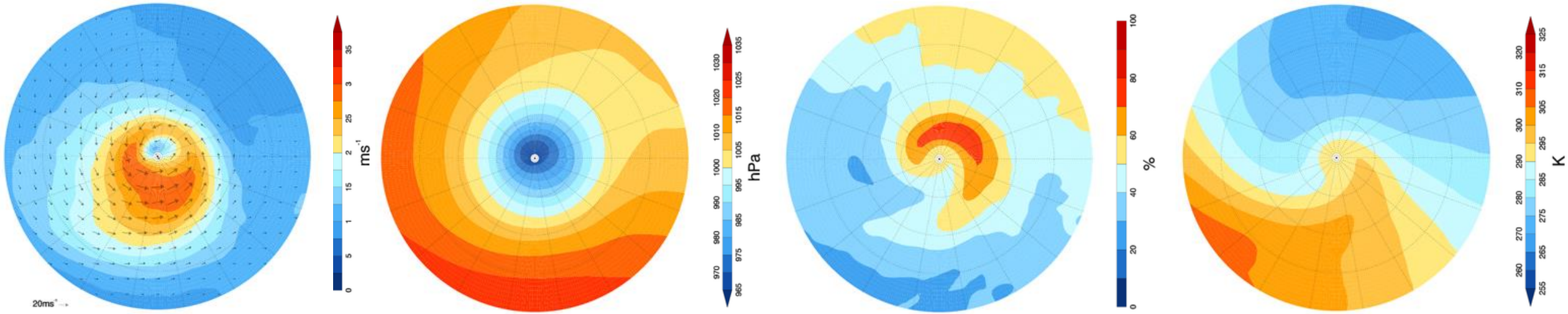
Midlatitude Cyclone Intensity Biases in Machine Learning Weather Prediction Models



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PRESENTATION OUTLINE

AIM: To compare the midlatitude cyclone forecast performance of traditional NWP models with machine learning weather prediction models

- Datasets
- Extratropical cyclone tracks
- Model evaluation
  - Cyclone track position and propoagation speed
  - Cyclone mslp error and bias
  - Cyclone 10m windspeed error and bias
- Summary

DATASETS

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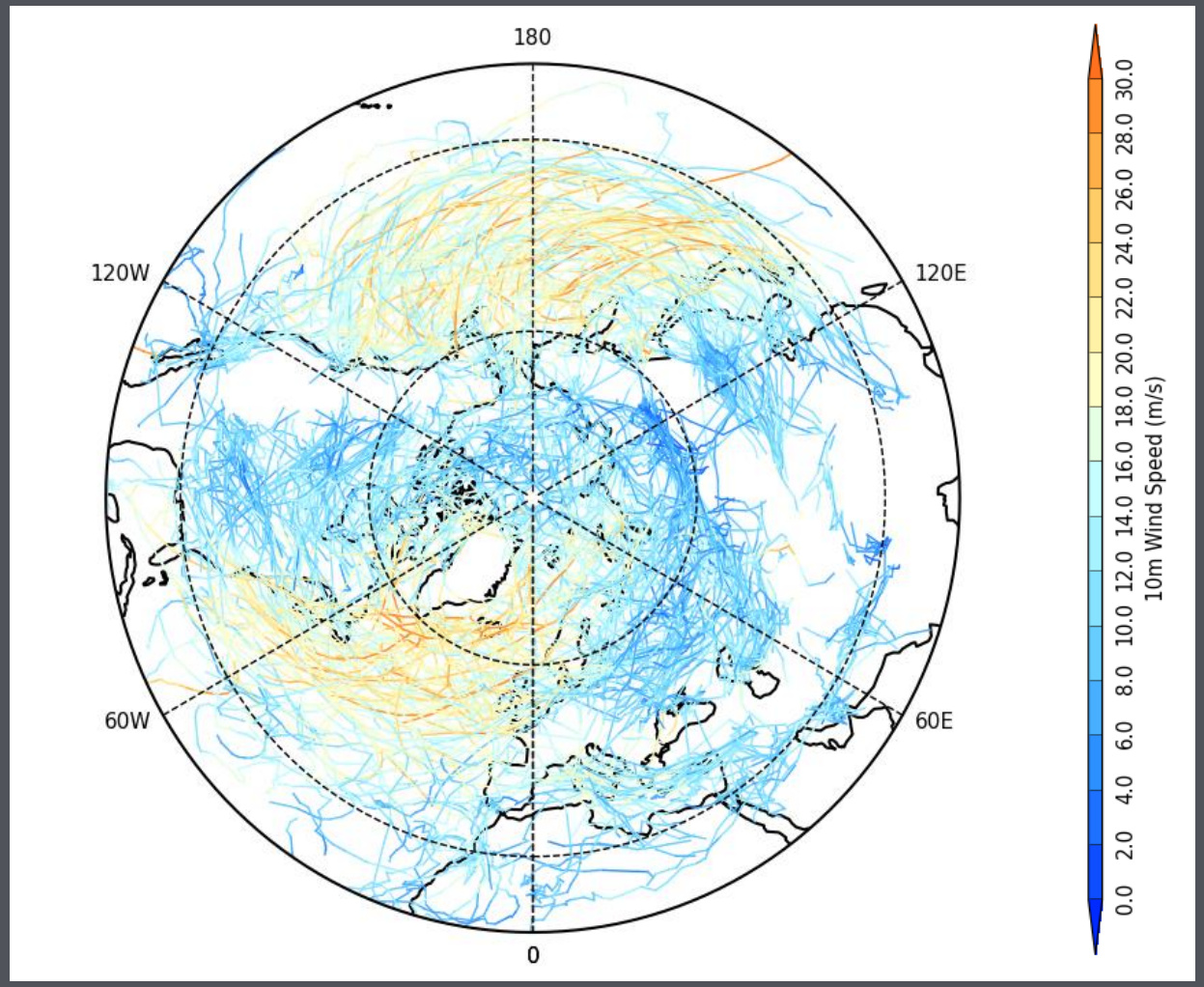
Model name	Model type	Grid spacing	Refs
IFS analysis	Analysis	0.1°	
ERA5	Reanalysis	0.25°	
IFS forecast	NWP	0.1°	
Pangu-Weather	MLWP	0.25°	*Bi et al. 2023*
GraphCast	MLWP	0.25°	*Lam et al. 2023*
FengWu	MLWP	0.25°	*Chen et al. 2023a*
ECMWF-AIFS	MLWP	0.25°	*Lang et al. 2024*
Aurora	MLWP	0.25°	*Bodnar et al. 2024*
FourCastNetv2	MLWP	0.25°	*Pathak et al. 2022*
FuXi	MLWP	0.25°	*Chen et al. 2023b*

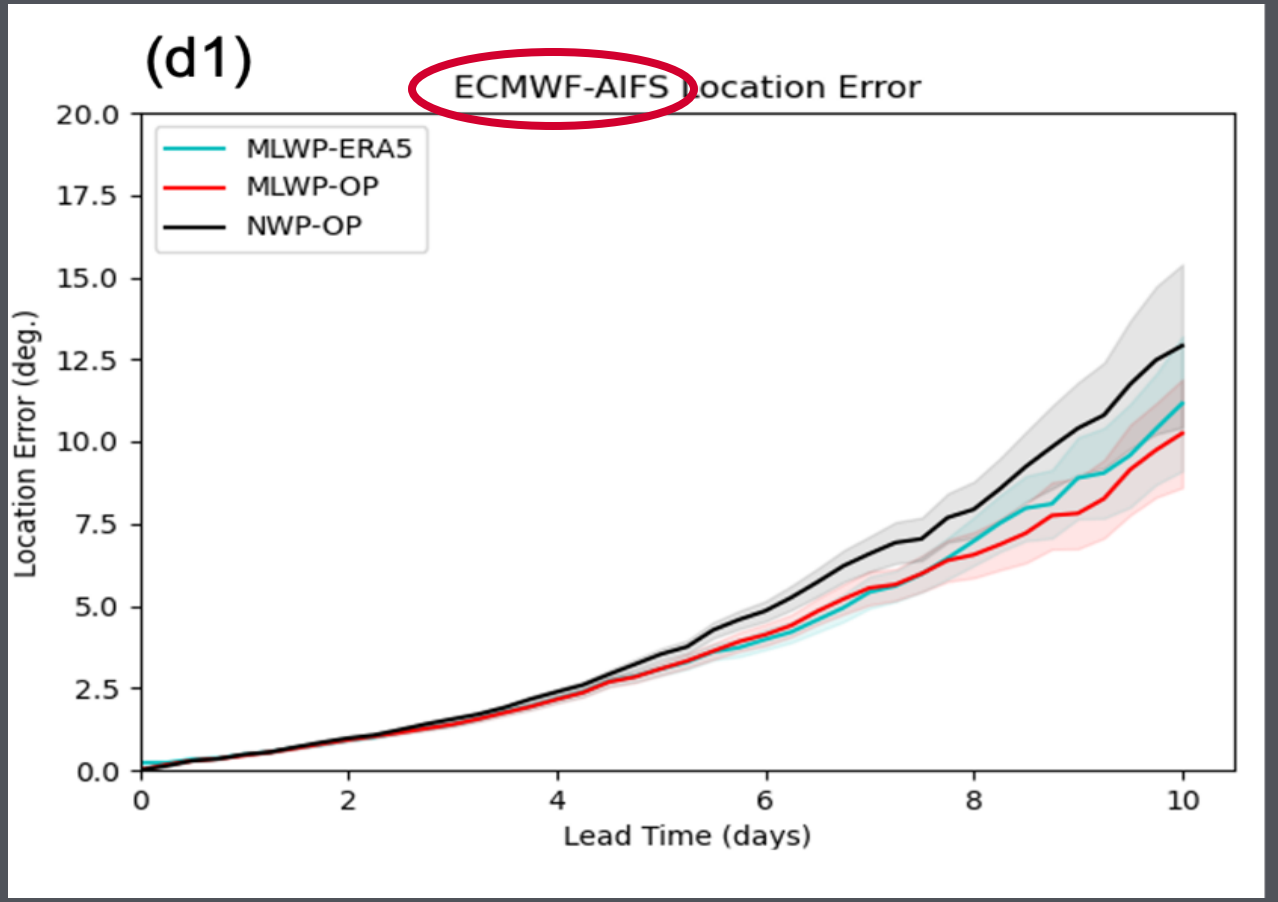
Datasets from analysis and reanalysis, numerical weather prediction (NWP) and machine learning weather prediction (MLWP)

NH MIDLATITUDE CYCLONE TRACKS



ECMWF IFS analysis NH midtlatitude cyclone tracks between Oct 2023 – Mar 2024. Tracks coloured according to the maximum 10 m windspeed within a 6° radius of the cyclone centre along the track

CYCLONE LOCATION INTENSITY ERROR



NH cyclone location error (deg) as a function of forecast lead time (days). MLWP forecast with respect to IFS analysis (MLWP-OP, red), ERA5 (MLWP-ERA5, cyan). For comparison NWP IFS forecast cyclone location error with respect to IFS analysis (NWP-OP, black). Shading represents 95% confidence intervals.

CYCLONE LOCATION INTENSITY ERROR

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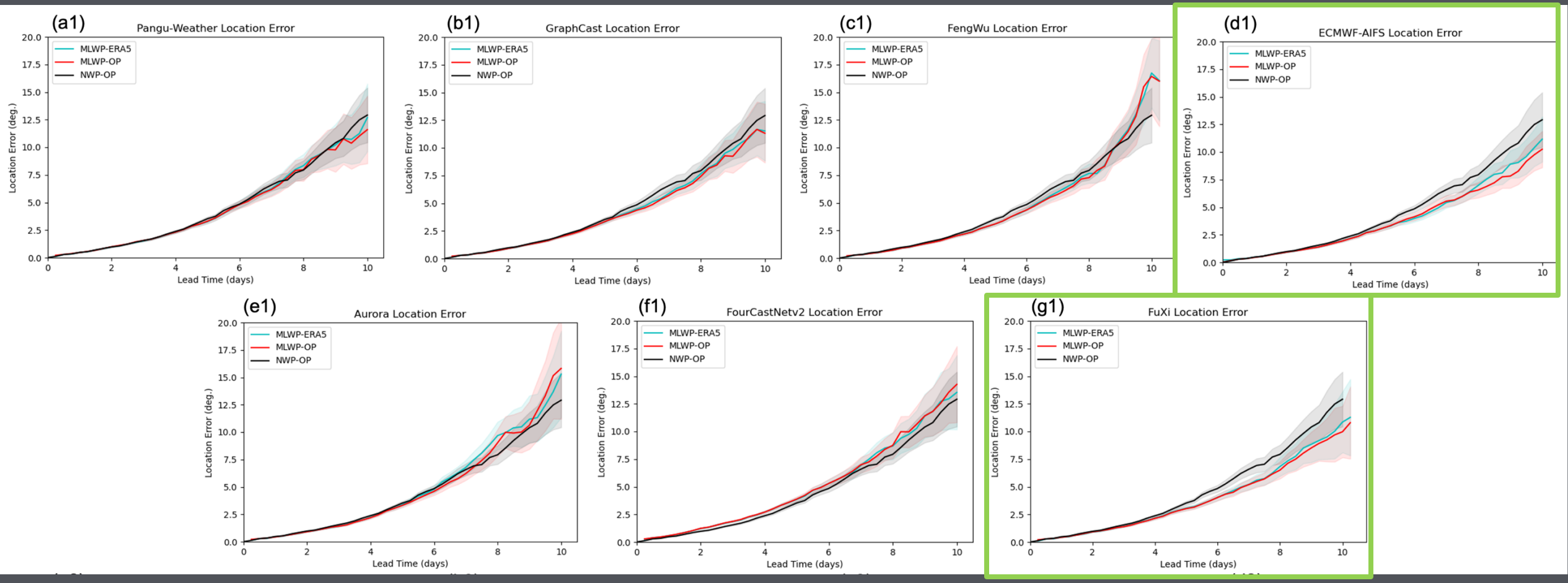

- Accuracy of the cyclone tracks decreases with lead times, and for all models is > 10◦ by day 10
- AIFS and FuXi exhibit improved track position compared to IFS forecast for 4-8 day lead times

CYCLONE PROPAGATION SPEED ERROR

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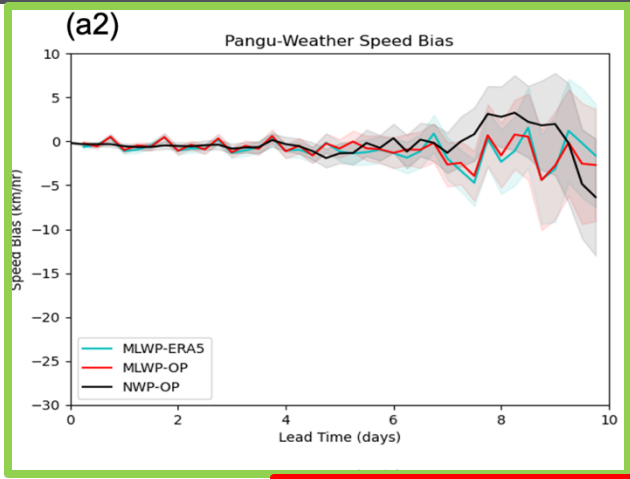
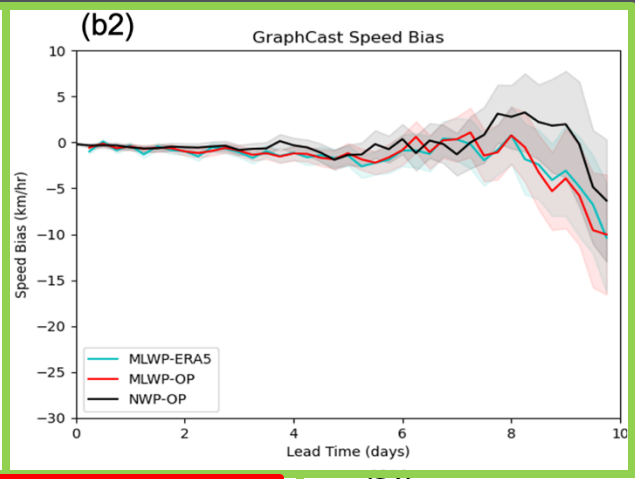
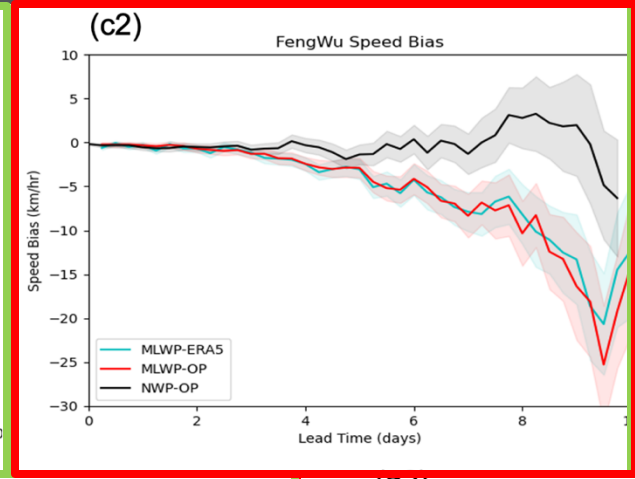
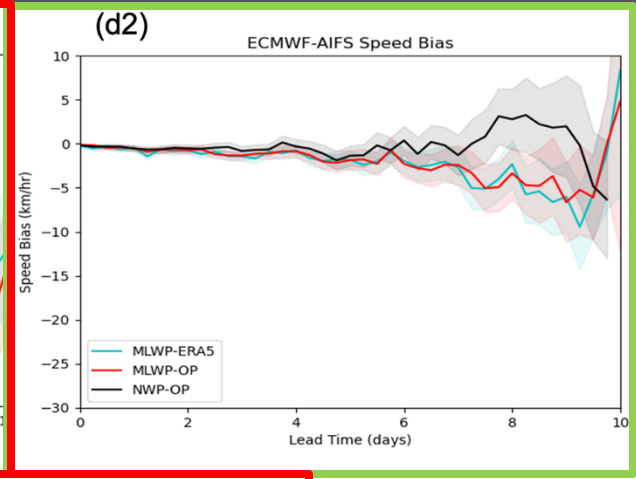
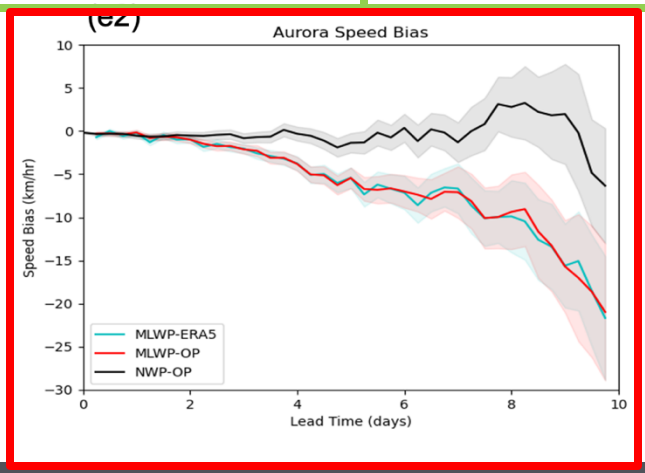
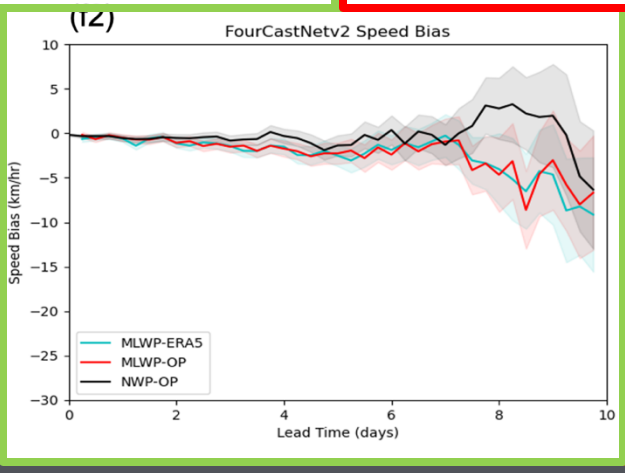


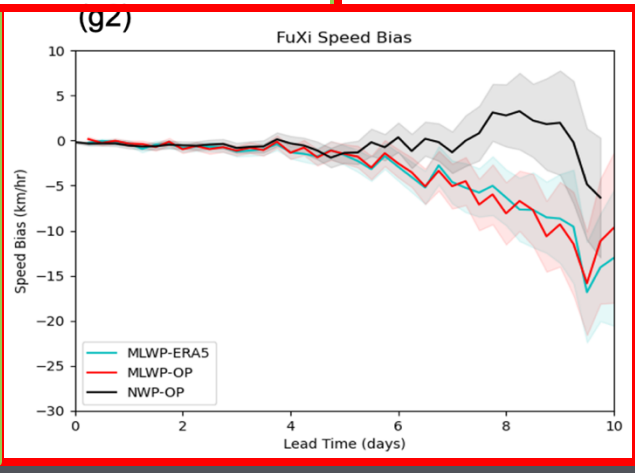






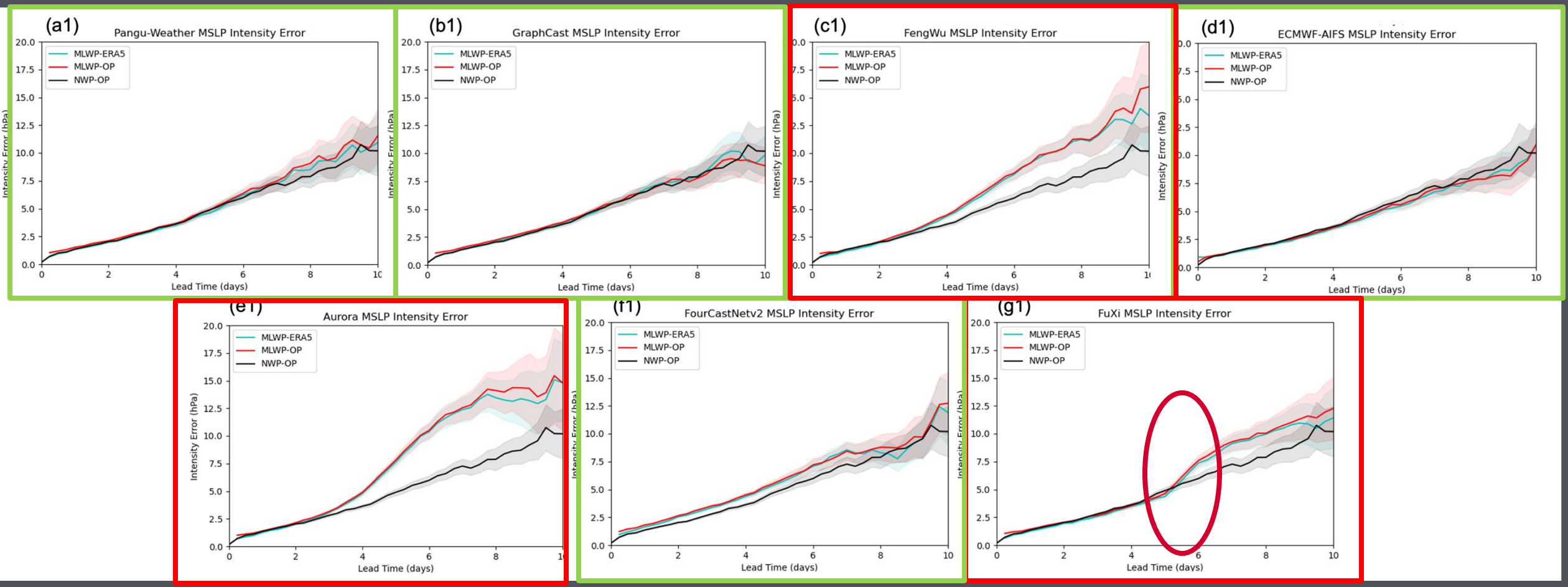






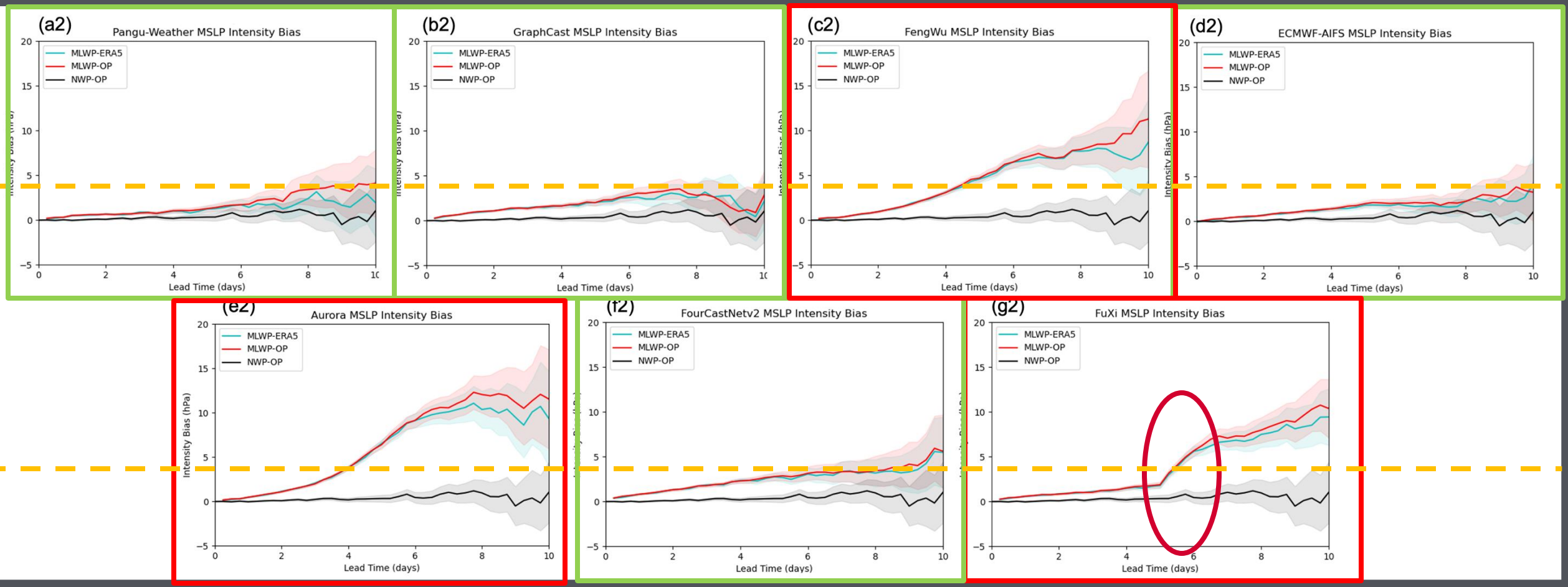
- IFS forecast cyclone propagation speed bias is close to zero for the first 7-days of the forecast (black)
- Pangu-Weather, GraphCast, AIFS and FourCastNetv2 have negligible propagation speed bias
- FengWu and Aurora and FuXi cyclones propagate too slowly from day 4 onwards

CYCLONE MSLP INTENSITY ERROR



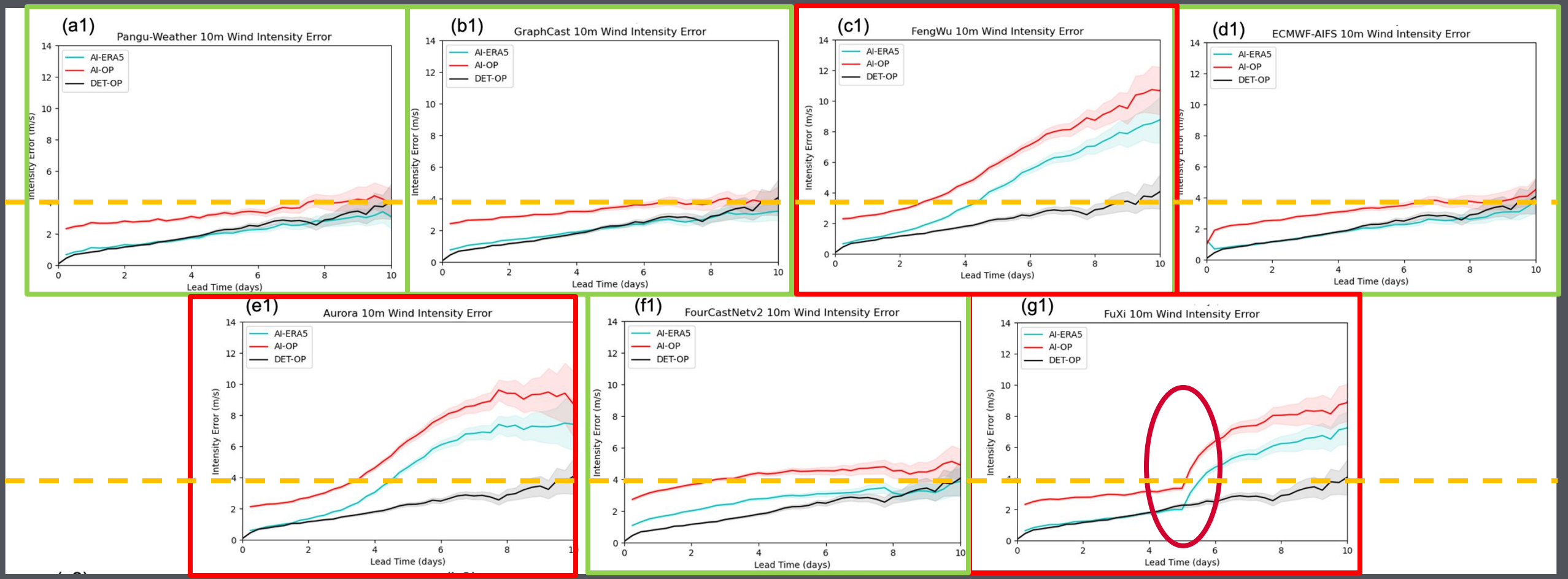
- The NWP IFS forecast cyclone MSLP error increases at a constant rate to 10 hPa by day 10 (black)
- At longer lead times, Pangu, GraphCast, AIFS and FourCastNetv2 remain similar to IFS forecast
- FengWu, Aurora and FuXi cyclone MSLP error growth rates become larger than NWP IFS forecast.
- FuXi shows an un-physical increase in cyclone MSLP error at 5 days

CYCLONE MSLP INTENSITY BIAS



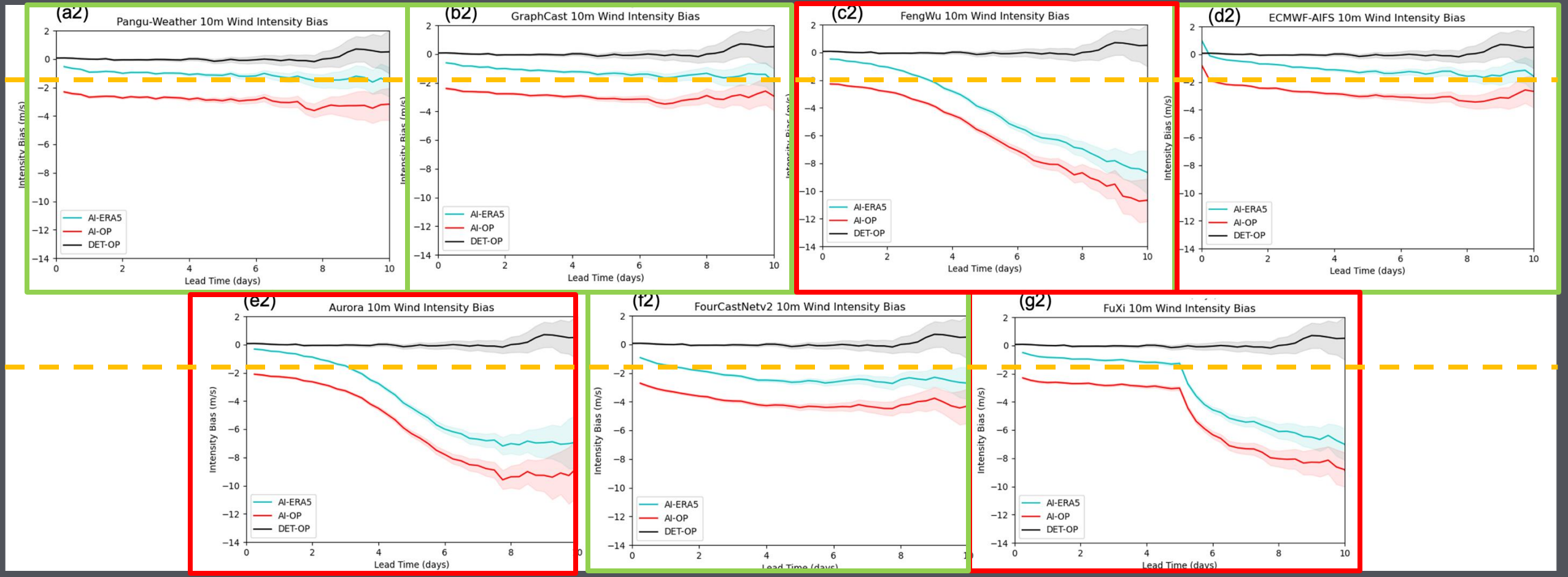
- There is a significant under-estimation of cyclone MSLP at all forecast lead times
- Under-estimation in cyclone MSLP is < 5 hPa for the Pangu, GraphCast, AIFS and FourCastNetv2
- FengWu, Aurora and FuXi the underestimation is approximately twice as large, 10 hPa by day 10

CYCLONE WIND INTENSITY ERROR



- IFS forecast error growth rate is fairly constant after 12 hours, ~4ms^{-1} by day 10 (black)
- Pangu, GraphCast, AIFS, FourCastNetv2 MLWP error growth rate is fairly constant, ~4ms^{-1} by day 10
- FengWu and Aurora the error growth rate increases, resulting in cyclone windspeed errors of 10ms^{-1} by day 10

CYCLONE WIND INTENSITY BIAS



- Systematic under-prediction of the cyclone windspeed
- Wind damage ≈ u^3 (over a threshold) so a forecast error of 1.5 ms^{-1} on a 25 ms^{-1} 10m windspeed, results in 12–19% underestimation of the predicted wind damage

SUMMARY

AIM: To compare the midlatitude cyclone forecast performance of traditional NWP models with machine learning weather prediction model

✓MLWP models can capture the position of midlatitude cyclone tracks with comparable accuracy to the NWP IFS forecast for lead times out to 10 days

✗ In some MLWP models (FengWu, Aurora and FuXi) the cyclones propagate too slowly

✗Cyclone MSLP minima are generally too shallow (by > 5 hPa at 10-day lead time) when compared to IFS analysis and ERA5, whereas NWP IFS forecast has similar absolute errors, but no bias.

✗MLWP models produce 10m cyclone windspeeds that are too weak (1-3ms^{-1}) when compared to IFS analysis and ERA5, whereas the NWP IFS forecast has no bias

EXTRA SLIDES

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