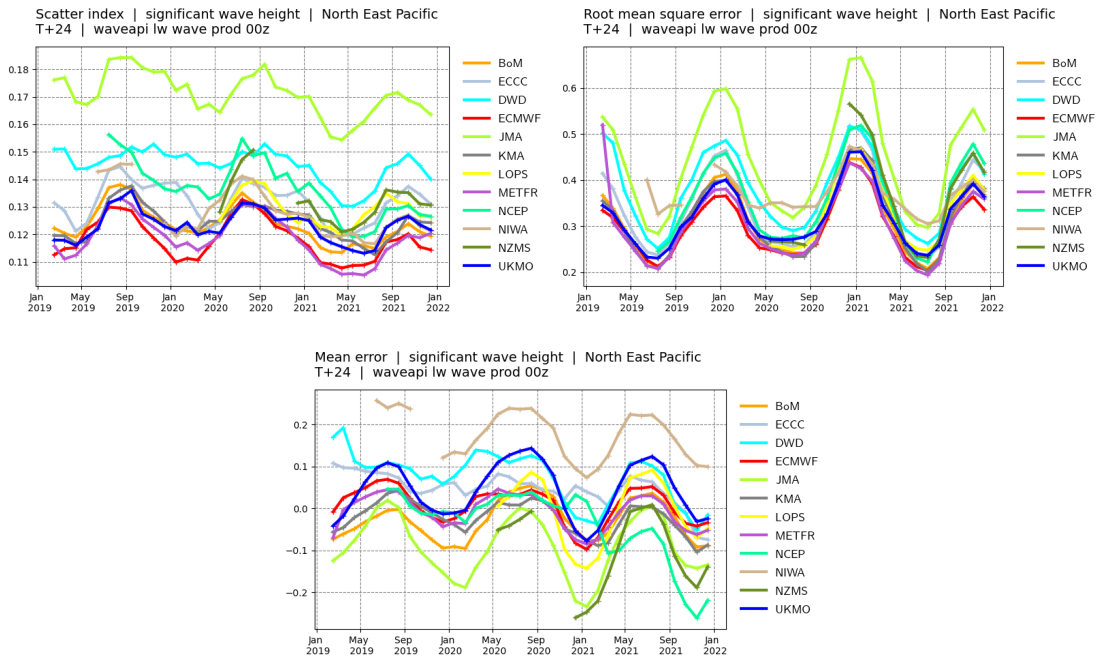


North West Atlantic. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

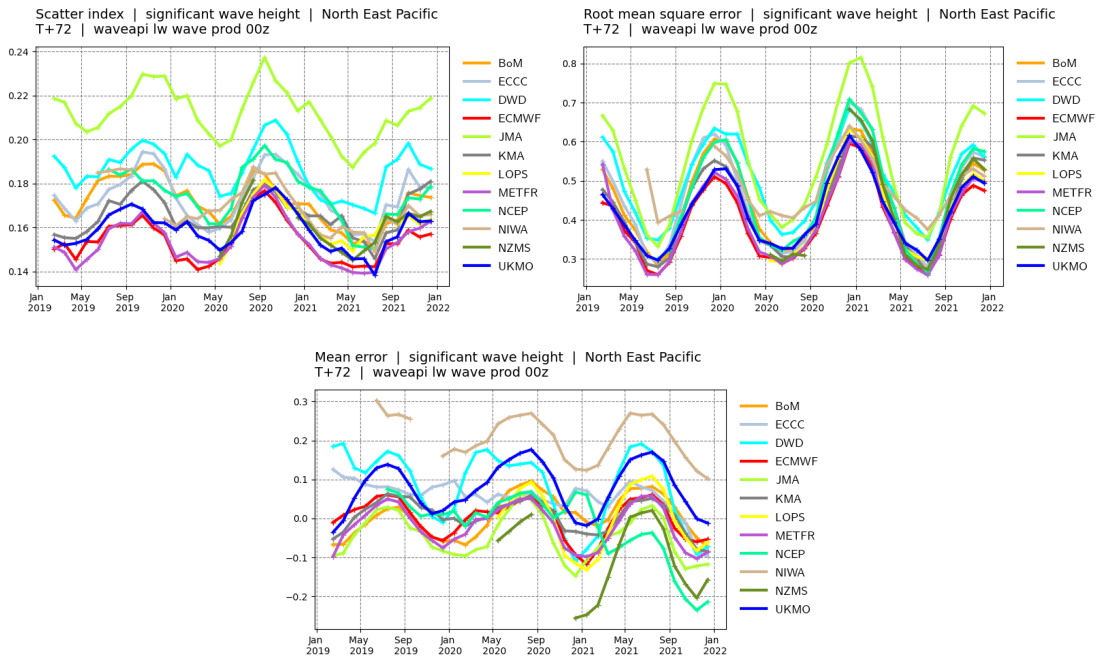
Buoys observations - from 20211201 to 20220228 - (swh)



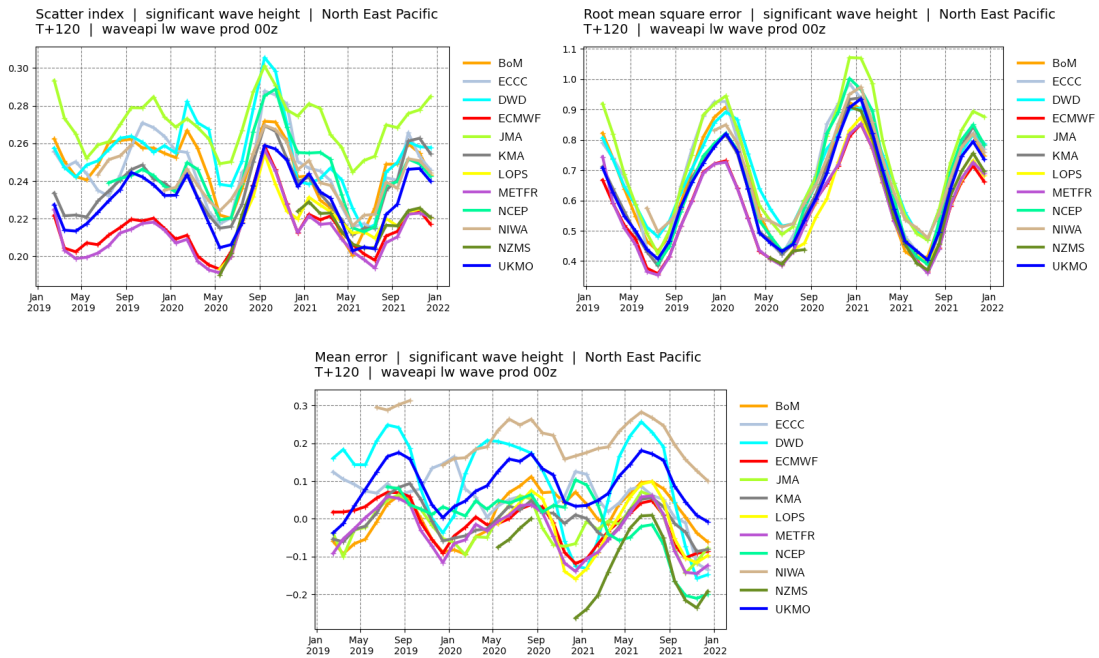
North East Pacific. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

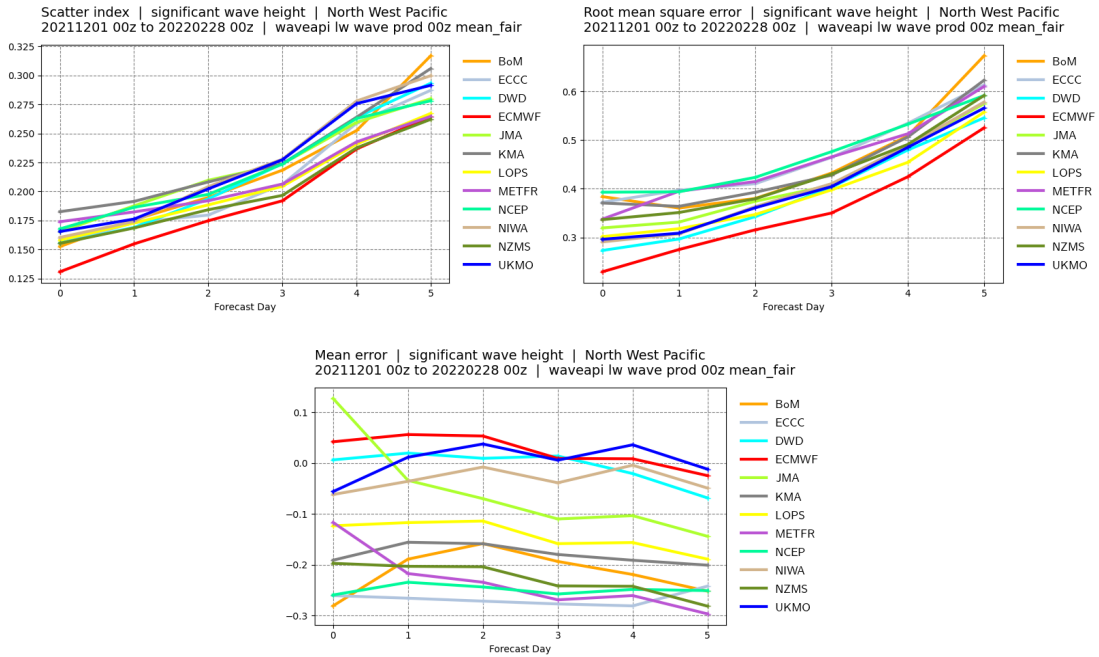
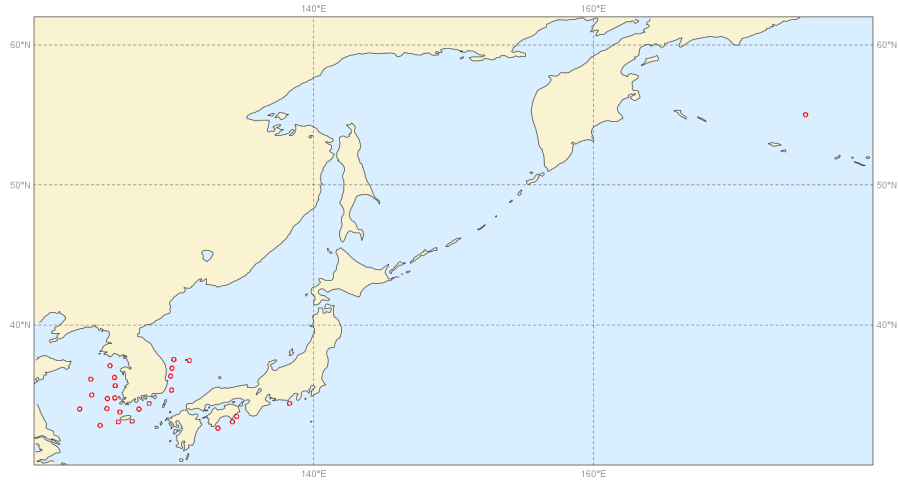


North East Pacific. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

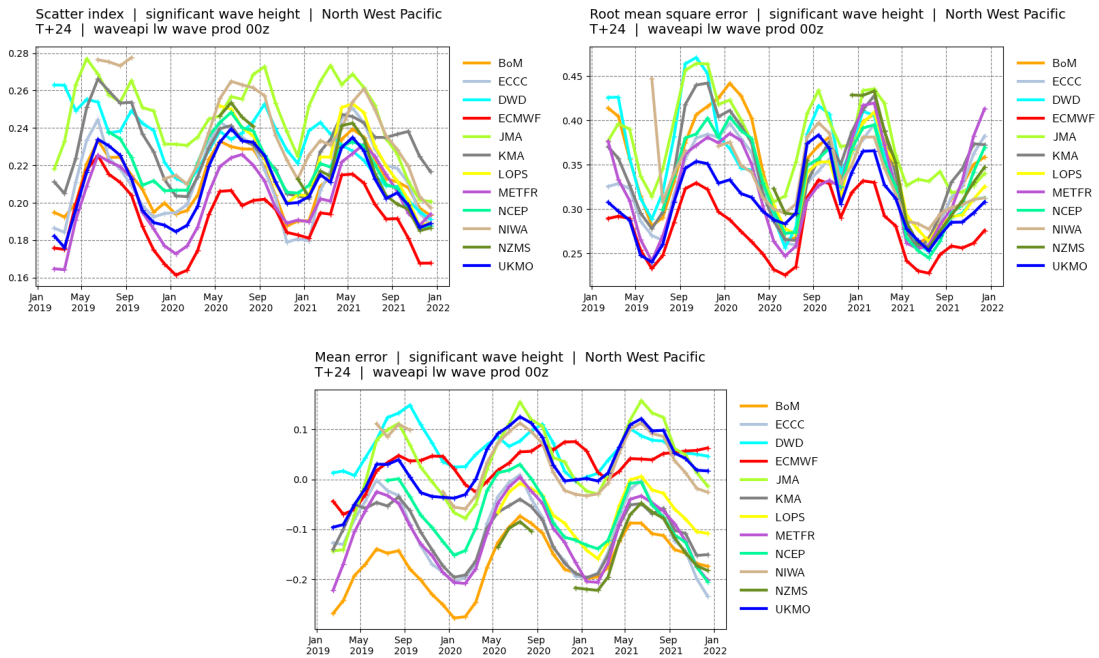


North East Pacific. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

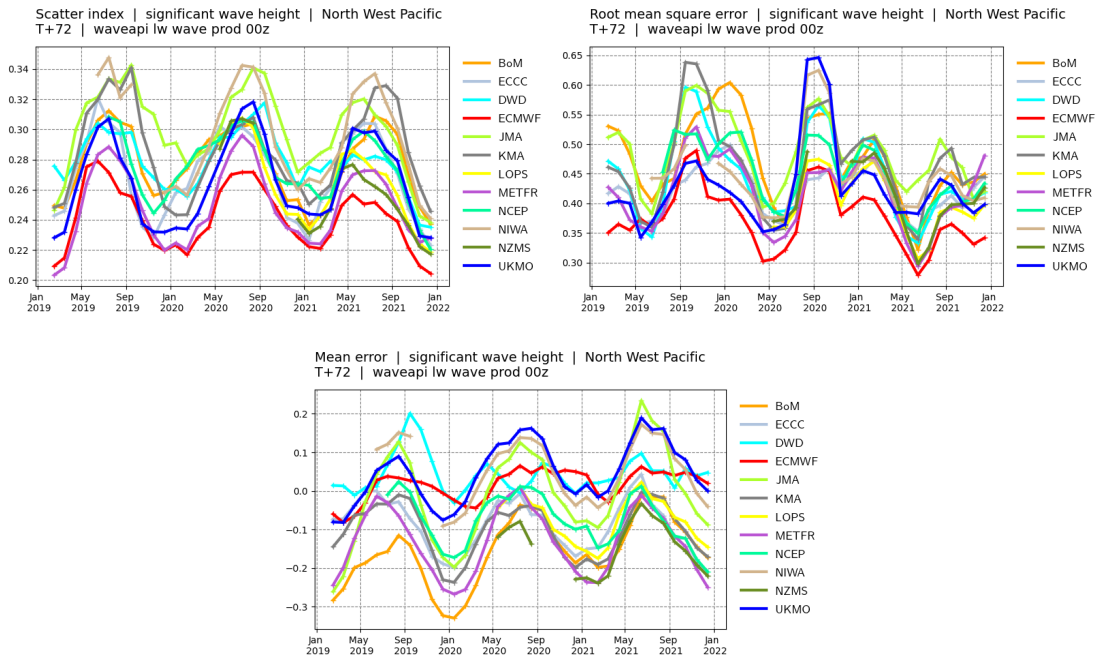
Buoys observations - from 20211201 to 20220228 - (swh)



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).

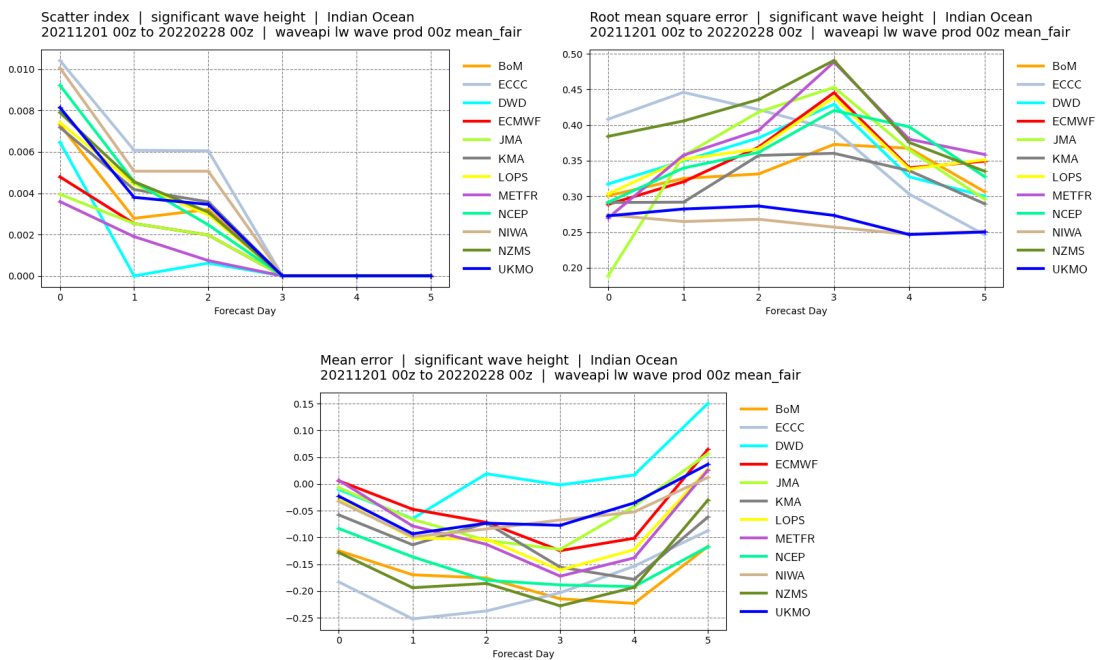
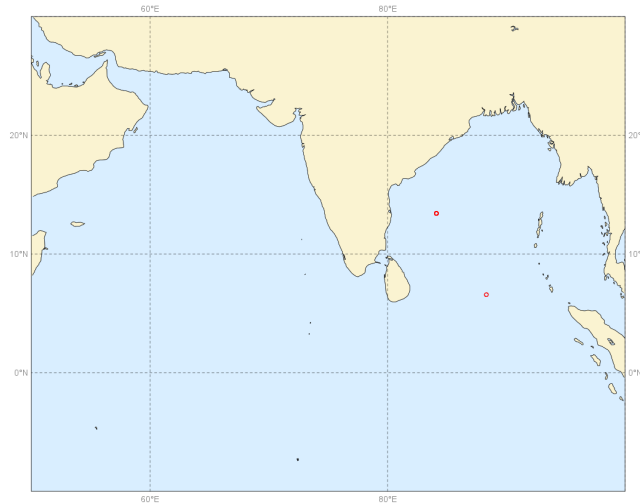


North West Pacific. Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

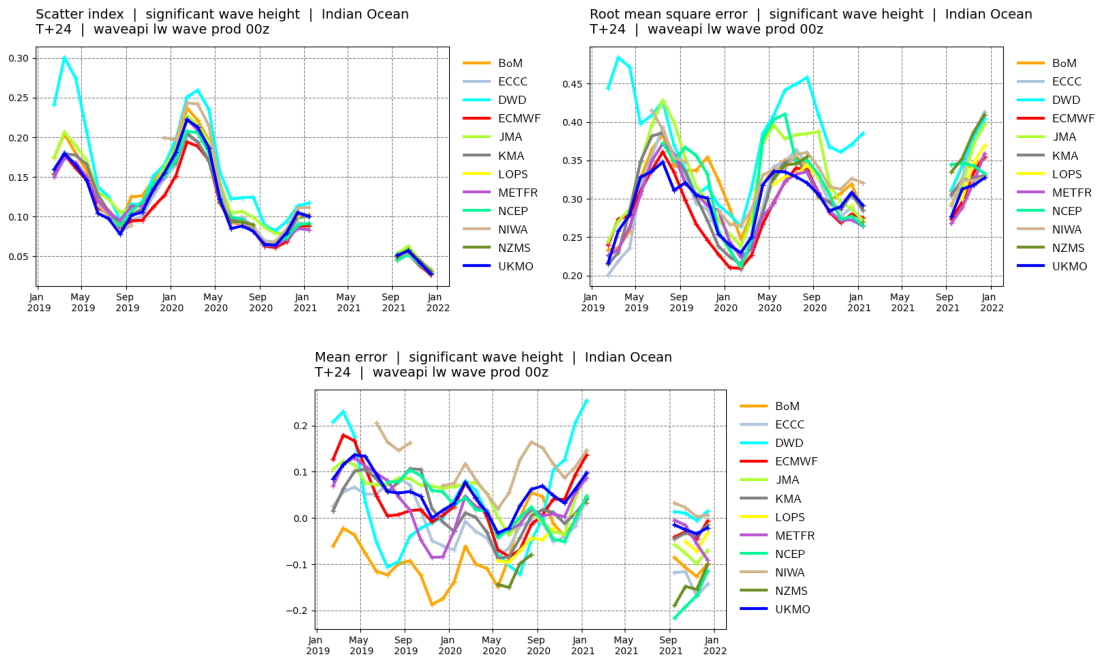


North West Pacific. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

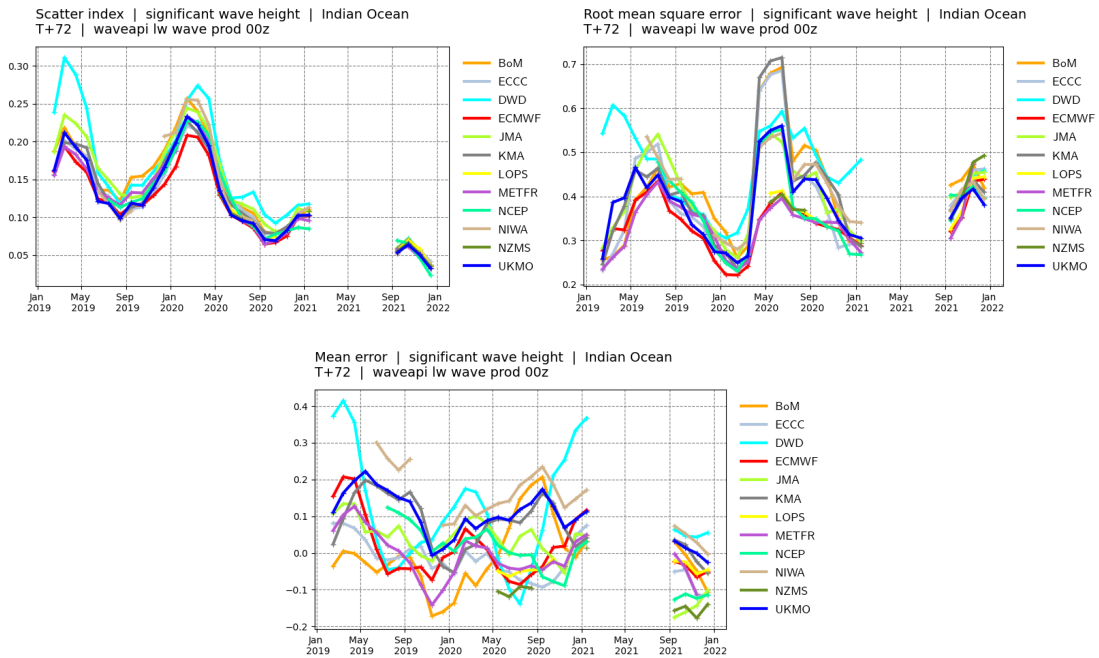
Buoys observations - from 20211201 to 20220228 - (swh)



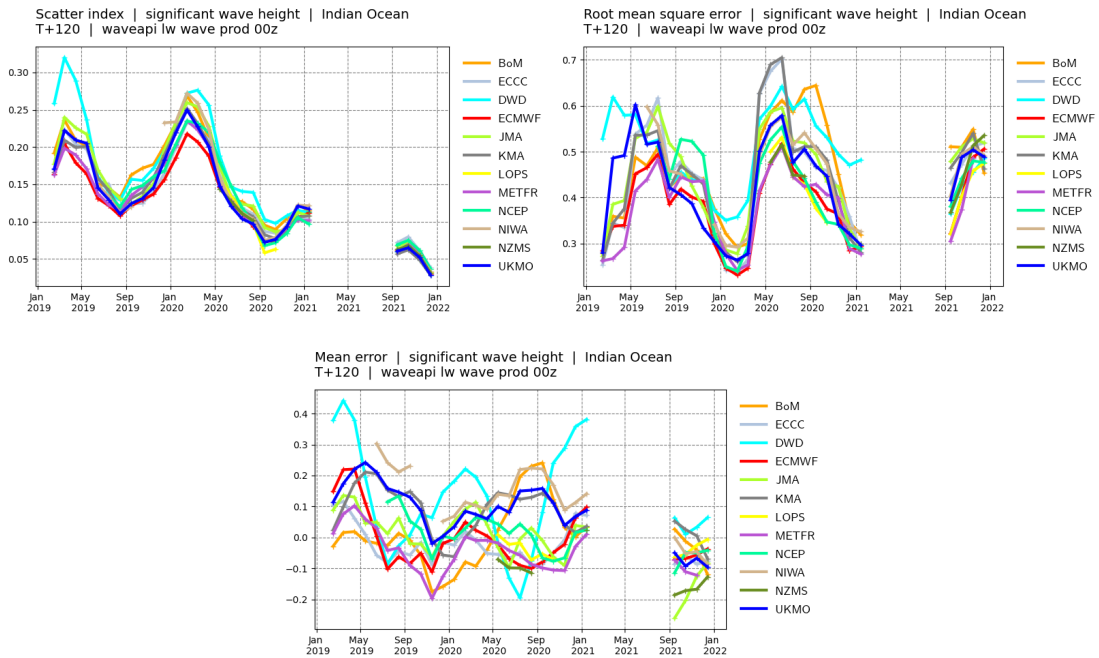
Indian Ocean. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

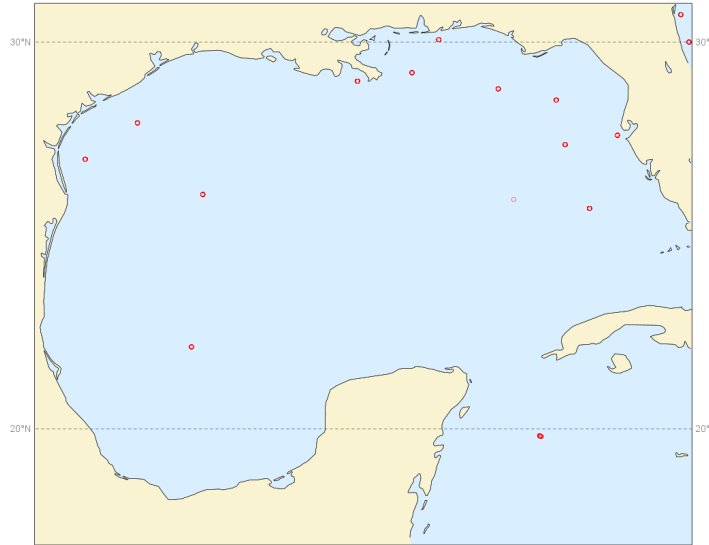


Indian Ocean. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

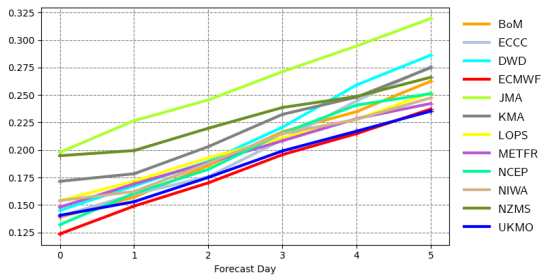


Indian Ocean. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

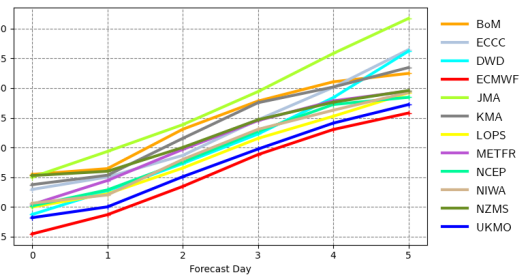
Buoys observations - from 20211201 to 20220228 - (swh)



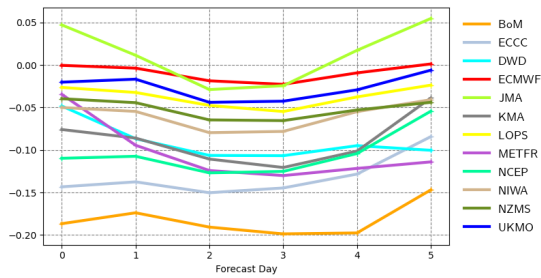
Scatter index | significant wave height | Gulf of Mexico
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



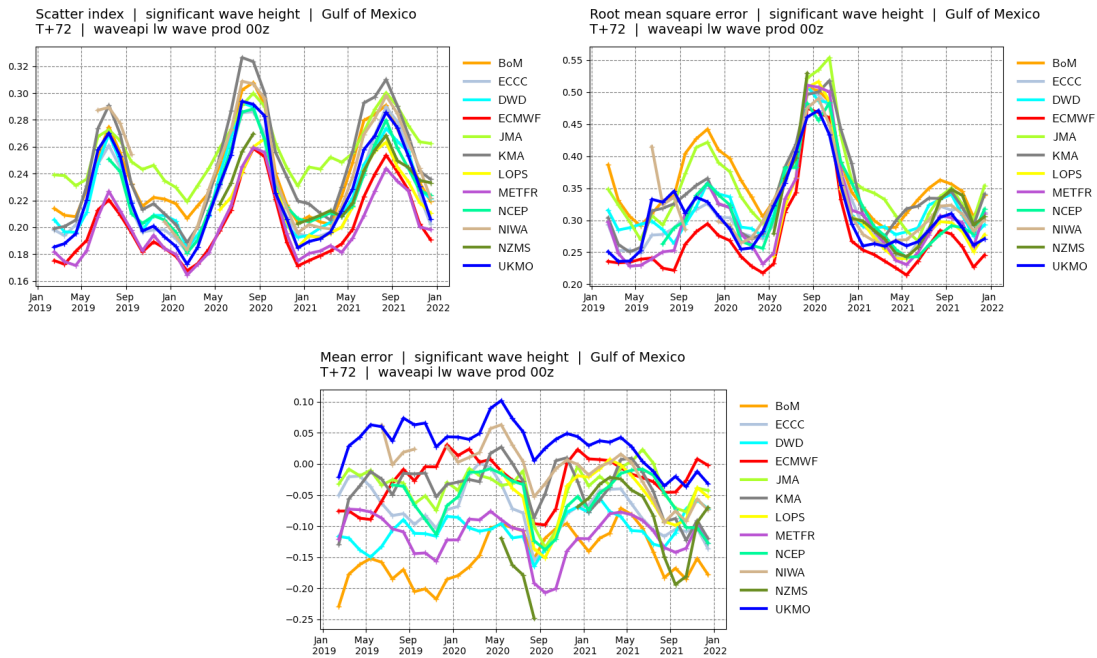
Root mean square error | significant wave height | Gulf of Mexico
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



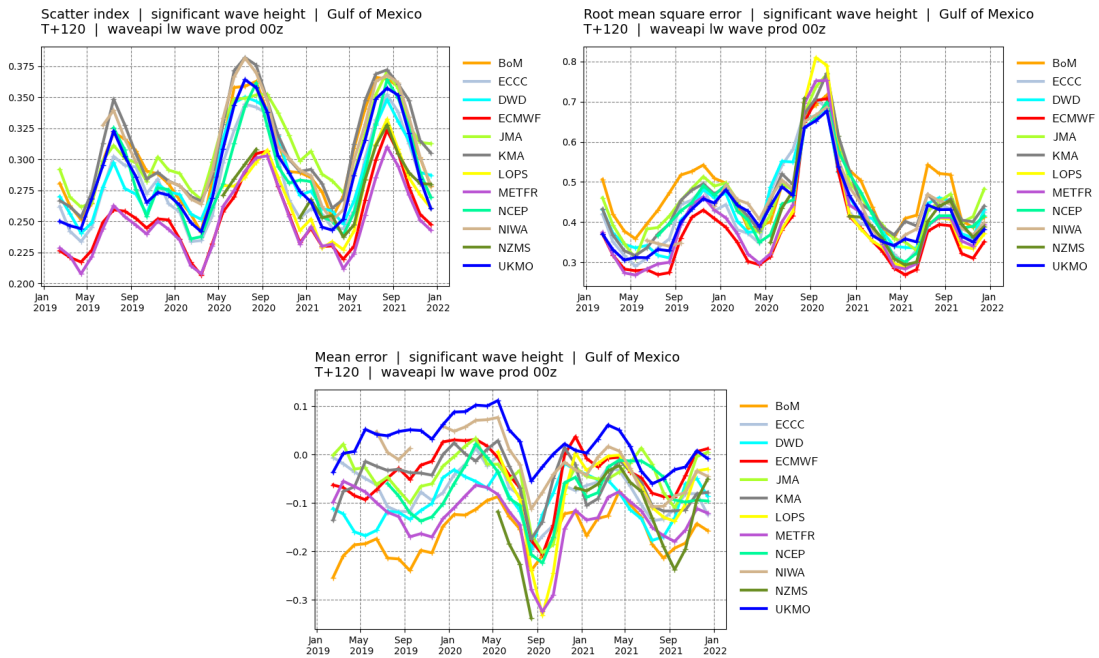
Mean error | significant wave height | Gulf of Mexico
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



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).

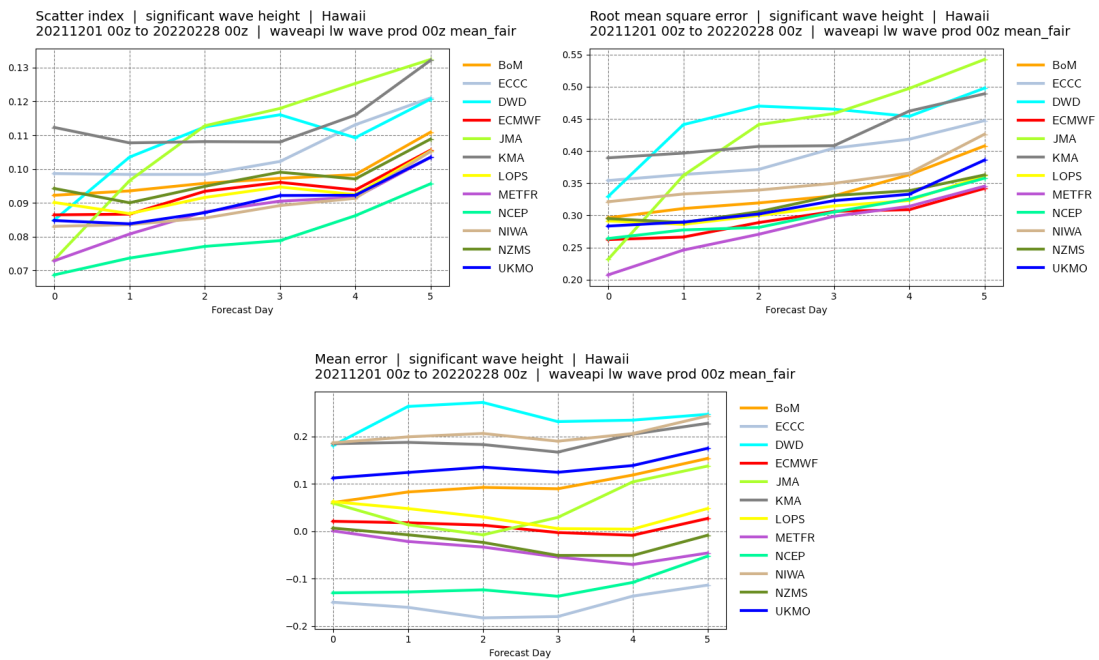
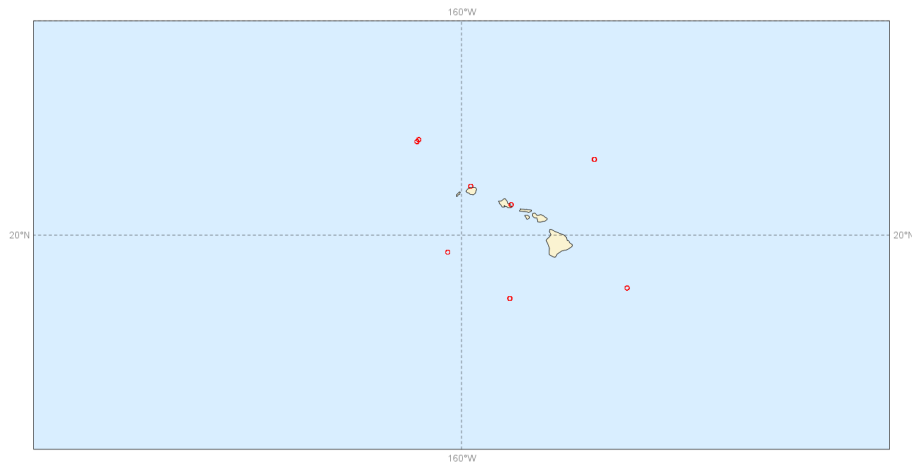


Gulf of Mexico. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

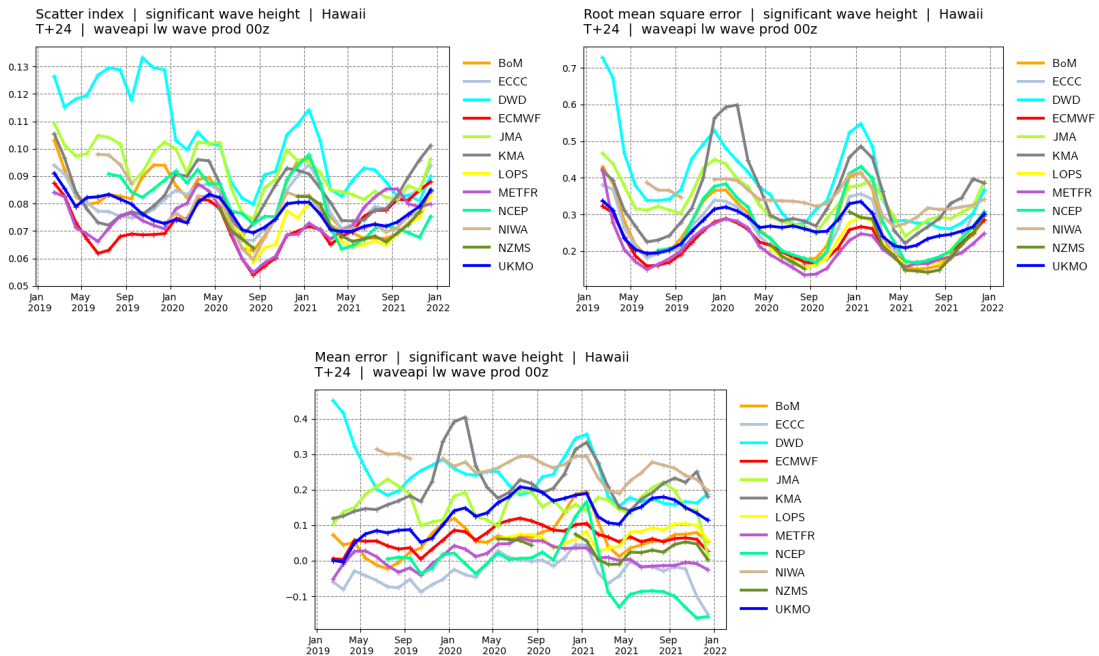


Gulf of Mexico. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

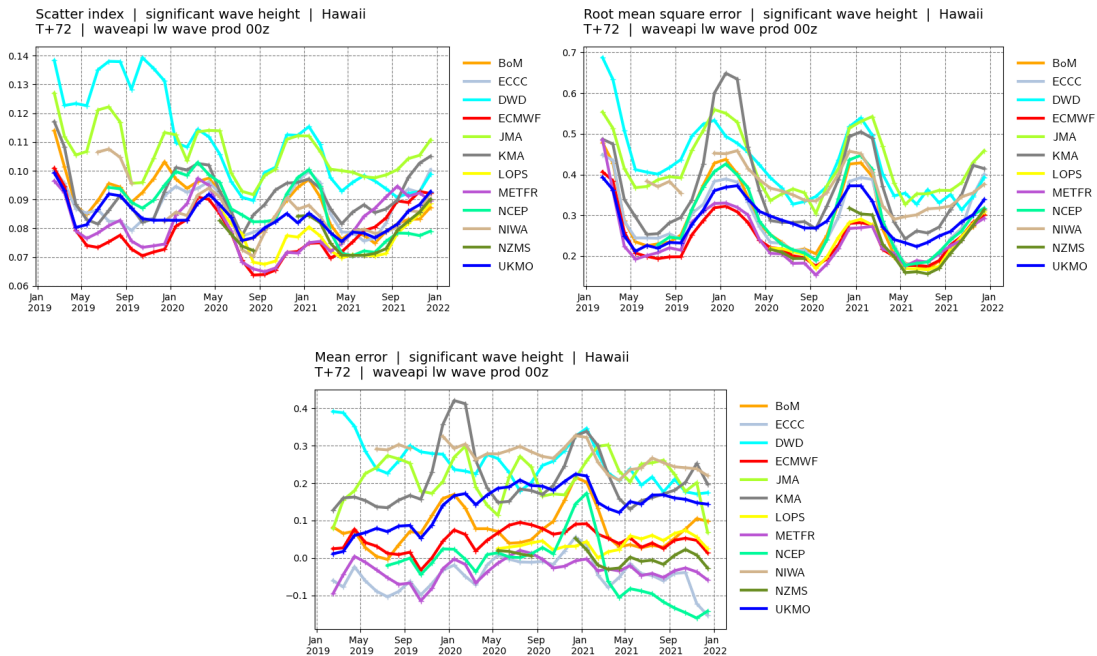
Buoys observations - from 20211201 to 20220228 - (swh)



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).

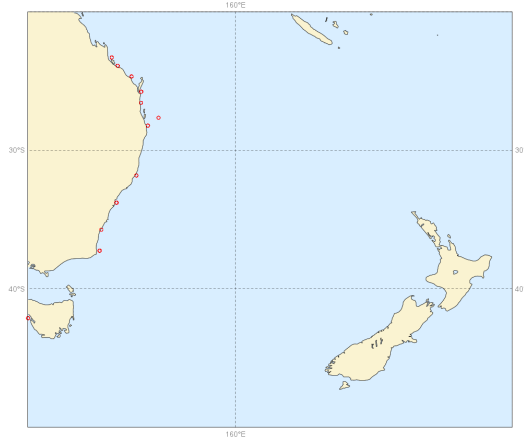


Hawaii. Scores time-series at **day 1**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

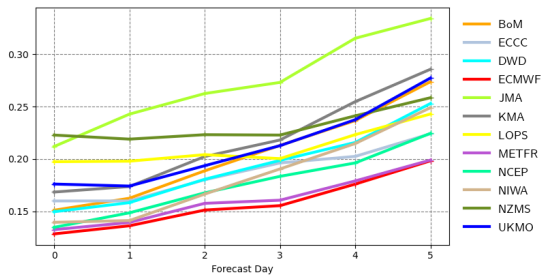


Hawaii. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

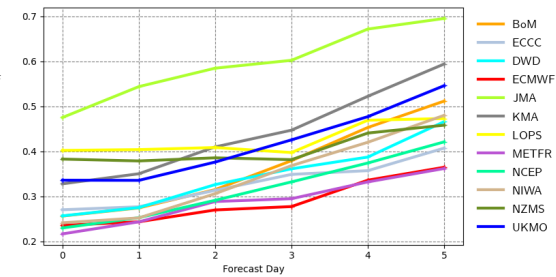
Buoys observations - from 20211201 to 20220228 - (swh)



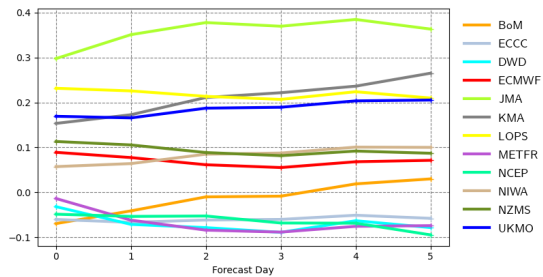
Scatter index | significant wave height | Eastern Australia and New Zealand
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



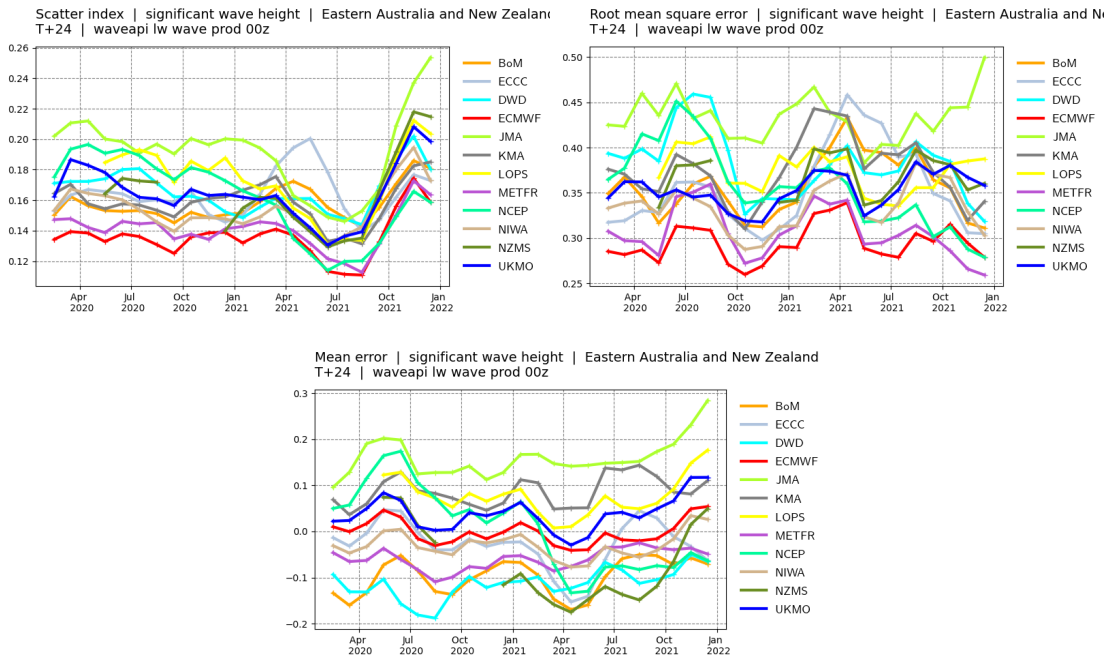
Root mean square error | significant wave height | Eastern Australia and New Zealand
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



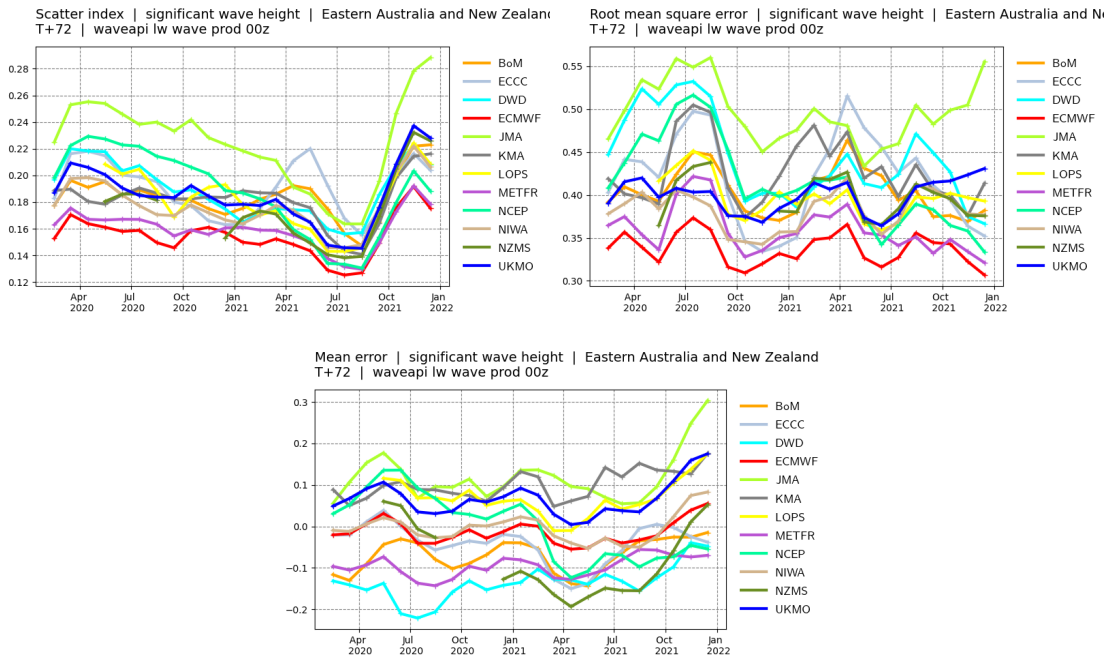
Mean error | significant wave height | Eastern Australia and New Zealand
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



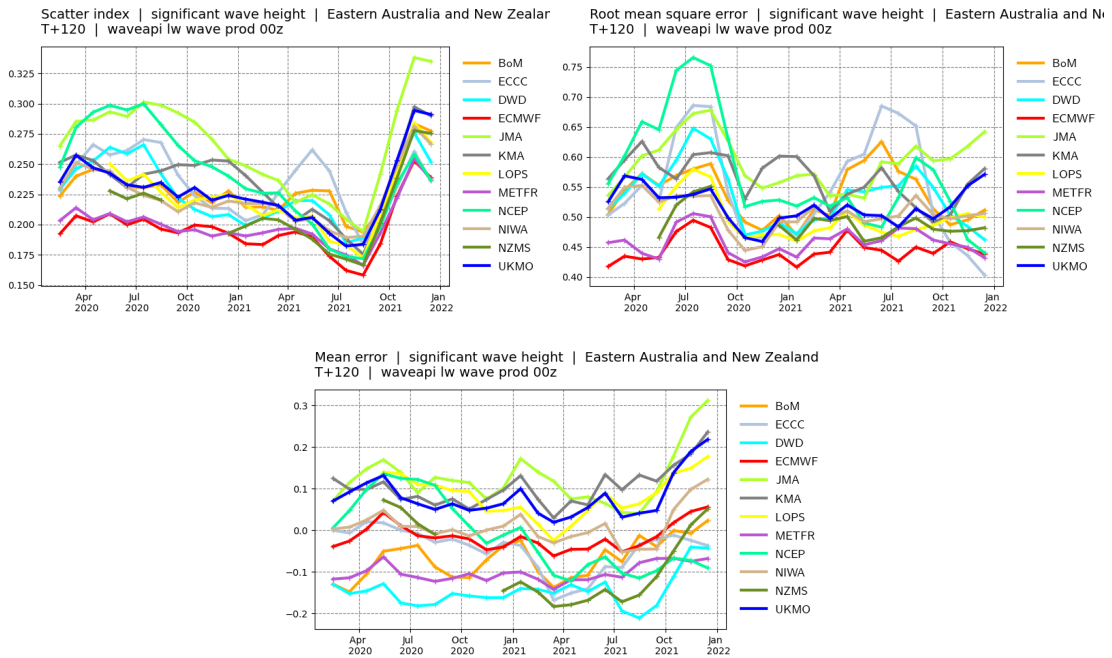
East Australia - New Zealand. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).

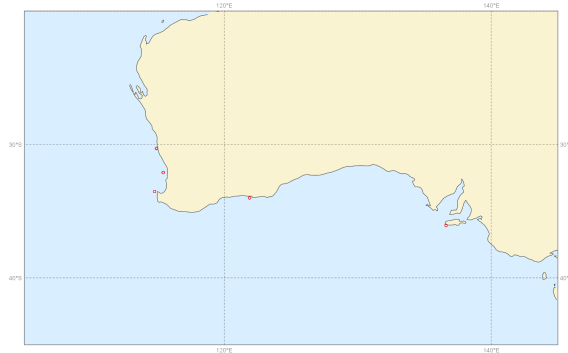


East Australia - New Zealand. Scores time-series at **day 3**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

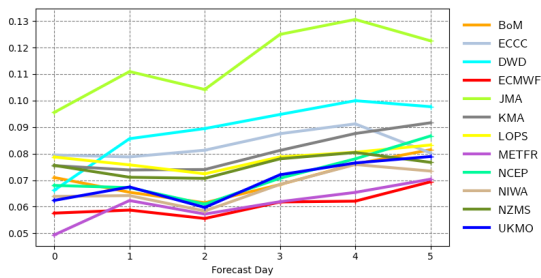


East Australia - New Zealand. Scores time-series at **day 5**. Top left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Top right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).

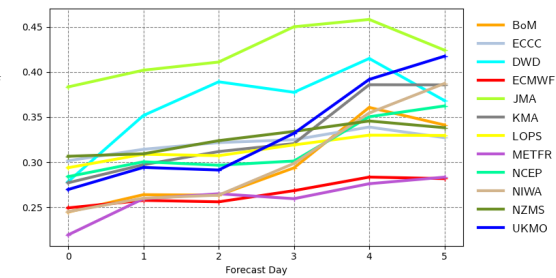
Buoys observations - from 20211201 to 20220228 - (swh)



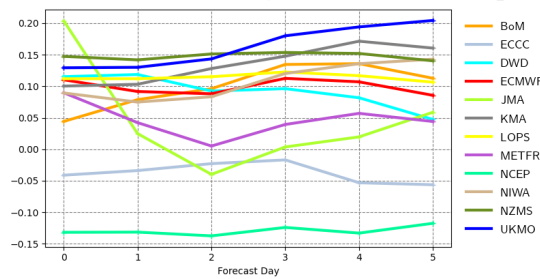
Scatter index | significant wave height | South Southwestern Australia
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



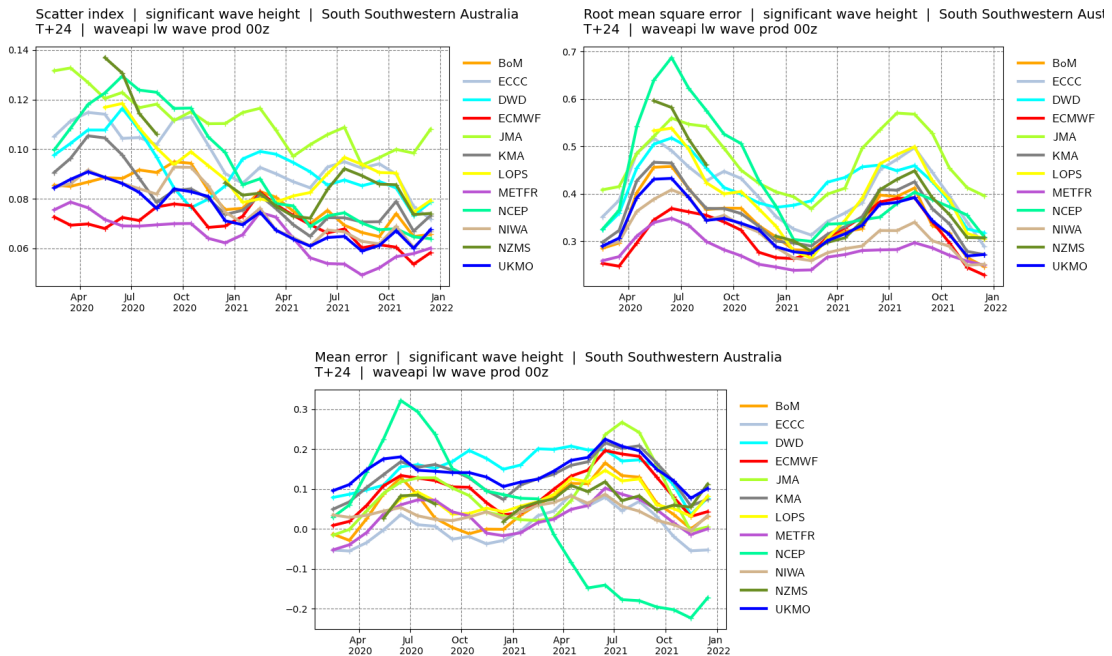
Root mean square error | significant wave height | South Southwestern Au:
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



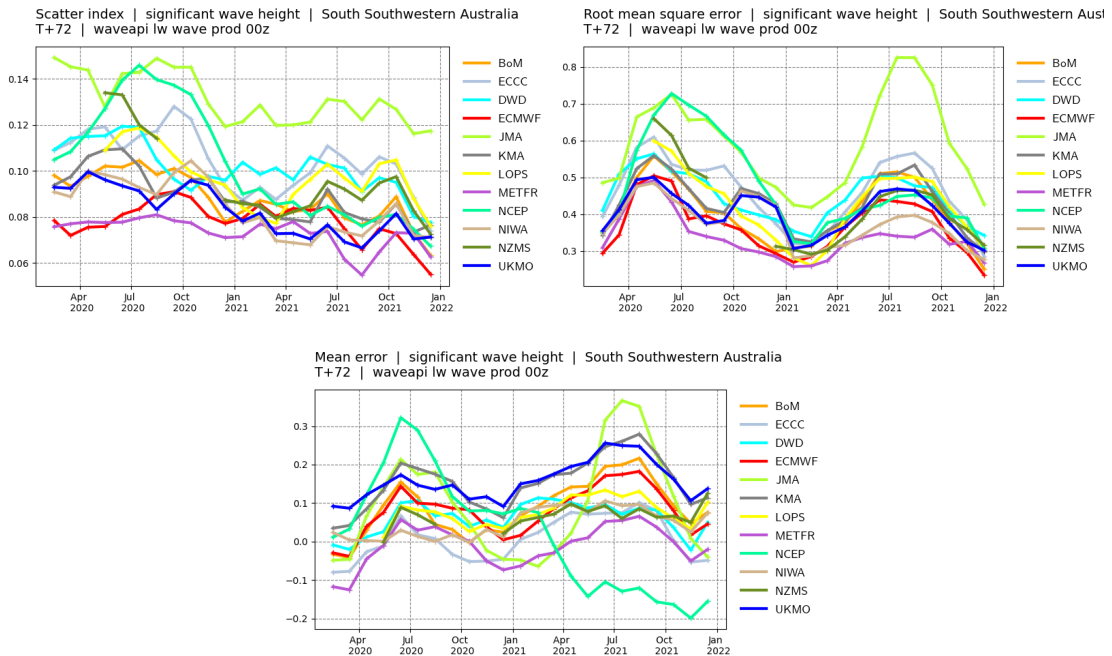
Mean error | significant wave height | South Southwestern Australia
20211201 00z to 20220228 00z | waveapi lw wave prod 00z mean_fair



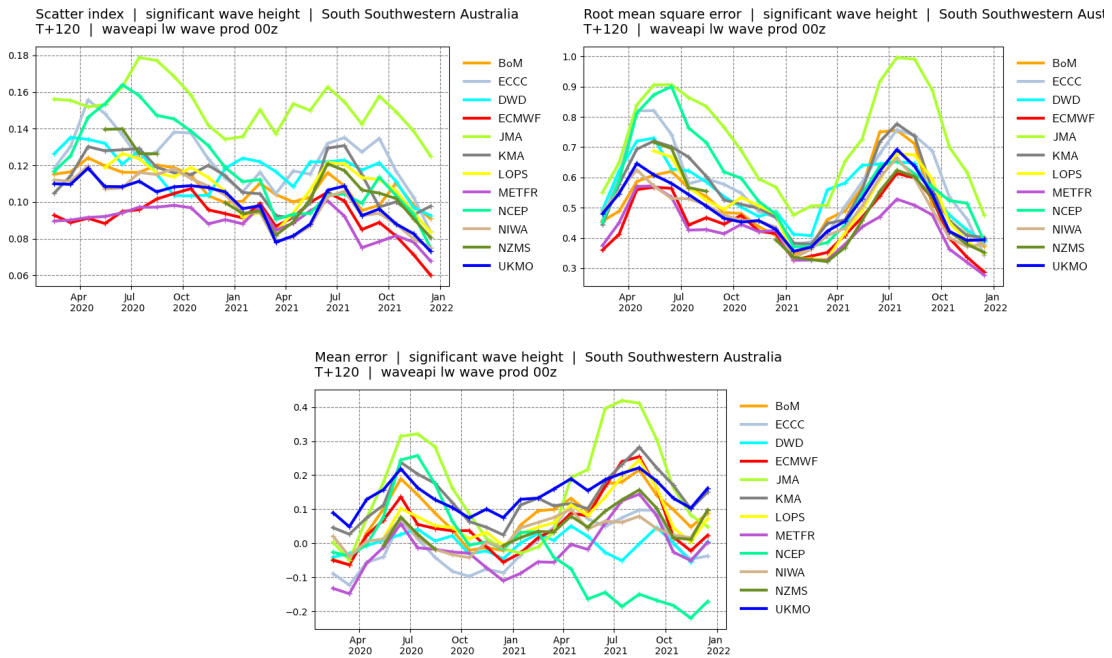
South South West Australia. Top panel: observation distribution. Middle left panel: Forecast scatter index (standard deviation of the difference normalised by the mean of the observations). Middle right panel: Forecast root mean square error (RMSE). Bottom panel: forecast mean error (bias).



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).