Current JMA ensemble-based tools for tropical cyclone forecasters

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- Introduction of JMA GSM and EPS
  - NWP systems
    - GSM
    - EPS
  - Products
    - Products
    - verification

JMA NWP SYSTEMS

JMA operates 3 NWP systems that provide Typhoon forecast.

○ GSM / Deterministic (GSM: global spectral model)
    support the track and Intensity forecast

○ TEPS (typhoon ensemble prediction system)
    provide possible scenarios for forecast tracks .

○ WEPS (one week ensemble prediction system)
    support track forecast and provide probabilistic information.

In Japan, only JMA provides typhoon forecast s to end-users.
So JMA NWP typhoon product mainly targets JMA forecasters.

NWP systems

JMA GSM

The GSM provides a primary basis of official typhoon forecast.
Typhoon forecast skill in the GSM is improving year-by-year (In 2008 and 2009, there are many TCs that were difficult to forecast) .

Deterministic systems can not provide "forecast confidence information", although the skill is very sensitive to the initial conditions. So we operate ensemble forecast systems.


GSM Mean Position Error 1996 –2009
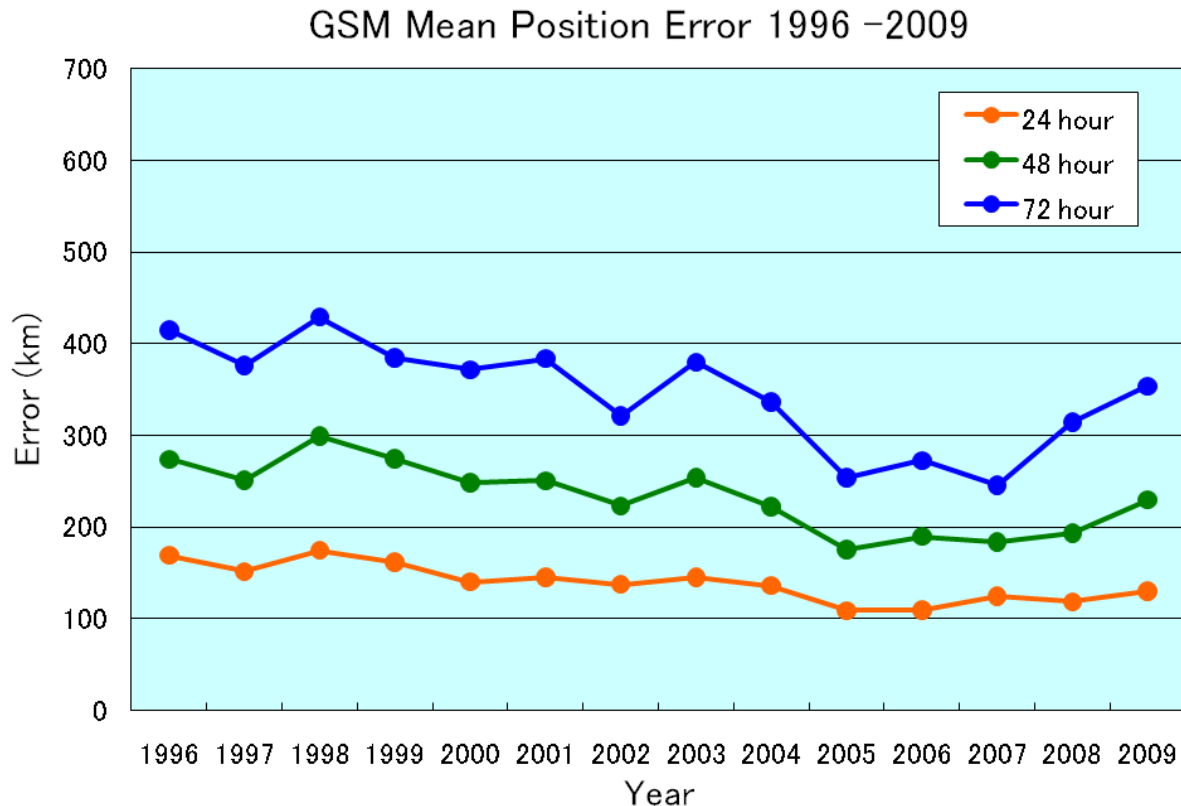
Spec of the Global Forecast System

	Deterministic	WEPS	TEPS
Horizontal Resolution	T959	T319	
Grid	Linear Reduced Gaussian grid		
Vertical Resolution	60 layers		
Model Top	0.1hPa		
Dynamical Process	2-time-level, Semi-Lagrangian, Semi-Implicit time integration scheme.		
Time Step	600 sec	1200 sec	
Run per day (initial time)	4 00,06,12,18UTC	1 12UTC	4(only where TCs exist 00,06,12,18UTC
Forecast length	84hour(00,06,18UTC) 216hour(12UTC)	216hour	132hour
analysis	4DVAR	Convert resolution from T959	

Runs per day and forecast length were determined by computer resources.
In 00, 06 and 18UTC, GSM run only 84hour because of computer resource limitation.
The number of run per day is important to catch up with rapidly changing TC position.

TC verification result of deterministic systems during 2008
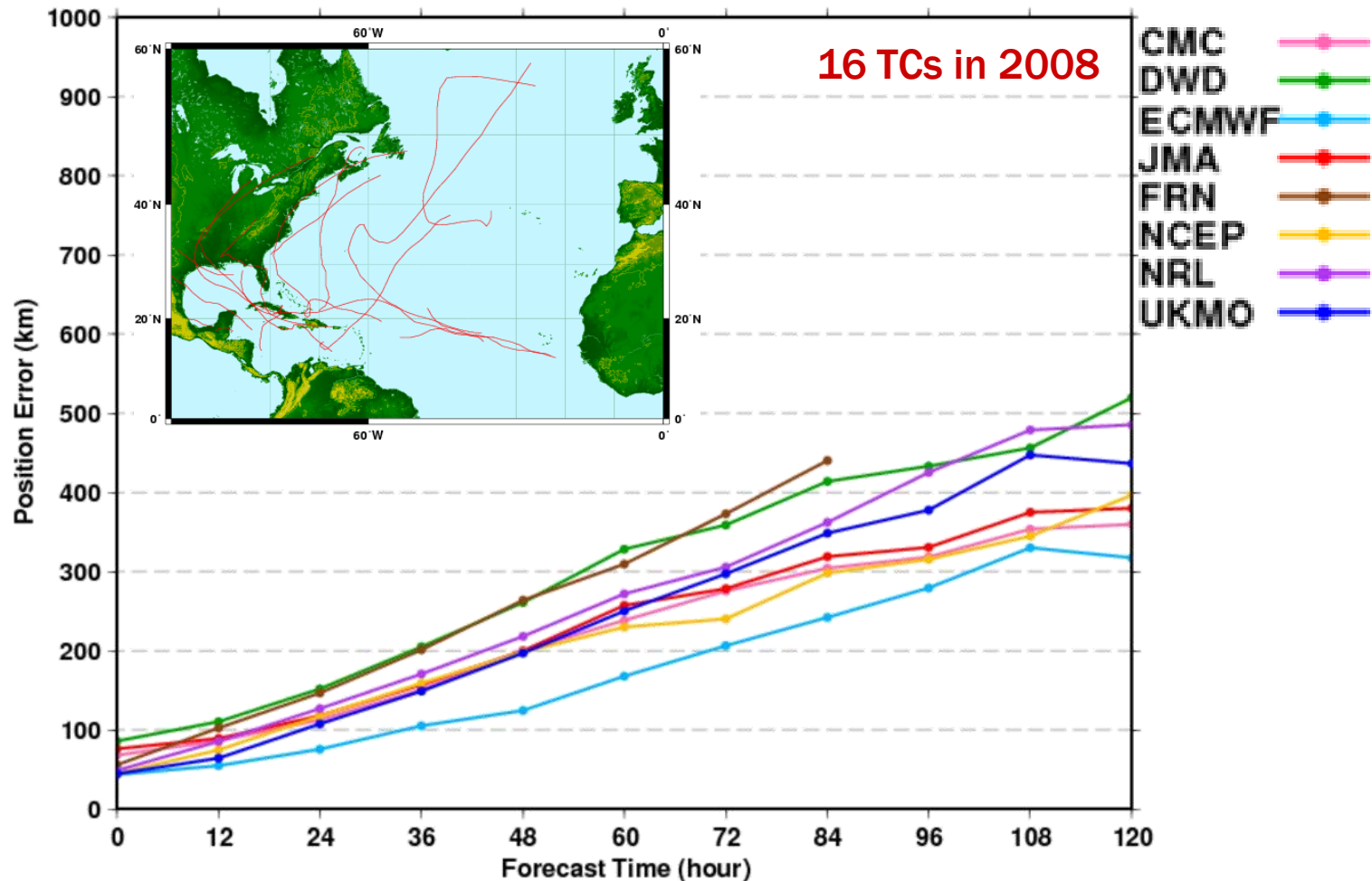# (from WGNE TC forecast intercomparison)

Intercomparison of Tropical Cyclone (2008)
Verification of western North-Pacific domain / Position Error

22 TCs in 2008
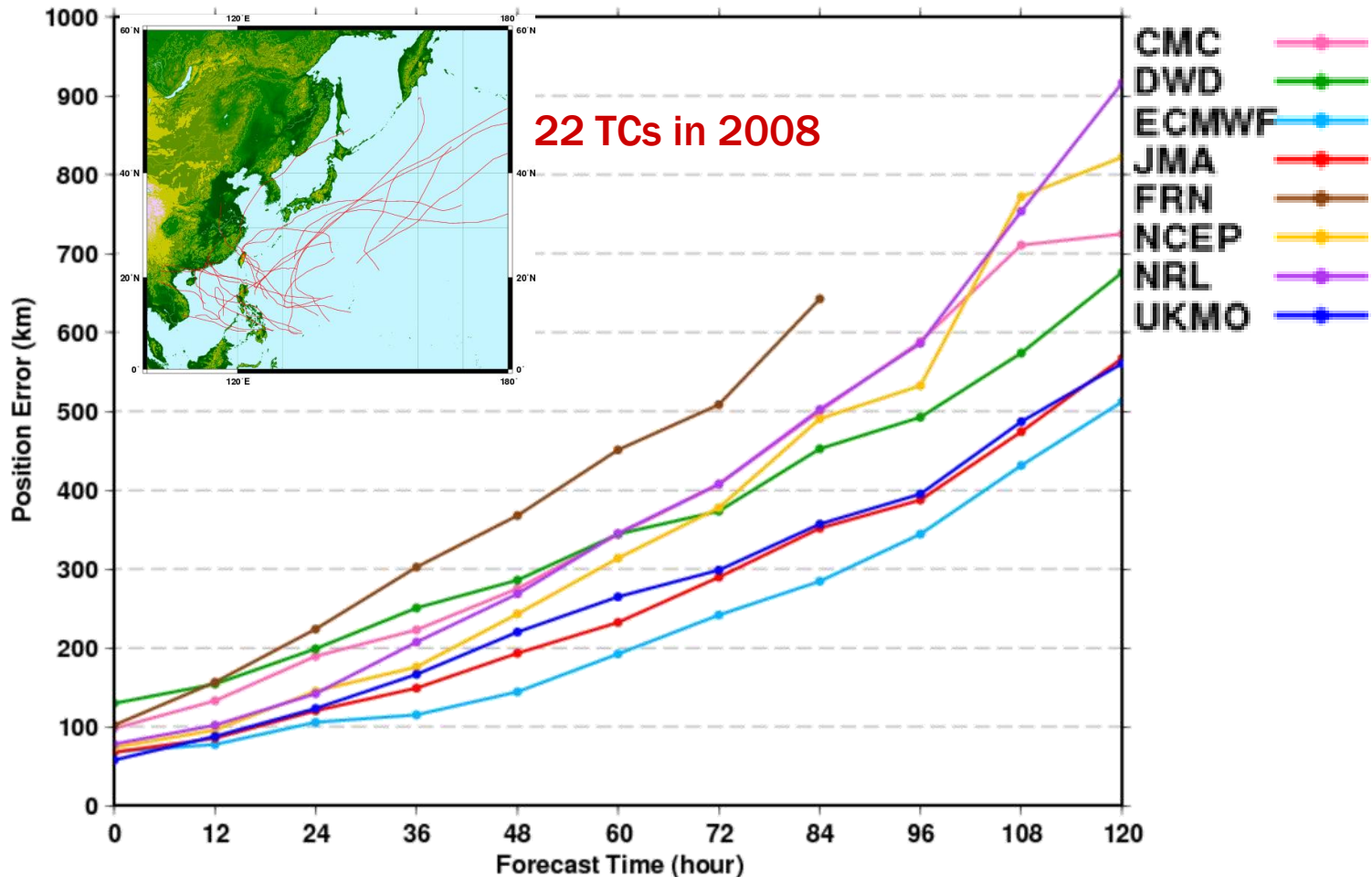
Verification of deterministic forecasts. TC tracks were made from MSLP by JMA tracking method. Analysis track is JMA best track. The degree of accuracy of ECMWF forecast was the best. JMA and UKMO were in the second group. Those difference s of accuracy correspond to about 12 hours difference of initial time.

Prepared by Daisuke Hotta and Takuya Komori (NPD/JMA)

Intercomparison of Tropical Cyclone (2008)
Verification of **North-Atlantic** domain / Position Error

16 TCs in 2008

Verification result in in North-Atlantic domain. In this region, ECMWF was also best. NCEP, CMC and JMA were in the second group. At initial time, the position error of JMA was large because JMA doesn't use Typhoon bogus in this region.

Prepared by Daisuke Hotta and Takuya Komori (NPD/JMA)

Intercomparison of Tropical Cyclone (2008)
Verification of eastern North-Pacific (ENP) domain/Position Error
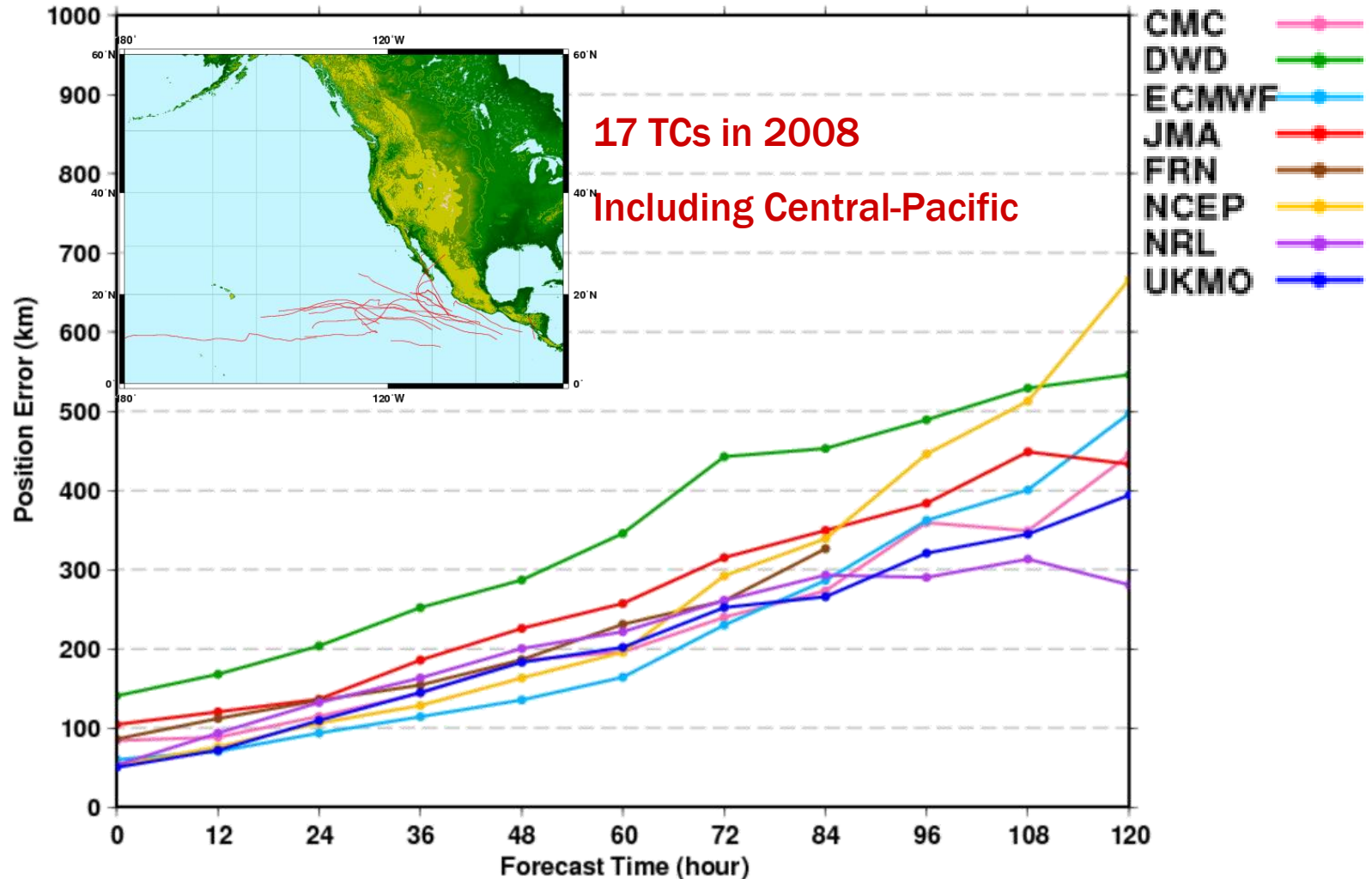
In this domain, the number of TC recurvature was few. So the position error was smaller than the it in other domain. The difference of position error between each centers was small.

Prepared by Daisuke Hotta and Takuya Komori (NPD/JMA)

JMA Ensemble Prediction System

	WEPS	TEPS
Ensemble Size	51	11
Initial Perturbation method	Singular Vector(SV) Method Total Energy Norm	
SV calculation Model (Top)	T63L40 (0.4hPa)	
SV target area	30N-90N (NH) 20S-30N (TR)	20N-60N, 100E-180E(WNPD) Typhoon Target (20°x10°)
SV Norm/ inner model physics	NH: dry/dry TR: moist/full	NWPD: dry/dry TT :moist/full
SV Optimization Time	NH:48 hours TR:24 hours	24 hours
Evolved SV	Use	No
Model Uncertainty Perturbations	No	No

The main differences between TEPS and WEPS are SV target area and operational form.

JMA has plan to increase TEPS member size and to increase horizontal resolution in the next computer system.

TEPS / SV Target Area

00UTC 09/30/2008

Typhoon target:

Lat.±5, Lon.±10.
Full physics.

T0815 "JANGMI"

T0816 "MEKKHALA"

T0817 "HIGOS"
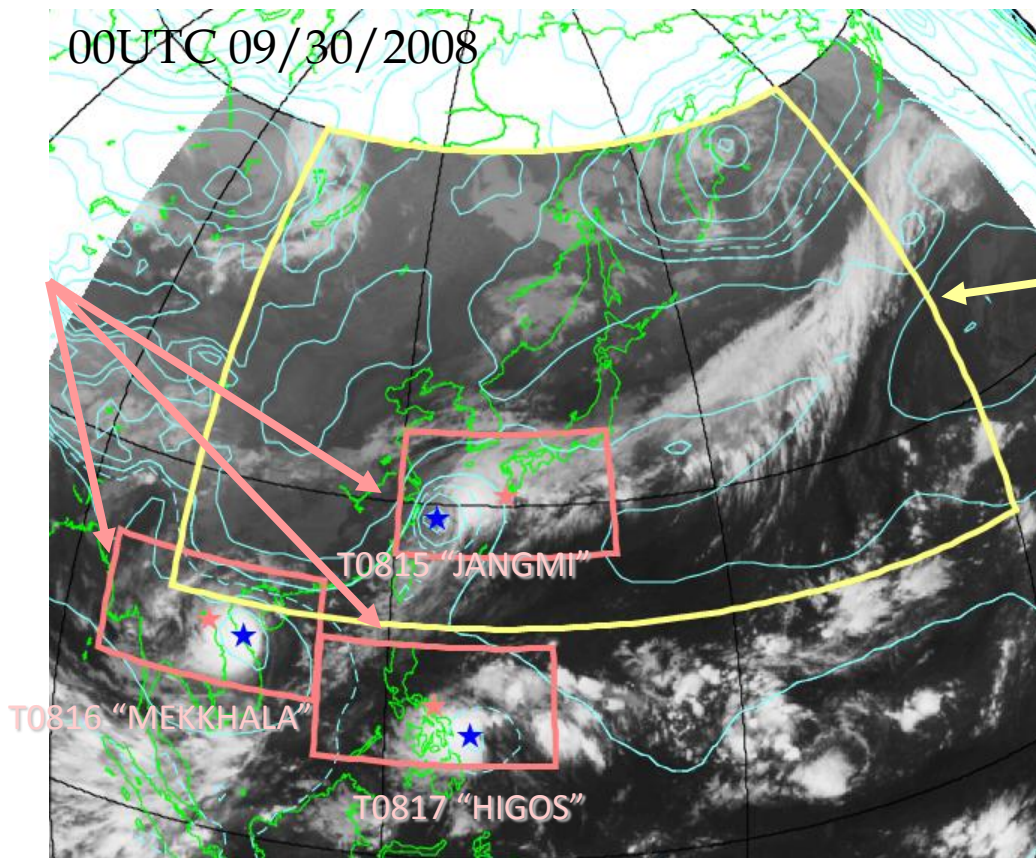
Fixed target:
Western North-
Pacific Domain

20-60N,100-180E
Dry physics

This is a sample of SV target areas on TEPS. In this case, there was 3 TC in RSMC Tokyo region. Blue star(★) is the TC center position on the analysis. Pink star(★) is the TC center position on the FT24h forecast. The typhoon center position of FT24 forecast is target area center.

Intensity forecast

Histogram of TC central pressure error (FT=72h) during 2009.
X-axis is Number of cases, Y-axis is forecast – analysis .

GSM(T959,20km)

EPS(T319,60km)
Control-run

vias

No signal

Develop   Weaken
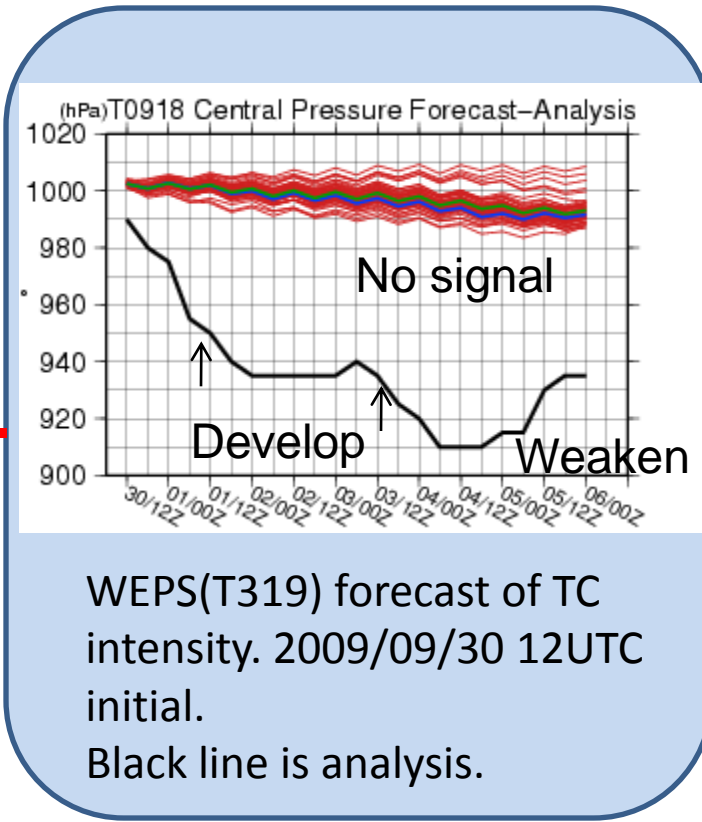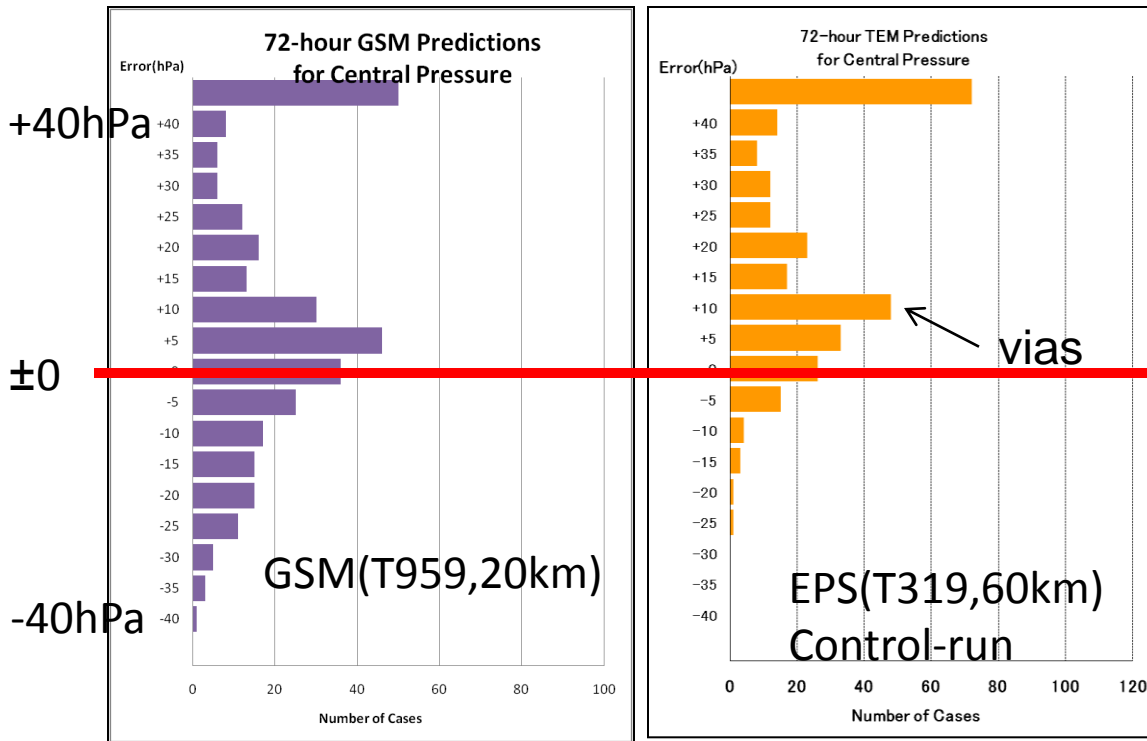
WEPS(T319) forecast of TC intensity. 2009/09/30 12UTC initial.
Black line is analysis.

In many cases, the TC intensity representation of EPS is shallow. The horizontal resolution T319 isn't enough to forecast intensity. It is difficult to forecast even change tendency. So GSM (T959) provides a primary basis of intensity forecast. We know that the horizontal resolution of the model is important to intensity forecast.

Products

Products should be ...

- Simple (Forecasters are busy, we know.)
  - Information of the products should be necessary and sufficient.(not verbose)
  - It is preferable to improve efficiency of forecaster's work.

- Quick (Real state of TC change quickly)
  - The forecasts every six hours are important.

EPS products
-Strike probability-

3day

5day
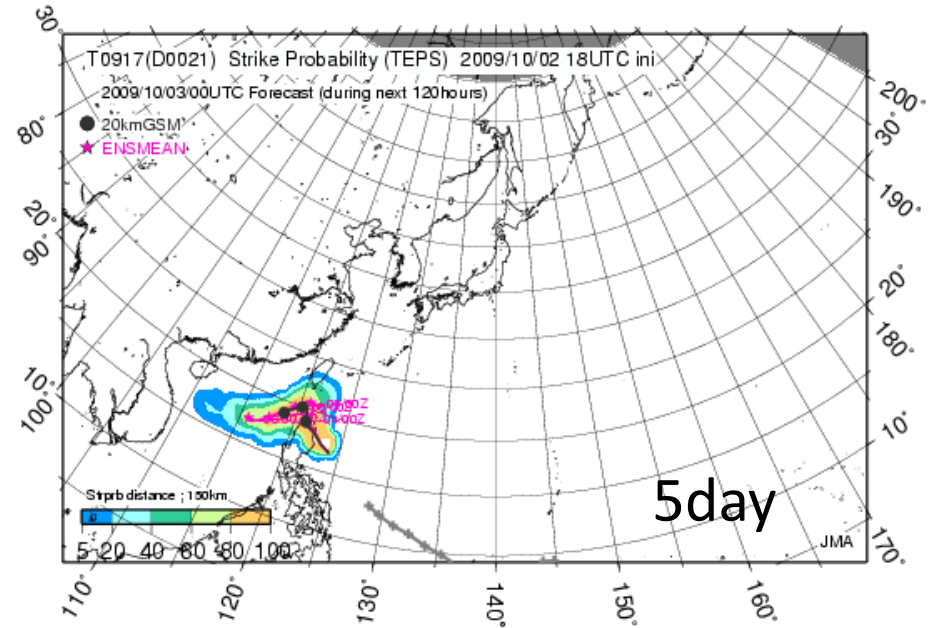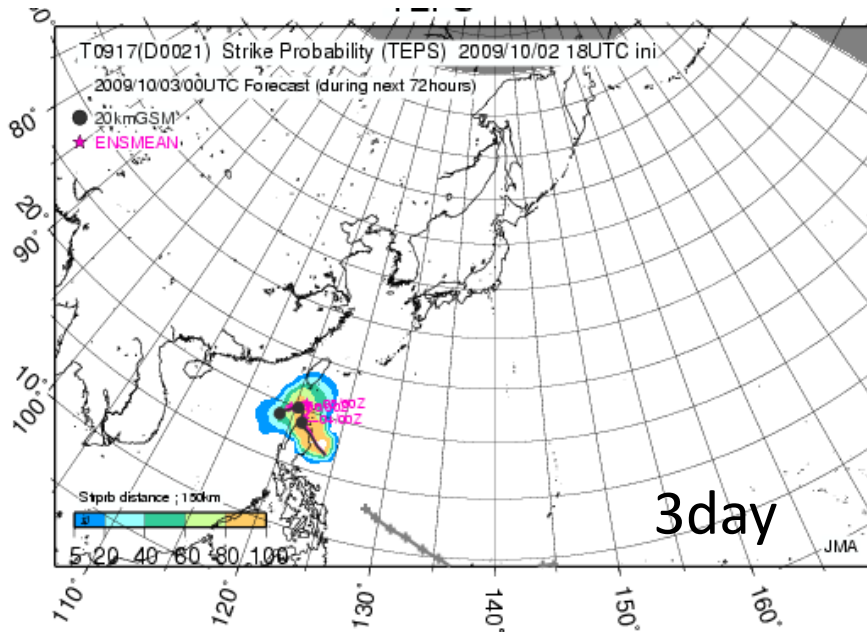
We provide two strike probability map from TC tracks in EPS. The GSM deterministic track (20km) and the ensemble mean track of EPS tracks are drawn . The ensemble mean track is the simple average of each member's track position.

The left(right) graph show a probability that TC will come close within 150km by 72 (120)hours later. Those thresholds were optimized to the format of JMA products .
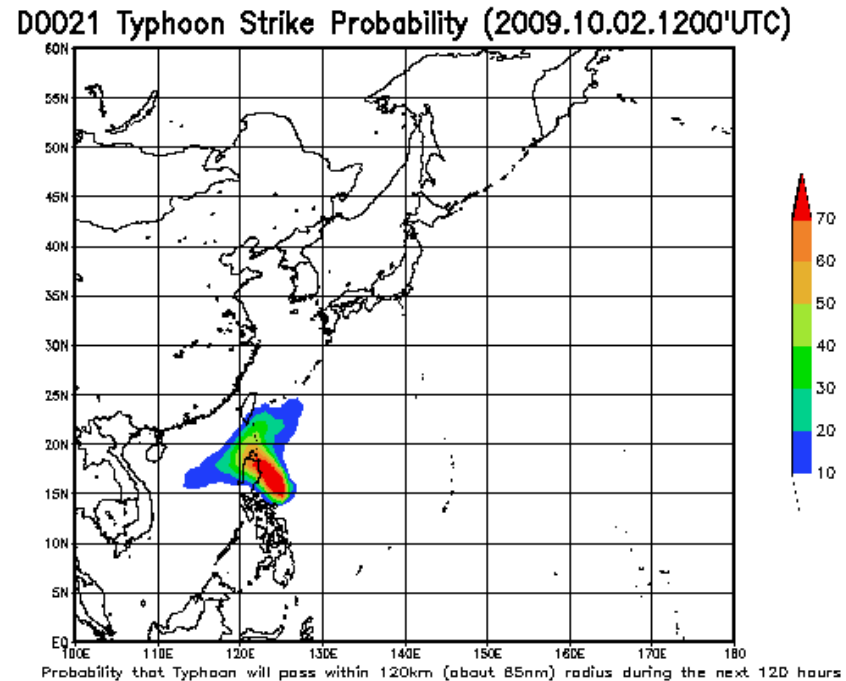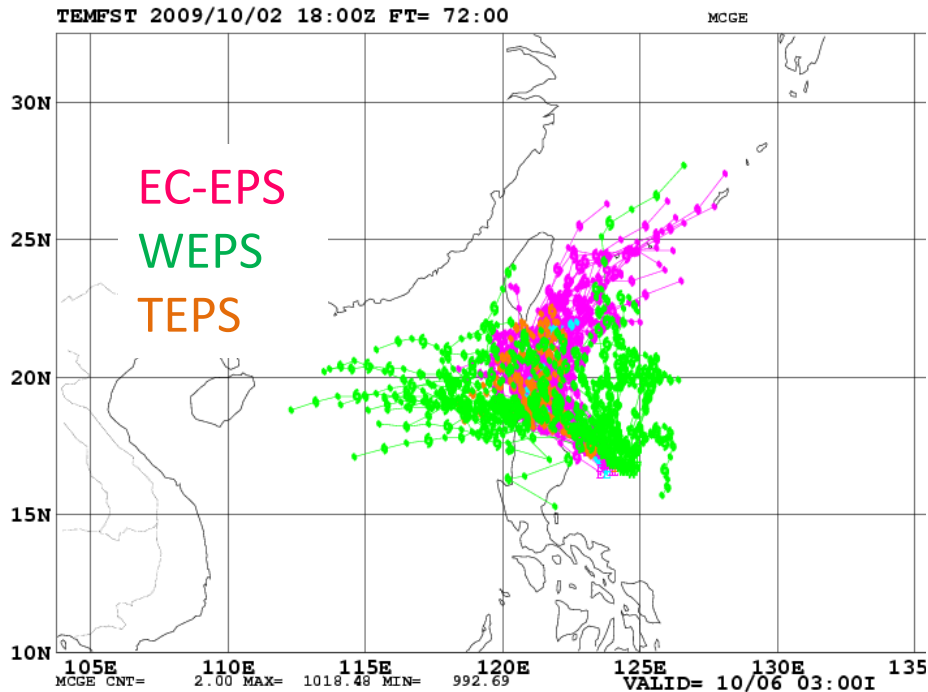
EPS products
-Three Category reliability graph-
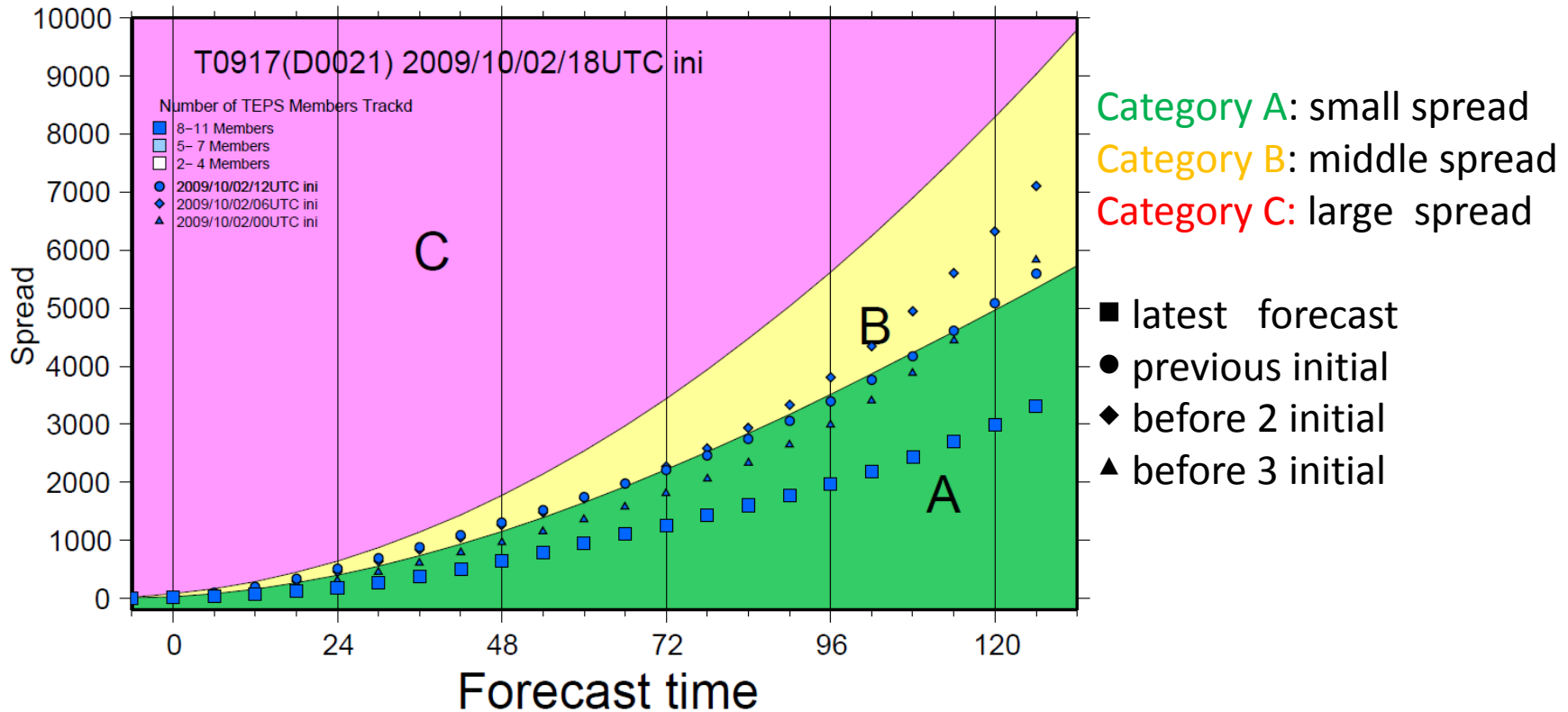
The Y-axis is a temporarily accumrated spread of tracks. The background color indicates the category of spread amplitude on each FT. In case A, the spread is small. In case C, the spread is large. The thresholds between categories were decided by the frequency distribution of the time integrated spread during last year. Category A-B-C included 40%- 40%-20% cases statistically.

EPS products
-3 EPS Ensemble-

EC-EPS
WEPS
TEPS

TEMFST 2009/10/02 18:00Z FT= 72:00   MCGE

MCGE CNT=   2.00 MAX= 1018.48 MIN=   992.69   VALID= 10/06 03:00I

D0021 Typhoon Strike Probability (2009.10.02.1200'UTC)

Probability that Typhoon will pass within 120km (about 65nm) radius during the next 120 hours

We provide a track map and strike probability. Those are created from TEPS, WEPS, EC-EPS, and 3 EPS ensemble. We add only EC-EPS forecasts to the multi model ensemble . Because it is the only EPS track available from the GTS. On this 3 EPS ensemble , latest available forecasts at the time of the map's creation are used.

We consult the ECMWF ensemble forecast. But the initial time of the available forecast is usually old.

TC verification result during 2009 in western North-Pacific domain

Tropical Cyclone Track forecast(2009) / deterministic Verification of western North-Pacific domain / Position Error

T0901_T0922 Position Error 2009 (No–Equalized Sample)
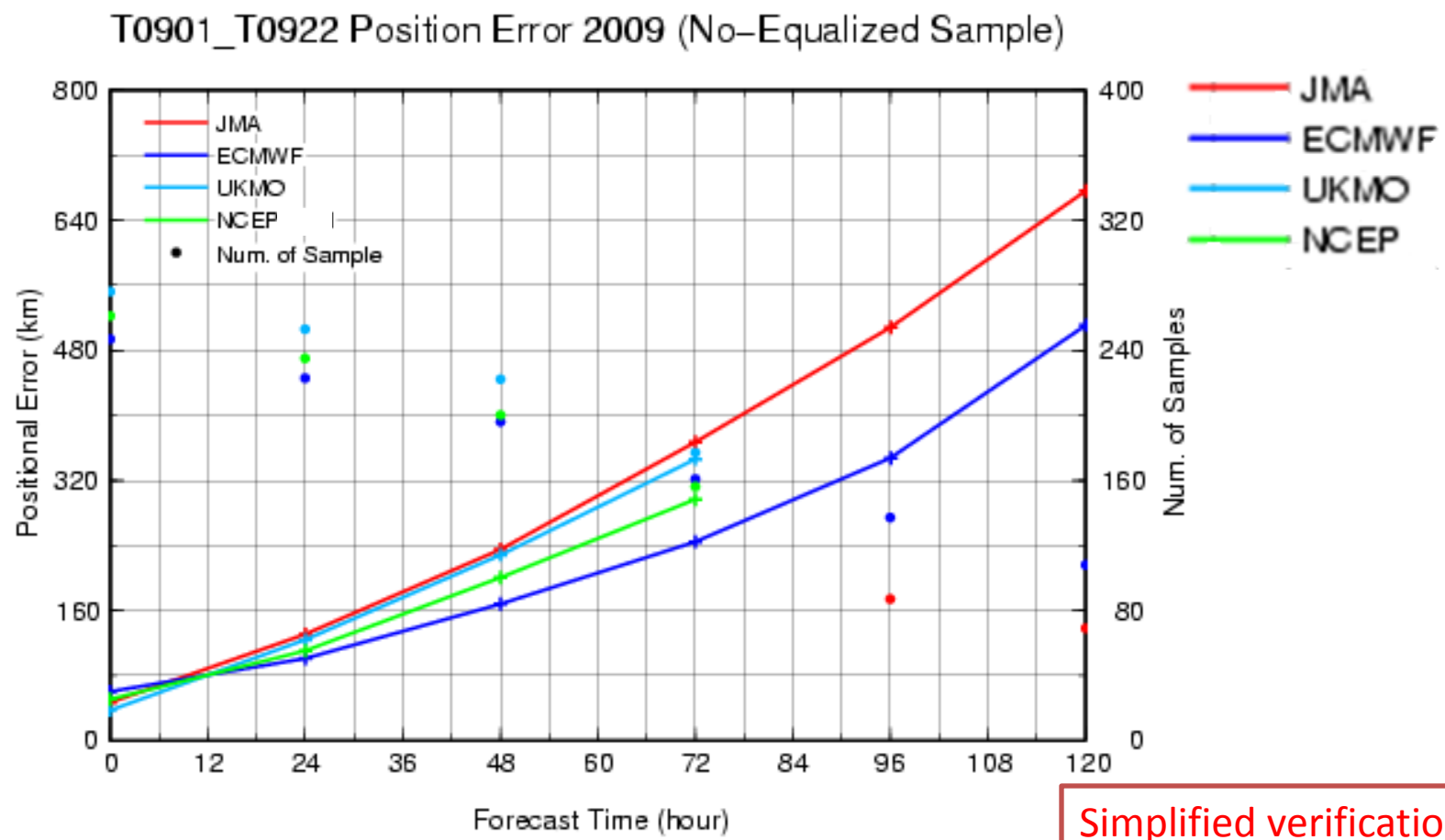
Simplified verification

Verification of deterministic forecast tracks during 2009 in western north-pacific domain. We used a MSLP GPV delivered by the GTS. The difference of accuracy between the JMA and ECMWF was broadened. Those differences correspond to about a 24 hours difference of initial time. The TC forecast of NCEP greatly improved over the period of 2008.

Control–run vs ensemble-mean Verification of TC position error.
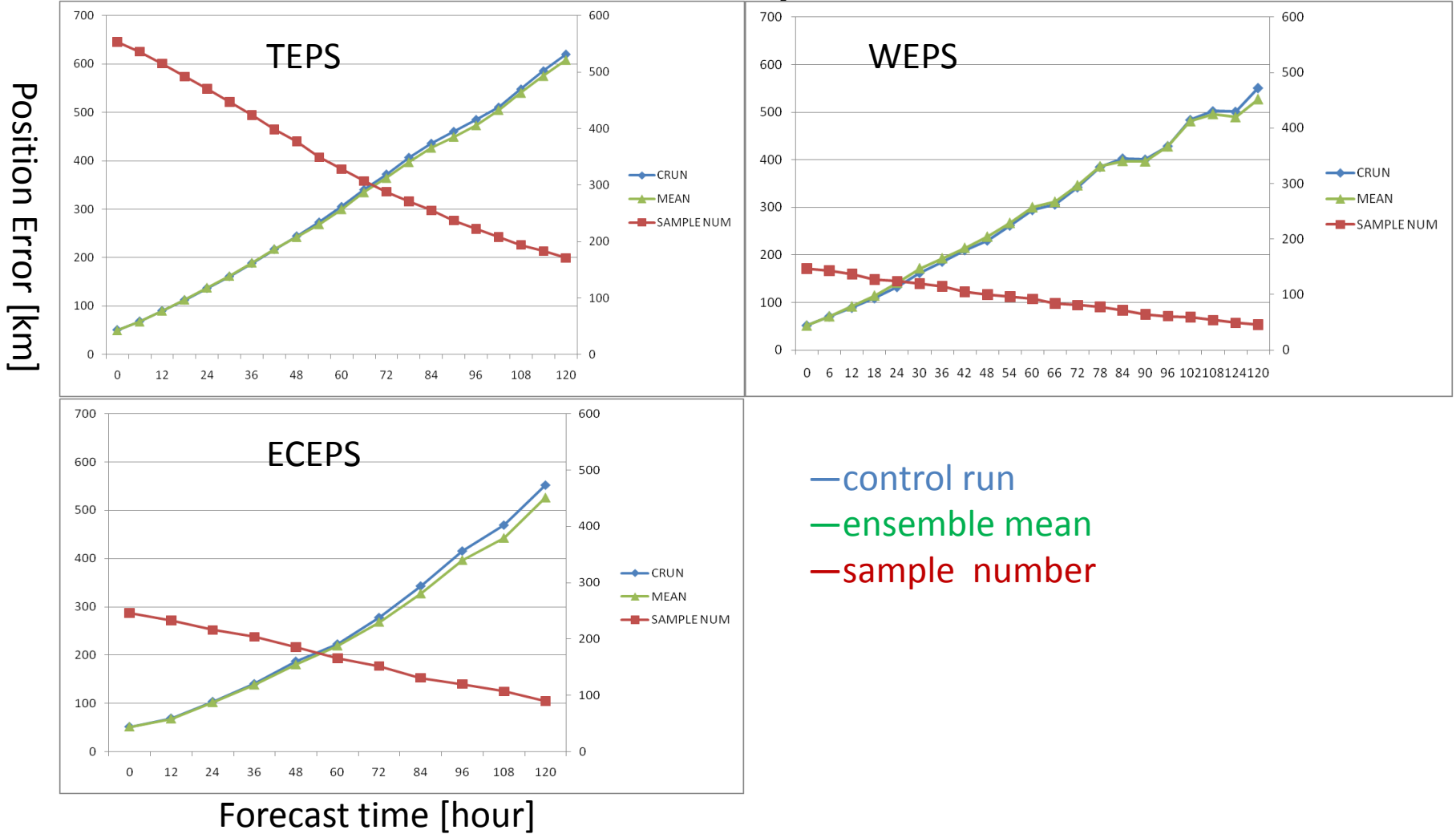
There is a little benefit of the ensemble mean for the track forecast. As for this property, any system is similar. In short range forecast time (~ 5 days), that improvement is less measurable.
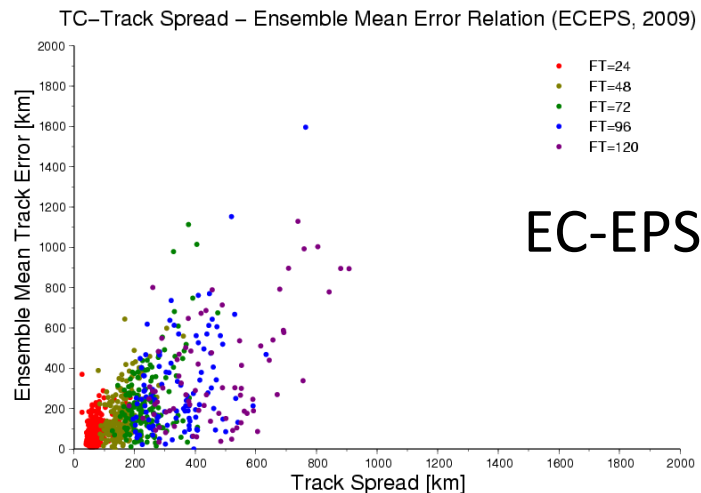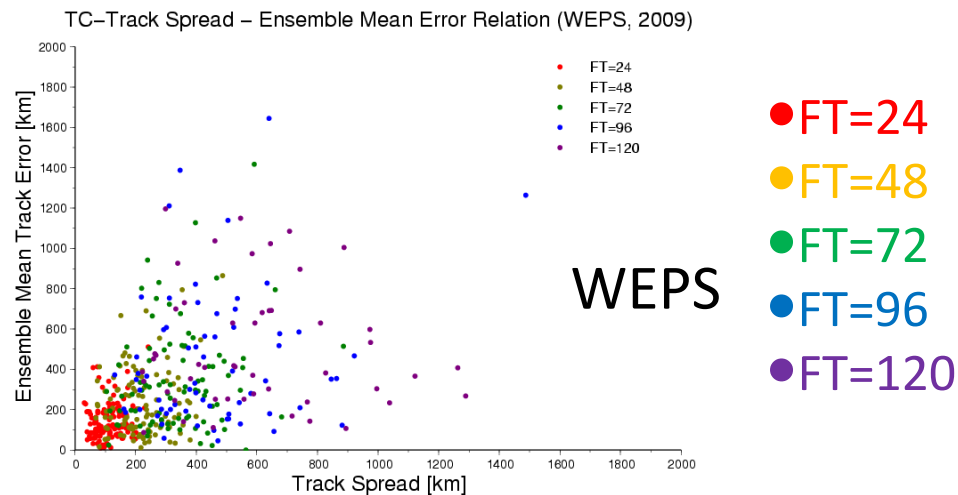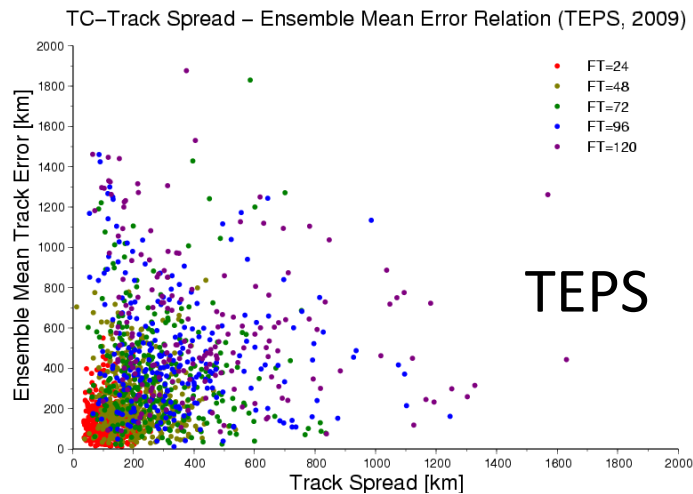
Verification of 3 Category Reliability

Position Error [km]

TEPS

WEPS

EC-EPS

平均A
平均B
平均C
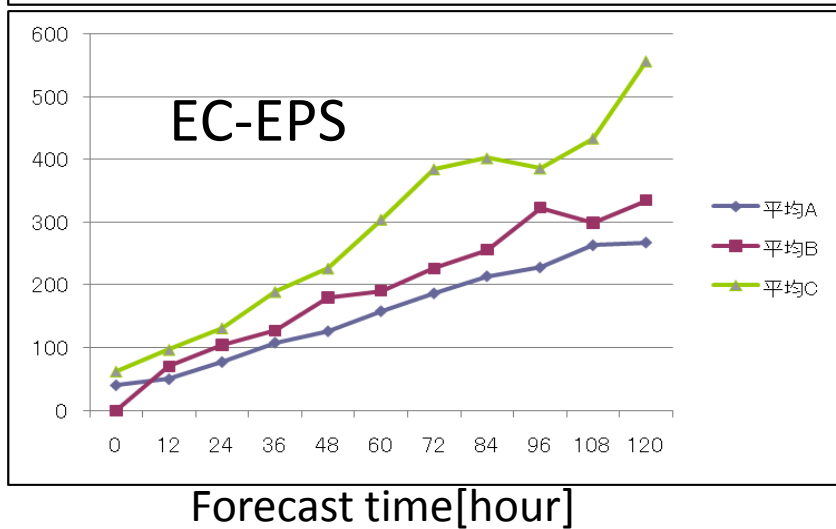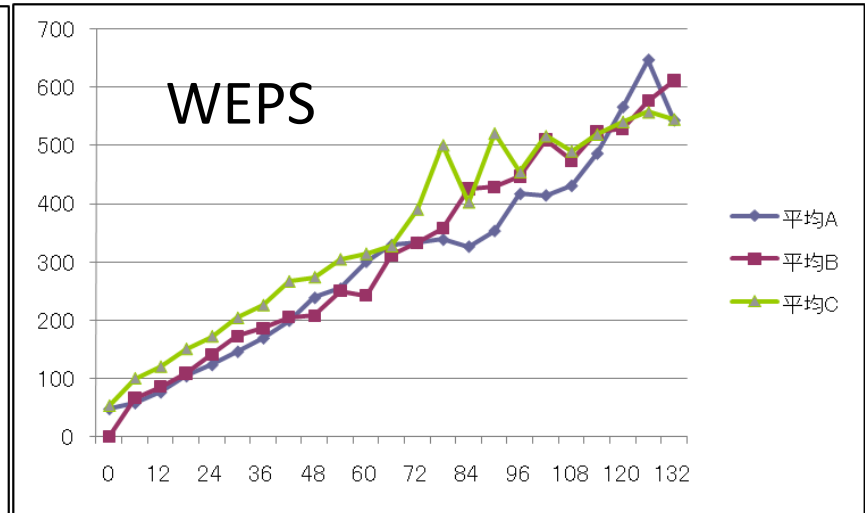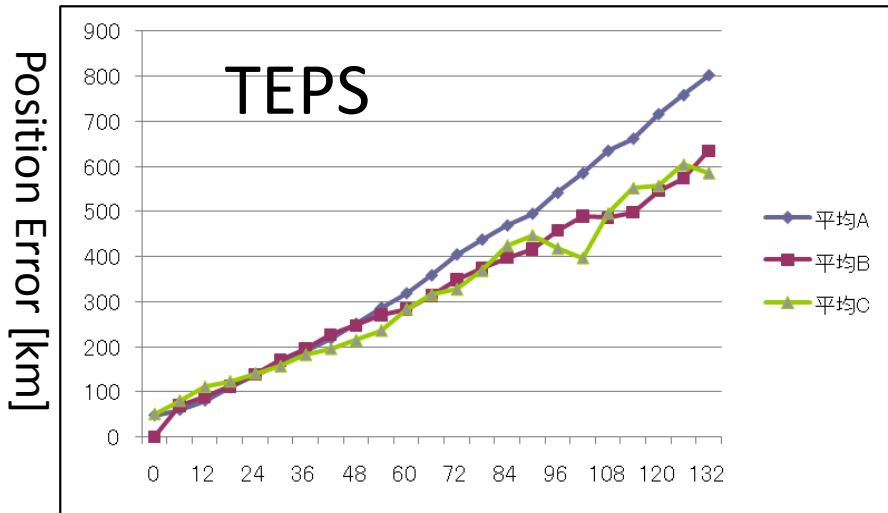
Category A: small spread
Category B: middle spread
Category C: large spread

Forecast time[hour]

The average of position error on each category. On TEPS, the spread and TC position error of ensemble mean has a negative correlation. On the WEPS, both have no correlation. On the other hand, those correlation of EC-EPS is better.

Spread vs Ensemble Mean Position Error scattering plot

TC–Track Spread – Ensemble Mean Error Relation (TEPS, 2009)

TEPS

TC–Track Spread – Ensemble Mean Error Relation (WEPS, 2009)

WEPS

●FT=24
●FT=48
●FT=72
●FT=96
●FT=120

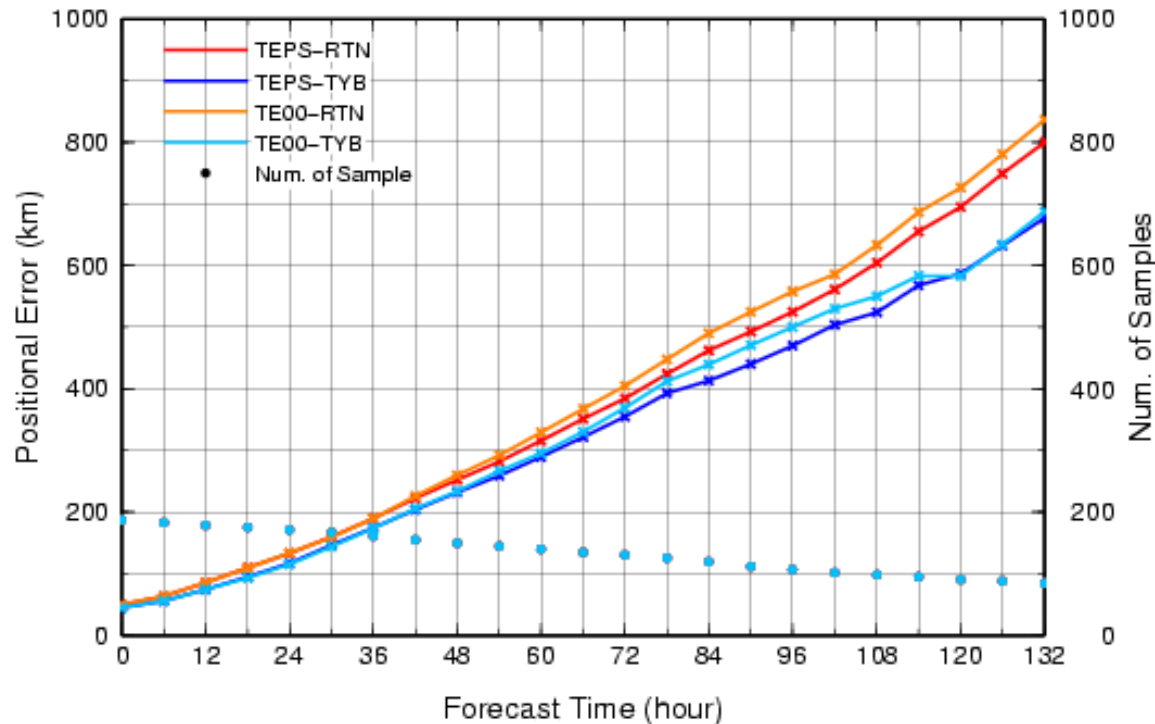TC–Track Spread – Ensemble Mean Error Relation (ECEPS, 2009)

EC-EPS

X-axis: Track spread [km]
Y-axis: Ensemble mean track error [km]

The result of TEPS is not good. The ensemble spread couldn't catch forecast uncertainty.
In addition, the time evolution of the spread was irregular.

On the WEPS, the number of "small-spread with large error " cases were less.

Recent work

Control run(OLD)
Ensemble mean(OLD)
Control run(NEW)
Ensemble mean(NEW)
2009/09/25 - 10/25

JMA improved typhoon
bogus!
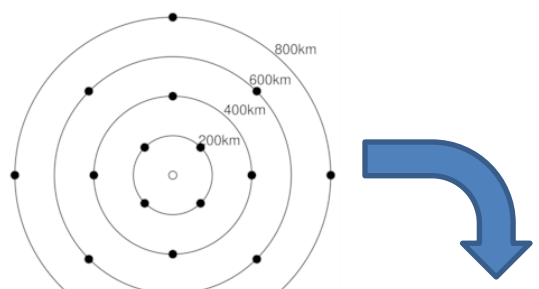   by Akira Okagaki(2010)

Future works

JMA plan to
- Improve the method to create initial perturbation of TEPS.
- Introduce the stochastic physics into WEPS and TEPS.
- Increase TEPS member size in the next computer system.
- Increase TEPS and WEPS horizontal resolution in the next computer system.
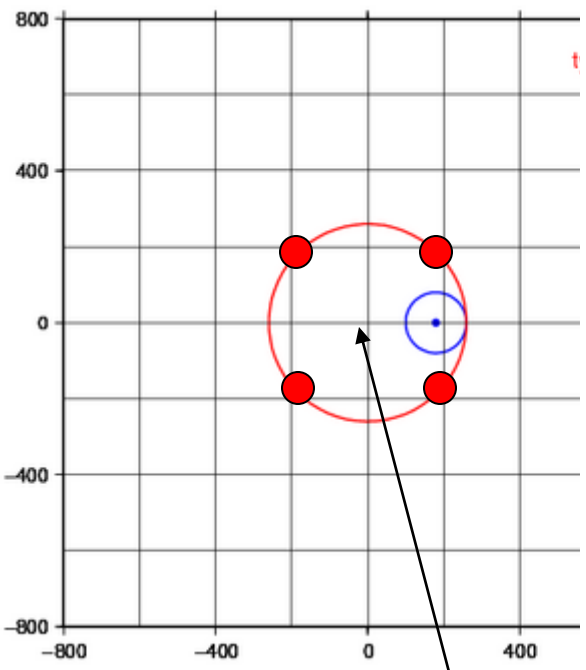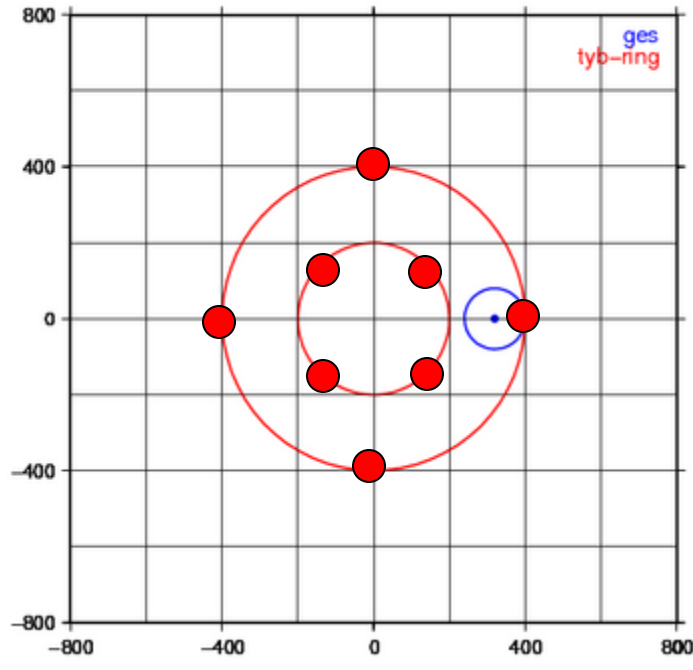
Improvement of Typhoon Bogus

old bogus

Reduce the number of pseudo observation point.
Those position and number is decided by the
position error of the first guess.

200km
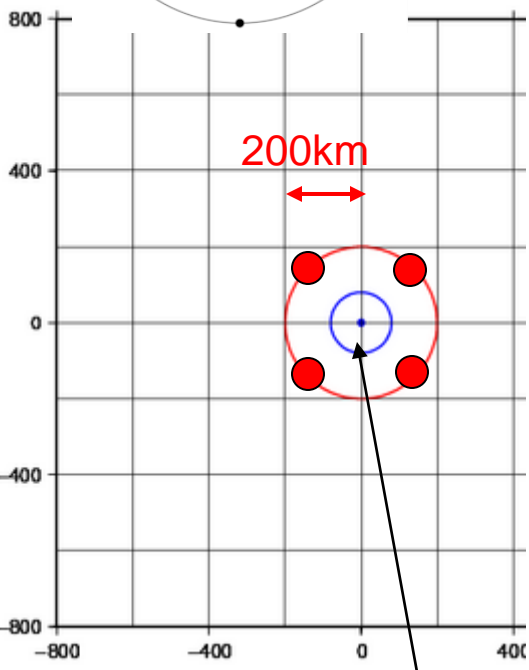
Guess center

Observation center

Summary

JMA operates 3 NWP systems that provide TC forecast
   GSM   : Support the track and intensity forecast
                Horizontal resolution: T959, forecast length: 84 hours
   TEPS   : provide possible scenarios of track forecast
                 Horizontal resolution: T319, forecast length: 132 hours
   WEPS : Support forecast tracks and probabilistic information.
                Horizontal resolution: T319, forecast length: 216 hours

The horizontal resolution T319 is rough to forecast TC intensity. It is difficult to forecast even change tendency. So GSM (T959) provides a primary basis of intensity forecast.

We provide a track map, strike probability and three category reliability graphs for JMA forecasters.

It is the number-one priority that EPS has basic skills to forecast the uncertainty. It is not easy, but we try to improve TEPS.

References

Nakagawa, M., 2009: Outline of the High Resolution Global Model at the Japan Meteorological Agency. *RSMC Tokyo-Typhoon Center Technical Review*, **11**, 1-13.

Yamaguchi, M. and T. Komori, 2009: Outline of the Typhoon Ensemble Prediction System at the Japan Meteorological Agency. *RSMC Tokyo-Typhoon Center Technical Review*, **11**, 14-24.
Those two articles are available at:
<http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev.htm

Method of TC verification using MSLP

TCs to be verified

TCs which intensity reached tropical storm (TS) with the maximum sustained wind of 34 knots or stronger are set as targets for this verification. The tropical depression (TD) stage of the targeted TCs is also included in this verification. However, the TCs which stayed at TD level all through their life are excluded.

Tracking Method
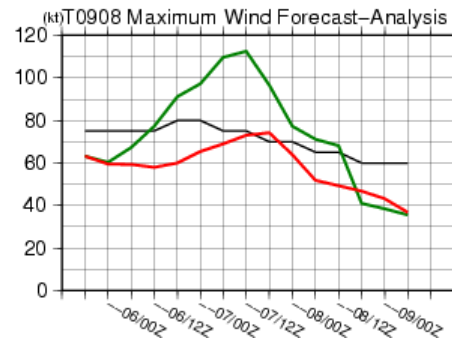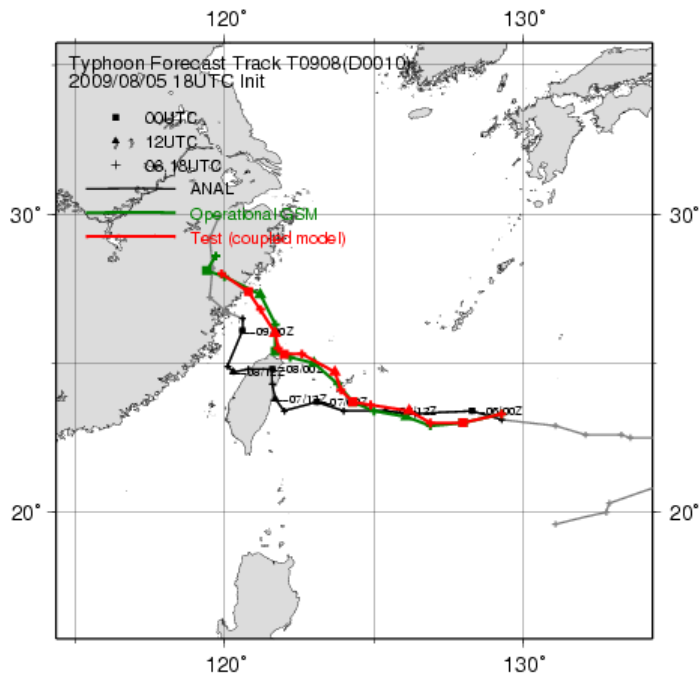
local pressure minimum:

a) First position (FT +0hr) : search from the best track position
b) Second position (FT +12hr) : search from the first position
c) Third and after (FT +24hr~) : search from estimated position
from the latest two positions

(all positions searched within a 500km radius)
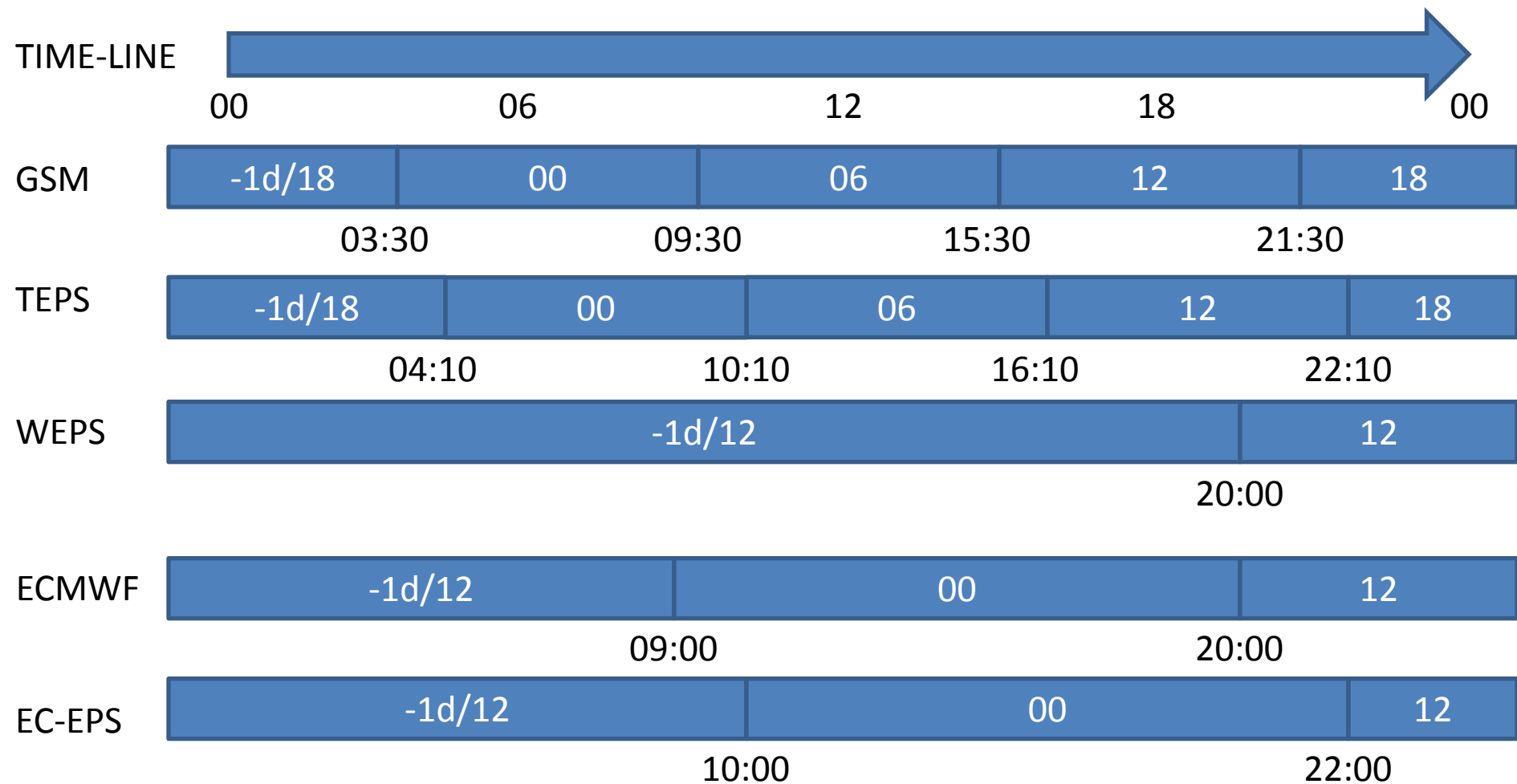
Impact of coupling
Typhoon intensity forecast for Typhoon Morakot

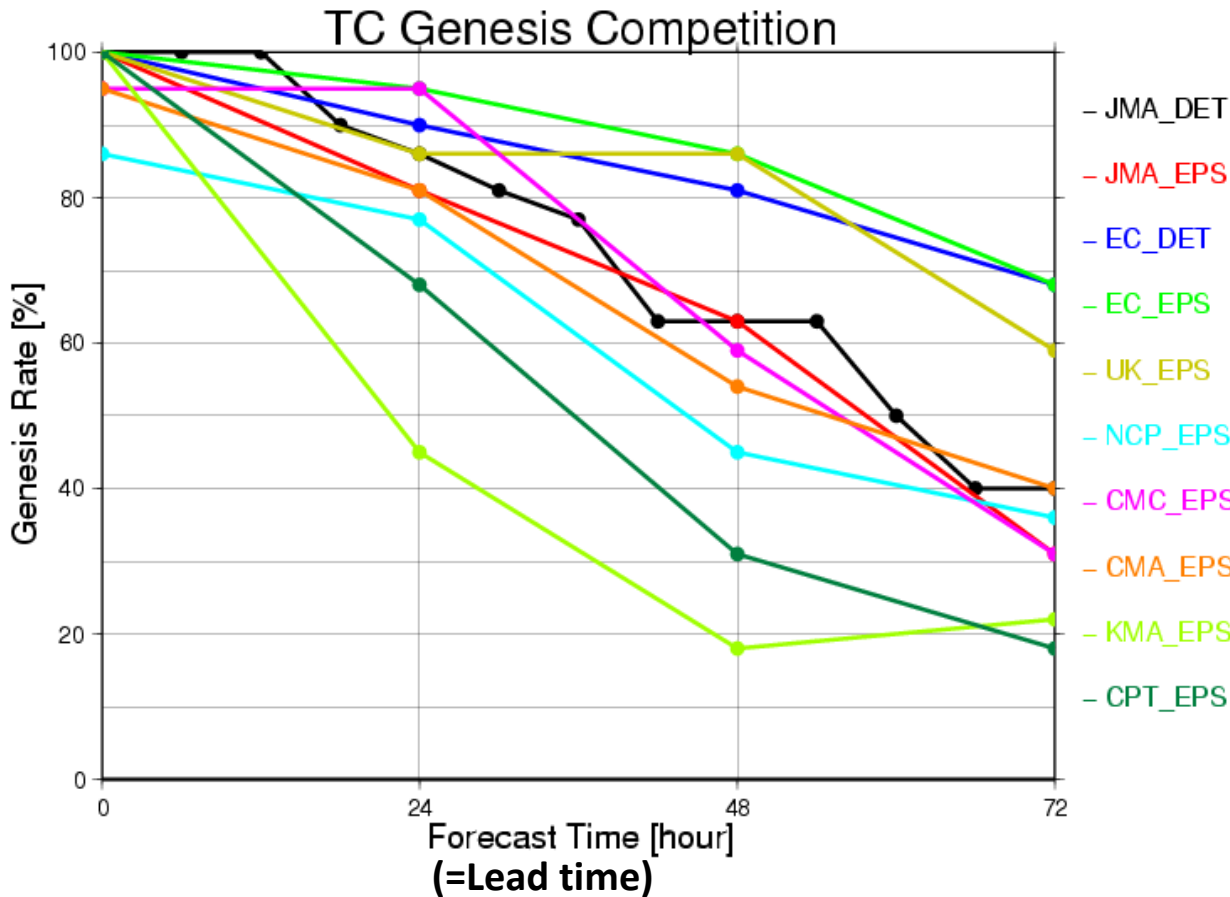T0908(D0010) Typhoon Forecast (Track and Intensity) -- 2009/08/05 18UTC --
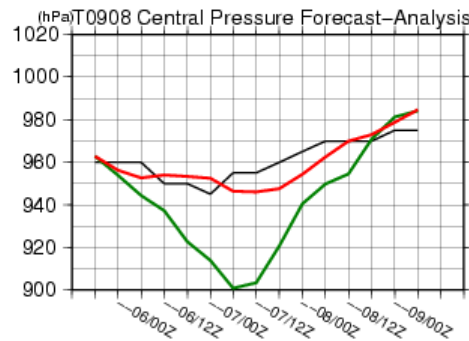
- Too strong in operational GSM (green)
- Coupling weaken the intensity (red)

The Time that Use of Result by Forecaster Become Possible

TIME-LINE	→

| | 00 | 06 | 12 | 18 | 00 |

GSM	-1d/18	00	06	12	18

| | 03:30 | 09:30 | 15:30 | 21:30 |

TEPS	-1d/18	00	06	12	18

| | 04:10 | 10:10 | 16:10 | 22:10 |

WEPS	-1d/12	12

| | 20:00 |

ECMWF	-1d/12	00	12

| | 09:00 | 20:00 |

EC-EPS	-1d/12	00	12

| | 10:00 | 22:00 |

Verification of TC genesis forecast in the WNP domain based on TIGGE data

TC Genesis Competition

– JMA_DET
– JMA_EPS
– EC_DET
– EC_EPS
– UK_EPS
– NCP_EPS
– CMC_EPS
– CMA_EPS
– KMA_EPS
– CPT_EPS

Center	Model Resolution	Verified Data Resolution
JMA (Deterministic)	TL959L60	0.25°
JMA	TL319L60	0.5625°
ECMWF (Deterministic)	TL799L91	0.5625°
ECMWF	TL399L62	0.5625°
UKMO	0.833° ×1.25° L38	0.5625°
NCEP	T126L28	0.5625°
CMC	0.9° L28	0.5625°
CMA	T213L31	0.5625°
KMA	T213L40	0.5625°
CPTEC	T126L28	0.5625°

*N.B. coloring is different from other figures.

Forecast data from the control run of Ensemble Prediction Systems are used (unless otherwise notified).

Comparison between ECMWF EPS and DET, JMA EPS and DET suggests that horizontal resolution may not be so important.
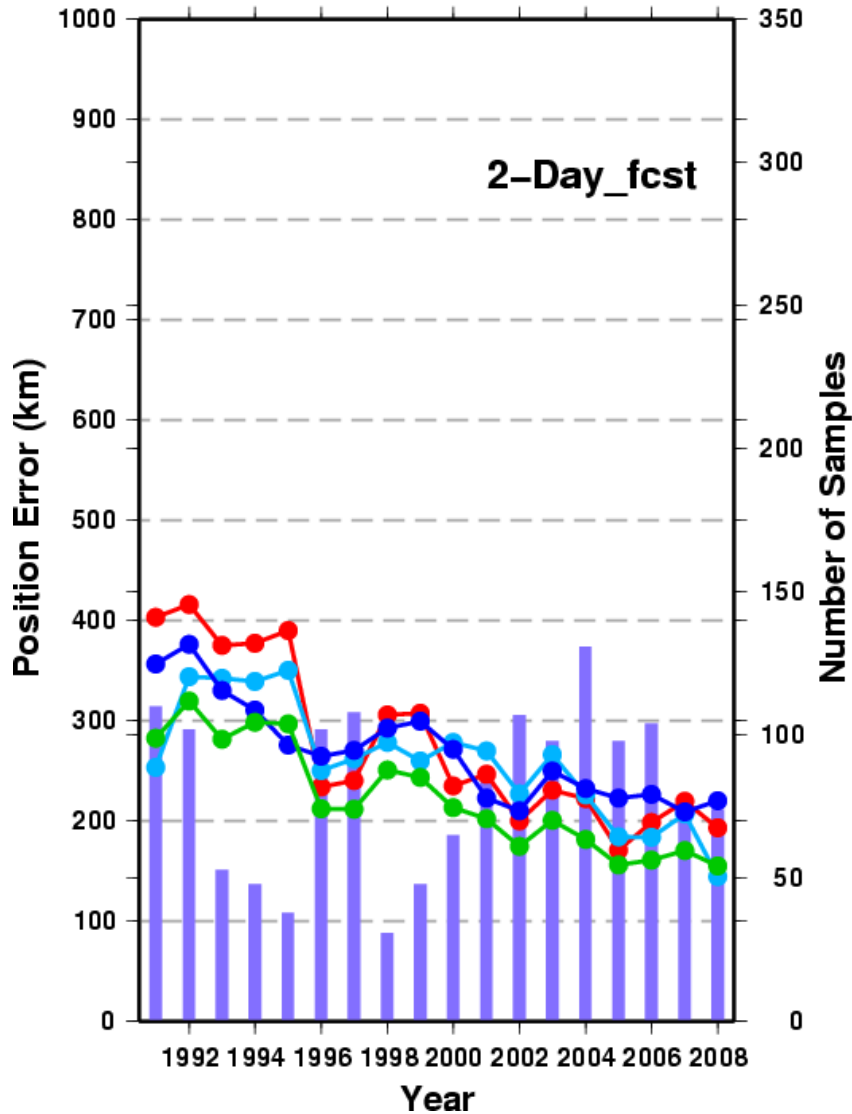
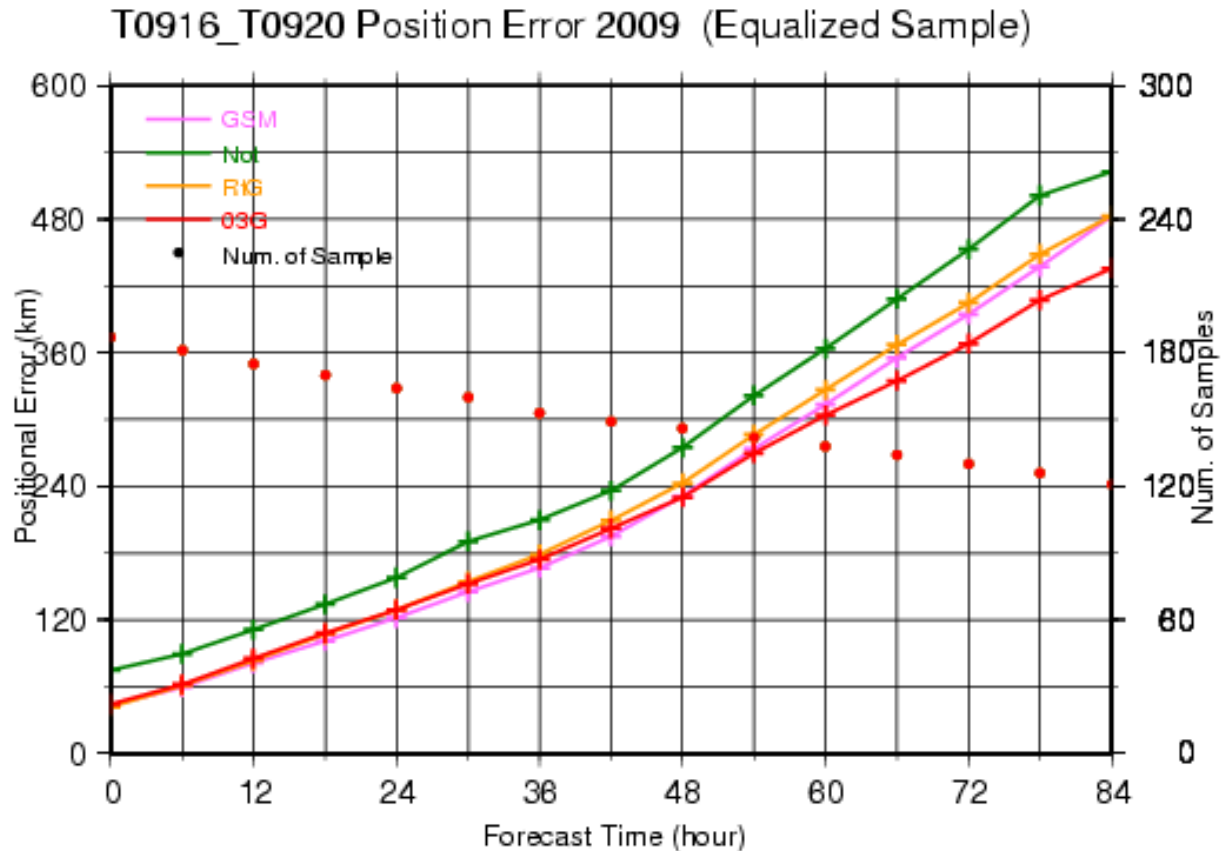# Time series of 2-day and 4-day forecast of JMA, ECM, UKM and 3centers ensemble in WNP domain.

JMA **ECM** **UKM** **ENS**

Impact of Typhoon bogus

T0916_T0920 Position Error 2009 (Equalized Sample)
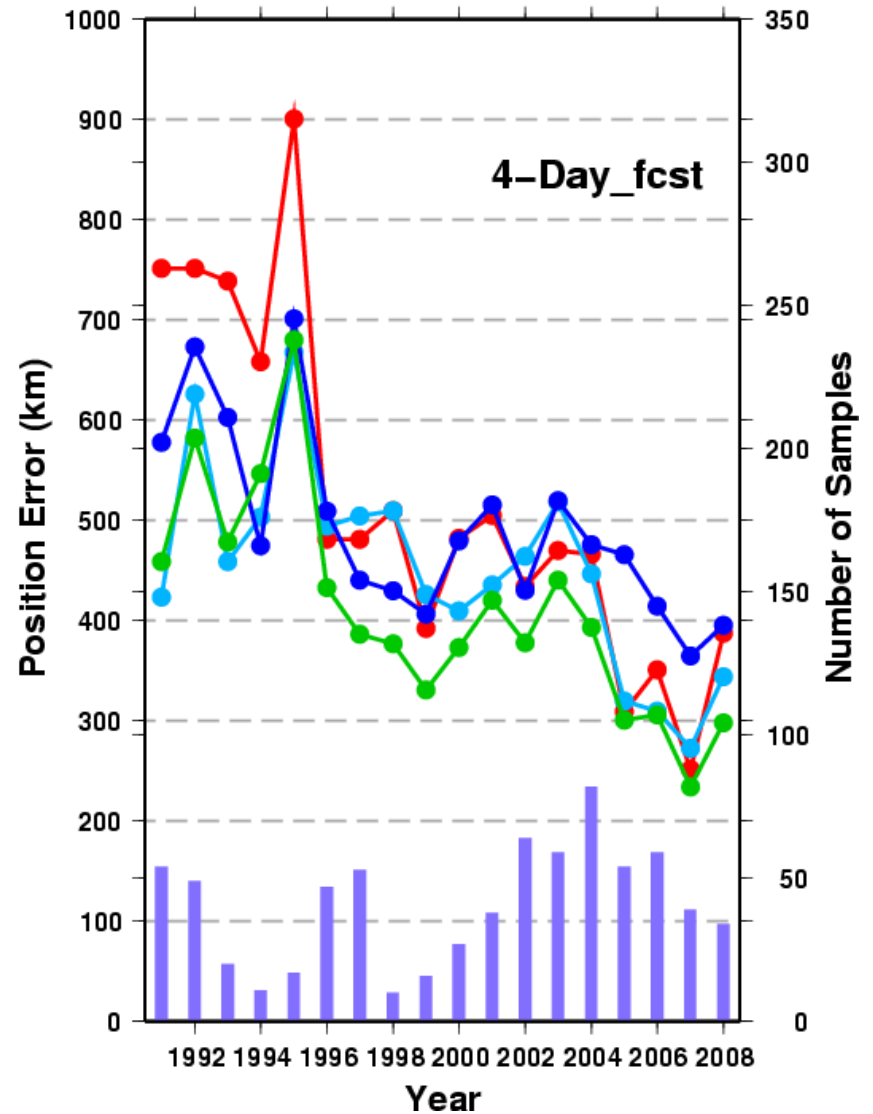
Without :bogus
With :bogus

conditions of TEPS run

TEPS run is conducted only when the following conditions are satisfied.

•Tropical cyclones of TS/STS/TY intensity exist in the responsibility area of RSMC Tokyo – Typhoon Center.

• Tropical cyclones of TS/STS/TY intensity are expected to move into the area within the next 24 hours

2007/5 ～ 12 test installation

Verification of 3 Category Reliability
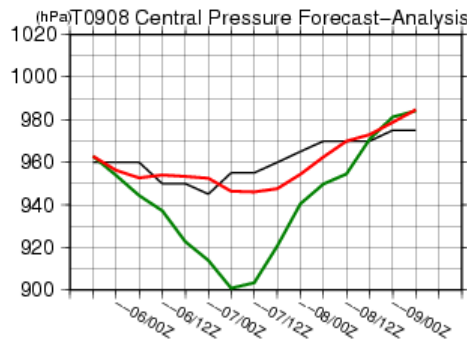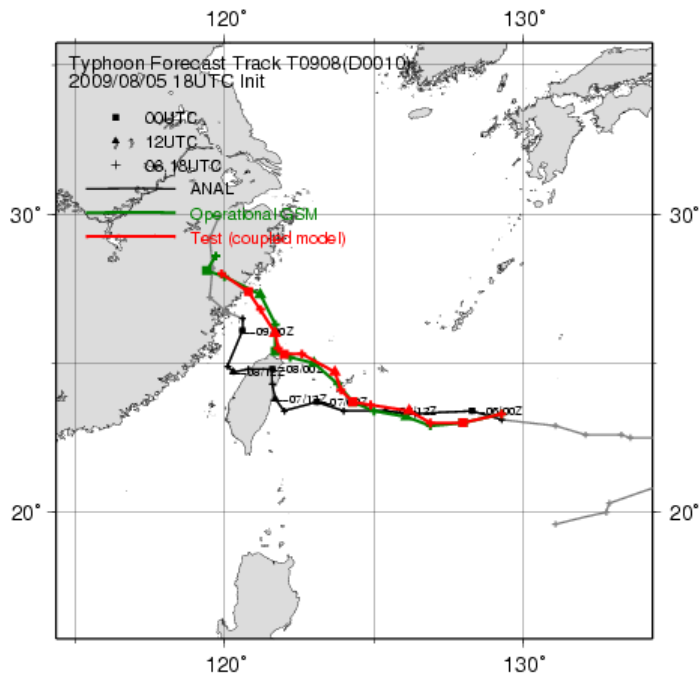

Category C: large spread
Category B: middle spread
Category A: small spread
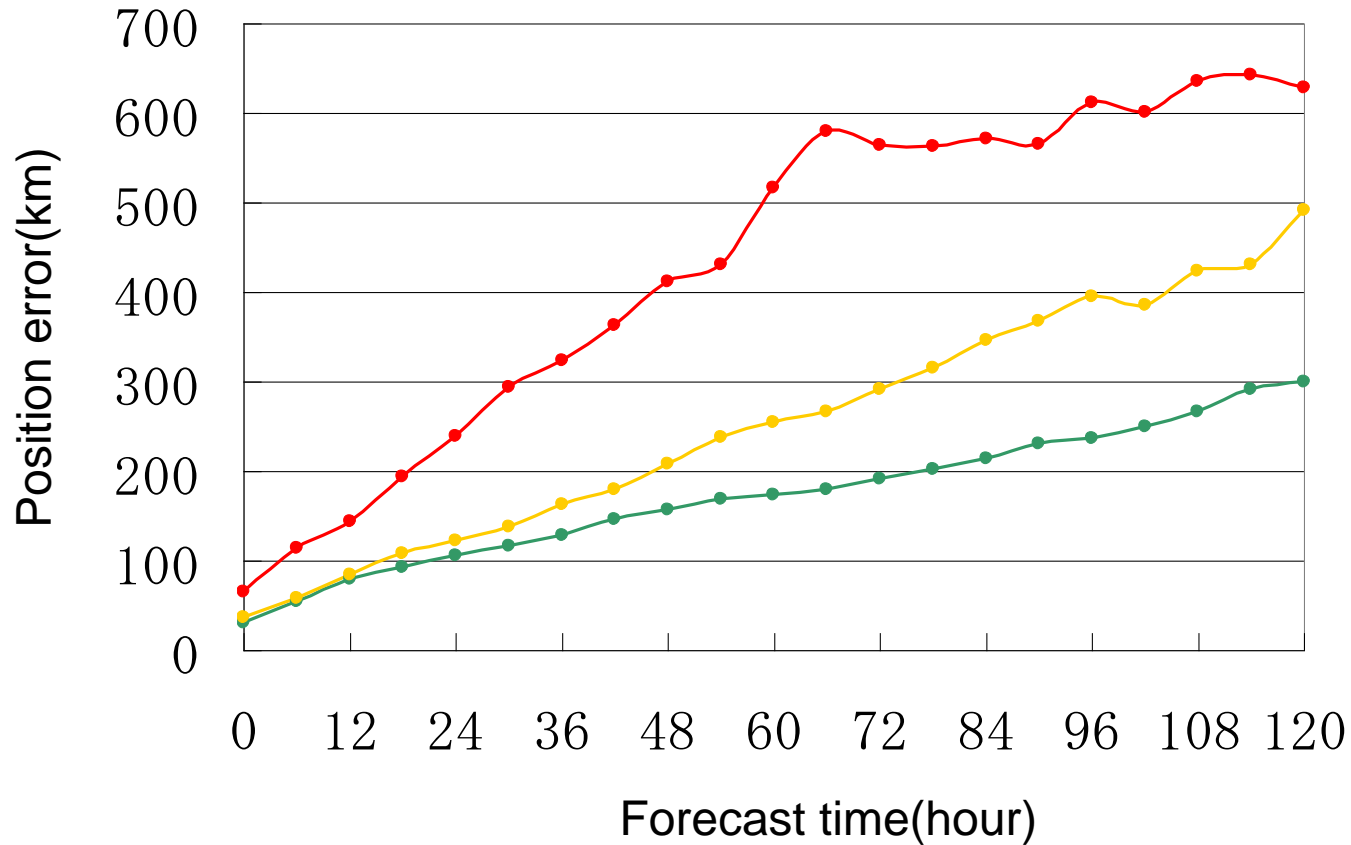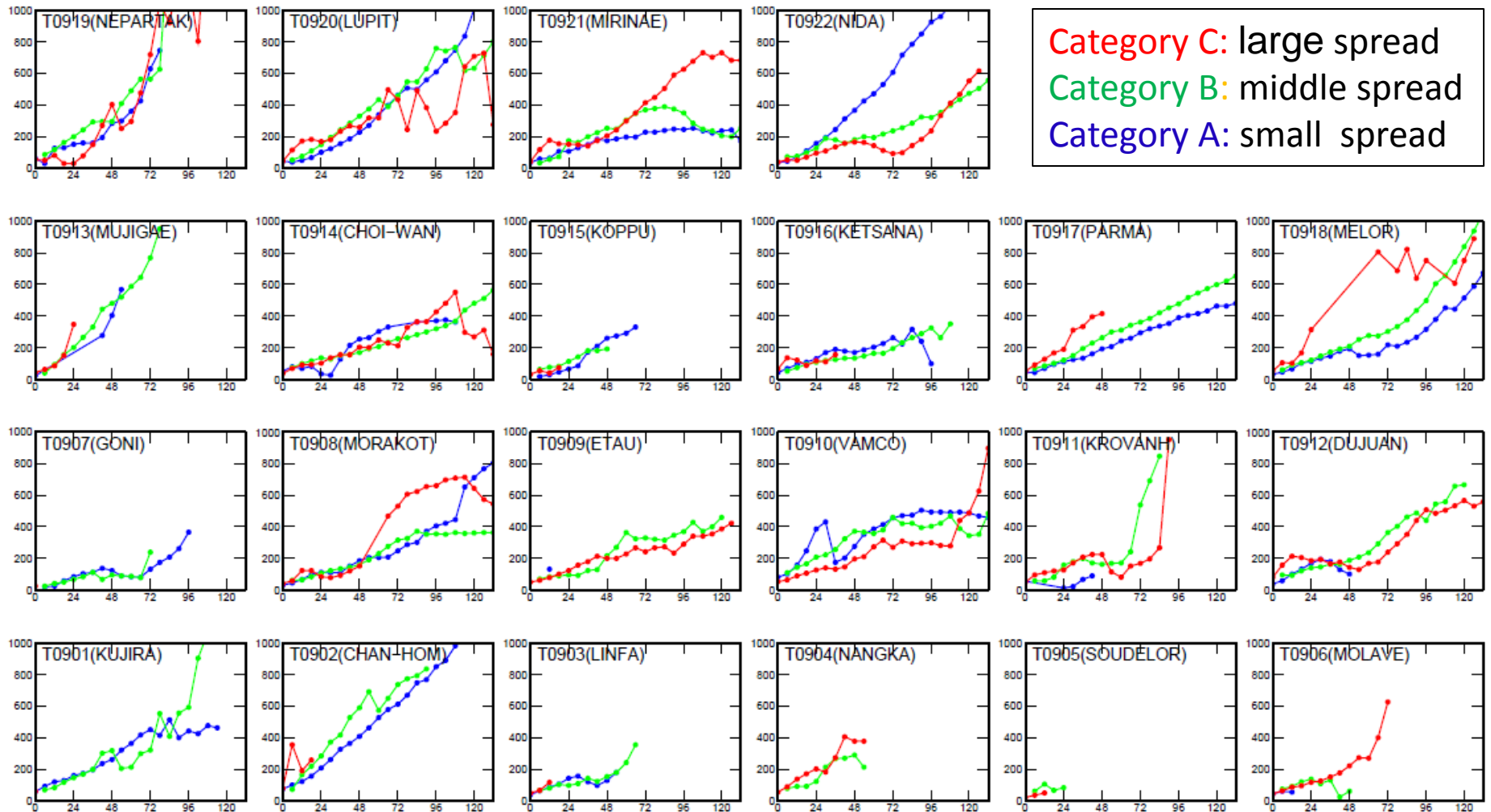
Impact of coupling
Typhoon intensity forecast for Typhoon Morakot

T0908(D0010) Typhoon Forecast (Track and Intensity) -- 2009/08/05 18UTC --

- Too strong in operational GSM (green)
- Coupling weaken the intensity (red)

TIGGE Real-Time Tropical Cyclone Data
for Regional Applications

North Western Pacific Tropical Cyclone (Track) Ensemble Forecast Research Project (NW Pacific TC Project)

a WWRP Research Development Project

Tetsuo NAKAZAWA, David PARSONS, David BURRIDGE
WMO/WWRP THORPEX

1

Towards the Global Interactive Forecast System (GIFS)

➤ The objective of the GIFS is to realise the benefits of THORPEX research by improving the delivery of improved forecasts of high-impact weather.

➤ As a first step, the GIFS-TIGGE working group set up a pilot project for the exchange of real-time tropical cyclone predictions using "Cyclone XML" format.

➤ Forecast and research demonstration projects are being developed by the GIFS-TIGGE WG and regional centres to predict tropical cyclone tracks and heavy rainfall
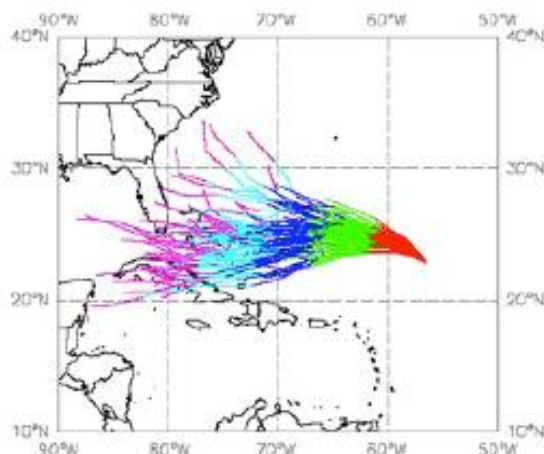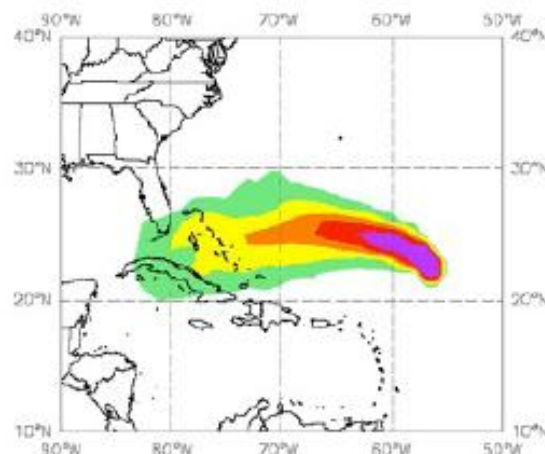
A First Step: NW Pacific Tropical Cyclone Ensemble Forecast Research Project

➢ A five-year regional project with both a research and operational component that will feed into national efforts such as **for the Shanghai MHEWS Project and Landfall Typhoon Forecast Demonstration Project.**

➢ Intent is to make **GIFS-TIGGE typhoon track data available to ESCAP/WMO Typhoon Committee members including RSMCs in real time beginning May 2010** via a password protected web site

➢ **The web site will also be linked to the WMO/TCP homepage.**

➢ Training for operational forecasters and evaluation of the utility of such data sets in a forecast environment

➢ Research efforts will attempt to develop and extract useful information from TIGGE ensemble data and develop products where appropriate

➢ **Product development to feed into the operational SWFDP in Africa and then in the S. Pacific**

➢ **Close Collaboration/Coordination with GIFS-RDP through TIGGE WG, ARC, WMO/TCP, WWRP/TCP, JWGFVR, RSMCs, and TCWCs**

A Sample Page of the NWP TC Project

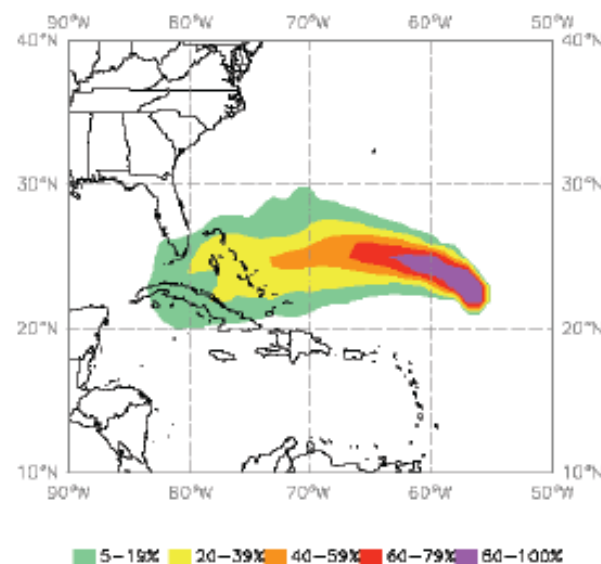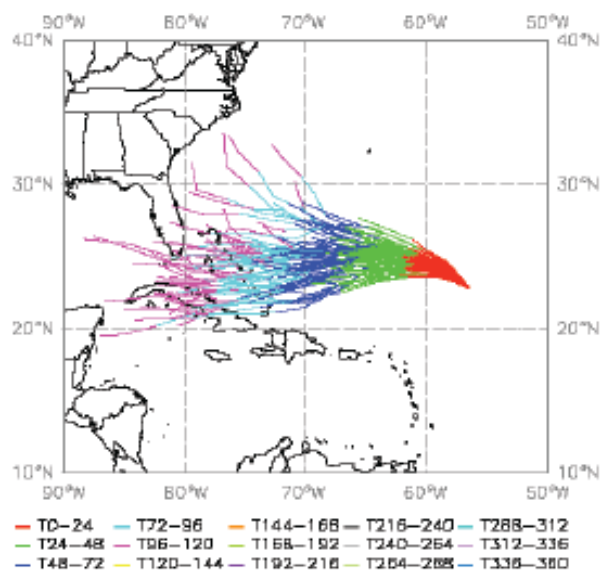## Tropical Cyclone Ensemble Information HomePage

Available in May 2010!

Summary

- A WMO/WWRP Forecast Demonstration Project, North Western Pacific Tropical Cyclone Ensemble Forecast Research Project, will deliver the information in real-time to ESCAP/WMP Typhoon Committee members and interested researchers over the globe, based on the TIGGE Tropical Cyclone CXML data.

- First track data, then intensity/precipitation data

- The web page, required ID and password, will be available in May 2010, after the permission of the real-time use of the data from the TIGGE WG.

- Training activities for forecasters should be included.

- Verification research activities with Joint WG on Forecast Verification Research under WWRP/WGNE

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