WGNE inter-comparison of Tropical Cyclone Track forecast 2022

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STANDARD VERIFICATION

Verification of Global Models

Data Specifications in 2022

NWP centre	Year of verification commencement	Horizontal resolution of provided data (degrees in longitude and latitude)	Model resolution as of 2022
BoM	2003	0.176 x 0.117	12kmL70
CMC	1994	1.0 x 1.0	15km L84
DWD	2000	0.25 x 0.25	13kmL90 (6.5km L60 for Europe)
ECMWF	1991	0.125 x 0.125	TCo1279L137
FRN	2004	0.1×0.1	T_L1798(C2.2)L105
JMA	1991	0.25 x 0.25	T_L959L128
KMA	2010	0.125 x 0.125	12kmL91
NCEP	2003	0.5 x 0.5	FV3(13km)L127
NCMRWF	2020	0.18 x 0.12	12kmL70
NRL	2006	0.5 x 0.5	T681L60
UKMO	1991	0.1406 x 0.094	10kmL70

Improvement of models for each centres in 2022 (1/2)

CMC

- 1 Dec. 2021 Upgrade to Version 8.0.0
  - Physics upgrades incl. adjustment to mid-level convection
  - Ozon as a prognostic variable
  - Start assimilation of AMSU-A ch.4
- 16 Feb. 2022 Addition of GPSRO observations from the GRACE-C and GRACE-D satellites
- 28 Jun. 2022 Upgrade to Version 8.1.0
  - Adapted to the new high performance computing infrastructure
- 03 Nov. 2022 Addition of surface observations received from ships

DWD

- 12 Oct. 2022 New ICON version (2.6.5-nwp0a)
  - Introduced a simple parameterization of the latent heating related to changes in subgrid-scale cloud cover
- 23 Nov. 2022 Resolution upgrade and new orography raw data
  - Increased the number of model levels (90 to 120 in the global domains)
  - Created a merged data set consisting of MERIT and REMA

FRN

- 29 Jun, 2022 New operational suite(46t1)
  - Updated ARPEGE physics (including Tiedtke-Bechtold convection scheme)
  - Improved the data assimilation system (ARPEGE 4D-VAR)

Improvement of models for each centres in 2022 (2/2)

JMA

- 30 Jun. 2022 Assimilation of EUMETSAT Dual-Metop AMV was started
- 13 Dec. 2022 Assimilation of AMV and CSR from Himawari-9 was started

KMA

- Dataset for WGNE TC verification was switched from UM to KIM in 2022

NCEP

- 29 Nov. 2022 Upgrade of the GFS to v16.3
  - Updated the land surface model
    - The model is addressed first by providing proper density to various frozen hydrometers
  - Upgraded the data assimilation model
    - Improving the use of observations
      - Feature-tracking winds from satellite
      - Scatterometry winds from satellite
      - Retrieved ozone from satellite
      - GNSS radio occultation
      - Satellite radiances
    - Enhancing near sea surface temperature analysis

UKMO

- 04 May. 2022 OS45 : Incorporation of GC4 (GA8/GL9/GO6)
  - Ocean coupling
  - Physics upgrades incl. convective memory.

TCs in 2022

TC season

Northern Hemisphere ： 1 January 2022 to 31 December 2022

Southern Hemisphere ： 1 September 2021 to 31 August 2022

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

25 (22) Western North Pacific [RSMC Tokyo]

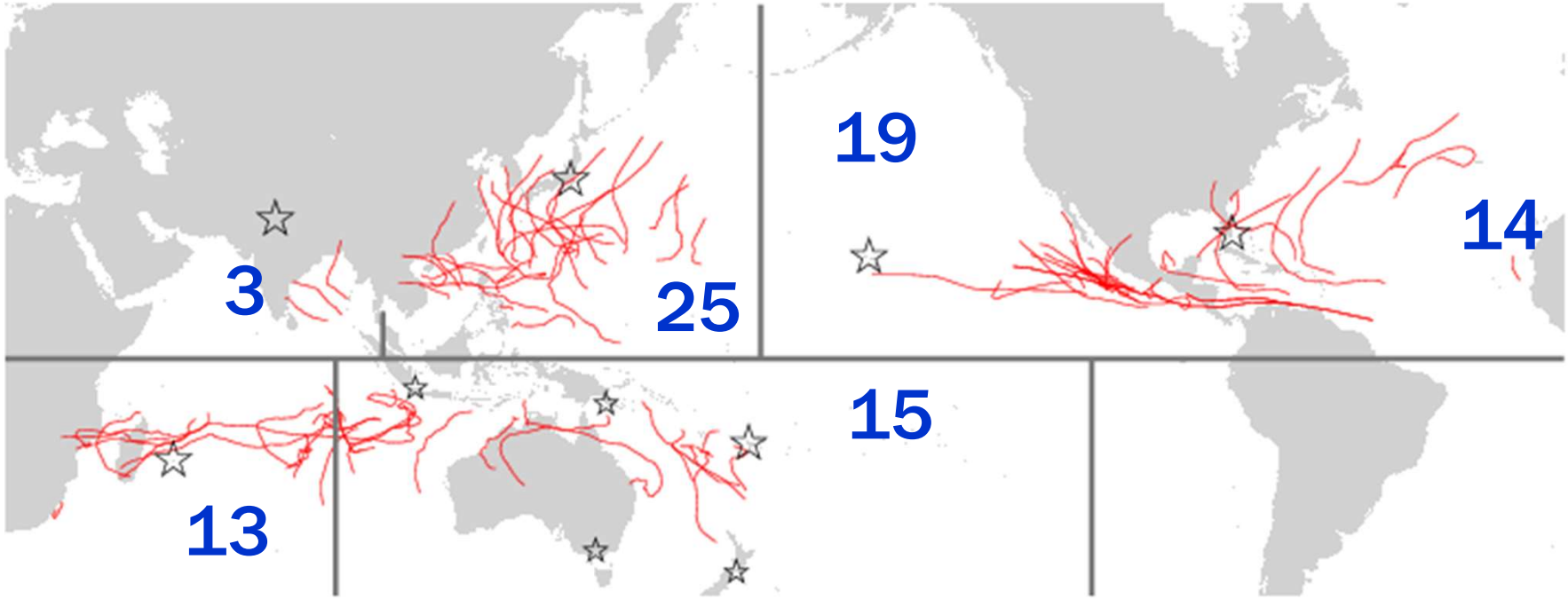
19 (19) Eastern North Pacific (including Central North Pacific) [RSMC Miami, Honolulu]

14 (21) North Atlantic [RSMC Miami]

3 (5) North Indian Ocean [RSMC New Delhi]

13 (11) South Indian Ocean [RSMC La Reunion]

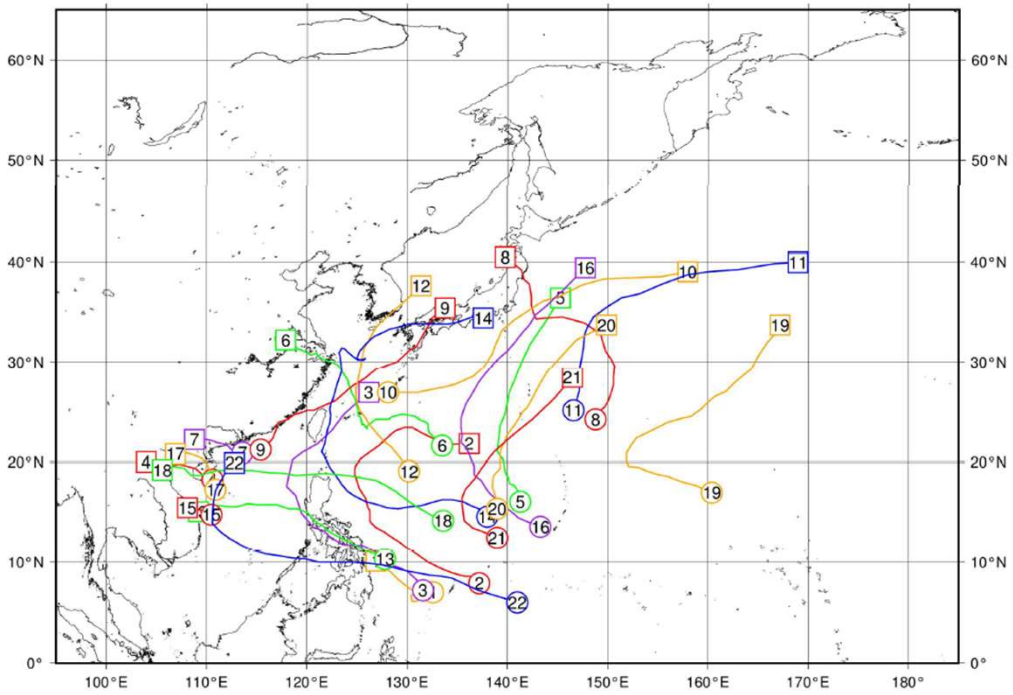
15 (11) Around Australia [RSMC Nadi and 4 TCWCs]



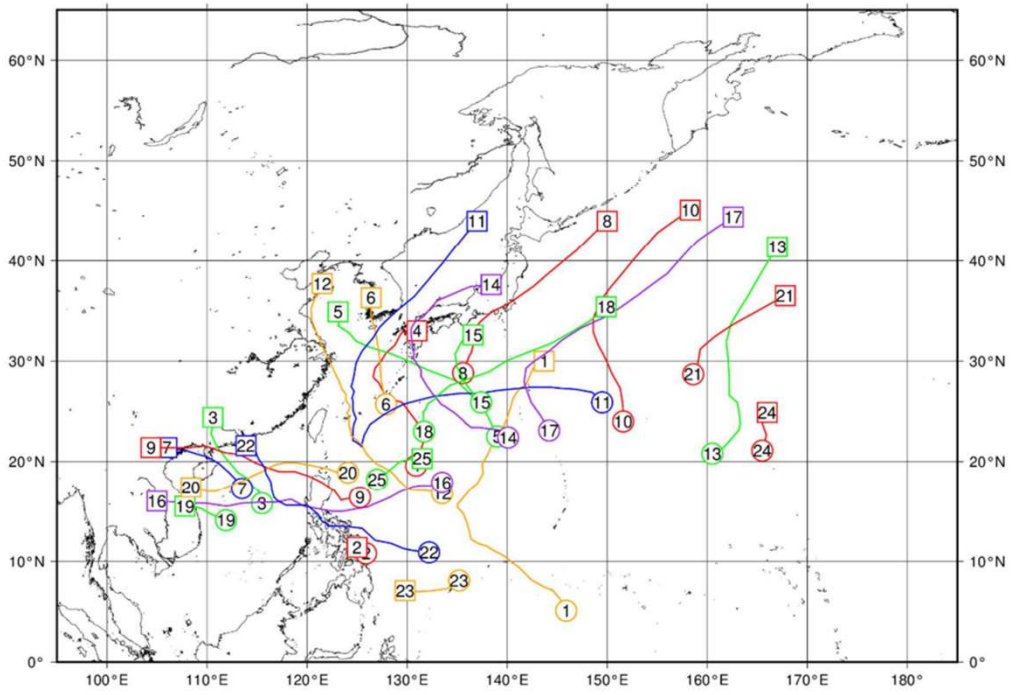
(*)The number of tropical cyclones in each region includes overlaps.

Best tracks over WNP

2021: 22 TCs



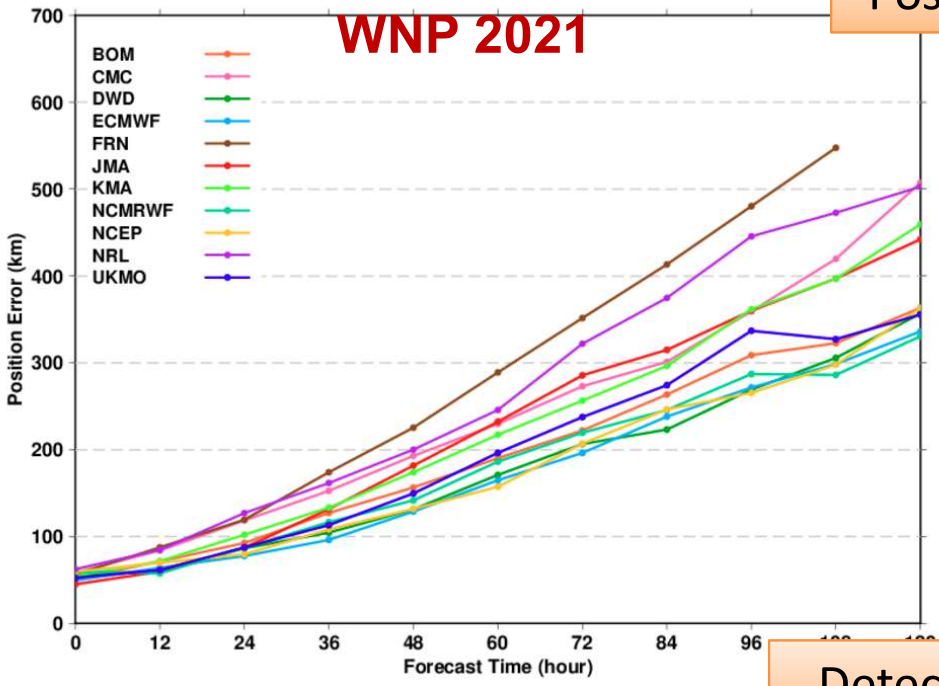
2022: 25 TCs

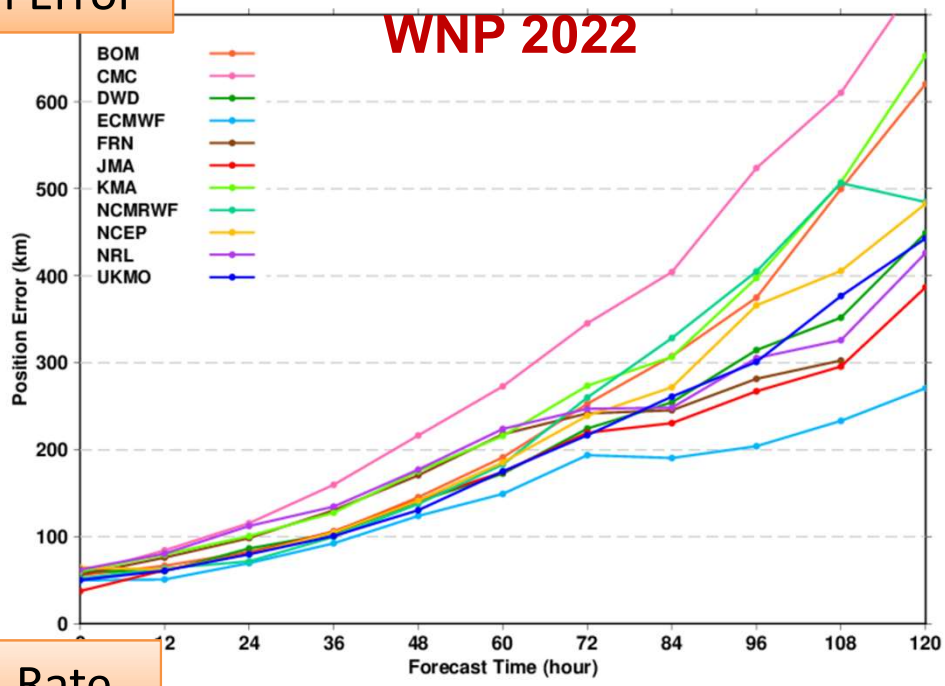


- More recurved and northward TCs in 2021
- Less lifespan of TCs in 2022

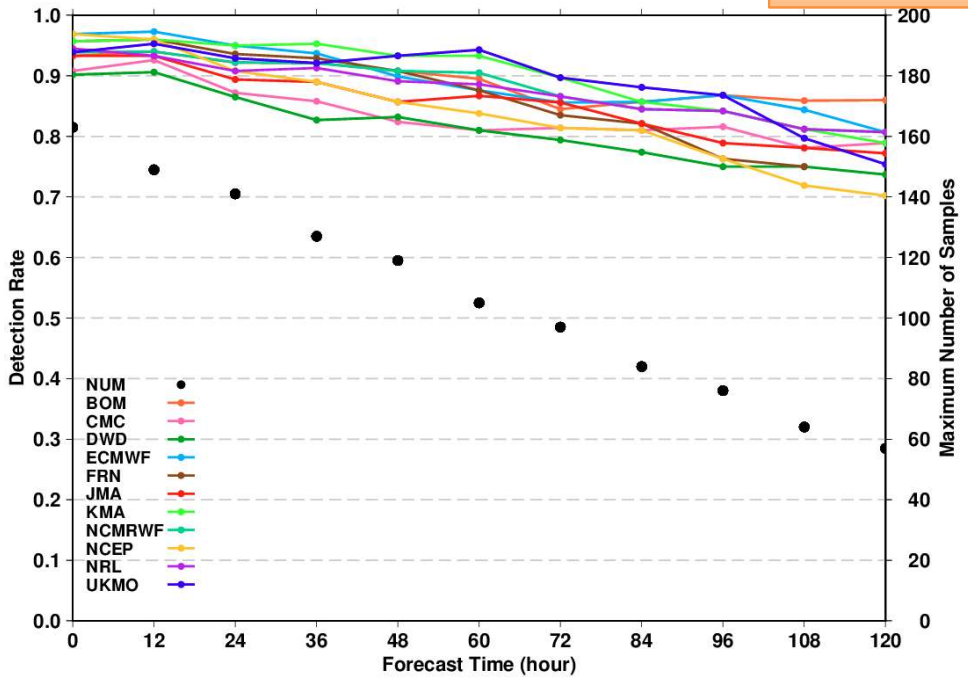
  (The mean lifespan in 2021: 5.5 days, in 2022: 3.7 days)

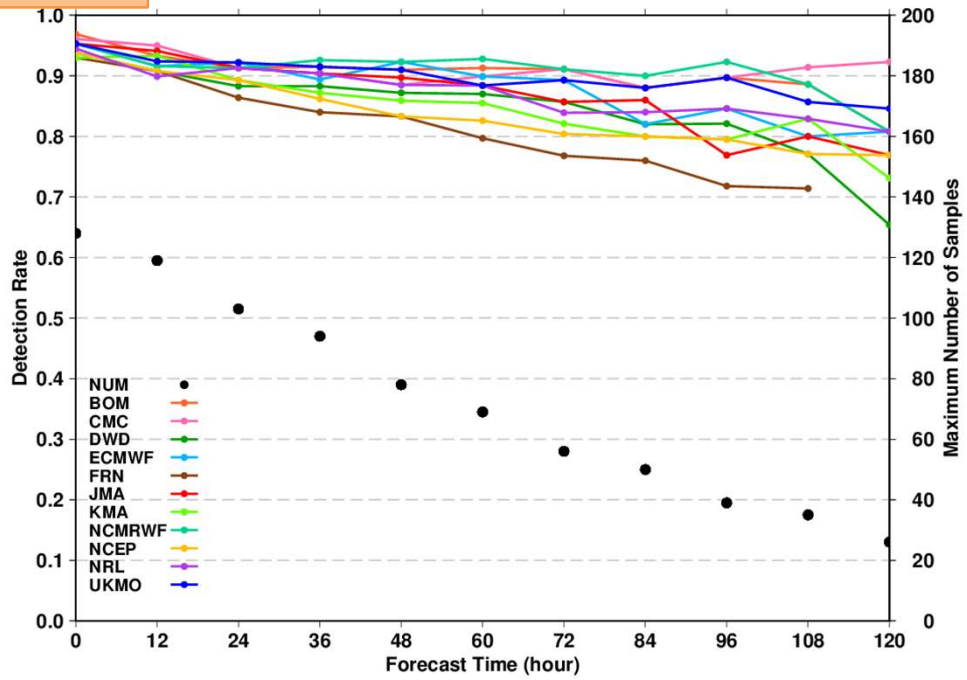
Position Error



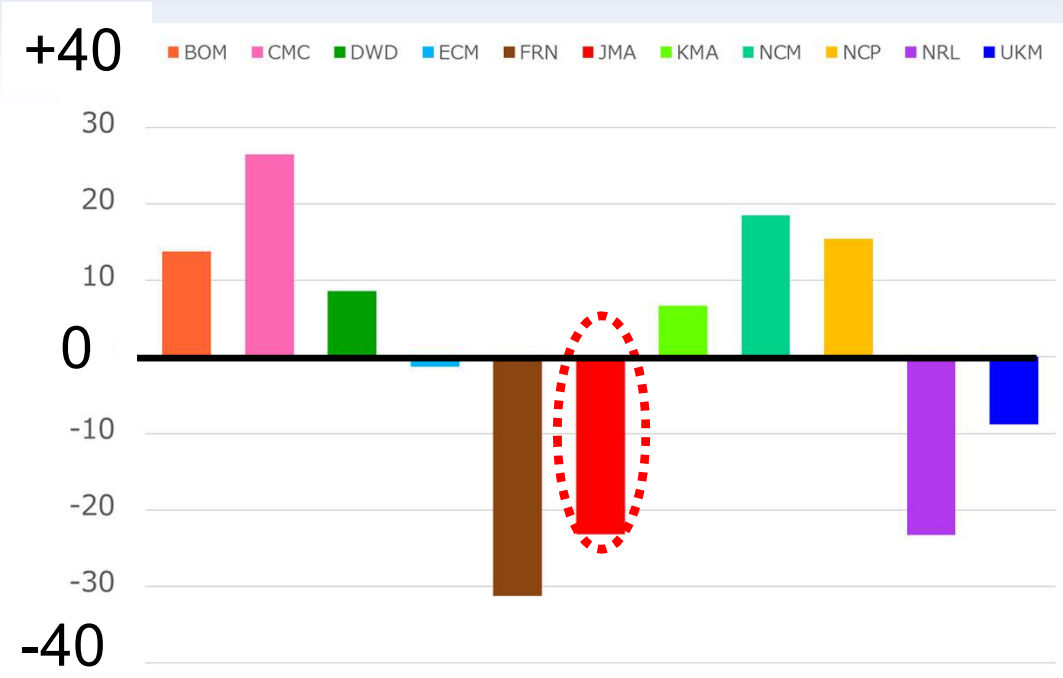


Detection Rate

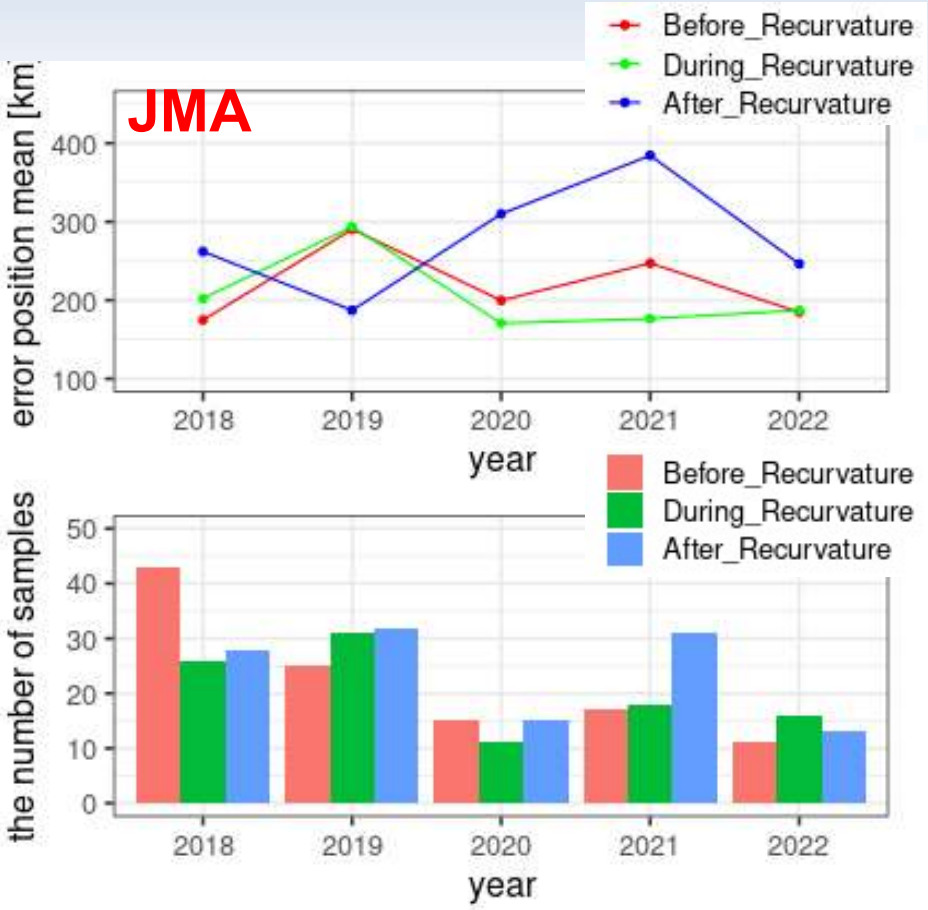




WNP mean TC position errors at T+72



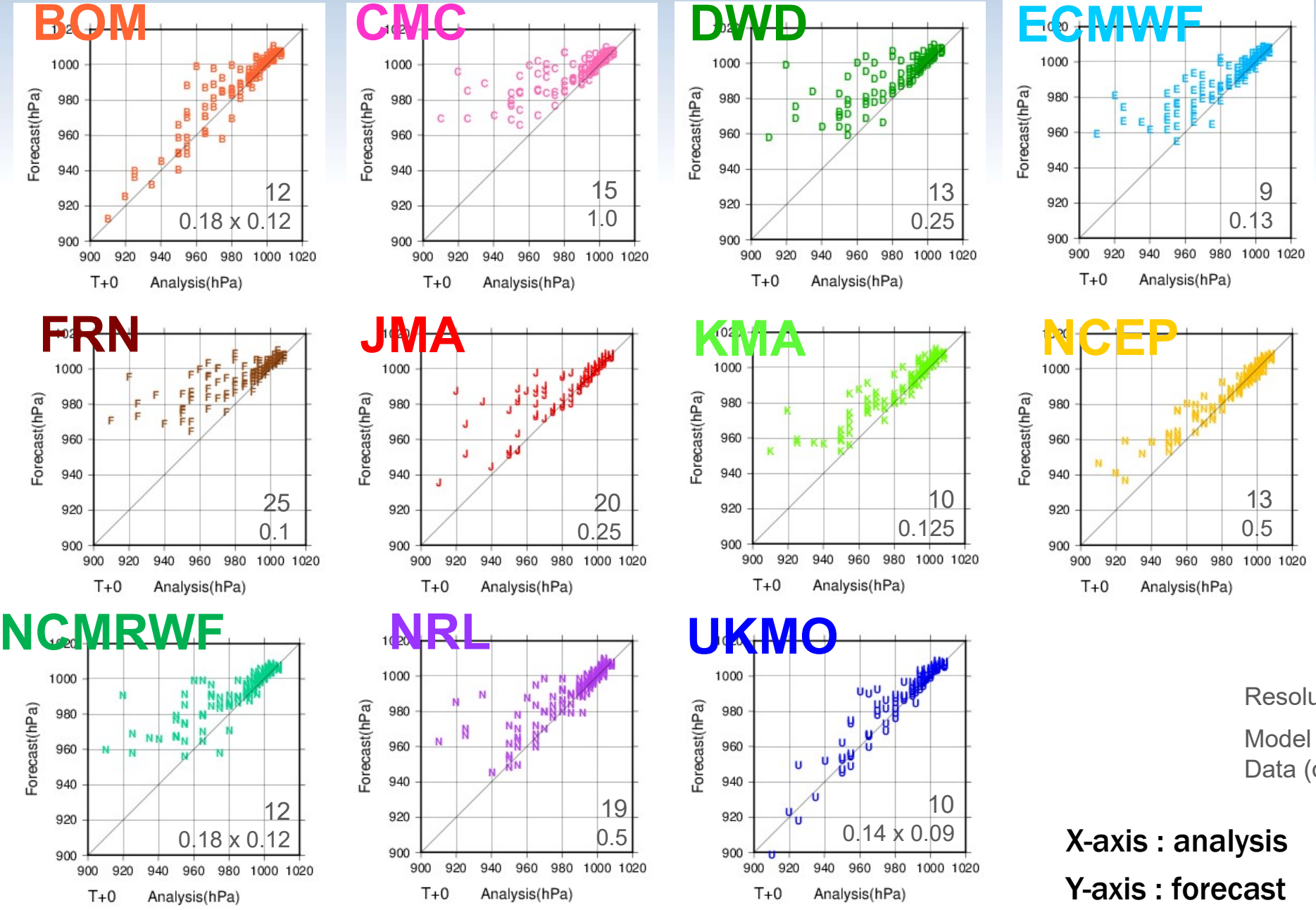
percent change from the previous year of position errors



- **The position errors in the JMA forecasts were decreased without major model upgrades in this TC season**

⇒ **Due to fewer recurved and northward TCs than 2021**

(a) WNP Central Pressure Scatter Diagram (T+0)



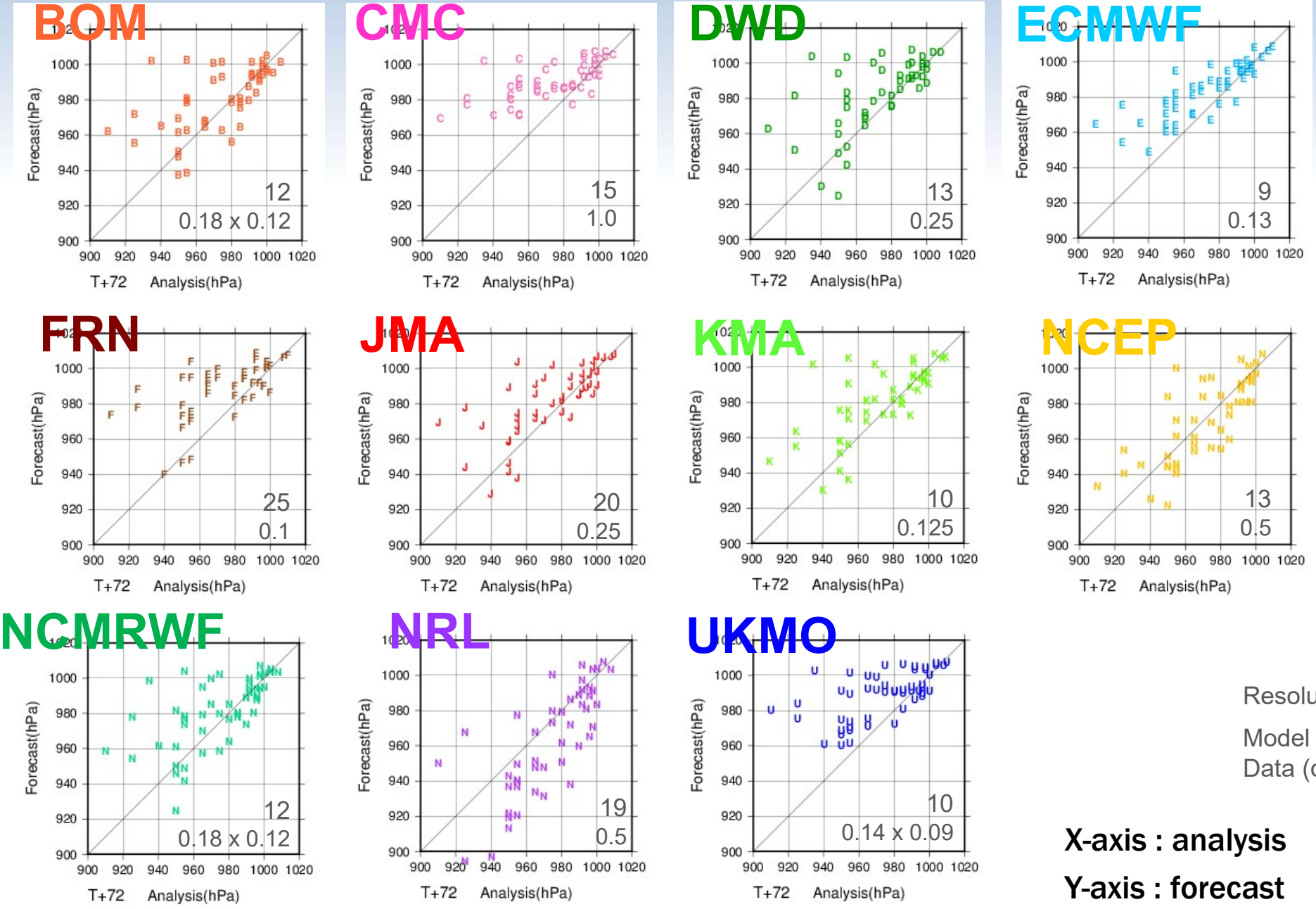
Resolution

Model (km)
Data (deg)

X-axis : analysis

Y-axis : forecast

(a) WNP Central Pressure Scatter Diagram (T+72)



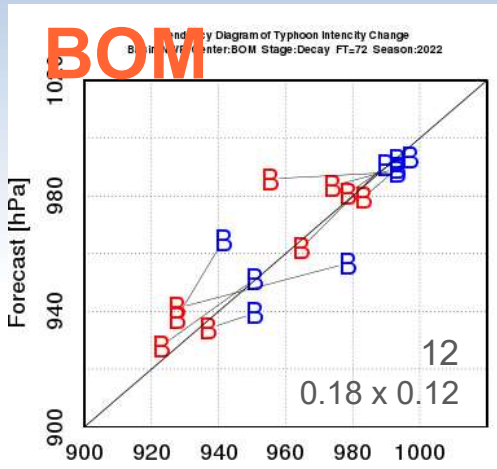
Resolution

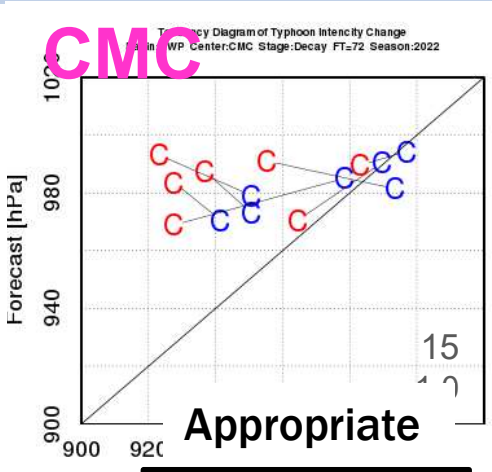
Model (km)
Data (deg)

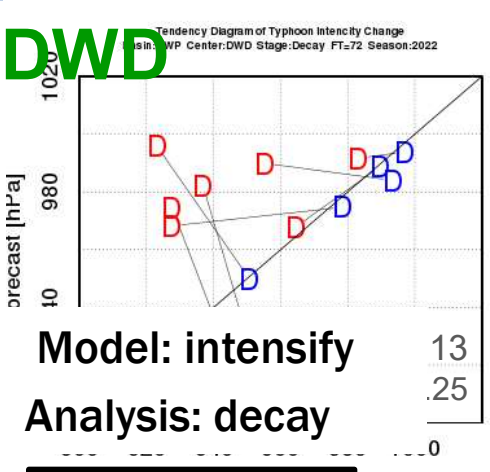
X-axis : analysis

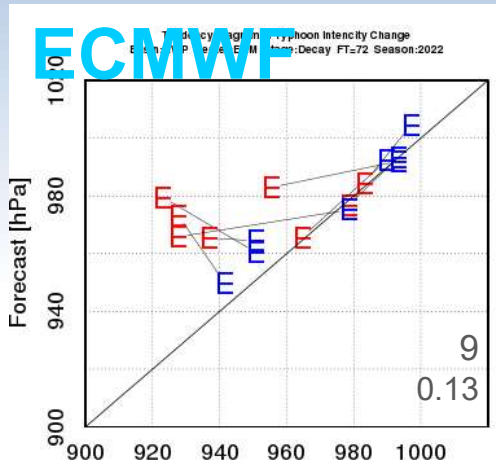
Y-axis : forecast

(a) WNP Tendency Diagram of TC Intensity Change





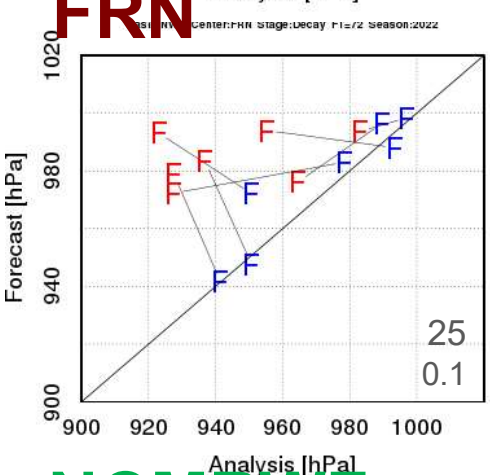


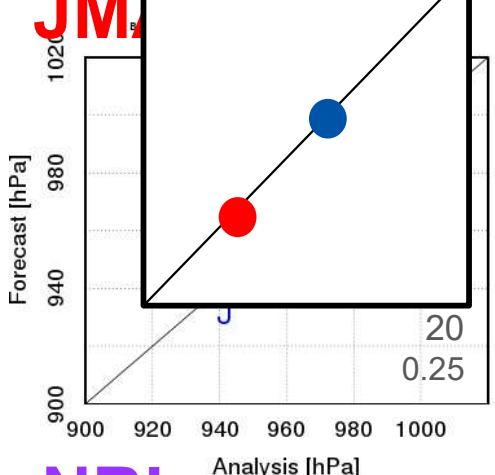


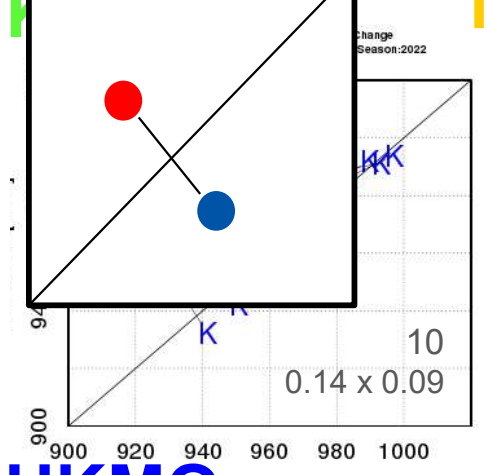
Model: intensify

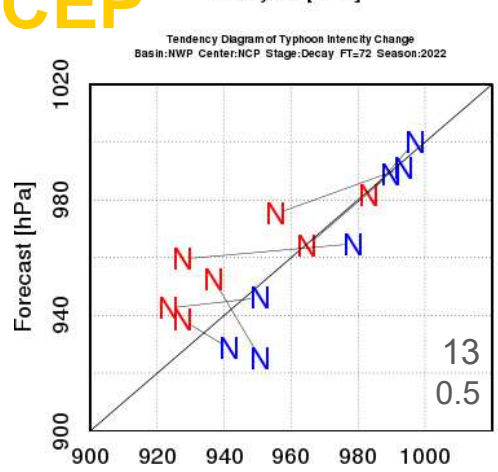
Analysis: decay

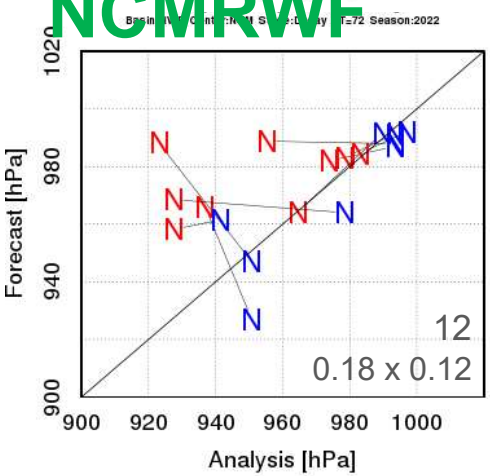
Appropriate

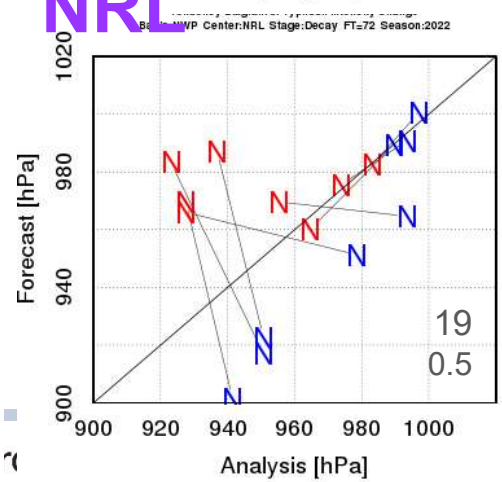


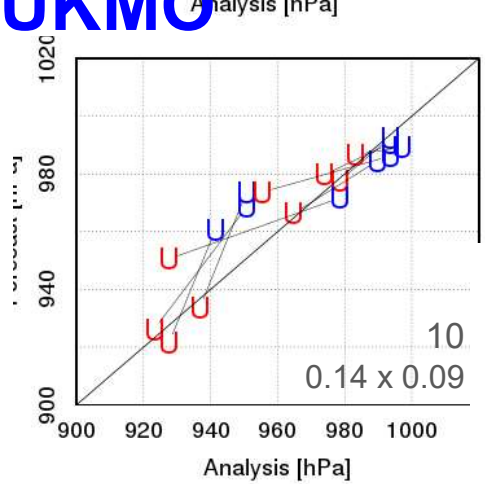












Stage : Decay

X-axis : analysis

Y-axis : forecast

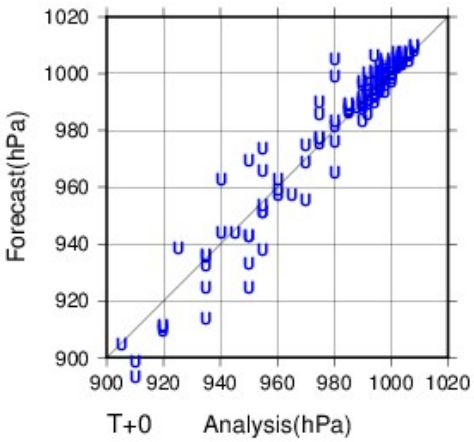
Red : T + 0

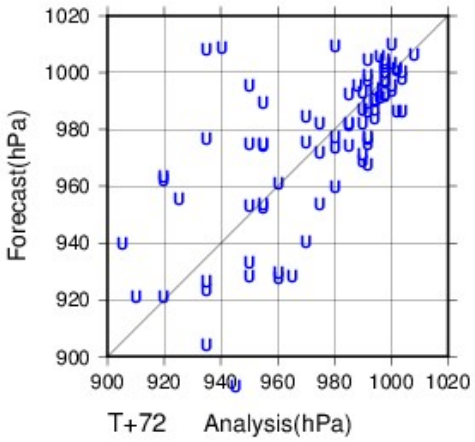
Blue : T + 72

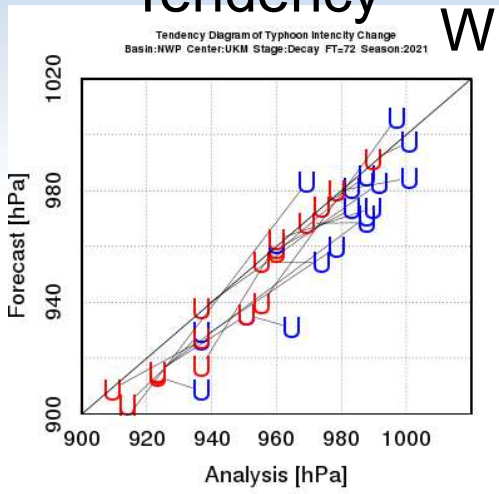
Model (km)
Data (deg)

Impact of model upgrade on TC intensity forecast

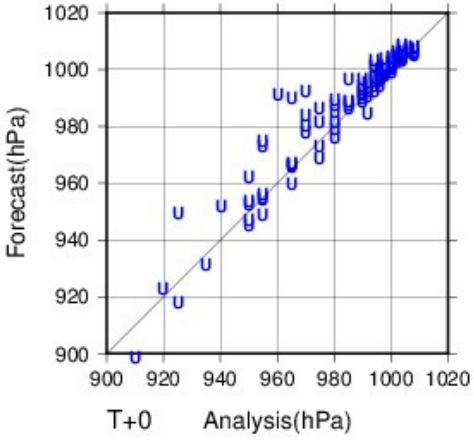
2021 **UKMO** T+0 T+72 Tendency WNP

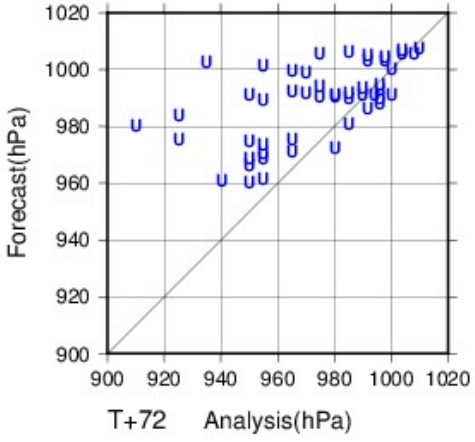


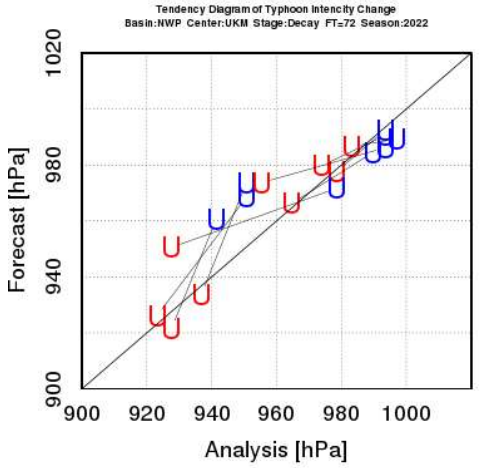




2022







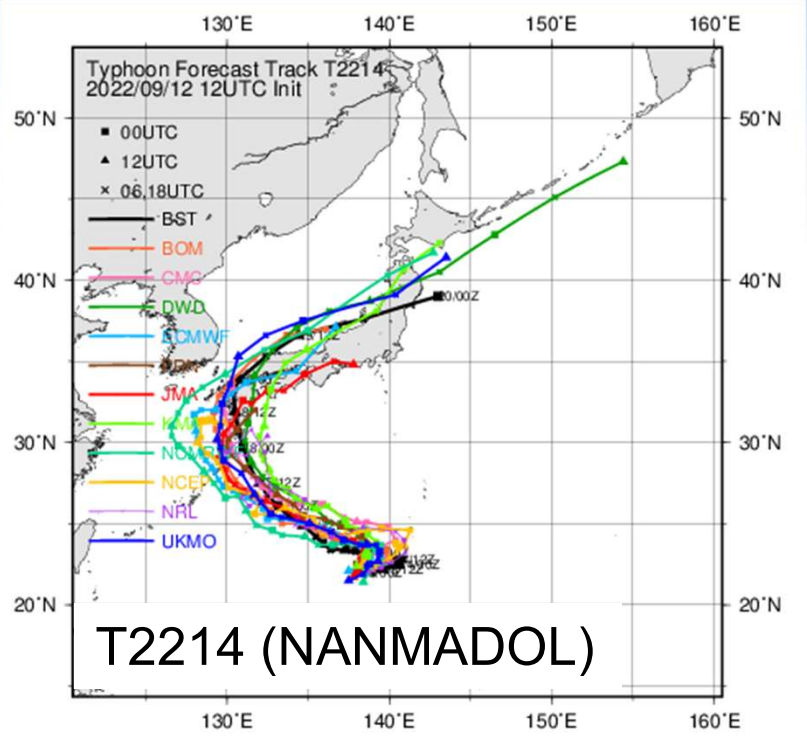
X-axis : analysis

Y-axis : forecast

Red : T + 0

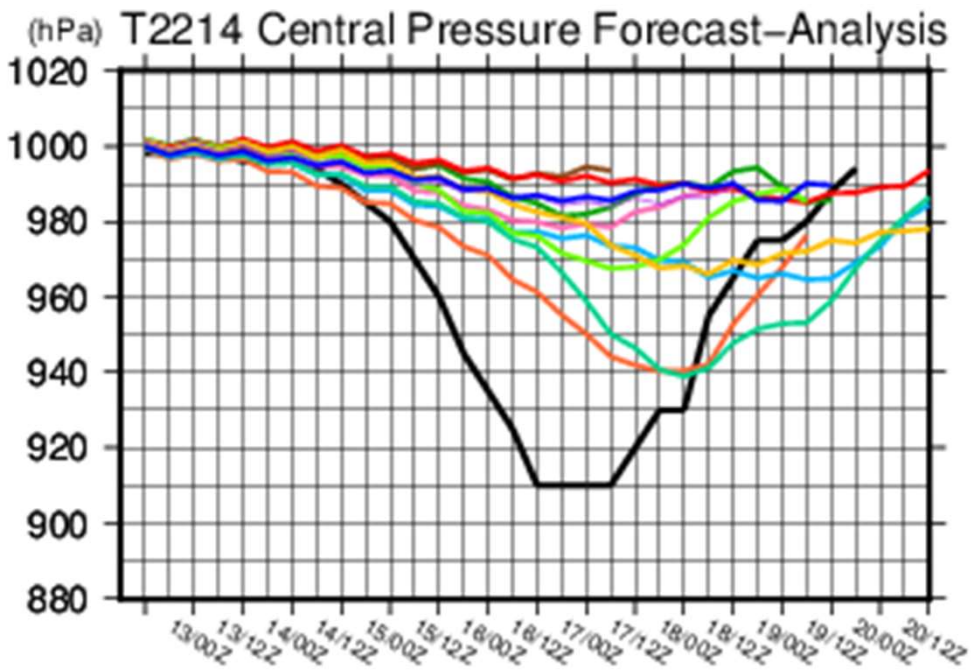
Blue : T + 72

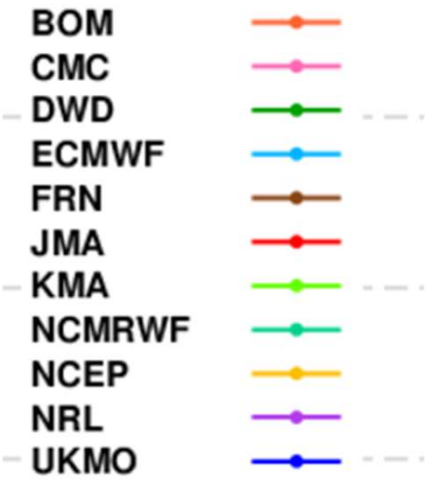
A case of rapid Intensification event in WNP



T2214 (NANMADOL)

Init: 2022-09-12 12UTC

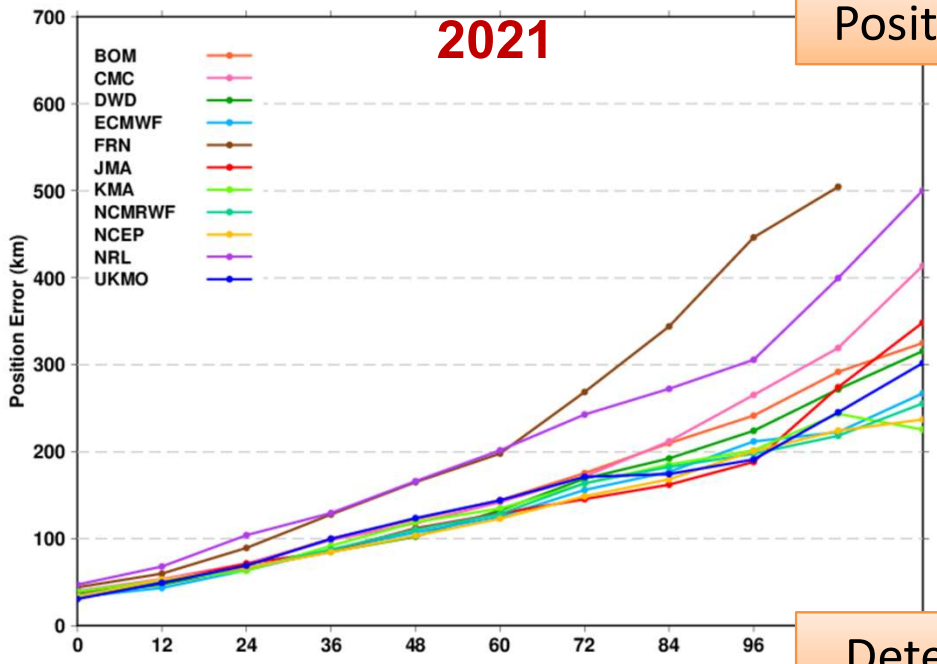


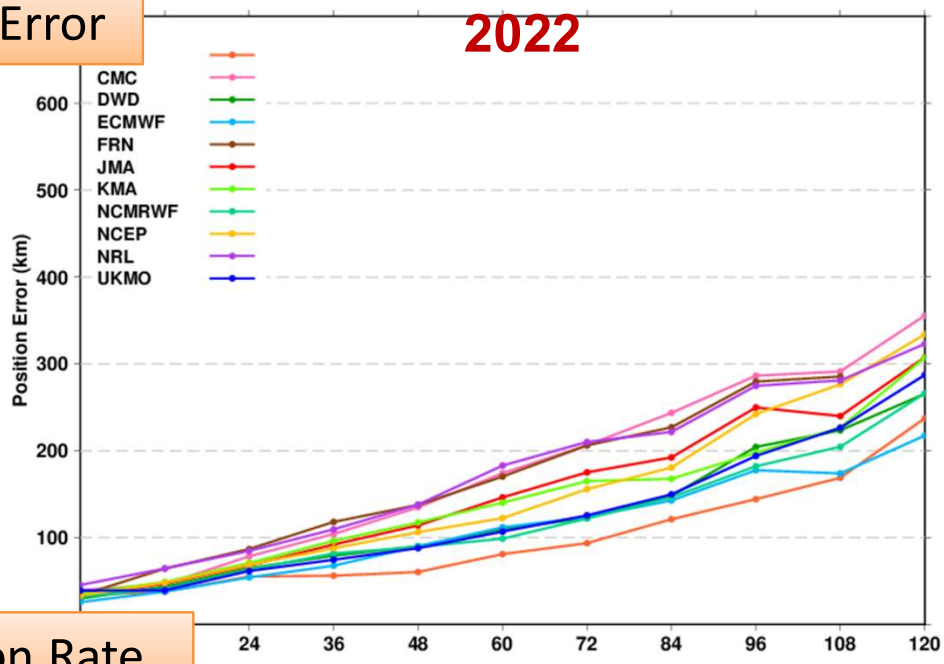


- **All of the participating global models have little predictability in rapid intensification events in WNP region.**

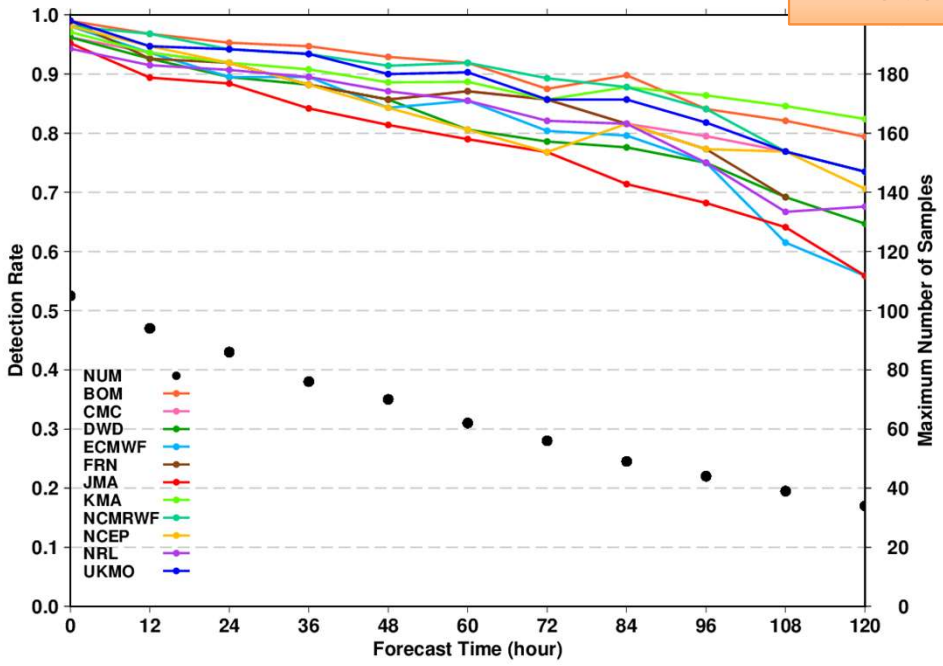
(b) North Atlantic (NAT)

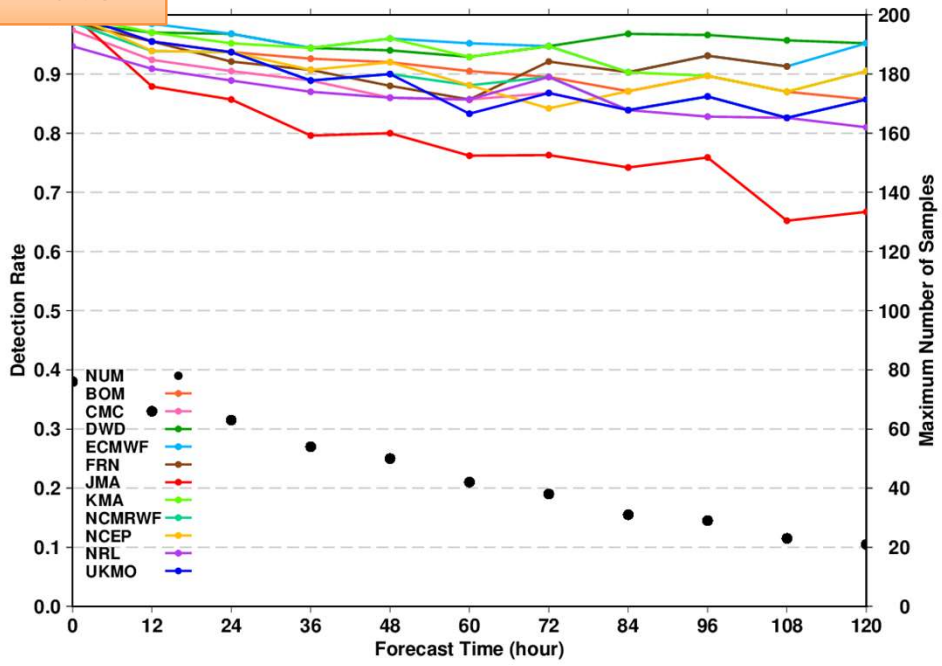
Position Error





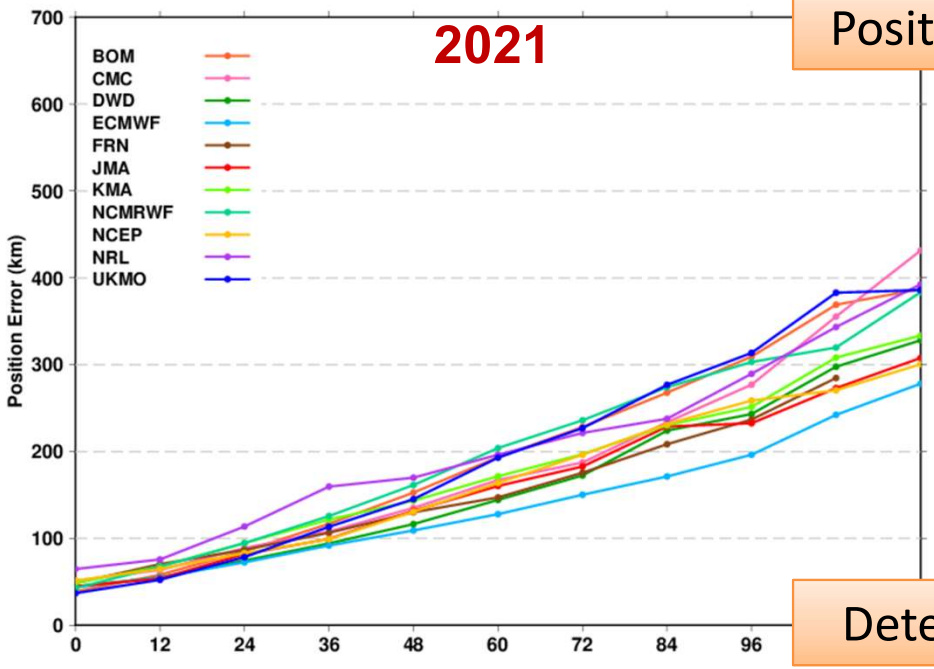
Detection Rate

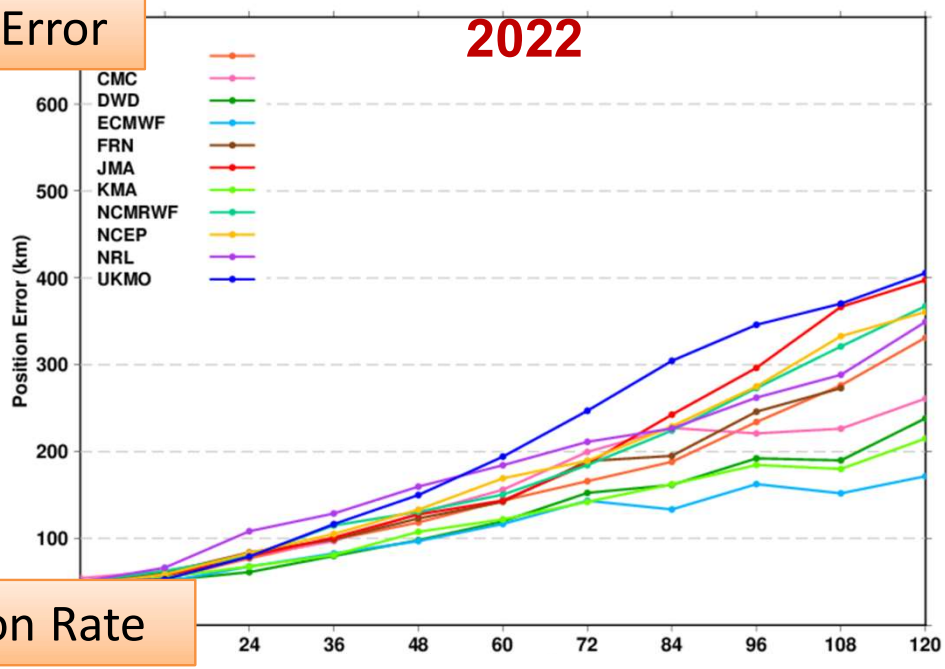




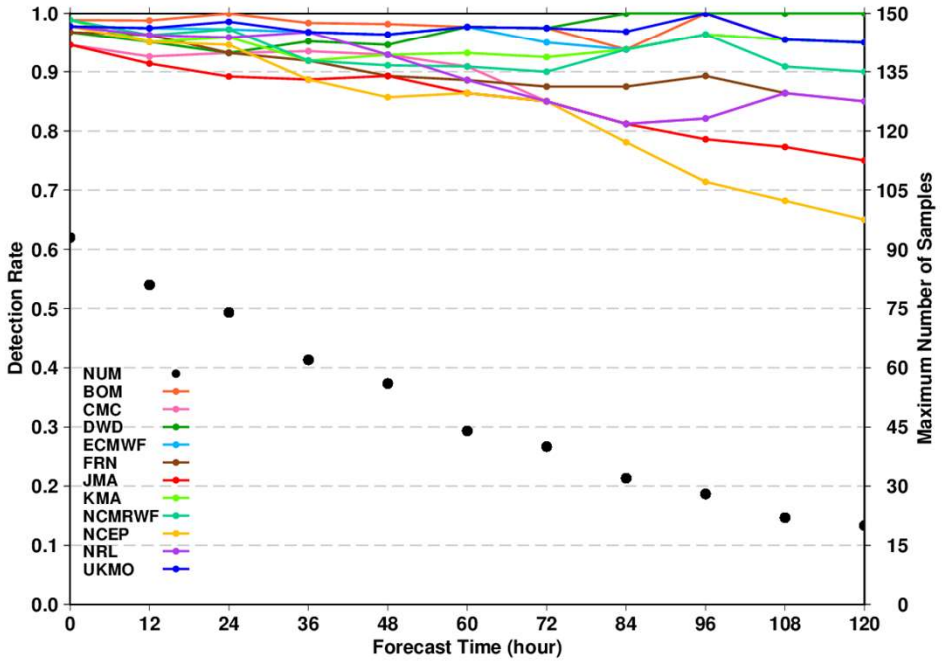
(c) Eastern North Pacific (ENP)

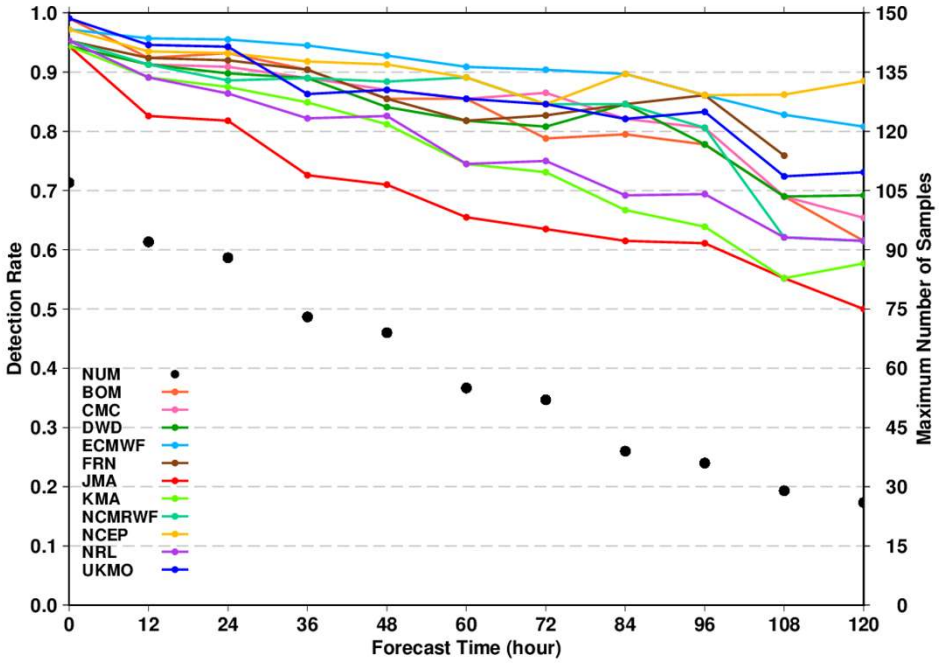
Position Error



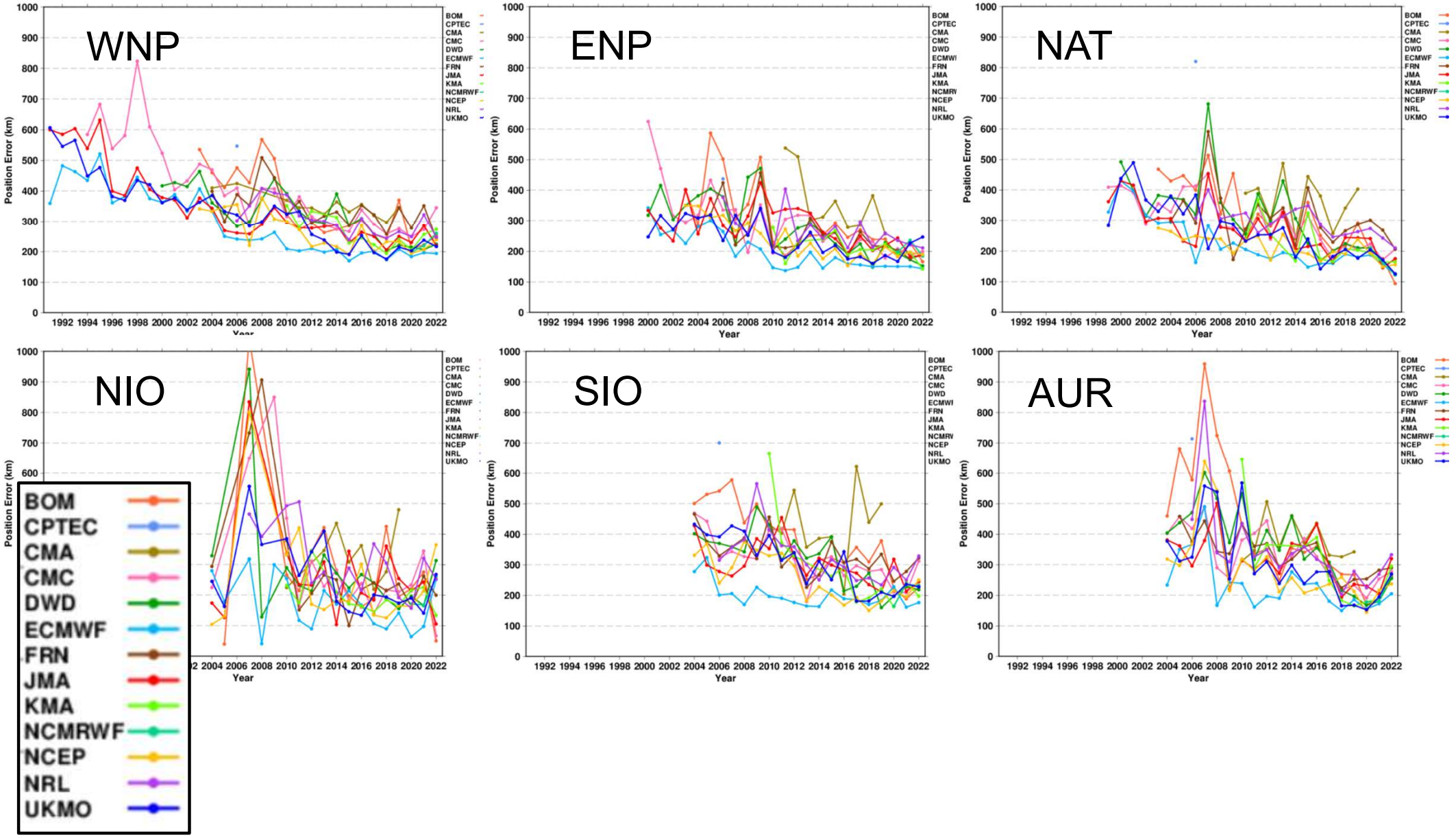


Detection Rate





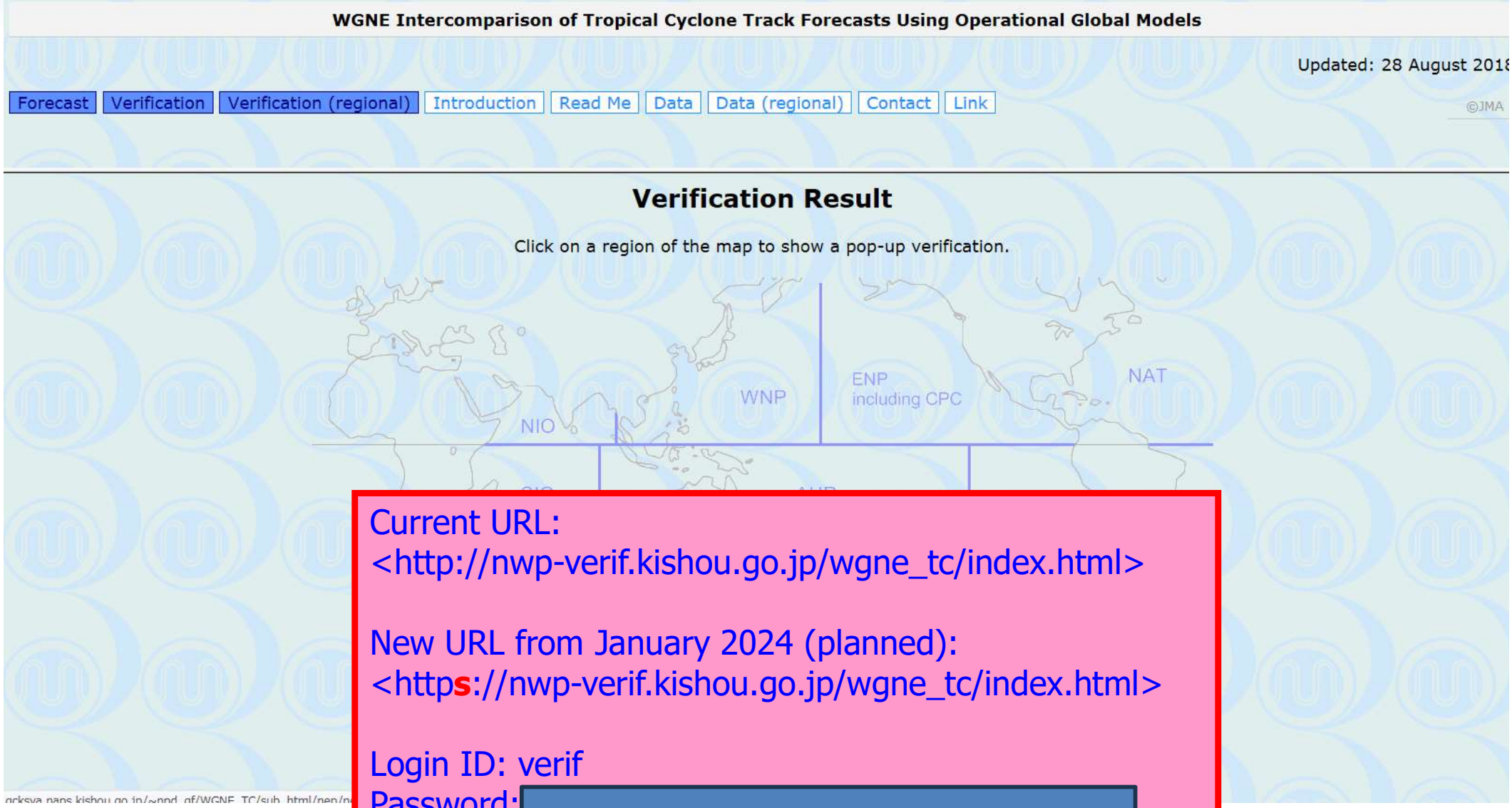
Transition of T+72 Position Error over Decades



Summary of verification 2022

- Position errors
  - Compared to the previous year, some centers' errors were larger. As a few exception, other centers (Meteo France and JMA) decreased the position errors in the WNP region.
    - Possible causes
      - updates of the models (e.g. Meteo France)
      - fewer recurved TCs (e.g. JMA).
- Intensity errors
  - Most of the models have difficulties in representing decay of TCs over the WNP area except the model of the Met Office.
    - Met Office represents the TC decay well regardless of ocean coupling
  - All of the models have little predictability in the rapid intensification events in WNP region.

TC intercomparison website is available!



Current URL:
<http://nwp-verif.kishou.go.jp/wgne_tc/index.html>

New URL from January 2024 (planned):
<https://nwp-verif.kishou.go.jp/wgne_tc/index.html>

Login ID: verif
Password: [redacted]
Contact: globalnwp@met.kishou.go.jp

Verification results for scientific papers

- Some plots in the WGNE TC verification are sometimes referred and/or used in scientific papers.
  - Sometimes requested to provide data for re-plotting, comparing the performance with the ML models etc.
- As long as these papers are in line with the promoting model development, it appears to be OK to make the data available if requested.
  - However it also depends on each participating center's data policy.
  - If you have any problems in making the verification results available in the context of data availability, please let me know.
- When we invite the NWP centres for WGNE TC verification next year, we will put the note on data availability
  - E.g. ***'datasets for verification results may be provided for scientific and non-commercial papers which are relevant to model development.'***

EXTRA SLIDES

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

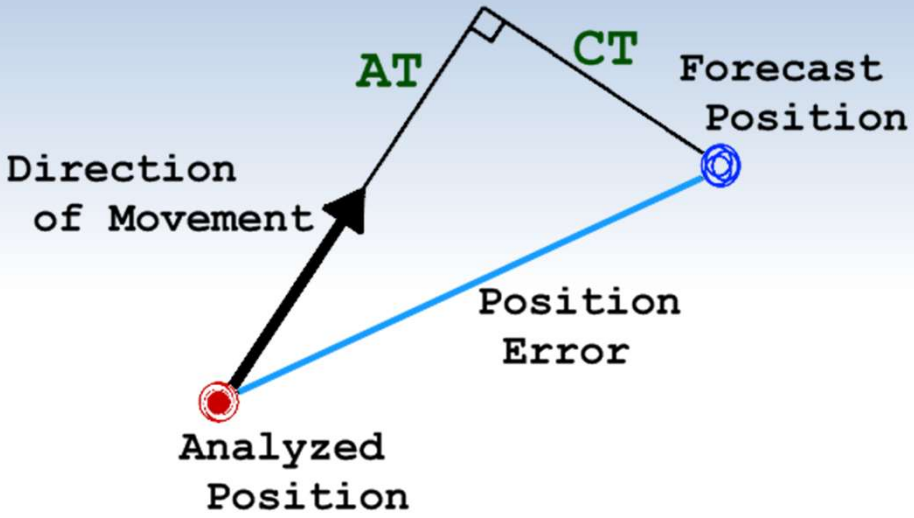
TCs are tracked using mean sea level pressure data provided by participating NWP centres. Under this method, the minimum pressure point is identified as the initial or predicted TC position.

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.

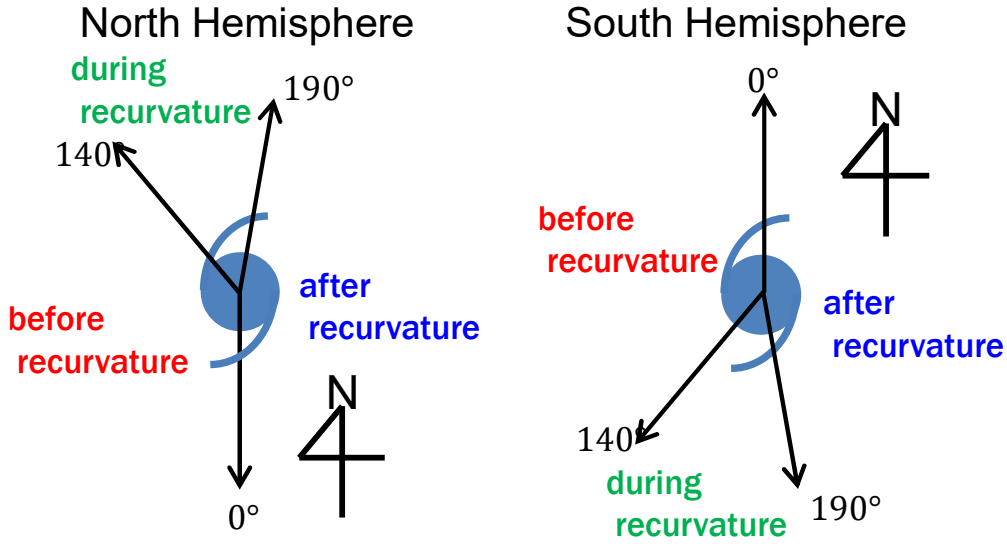
Definitions

- **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

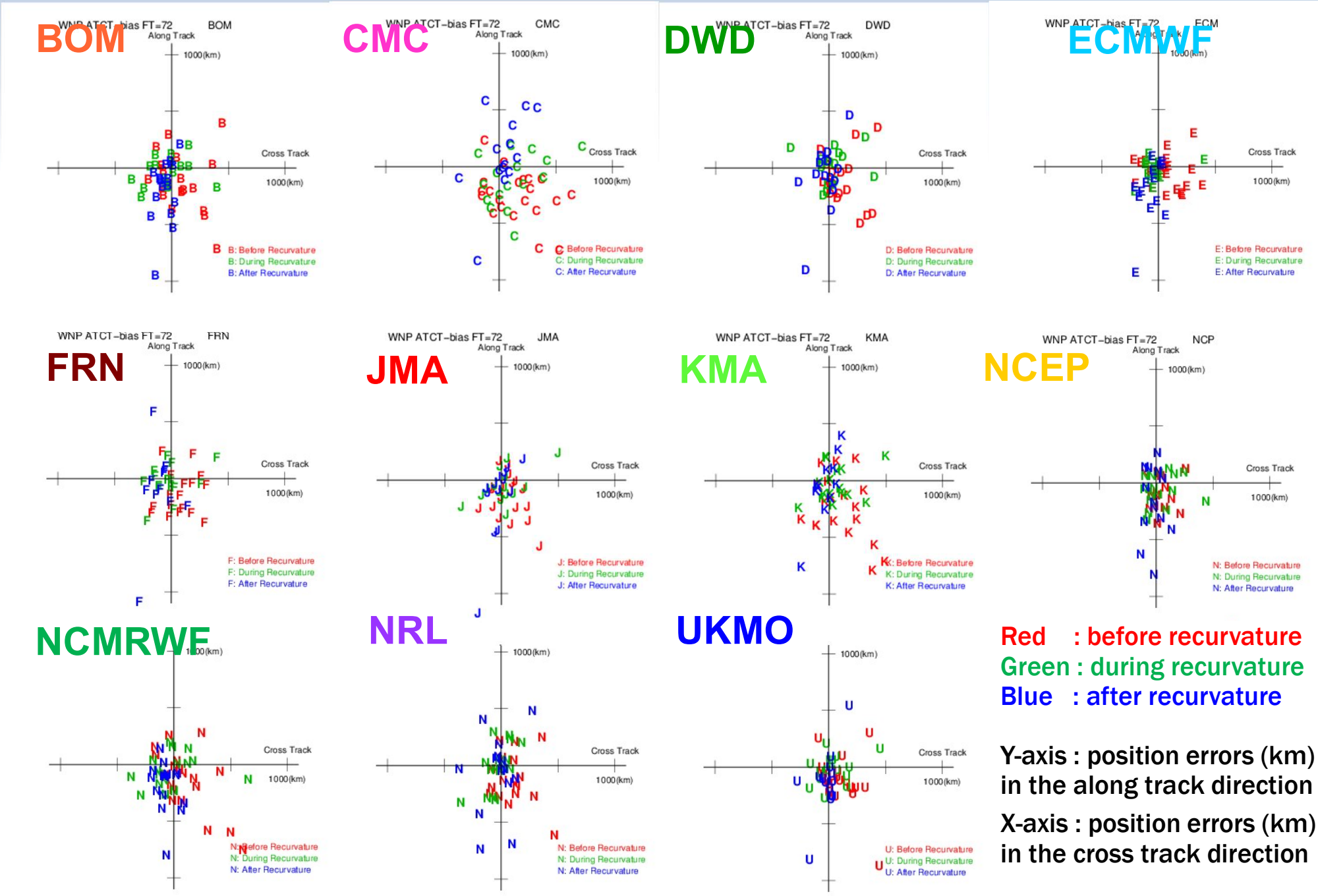
* NCEP employees combination of multiple initialization schemes (Kleist et al. 2016).
* JMA, CMA: only over Western Pacific Ocean

- 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

(a) WNP AT-CT Bias (T+72)

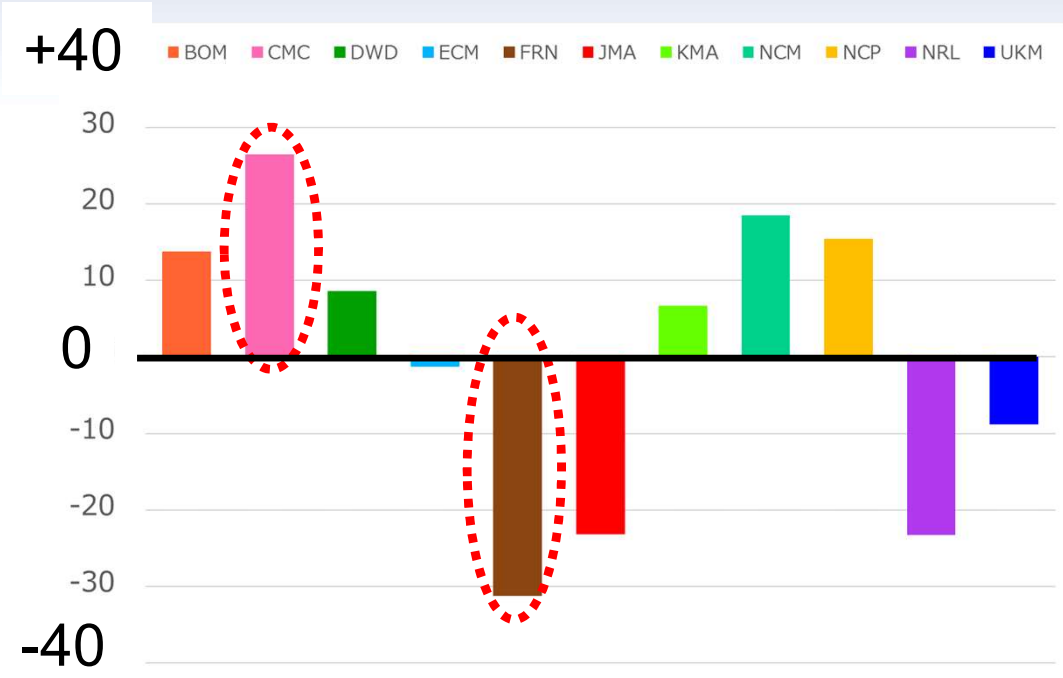


Red : before recurvature
Green : during recurvature
Blue : after recurvature

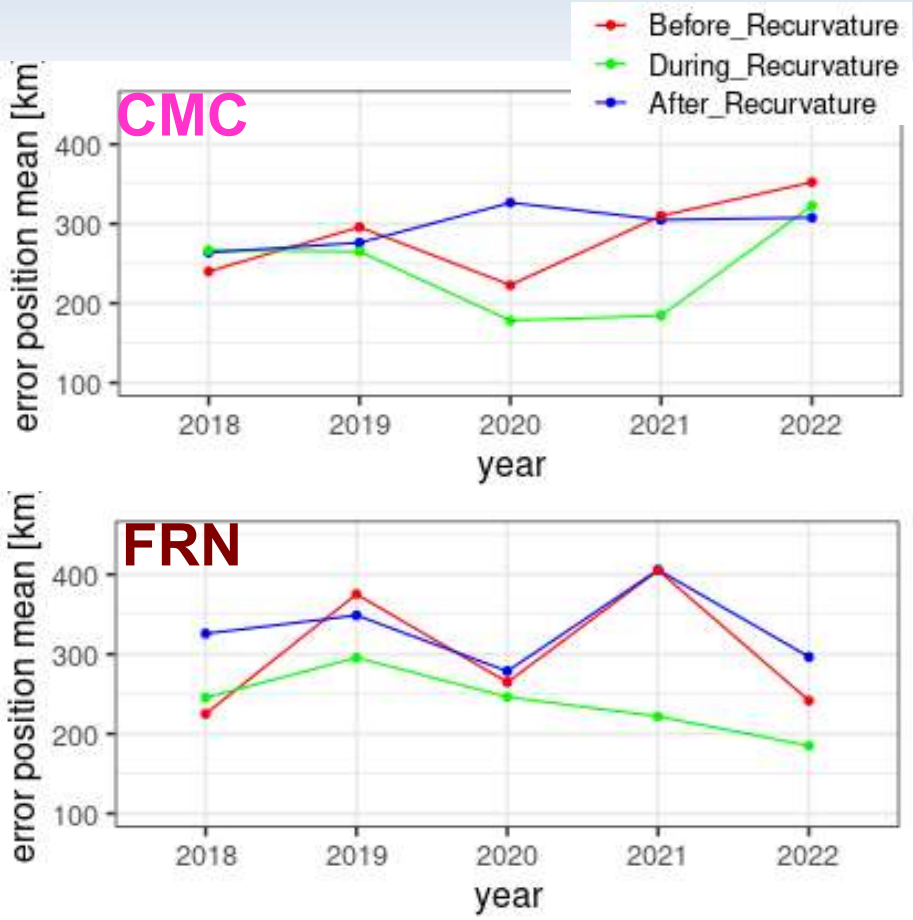
Y-axis : position errors (km) in the along track direction

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

WNP mean TC position errors at T+72



percent change from the previous year of position errors

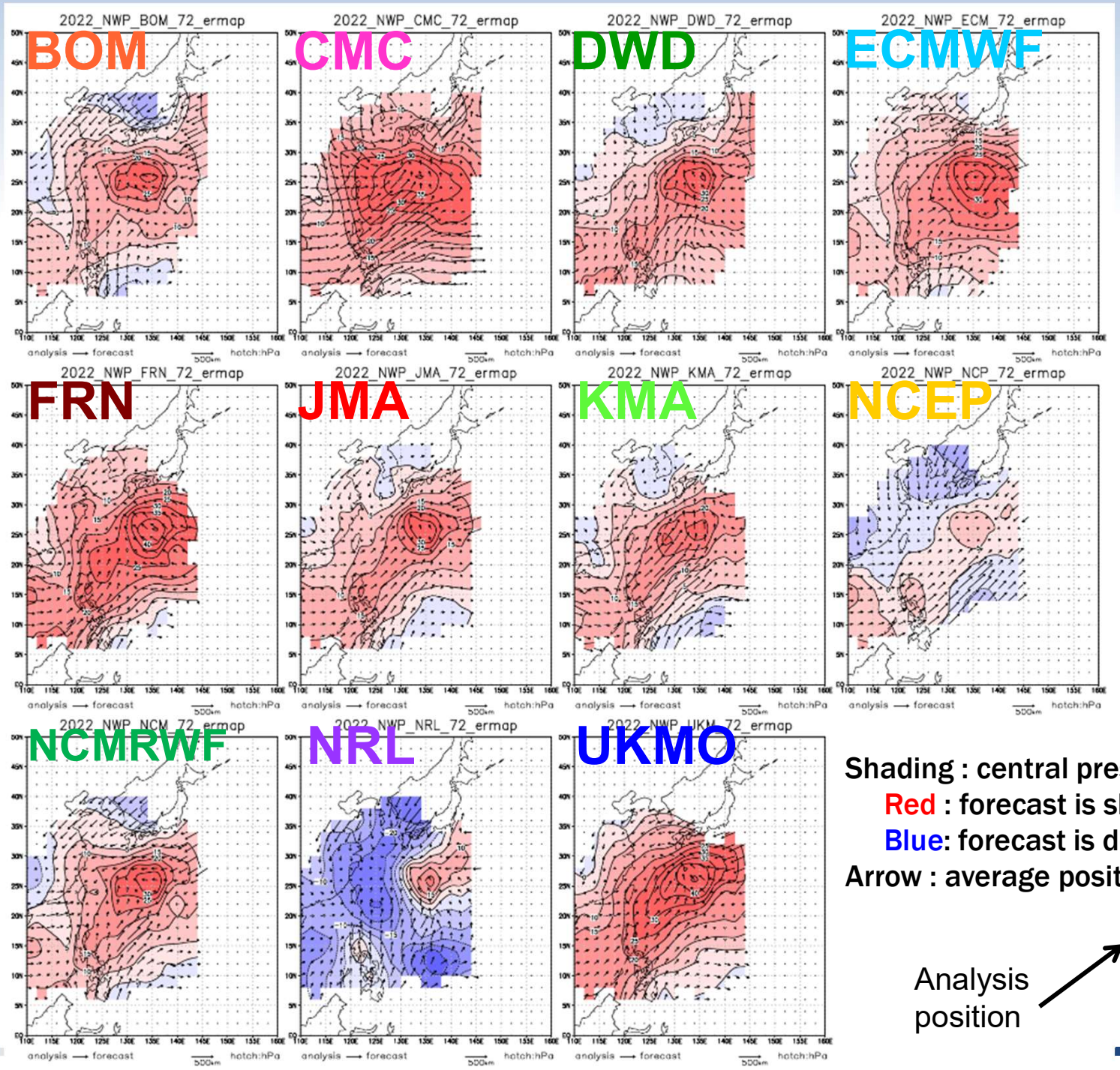


- **Increase position error of CMC at the during recurvature**
- **Decrease position error of Meteo France regardless of recurvature**

⇒ These results are inferred to be due to the model updates

(Upgrade to version 8.0.0 the GDPS in Dec. 1st 2021 & Update the ARPEGE physics in Jun. 29th 2022)

(a) WNP Error Map T+72



Shading : central pressure error (hPa)

Red : forecast is shallow

Blue: forecast is deep

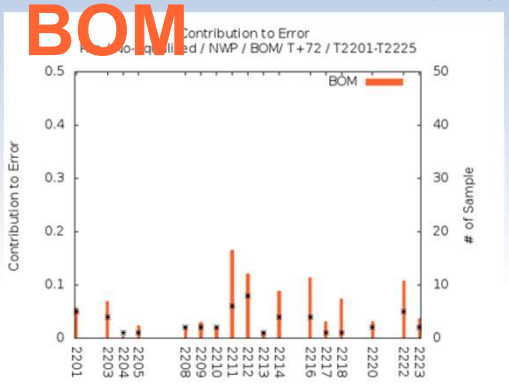
Arrow : average position error

Forecast position

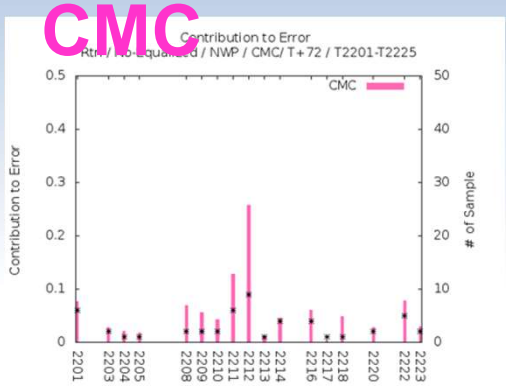
Analysis position

(a) Contribution to Error (WNP, T+72)

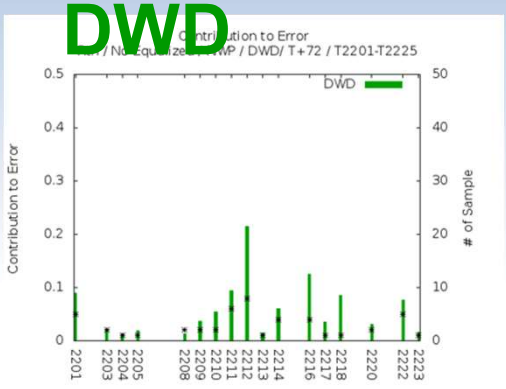
BOM



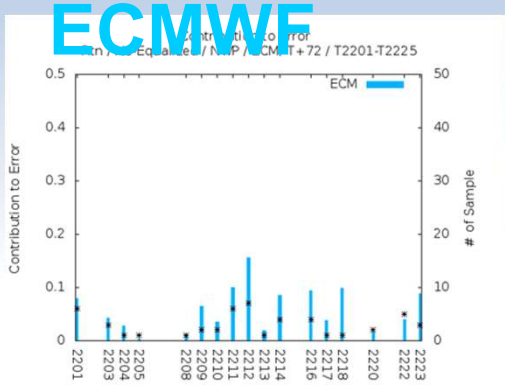
CMC



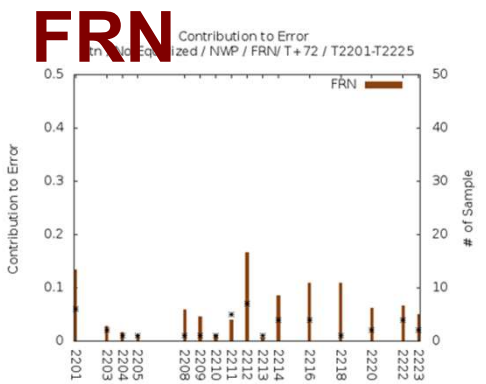
DWD



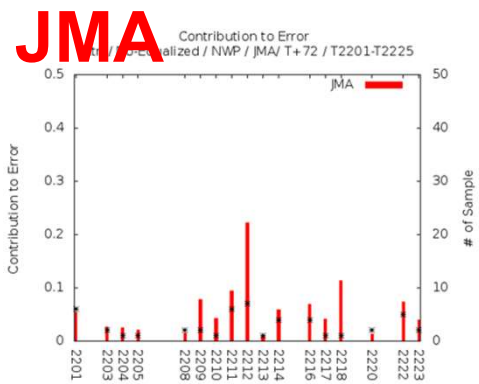
ECMWF



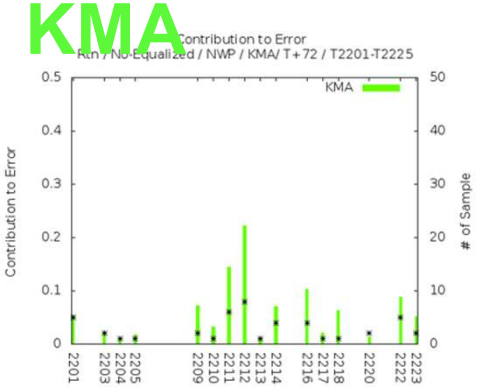
FRN



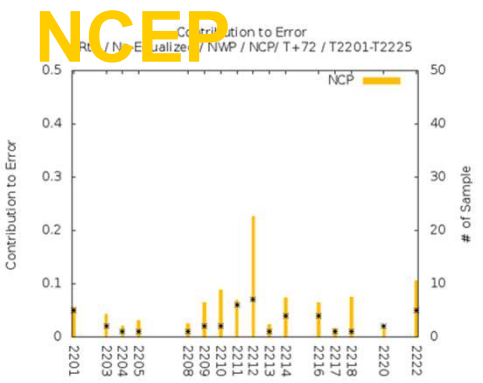
JMA



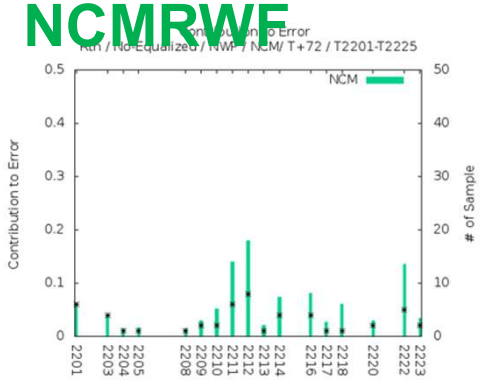
KMA



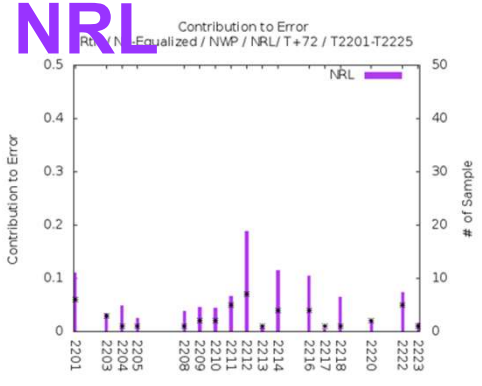
NCEP



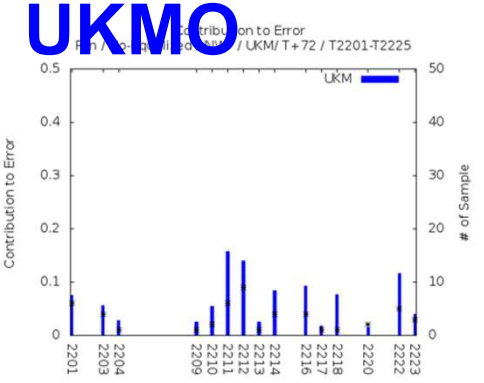
NCMRWF



NRL



UKMO



$$\frac{e_i \frac{n_i}{N}}{\sum_{i=1}^{M} e_i \frac{n_i}{N}}$$

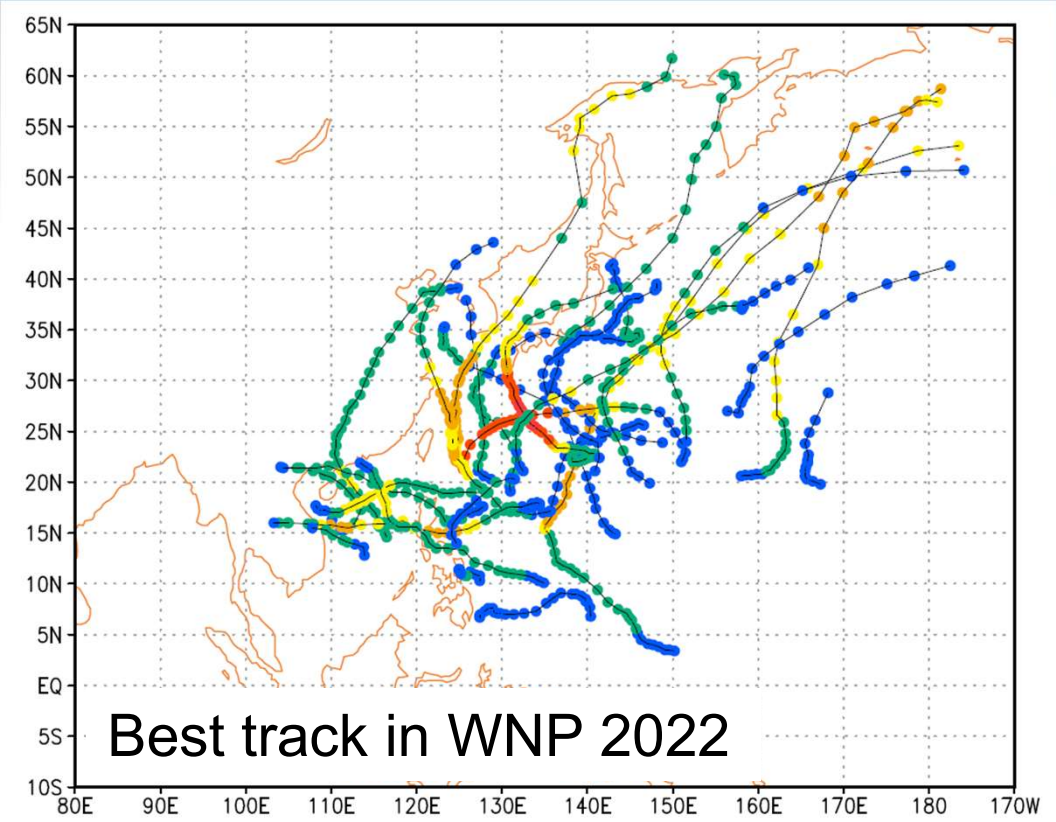
e_i : mean error of i th TC

n_i : number of forecasts for i th TC

M : number of TCs in a year

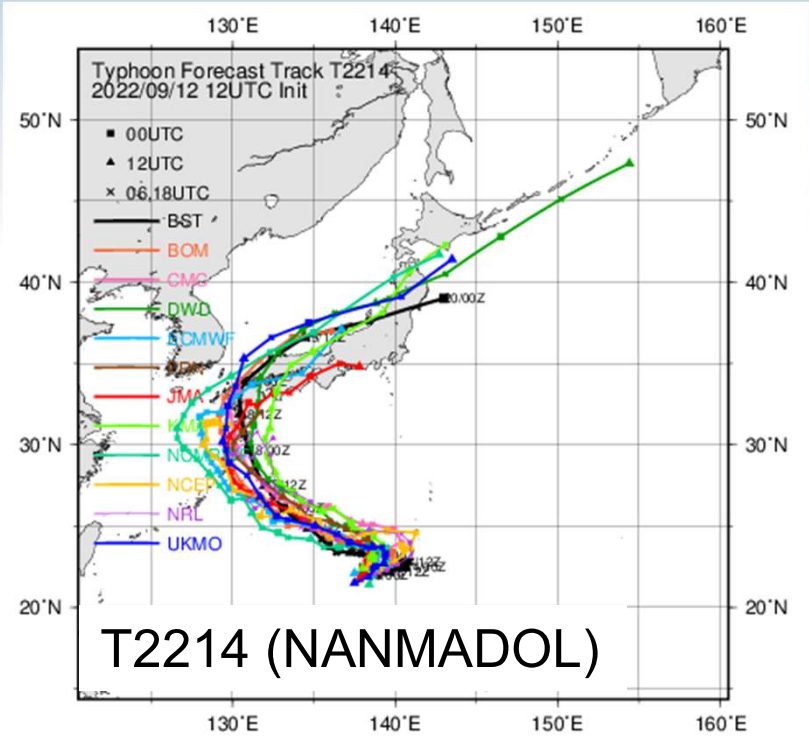
$$N = \sum_{i=1}^{M} n_i$$

A case of rapid Intensification event in WNP

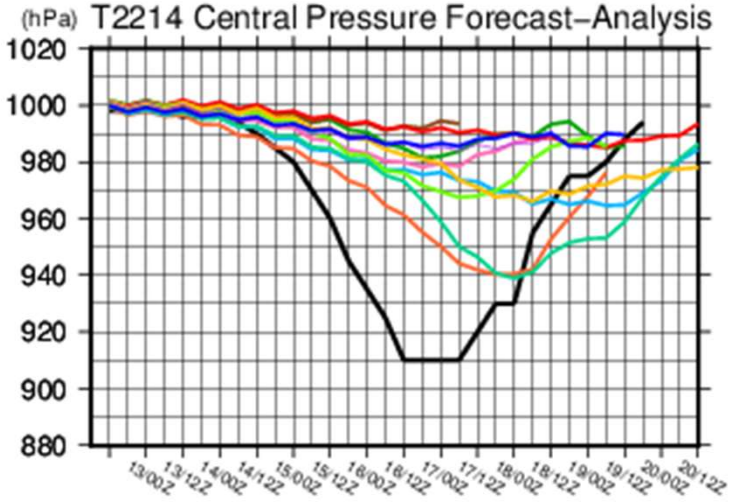


* Color of points means the central pressure of each TCs

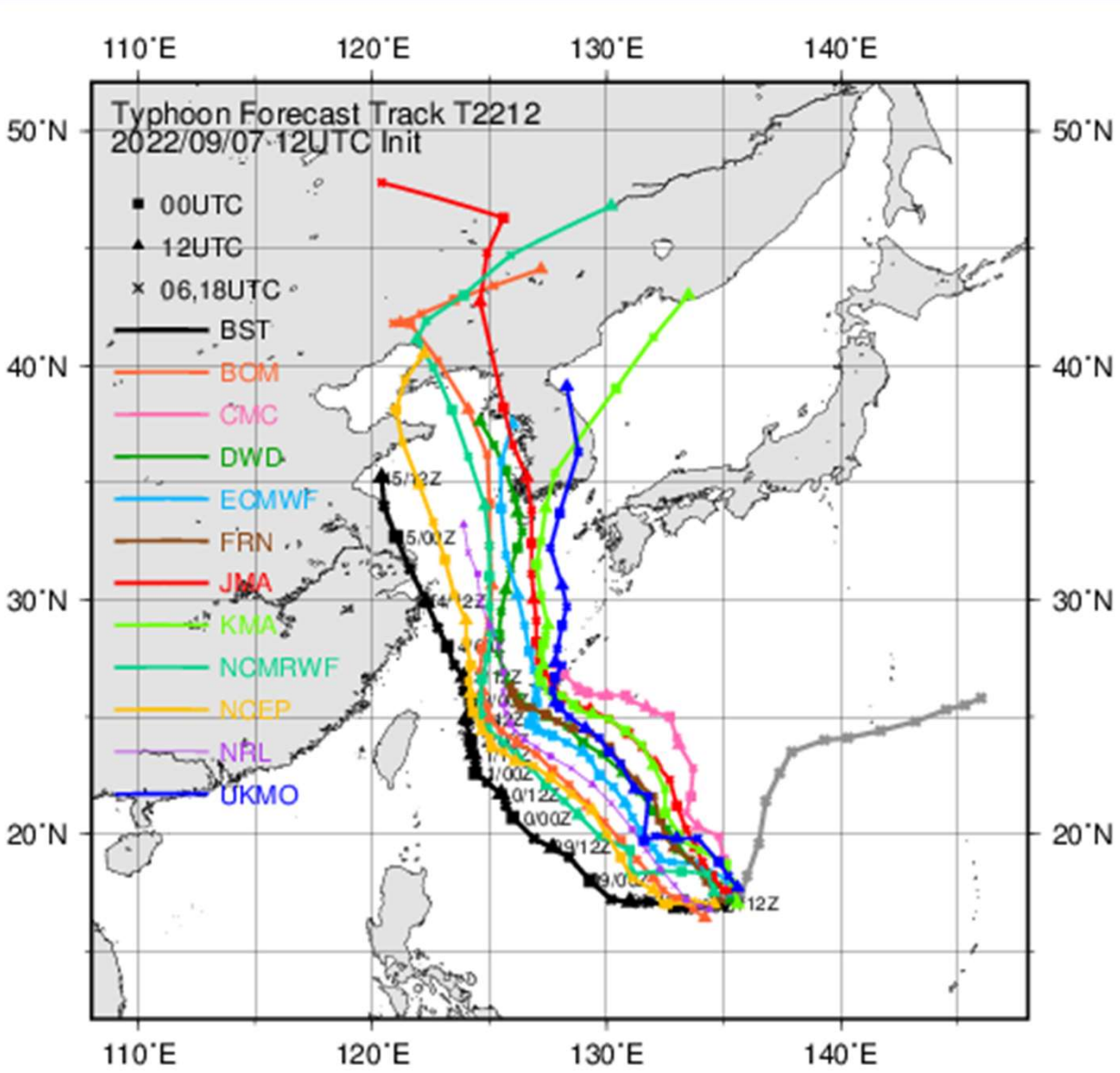
- **The error maps on previous slide suggest that all of the models have little predictability in rapid intensification events in WNP region.**



Init: 2022-09-12 12UTC



Cases of Typhoon T2212“MUIFA” (2022)



- **The models have obvious northward bias at before recurvature**

Cases of Typhoon T2214“NANMADOL” (2022)