WGNE inter-comparison of Tropical Cyclone Track forecast 2021

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STANDARD VERIFICATION

Verification of Global Models

Data Specifications in 2021

NWP centre	Year of verification commencement	Horizontal resolution of provided data (degrees in longitude and latitude)	Model resolution as of 2021
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	TCo1280L137
FRN	2004	0.1×0.1	T_L1798(C2.2)L105
JMA	1991	0.25 x 0.25	T_L959L128
KMA	2010	0.1406 x 0.094	10kmL70
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 2021 (1/2)

CMC

- 26/01/2021 Addition and replacement of satellite radiance observation
- 01/12/2021 Upgrade to Version 8.0.0
  - ➢ Improve atmospheric data assimilation and objective analysis (Use of control variable Ozone), assimilated radiance data, other data used, treatment of aircraft data, satellite radiance bias correction, background-error covariance, Ozone assimilation method, Ozone satellite data)
  - ➢ Improve Forecast (prognostic variables, derived variables, prognostic Ozone, the Earth's surface, surface layer, elevated (mid-level) convection)

DWD

- 14/04/2021 New ICON version (2.6.2-nwp2)
  - ➢ Use new radiation scheme (RRTM to ecRad)
  - ➢ Replace empirical lookup table values depending on the land use class
- 08/09/2021 New ICON version (2.6.3-nwp1)
  - ➢ Tuning update and improved process formulation in subgrid-scale orography parameterization
  - ➢ Improved numerical formation of the vertical nest interface condition
- 17/11/2021 New ICON version (2.6.4-nwp1)
  - ➢ Improvements / corrections in the SST analysis

ECMWF

- 11/05/2021 Upgrade IFS to Cycle47r2
- 12/10/2021 Upgrade IFS to Cycle47r3
  - ➢ Improved the representation of moist physics in the model
  - ➢ Increased satellite observation usage in cloudy regions in data assimilation

Improvement of models for each centres in 2021 (2/2)

JMA

- 30/03/2021 Major upgrade was made to the Global Spectral Model (GSM)
  - ➢ increase of the number of vertical layers from 100 to 128
  - ➢ Improvements to the 4DVAR-LETKF hybrid data assimilation
    - ➢ Increase of ensemble members from 50 to 100
    - ➢ Increase of weight for ensemble-based background error covariance
  - ➢ revision of the global snow analysis
  - ➢ introduction of the global soil moisture analysis
- 29/06/2021 All-sky assimilation of microwave water-vapor sounder from GMI/GPM, ATMS/NOAA-20, Suomi-NPP, SSMIS/DMSP-F17, F18, SAPHIR/Megha-Tropiques, MWHS-2/FY-3C was started
  - ➢ Assimilation of AMV and CSR from GOES-17 was started.
  - ➢ Bias correction method for aircraft-based observations was revised.
- 24/11/2021 Assimilation of Metop-C/IASI was started

NCEP

- 22/03/2021 GFS V.16 Upgrade
  - ➢ increase the number of vertical layers (64 to 127) and extend the model top (~55km to ~80km)
  - ➢ the wave model(Multi_1) is merged into the GFS system
  - ➢ Improved physical processes (gravity wave, planetary boundary layer)
  - ➢ Improved data assimilation system (land initial condition, model space localization, observation operator, 4D-IAU, etc)

TCs in 2021

TC season

Northern Hemisphere : 1 January 2021 to 31 December 2021

Southern Hemisphere : 1 September 2020 to 31 August 2021

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

22 (23) Western North Pacific [RSMC Tokyo]

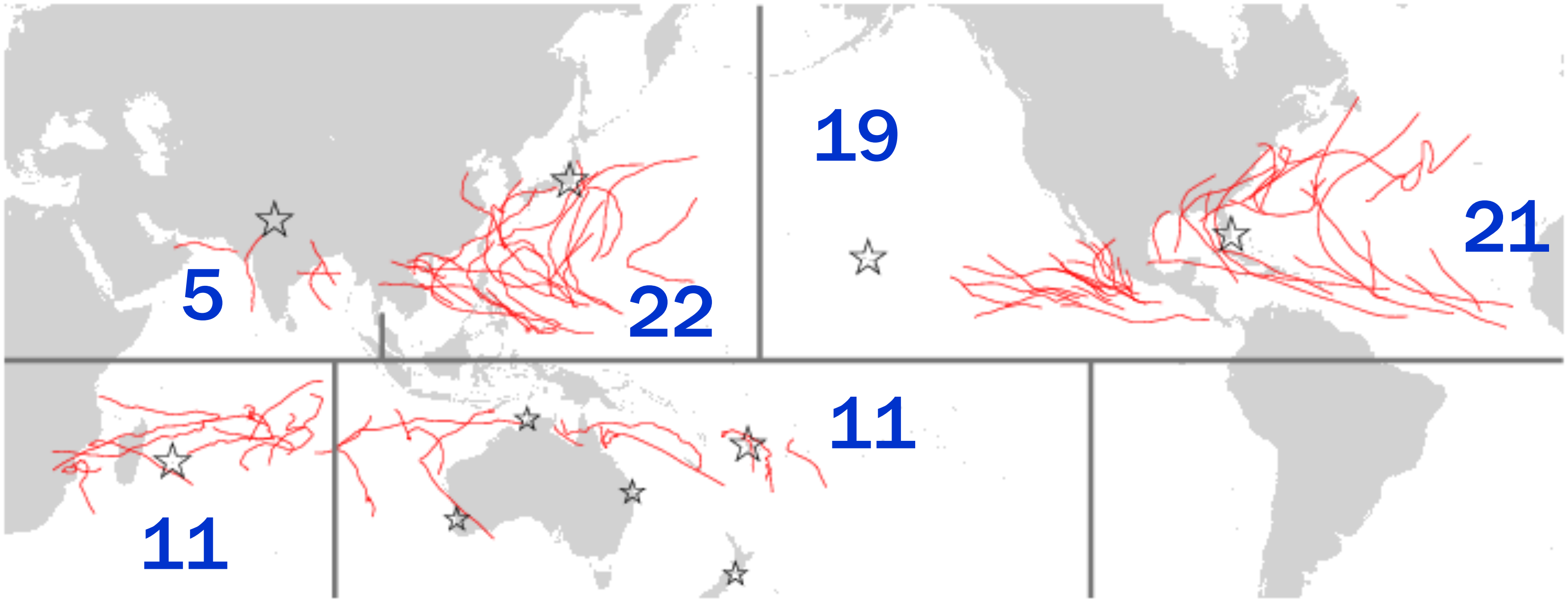
19 (17) Eastern North Pacific (including Central North Pacific) [RSMC Miami, Honolulu]

21 (30) North Atlantic [RSMC Miami]

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

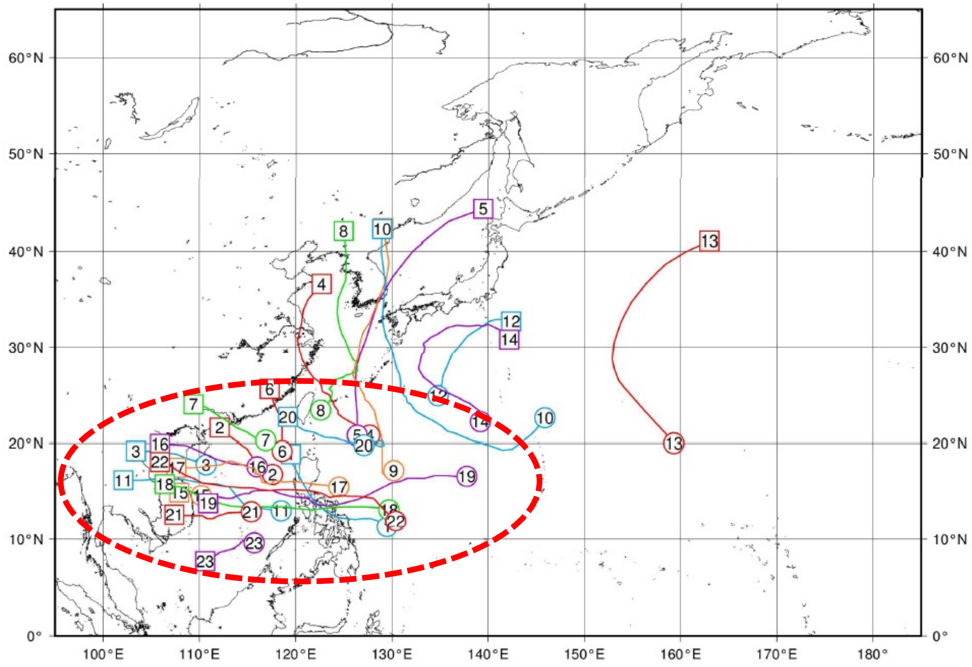
11 (10) South Indian Ocean [RSMC La Reunion]

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

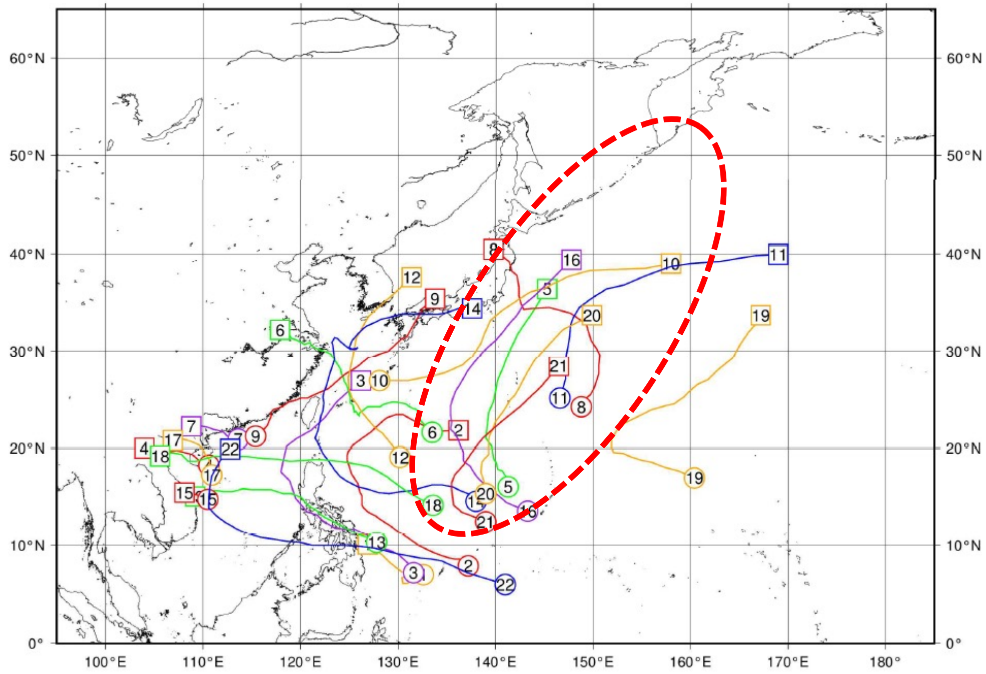


Best tracks over WNP

2020: 23 TCs



2021: 22 TCs

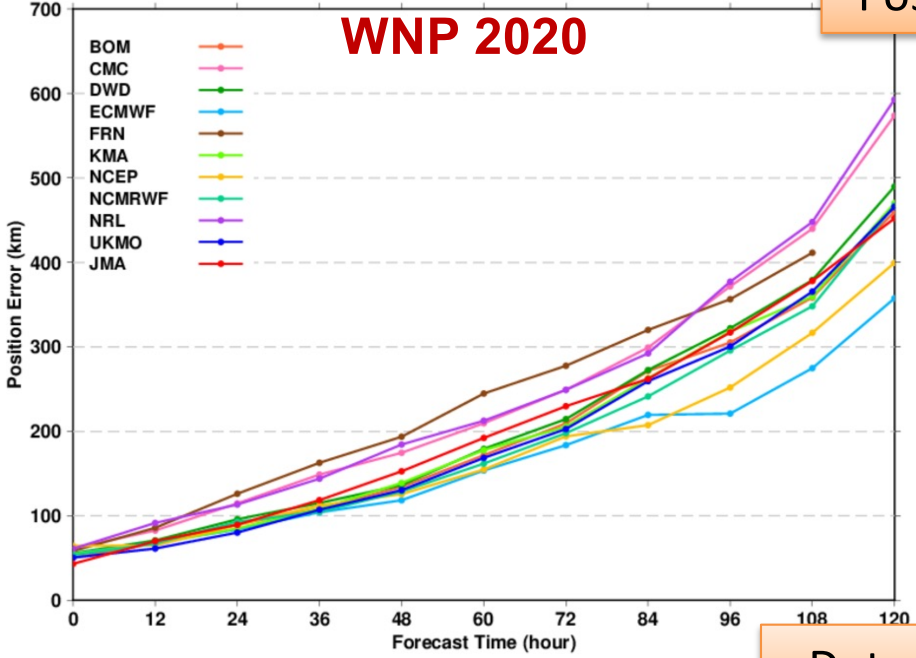


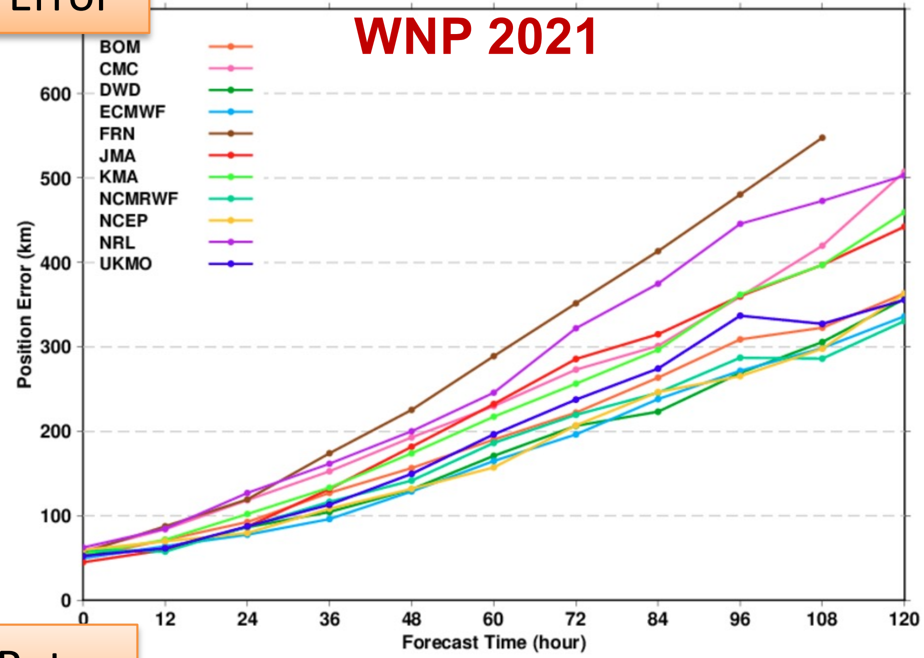
＊ More westward TCs in 2020

＊ More recurved and northward TCs in 2021

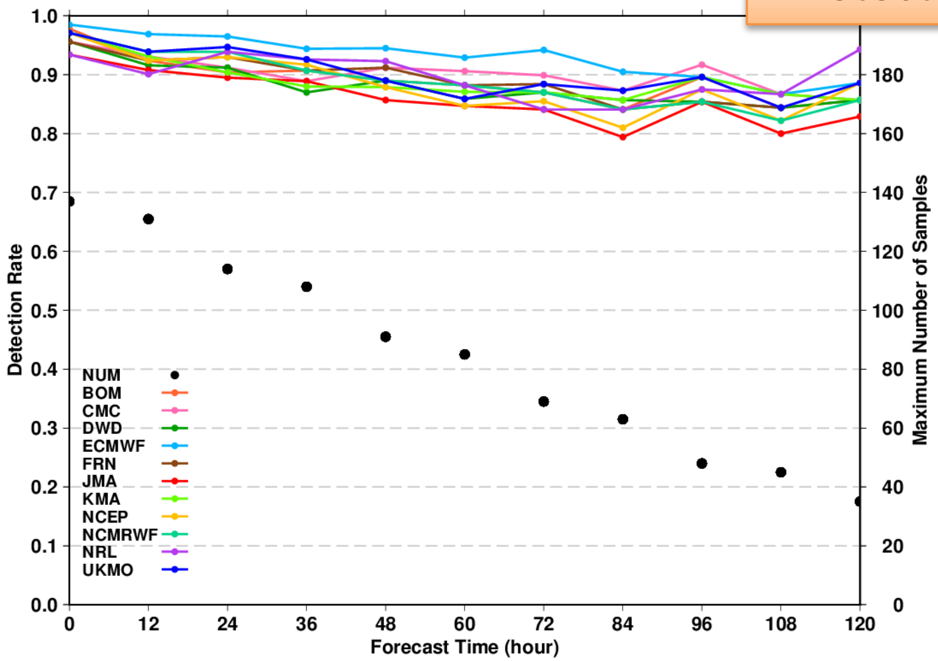
https://www.jma.go.jp/jma/press/taihuu.html

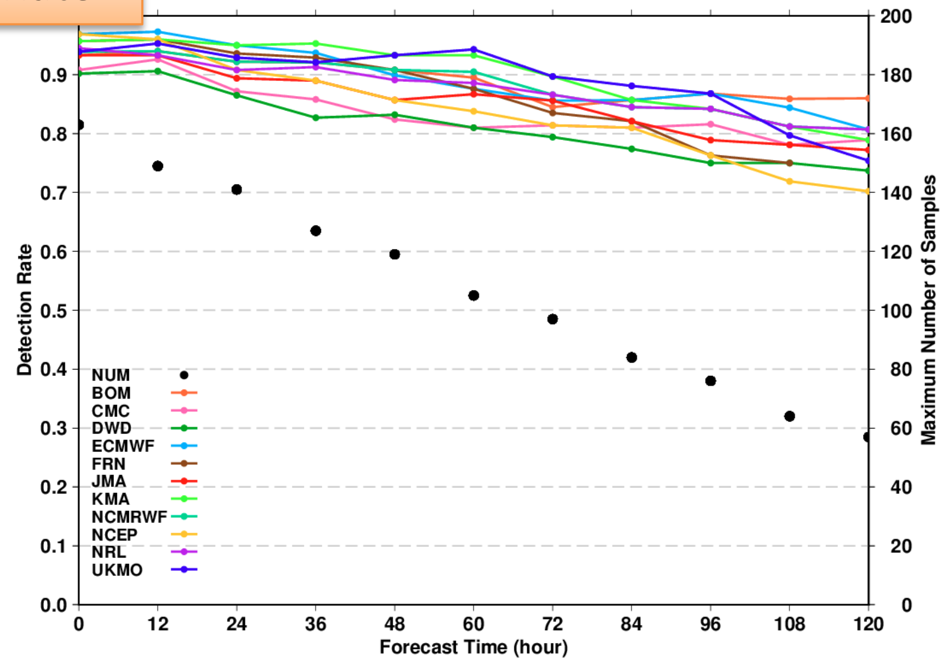
Position Error



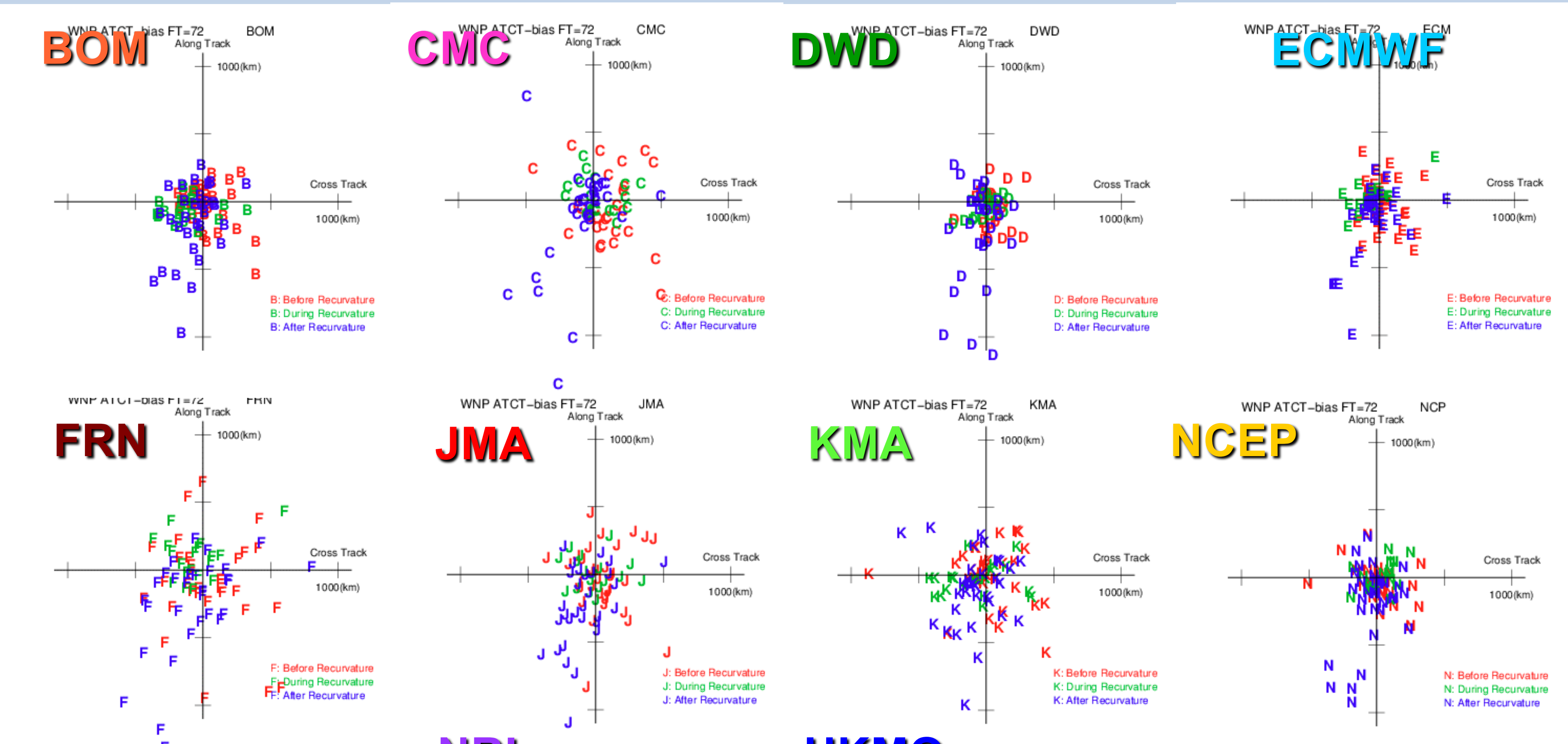


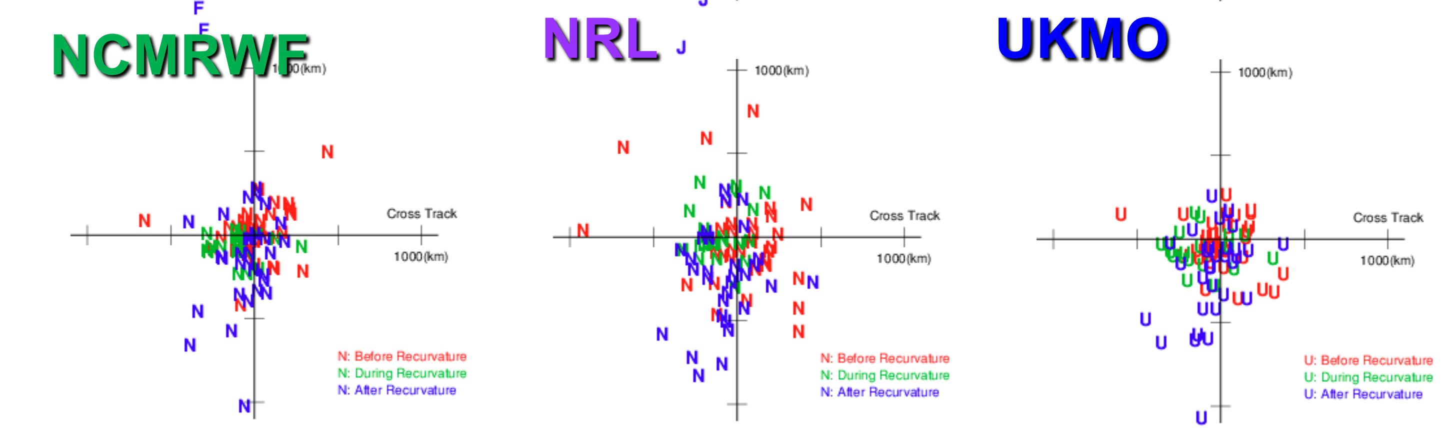
Detection Rate





(a) WNP AT-CT Bias (FT=72)



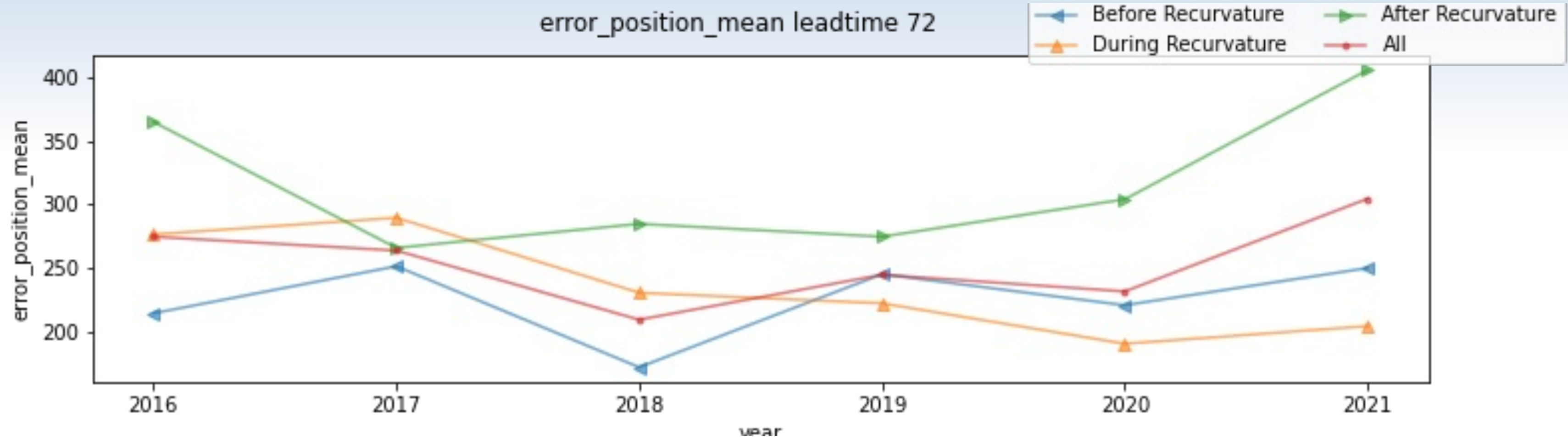


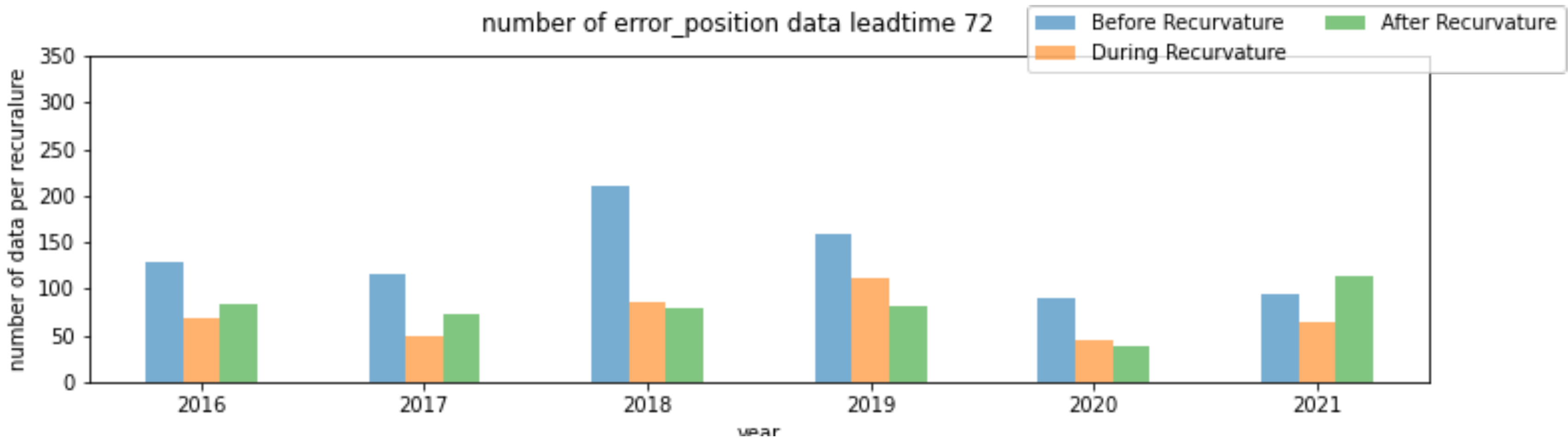
Red : before recurvature
Green : during recurvature
Blue : after recurvature

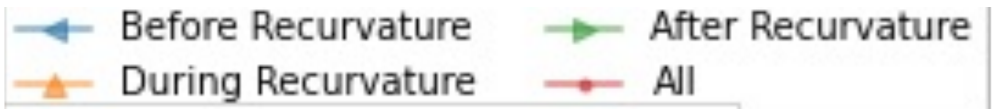
Y-axis : position errors (km) in the along track direction

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

Mean TC position errors at T+72

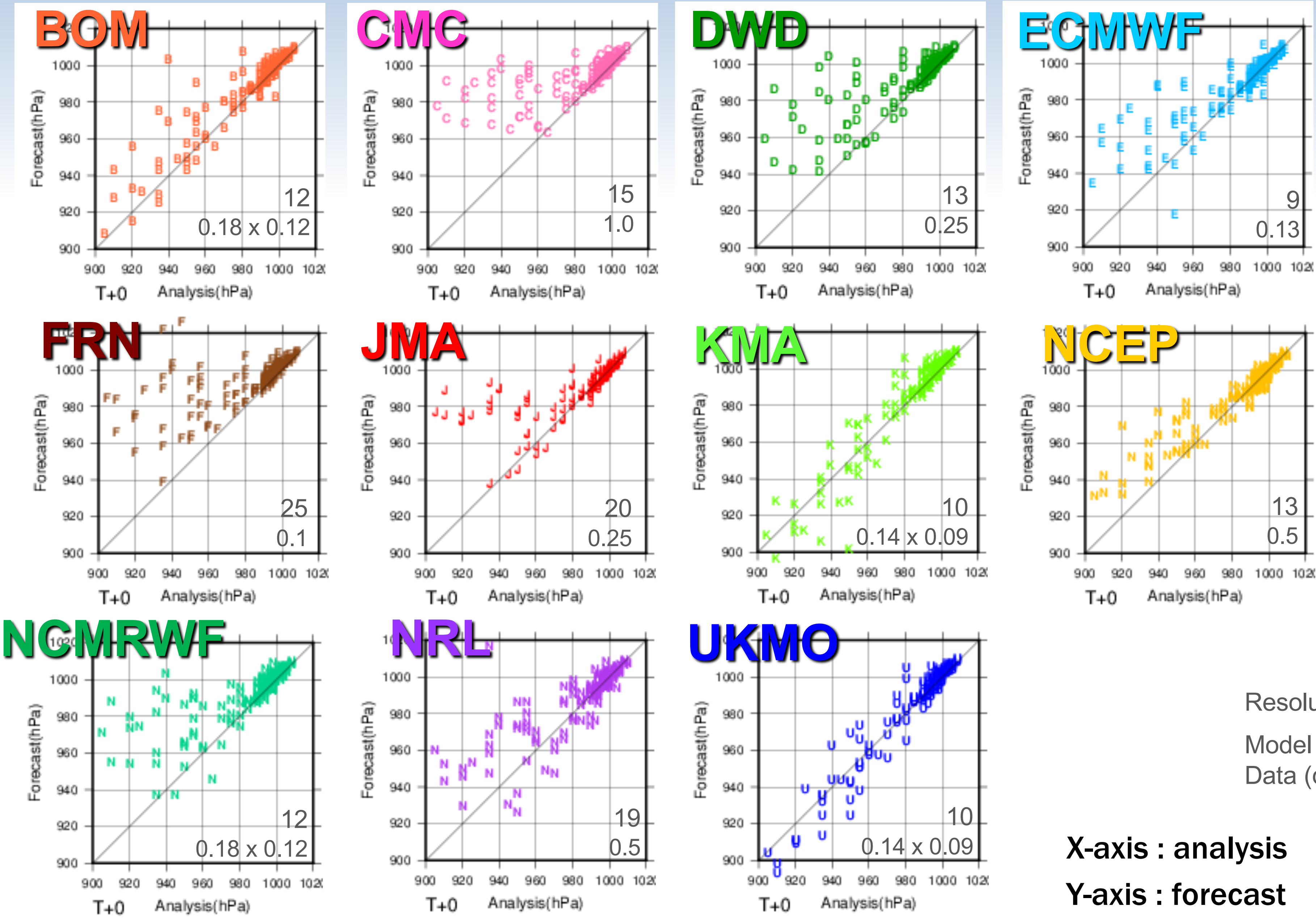






Larger position error and number of samples at the after recurvature

(a) WNP Central Pressure Scatter Diagram (FT=0)



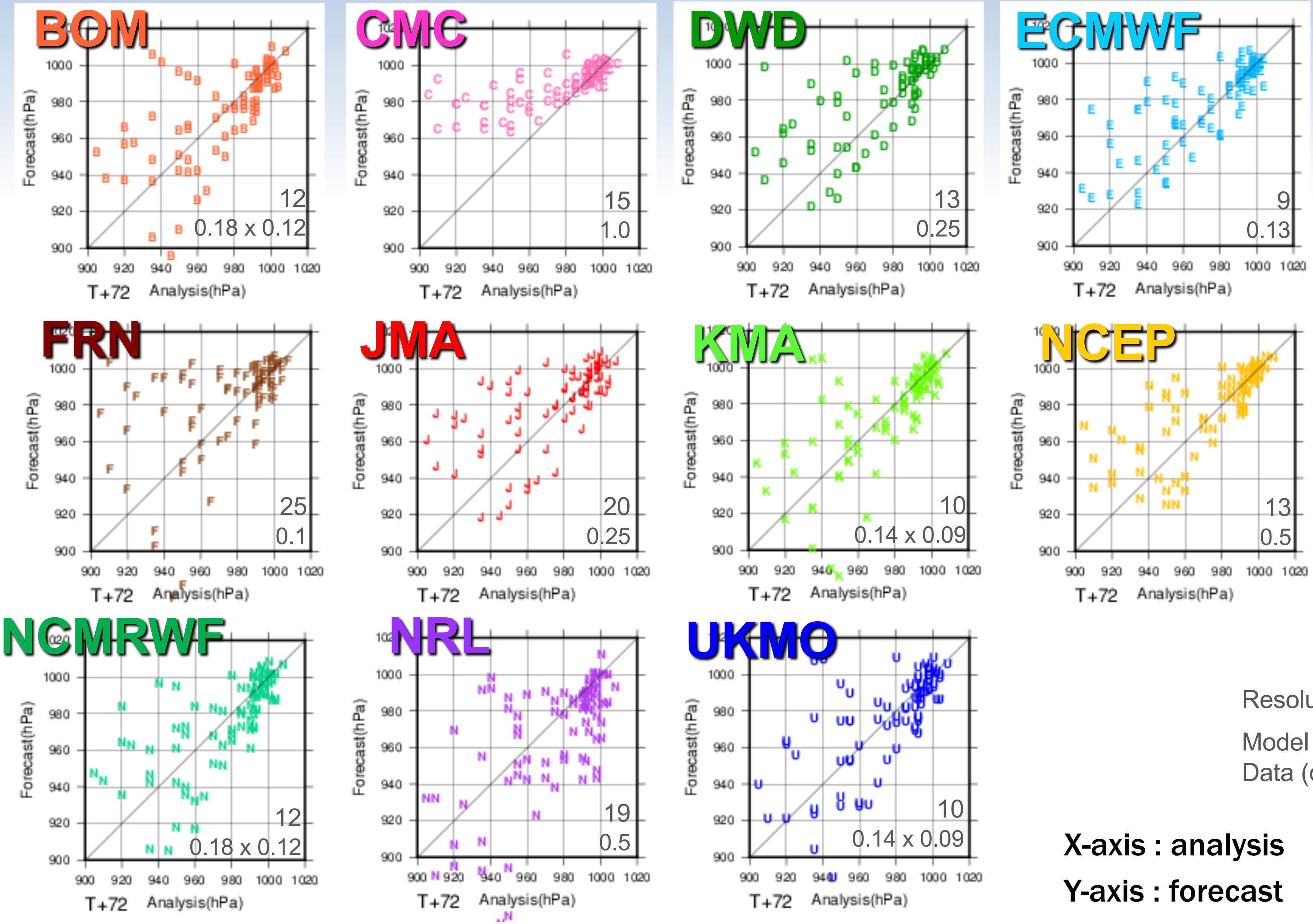
Resolution

Model (km)
Data (deg)

X-axis : analysis

Y-axis : forecast

(a) WNP Central Pressure Scatter Diagram (FT=72) 2021



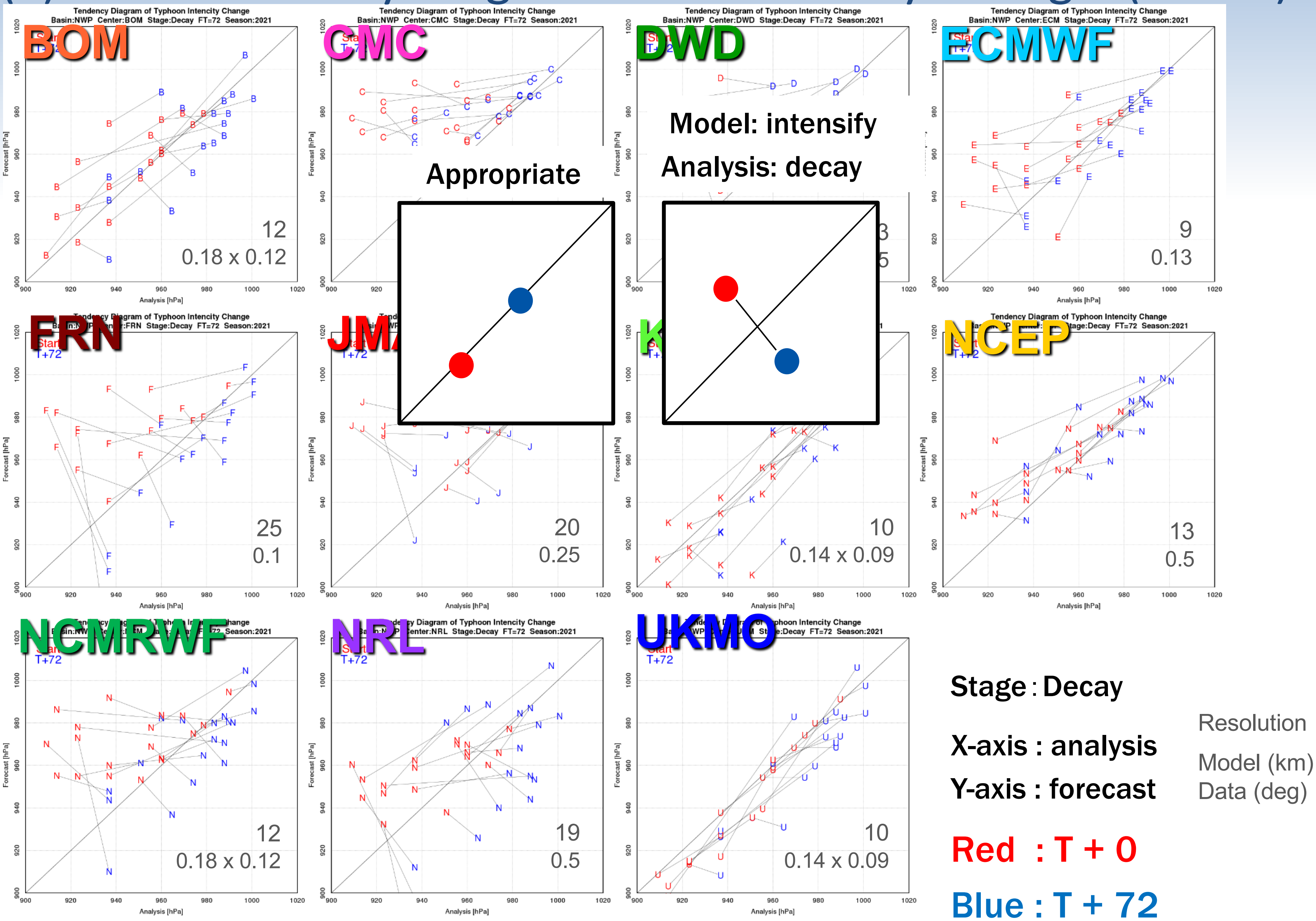
Resolution

Model (km)
Data (deg)

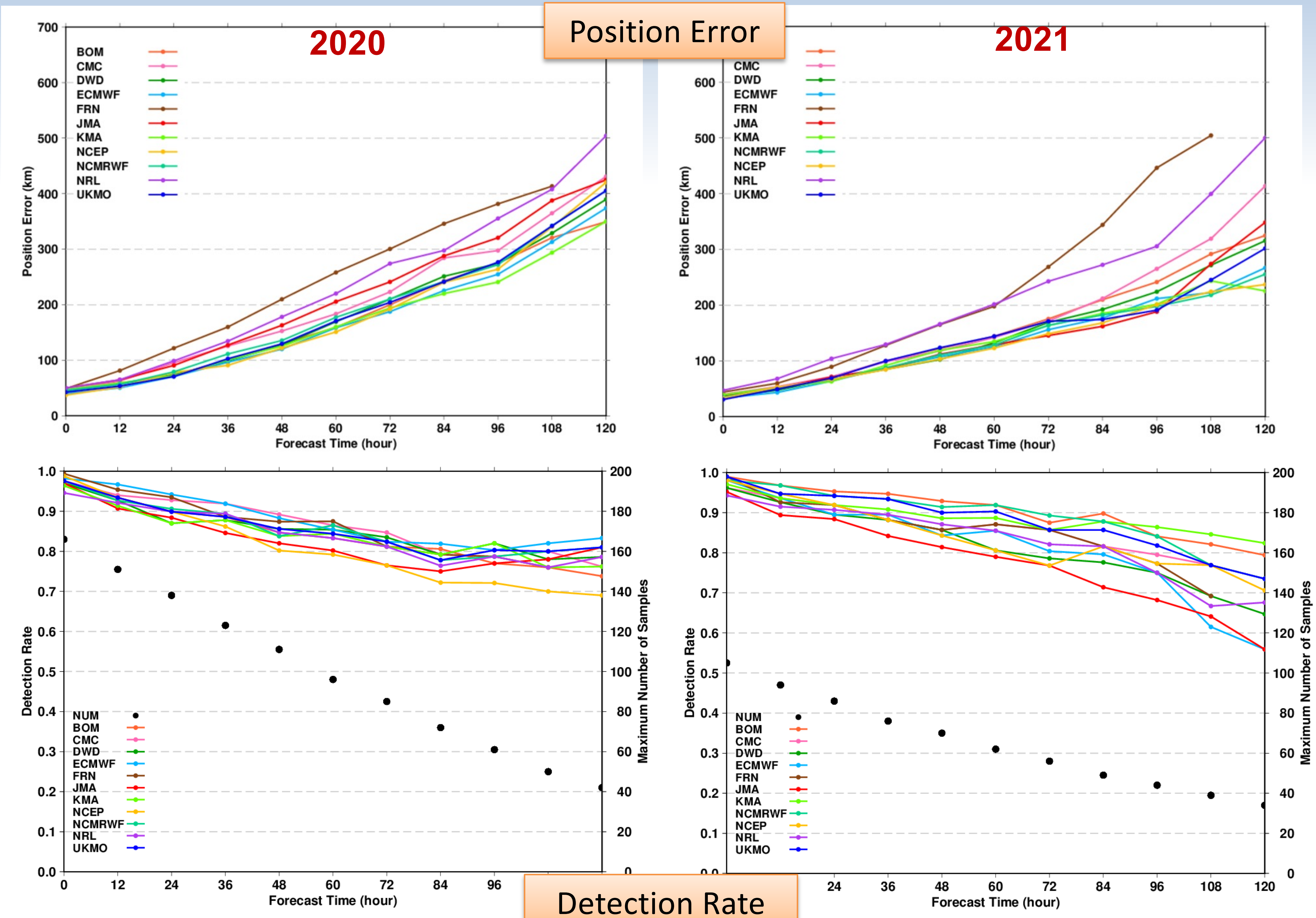
X-axis : analysis

Y-axis : forecast

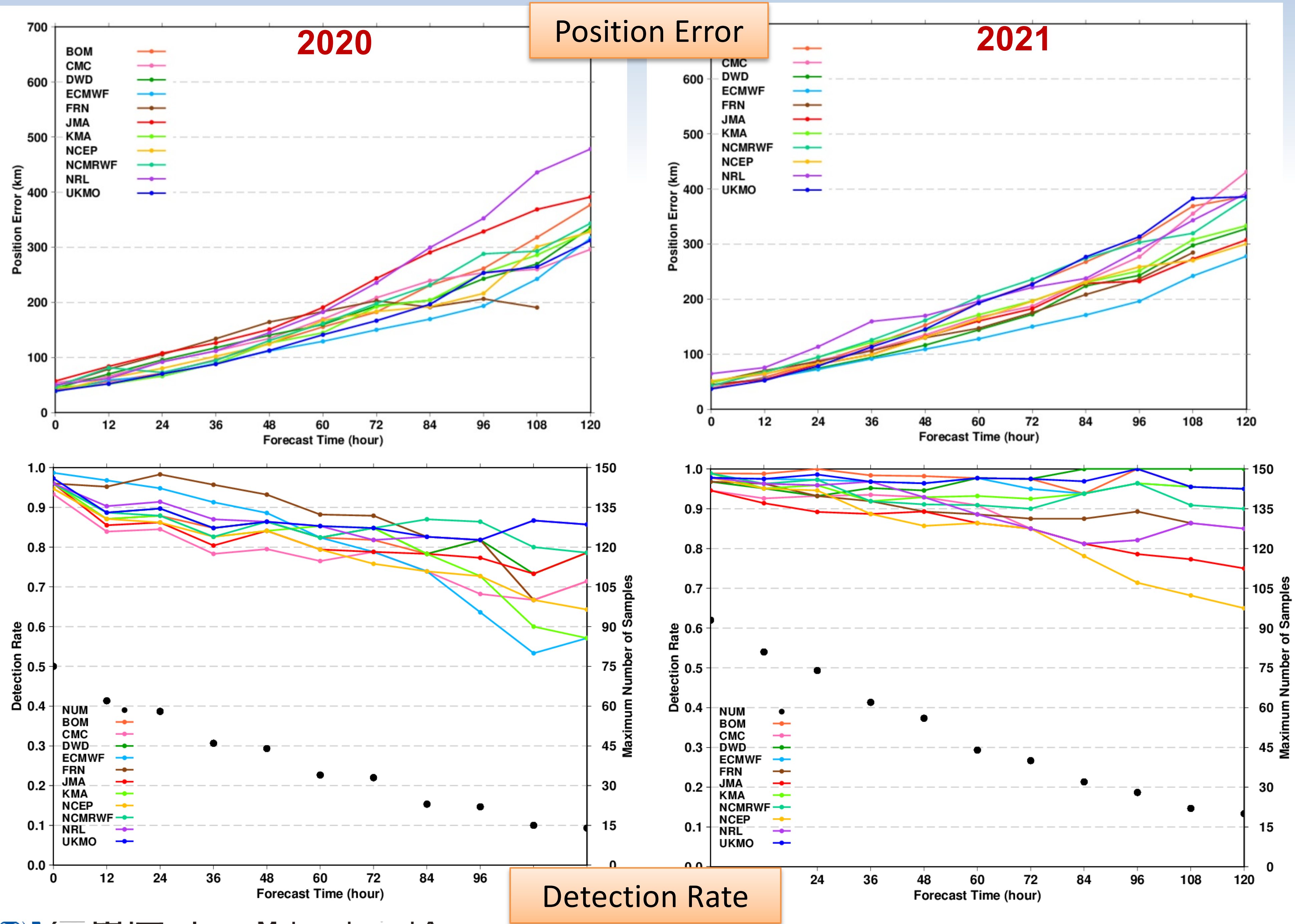
(a) WNP Tendency Diagram of TC Intensity Change (FT=72)



(b) North Atlantic (NAT)

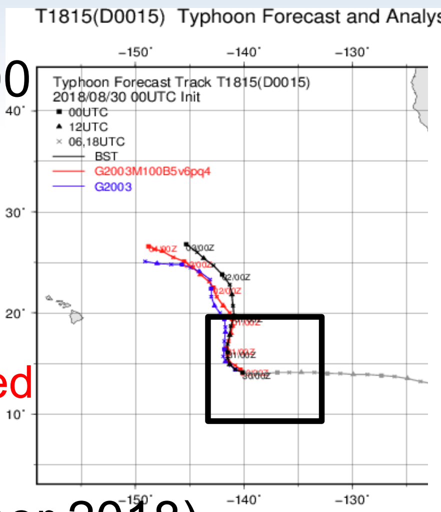


(c) Eastern North Pacific (ENP)

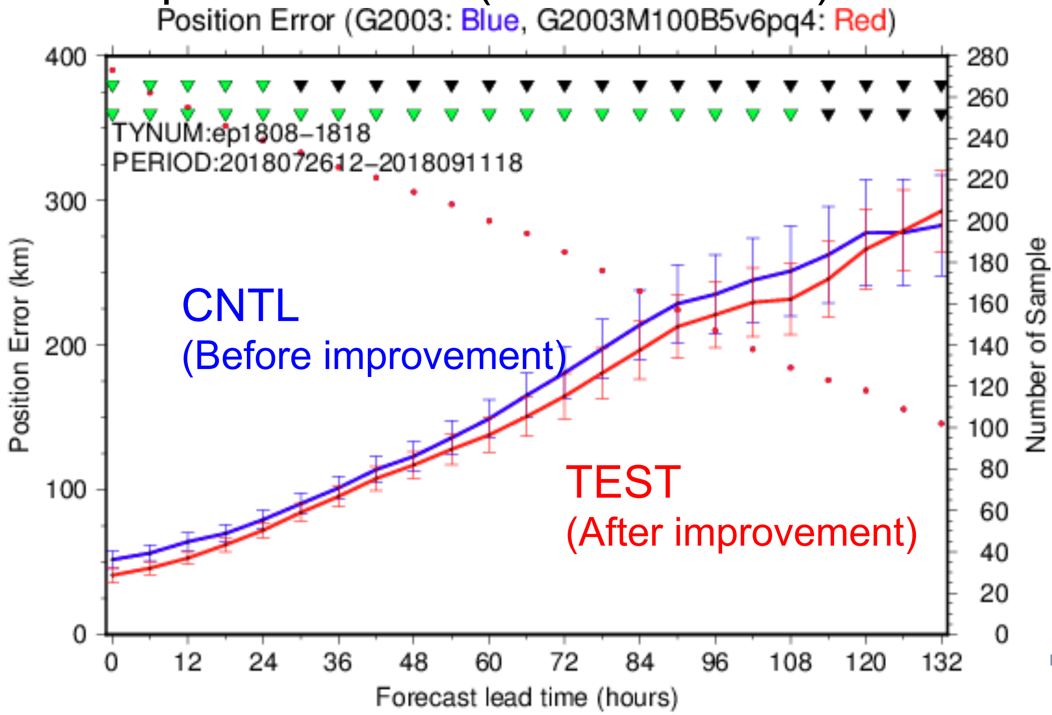


Position error reduction over ENP seen in the development of improving the 4DVAR-LETKF hybrid DA at JMA

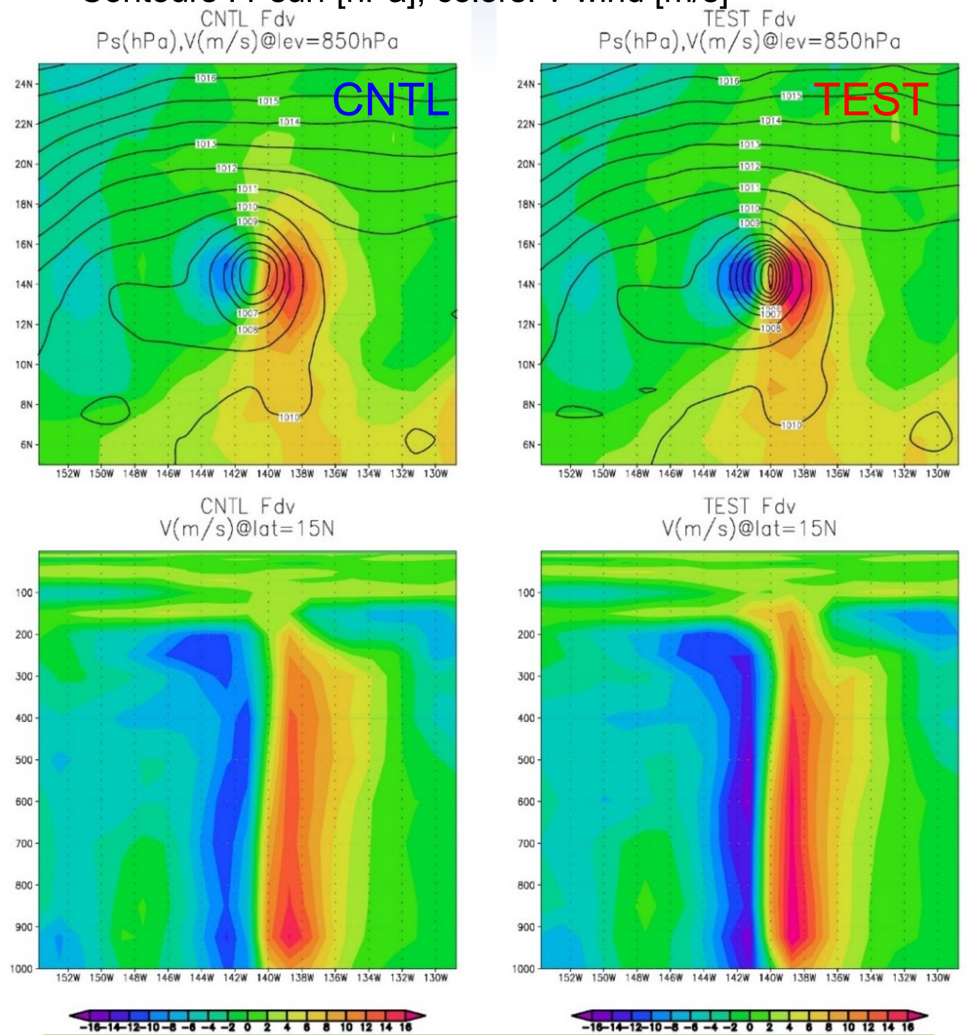
- Increase of ensemble members from 50 to 100
- Increase of weight for ensemble-based background error covariance
- Note that no TC-specialized initialization over ENP



TC position error (Summer 2018)

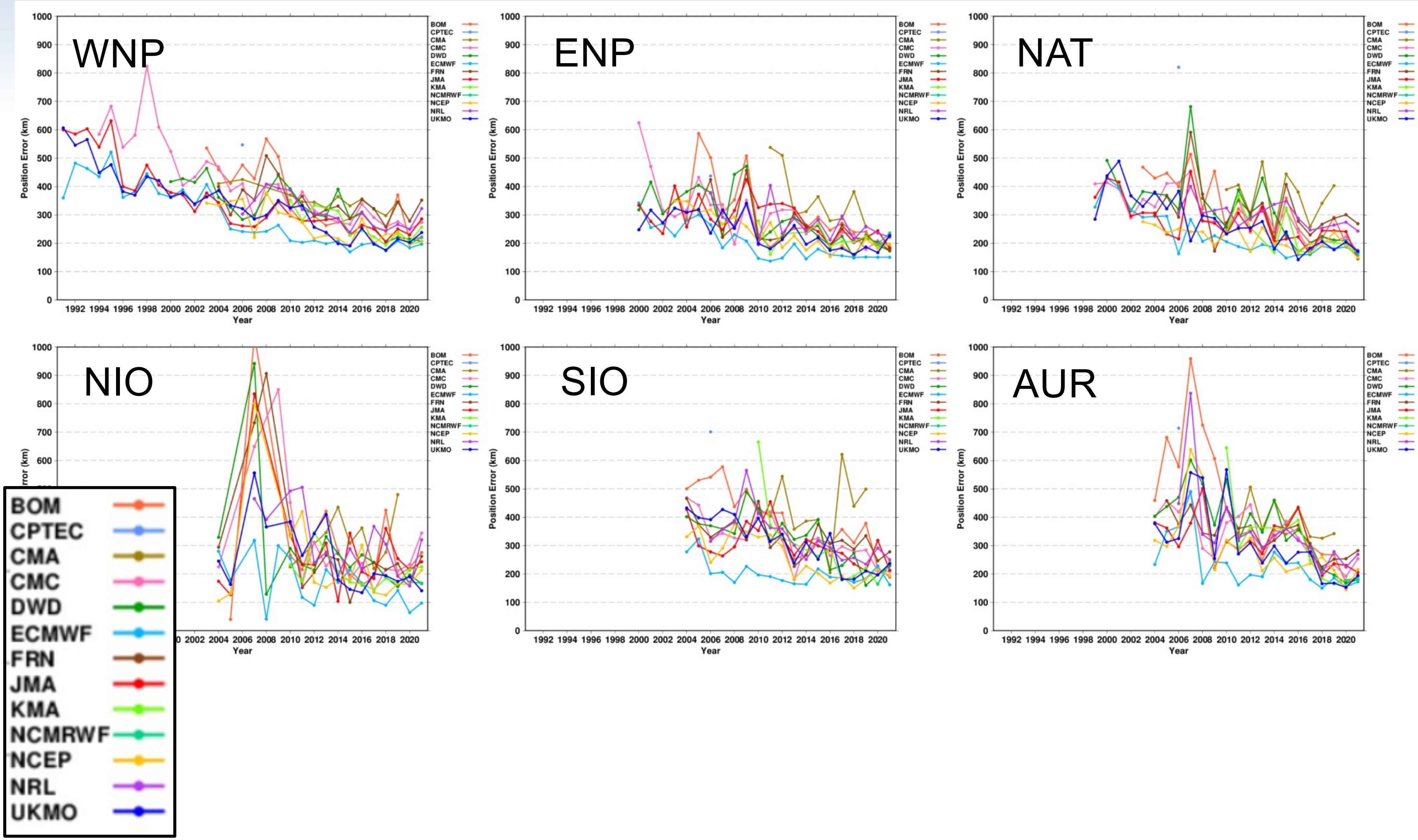


Structure of Hurricane Miriam (2018) at UTC 30 Aug. 2018
Contours : Psurf [hPa], colors: v-wind [m/s]

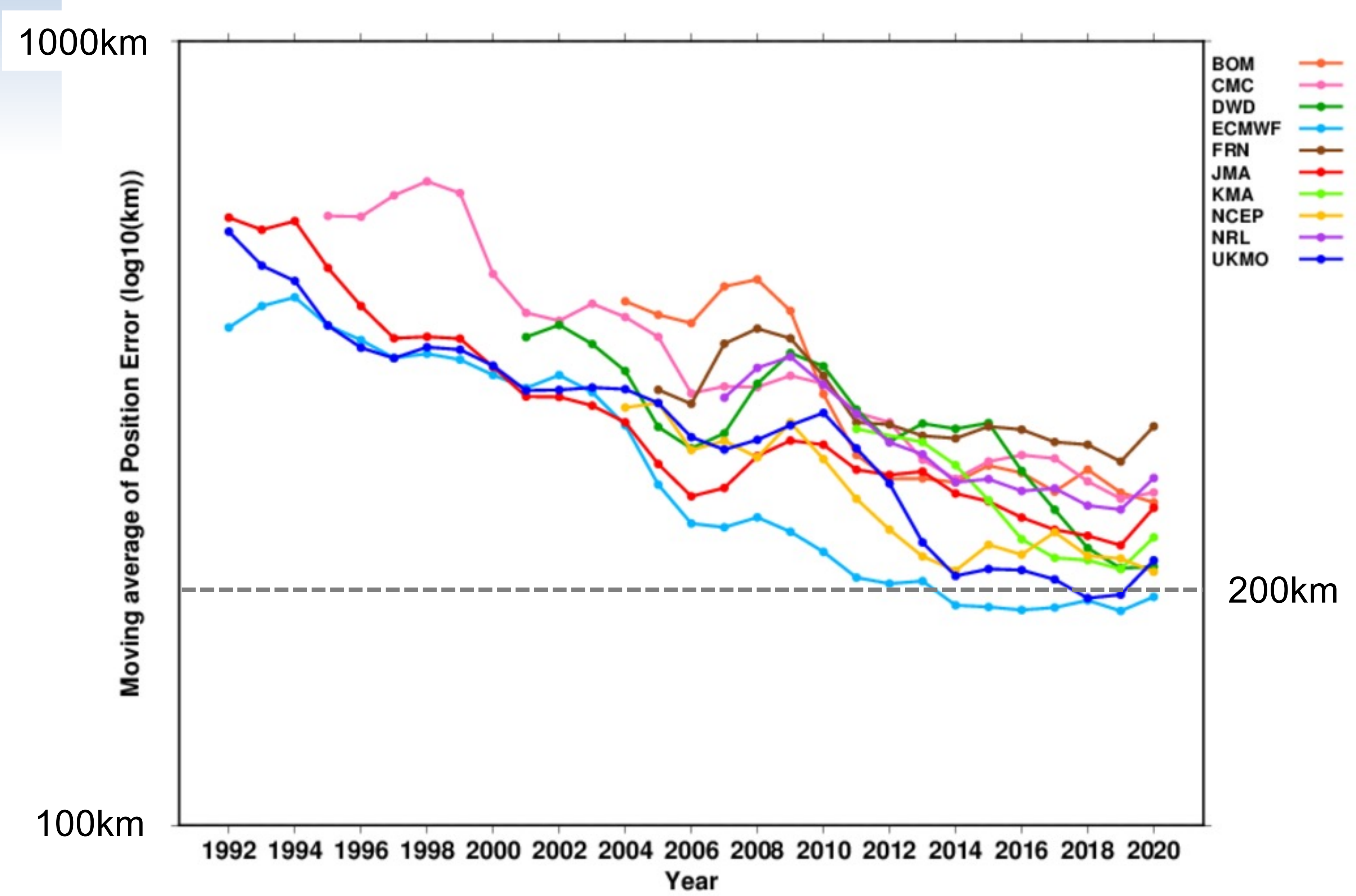


The deeper TC in TEST feels upper tropospheric winds as the steering flow ?

Transition of FT=72 Position Error over Decades



WNP : 3-year moving average with logscale



Summary of verification 2021 (1/2)

- Position errors
  - larger track errors are seen over WNP 2021 than 2020.
    - Due to more recurved and northward TCs
    - Hence, slow bias after re-curvature, a well-known common bias, was clearly seen.
  - Significant reduction of the position errors over NAT and ENP are seen in the JMA forecasts.
    - Also seen in the development stage of improvements to the hybrid data assimilation, which was incorporated in 2021.
    - Suggests importance of sophisticated DA methods as TC initialization (but not specialized for TCs) for position forecasts
  - The slow down of recent improvement in TC position forecast is seen even in the log-scale.

Summary of verification 2021 (2/2)

- Intensity errors
  - Characteristics of “shallower TCs at T+0 and representing deep TCs in the forecasts” still exist.
  - Several models have difficulties in representing decay of TCs over the WNP area
    - The models tend to overestimate these intensities
      - Presumably due to the decay in delay
    - As a few exception, the Met Office and KMA performed well.

TC intercomparison website will be available soon!

WGNE Intercomparison of Tropical Cyclone Track Forecasts Using Operational Global Models

Updated: 28 August 2018

Forecast | Verification | Verification (regional) | Introduction | Read Me | Data | Data (regional) | Contact | Link

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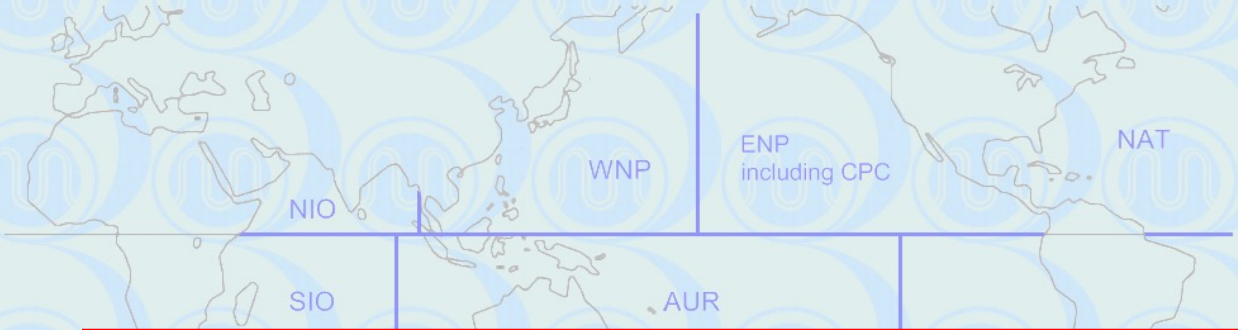
Verification Result

Click on a region of the map to show a pop-up verification.



<http://nwp-verif.kishou.go.jp/wgne_tc/index.html>
Login ID: verif
Password: wgne2022 (beyond 1 November 2022)
Contact: globalnwp@met.kishou.go.jp

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

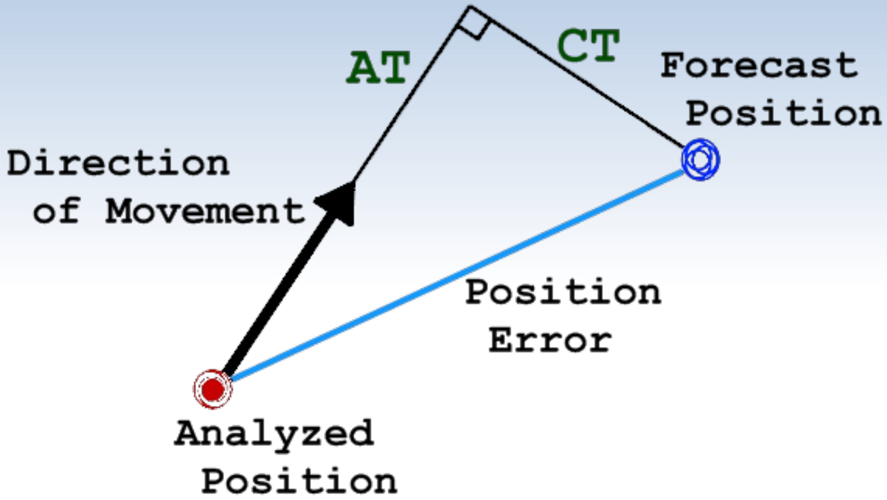
TCs are tracked using mean sea level pressure data provided by participating NWP centres. Under this method, the minimum pressure point is identified as the initial or predicted TC position.

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.

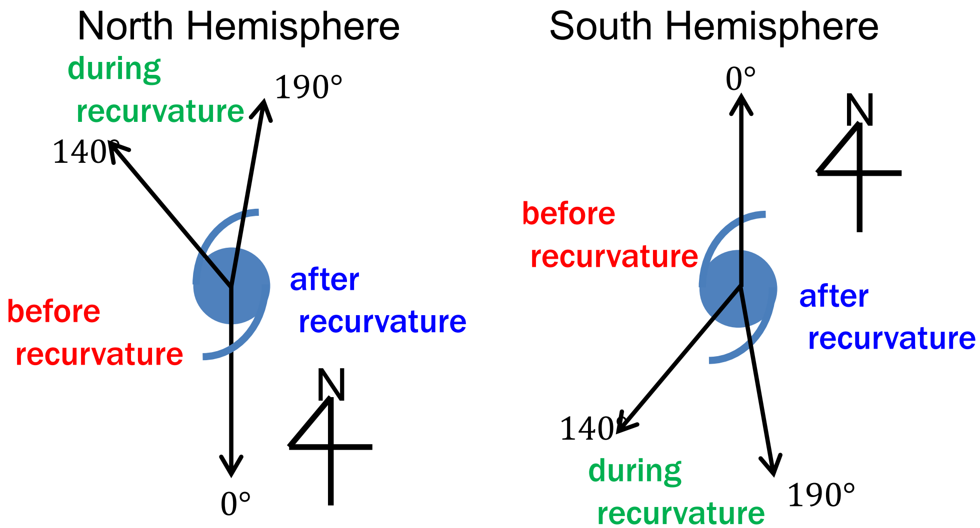
Definitions

- **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

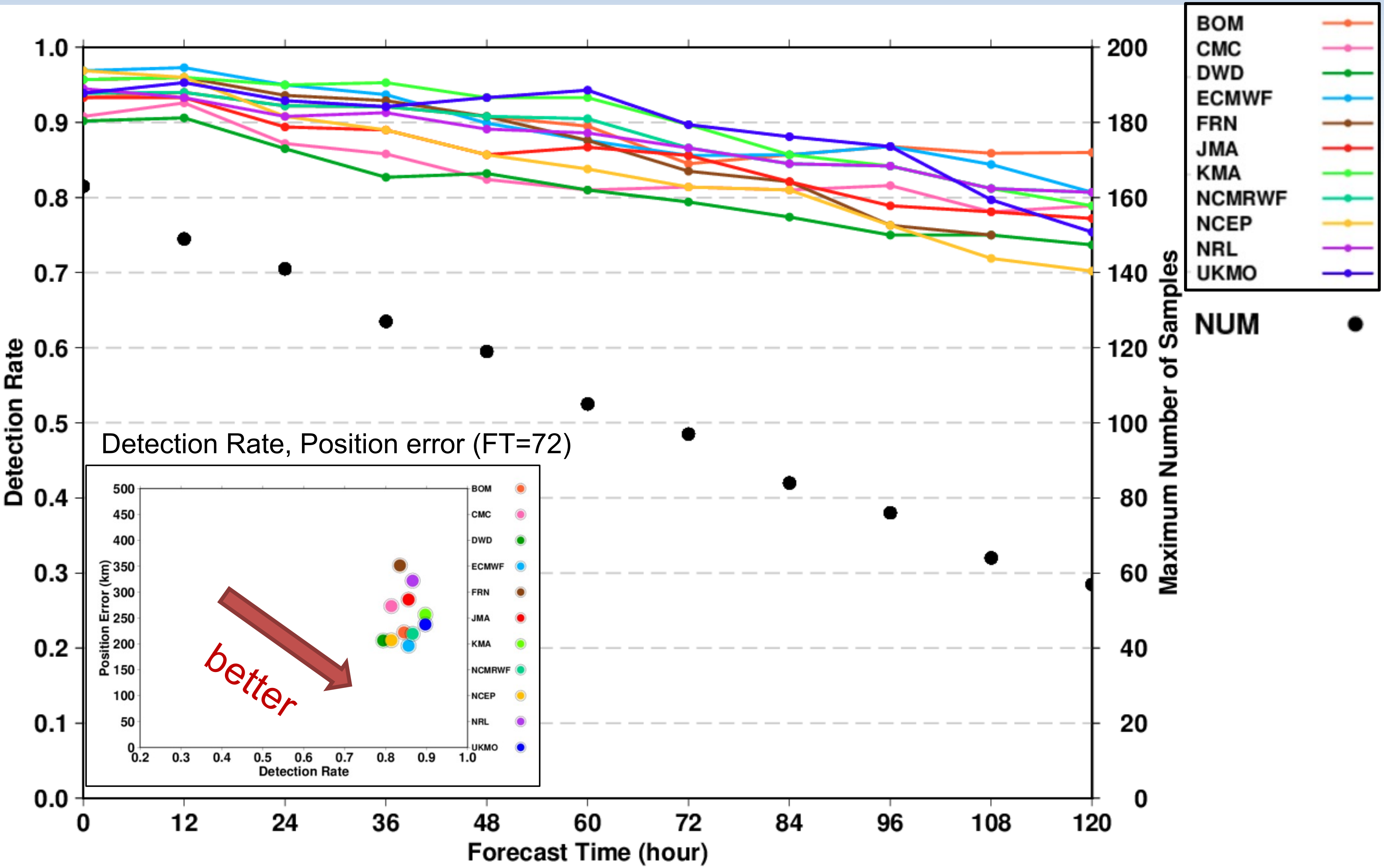
Notes
* NCEP employees combination of multiple initialization schemes (Kleist et al. 2016).
* JMA, CMA: only over Western Pacific Ocean

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

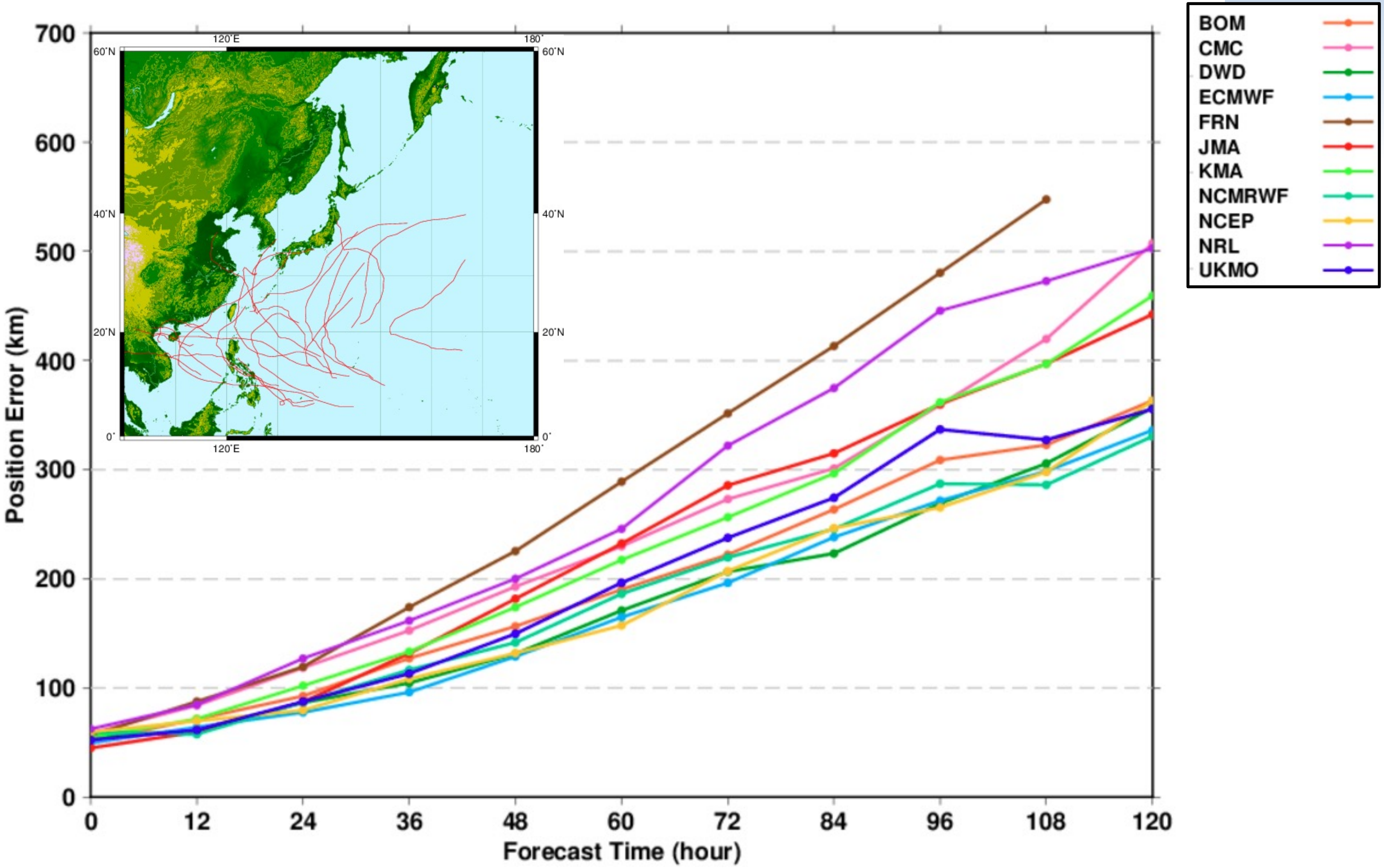
Trends in choice of TC initialization schemes

- 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

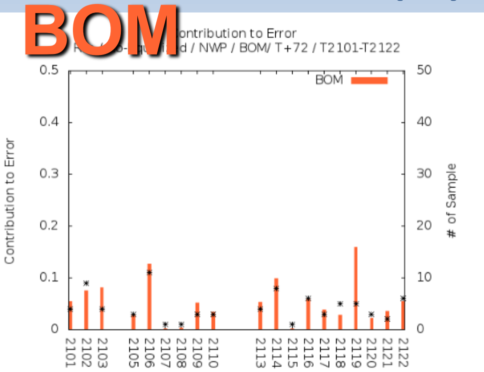
(a) WNP Detection Rate

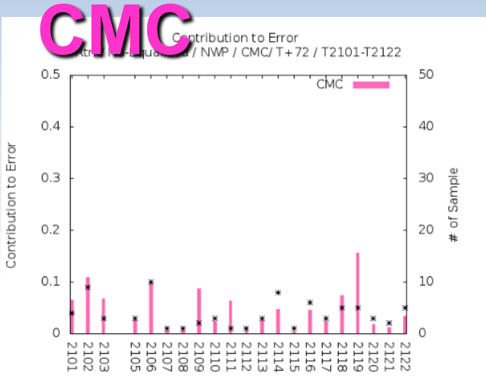


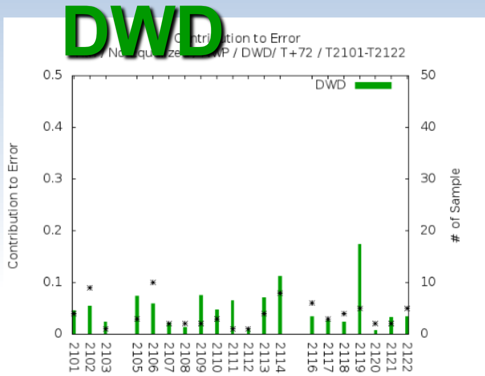
(a) Western North Pacific (WNP) Position Error

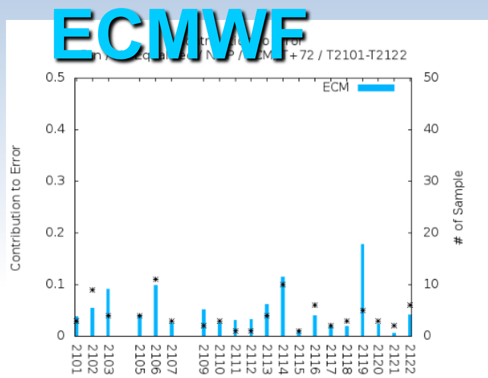


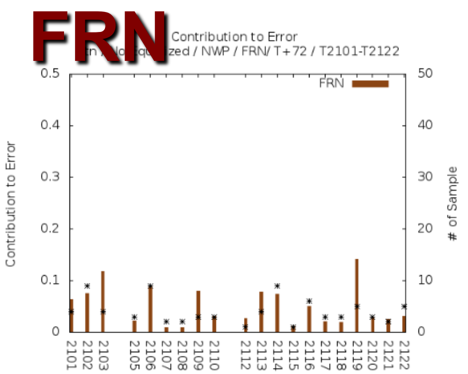
(a) Contribution to Error (WNP, FT=72)

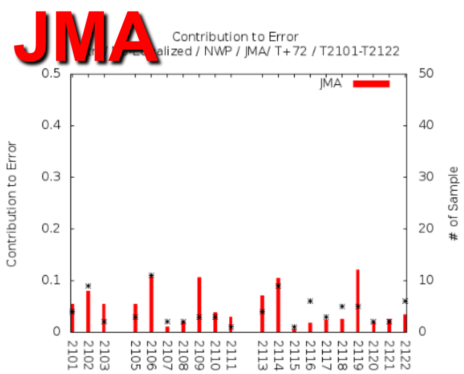


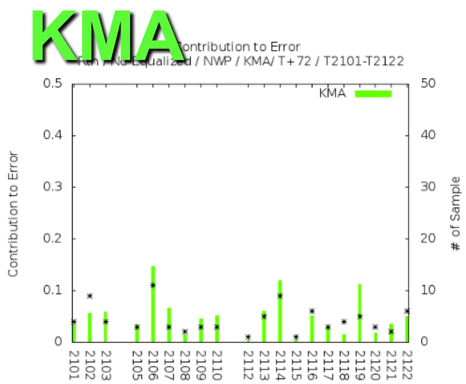


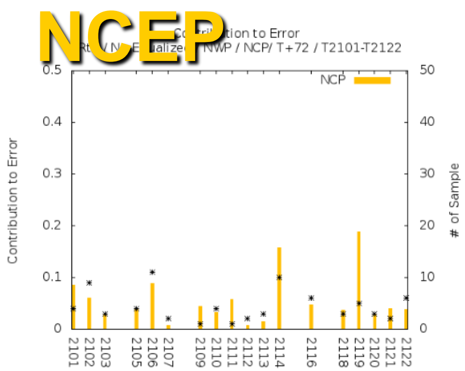


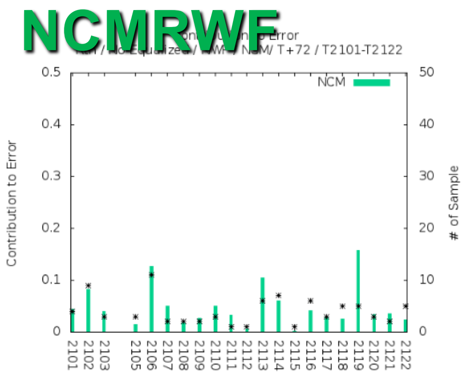


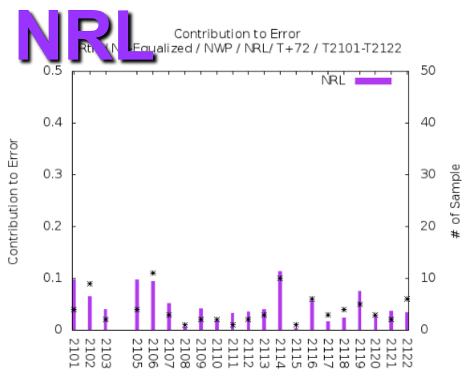


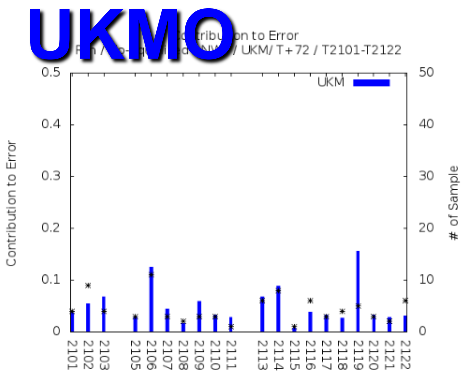












$$\frac{e_i \frac{n_i}{N}}{\sum_{i=1}^{M} e_i \frac{n_i}{N}}$$

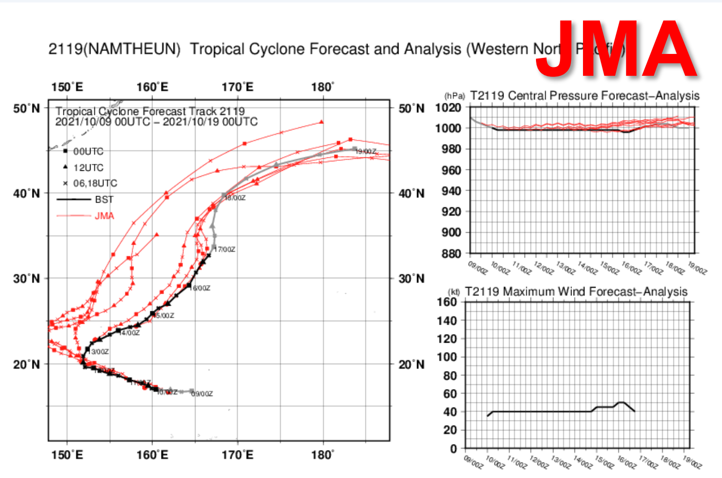
e_i : mean error of i th TC

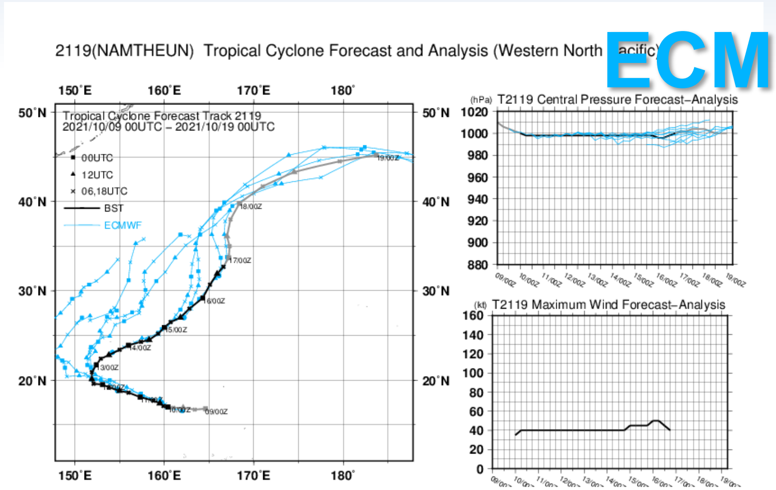
n_i : number of forecasts for i th TC

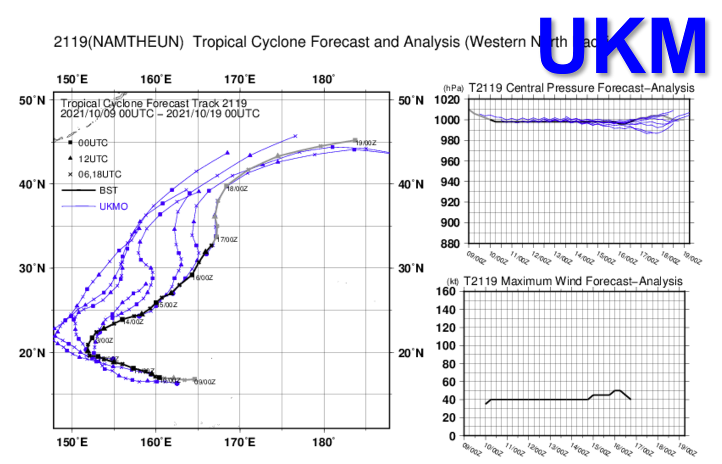
M : number of TCs in a year

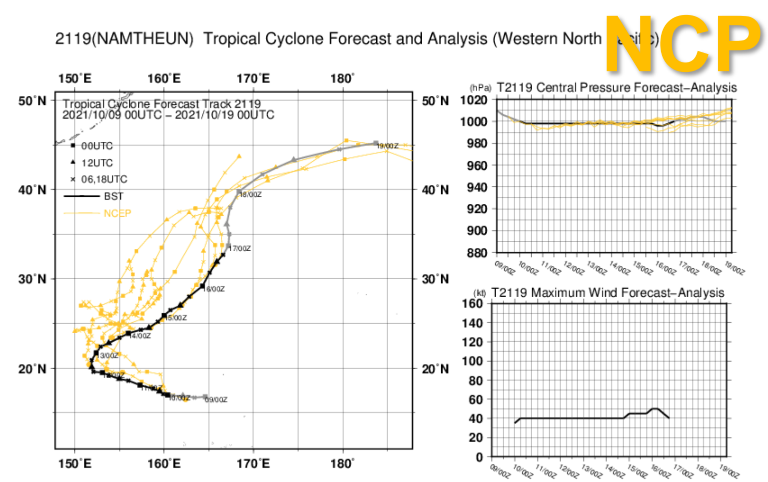
$$N = \sum_{i=1}^{M} n_i$$

Cases of Typhoon T2119“NAMTHEUN” (2021)





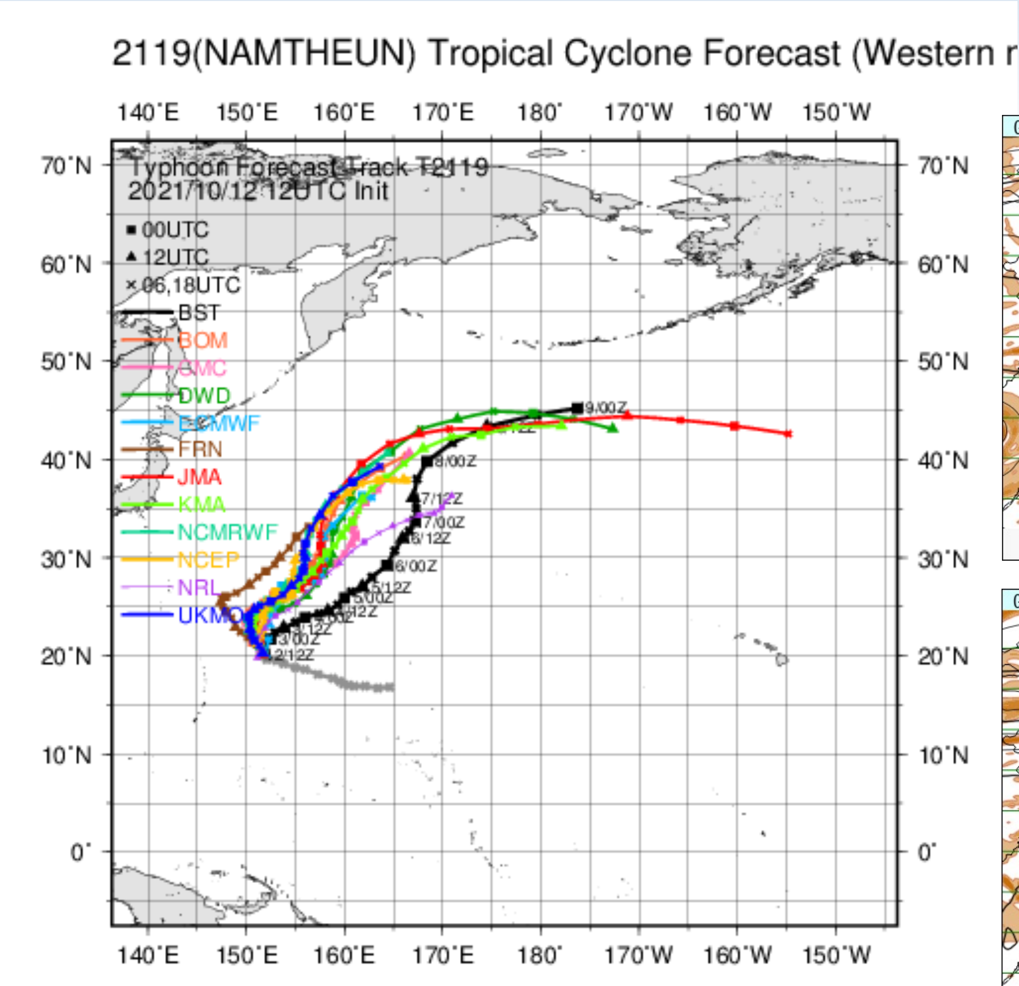




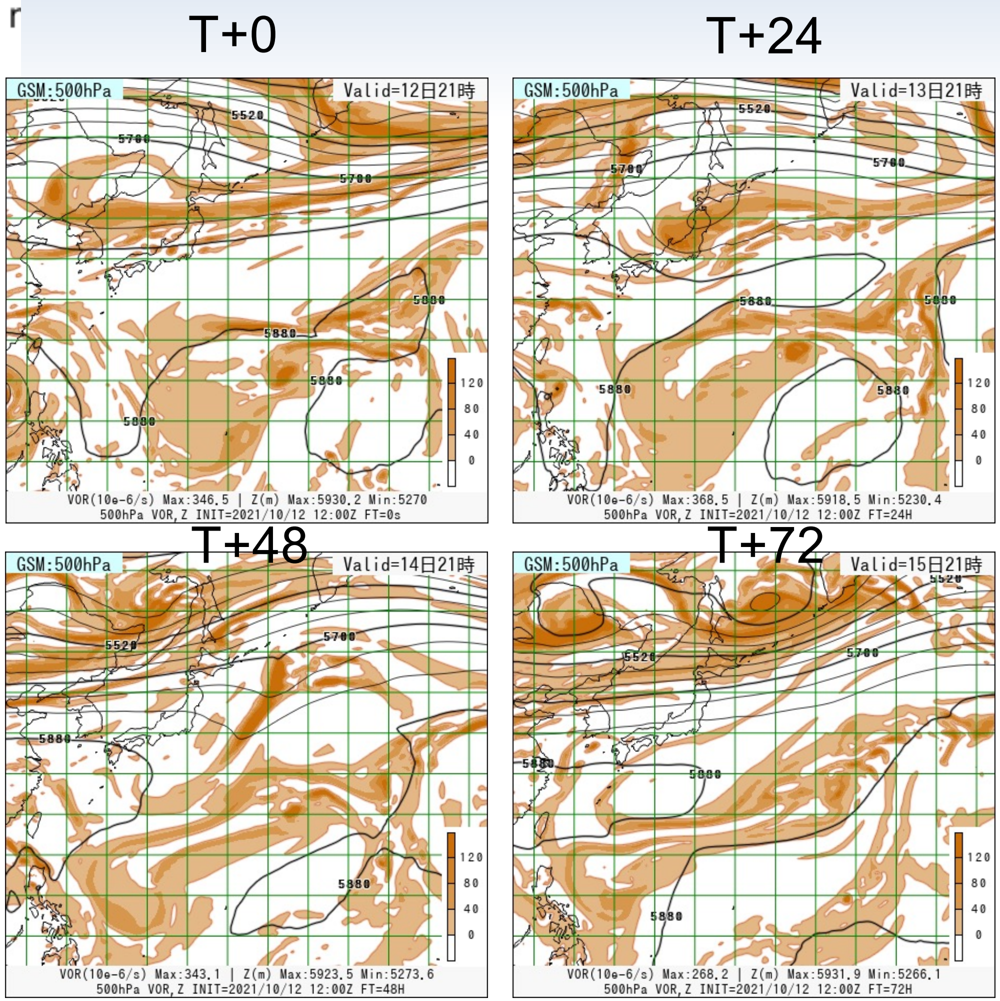
- Models tend move TCs more north westward

Cases of Typhoon T2119"NAMTHEUN" (2021)

Initialized at 12 UTC 12 Oct. 2021



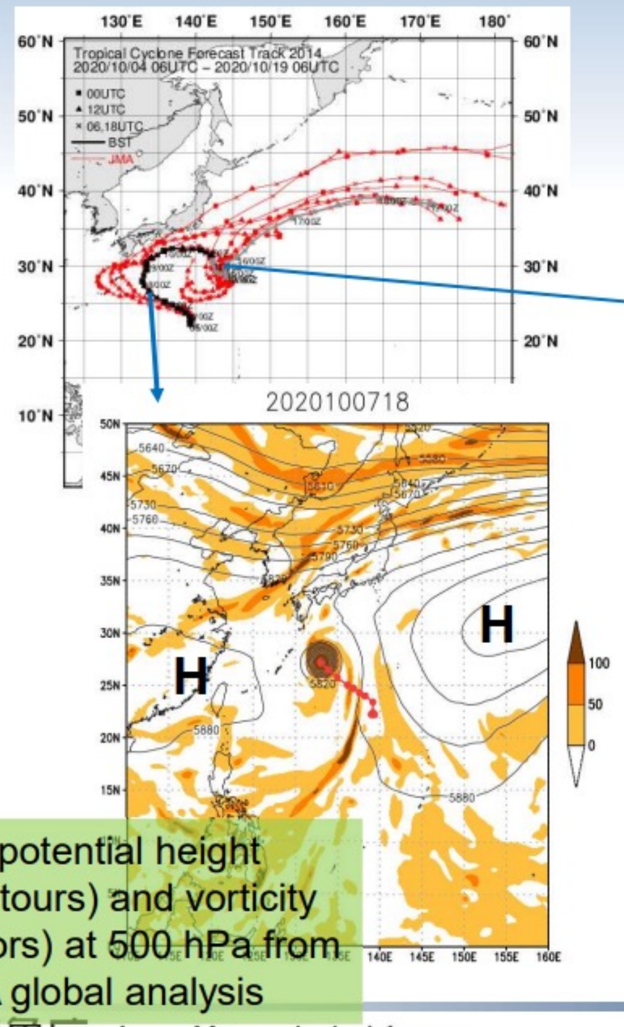
Relative vorticity (colors) and geopotential height (contours) at 500hPa



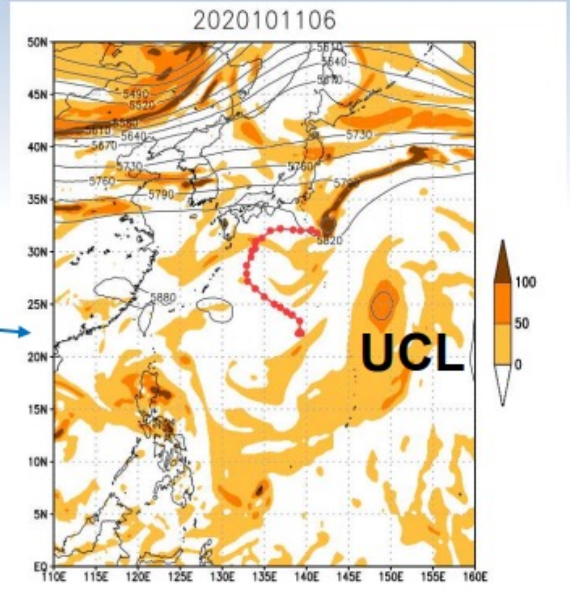
NAMTHEUN moved northward between two ridges.

-> The environmental conditions were similar to those in a case of Typhoon "Chan-Hom" (2020) which was recognized as a difficult case to predict the TC positions

Tropical Cyclone “Chan-hom”: environmental conditions



Geopotential height (contours) and vorticity (colors) at 500 hPa from JMA global analysis



・Before recurvature : between subtropical high and high pressure over China.

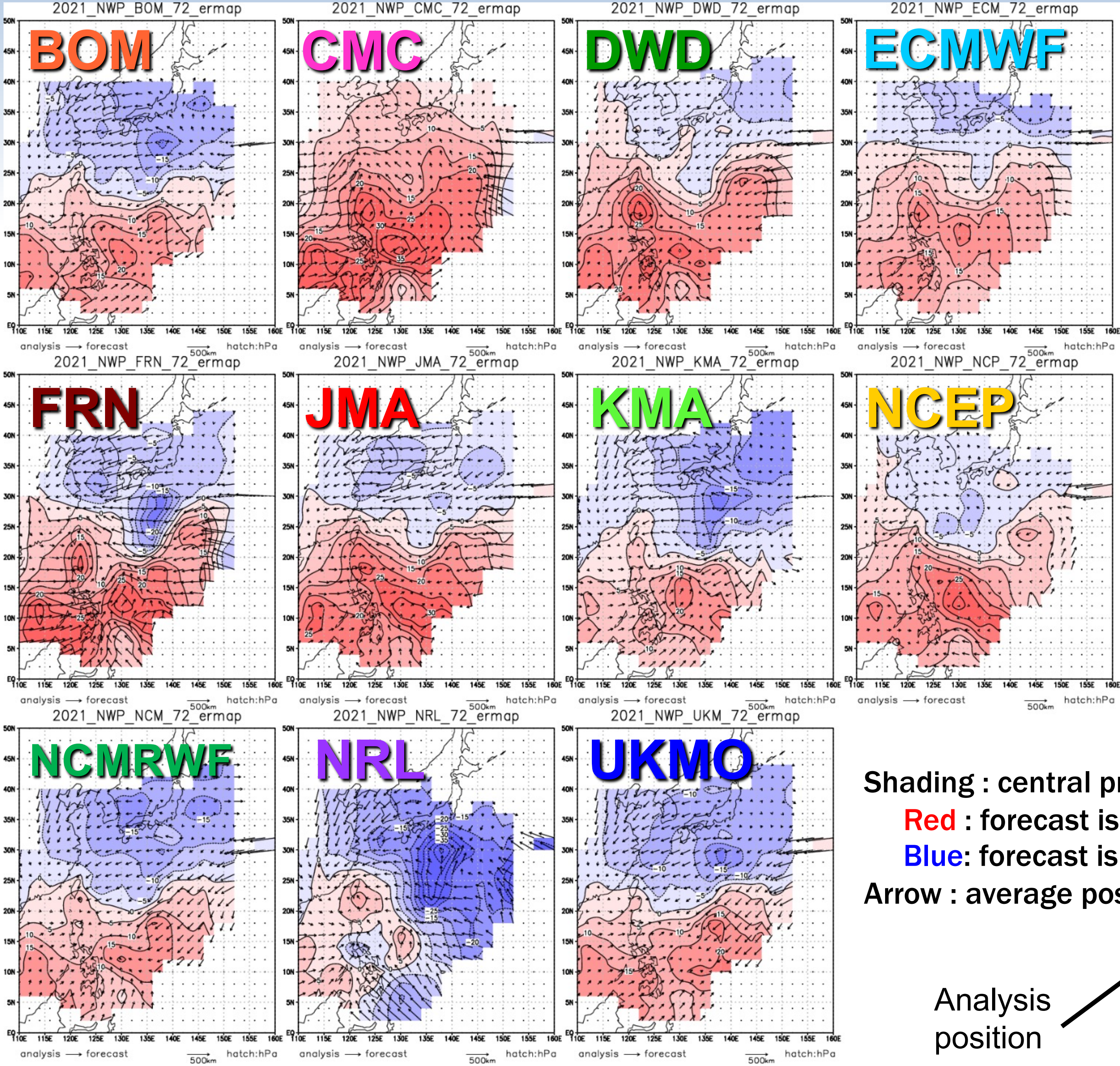
- Known as a environmental condition in which TC track errors tend to be large (e.g. Tang et al. 2019, 2021)

・After recurvature : interaction with another upper cold low may make TC track difficult.

気象庁 Japan Meteorological Agency

https://wgne.net/wp-content/uploads/2021/11/WGNE36_Ujiie_tcverif.pdf

(a) WNP Error Map (FT=72)



Shading : central pressure error (hPa)

Red : forecast is shallow

Blue: forecast is deep

Arrow : average position error

Analysis position → Forecast position