WGNE inter-comparison of Tropical Cyclone Track forecast 2024

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<https://nwp-verif.kishou.go.jp/wgne_tc/index.html>

Login ID: verif
Password: wgne2025 (beyond 1 November 2025)
Contact: globalnwp@met.kishou.go.jp

STANDARD VERIFICATION

Verification of Global Models

Data Specifications in 2024

NWP centre	Year of verification commencement	Horizontal resolution of provided data (degrees in longitude and latitude)	Model resolution as of 2024
BoM	2003	0.176 x 0.117	12kmL70
CMC	1994	1.0 x 1.0	15km L84
DWD	2000	0.25 x 0.25	13kmL120 (6.5km L74 for Europe)
ECMWF	1991	0.125 x 0.125	TCo1279L137
FRN	2004	0.1×0.1	T_L1798(C2.2)L105
JMA	1991	0.125 x 0.125	TQ959L128
KMA	2010	0.125 x 0.125	12kmL91
NCEP	2003	0.5 x 0.5	13km FV3-based, C768 L127
NCMRWF	2020	No Data	12kmL70
NRL	2006	Non-participation	T681L60
UKMO	1991	0.1406 x 0.094	10kmL70

Improvements of global deterministic models for each centre in 2024 (1/2)

- **CMC**
  - 2024.06.11 : Upgrade to version 9.0.0 of the GDPS
  - 2024.10.23 : Addition of new satellite observation sources in the GDPS
- **DWD**
  - 2024.01.24 : Include bottom heat flux in sea-ice scheme, plus minor change
  - 2024.03.27 : Operationalisation of mixed ICON-ART mineral dust ensemble
  - 2024.04.17 : Revision of ensemble perturbations, updated greenhouse gas concentrations, plus minor change
  - 2024.05.22 : Retuning of soil moisture adjustment and adaptive surface friction, introduction of ensemble perturbations of soil moisture, and changes in the assimilation of satellite radiances
  - 2024.07.31 : Assimilation of US-METAR and use of observations with WIGOS station identifiers

Improvements of global deterministic models for each centre in 2024 (2/2)

- **DWD (cont.)**
  - 2024.10.30 : Assimilation of IASI over land, Aerosol and trace gas detection for IASI
  - 2024.12.04 : Extension of adaptive parameter tuning, plus minor tuning changes in parameterizations and numerics
- **ECMWF**
  - 2024.11.12 : Implementation of IFS Cycle 49r1
- **Météo-France**
  - 2024.10.14 : New e-suite (48t1) has been declared operational
- **JMA**
  - 2024.05.05 : Assimilation of the ATMS and CrIS data from NOAA-21 was started
- **KMA**
  - 2024.05.14 : Update of KIM version to v3.9

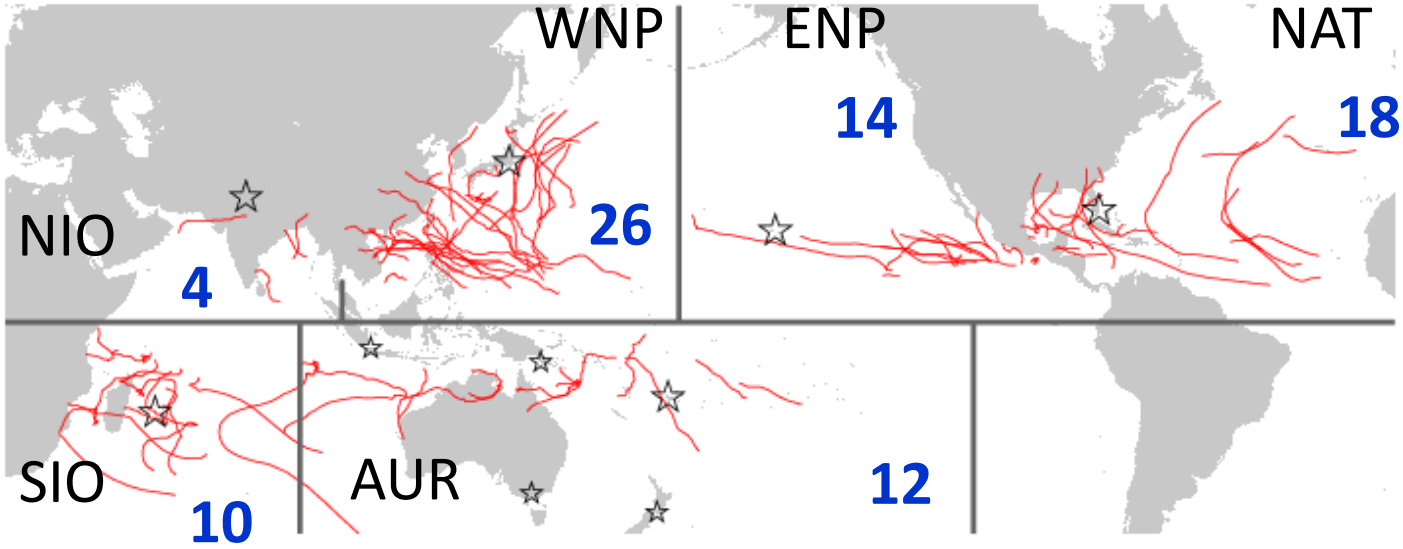
TCs in 2024

TC season

Northern Hemisphere ： 1 January 2024 to 31 December 2024
Southern Hemisphere ： 1 September 2023 to 31 August 2024

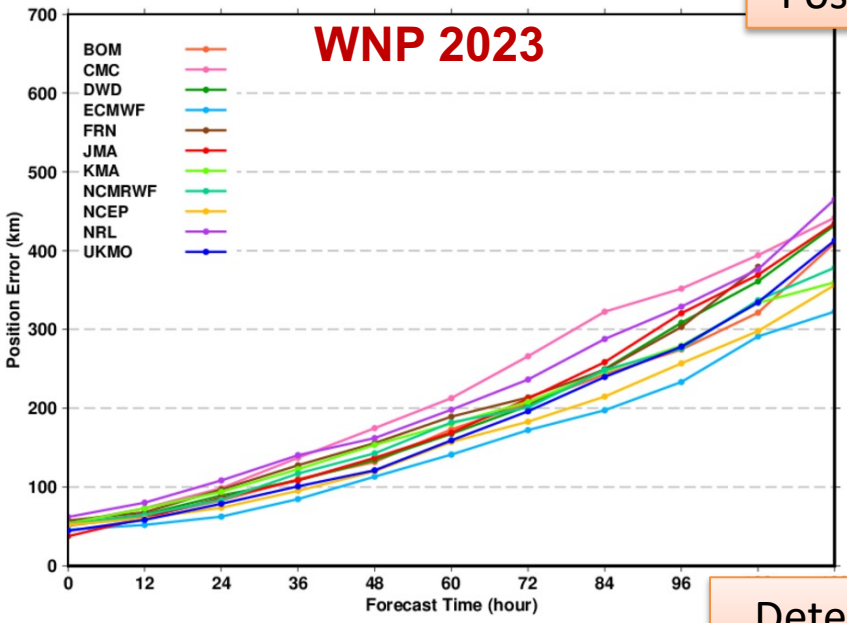
Number of TCs* (LY) [best track data provider]

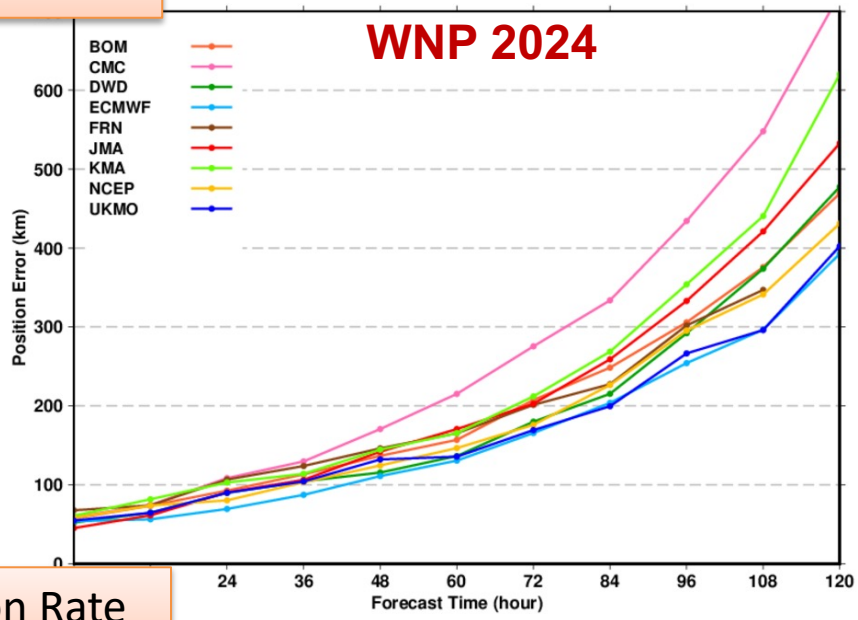
26 (17) Western North Pacific [RSMC Tokyo]
14 (17) Eastern North Pacific (including Central North Pacific) [RSMC Miami, Honolulu]
18 (20) North Atlantic [RSMC Miami]
4 (6) North Indian Ocean (including preliminary data) [RSMC New Delhi]
10 (9) South Indian Ocean [RSMC La Reunion]
12 (11) Around Australia [RSMC Nadi and 4 TCWCs]



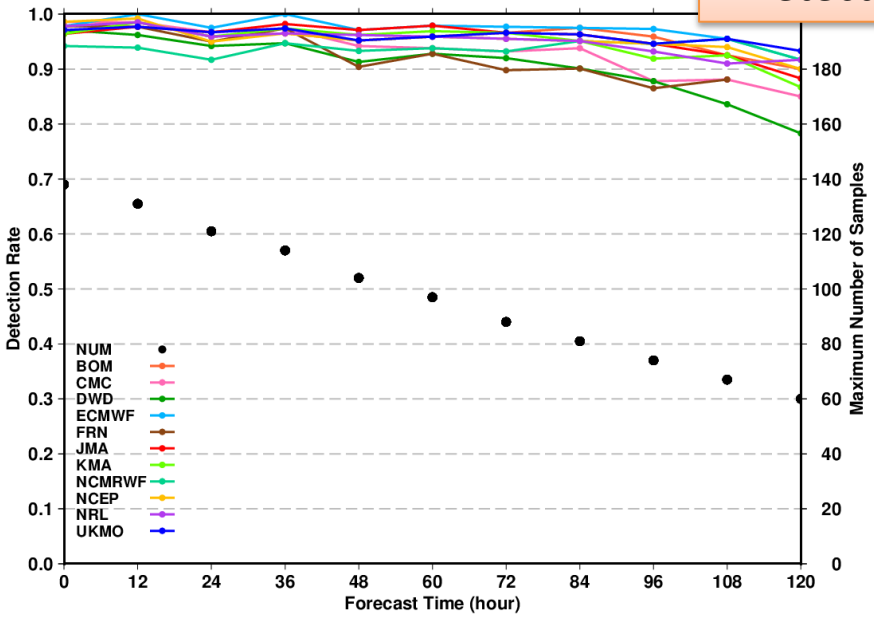
(*)The number of tropical cyclones in each region includes overlaps.

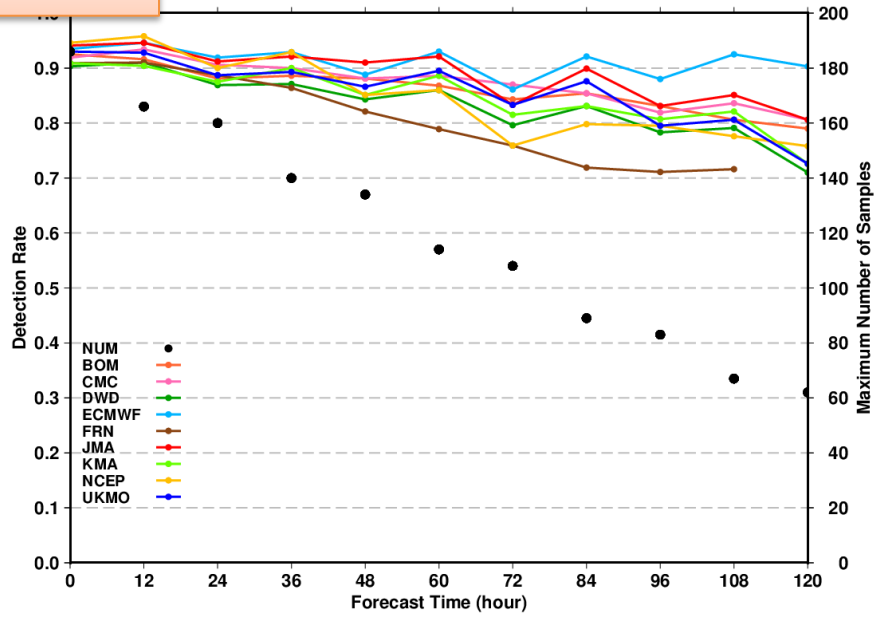
Position Error





Detection Rate





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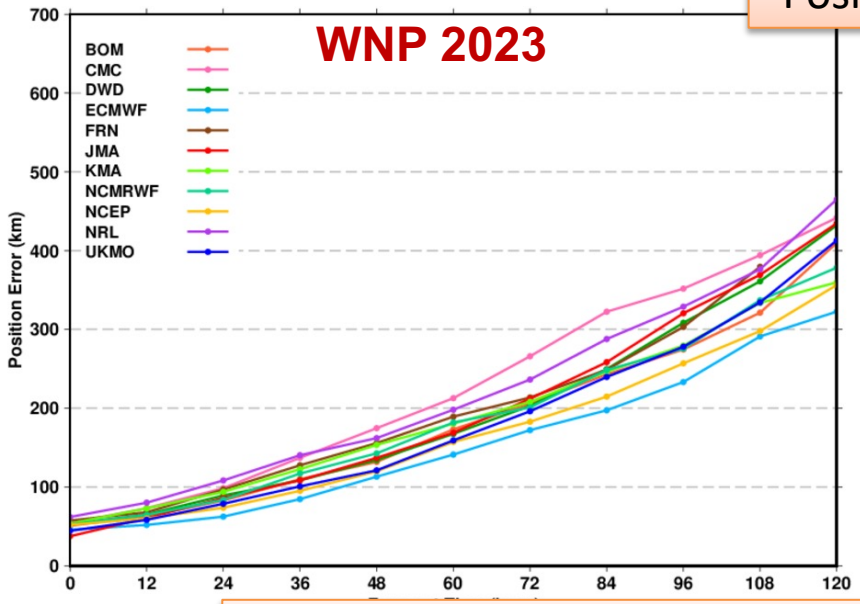
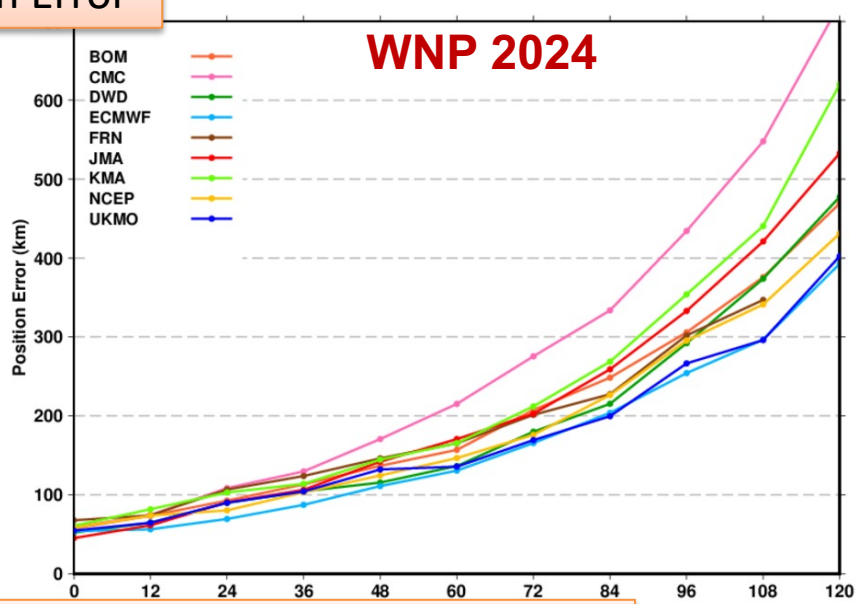
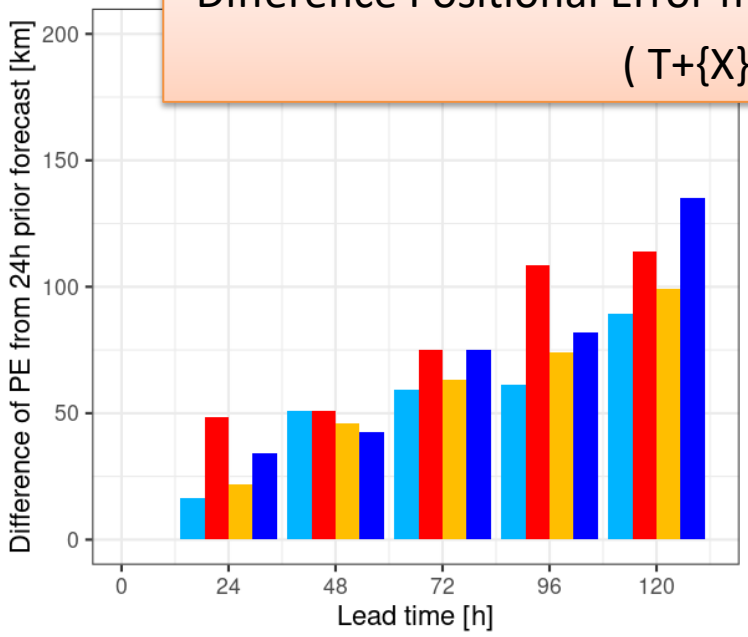
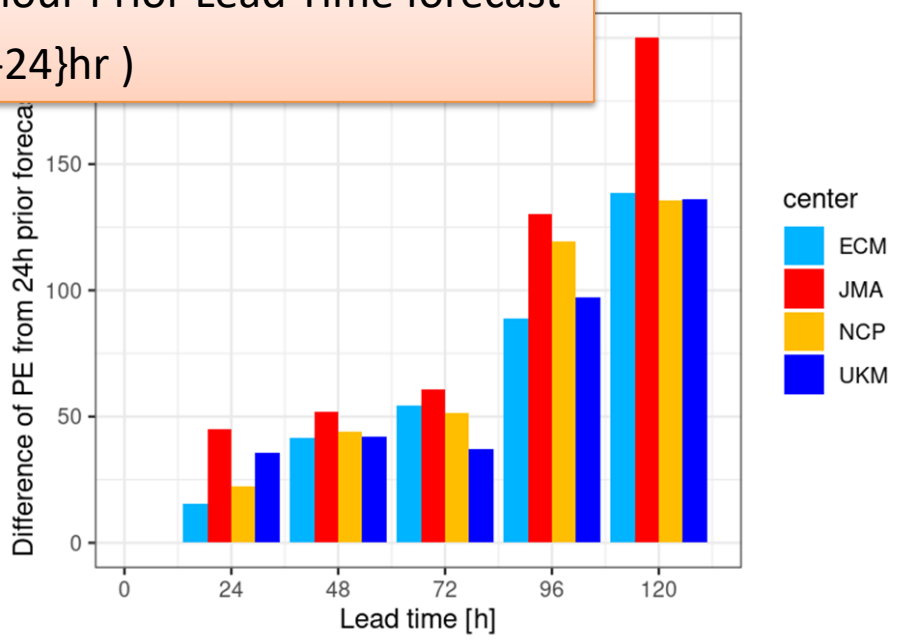




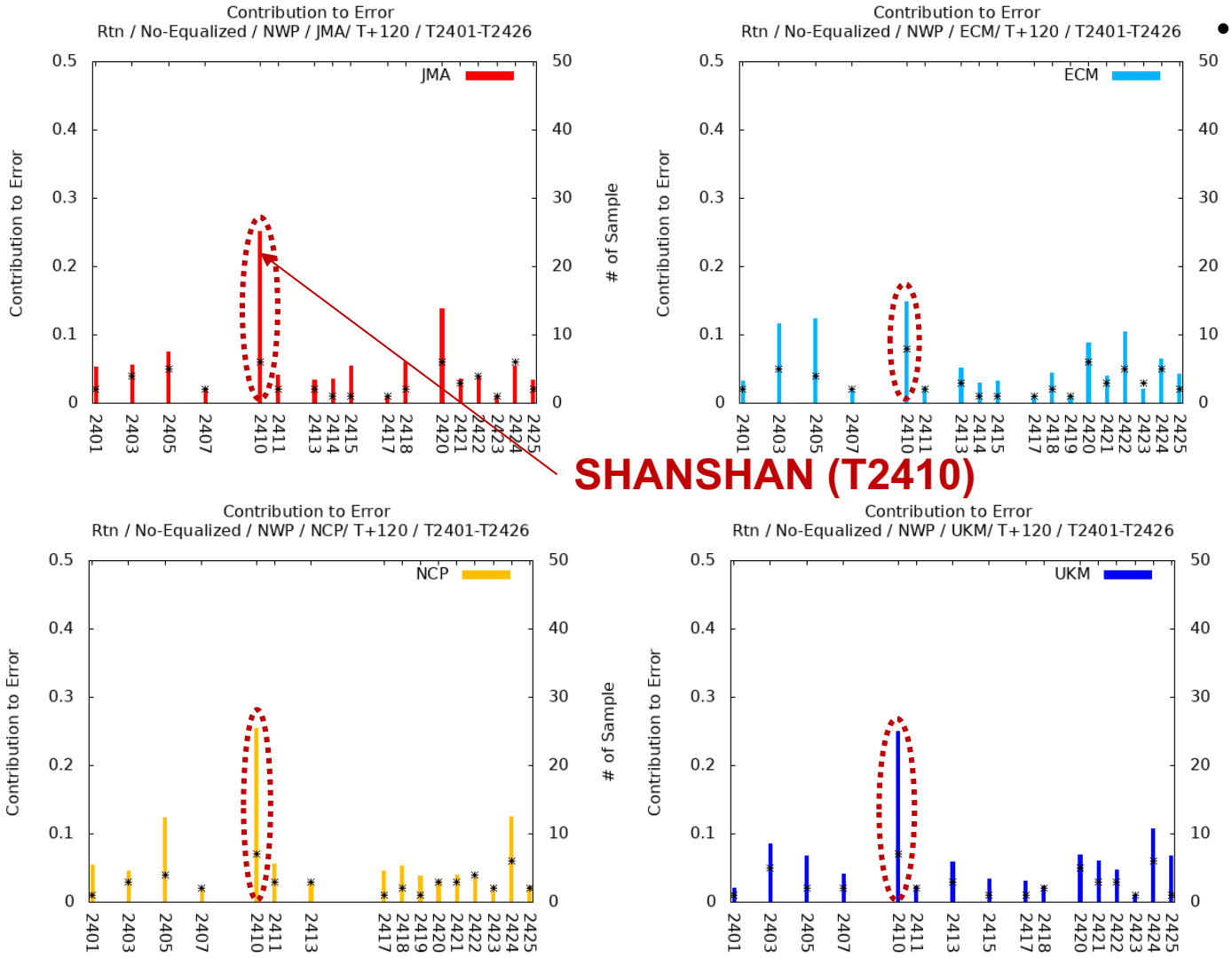
Difference Positional Error from 24-hour Prior Lead Time forecast

(T+{X}hr-T+{X-24}hr)

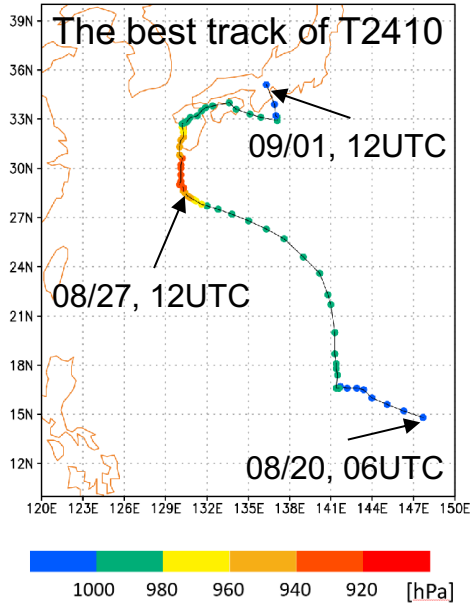




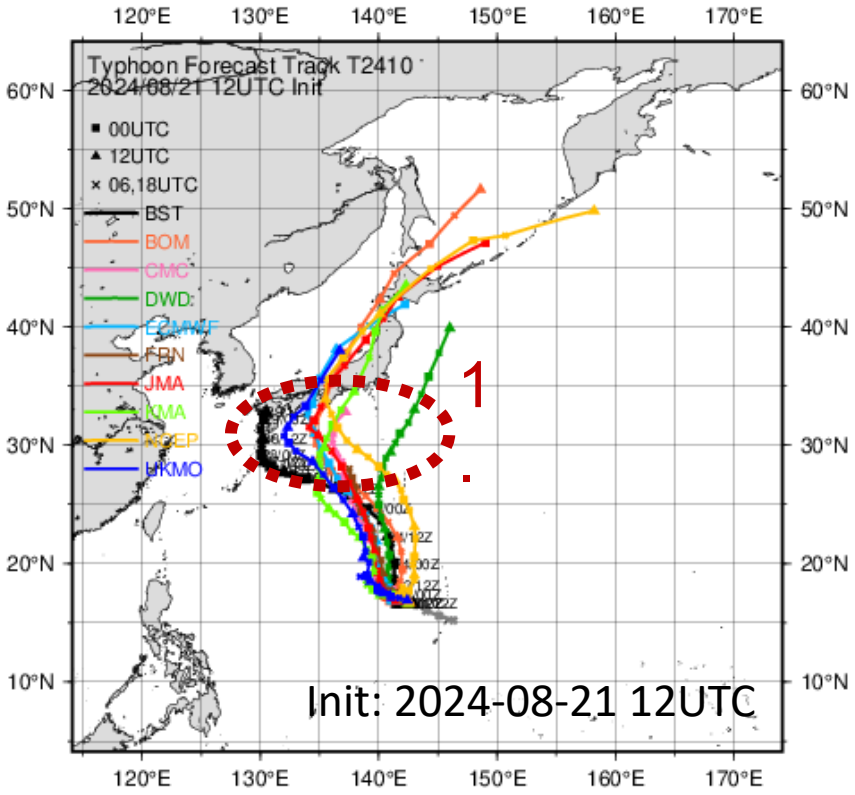
Contribution to Positional Error (WNP, T+120)

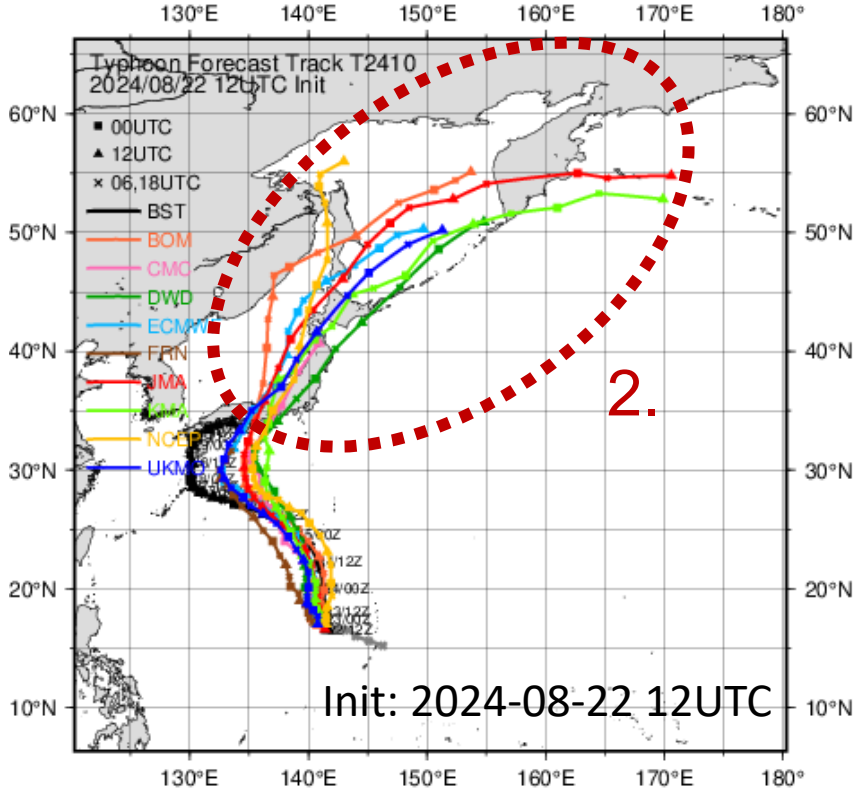


- Typhoon SHANSHAN (T2410) was a significant contributor to the annual mean total position error in the five-day forecasts by JMA and other centres.



Each track forecast of SHANSHAN (T2410)

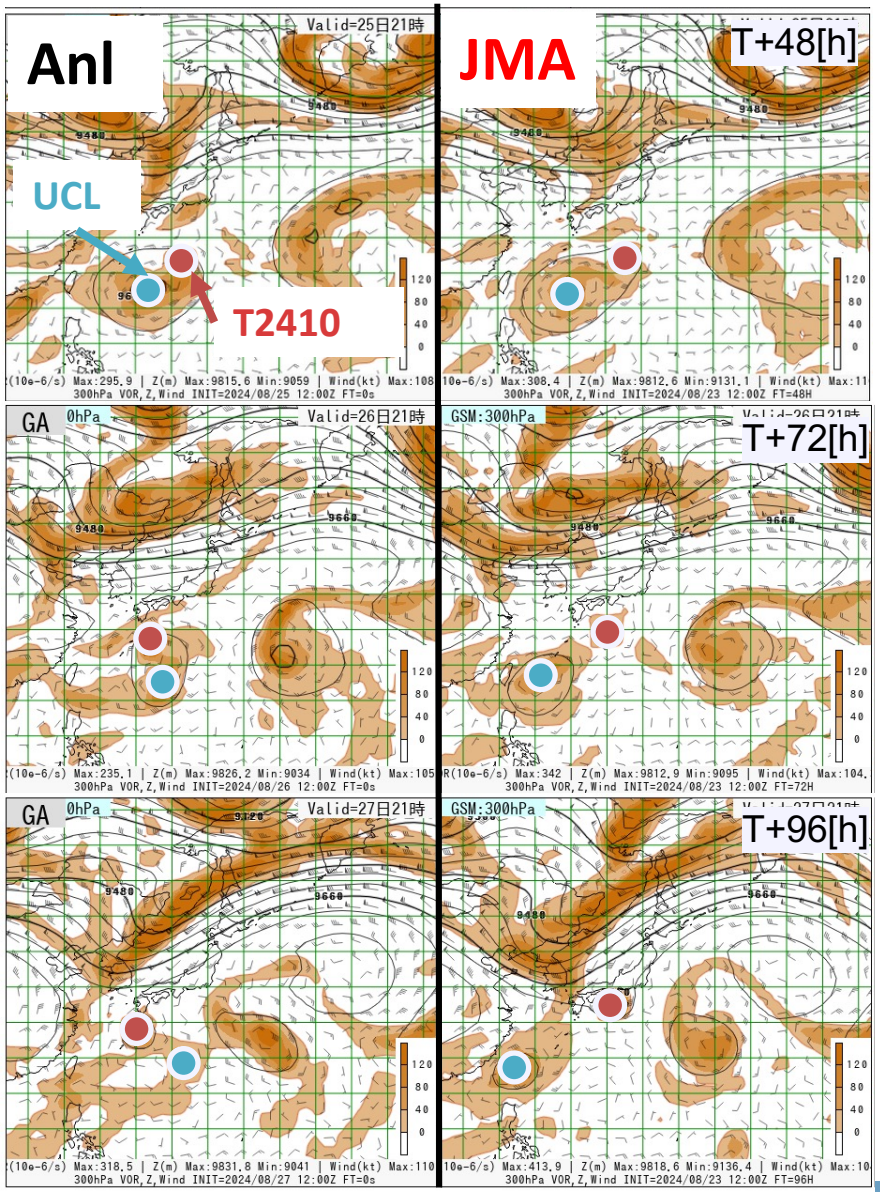




1. The points of recurvature in these track forecasts were displaced eastward.
2. Several forecasts showed the tracks were faster and further north than the best track.

⇒ The two factors are the primary causes for the increased positional error in the five-day forecasts.

Possible reasons for the two factors

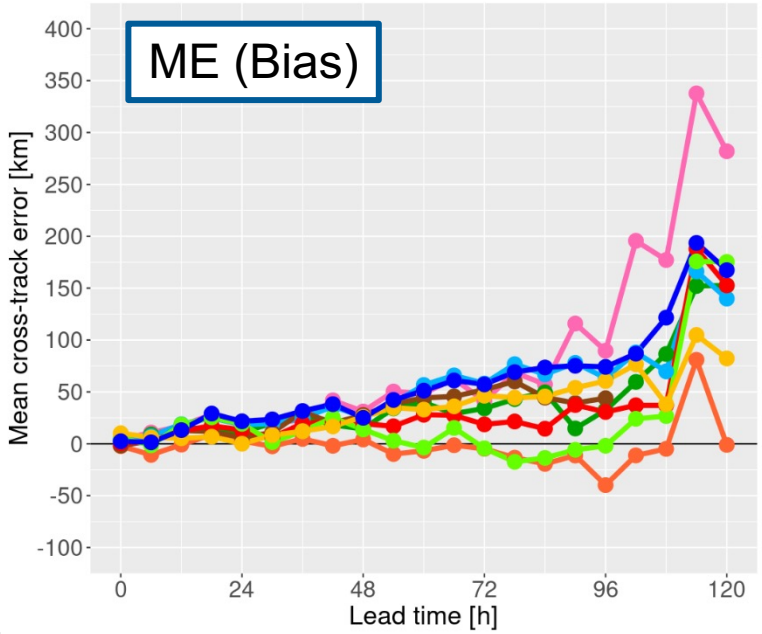


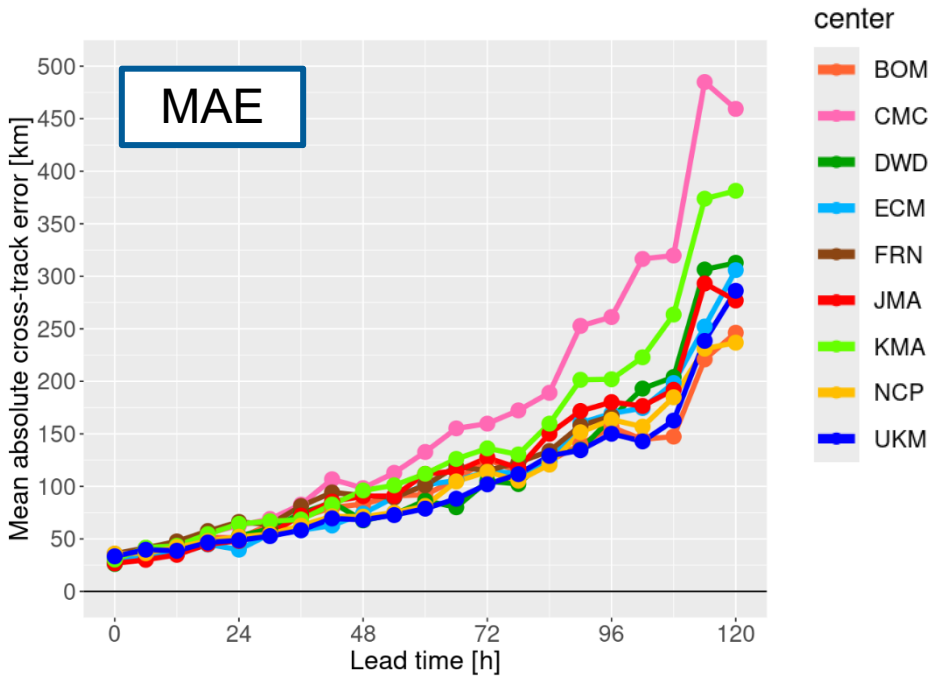
- The forecast showed a greater separation between the Upper Cold Low (UCL) and T2410 than the analysis, which resulted in an eastward shift in the point of recurvature (Factor 1) and an acceleration of its northward track.
- The early northward movement caused T2410 to be caught by the mid-latitude jet, which further accelerated its speed to the north (Factor 2).
- The interaction with the UCL may also make TC track forecast difficult in other models.

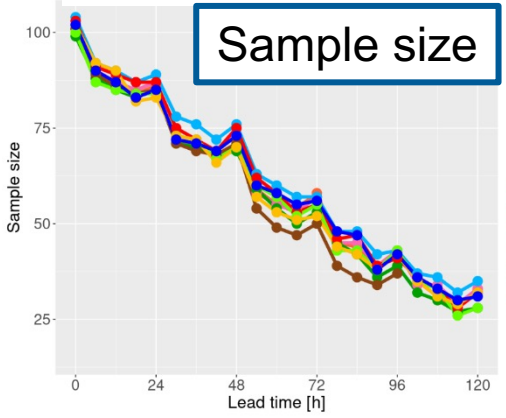
Contours : Geopotential height [m] at 300 hPa
Shades : Relative vorticity [10^-6/s] at 300 hPa
●: T2410, ●: Upper Cold Low
Left : JMA global analysis for the corresponding time
Right : Forecast by JMA global spectral model
Initial : 2024-08-23 12UTC

WNP Cross-Track error by lead time

Cross-track (Before recurvature)



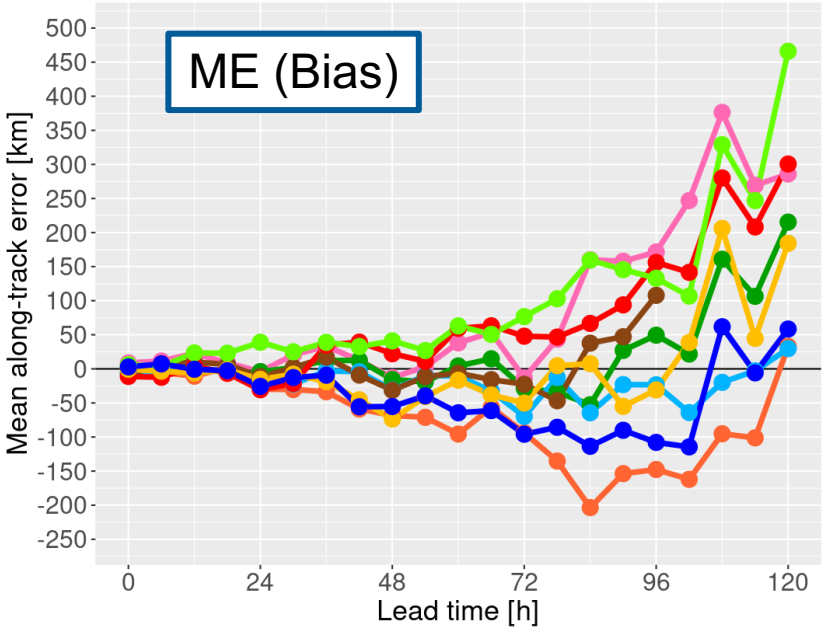


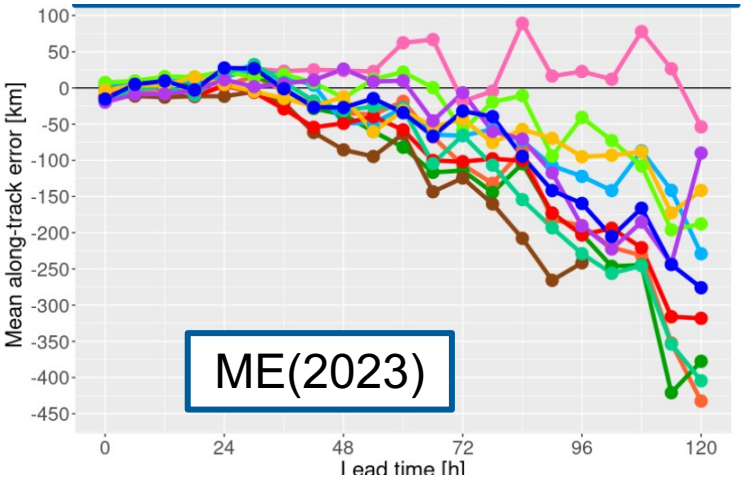


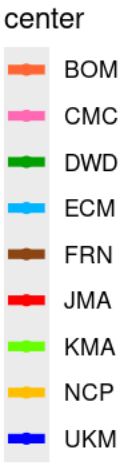
- Forecasts from most centres show right-track bias (northward bias).
  - This trend continues from the previous year.
- Centres with smaller biases do not necessarily have smaller mean absolute error.

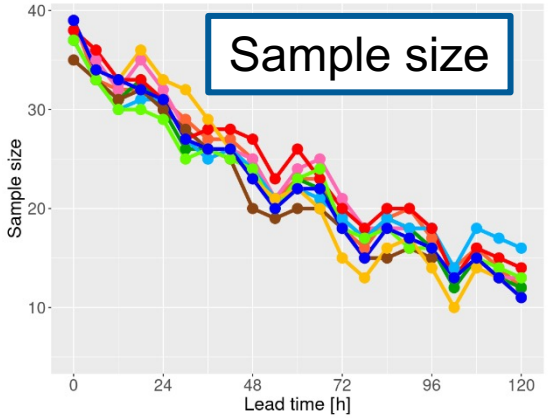
WNP Along-Track error by lead time

Along-track (After recurvature)



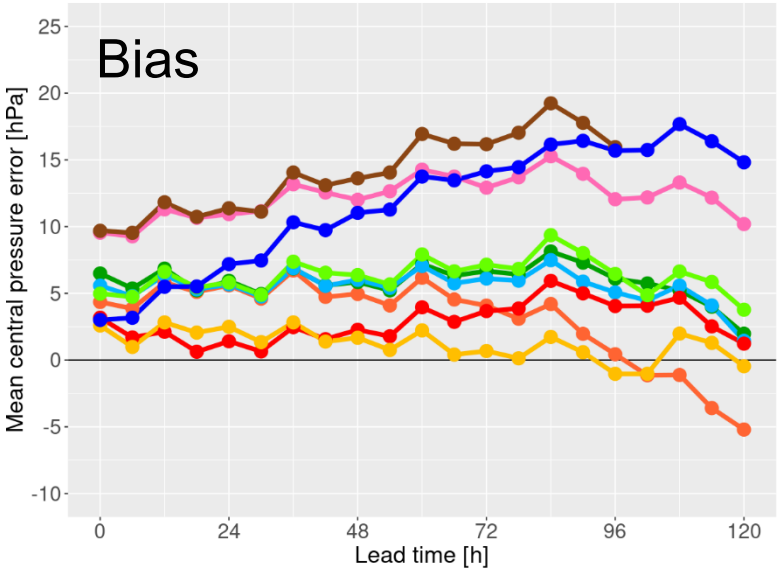


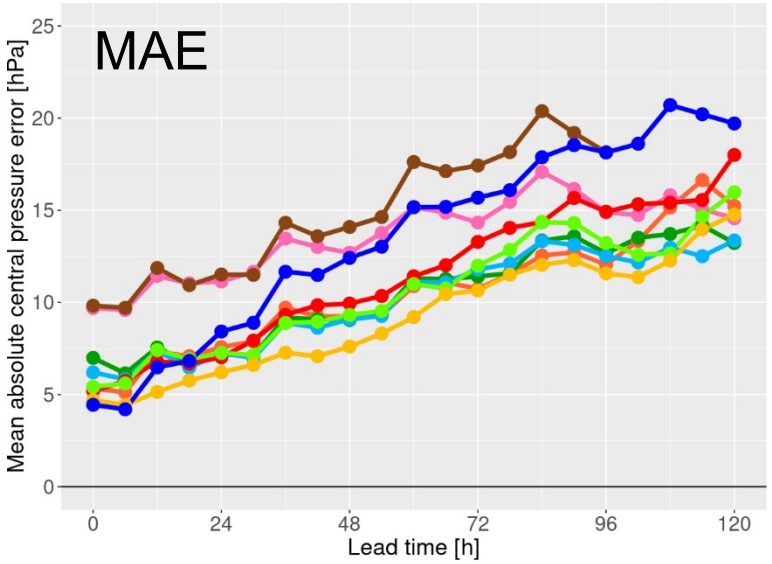


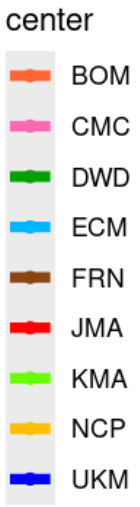


- Forecasts from some centres show positive along-track bias, particularly for lead time beyond three days.
  - This means the forecasted TC track was faster than the best track. The trend was not seen in the previous year.
- One of the main reasons for this trend is the track forecasts for T2410.

WNP Central Pressure Mean Error and Mean Absolute Error



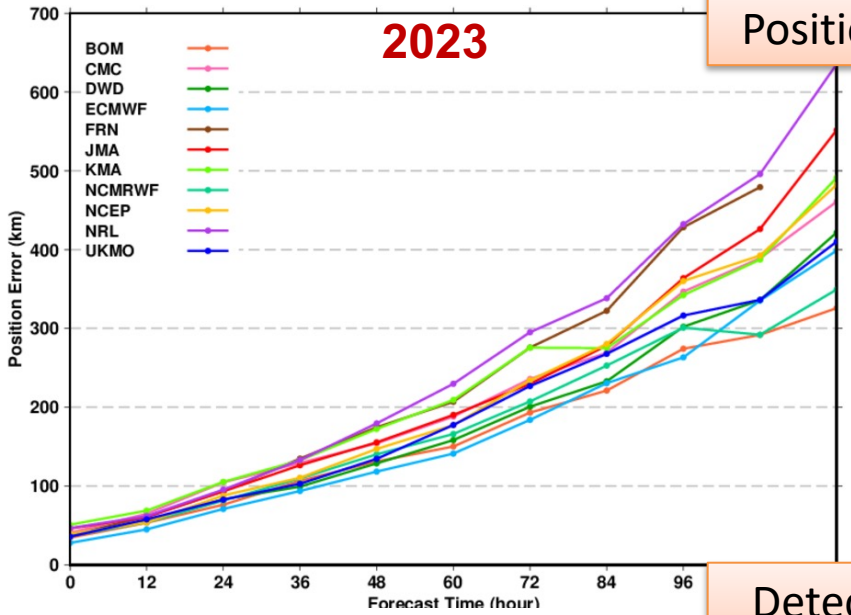


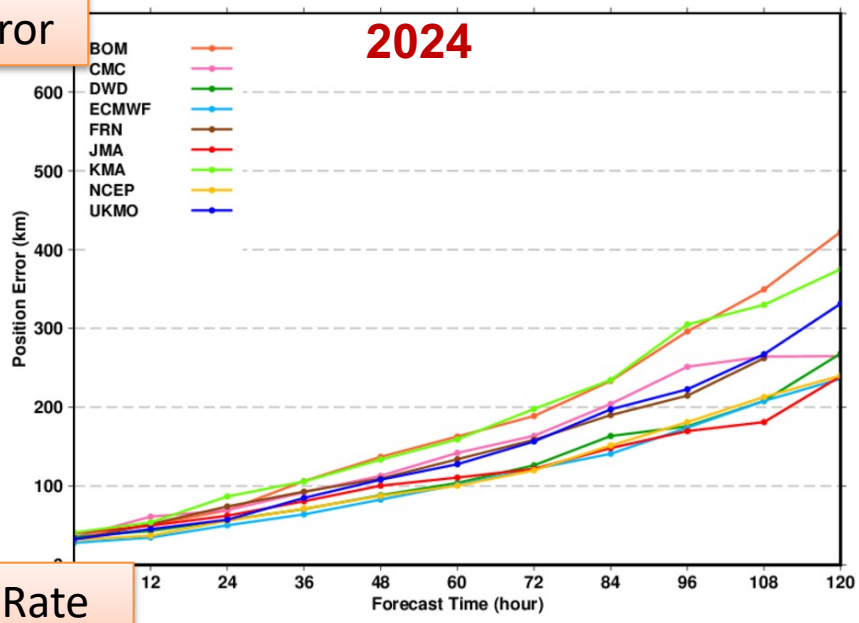


- More than half of models have positive biases throughout T+0 to T+120.
  - In particular, the positive bias of Met Office model increases as lead time progresses.
- NCEP model has smaller bias and MAE than those of other models.
  - This suggests that the NCEP model has small bias without cancellation of too strong and too weak TC cases.
- These trends were also present the previous year.

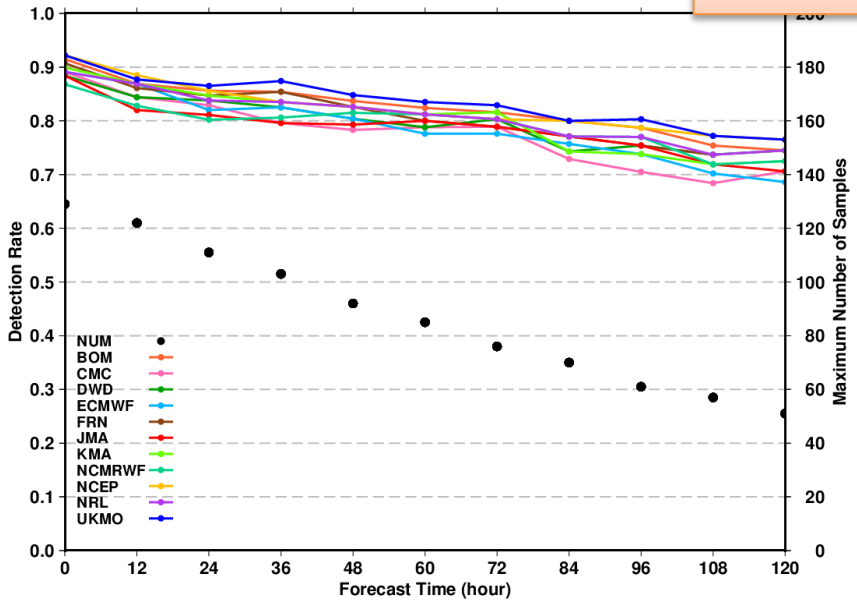
North Atlantic (NAT)

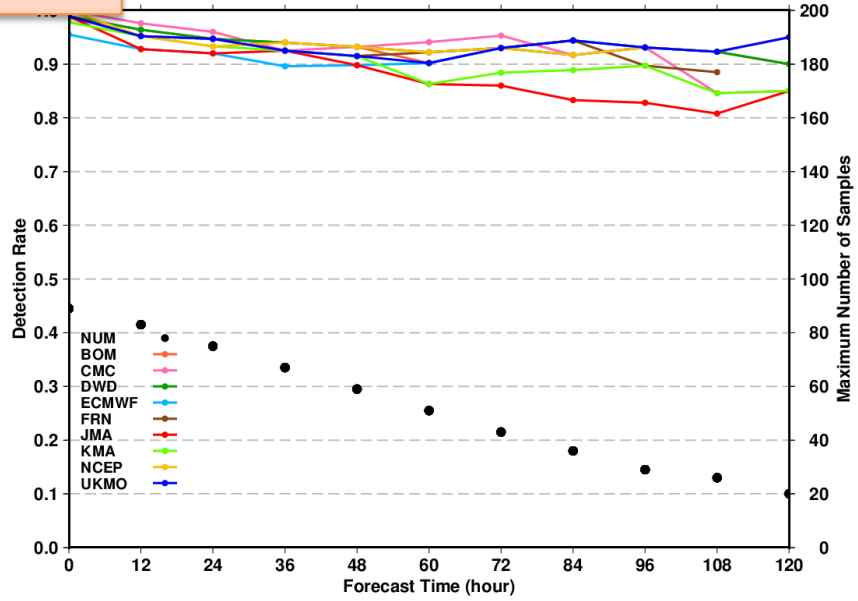
Position Error





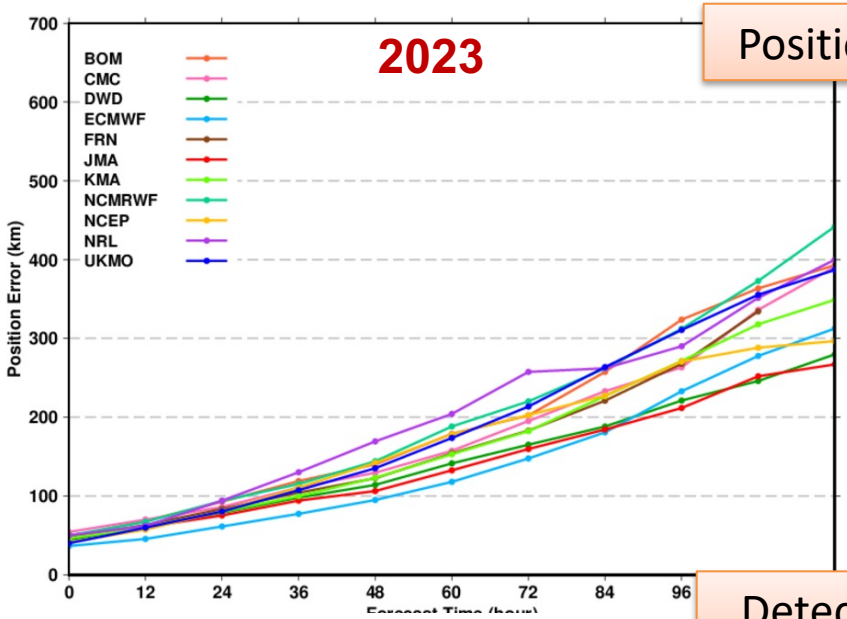
Detection Rate

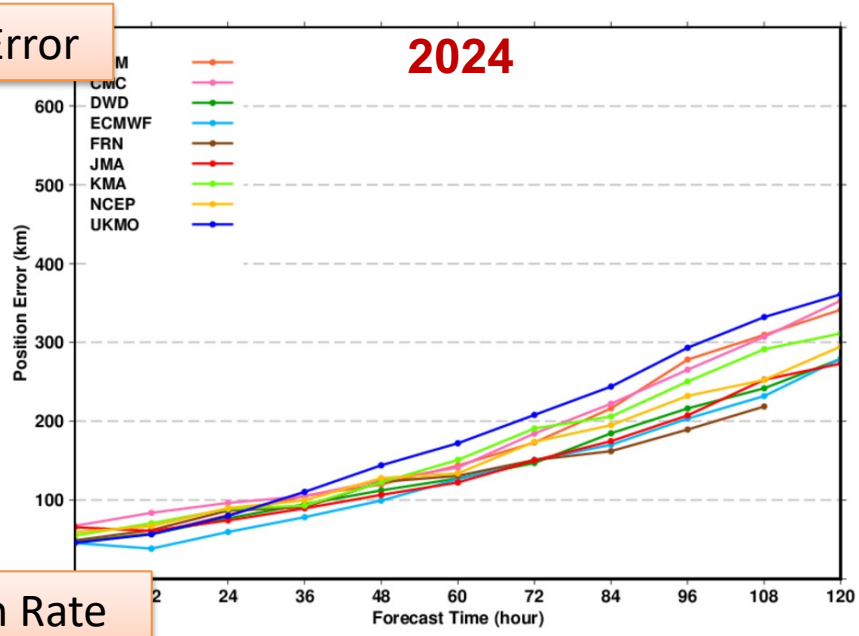




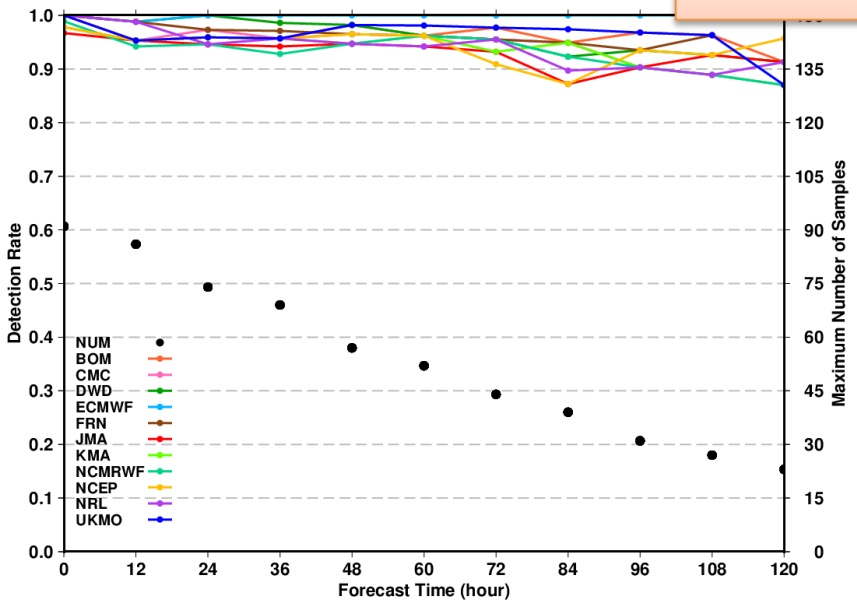
Eastern North Pacific (ENP)

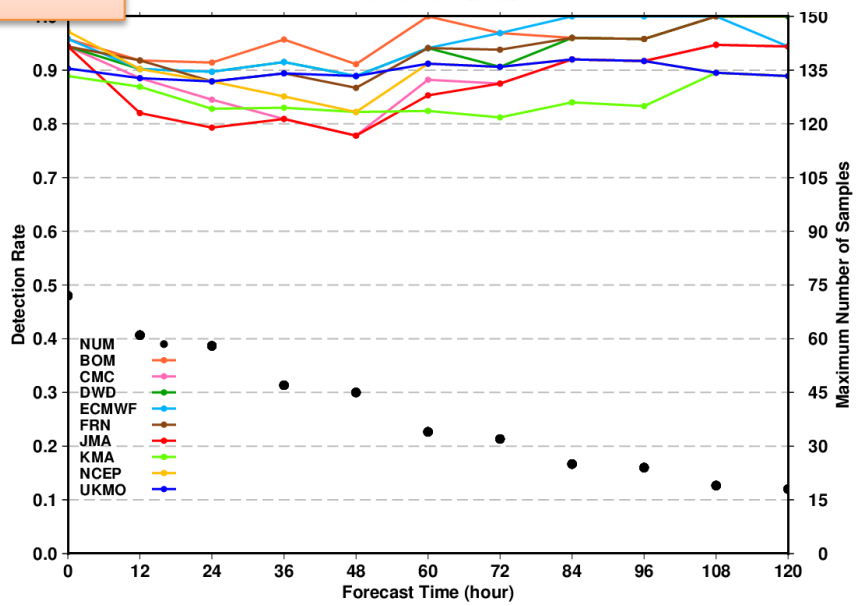
Position Error



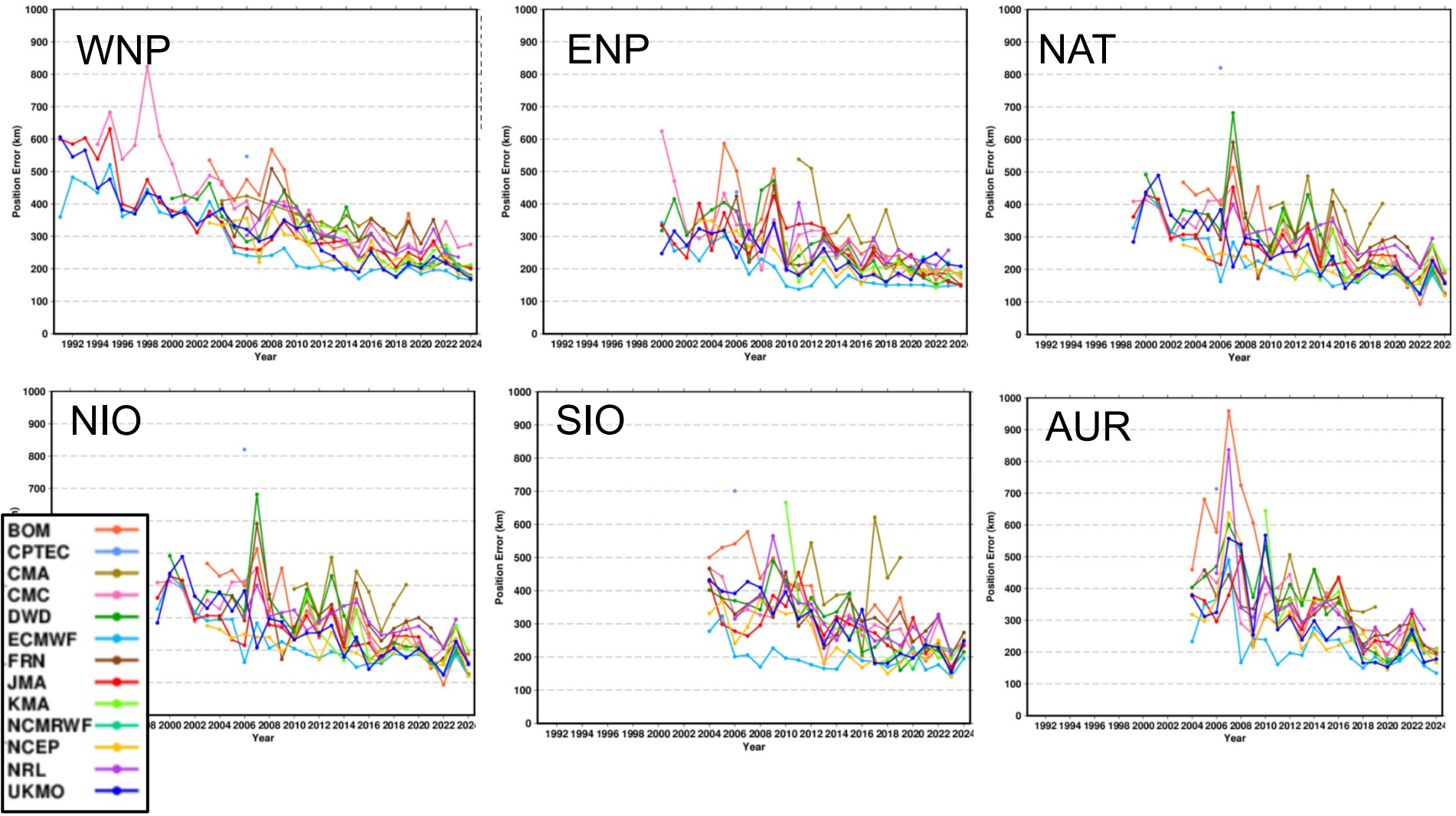


Detection Rate

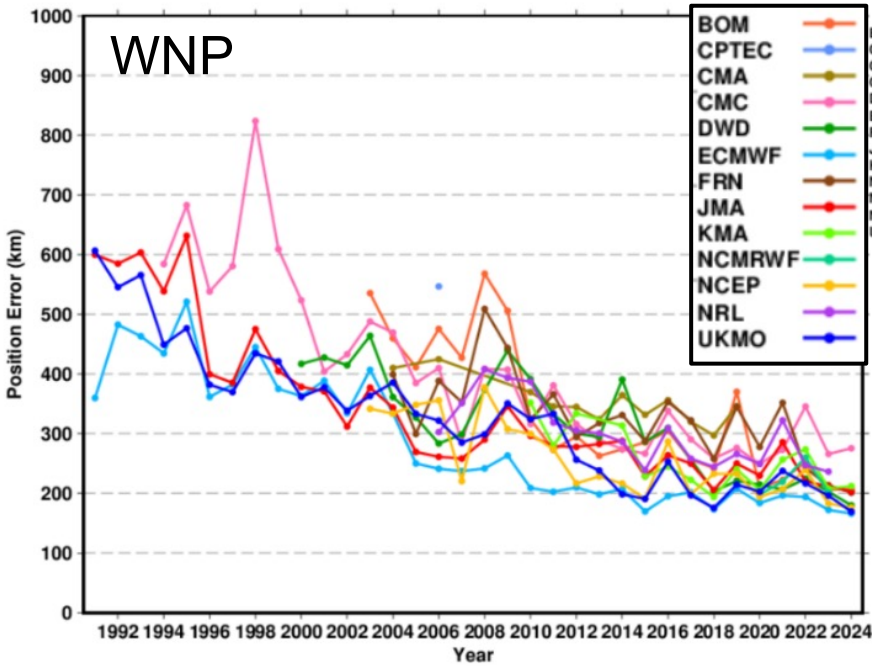


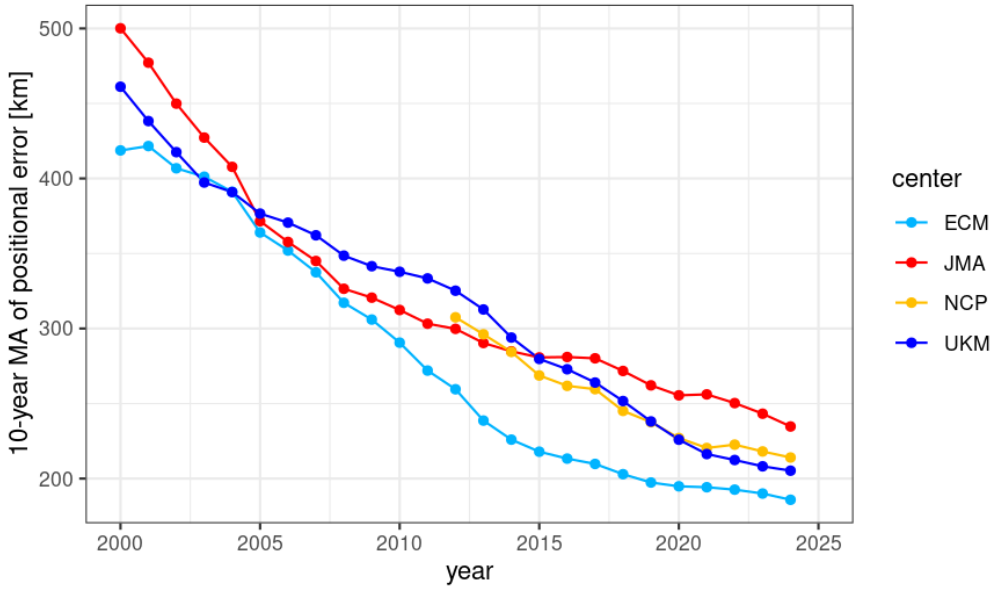


Transition of T+72 Position Error over Decades



Transition of T+72 Position Error over Decades Focusing on WNP basin





10-year Trailing Moving Average of positional error

Summary of verification 2020 (1/2)

- NCMRWF newly joined verification.
- Position errors
  - Smaller track errors are seen over WNP 2020 than 2019.
  - Slow bias after re-curvature, a well-known common bias, was still seen in 2020.
  - TCs which contribute to the annual mean track error (large error with a number of samples) are common among centres possibly due to environmental conditions. e.g. Tropical cyclone "Chan-hom"
  - TC position errors have decreased gradually in each region.
    - However, the error reduction has been slow-down recently .
    - "200km barrier" at T+72 in the annual mean errors?

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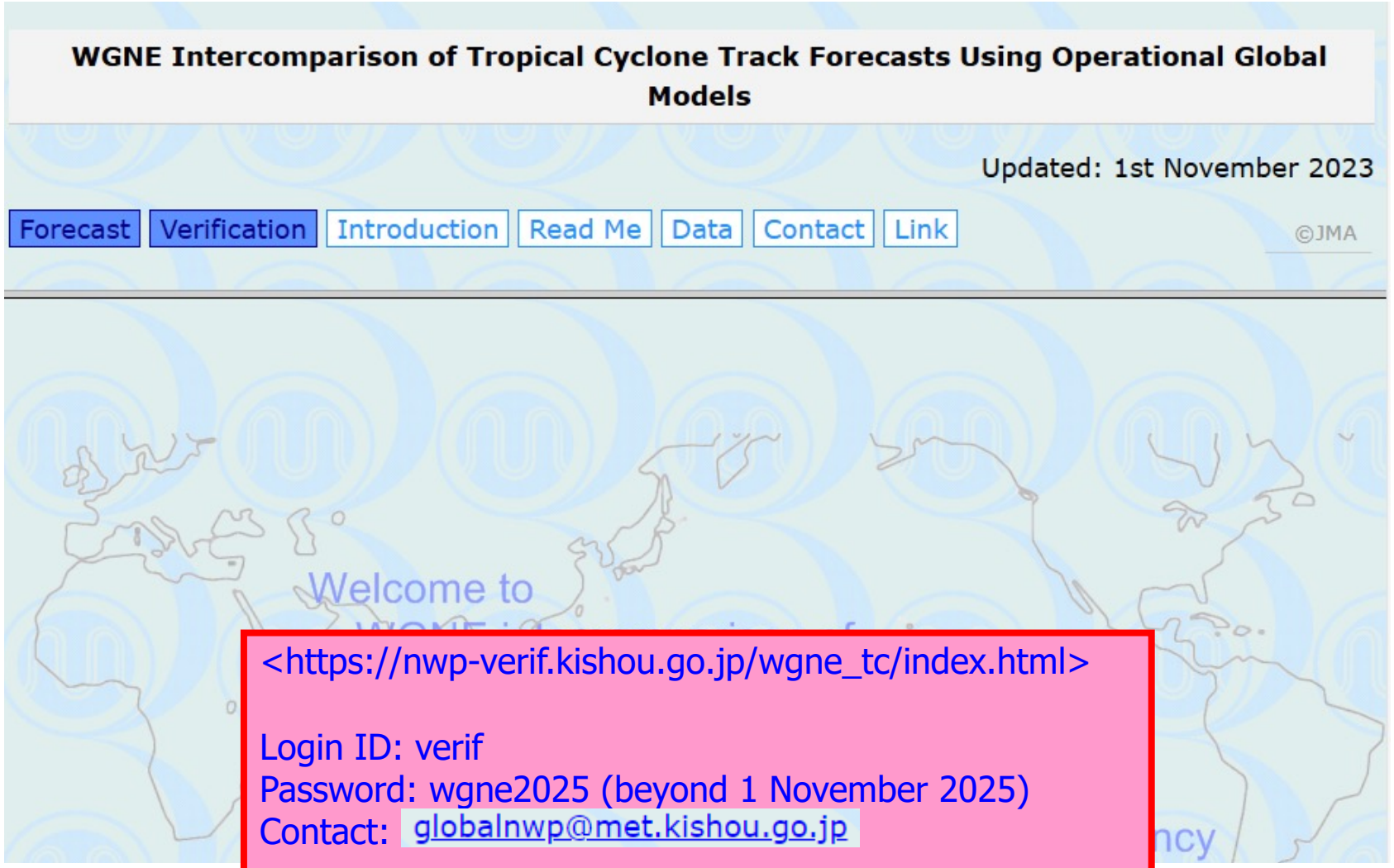
- The rate of improvement in tropical cyclone track forecast accuracy has slowed in recent years.
  - We referred to it as a "200km barrier" at the meeting four years ago.
- However, verification results from the last two to three years suggest that the barrier is being broken.
  - In other words, there is still room for further improvement in accuracy.

Summary of verification 2024

- **Position errors**
  - The error for the three-day track forecast has been steadily decreasing.
    - Although the rate of decrease has slowed, there is still room for further improvement in accuracy.
  - The error for the five-day track forecast by all centres are apparently larger in the WNP basin in 2024 than in 2023.
    - Large error in typhoon SHANSHAN (T2410) is likely to be the primary factor.
  - In most of NWP models, T2410 was caught by the mid latitude jet, that resulted in the large track (fast-moving) errors after recurvature.
    - Relative position and interaction with an UCL may determine whether T2410 was trapped by the jet
    - This is likely to be a reason for unclear slow bias after recurvature, a widely recognized common bias among models seen in previous years.
- **Intensity errors**
  - Over half the models have positive biases in WNP basin over five-day forecast period: consistent with the verification in previous year.
    - NCEP model performed well in terms of both bias and MAE.

TC intercomparison website is available!



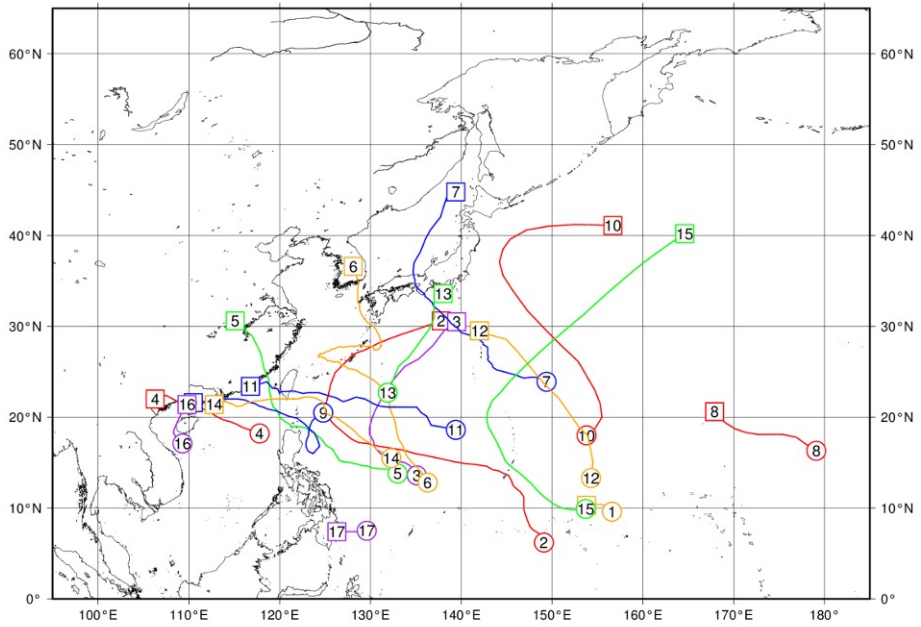
<https://nwp-verif.kishou.go.jp/wgne_tc/index.html>

Login ID: verif
Password: wgne2025 (beyond 1 November 2025)
Contact: globalnwp@met.kishou.go.jp

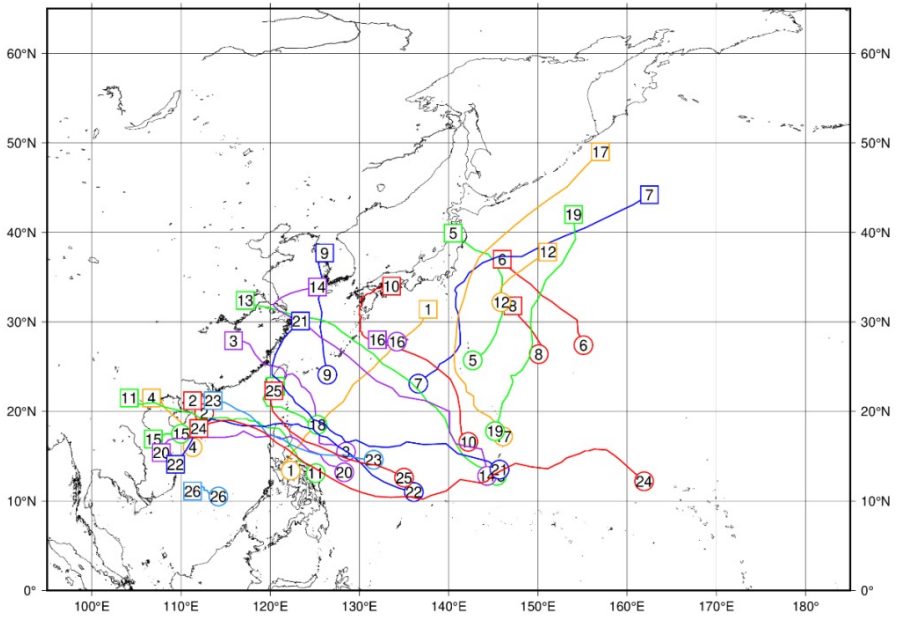
EXTRA SLIDES

Best tracks over WNP

2023: 17 TCs

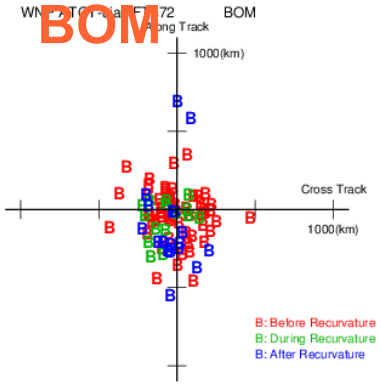


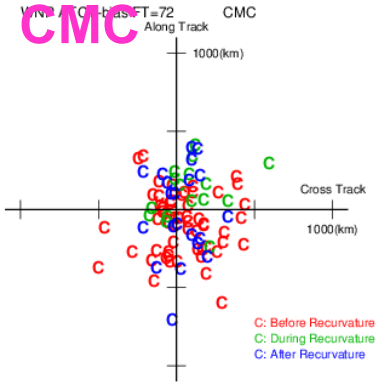
2024: 26 TCs

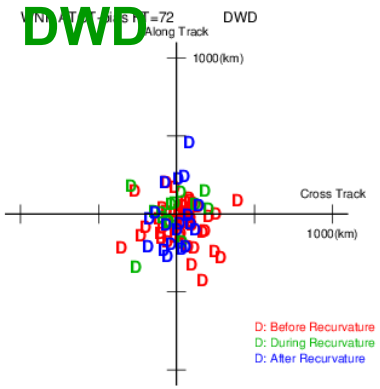


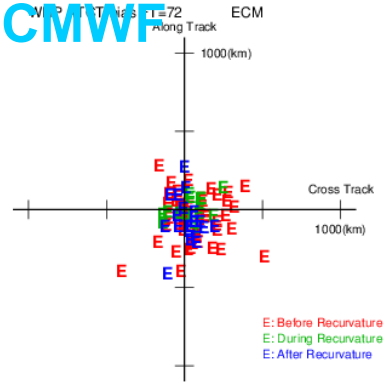
- The number of TCs in 2024 was on a par with the climatological normal frequency of 25.1.
- TC formation was low until August, a shift from the El Niño-influenced spring and early summer to conditions conducive to storm development.

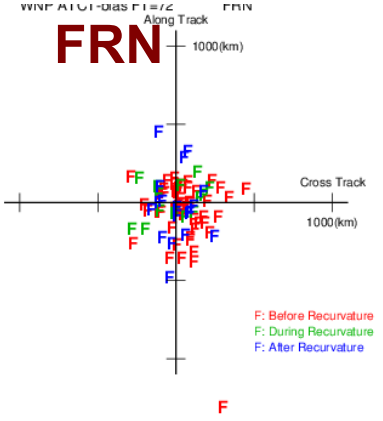
WNP Along/Cross-Track error (T+72)

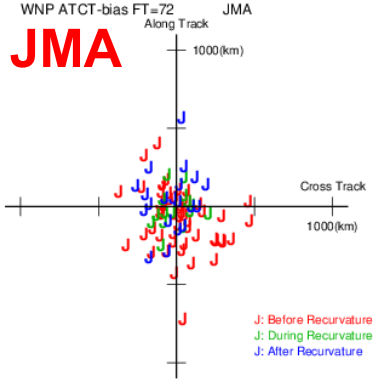


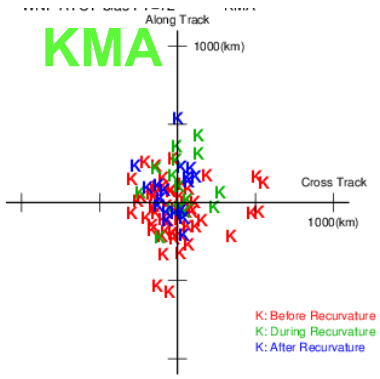


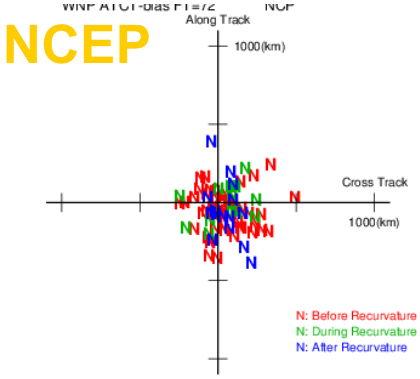


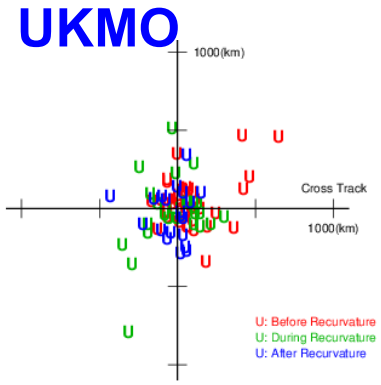










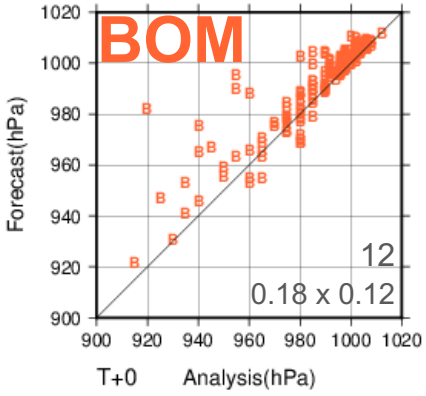


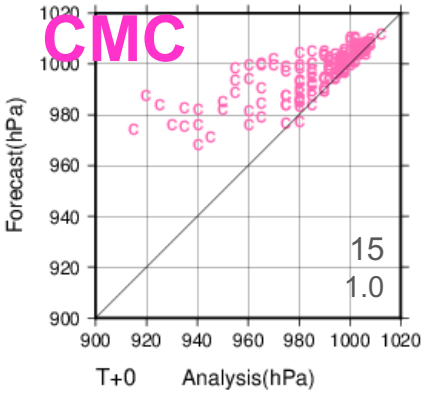
Red : before recurvature
Green : during recurvature
Blue : after recurvature

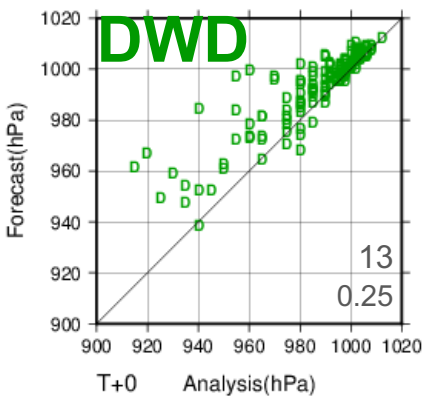
Y-axis : position errors (km) in the along track direction

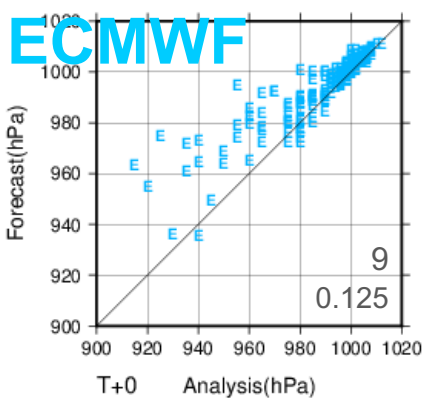
X-axis : position errors (km) in the cross track direction

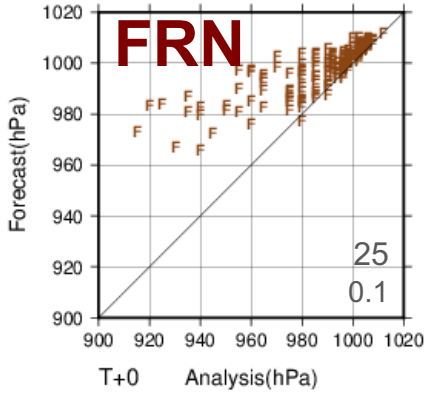
WNP Central Pressure Scatter Diagram (T+0)

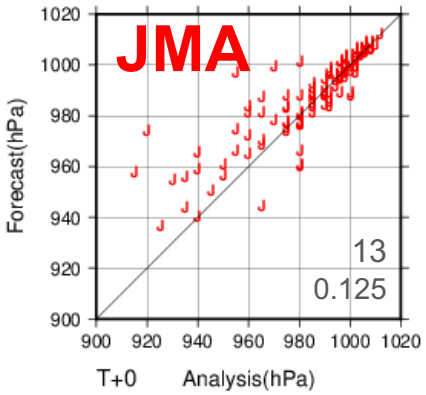


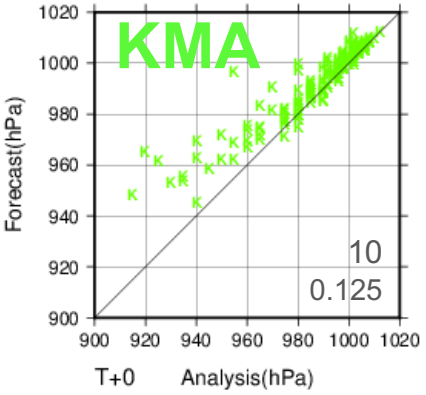


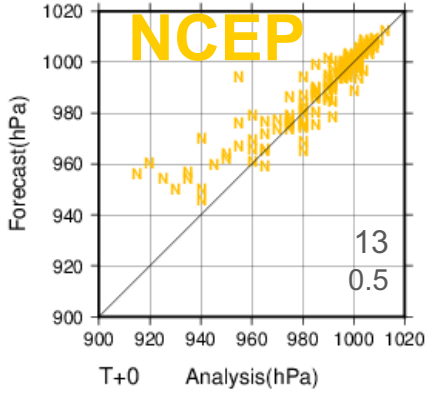


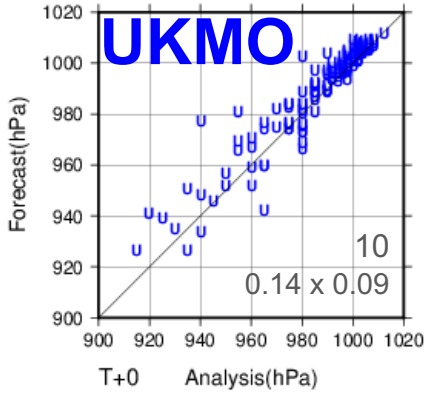












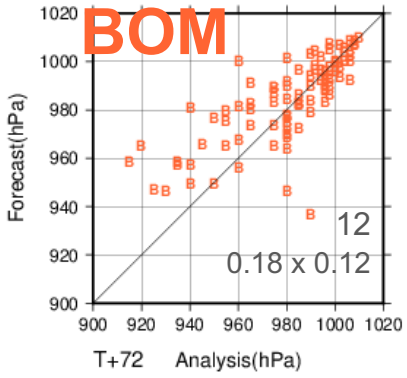
Resolution

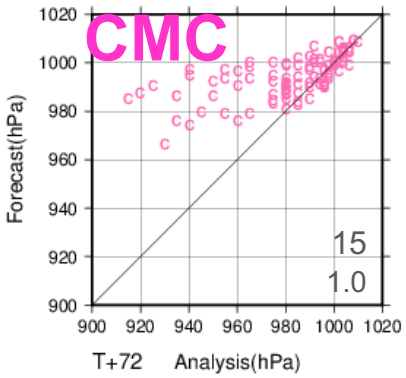
Model (km)
Data (deg)

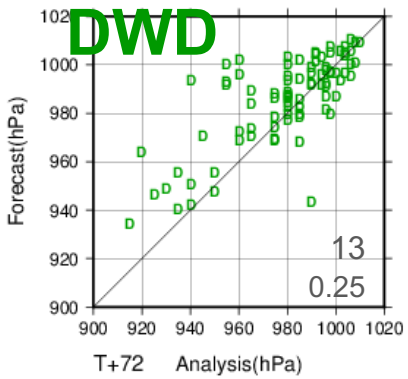
X-axis : analysis

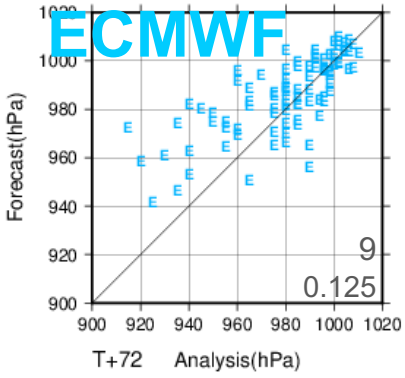
Y-axis : forecast

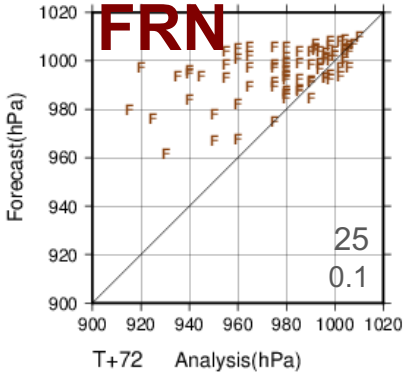
WNP Central Pressure Scatter Diagram (T+72)

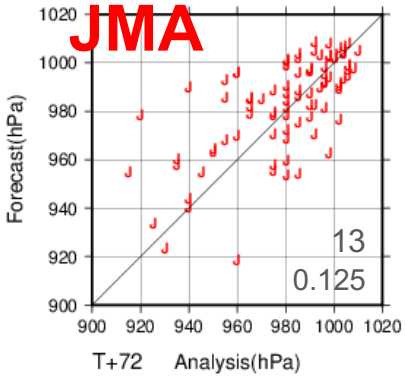


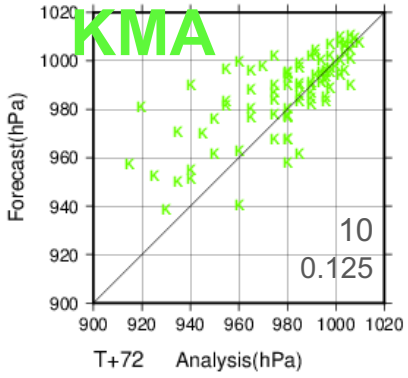


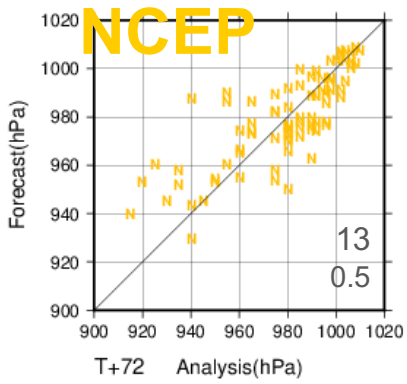


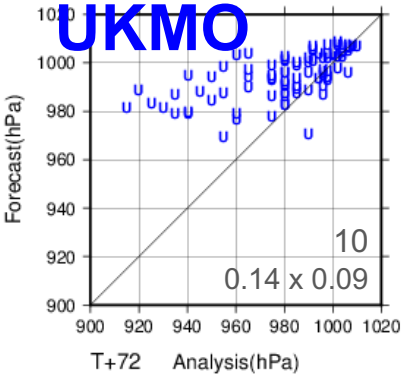












Resolution

Model (km)
Data (deg)

X-axis : analysis

Y-axis : forecast

Verification Method using MSLP

Target TCs

TC best track data provided by individual RSMCs are used in verification, with focus on cyclones reaching tropical storm (TS) intensity with maximum sustained winds of 34 knots or stronger. The tropical depression (TD) stage of targeted TCs is also included in this verification~~, and TCs remaining at TD level throughout their lifespan are excluded.~~

Tracking Method

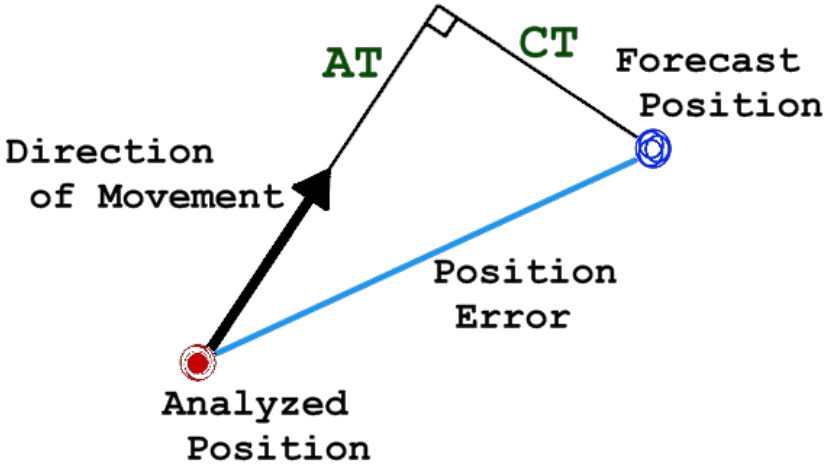
TCs are tracked using mean sea level pressure data provided by participating NWP centres. Under this method, the minimum pressure point is identified as the initial or predicted TC position.

1) First position (FT+0hr) is searched within a 500 km radius of a best track position.
2) Second position (FT+6hr) is searched within a 500 km radius of the first position.
3) Subsequently (FT+12hr~), a TC position within a 500 km radius of a reference point determined from linearly extrapolation of the latest two positions is identified.

Tracking ends when no appropriate minimum pressure point is found.

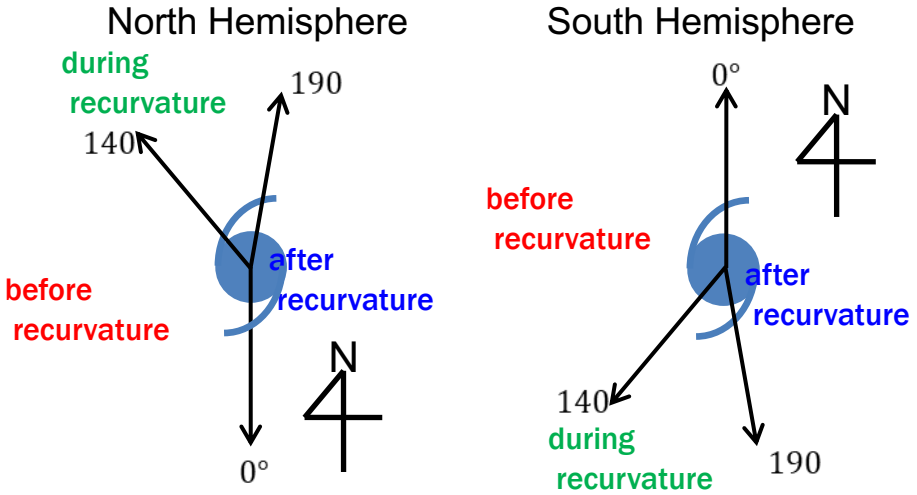
Definitions

- **Position Error〔km〕:**
  distance between the best track (analyzed) position and the forecast position



- **Along Track – Cross Track bias**
  AT (along-track) bias : bias in the direction of TC movement
  CT (cross-track) bias : bias in the direction perpendicular to TC movement

- **Recurvature**
  Before
  During
  After



- **Detection Rate**
  Detection Rate (t) = A(t)/ B(t) , where:
  A(t) : number of events in which a TC is analyzed at time t with the condition that the NWP model successively expresses the TC until time t
  B(t) : number of events in which a TC is analyzed at time t.

TC initialization schemes employed in the participating centres

TC initialization scheme	subtype	centres
Bogus	vortex insertion	None
	synthetic observation	CMA, JMA, KMA, NCEP, NRL
TC relocation		None
Assimilating central pressure obs. from TC warning centres		BoM, Met Office, NCEP
None		CMC, DWD, ECMWF, Meteo France

source: WGNE-31 presentation on TC verification, BoM(2019), Heming (2016) and Heming et al. (2019) and input from participating centres

Notes

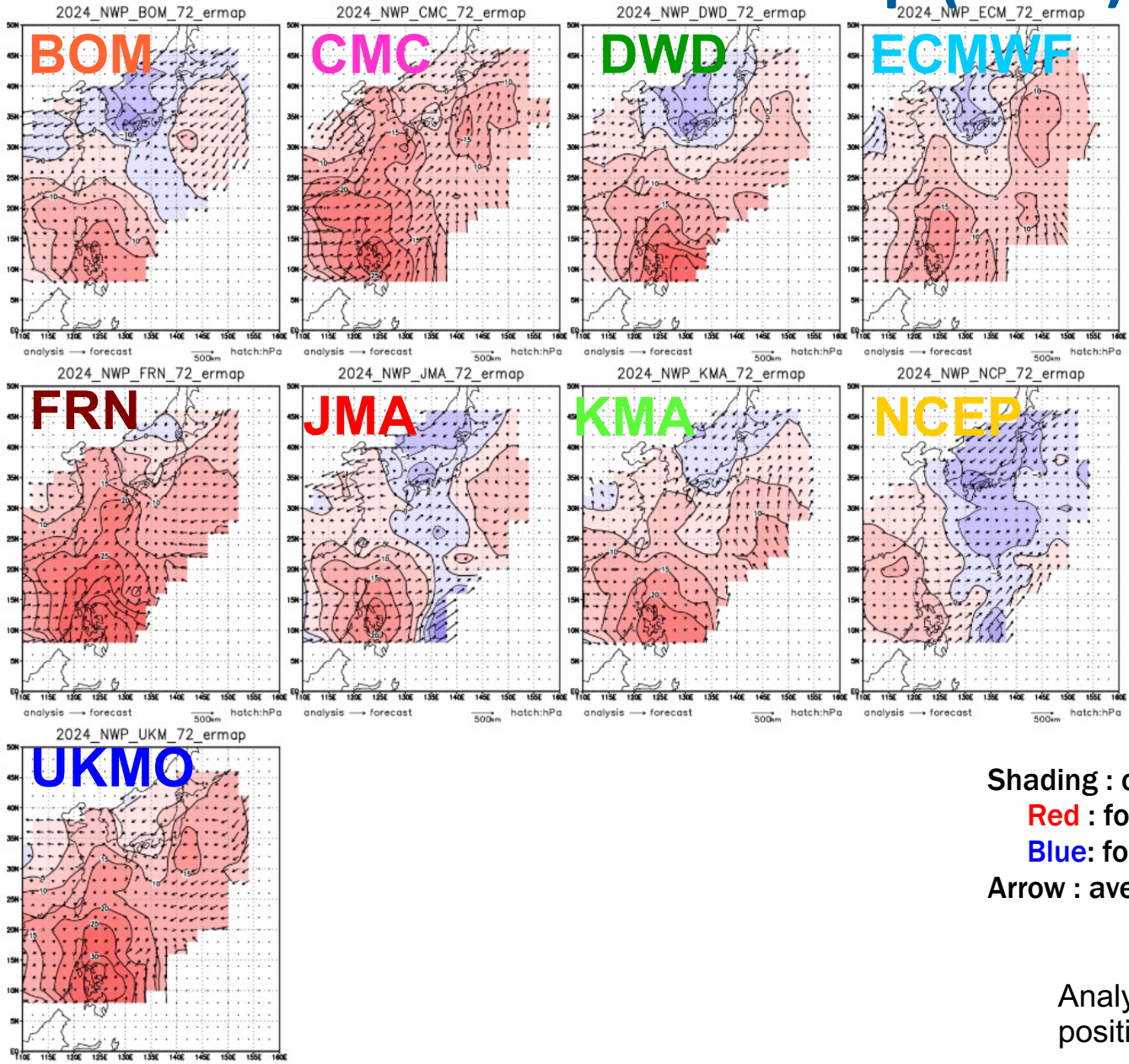
* NCEP employees combination of multiple initialization schemes (Kleist et al. 2016).
* JMA, CMA: only over Western Pacific Ocean

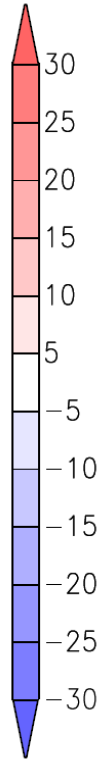
- Synthetic observation, using central pressure, and no TC-specialized initialization are major choice
- No participating centre employees vortex insertion or TC relocation type schemes.
-

Trends in choice of TC initialization schemes

- As models and/or data assimilation systems can represent TCs better, TC initialization schemes tend to be less artificial or less specialized for TCs.
- Examples:
  - Heming et al. (2016) : Met Office has upgraded the TC initialization schemes to harness with the model's capability.
  - Kadowaki (2005): JMA switched the TC initialization scheme from a vortex-insertion type TC bogus to a synthetic observation type TC bogus along with introduction of 4DVAR
  - Kazumori and Kadowaki (2017) and Geer et al. (2018) : Introduction of all-sky assimilation improved the representation of TCs

WNP Error Map (T+72)





Shading : central pressure error (hPa)
Red : forecast is shallow
Blue: forecast is deep
Arrow : average position error