WGNE inter-comparison of Tropical Cyclone Track forecast 2023

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Avalibable from: https://nwp-verif.kishou.go.jp/wgne_tc/index.html

Login ID: verif
Password: wgne2024 (beyond 1 November 2024)
Contact: globalnwp@met.kishou.go.jp

STANDARD VERIFICATION

Verification of Global Models

Data Specifications in 2023

NWP centre	Year of verification commencement	Horizontal resolution of provided data (degrees in longitude and latitude)	Model resolution as of 2023
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	0.25 x 0.25 (~Mar. 13) 0.125 x 0.125 (Mar. 14~)	TL959L128 (~Mar. 13) TQ959L128 (Mar. 14~)
KMA	2010	0.125 x 0.125	12kmL91
NCEP	2003	0.5 x 0.5	13km FV3-based, C768 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

Improvements of models for each centre in 2023 (1/2)

- **CMC**
  - 2023.01.04 : Replacement of Atmospheric Motion wind Vectors from GOES-17 by those from GOES-18
  - 2023.02.15 : Addition of GPSRO observations from the Sentinel-6A satellite
  - 2023.03.08 : Correction to the quality control of snow depth from Canadian automatic stations
  - 2023.07.05 : Addition of commercial GNSS-RO observations from Spire
  - 2023.09.14 : Addition of commercial GNSS-RO observations from PlanetIQ
  - 2023.11.02 : Addition of CSR observations from the GOES-18 satellite
- **DWD**
  - 2023.01.05 : Switch radiances and atmospheric motion vectors from GOES-17 to GOES-18. New version of data assimilation code
  - 2023.01.25 : Use of a new version of RTTOV coefficient files. Assimilation of MWHS-2 data, etc.
  - 2023.03.15 : Modification of shallow-convection scheme, etc.
  - 2023.03.29 : Switch radiances and atmospheric motion vectors from Meteosat-10 to Meteosat-11. New version of data assimilation code
  - 2023.05.03 : Use of high-density MODE-S aircraft observation

Improvements of models for each centre in 2023 (2/2)

- **DWD**
  - 2023.06.28 : Improved processing in situations with partially missing satellite radiance, etc.
  - 2023.07.19 : Update to DACE, switch on again assimilation of SARAL
  - 2023.09.06 : Update of ICON version to 2.6.6-nwp0
  - 2023.09.14 : Assimilation of ATMS on NOAA-21, etc.
  - 2023.10.04 : Update of data assimilation code DACE
  - 2023.11.28 : Update of ICON version to 2.6.6-nwp1
- **ECMWF**
  - 2023.06.27 : Implementation of IFS Cycle 48r1
- **JMA**
  - 2023.03.14 : Major upgrade was made to the Global Spectral model (GSM)
    - Incl. resolution upgrade (TL959(~20km) to TQ959(~13km)) and orography ancillary data update
  - 2023.05.14 : Assimilation of AMV and CSR on GOES-18 and Meteosat-11
- **KMA**
  - 2023.02.23 : Update of KIM version to v3.8

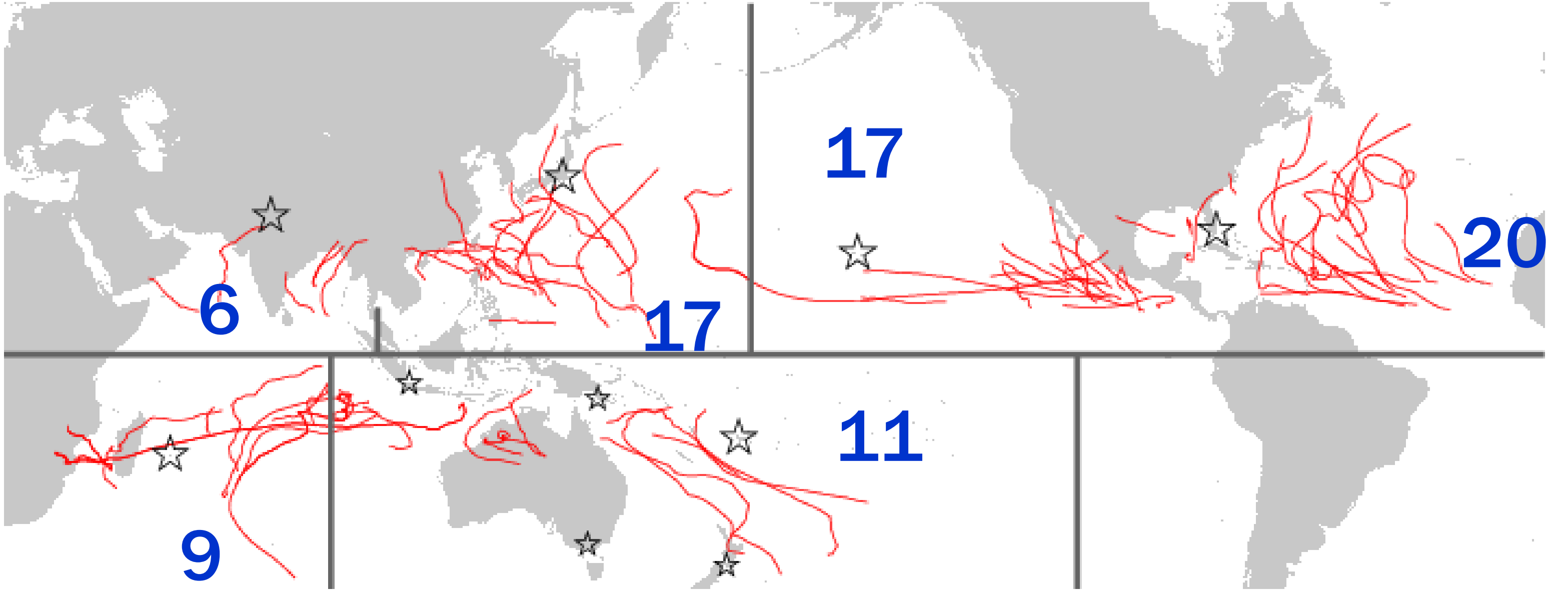
TCs in 2023

TC season

Northern Hemisphere : 1 January 2023 to 31 December 2023
Southern Hemisphere : 1 September 2022 to 31 August 2023

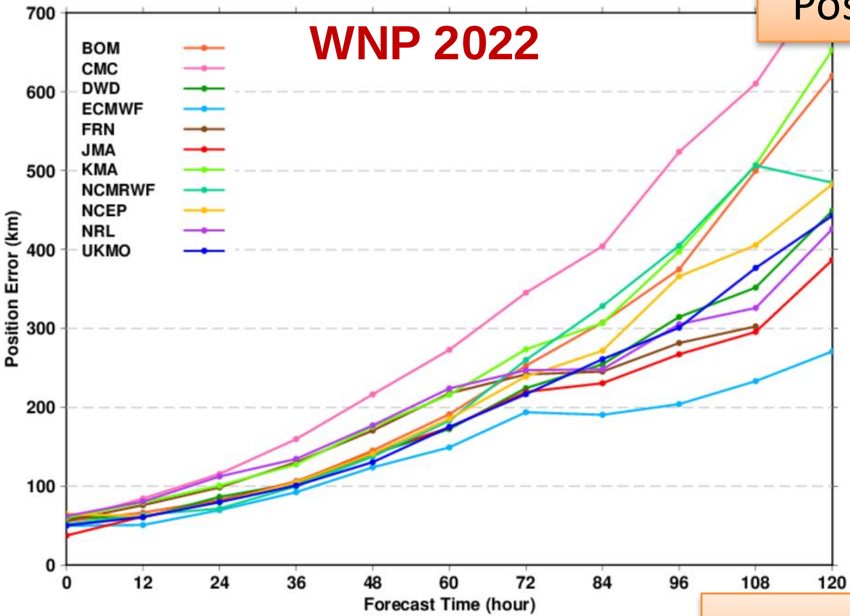
Number of TCs* (LY) [best track data provider]

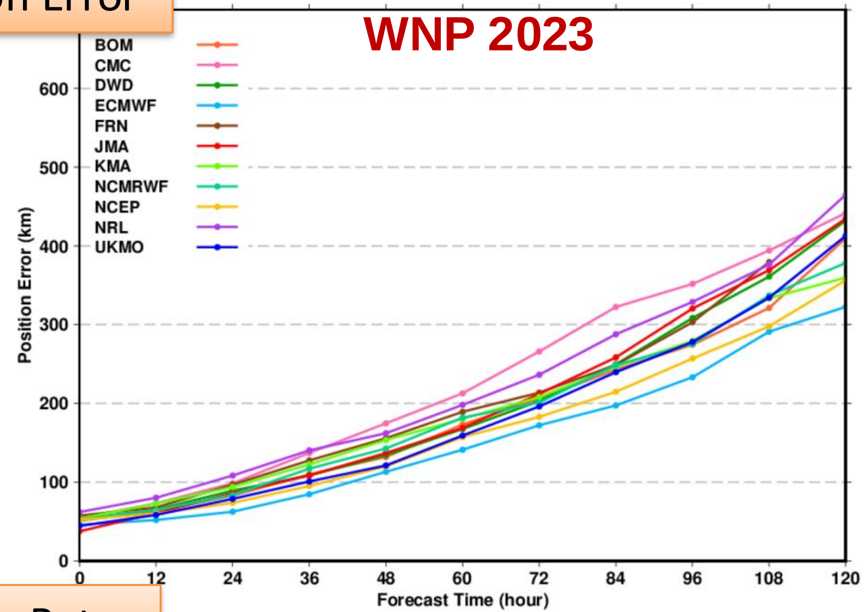
17 (25) Western North Pacific [RSMC Tokyo]
17 (19) Eastern North Pacific (including Central North Pacific) [RSMC Miami, Honolulu]
20 (14) North Atlantic [RSMC Miami]
6 (3) North Indian Ocean [RSMC New Delhi]
9 (13) South Indian Ocean [RSMC La Reunion]
11 (15) Around Australia [RSMC Nadi and 4 TCWCs]



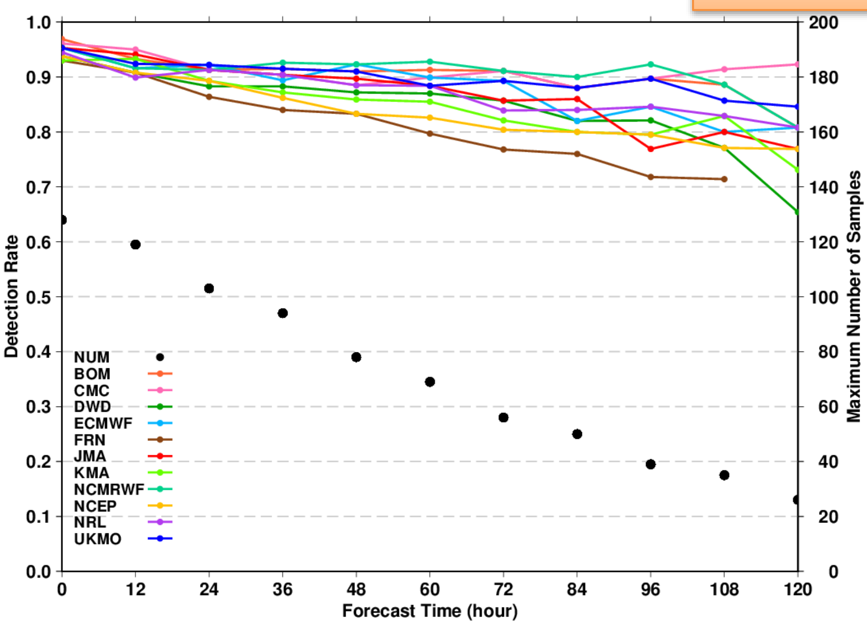
(*)The number of tropical cyclones in each region includes overlaps.

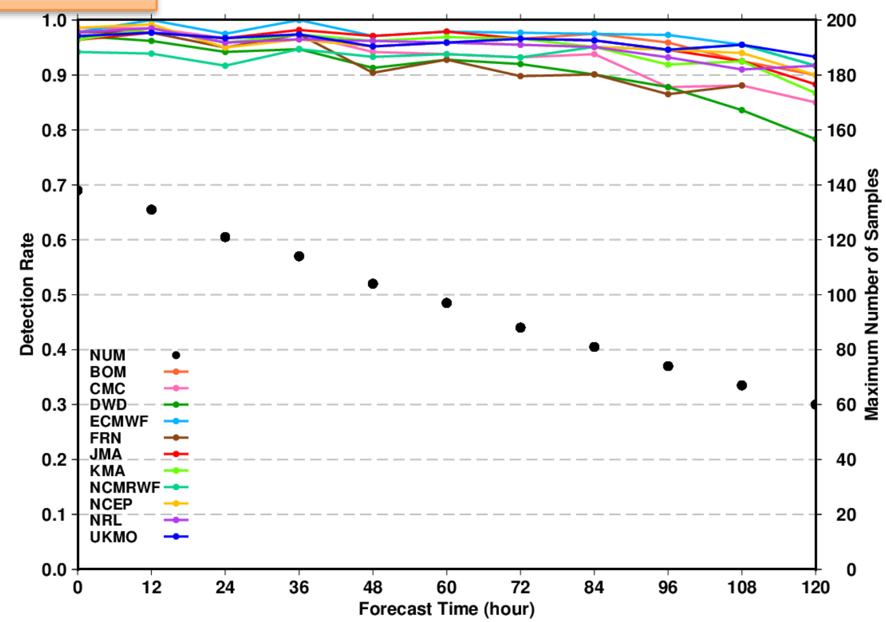
Position Error



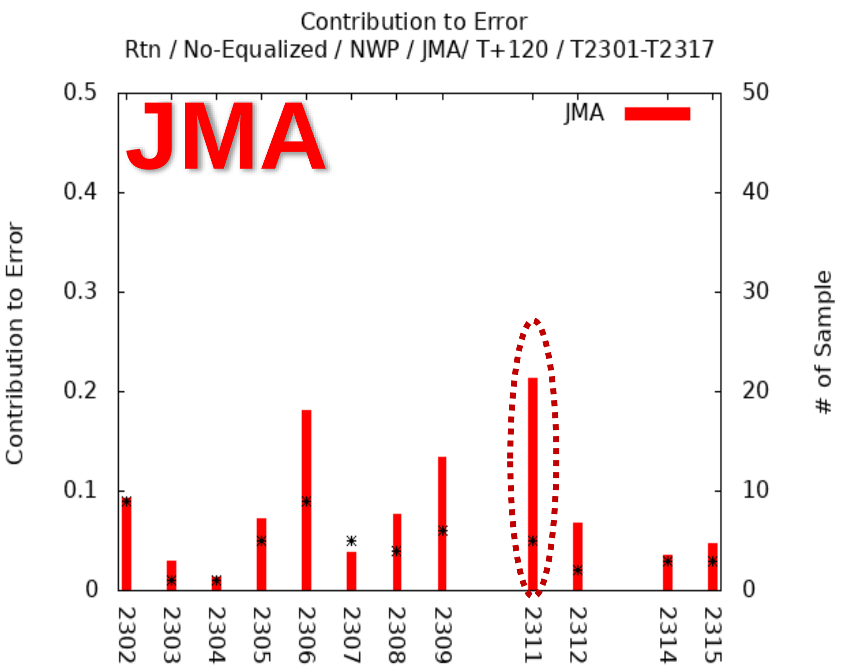


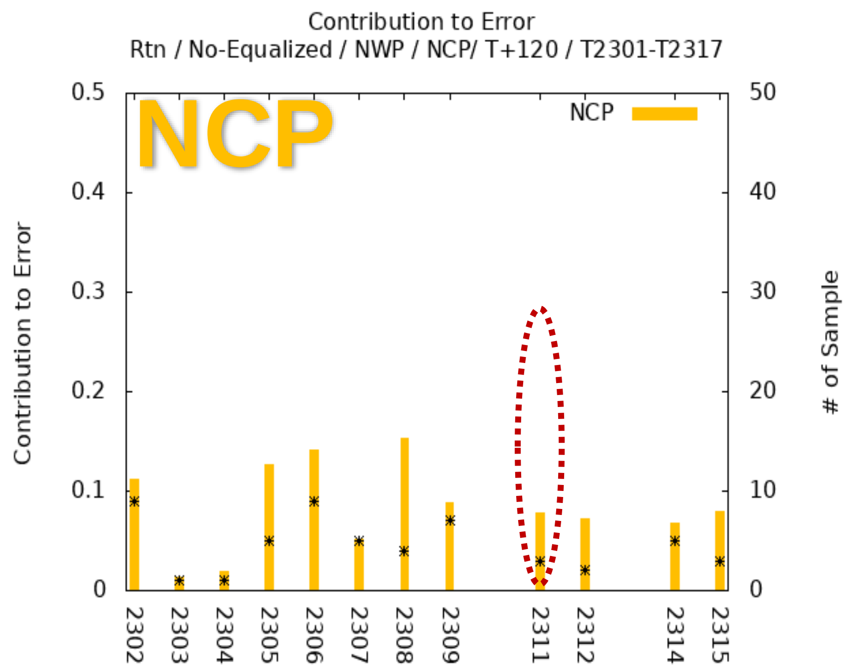
Detection Rate





Contribution to Error (WNP, T+120)





- T2311 (Typhoon HAIKUI) contributed to the annual mean total position error of JMA(and other several centers)'s five-day forecasts, on the other hand, the case had no significant effect on that of NCEP.

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

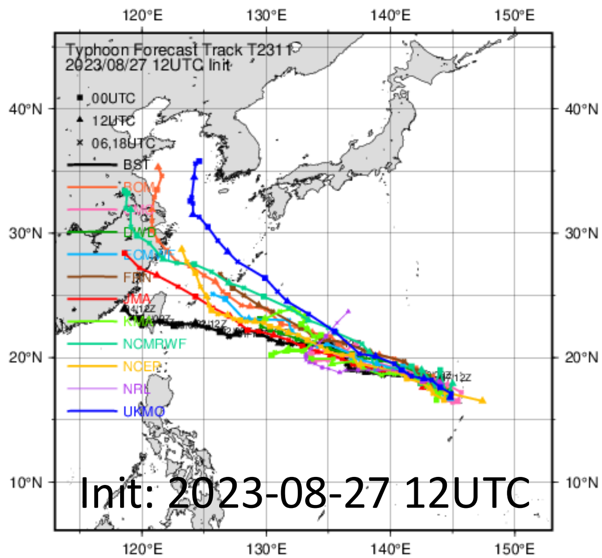
e_i : mean error of i th TC

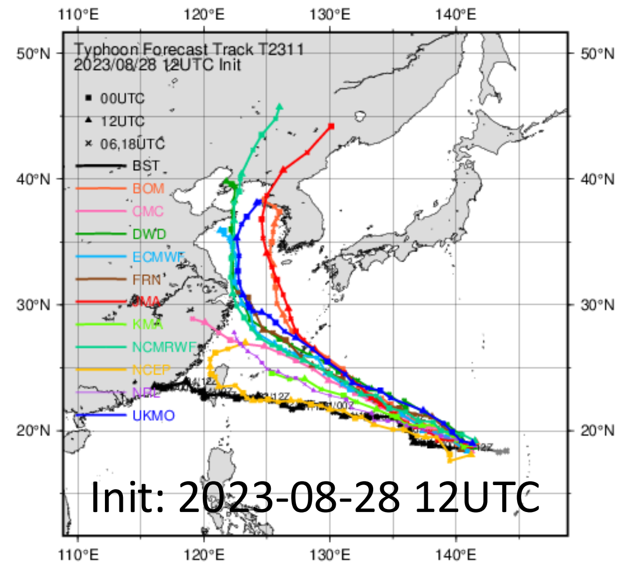
n_i : number of forecasts for i th TC

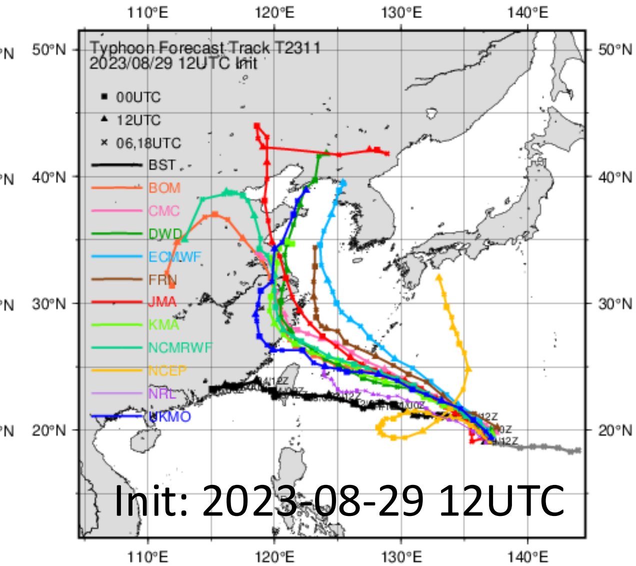
M : number of TCs in a year

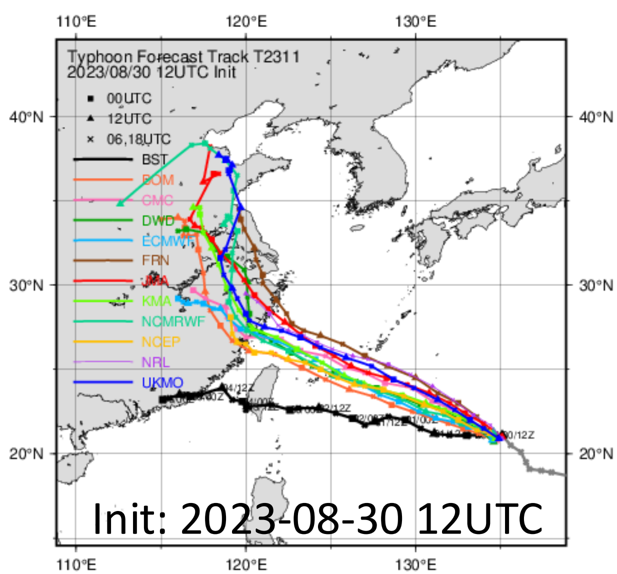
$$N = \sum_{i=1}^{M} n_i$$

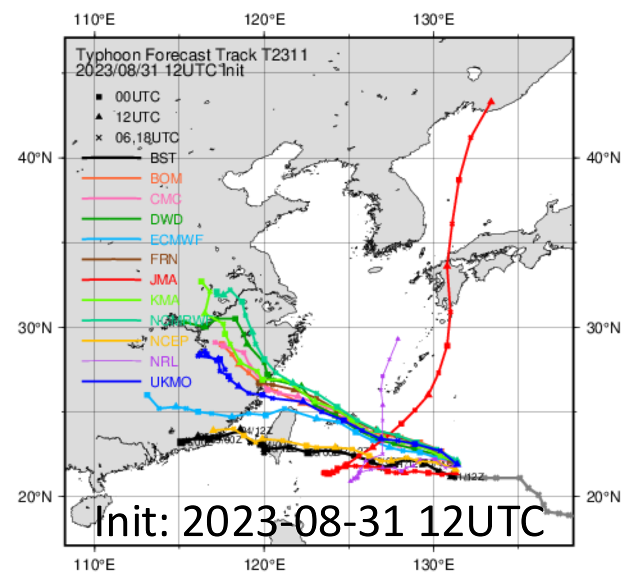
Each track forecast of Typhoon "HAIKUI"











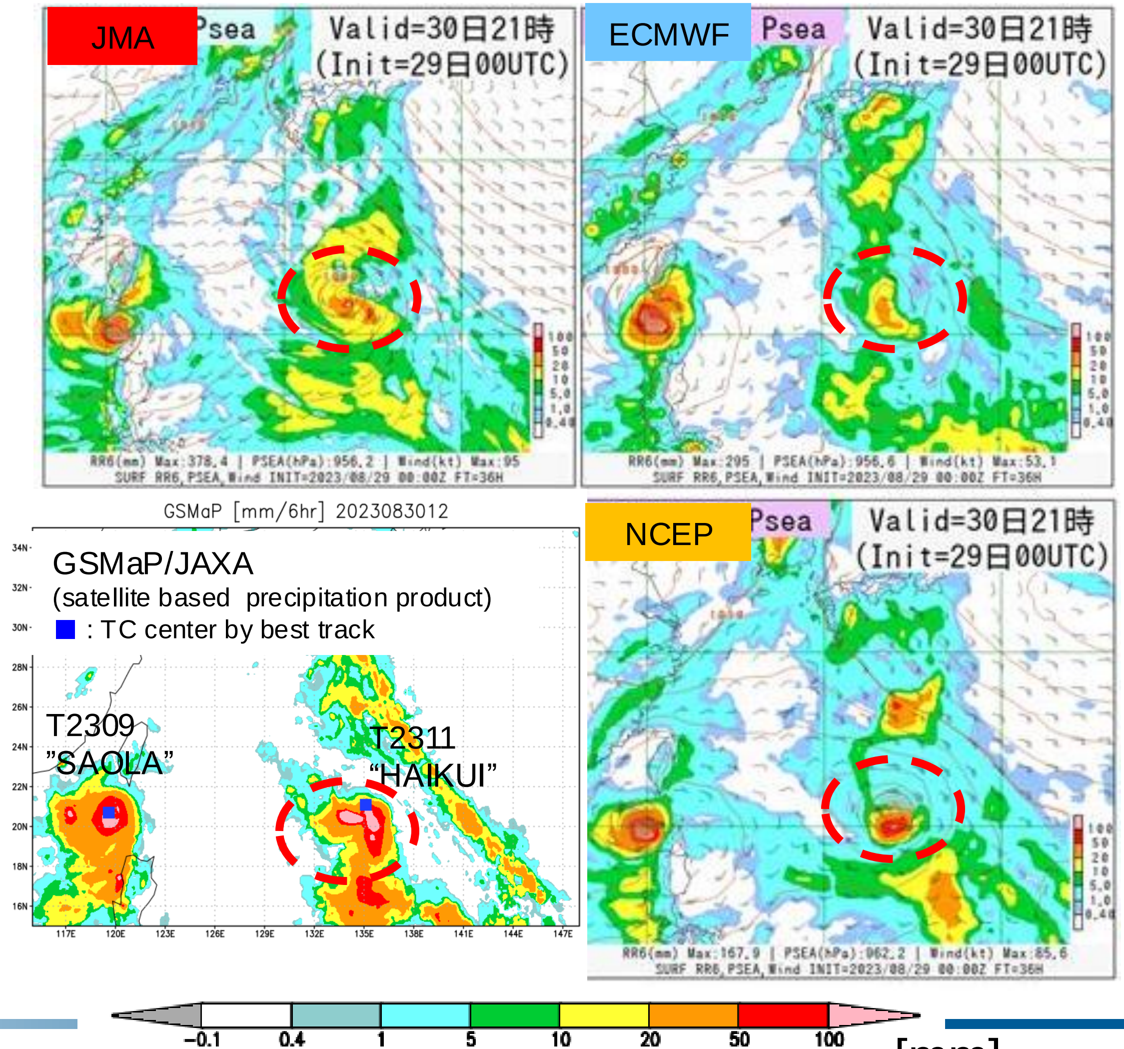
- Northward moving bias is seen in NWP models.
- In several cases, NCEP showed smaller northward bias.

BOM
CPTEC
CMA
CMC
DWD
ECMWF
FRN
JMA
KMA
NCMRWF
NCEP
NRL
UKMO

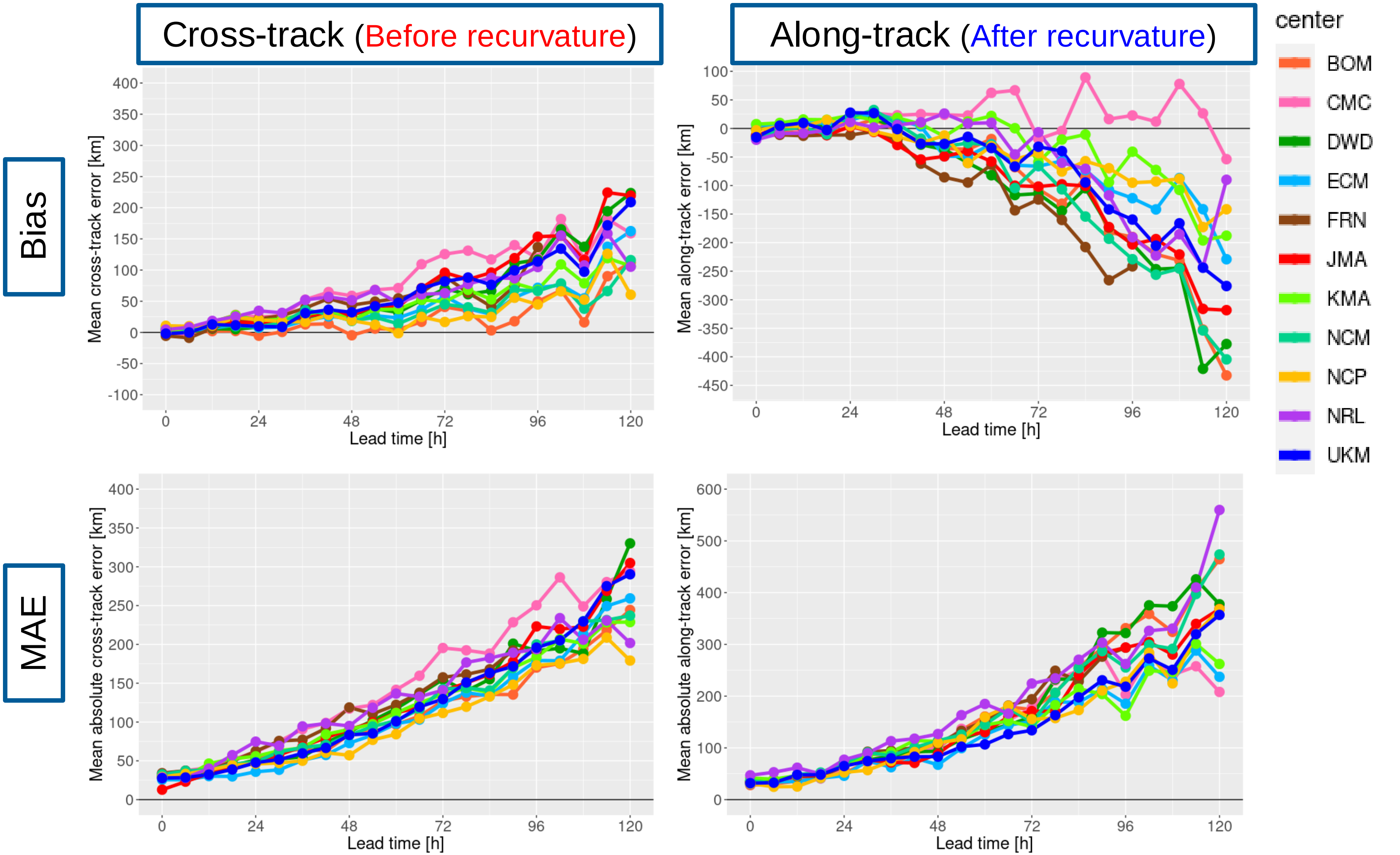
Possible reasons for smaller errors in NCEP

- Possibility 1: difference in environmental flow
  - Stronger subtropical high. in the models other than NCEP
- Possibility 2: difference in representation of axis-asymmetric component of diabatic heating
  - NCEP represents strong precipitation at south of the T2311's center
    - tends to move TC centers southward.

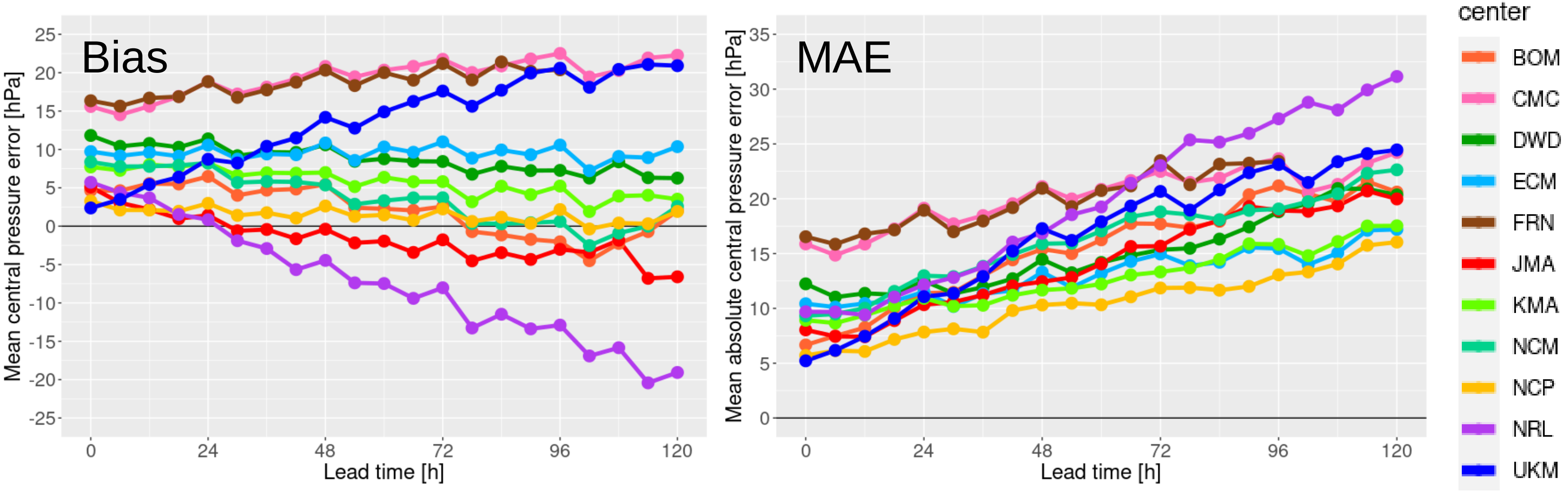
6hour accumulated precipitation [mm]
Forecast leadtime: 36hr
valid at 12UTC 29 Aug. 2023



WNP Along/Cross-Track error by lead time



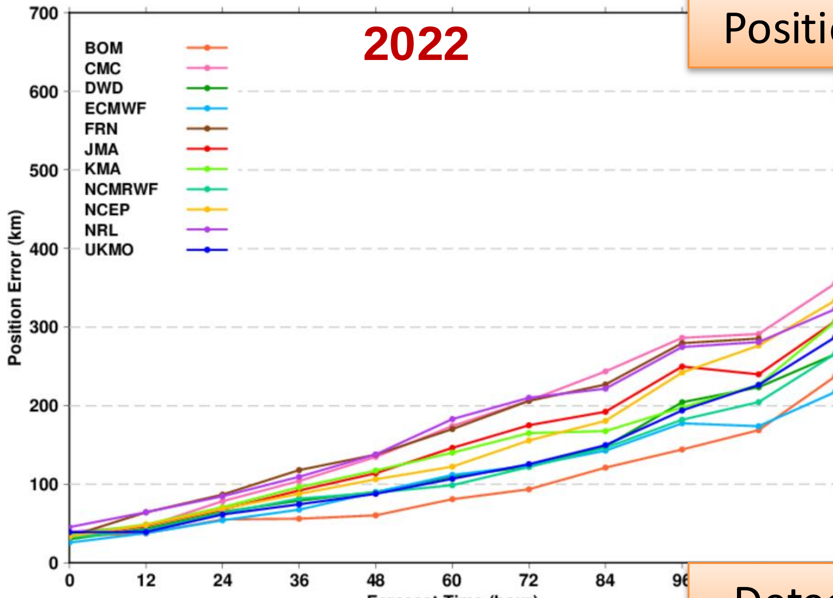
WNP Central Pressure Mean Error(Bias) and Mean Absolute Error

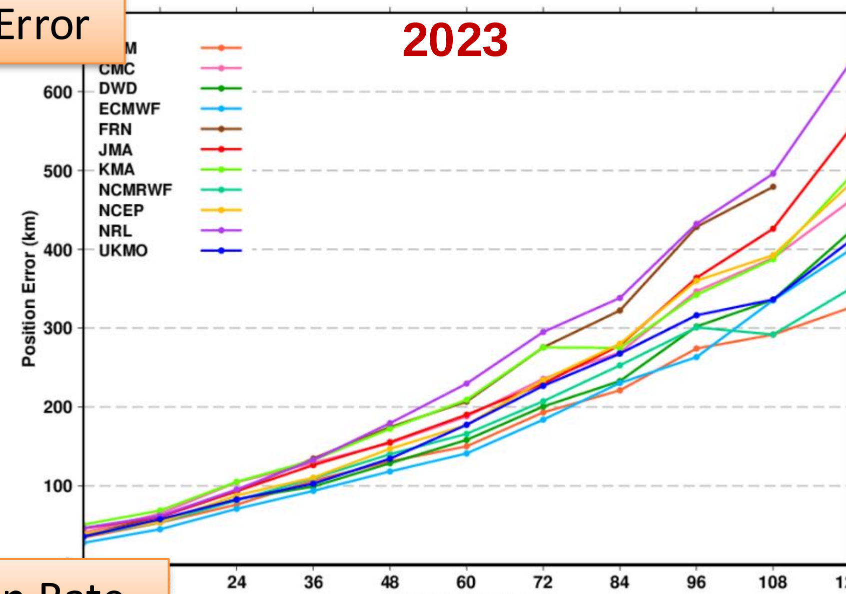


- More than half of models have positive biases throughout T+0 to T+120.
  - In particular, the positive bias of Met Office model increases as lead time progresses.
  - On the other hands, the negative bias of NRL model enlarges as lead time advances.
- NCEP model has small bias and MAE than those of other models.

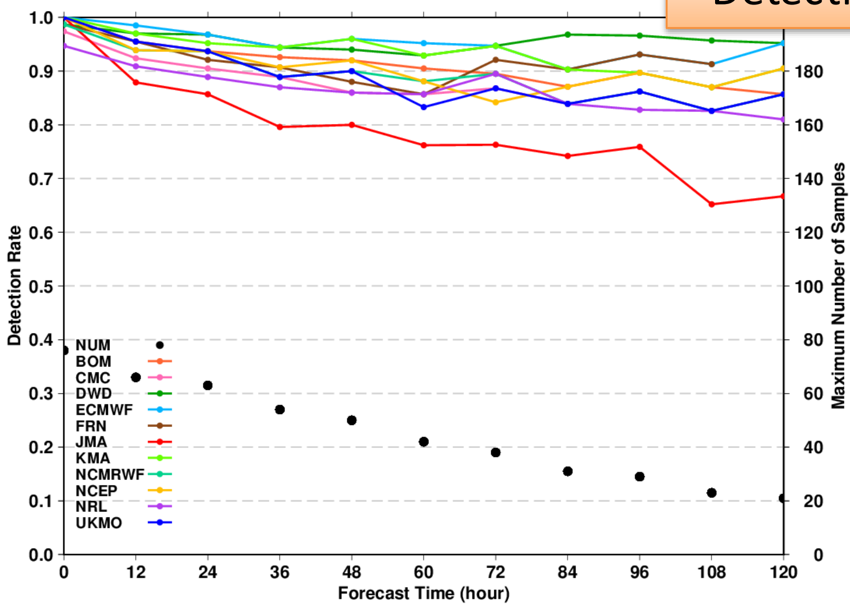
North Atlantic (NAT)

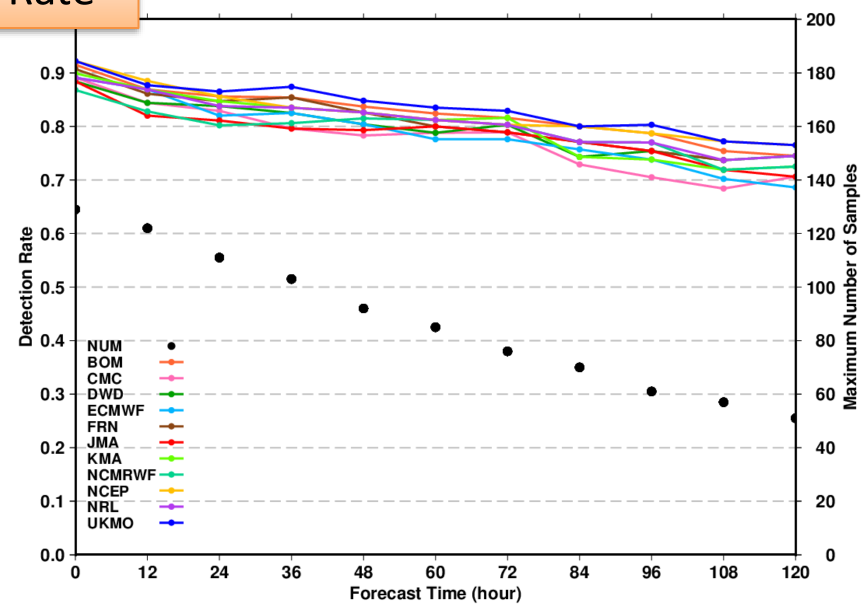
Position Error





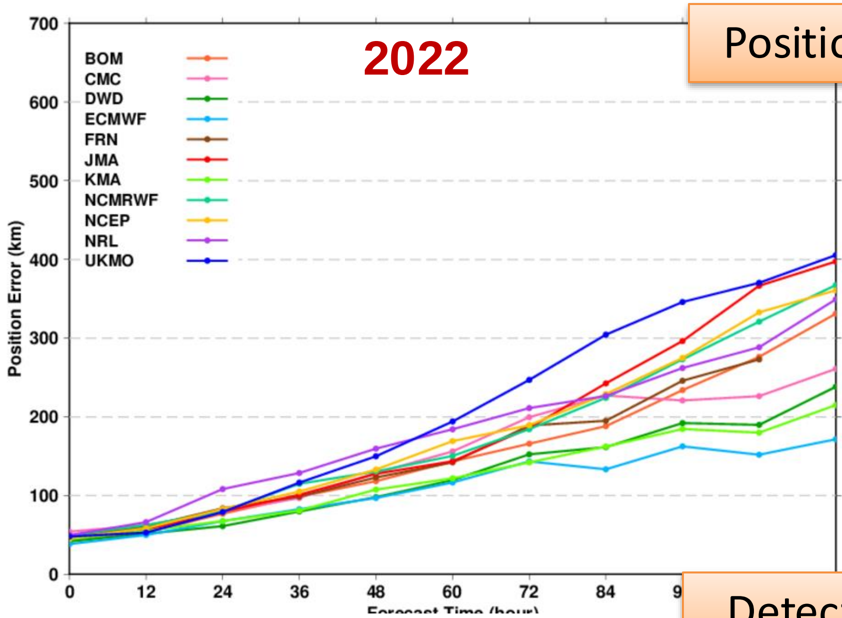
Detection Rate

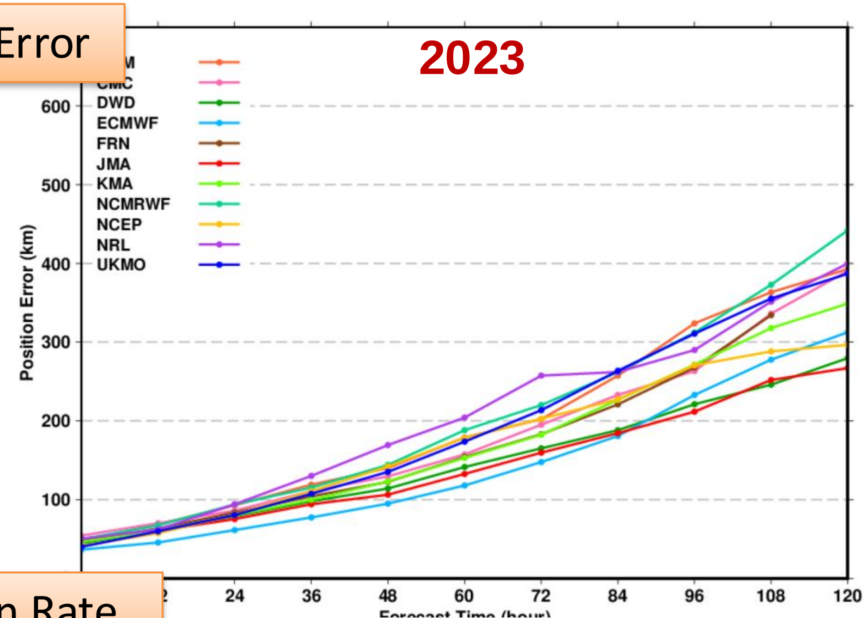




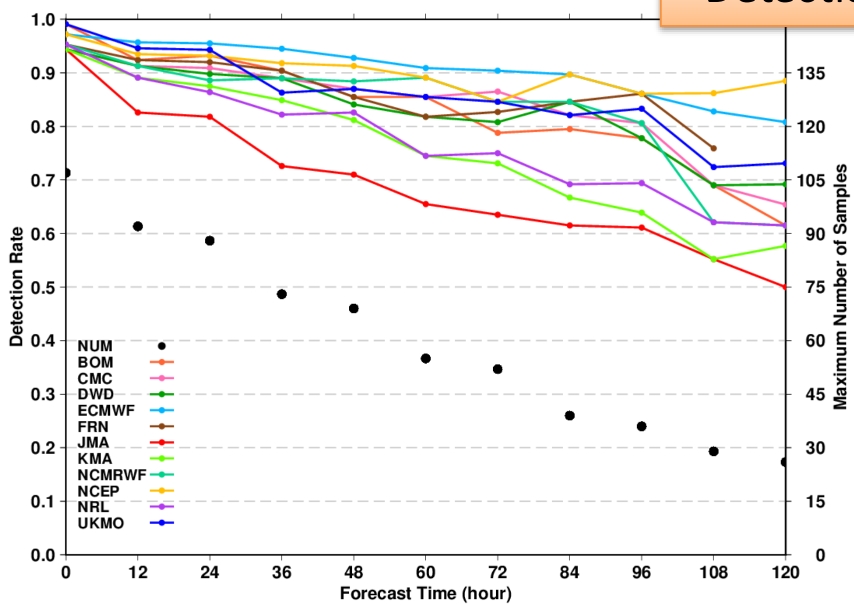
Eastern North Pacific (ENP)

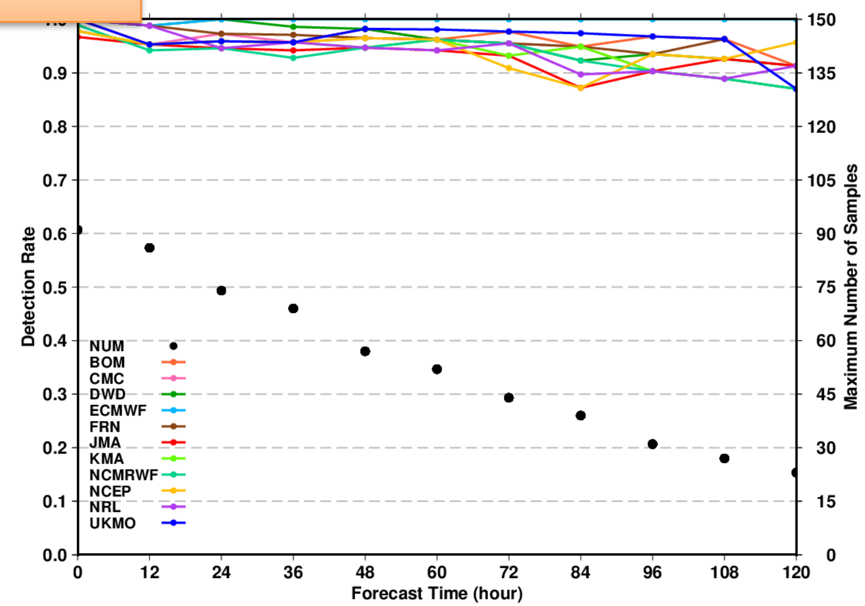
Position Error



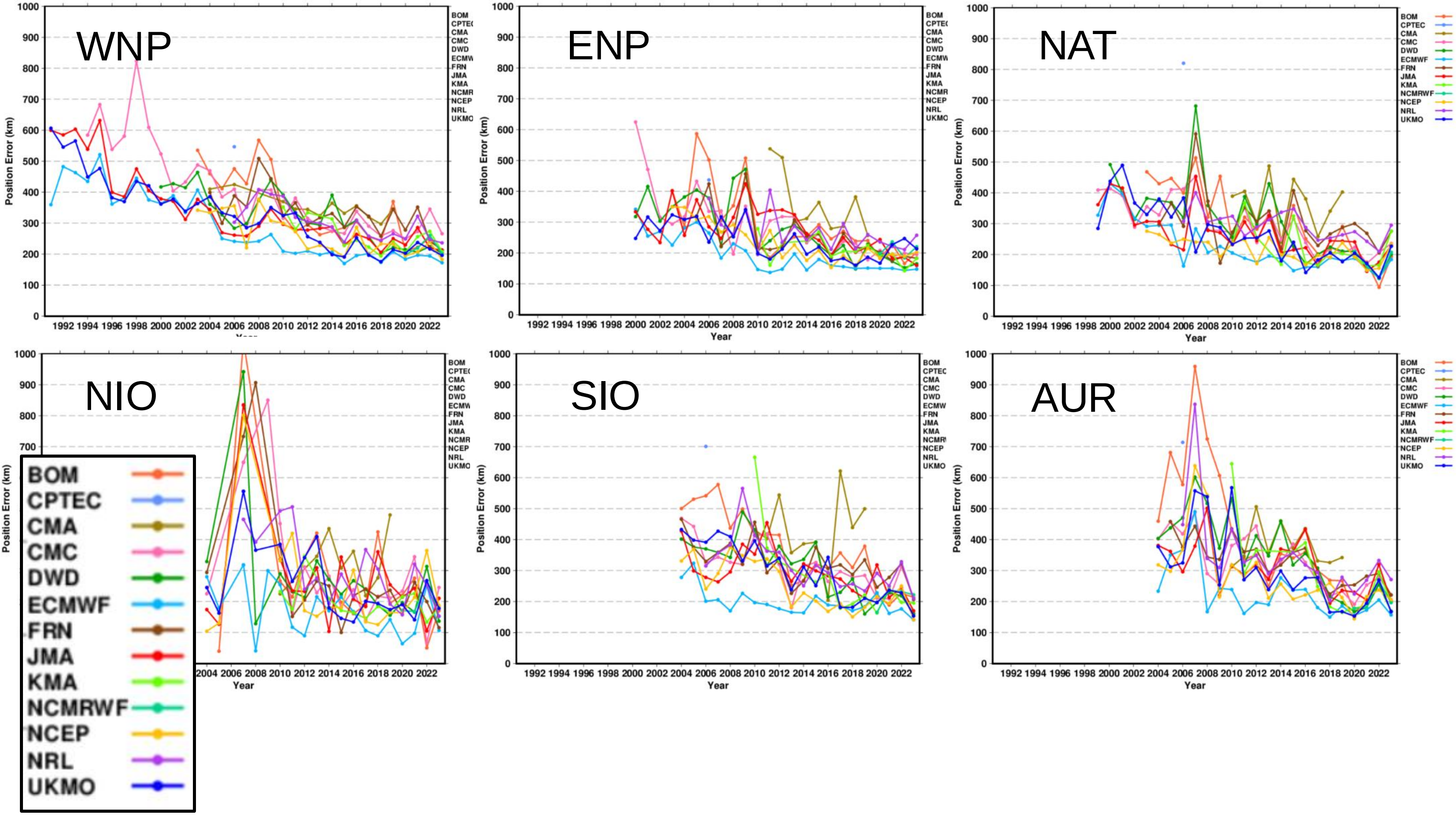


Detection Rate





Transition of T+72 Position Error over Decades



Summary of verification 2023 (1/2)

- Position errors
  - Compared to the previous year, all centres' errors at T+72 were decreased.
    - Probably due to year-by-year variation rather than each model's upgrade.
  - New findings on known common biases in WNP basin
    - Northward bias before recurvature
      - NCEP performed relatively well in both statistical verif. and some case studies.
    - Slow bias after recurvature
      - CMC's bias was relatively small ?
  - Higher detection rates in JMA's forecasts are seen in NAT and ENP basin compared with the previous year.

Summary of verification 2023 (2/2)

- Intensity errors
  - Over half the models have positive biases in WNP basin over five-day forecast period.
    - Met Office model tends to increase positive bias and NRL model tend to enlarge negative bias as lead time progresses.
    - NCEP model performed well in terms of both bias and MAE.
  - The characteristic of JMA model was changed on TC intensity forecast due to upgrade in Mar. 2023.
    - Tend to reproduce deeper central pressure of TCs than the previous version.

Another topic on TC intensity forecast

A paper on reducing weak TC intensity bias in the CMC (Canada)'s global model triggered by the WGNE TC verification and DIMOSIC projects, as Ron reported at WGNE-38, was published !

MARCH 2024 MCTAGGART-COWAN ET AL. 837

Reducing a Tropical Cyclone Weak-Intensity Bias in a Global Numerical Weather Prediction System

RON MCTAGGART-COWAN,[a] DAVID S. NOLAN,[b] RABAH AIDER,[a] MARTIN CHARRON,[a] JAN-HUEY CHEN,[c] JEAN-FRANÇOIS COSSETTE,[a] STÉPHANE GAUDREAULT,[a] SYED HUSAIN,[a] LINUS MAGNUSSON,[d] ABDESSAMAD QADDOURI,[a] LEO SEPAROVIC,[a] CHRISTOPHER SUBICH,[a] AND JING YANG[a]

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[c] *NOAA/Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey*
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(Manuscript received 30 August 2023, in final form 16 January 2024, accepted 18 January 2024)

Annual WGNE tropical cyclone assessments performed by the JMA have indicated that these biases are larger than those of other global modeling systems (Yamaguchi et al. 2017). An updated 2021 assessment (Fig. 2) confirms that there has been no notable improvement in GDPS biases despite model upgrades and the reduction of grid spacing from 0.35° to 0.135° over the intervening period. The model continues to suffer from a conditional intensity bias: tropical cyclones with best track central pressures above 980 hPa are associated with a limited weak-intensity bias, while stronger storms suffer from a large intensity deficit (Fig. 2a). Other global modeling systems included in the assessment appear to be more capable of representing the full range of storm intensities (Figs. 2b–d), with the UKMO model predicting particularly strong storms (Fig. 2c).

McTaggart-Cowan et al. (2024, *Mon. Wea. Rev.*)

Toward next year's verification

- As in this year's verification, following data provision policy is adapted.
  - verification results / processed datasets may be provided for scientific and non-commercial papers which are relevant to model development.
- Participation opens to ML-based models
  - same data format and data provision policy as for physics-based models
    - Gridded data for the latest year (2024) are mandatory, data for recent a few years are also welcome.
  - More detailed information for the specification required (e.g. method, training data, training period, initial data etc...)
- Call for participation will be announced in the beginning of the next year (Jan. ~ Feb. 2025).

TC intercomparison website is available!

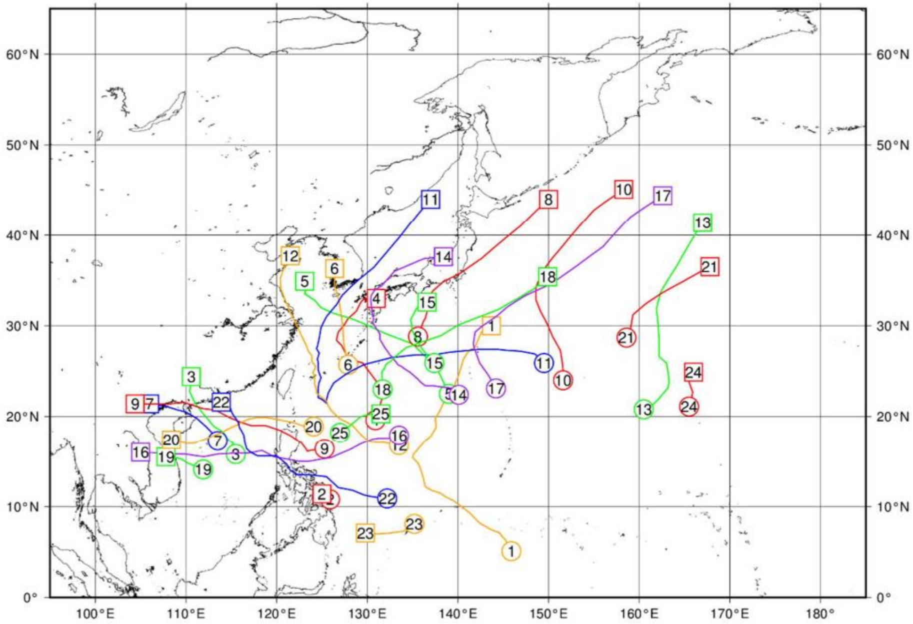
<https://nwp-verif.kishou.go.jp/wgne_tc/index.html>

Login ID: verif
Password: wgne2024 (beyond 1 November 2024)
Contact: globalnwp@met.kishou.go.jp

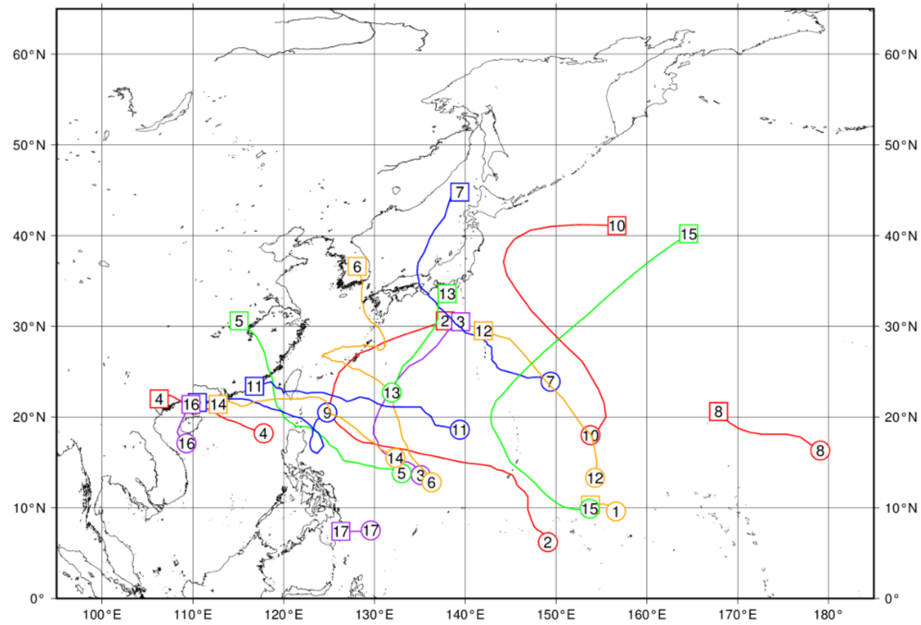
EXTRA SLIDES

Best tracks over WNP

2022: 25 TCs



2023: 17 TCs

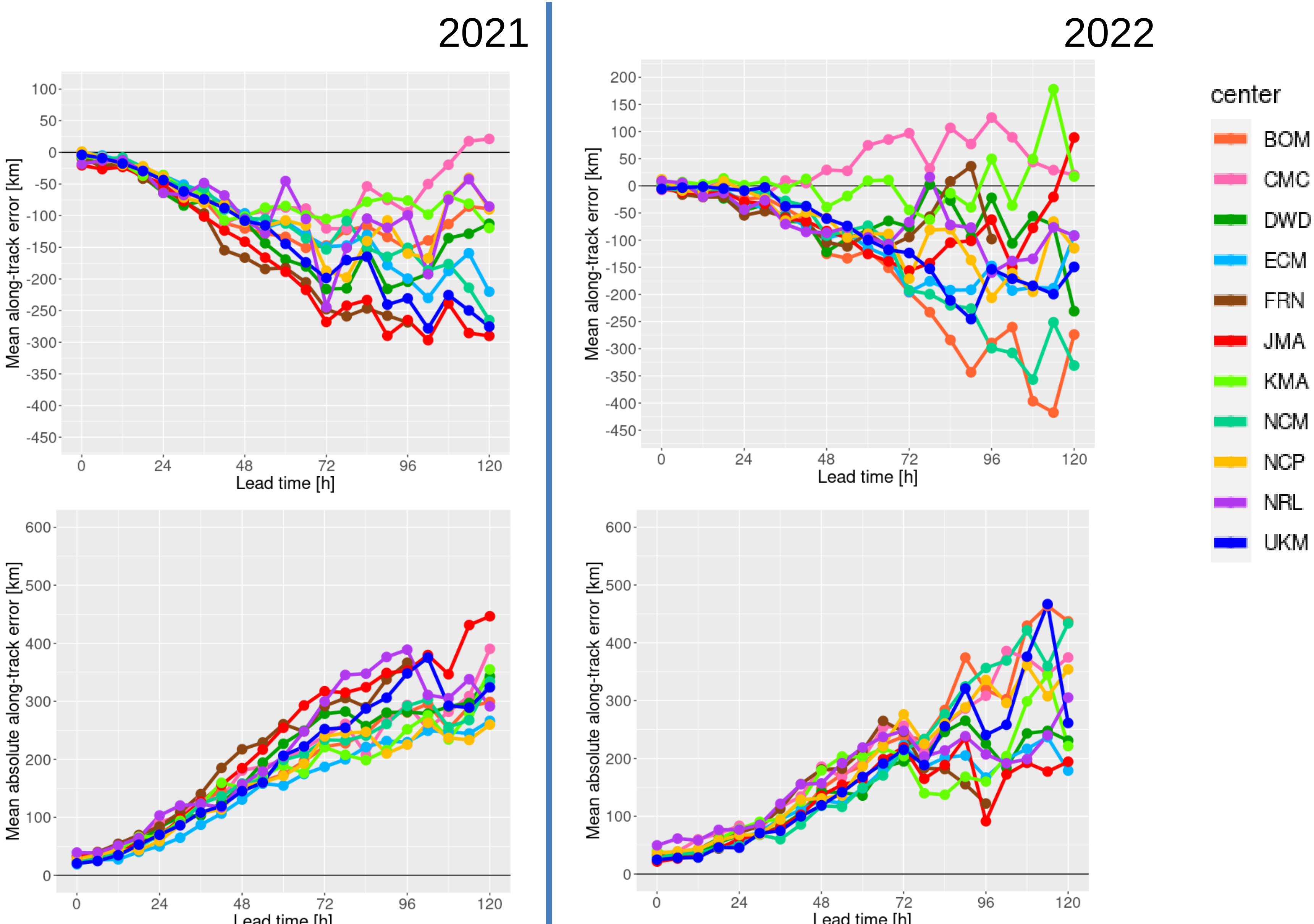


- Less the number of TCs in 2023 than that of the climatological normal frequency (the normal value is 25.1).
- Genesis positions of TCs in low-latitudes showed a tendency to shift eastward compared with the previous year.

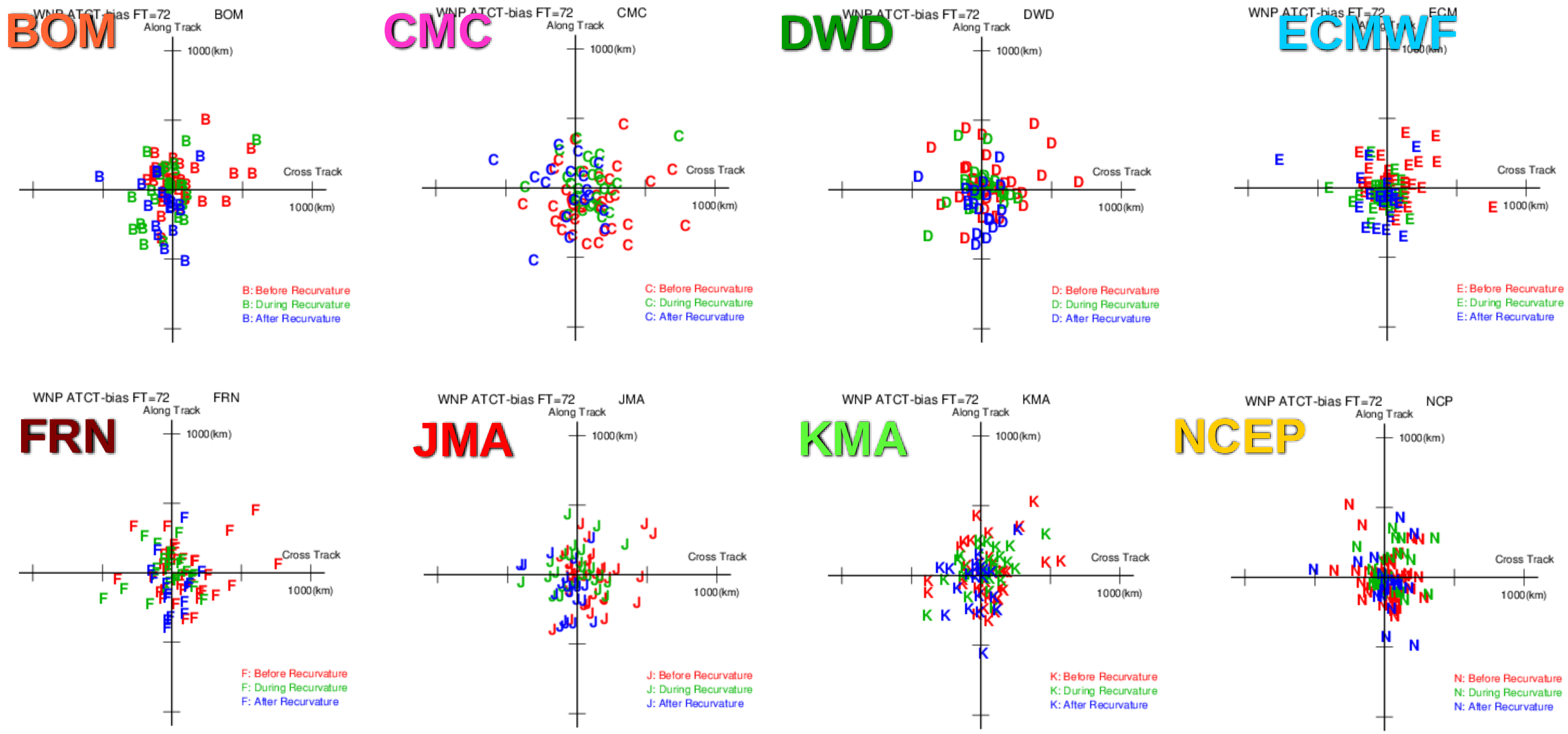
Along-track (After recurvature)

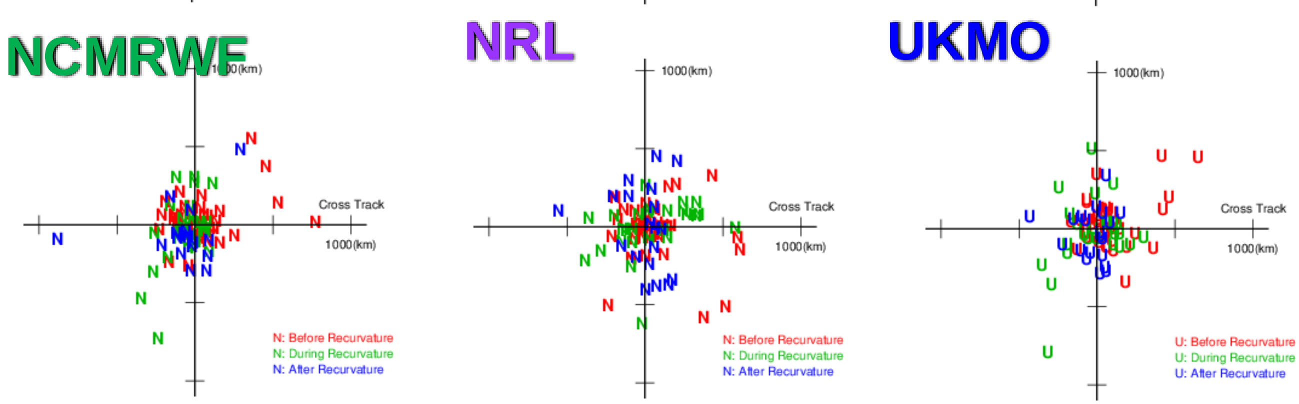
Bias

MAE



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



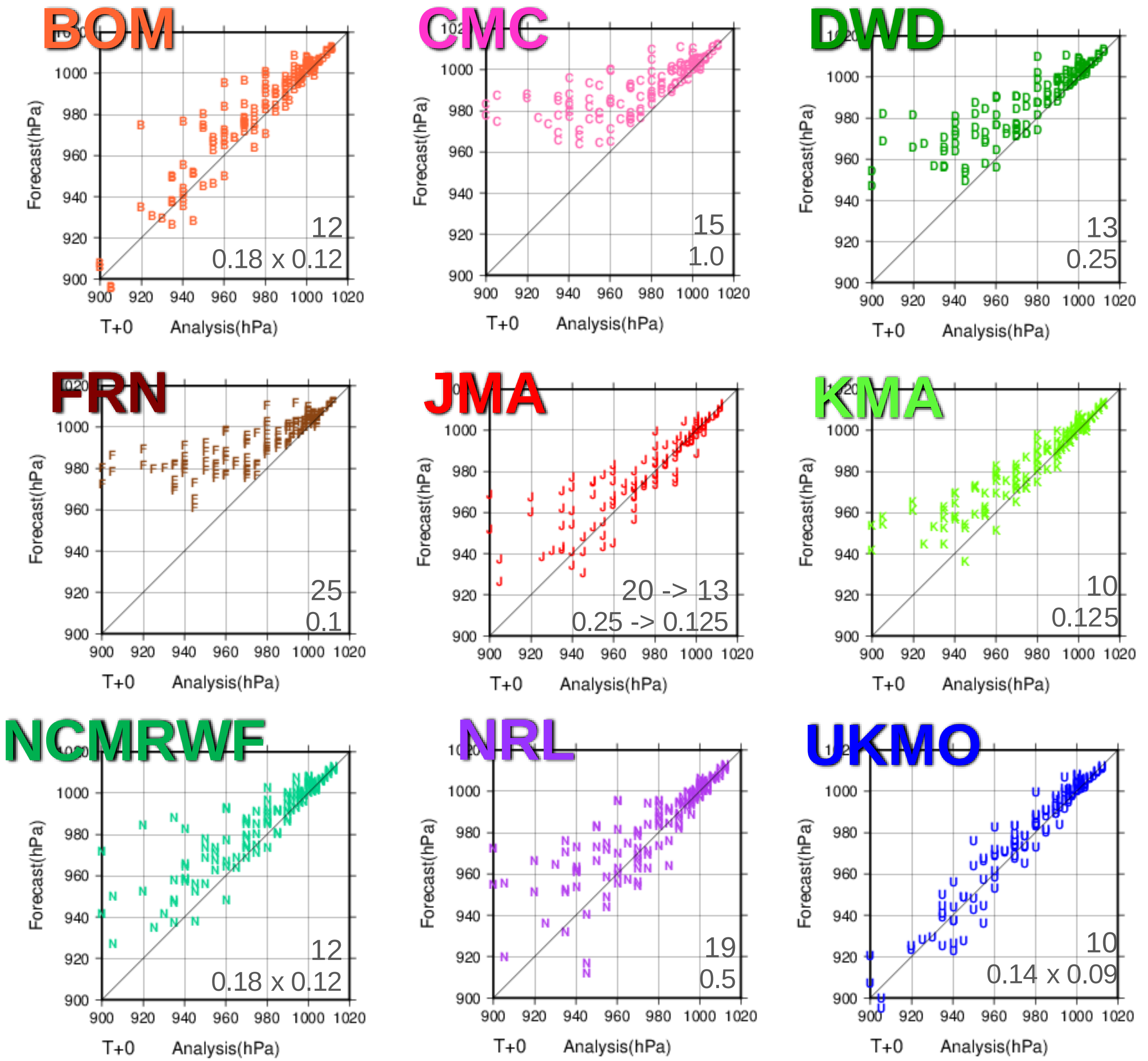


Red : before recurvature
Green : during recurvature
Blue : after recurvature

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)



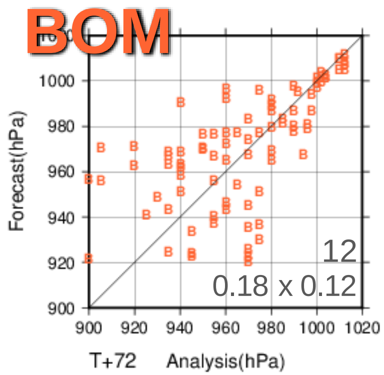
Resolution

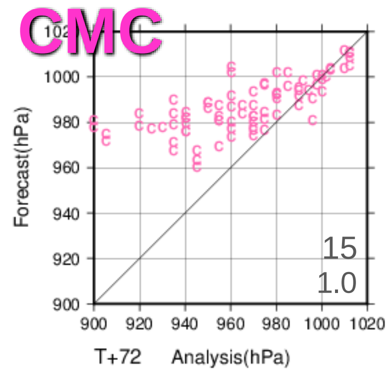
Model (km)
Data (deg)

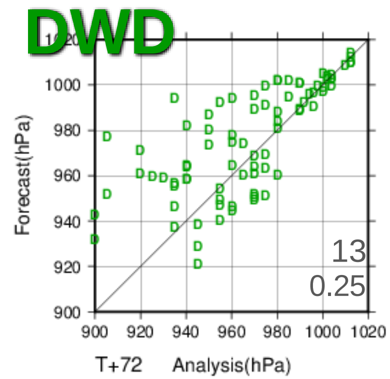
X-axis : analysis

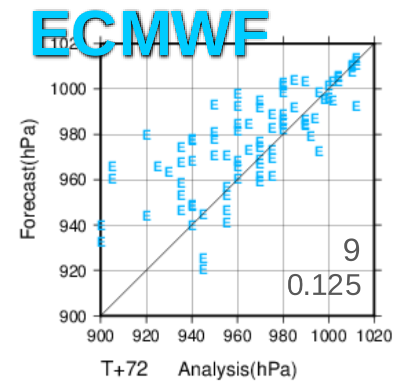
Y-axis : forecast

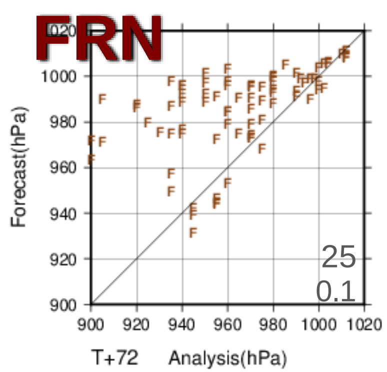
WNP Central Pressure Scatter Diagram (T+72)

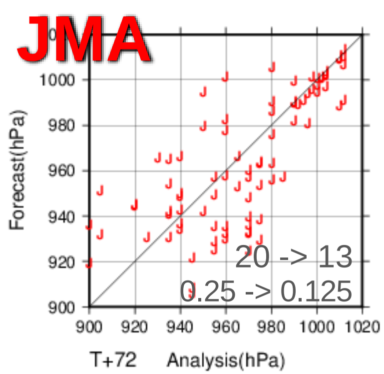


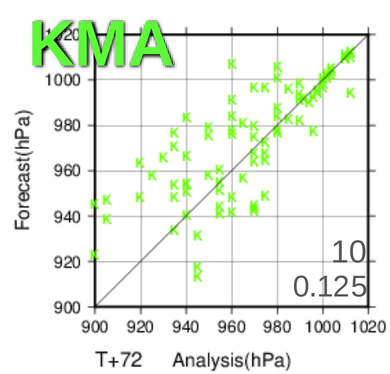


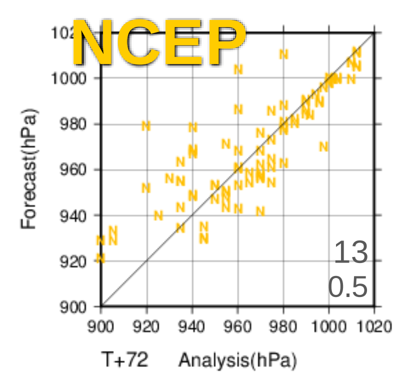


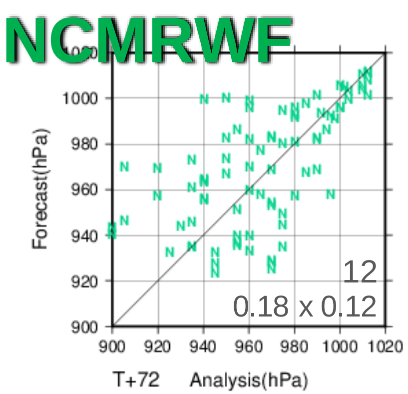


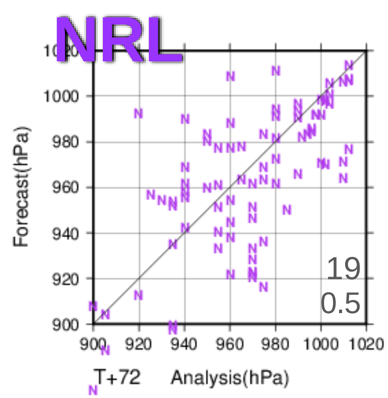


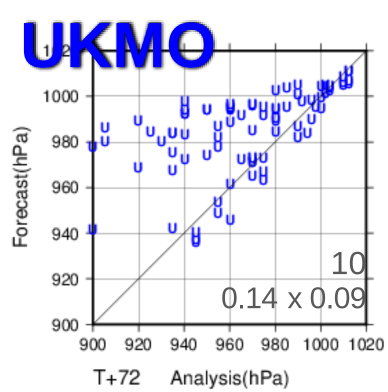












Resolution

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

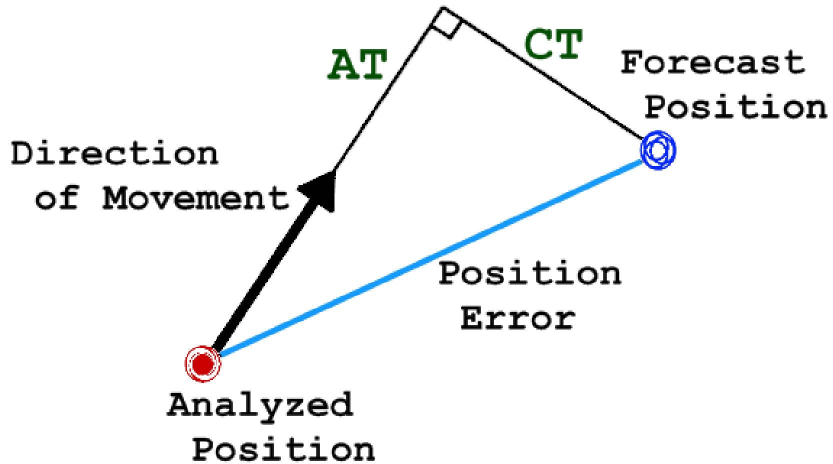
TCs are tracked using mean sea level pressure data provided by participating NWP centres. Under this method, the minimum pressure point is identified as the initial or predicted TC position.

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.

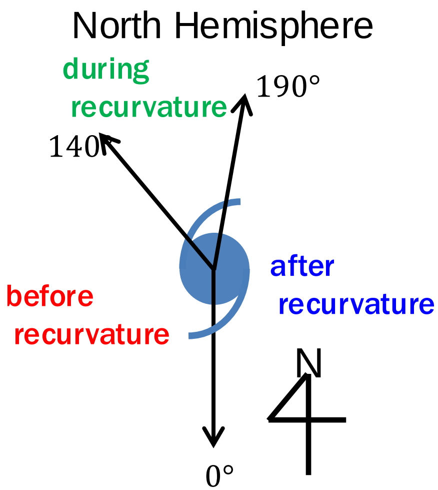
Tracking ends when no appropriate minimum pressure point is found.

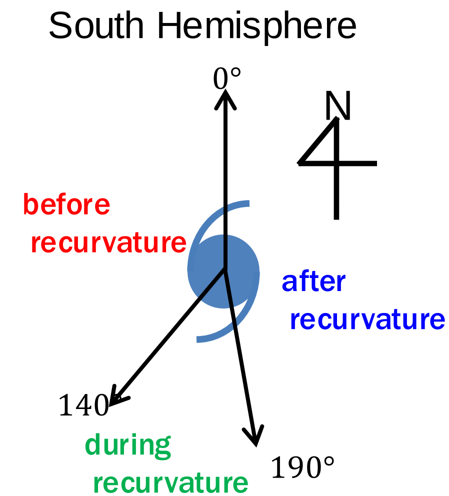
Definitions

- **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

Improvements of models for each centre in 2023

- **CMC**
  - 4 Jan. 2023
    - Replacement of Atmospheric Motion wind Vectors from GOES-17 by those from GOES-18 in the GDPS
  - 15 Feb. 2023
    - Addition of GPSRO observations from the Sentinel-6A satellite in the GDPS
  - 8 Mar. 2023
    - Correction to the quality control of snow depth observations from Canadian automatic stations in the GDPS
  - 5 Jul. 2023
    - Addition of commercial GNSS-RO observations from Spire in the GDPS
  - 14 Sep. 2023
    - Addition of commercial GNSS-RO observations from PlanetIQ in the GDPS
  - 2 Nov. 2023
    - Addition of CSR observations from the GOES-18 satellite in the GDPS

Improvements of models for each centre in 2023

- **DWD**
  - 5 Jan. 2023
    - Switch from GOES-17 to GOES-18 radiances and atmospheric motion vectors
    - New version of data assimilation code
  - 25 Jan. 2023
    - Use of a new version of RTTOV coefficient files
    - Assimilation of MWHS-2 data
    - Output of LPI_CON_MAX (maximum lightning potential index)
  - 15 Mar. 2023
    - Modification of shallow-convection scheme
    - Extension of model-DA coupling for optimizing T2M and RH2M scores
    - Wind-speed dependent density of fresh snow
    - Limitation of SSO blocking correction in gust parameterization
    - Extension of FF10M assimilation and related adaptive surface friction
    - Removal of artificial turbulence tuning in the tropics
    - Modification of Charnock parameterization for ocean surface roughness

Improvements of models for each centre in 2023

- **DWD**
  - 29 Mar. 2023
    - Switch from Meteosat-11 to Meteosat-10 radiances and atmospheric motion vectors
    - New version of data assimilation code
  - 3 May 2023
    - Use of high-density MODE-S aircraft observation
  - 28 Jun. 2023
    - Improved processing in situations with partially missing satellite radiances
    - New topography data in satellite radiances preprocessing
    - New surface type determination for satellite radiances
    - Lambertian reflection in RTTOV for snow/ice surfaces
    - Use AMSU-A channel 6 and ATMS channel 7 over land/ice surfaces
    - Use other MHS FOVs
  - 19 Jul. 2023
    - Update to DACE
    - Switch on again assimilation of SARAL

Improvements of models for each centre in 2023

- **DWD**
  - 6 Sep. 2023
    - Update of ICON version to 2.6.6-nwp0
  - 14 Sep. 2023
    - Assimilation of ATMS on NOAA-21
    - Switch to an alternative data stream for AMSU-A on NOAA-15
    - Improved quality control for AMSU-A channel 7 on Metop-B
    - Increase obs. Error for AMSU-A channel 8 on Metop-C
  - 4 Oct. 2023
    - Update of data assimilation code DACE
  - 28 Nov. 2023
    - Update of ICON version to 2.6.6-nwp1
      - Assimilation of additional GNSS radio occultations
      - Change in the bias correction for the MWHS-2 sounding instrument
      - Retuning of the SSO scheme and a turbulence source term in ICON to reduce systematic errors in northern hemispheric winter, particularly over the Tibetan plateau
      - Use of an inversion diagnostic in the cloud cover scheme to improve the representation of stratocumulus clouds

Improvements of models for each centre in 2023

- **ECMWF**
  - 27 Jun. 2023
    - Implementation of IFS Cycle 48r1
      - Assimilation
        - » Increase of HRES 4Dvar inner loop resolution to TL511
        - » Switch to OPPS, the object-oriented prediction system
        - » Reduced thinning of ASCAT L2 products
        - » Various optimisations for hyperspectral IR sounders
        - » Upgrade RTTOV to v13
        - » ATMS snow, Lambertian, slant-path
        - » Improved treatment of surface-sensitive channels in all-sky
      - Observation
        - » Improved observation pre-processing
        - » Assimilation of microwave imagers over land surfaces

Improvements of models for each centre in 2023

- **ECMWF**
  - 27 Jun. 2023
    - Implementation of IFS Cycle 48r1
      - Model
        - » Improved water and energy conservation (dynamics and physics)
        - » Radiatively interactive prognostic ozone using new HLO scheme
        - » Multi-level snow scheme
        - » New precipitation category – freezing drizzle
        - » Revised climate fields – improved orographic fields for atmospheric drag and water related representation (i.e. glacier mask, land-sea mask, lake cover, lake depth)
        - » Revised computation of Semi-Lagrangian advection departure points
        - » New model top sponge layer formulation and semi-Lagrangian vertical filter
        - » Revised SPPT, removed cloud saturation adjustment from tendency perturbations

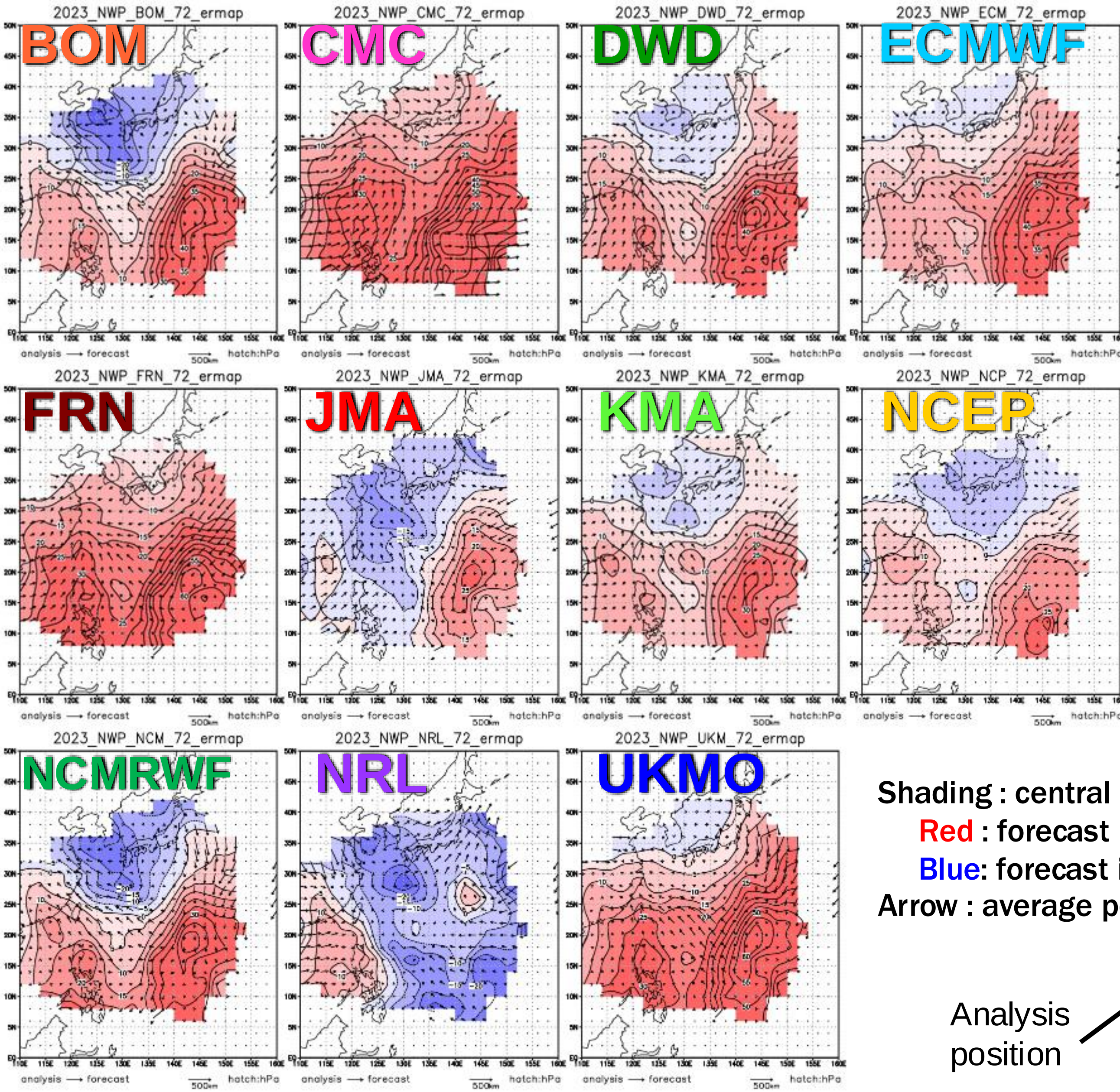
Improvements of models for each centre in 2023

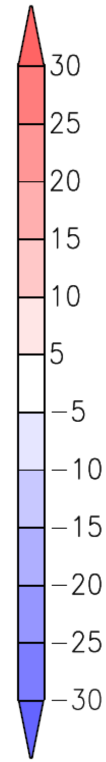
- **JMA**
  - 14 Mar. 2023
    - Major upgrade was made to the Global Spectral Model (GSM).
      - Increase of the horizontal resolution
      - Incorporation of quadratic grid: from TL959(linear grid, approx. 20km grid spacing) to TQ959 (quadratic grid, approx. 13km grid spacing) with refinement of numerical diffusion in the model and filters for mean orography
      - Replacement of the source data set for orographic ancillary files: GTOPO30 to MERIT DEM + RAMP2
      - Revision of several physical processes such as non-orographic gravity wave, boundary layer, orographic drag and radiation.
      - Improvement of lake surface process
      - Revision of the global snow depth analysis
      - Assimilation of Suomi-NPP, NOAA-20/VIIRS AMV was started
  - 14 May 2023
    - Assimilation of AMV and CSR from GOES-18 was started.
    - Assimilation of AMV and CSR from Meteosat-10 switching from Meteosat-11 was started.

Improvements of models for each centre in 2023

- **KMA**
  - 23 Feb. 2023
    - Update of KIM version to v3.8
      - Expanded usage of observation data
      - Improved data assimilation method of KIM
      - Improved physical processes(sea-ice, cloud)

WNP Error Map (T+72)





Shading : central pressure error (hPa)

Red : forecast is shallow

Blue: forecast is deep

Arrow : average position error

Analysis position → Forecast position