

Applications of probabilistic forecasting at JMA

Expert Meeting on the Application of Probabilistic Forecast

Shanghai, China

24-28 Sep. 2007

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JMA Home Page

JMA Home Page

JMA provides applications of probabilistic forecasting through JMA homepage (<http://www.jma.go.jp/jma/indexe.html>)

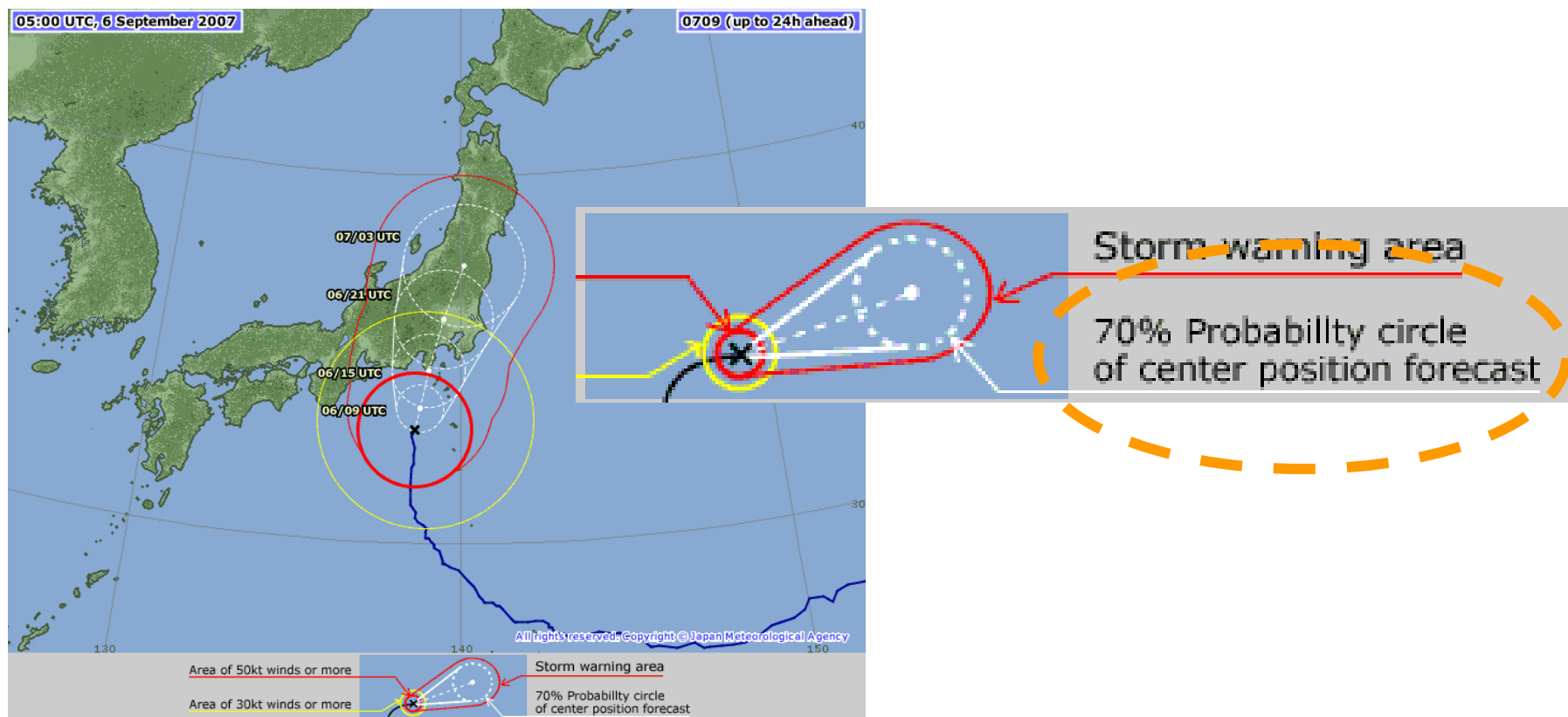
The screenshot shows the JMA Home Page in Microsoft Internet Explorer. The browser window title is "Japan Meteorological Agency - Microsoft Internet Explorer". The address bar shows "http://www.jma.go.jp/jma/indexe.html". The page content includes:

- Header:** Japan Meteorological Agency logo, navigation menu (Home, News Release, Weather/Earthquake, User's Guide, Mission, For NMHSs), and language selection (Japanese).
- Main Content:**
 - Weather, Climate & Earthquake Information:**
 - Warnings/Advisories:** Weather, Warnings/Advisories, Marine Warnings, Tropical Cyclone Information.
 - Earthquakes and Volcanoes:** Tsunami, Warnings/Advisories, Earthquake Information, Prediction of Tokai Earthquake, Volcano Information, Volcanic Ash.
 - Weather Forecasts and Analyses:** Daily Forecasts, Distribution/Three-hourly Forecasts, One-week Forecasts, Seasonal Forecasts.
 - Weather Maps:** Analysis & Forecast of Precipitation, Radar & Precipitation Nowcast, Aeolian Dust Information, UV index.
 - Latest Weather:** Satellite Imagery, Weather Observation Map/Table, Weather at Airport.
 - Climate and Ocean:** Climatic Statistics, Oceanographic Observation, Sea Wave (around Japan), Sea Wave (Western North Pacific).
 - News Release:**
 - Earthquake Early Warning: New Contents (30/08/2007) New !**
 - Earthquake Early Warning Starting 1 October 2007 (leaflet)
 - What is the Earthquake Early Warning
 - Examples of Response to an Earthquake Early Warning
 - Third WCRP International Conference on Reanalysis to be held in Tokyo in January 2008 (14 August 2007) New !
 - New Product available: ClimatView - Interactive Climate Database (For National Meteorological and Hydrological Services) (13 August 2007) New !
 - An outline of reinforced or new contents of the JMA's Website
 - HIRID and WEFAX will be discontinued on 12 March 2008 (25 July 2007). <--- Important notice**
 - Photo Gallery:**
 - Seventh Typhoon Committee Training Seminar at the RSMC Tokyo - Typhoon Center (18-27 July 2007)
 - Fifth Asian THORPEX Regional Committee Meeting was held in Tsukuba, Japan (25-26 July 2007)
- About JMA:**
 - Basic Information:** JMA's Goal
 - Activities:** Observations - Meteorological Satellite
 - Major International Roles:** RSMC Tokyo - Typhoon Center

The browser's taskbar shows the Start button, several open applications (Internet Explorer, Windows Explorer, WMO_PWS_Applic..., 200501Overview.p...), and the system clock showing 18:33 on 8/25/2007.

Typhoon Track Forecast @ JMA Home Page

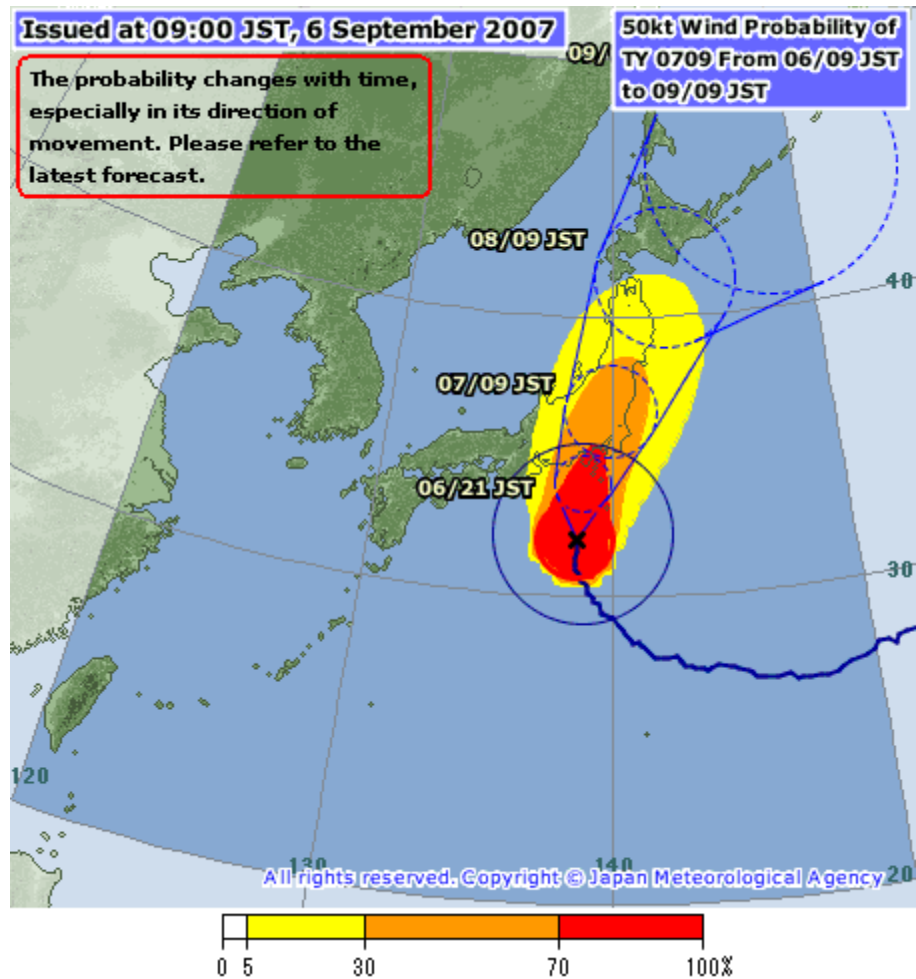
The forecast uncertainty on TC central position is described in a circle, whose radius is decided on a statistical method, using information about current TC position and intensity.



Issued at 05UTC 6 Sep. 2007

Typhoon FITOW

Typhoon Strike Probability @ JMA Home Page



Issued at 00UTC 6 Sep. 2007

Typhoon FITOW

Typhoon Strike Probability

Definition;

A probability with which sustained wind speed reaches 50kt over the next 3 days.

As of now (Sep. 2007), the areaseize of the TC striking area is estimated using a statistical method, not EPS.

Future issue is optimizing the areaseize using ensemble spread.

Probability Forecast of Rain @ JMA Home Page




JMA provides 6-hourly probability forecast of rain up to 2 days ahead, using kalman filter technique.

Multiple regression method

$$y = a_0 + a_1X_1 + a_2X_2 + \dots$$

y : objective variable (ex. Probability of rain)
 a : coefficients
 x : explaining variable (model output)

(/: ☁️ | : occasionally or partly)

Osaka-fu		Three-hourly Forecasts	Probability of Precipitation	Temperature Forecast
Today 13 September 	FINE BECOMING CLOUDY	00-06 --% 06-12 --% 12-18 10% 18-00 30%	Osaka Daytime High 33° C	
Tomorrow 14 September 	RAIN AT TIMES	00-06 30% 06-12 40% 12-18 50% 18-24 30%	Osaka Morning Low 23° C Daytime High 32° C	
Day after tomorrow 15 September 	RAIN AT TIMES	One-week Forecasts		

JMA uses kalman filter method to update the coefficients and gets to the probability of 6-hourly precipitation forecast up to 2 days ahead.

One week forecast for end users

週間天気予報

The forecasts are almost based on one week EPS.

日付	15 金	16 土	17 日	18 月	19 火	20 水	21 木
天気	雨	雨後曇り	曇り	晴れ時々曇り	晴れ時々曇り	晴れ時々曇り	晴れ時々曇り
降水確率(%)						20	20
最低気温(°C)		21(±2)	21(±2)	22(±2)	23(±2)	23(±1)	23(±2)
最高気温(°C)		25(±2)	27(±2)	27(±2)	28(±2)	27(±2)	27(±2)
日別信頼度						B	B
平年値	降水量の合計			最低気温		最高気温	
銚子	平年値			平年値		28.0°C	

Categorical weather forecast
Probability of daily precipitation (%)
Minimum and maximum temperatures with variability range
Reliability index (A,B or C)
Climatological data for reference

Weather outlook
 向こう一週間は、期間の前半は気圧の谷や前線の影響で曇りや雨の日が多いでしょう。期間の後半は高気圧に覆われて晴れる日が多い見込みで、気温は、最高気温・最低気温共に、期間の前半は平年並か平年より低い日が多い見込みです。期間の後半は平年並の所が多いでしょう。降水量は平年より多いでしょう。

週間天気予報の信頼度

- A(高い信頼度): 予報期間前半の平均的な精度と同程度 (B(中程度の信頼度)、予報期間後半の平均的な精度と同程度)

One Week Forecast @ JMA Home Page

The forecast uncertainty on weather predictions is described in a “character”, A, most reliable, B and C, least reliable, using information of ensemble spread by medium-range EPS. The information is update every day.

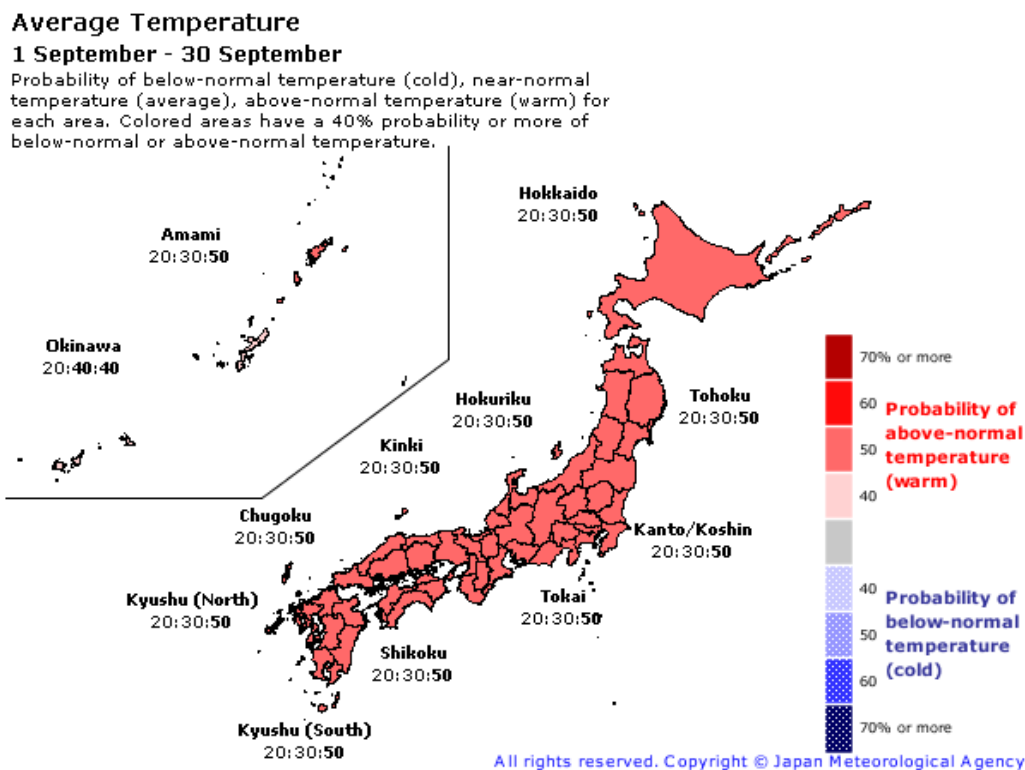
Date	21 Fri	22 Sat	23 Sun	24 Mon	25 Tue	26 Wed	27 Thu
Ishikari/Sorachi/Shiribeshi Chiho <small>Daily Forecast</small>	RAIN AT TIMES 	PARTLY CLOUDY 	PARTLY CLOUDY 	PARTLY CLOUDY 	RAIN AT TIMES 	RAIN AT TIMES 	MOSTLY CLOUDY
Probability of Precipitation (%)	20/20/30/50	10	10	20	50	50	30
Sapporo	Low (° C)	19	19 (±2)	14 (±4)	15 (±4)	13 (±4)	13 (±4)
	High (° C)	27	23 (±3)	21 (±3)	22 (±2)	21 (±4)	20 (±4)
Reliability	/	C	A	B	B	B	B
Normal	Precipitation		Low		High		
Sapporo	11 - 34mm		11.7 ° C		20.6 ° C		

Issued at 02UTC 20 Sep. 2007

One-Week Forecast

One Month Forecast @ JMA Home Page

JMA One month EPS provide probabilistic information on average temperature, precipitation, sunshine and snowfall over the next 4 weeks. The information is updated once a week.



Issued at 02UTC 01 Sep. 2007

Probabilistic forecast of average temperature in Sep. 2007

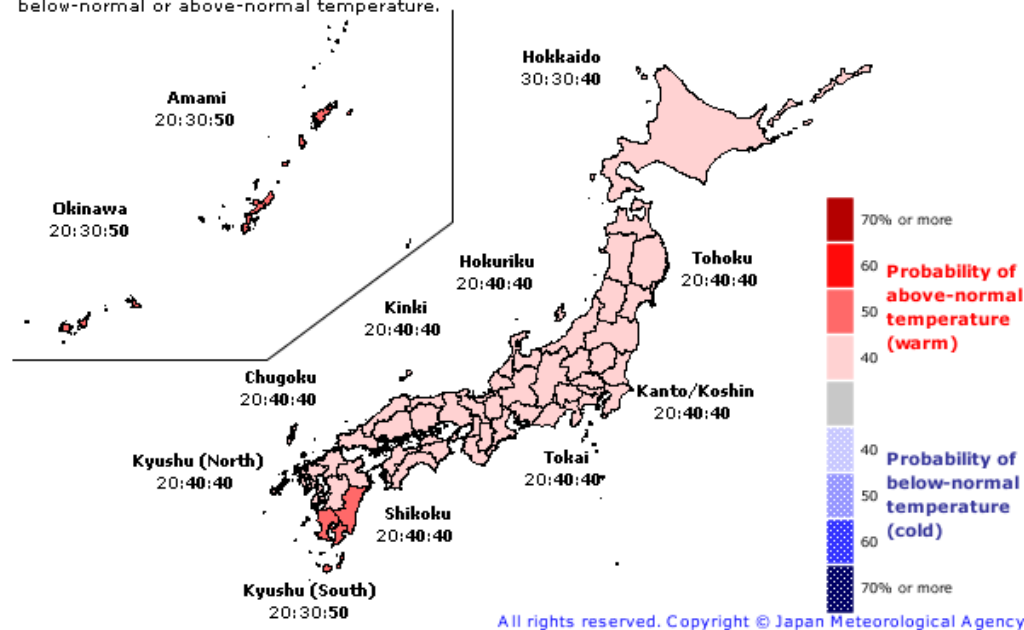
Seasonal Forecast @ JMA Home Page

JMA seasonal EPS provide probabilistic information on average temperature, precipitation, sunshine and snowfall over the next three months. The information is updated once a month.

Average Temperature

September - November

Probability of below-normal temperature (cold), near-normal temperature (average), above-normal temperature (warm) for each area. Colored areas have a 40% probability or more of below-normal or above-normal temperature.



Issued at 02UTC 01 Sep. 2007

Probabilistic forecast of average temperature during Sep to Nov. 2007

JMA's Pilot Project for EPS products

JMA's Pilot Project for EPS products

JMA started a pilot project on which EPS products by JMA medium-range EPS are available through internet. This pilot project was built to support NMHCs in Region II, based on the concept of the GDPFS manual.



Japan Meteorological Agency

This website provides products derived from the Japan Meteorological Agency (JMA) to National Meteorological Centers (NMHCs) as part of a pilot project of JMA aiming at improving the quality of EPS products.

For further improvement of JMA's EPS and its products, users' feedback, especially on comparison of EPS products with local observation and actual weather, is welcomed and should be directed to the JMA Medium-range EPS group at the following email address: eps-admin@naps.kishou.go.jp.

Information on this website is guidance and intended to be provided for use by forecasters and meteorologists in NMHCs. Please consult your national meteorological agency/administration for official forecasts of your country, region and/or local area.

EPS products

Weather Chart Guidance "Stamp maps" (WPacific, Asia, SouthChinaSea)	
Probability Guidance "Probability maps" (WPacific, Asia)	
Time-series Point Guidance "EPSgram"	

Training Materials (Related Links)

- "Ensemble Forecasting Explained" operated by the COMET program

EPS of JMA

JMA has operated EPS for one-week forecasting since March 2001. A low-resolution version (TL159L40) of the JMA global spectral model (TL319L40) is used in the one-week EPS. The one-week EPS runs up to nine days once a day at 12 UTC, with fifty-one ensemble members: one unperturbed forecast, and forecasts from fifty perturbed initial fields generated by the Breeding of Growing Modes (BGM) method.

- Specifications of the NWP models and the EPSs at JMA
- "Report on applications of EPS for severe weather forecasting" at Meeting of WMO Expert Team on EPS

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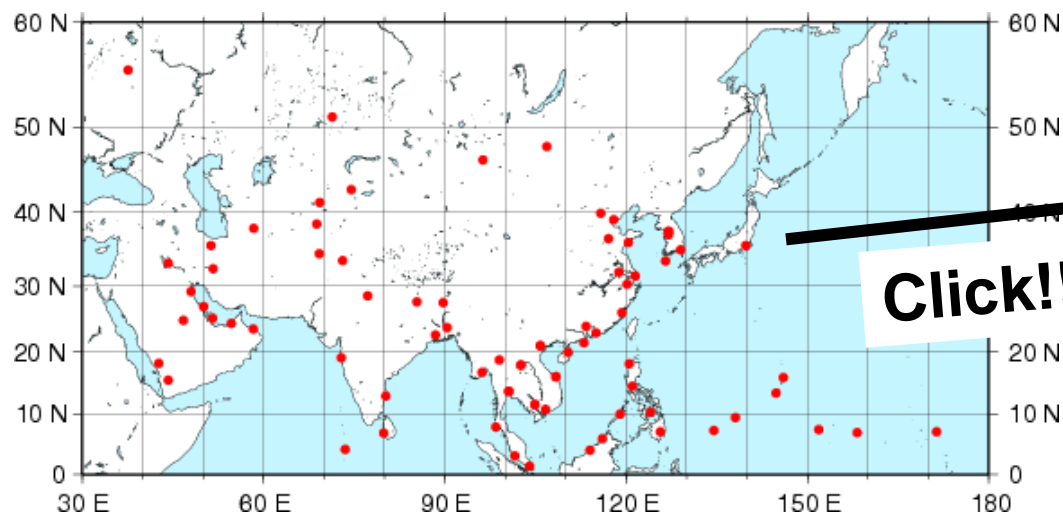
- JMA does not warrant accuracy and quality of products provided through the EPSWEB.
- JMA assumes no liability or responsibility for any problem arising from the use of products provided through the EPSWEB.

[Alteration of services]

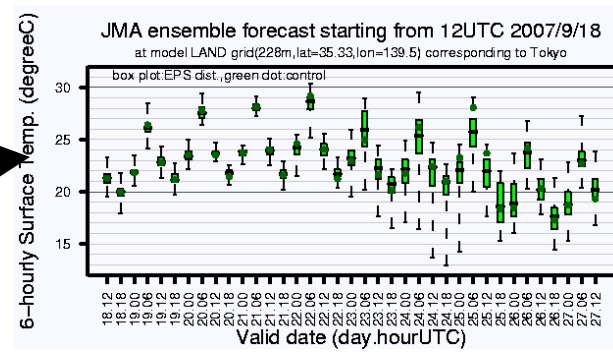
EPS products

1 Weather Chart Guidance "Stamp maps" (WPacific, Asia, SouthChinaSea)	
2 Probability Guidance "Probability maps" (WPacific, Asia)	
3 Point Guidance "EPSgram"	

EPSgram for about 70 points in Region II

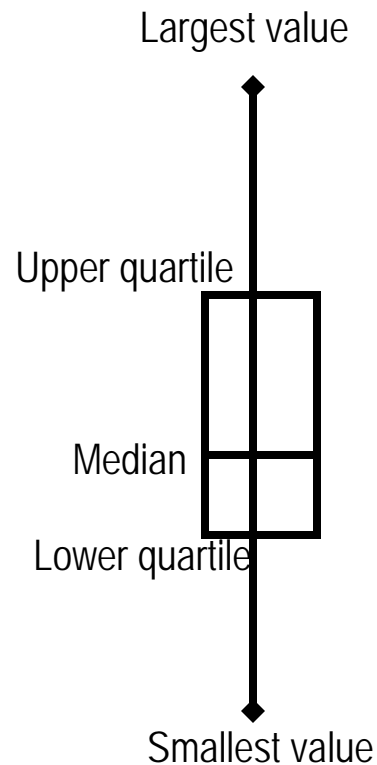


Click!!



Moscow	ABHA	COLOMBO	CHIANG MAI	JINAN	MAJUORO/MARSHAL IS.
ASTANA	BAHRAIN(INT. AIRPORT)	MALE	BANGKOK	QINGDAO	KOROR, PALAU WCI.
BISHKEK	DOHA INTERNATIONAL AIRPORT	ALTAI	PHUKET	NANJING	YAP, CAROLINE IS.
TASHKENT	ABU DHABI INTER. AIRPORT	ULAANBAATAR	KUALA LUMPUR/SUBANG	SHANGHAI	BRUNEI AIRPORT
DUSHANBE	SEEB, INTL AIRPORT	KATHMANDU AIRPORT	SINGAPORE CHANGI AIRPORT	HANGZHOU	KOTA KINABALU
ASHGBAT	SANA'A	KOWLOON	HANOI	FUZHOU	LAOAG
KING KHALED INT. AIR	ISLAMABAD	TAIPA GRANDE	DA NANG	GUANGZHOU	MANILA
KUWAIT INTERNATIONAL AIRPORT	DHAKA	SEOUL	TAN SON HOA (Ho Chi Minh)	HAIKOU	PUERTO PRINCESA
BAGHDAD	NEW DEHLI/SAFDARJUNG	BUSAN	VIENTIANE	NWSO AGANA, GUAM	MACTAN
TEHRAN-MEHRABAD	CALCUTTA/DUM DUM	JEJU	PHNOM-PENH/POCHEN TONG	SAIPAN (CG)	DAVAO AIRPORT
ESFAHAN	BOMBAY/SANTACRUZ	TOKYO	BEIJING	CHUUK, ECI	
KABUL AIRPORT	MADRAS/MINAMBAKKAM	YANGON	TIANJIN	POHNPEI, CAROLINE IS.	

Interpretation of box plot



Interpretation
of boxplots

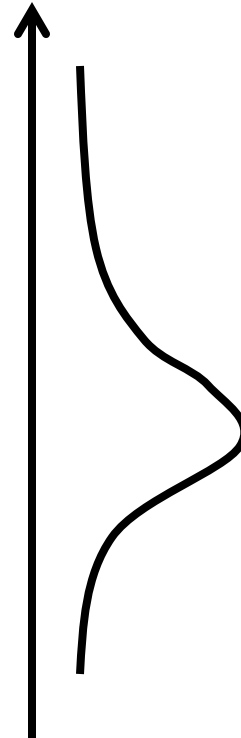


Image
of PDF

“Box plot” represent the distribution of the forecast by ensemble prediction system.

Surface temperature (degree C)

The first quartile

median

The third quartile

Initial time

max

min

control

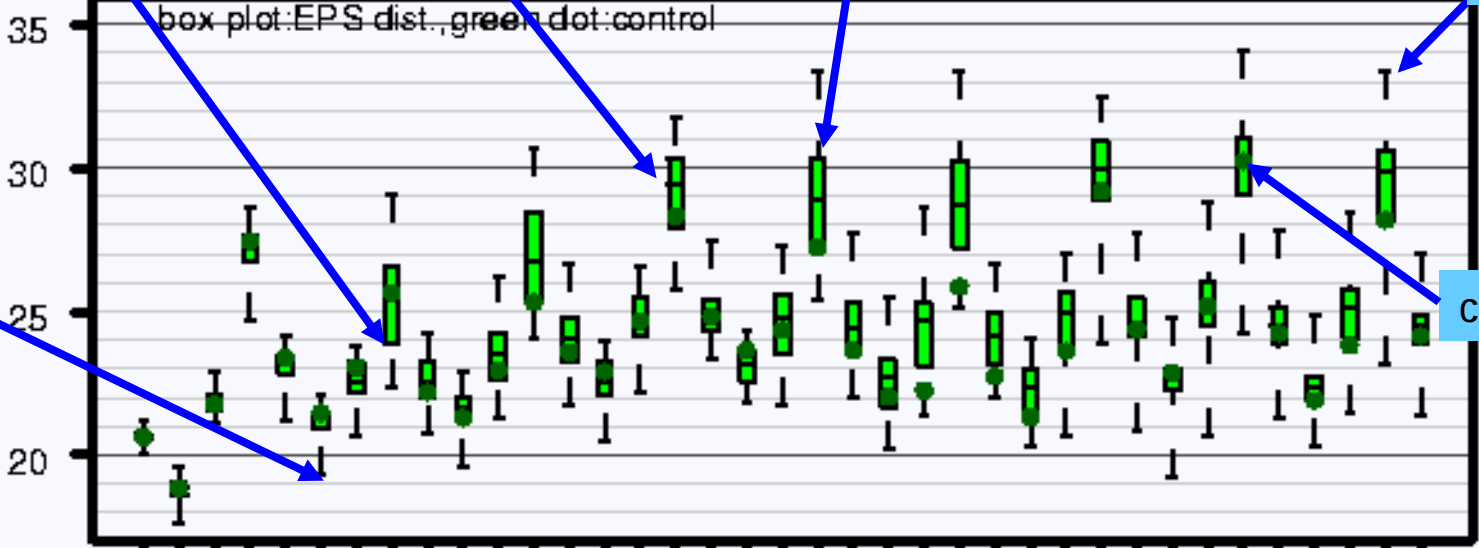
Element

6-hourly Surface Temp. (degreeC)

JMA ensemble forecast starting from 12UTC 2007/7/19

at model LAND grid(228m,lat=35.33,lon=139.5) corresponding to Tokyo

box plot:EPS dist., green dot:control



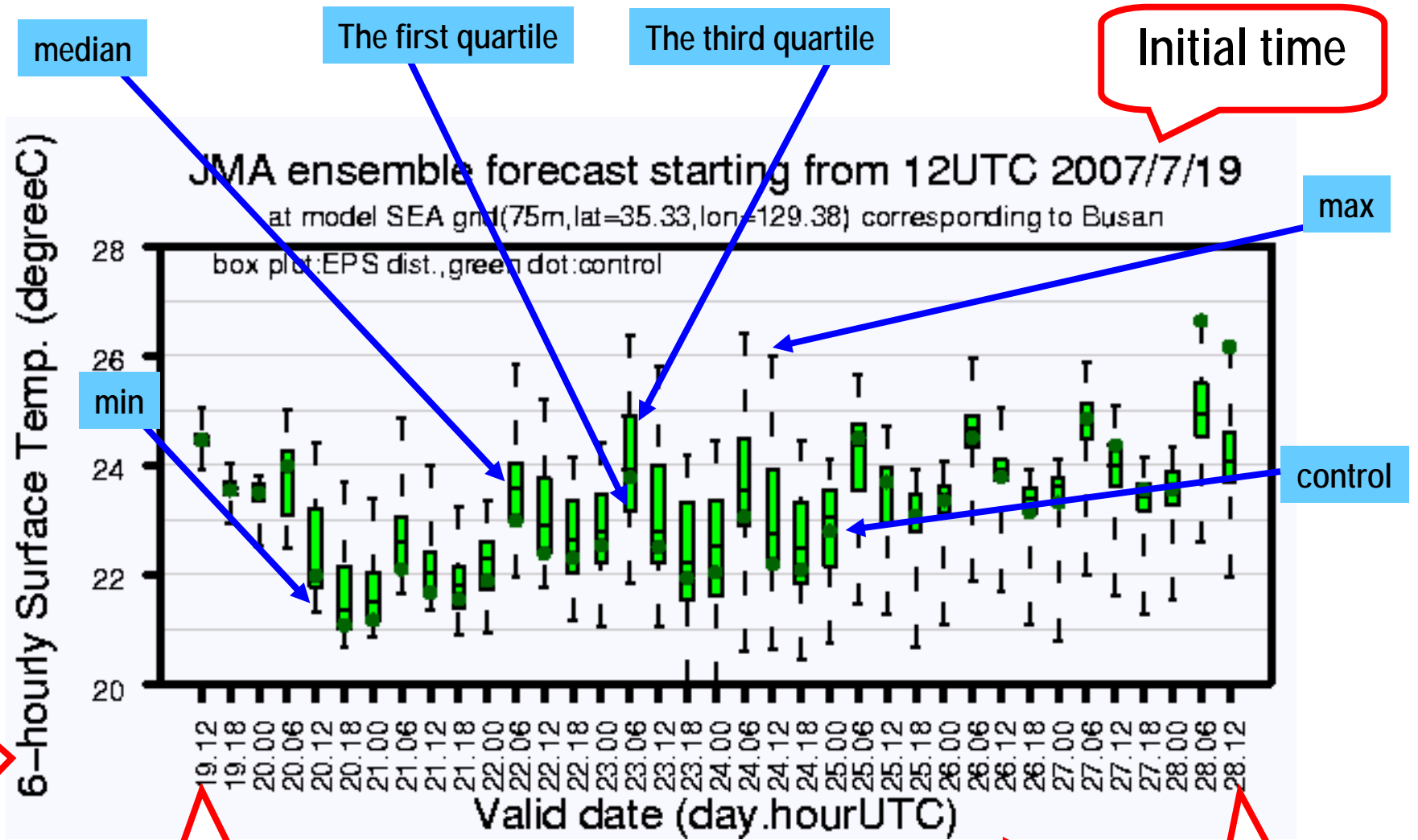
Valid date (day.hourUTC)

6 hourly

FT+0

FT+216

Precipitation rate (mm/6hr)



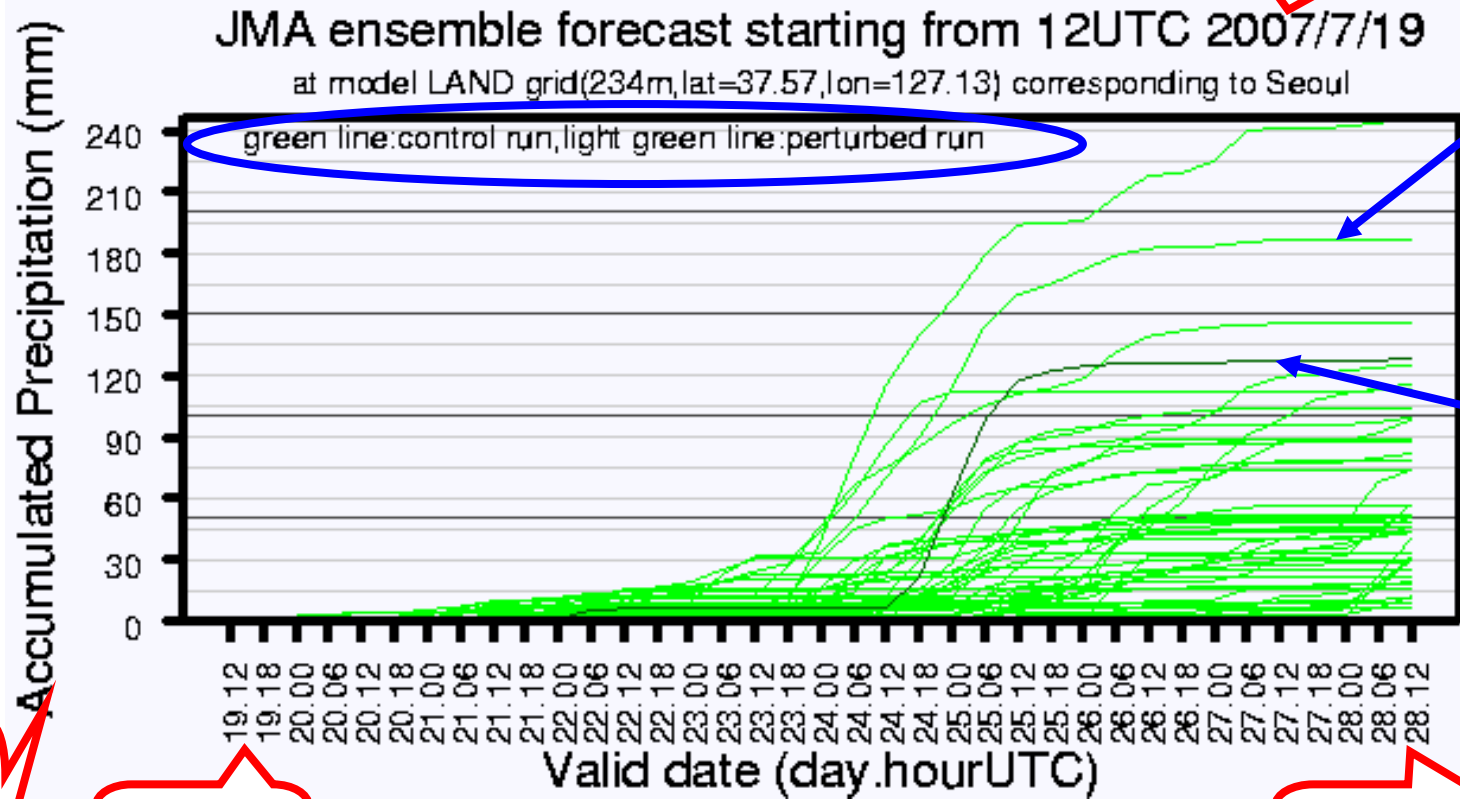
Element

FT+6

6 hourly

FT+216

Accumulated precipitation (mm)



Initial time

perturbed run

control

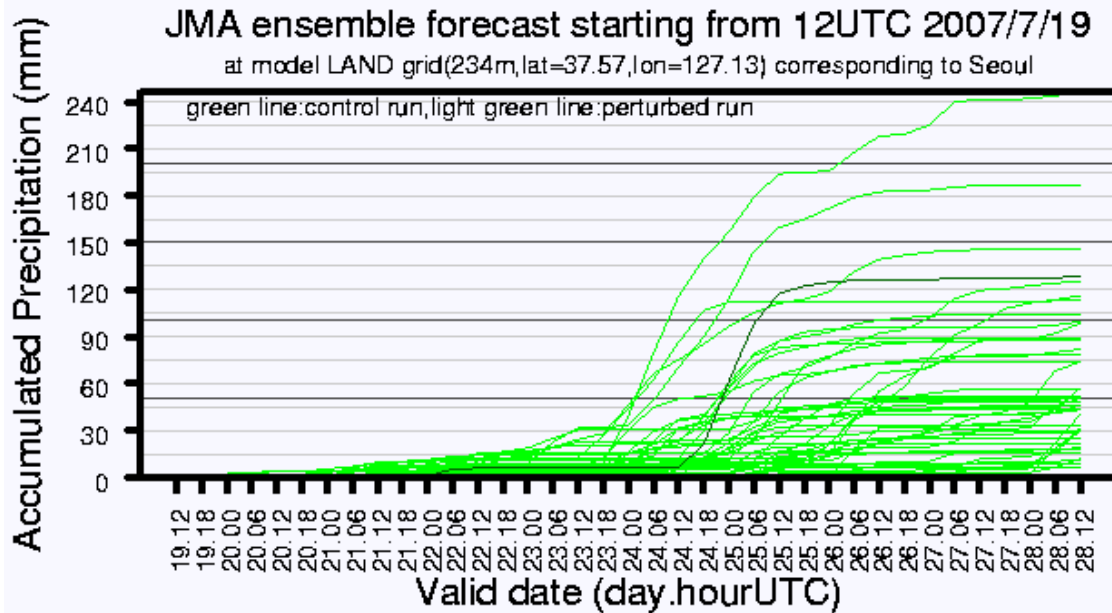
Element

FT+0

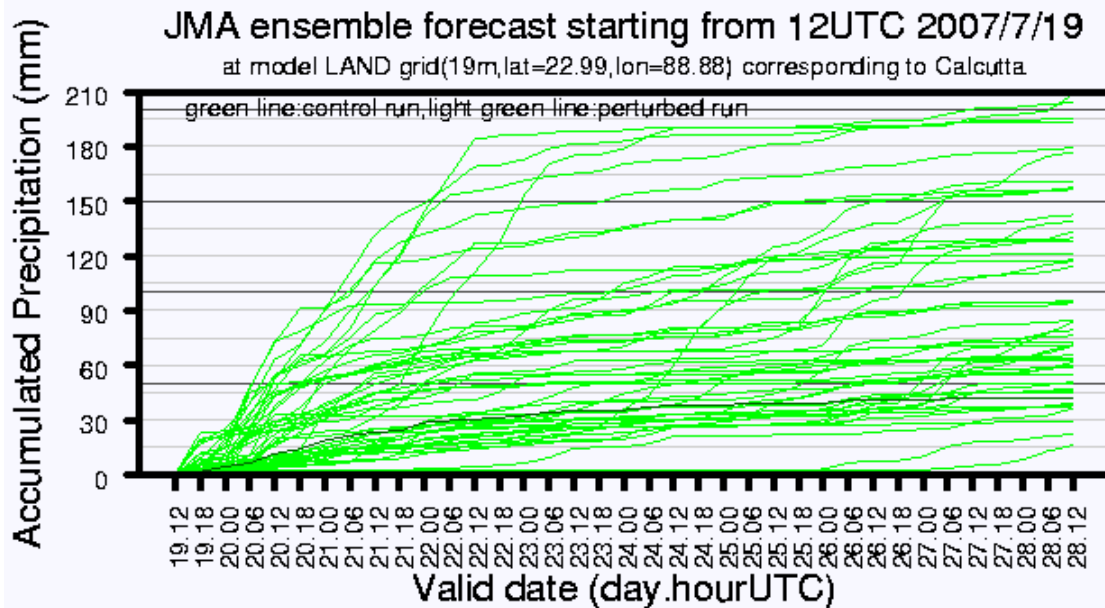
6 hourly

FT+216

Accumulated precipitation (mm)

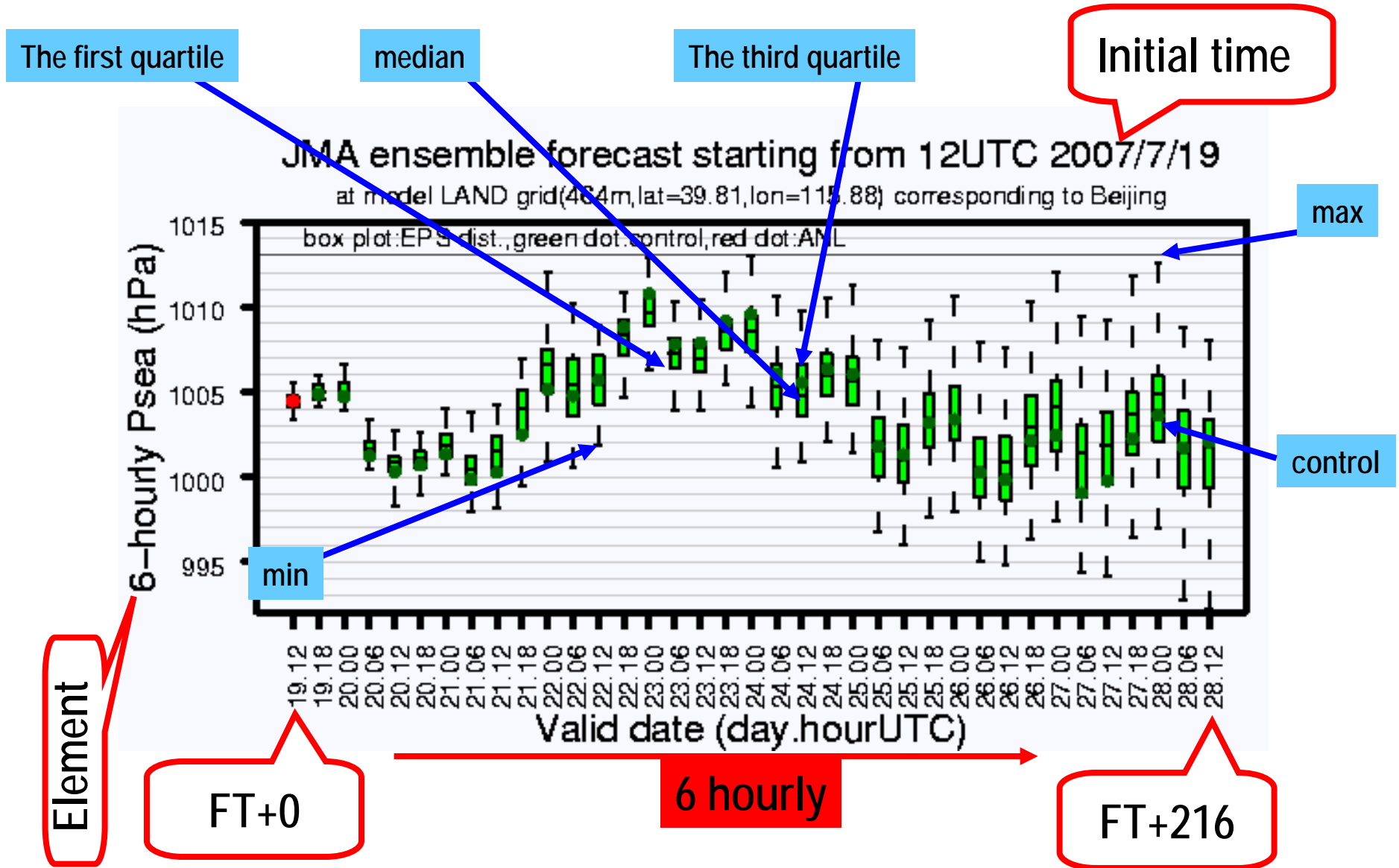


Heavy rain is predicted with some ensemble members at 24th July.

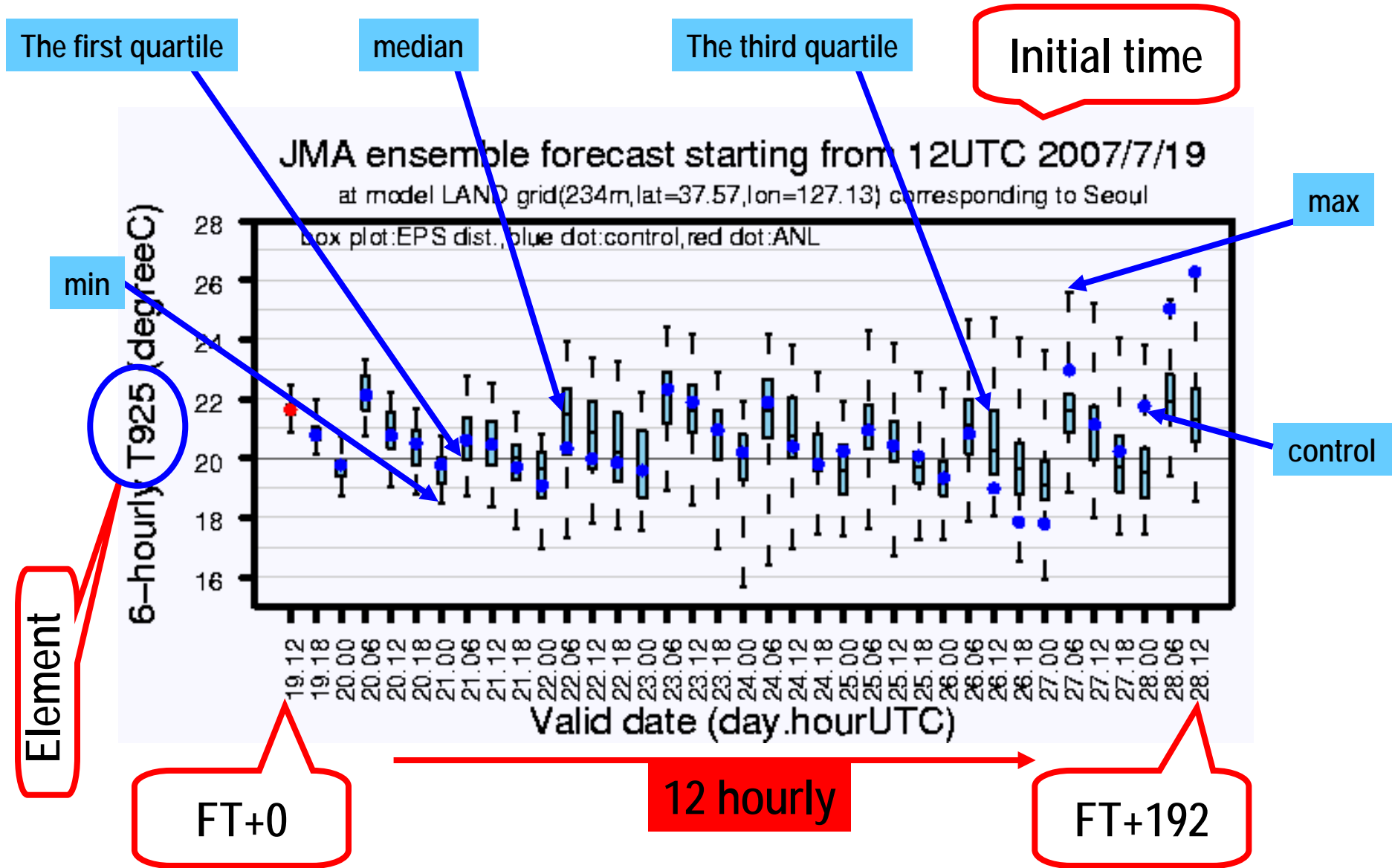


Heavy rain is predicted with many ensemble members.

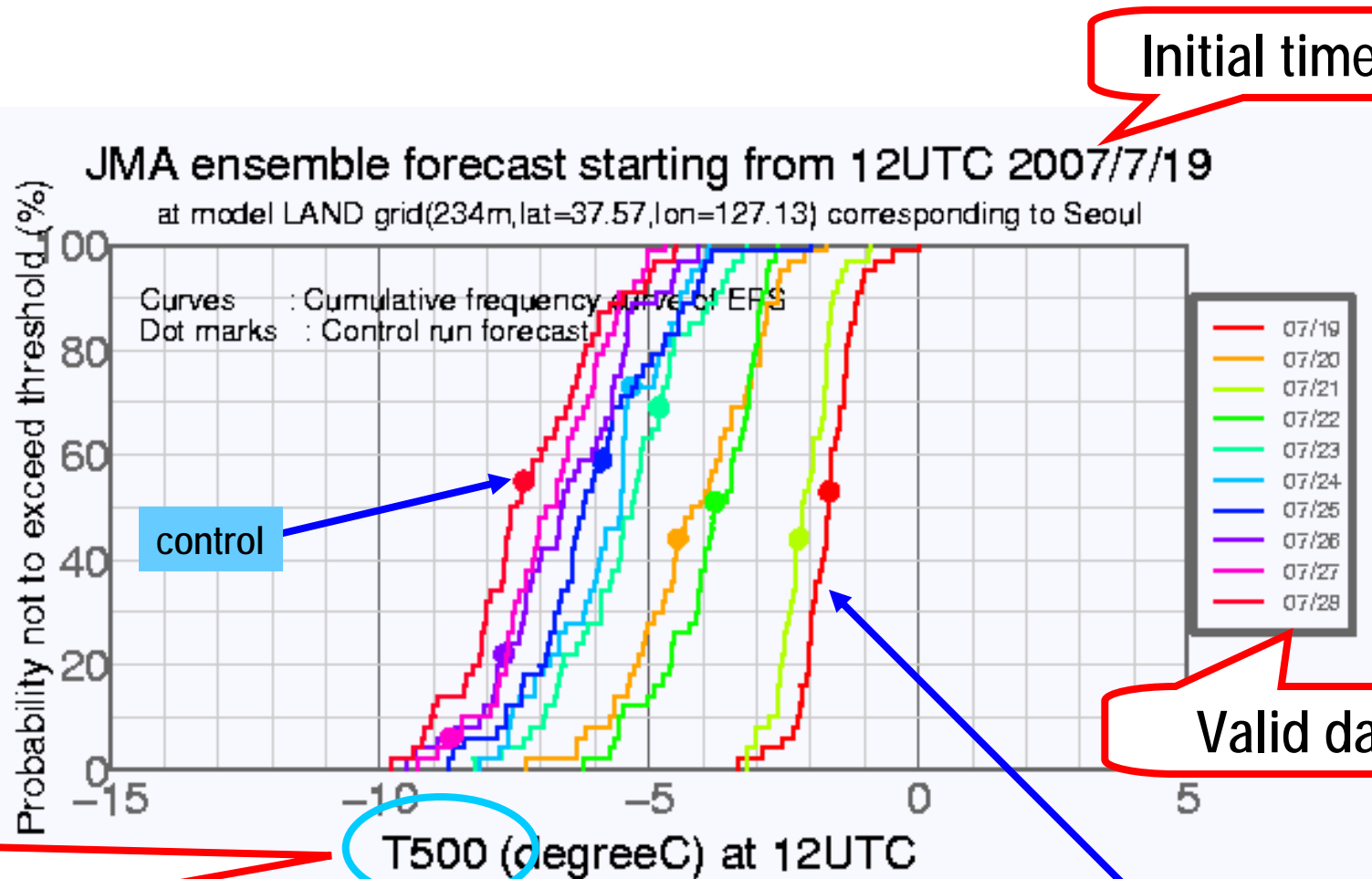
Sea level pressure (hPa)



Upper air temperature (degree C)



Upper air temperature (degree C) Probability (%) not to exceed threshold



Application of One-week EPS for heavy rain forecast

Plots of the accumulated rain observed by the rain gauge for 5 days



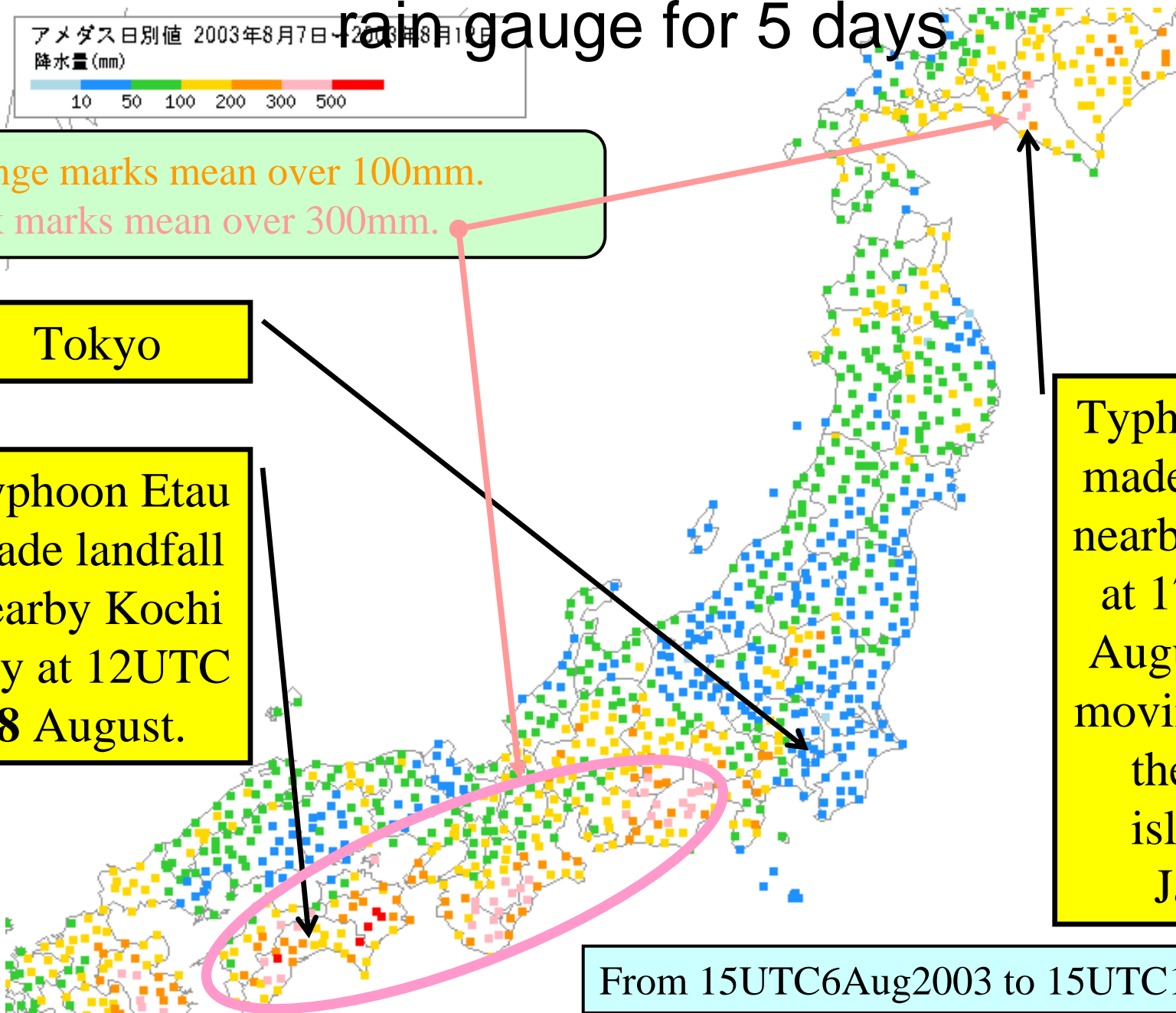
Orange marks mean over 100mm.
Pink marks mean over 300mm.

Tokyo

Typhoon Etau made landfall nearby Kochi city at 12UTC 8 August.

Typhoon Etau made landfall nearby Hidaka at 17UTC 9 August after moving across the main island of Japan.

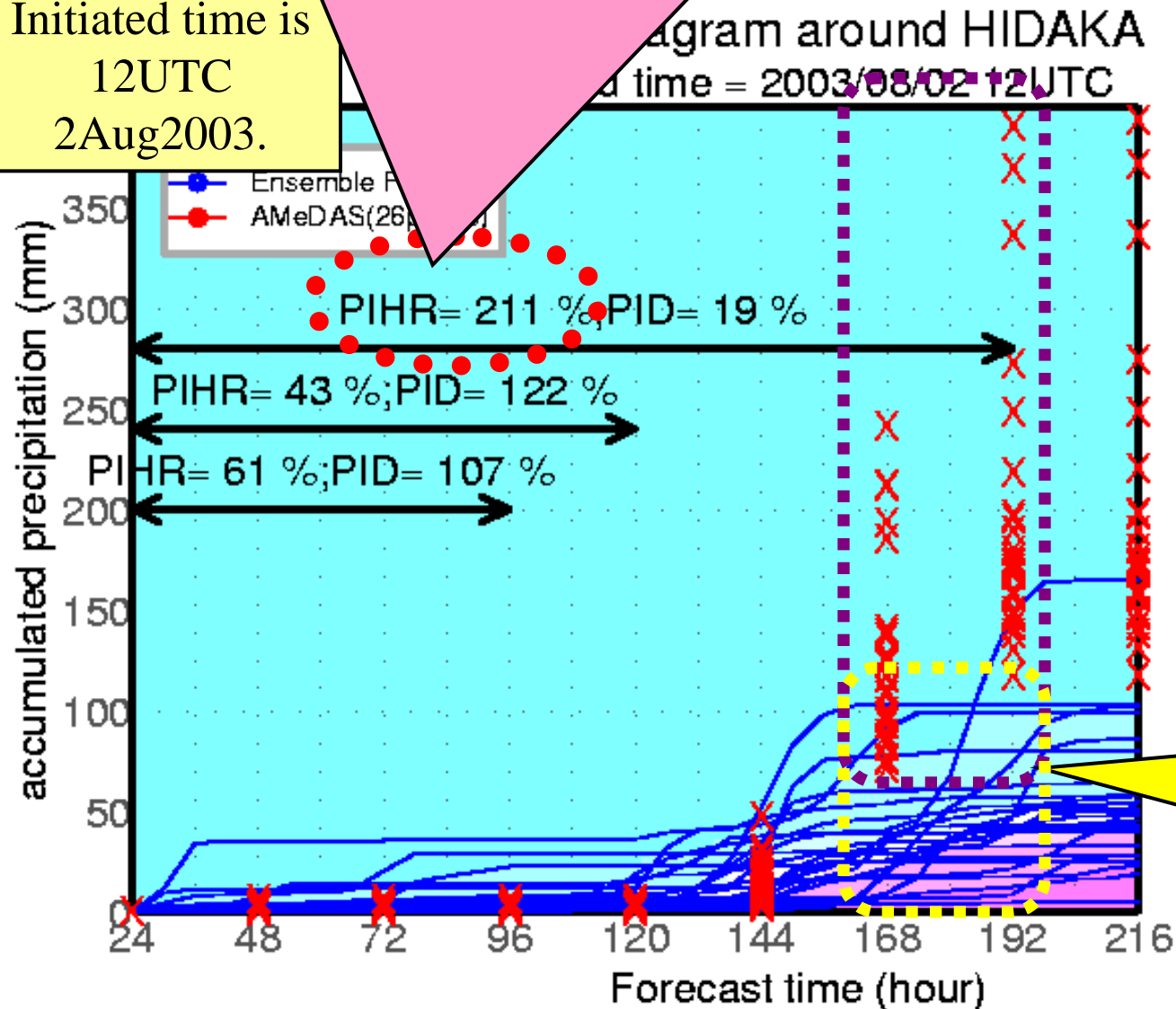
From 15UTC6Aug2003 to 15UTC11Aug2003



Accumulated precipitation around Hidaka

PIHR(Potential Index of a Heavy Rainfall) marks 211%, saying a high possibility of an abnormal rainfall in this period shown as the arrow.

Initiated time is
12UTC
2Aug2003.



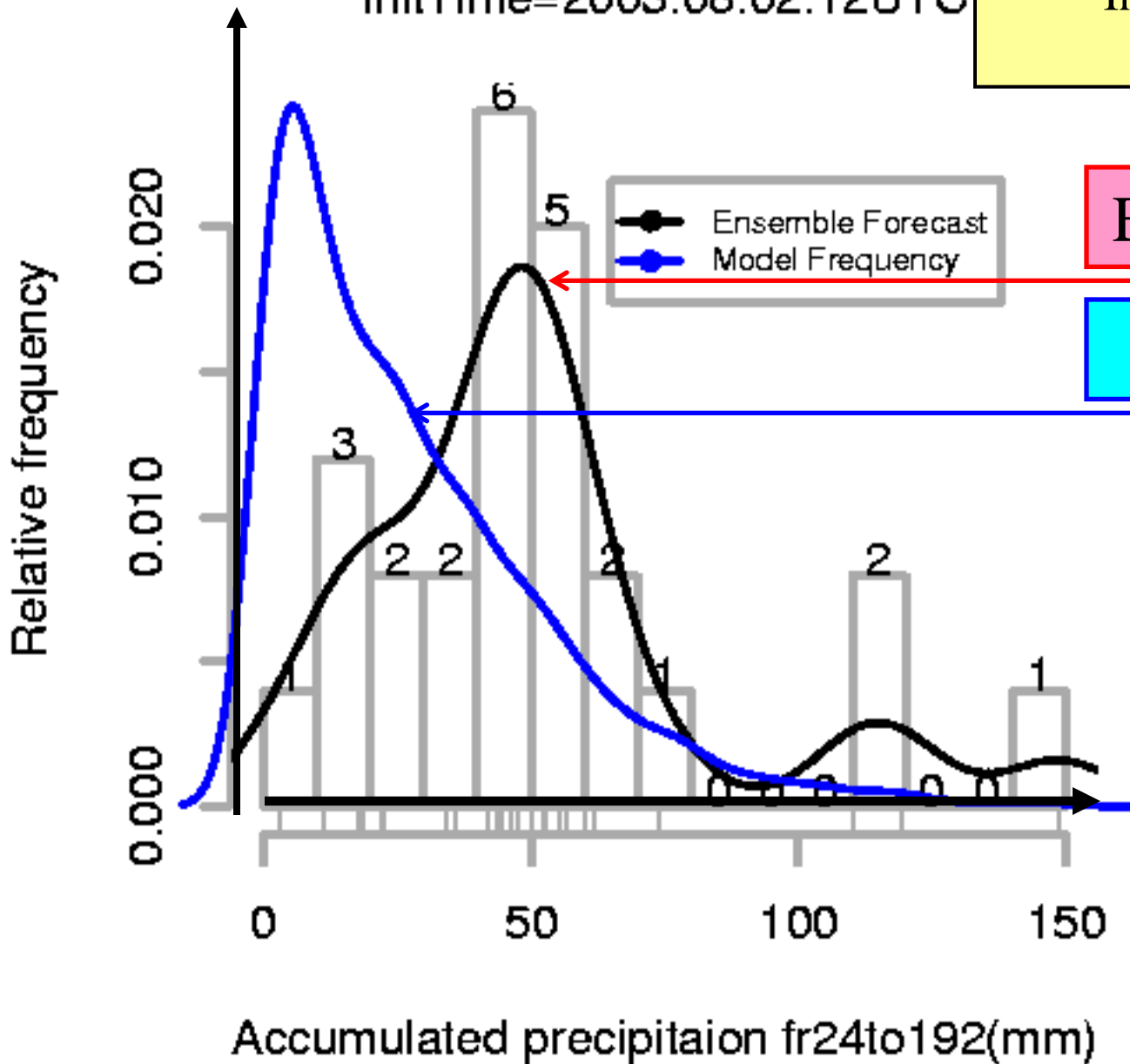
Any forecast was not enough to estimate the amount of the heavy rainfall.

How to calculate PI (1)

JMA-EPS HIDAHA(lat=42.88,lon=142.44)

InitTime=2003.08.02.12UTC

Initial time is 12UTC
2Aug2003.



Ensemble forecast

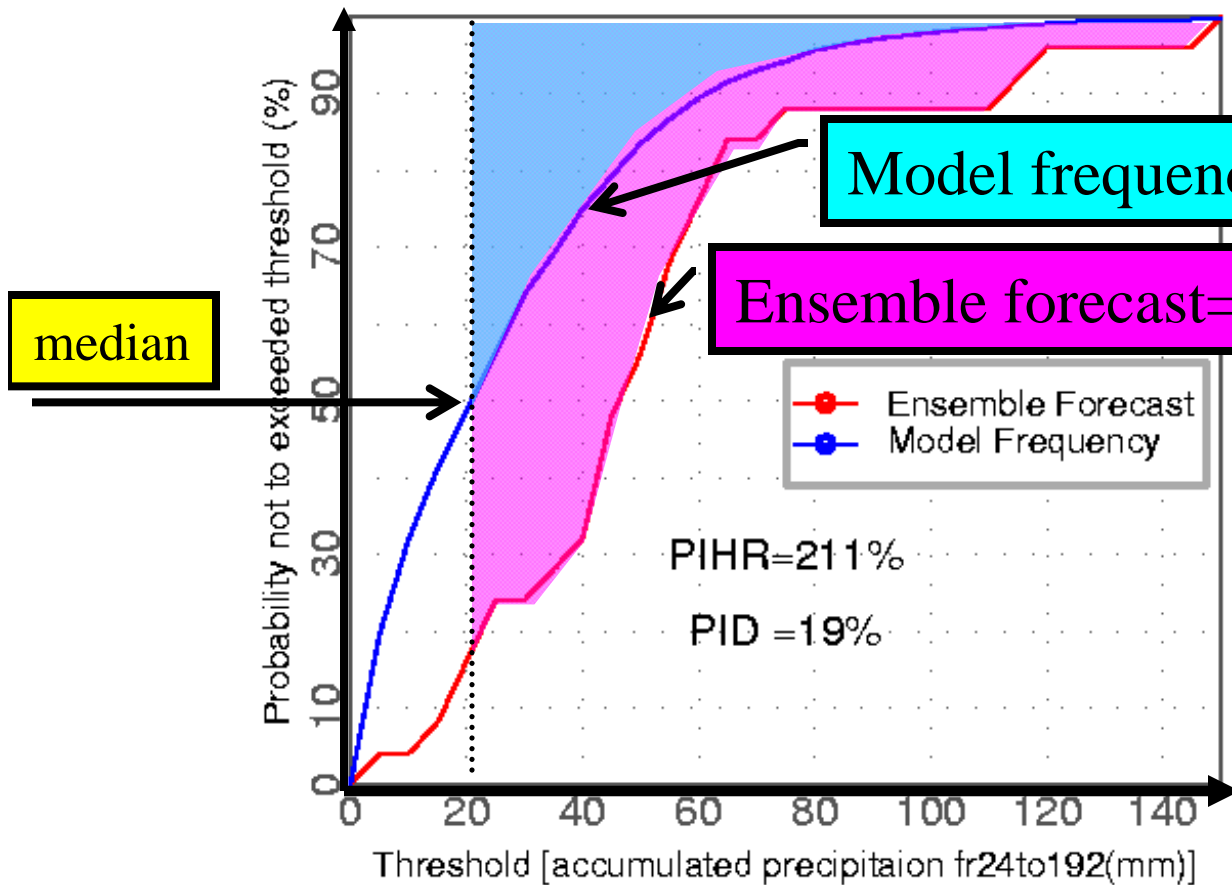
Model climate

The EPS distribution is compared with the model climate, not observed distribution.

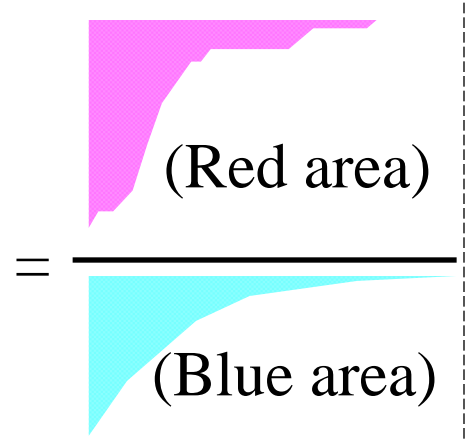
How to calculate PI (2)

The potential index is made from a difference between probability distribution function (PDF) of the EPS and that of the model climate.

Distribution Function HIDAKA (lat=42.88, lon=142.44)
InitTime=2003.08.02.12UTC

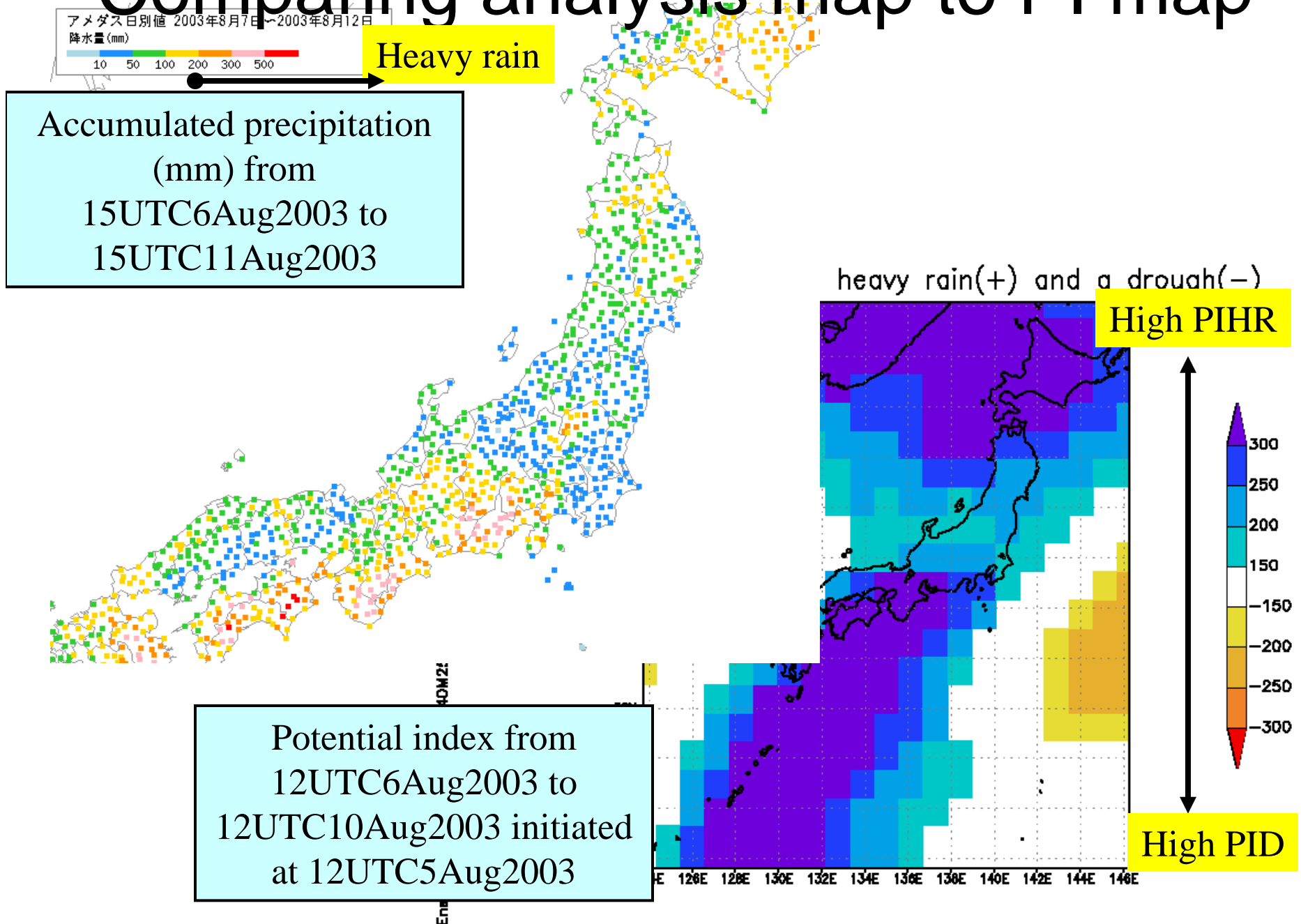


$$PIHR = \frac{\int_{1/2}^1 (1 - F(p)) dp}{\int_{1/2}^1 (1 - p) dp}$$



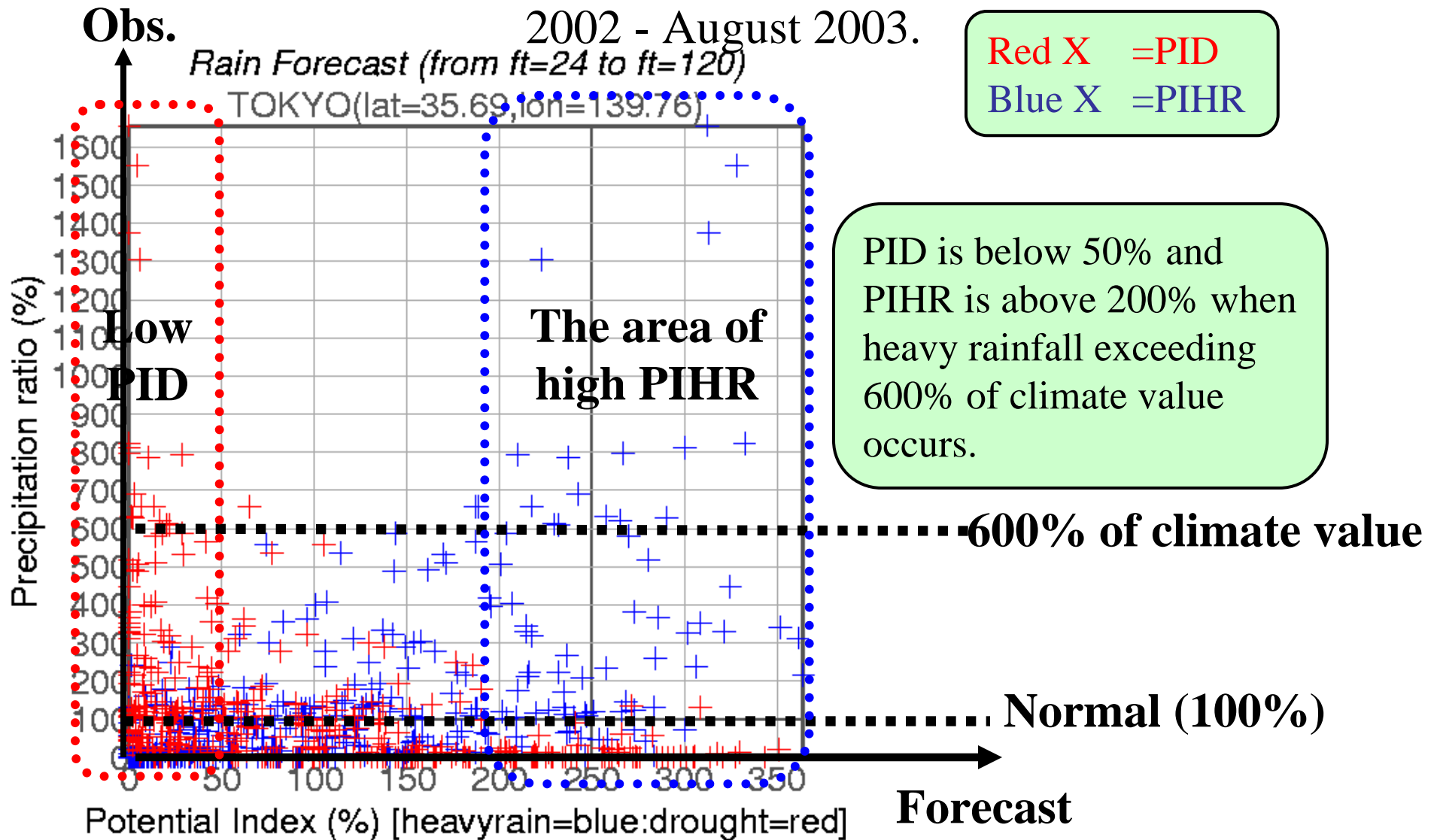
$$PID = \frac{\int_0^{1/2} F(p) dp}{\int_0^{1/2} p dp}$$

Comparing analysis map to PI map



Verification of PI

Scatter diagram for forecasts and the precipitation ratio (the rain gauge data) from 24hr to 120 hr at TOKYO for 365 cases for September

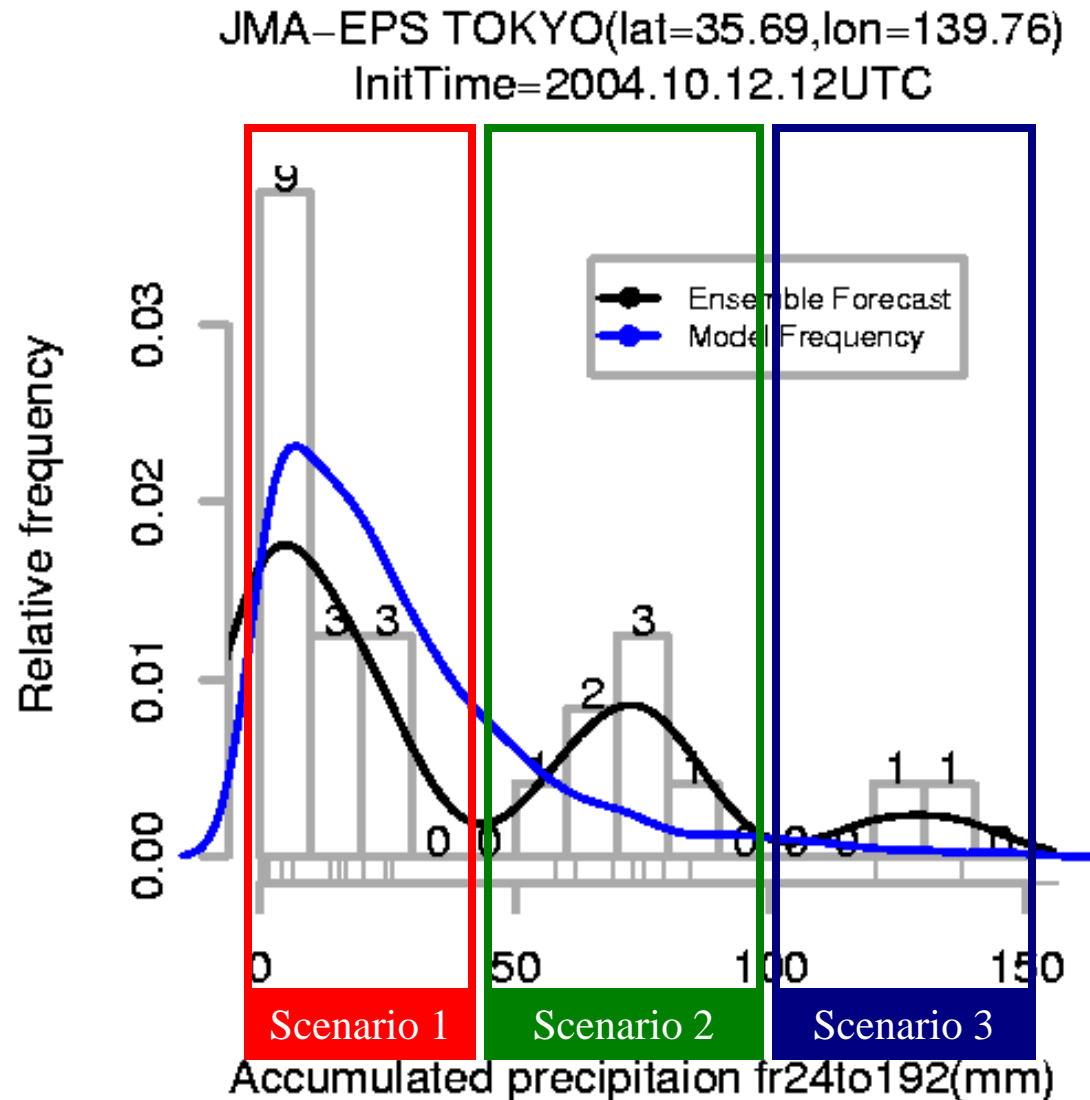


How to get a forecast scenario

- Histogram
- Spaghetti / Plume diagram
- Cluster analysis

Rainfall PDF derived from JMA-EPS

Histogram of accumulated precipitation from 24hr to 216hr at T106 land grid-point closest to Tokyo predicted by the 25 ensemble members. The initial time is 12UTC on 12th October 2004. Black line indicates a density function of the histogram. Blue line indicates a density function of daily model climate.

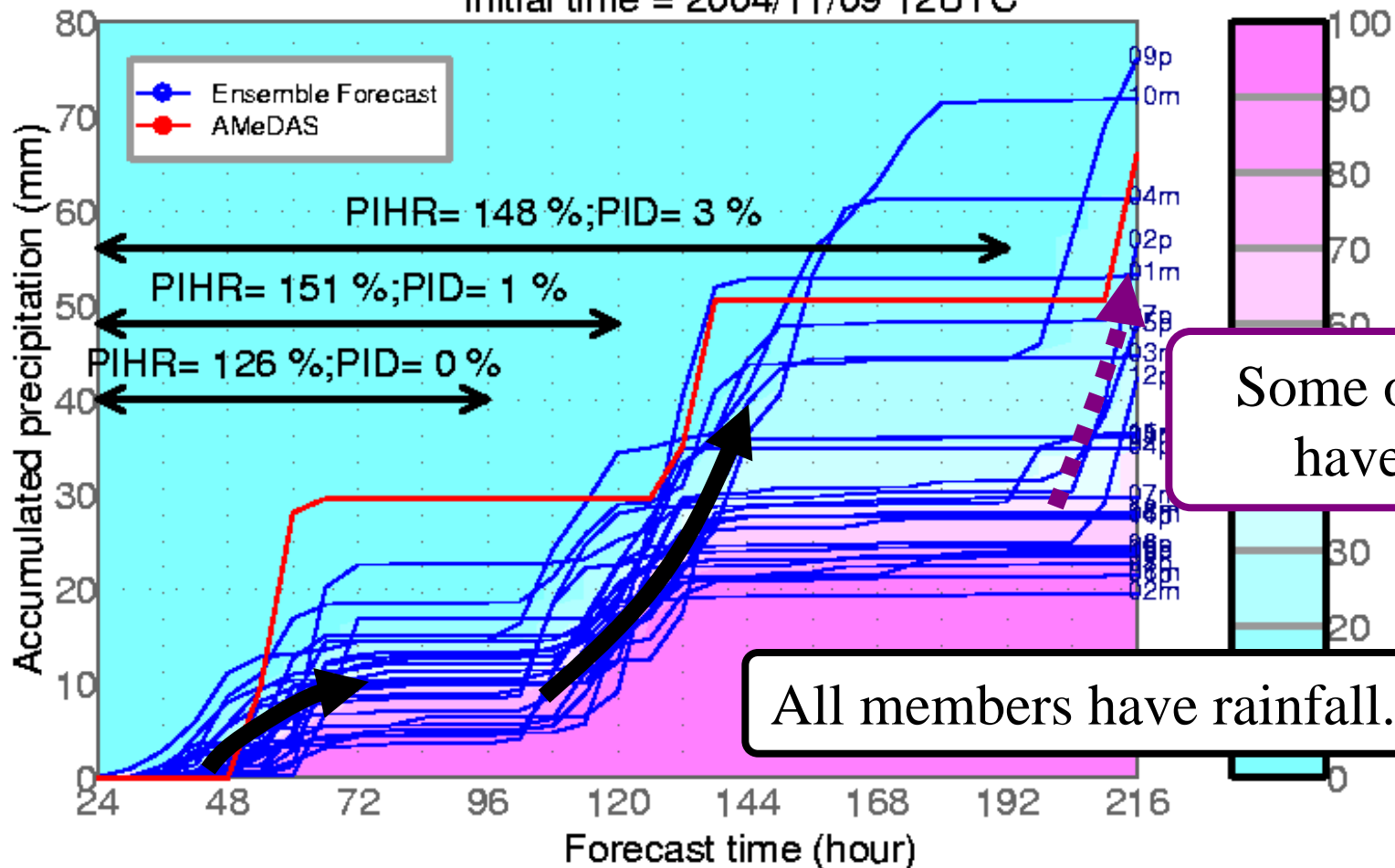


Accumulated precipitation at Tokyo

Plume diagram of accumulated precipitation at T106 land grid-point closest to Tokyo predicted by the 25 ensemble members (blue lines) as a function of forecast time from 24hr to 216hr. The initial time is 12UTC on 9th November 2004. Red line indicate the accumulated precipitation observed by the rain gauge at Tokyo. The shading shows a probability of accumulated precipitation defined as the occurrence ratio in EPS. Potential indices (PIHR and PID) are indicated for the period shown as arrows.

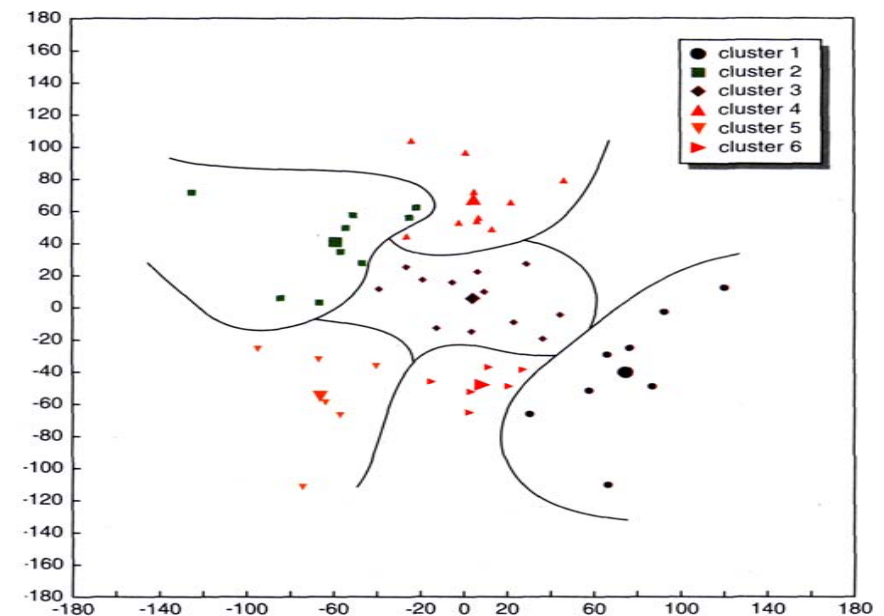
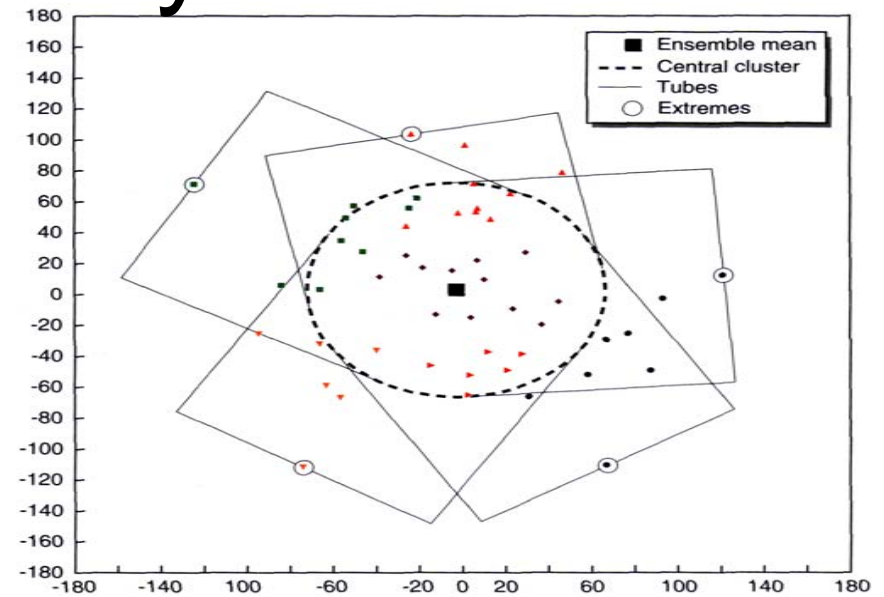
Plume diagram TOKYO(lat=35.69,lon=139.76)

Initial time = 2004/11/09 12UTC

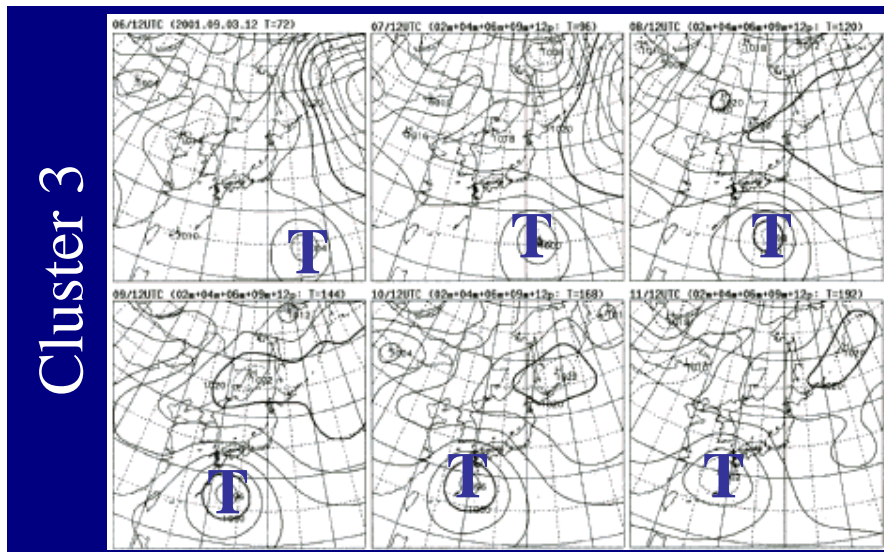
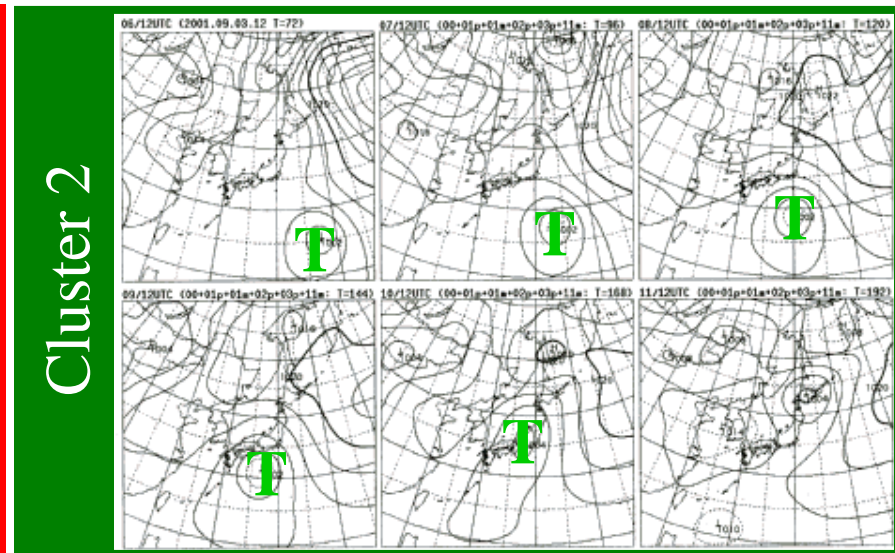
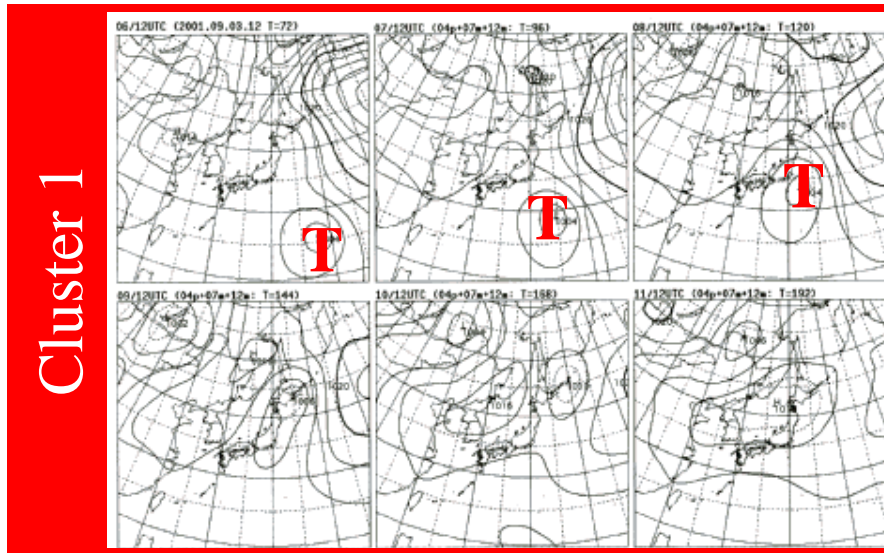


Cluster analysis

- Cluster analysis
 - JMA introduces Ward method.
- Tube method
 - developed by ECMWF
 - JMA also introduce a central cluster derived from a tube method.



JMA cluster analysis



Each panel has six maps, showing daily charts 72 to 192 hours ahead. Initial time is 12UTC on 3rd September 2001.

The typhoon moves toward the eastern part of Japan.

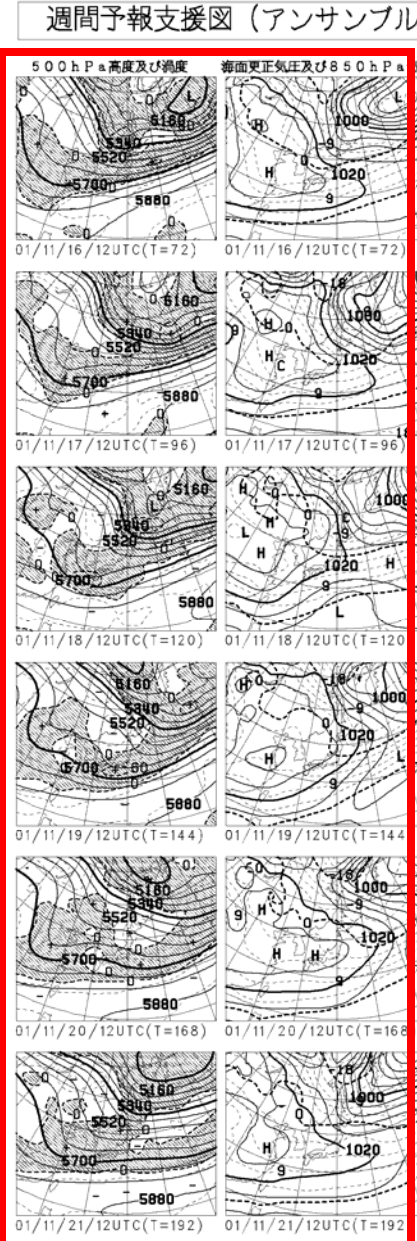
The typhoon moves toward central part of Japan

The typhoon moves toward south-western part of Japan.

A series of JMA EPS products

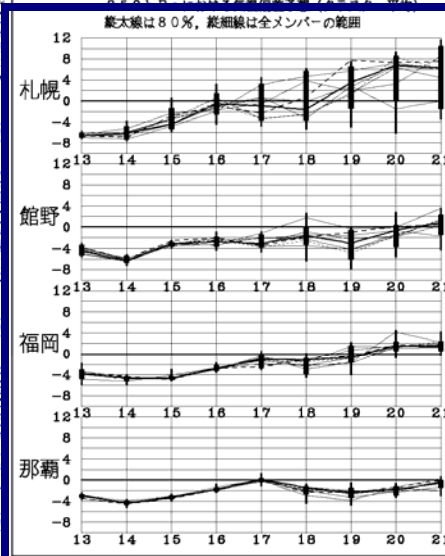
Central cluster charts

Left column is daily forecast maps of 500hPa geopotential height 72 to 192 hours ahead as an average of central cluster members of EPS. The next column is for 850hPa potential temperature



Cluster-analyzed spaghetti diagram

Six figures are daily spaghetti diagram 72 to 192 hours ahead. 25 members are grouped into 5 clusters. Average of members in each cluster for 500hPa geopotential height (solid line), PoP (dash line) and normalized spread (number) are shown.



Cluster-analyzed plume diagram

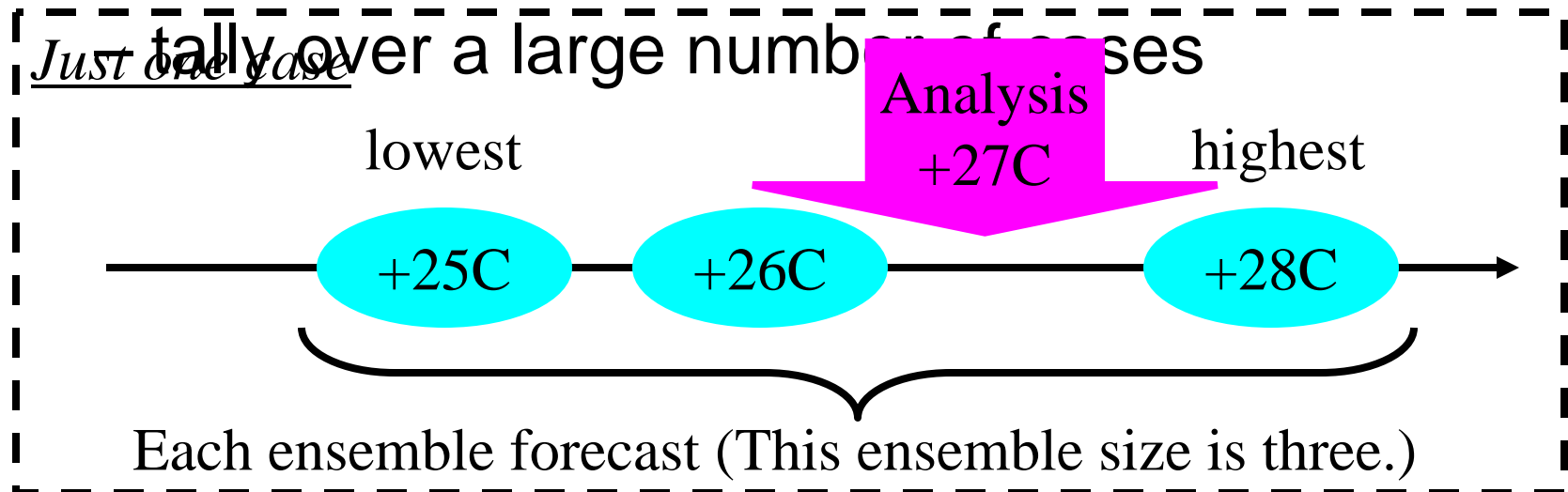
The figure shows 5 cluster averages, control forecast and high-resolution forecast of temperature anomaly at 850hPa for four cities of Japan

Whether the ensemble
forecast captures the analysis
or not?

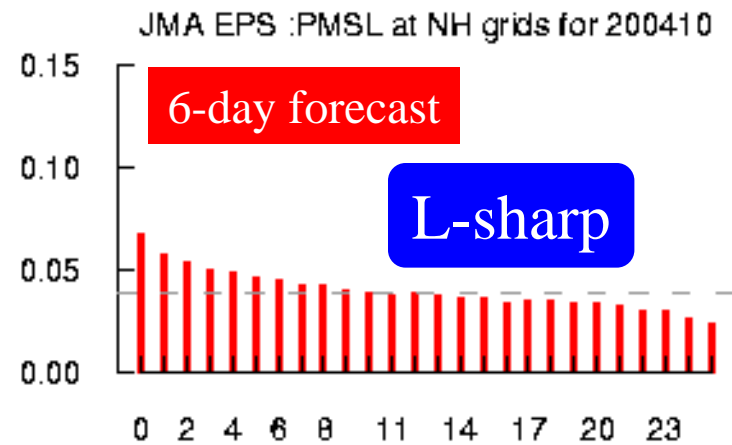
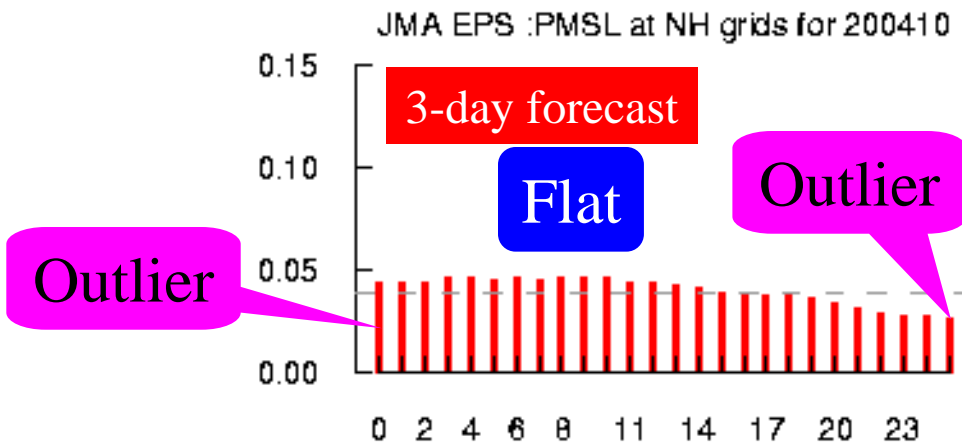
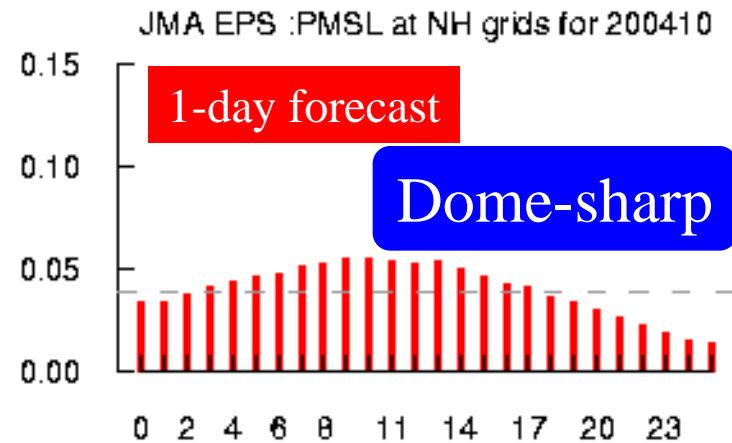
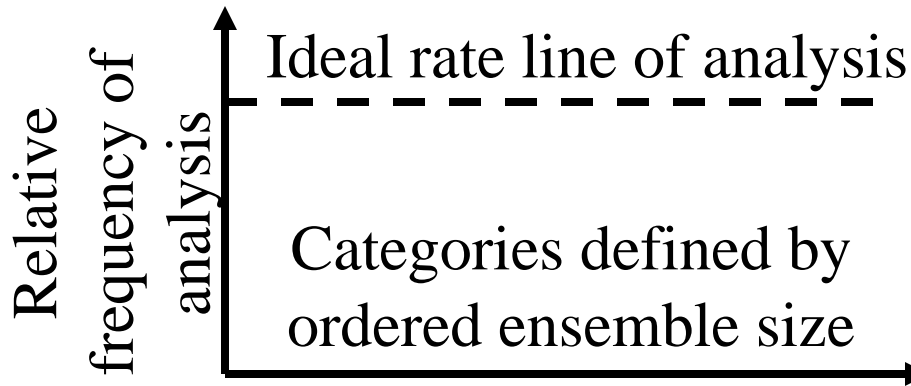
Talagrand diagram (1)

- Preparation

- order the members of the ensemble forecast from lowest to highest
- identify $n+1$ ranges including the two extremes
- identify the location of the observation



Talagrand diagram (2)



Three talagrand diagrams for 1-, 3- and 6-day ensemble forecasts of sea level pressure in the Northern Hemisphere extratropics.

Talagrand diagram (3)

- Interpretation
 - Flat indicates the ensemble spread is suitable so that the ensemble forecast capture the analysis well.
 - A U-shaped distribution indicates the ensemble spread is not enough to capture the analysis.
 - A dome-shaped distribution indicates the ensemble spread is too large.
 - L-shaped and J-shaped distributions indicate the NWP model has over- and under-forecasting bias, respectively.

Operational use of One-week EPS

- **Stamp map**
- **The ensemble mean and spread**
- **Reliability Index**
- **Guidance of the maximum and minimum temperature**

One week forecast for end users

週間天気予報

The forecasts are almost based on one week EPS

日付	15 金	16 土	17 日	18 月	19 火	20 水	21 木
天気	雨	雨後曇り	曇り	晴れ時々曇り	晴れ時々曇り	晴れ時々曇り	晴れ時々曇り
降水確率(%)	70	70	70	70	70	20	20
最低気温(℃)	21(±2)	21(±2)	22(±2)	23(±2)	23(±2)	23(±1)	23(±2)
最高気温(℃)	27(±2)	27(±2)	27(±2)	28(±2)	28(±2)	28(±1)	27(±2)
日別信頼度	A	A	A	A	A	B	B
平年値	降水量の合計			最低気温		最高最低気温	
銚子	平年並			平年並		最高気温 28.0℃	

Categorical weather forecast

Probability of daily precipitation (%)

Minimum and maximum temperatures with variability range

Reliability index (A,B or C)

Climatological data for reference

Weather outlook

概況
関東甲信地方
向こう一週間は、期間の前半は気圧の谷や前線の影響で曇りや雨の日が多いでしょう。期間の後半は高気圧に覆われて晴れる日が多い見込みで気温は、最高気温・最低気温共に、期間の前半は平年並か平年より低くなる見込みです。期間の後半は平年並の所が多いでしょう。降水量は平年より多いでしょう。

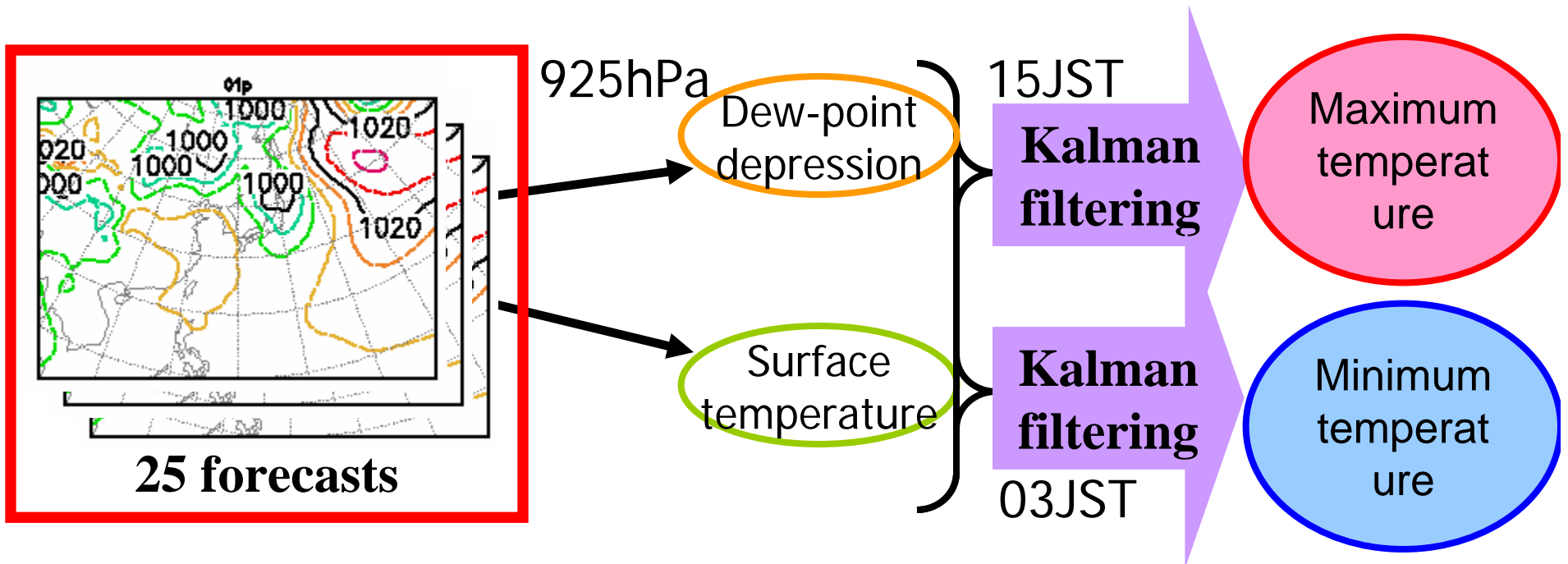
週間天気予報の信頼度

- A(高い信頼度): 予報期間前半の平均的な精度と同程度 (B(中程度の信頼度)、予報期間後半の平均的な精度と同程度)

Application of one-week EPS to temperature forecast

How to calculate the daily maximum and minimum surface temperature

- The daily maximum and minimum surface temperatures at about 180 cities of Japan are calculated for each member by using a Kalman filtering technique.
- Ensemble GPVs at target cities are calculated through interpolation.
- The maximum and minimum temperatures are calculated using the previous Kalman filtering coefficients and two predictors at 15JST and 03JST, respectively.



Probability Density Function of the daily maximum temperature

Surface temperature at 15JST derived from one-week EPS

GPV T2m Interpolated to TOKYO

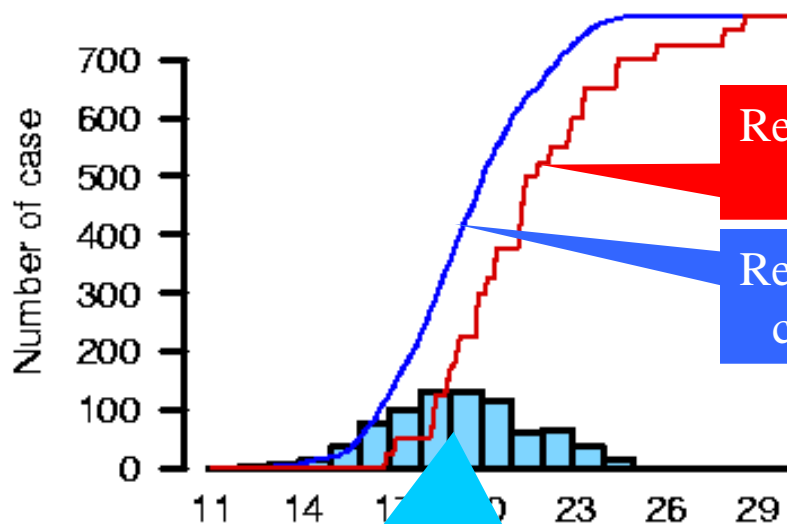
Lead time : 5days ; Peiod : 2003/10/1 – 2003/10/31

Kalman filtering

Maximum temperature

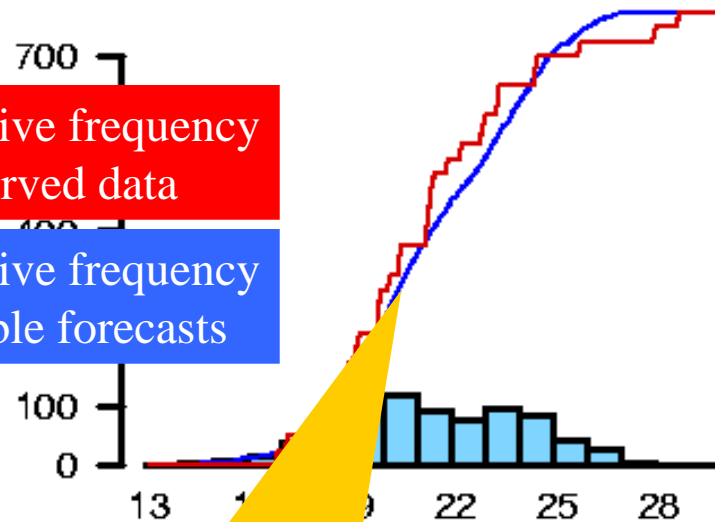
Guidance Tmax at TOKYO

Lead time : 5days ; Peiod : 2003/10/1 – 2003/10/31



Relative Cumulative frequency curve of observed data

Relative Cumulative frequency curve of ensemble forecasts

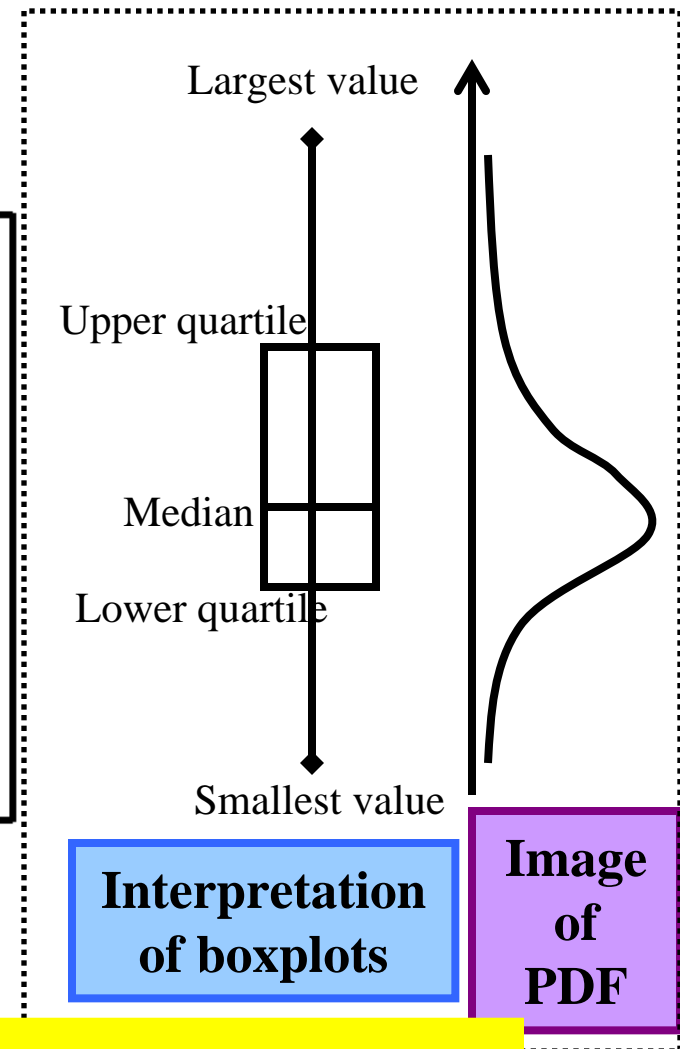
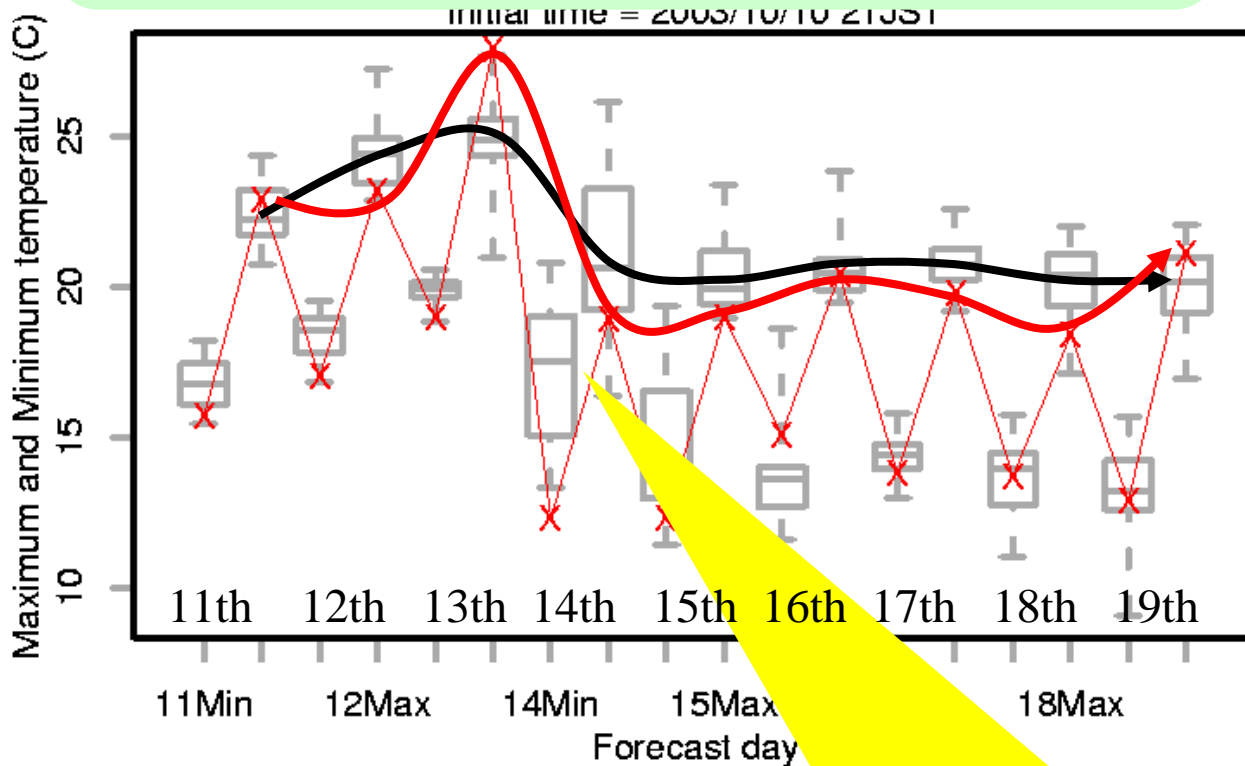


The bias is removed!!

Frequency distribution of all ensemble 5-days forecasts at TOKYO for 1st-31th October 2003

EPSgram of daily Max/Min guidance

Initial time : 12UTC10October2003
Valid day : 11,12,13,14,15,16,17,18,19
Target point : TOKYO



X marks : Observed value
Boxplots : Ensemble guidance

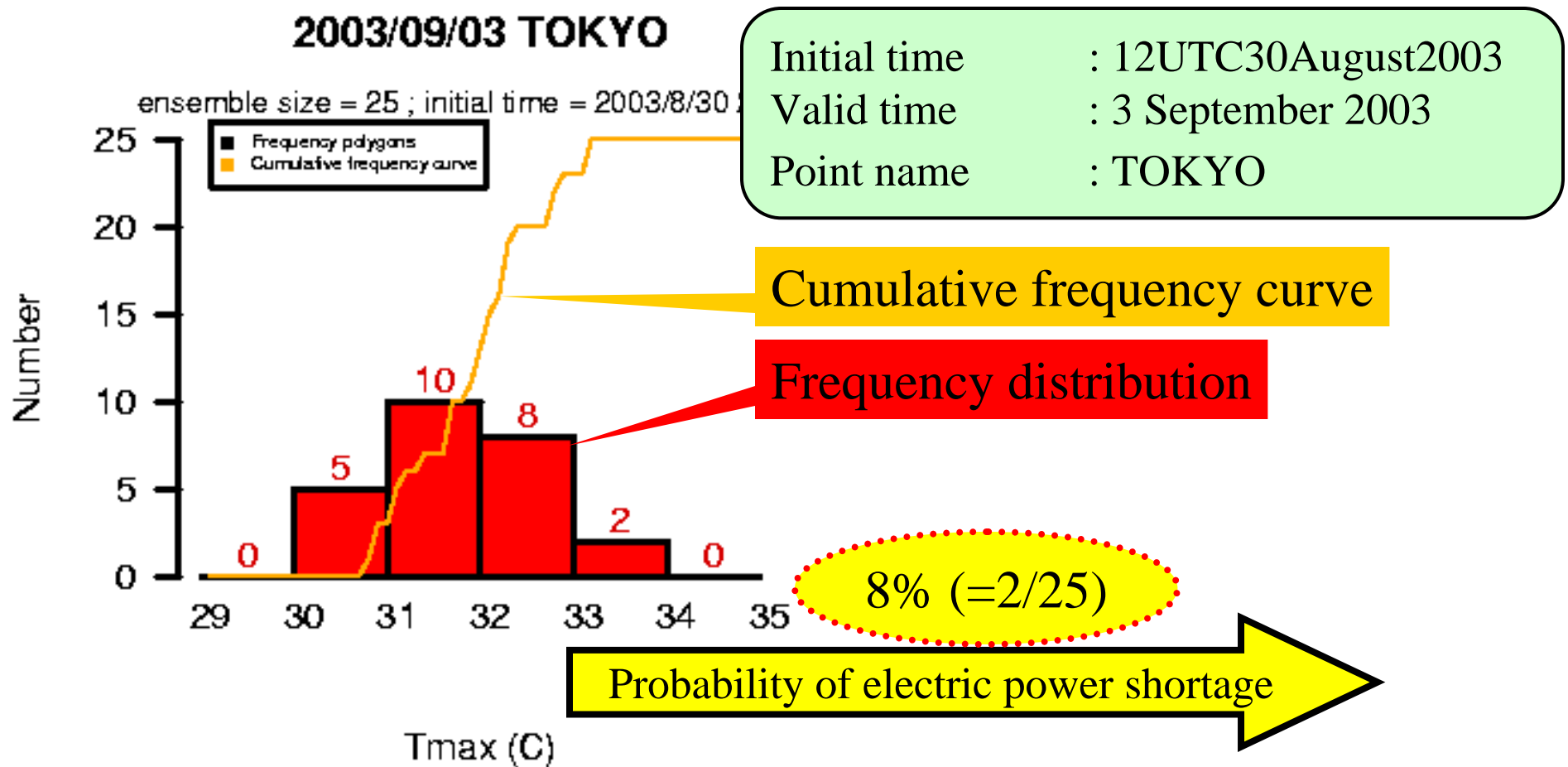
The ensemble guidance says that the spread is large when the trend of the max. temp. changes.

Product of extreme high temperature

- Offered to forecasters and Electric Power Company
- They use as a probabilistic measure of the extreme high temperature.
- If the maximum temperature exceeds a certain level (33C at Tokyo), consumption of electric power increases rapidly to exceeds the limit of supply, resulting in power shortage.

PDF of daily maximum temperature

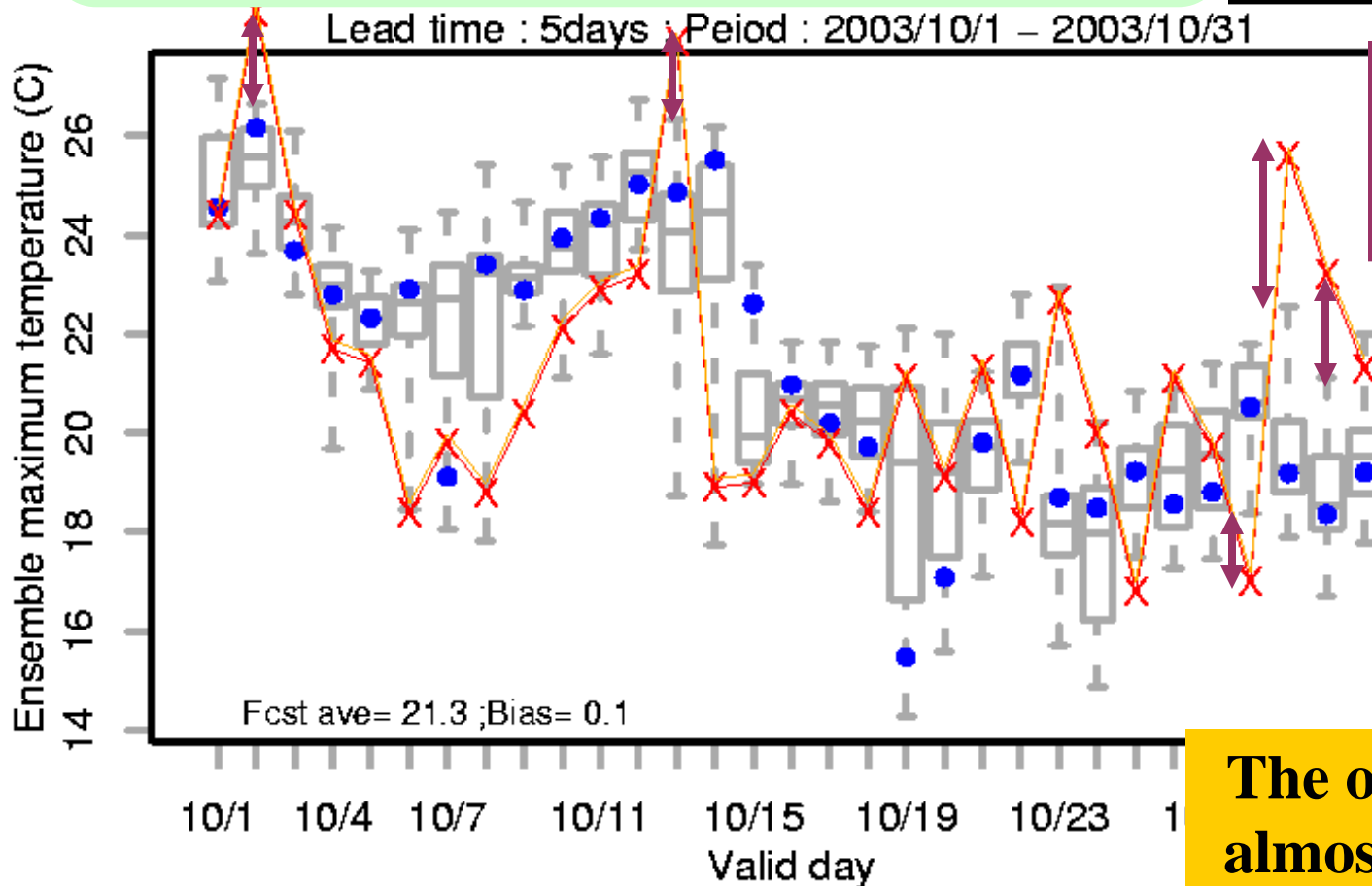
The maximum temperatures at about 180 cities of Japan are calculated for each member by using a Kalman filtering technique. The PDF is a frequency distribution of one week EPS members at 9 local sites in Tokyo metropolitan area. The lead time is 3day.



Verification of daily Maximum guidance

Valid day : from 1st to 31th of October 2003
Forecast day : 5 days
Target point : TOKYO

X marks : Observed value
Boxplots : Ensemble guidance
Blue dots : Control guidance



The spread is not enough to catch the extreme cases.

The observed value is almost in the range of the ensemble guidance.

Conclusion of the application of One-week EPS to temperature forecast

- Temperatures derived from EPS represent the actual PDF very well.
- The Kalman filtering is effective to remove the systematic bias from the model results such as surface temperature derived from EPS.
- Extreme cases, especially surface variables, are not always caught up by all ensemble members.
 - Increase of the ensemble size
 - Introduction of a new guidance for expanding the spread
 - Introduction of another calibration technique (say later)

Typhoon EPS

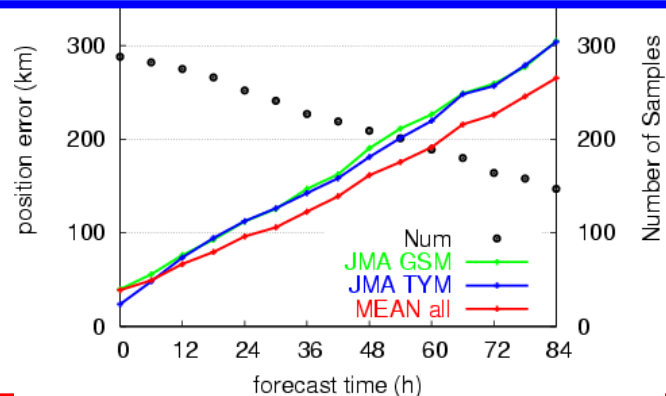
Motivation for developing Typhoon EPS

JMA plans to operate the Typhoon Ensemble Prediction System (EPS) from the TC season in 2008, following experimental operations in 2007.

Motivation 1

Expected error reduction of deterministic track forecasts by using statistical methods such as ensemble mean or cluster analysis.

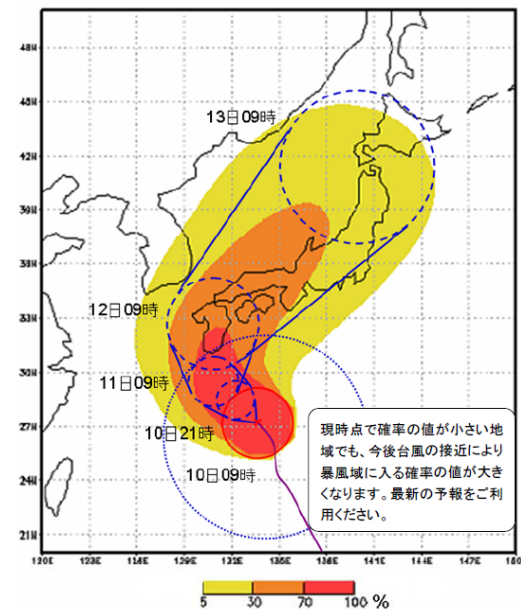
Mean distance error of **ensemble mean** track forecasts consisted of ECMWF, UKMO, JMA-GSM and JMA-TYM



Mean track forecasts error can be statistically improved. Error reduction is over 30km at +72h.

Motivation 2

Estimating track forecasts uncertainties which differ from day to day and applying to beneficial use of probabilistic track forecasts.



Specifications of the Typhoon EPS

The operation of TYM will be stopped in this November when the Typhoon EPS starts its operation.

	Current TYM	Typhoon EPS
NWP model	regional model	global model
resolution	24(km) x 24(km) with 40 layers	60(km) x 60(km) with 60 layers
initial time	00, 06, 12, 18UTC	00, 06, 12, 18UTC
forecast time	84 hours	132 hours
number of targeted typhoons	2	3
member size	1 (deterministic forecast)	11 (1 non-perturbed run + 10 perturbed run)
initial condition	-	singular vector method
model ensemble technique	-	not considered

Intensity forecasts are supported by 20km GSM which will be operated from this November.

3 typhoons at the same time !!!

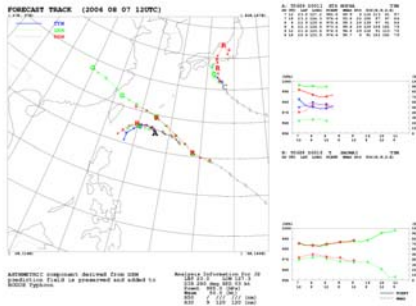
We sometimes have 3 or more TCs at the same time in the Western North Pacific

Typhoon track forecasts for typhoon MARIA, SAOMAI, BOPHA
initial time 2006.08.07.12 UTC

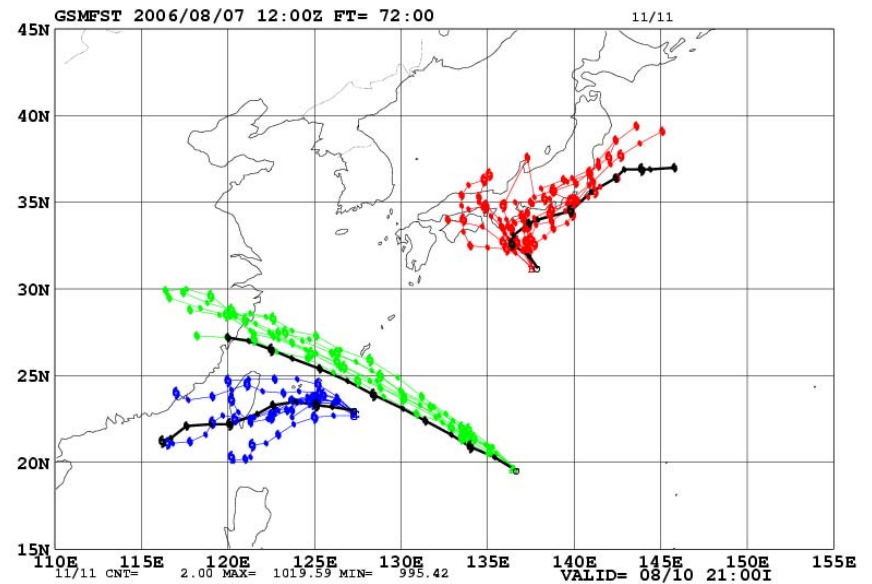
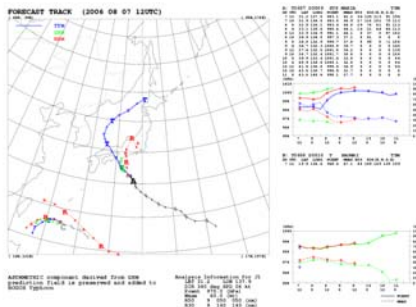
Current TYM

Typhoon EPS

J1



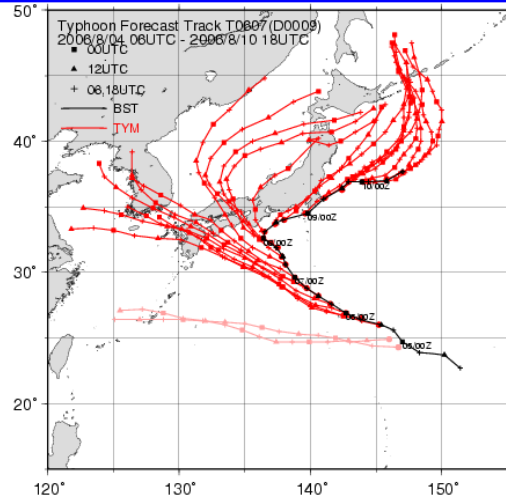
J2



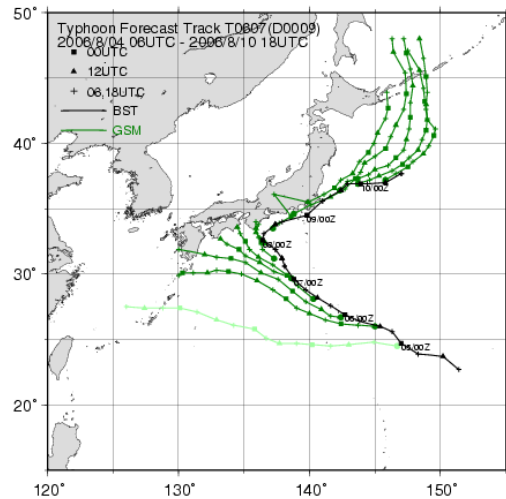
Case Study: Typhoon MARIA (T0607)

All track forecasts by TYM and GSM for MARIA.
Initial time is from 2006.08.05.00 to 2006.08.10.18 UTC.

TYM forecasts

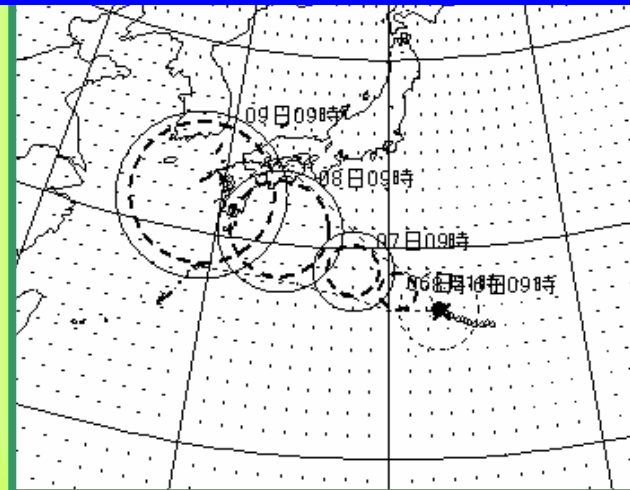


GSM forecasts

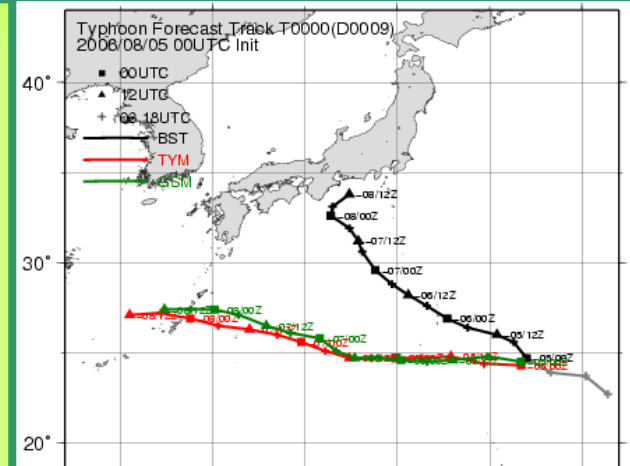


Initial time: 2006.08.05.00UTC

Current forecast



TYM and GSM



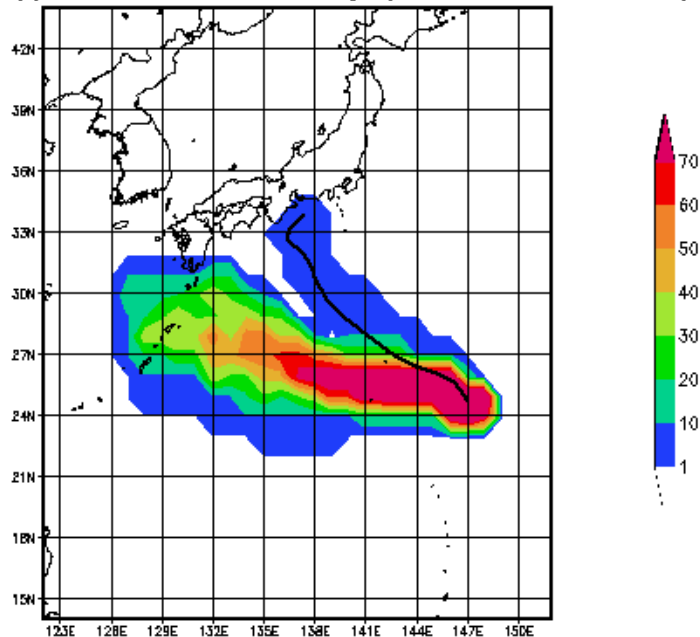
In the early stage of MARIA, TYM and GSM failed to express the recurvature.

Typhoon EPS for MARIA

Initial time: 00UTC 5Aug 2006

Typhoon ensemble forecast
(strike probability map)

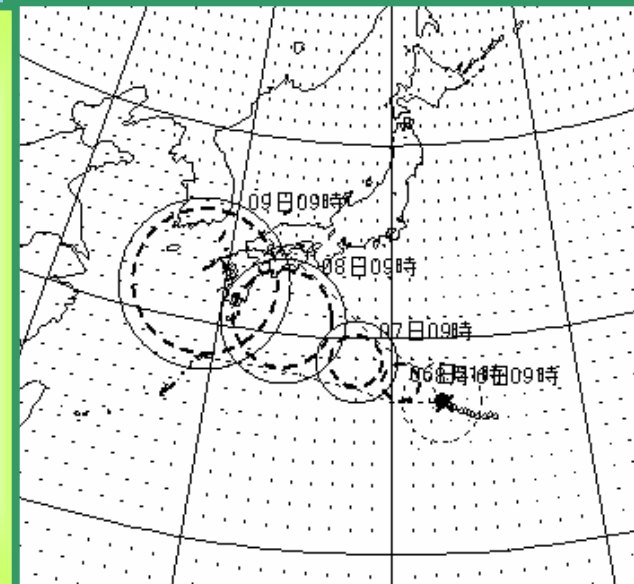
D0009 Typhoon Strike Probability (2006.08.05.0000UTC)



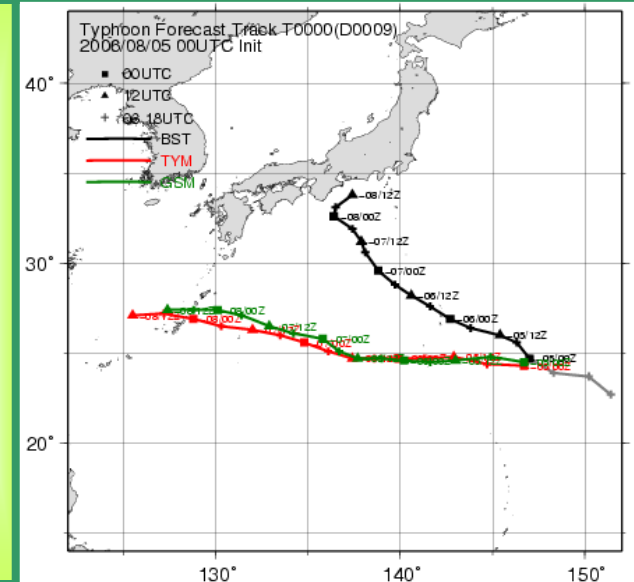
Probability that Typhoon will pass within 120km (about 85nm) radius during the next 64 hours

Typhoon EPS indicates the probability of landing around Tokai district.

Current forecast



TYM and GSM



Statistical verification results

We conducted a numerical experiment on the Typhoon EPS. The experiment period is Aug. and Sep. in 2004.

Deterministic forecasts

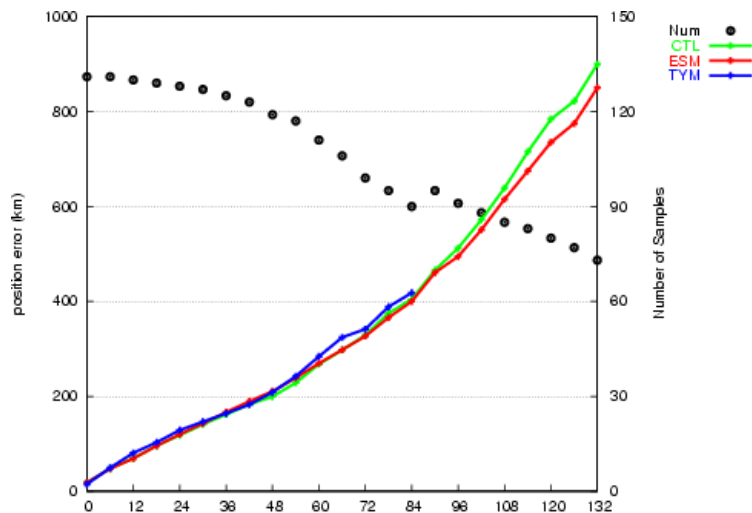
Mean distance error of TC track forecasts

Forecast range is 132hours (see X axis)

Blue line : JMA TYM

Green line : Control run (non-perturbed run)

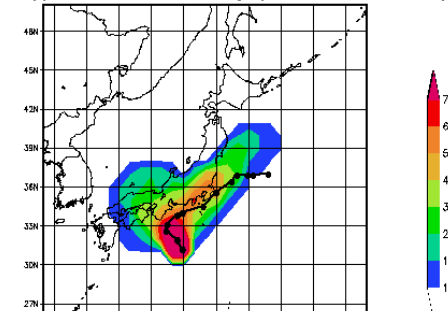
Red line : Ensemble mean



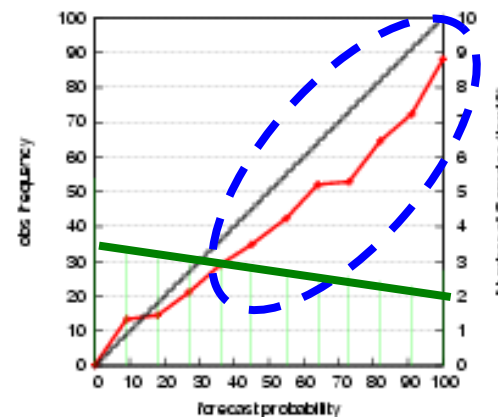
Mean track forecasts error is smaller than that of TYM. Error reduction is about 10km at +72h.

Probabilistic forecasts

D0009 Typhoon Strike Probability (2006.08.07.1200UTC)



Reliability Diagram



Brier Score

Strike Probability Reliability ———
 Number of Samples ———
 Perfect Reliability ———

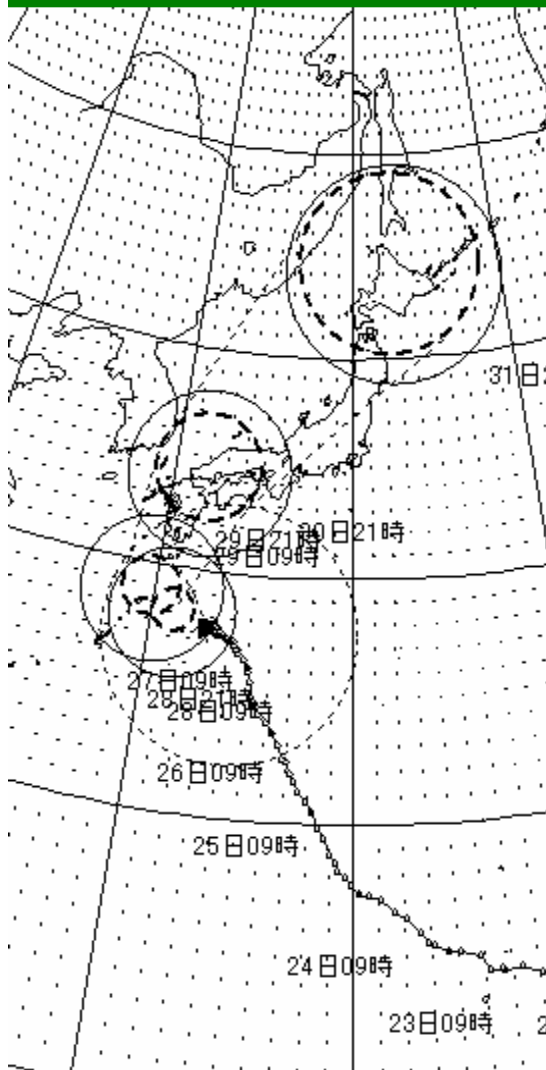
br = 0.0081
 br_rel = 0.0003
 br_res = 0.0046
 br_unc = 0.0124
 bss = 0.5272
 N = 254042.6
 M = 3200.500
 M / N = 1.2598281E-02

High reliability and plus brier skill score.

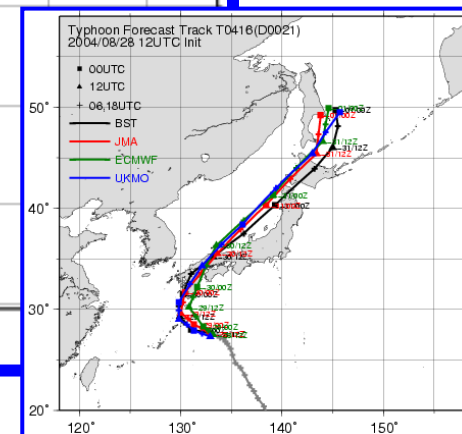
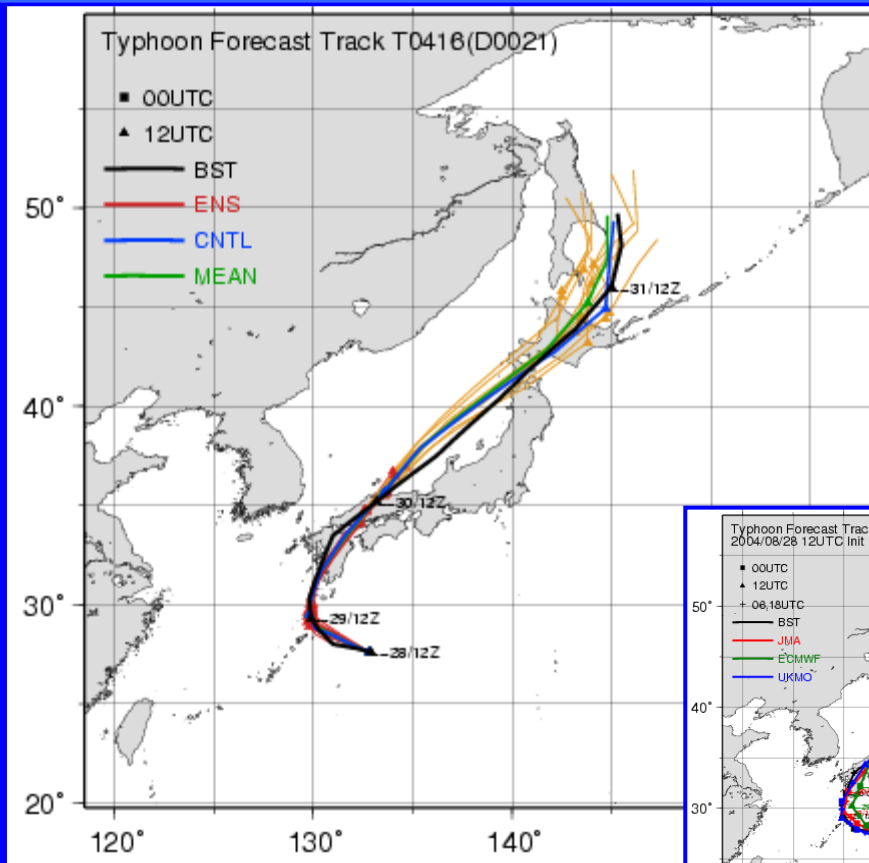
Preliminary research on the beneficial use of ensemble spreads

Initial time: 12UTC 28Aug 2004

Current forecast



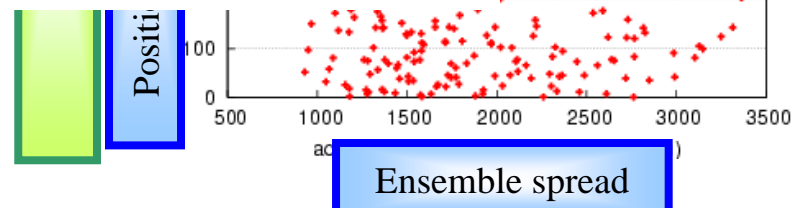
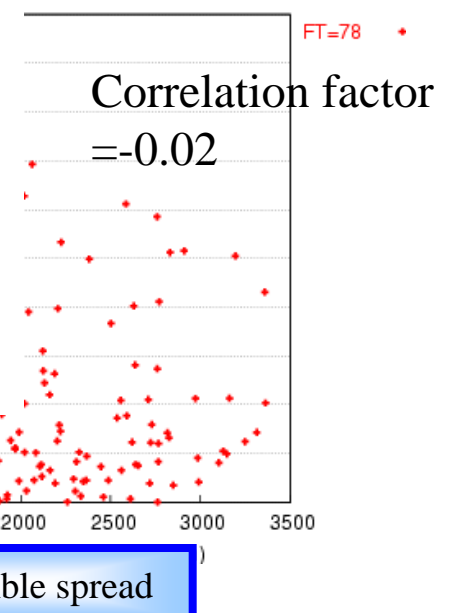
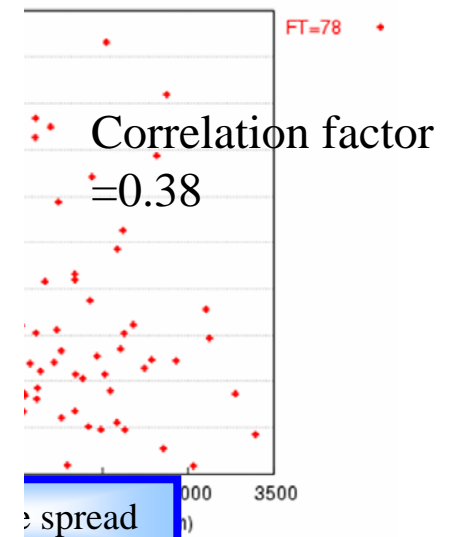
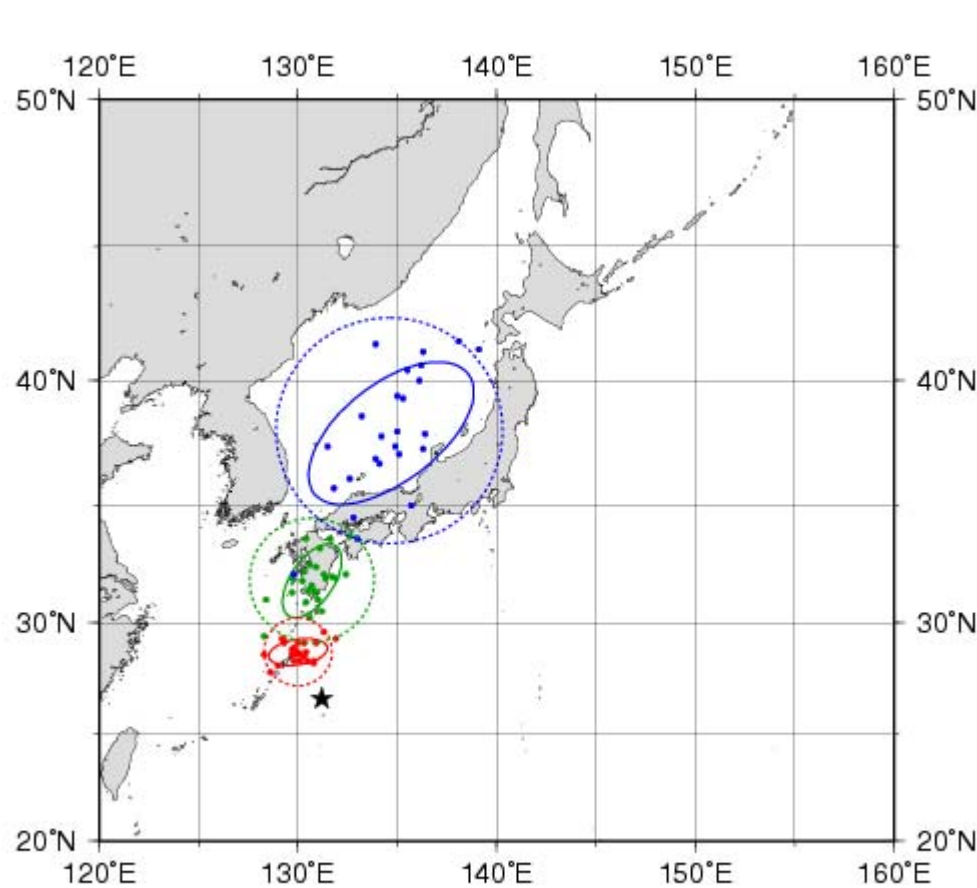
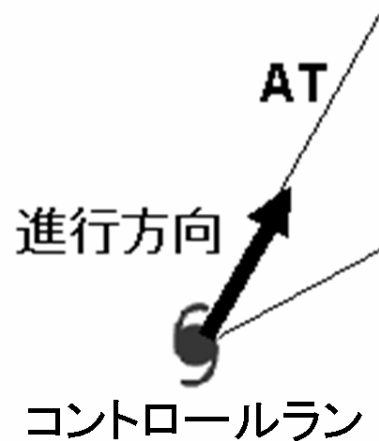
Black: best track
Blue: unperturbed run (control run)
Red: perturbed run(s)
Mark is plotted every 24 hours TEPS



The spread of typhoon track forecasts enable to optimize the error circle's size, which is based on a statistical value in the current system.

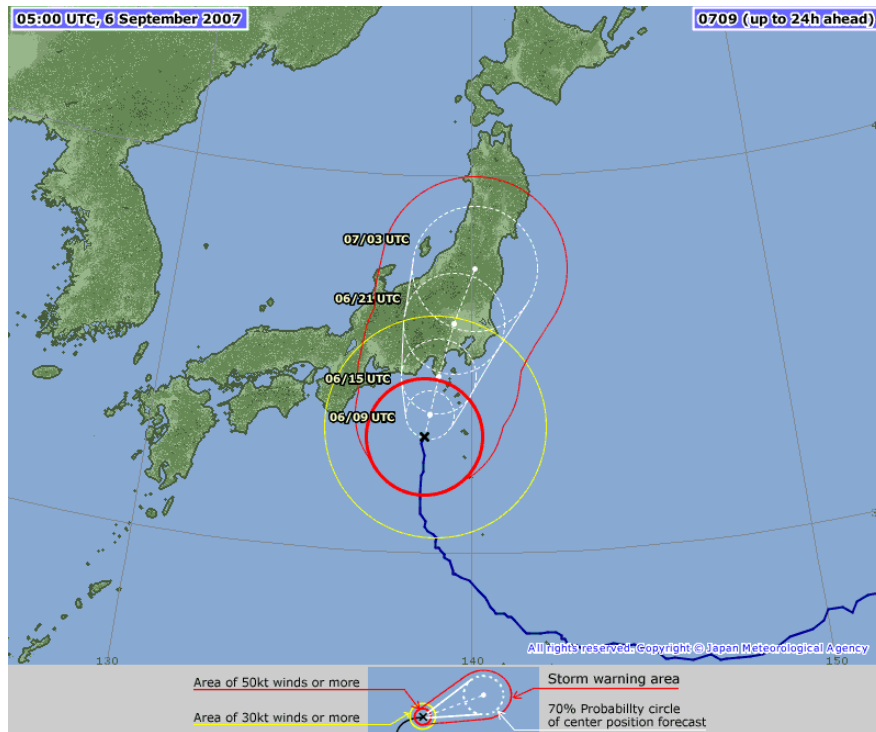
Preliminary research on the beneficial use of ensemble spreads

スプレッドをコントロール
沿った成分(AT)と直
て検証した。統計期
期間で、3日予報の



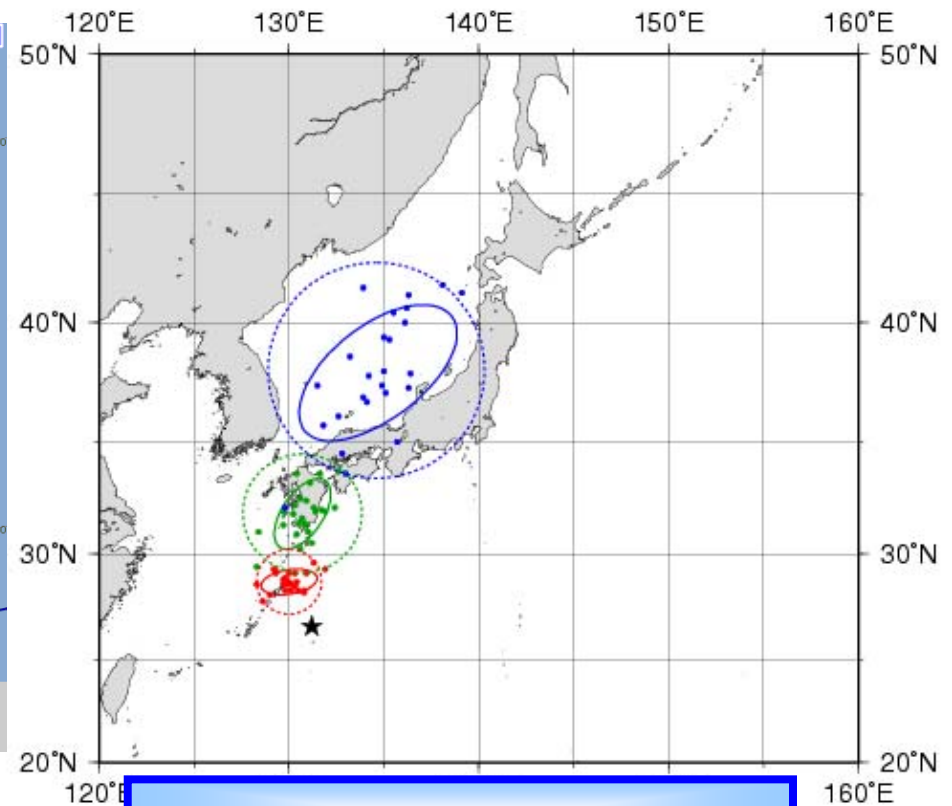
New application for typhoon track forecasts

The forecast uncertainty on TC central position is described in a circle, whose radius is decided on a **statistical method**, using information about current TC position and intensity.



Current Application

The area which represents forecast uncertainty could be optimized by using **ensemble spread**, which changes day by day, typhoon by typhoon.

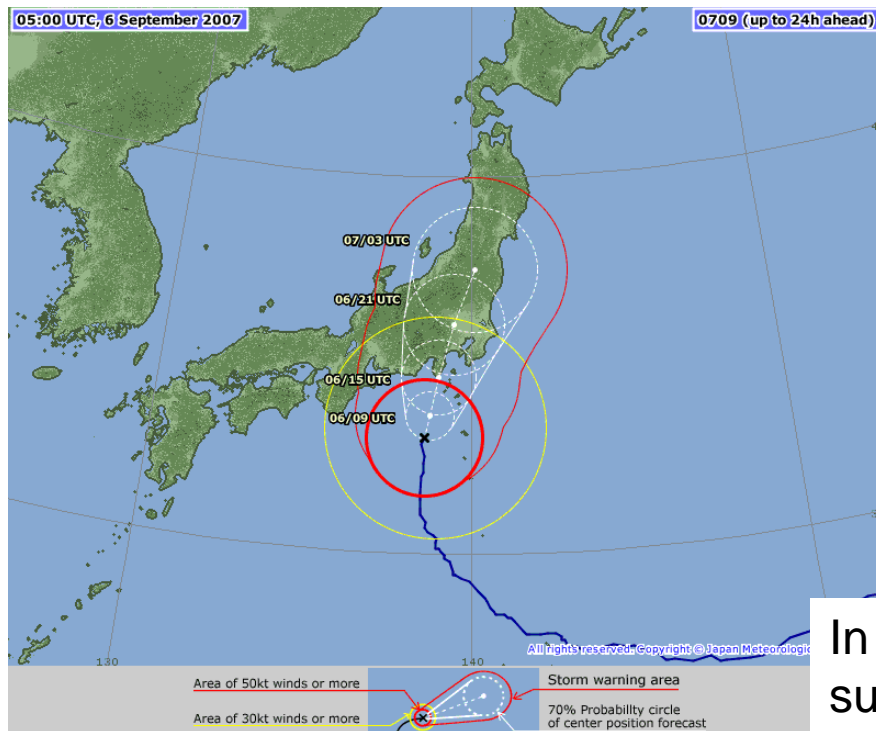


Application in the future

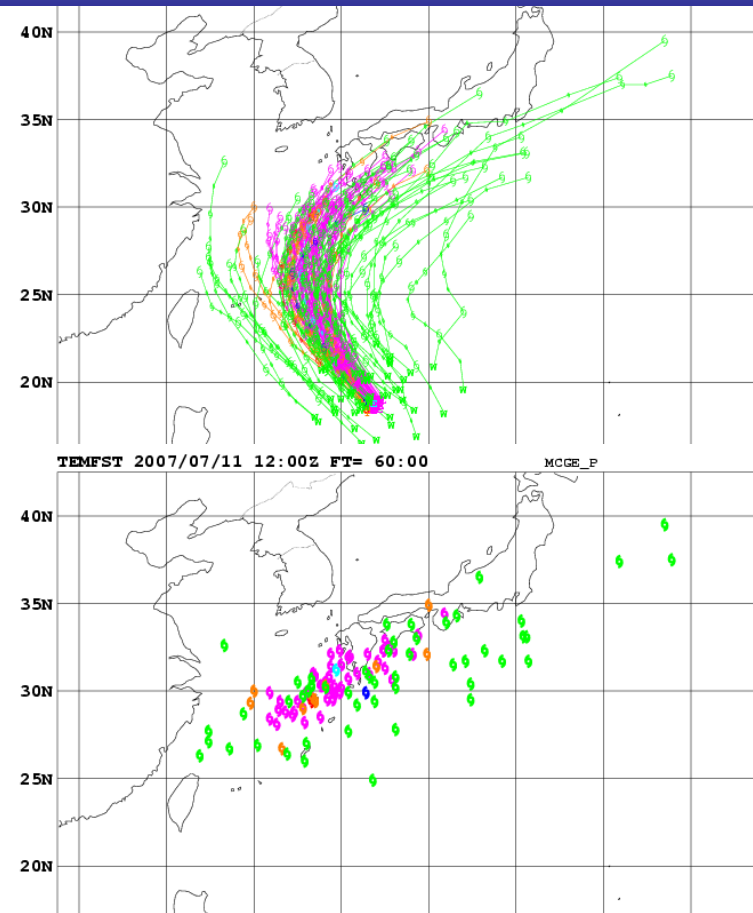
Circle is good ?

to express forecast uncertainty on typhoon track movements?

The forecast uncertainty on TC central position is described in a circle, whose radius is decided on a **statistical method**, using information about current TC position and intensity.



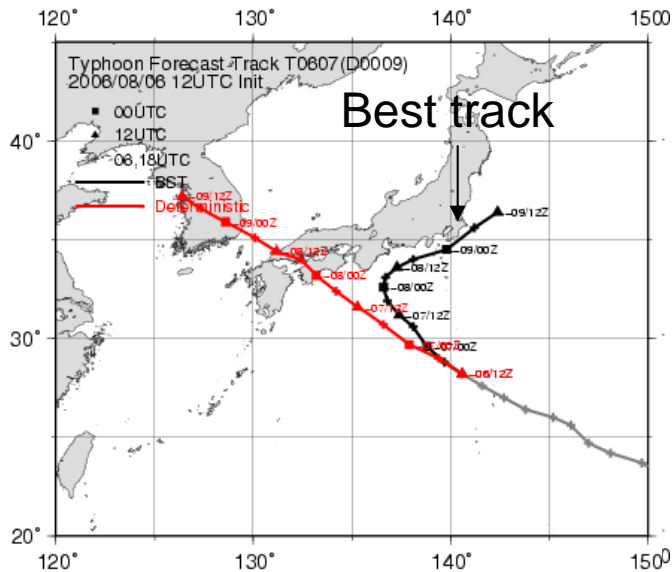
Current Application



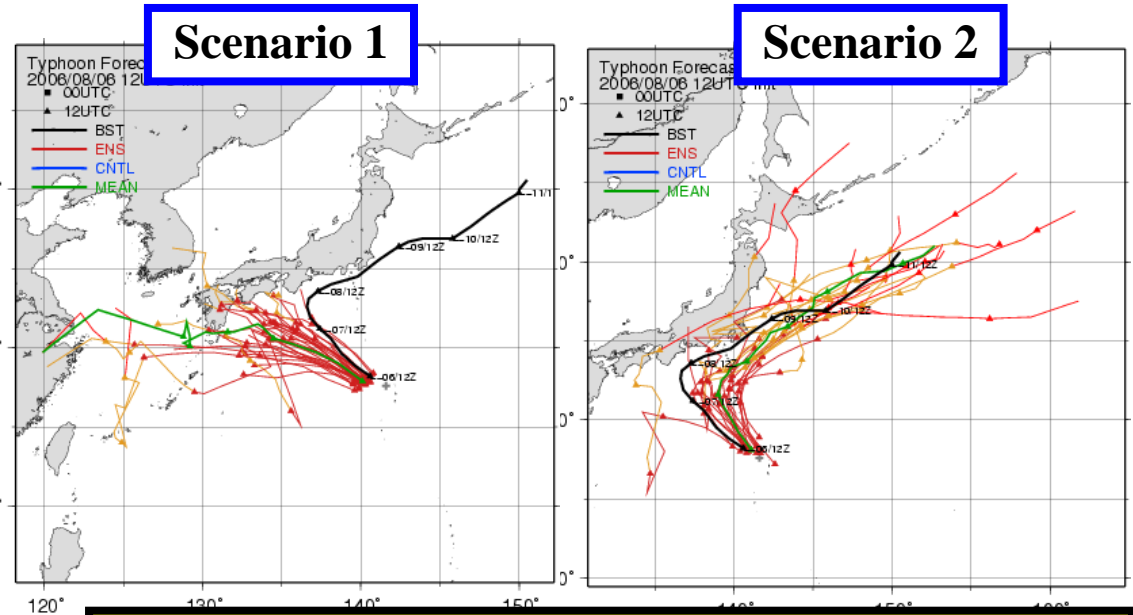
In the stage that typhoon is going along with subtropical jet, forecast uncertainty is relatively large in the direction of movement, compared with that in the crosswise direction.

Cluster Analysis

- case study : typhoon MARIA-



Deterministic forecast (red line)
Initial: 2006.08.06 12UTC

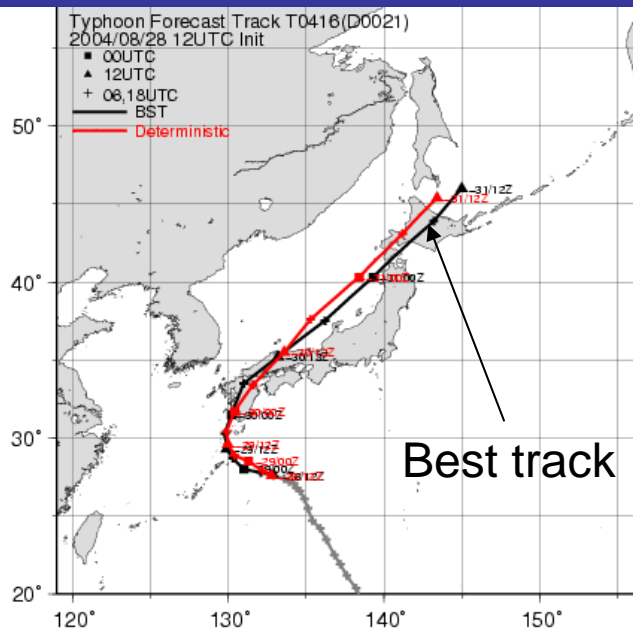


Example of probabilistic forecast
Two scenarios (see green line) suggested

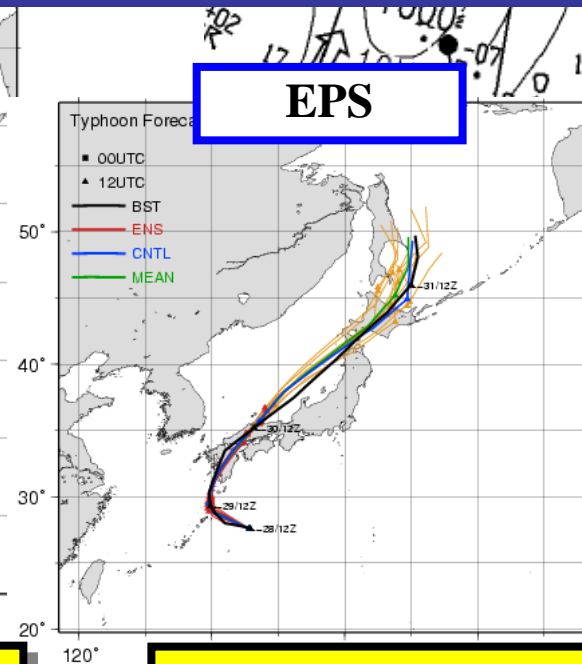
Even if the best likely solution, or deterministic forecast, goes wrong, several other scenarios presented help people act accordingly, and in some cases they can prepare for the anticipated damage well in advance.

Cluster Analysis

- case study : typhoon CHABA-

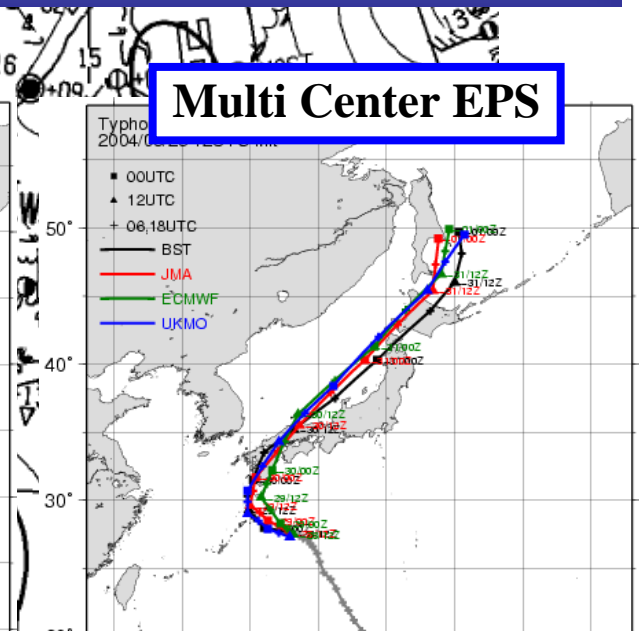


Deterministic forecast (red line)
Initial: 2004.08.28 12UTC



EPS

Example of probabilistic forecast.
Conceivable scenario is only one!



Multi Center EPS

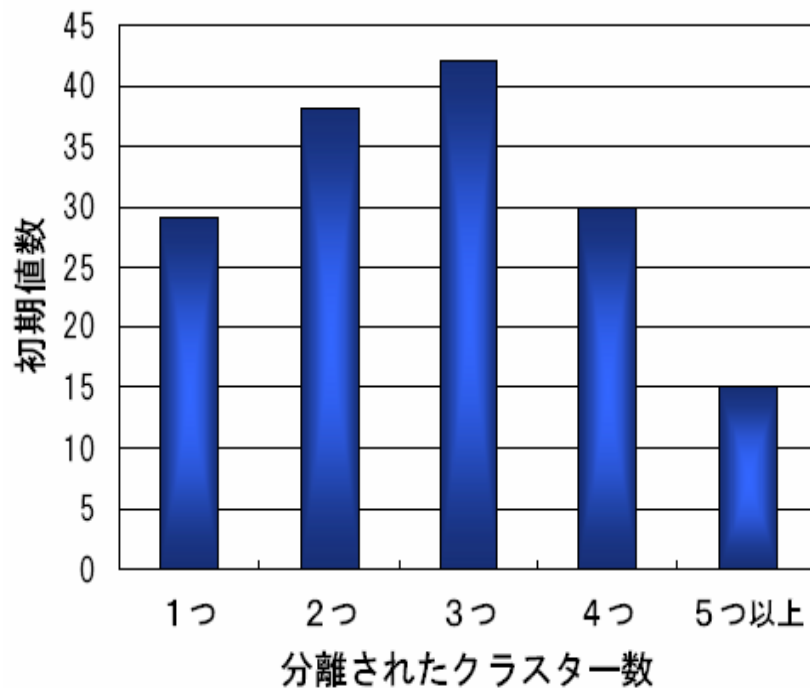
If the number of possible scenarios is only one, it means the scenario is a highly likely scenario. People can act accordingly and in areas where the possibility of the typhoon striking is estimated 0 they can avoid taking unnecessary actions against the typhoon approaching.

Uncertainty information derived from a cluster analysis

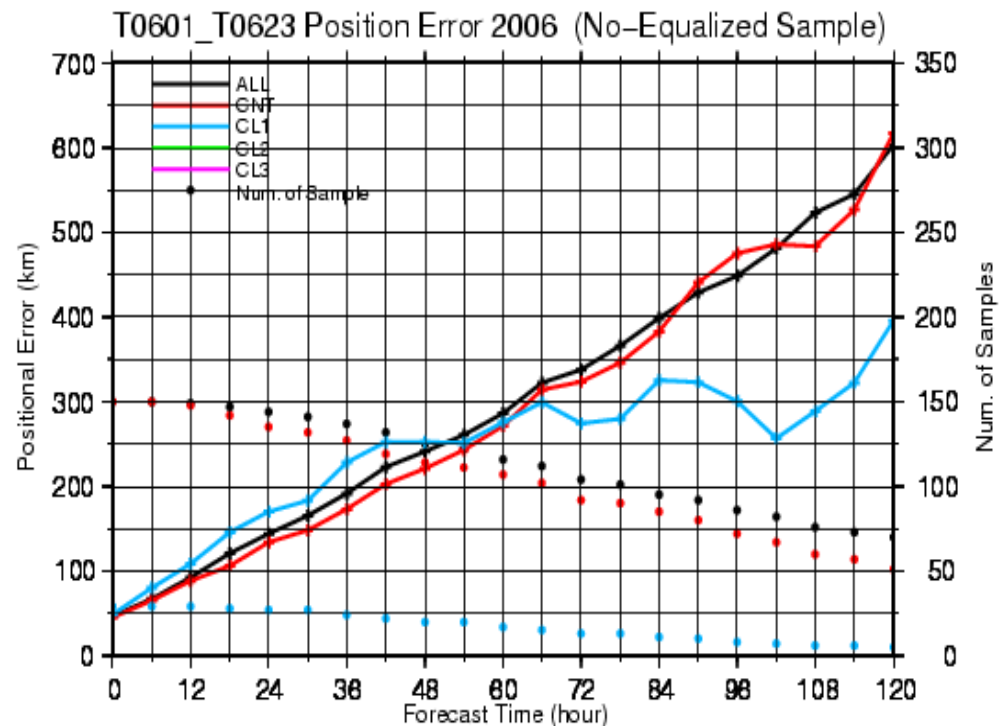
- Typhoon track forecasting -

Frequency distribution of the analyzed number of cluster. Verification period is 2006.

2006年 (WD 5.0)



ensemble mean of the only cluster vs
control run vs ensemble mean



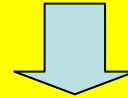
In the cases where the number of clusters is analyzed only one, a statistical verification shows the ensemble mean of the cluster have smaller error (light blue), compared with the average forecast error by control run or “simple” ensemble mean over a year (red or black).

Case Study : The analyzed number of cluster is 1

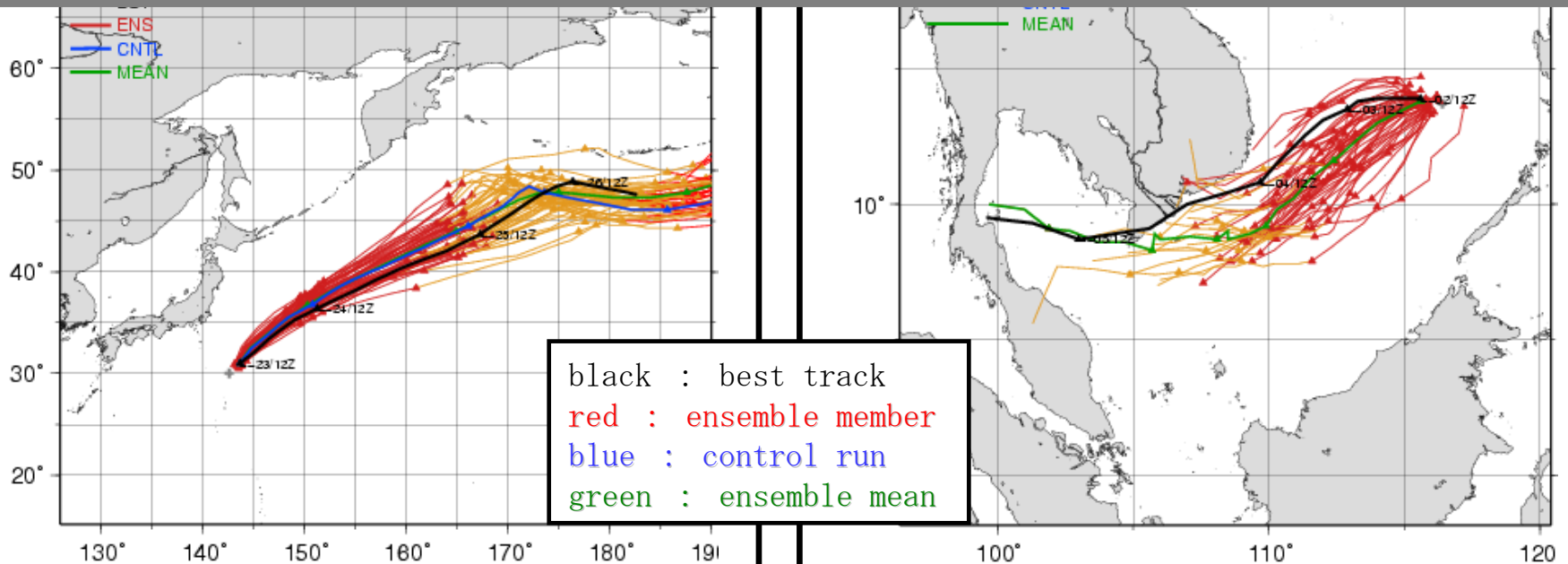
2006年9月23日 T0614 (left)

2006年12月2日 T0621 (right)

In below cases the ensemble mean of the cluster have smaller error (light blue), compared with the average forecast error by control run or “simple” ensemble mean over a year(red or black).



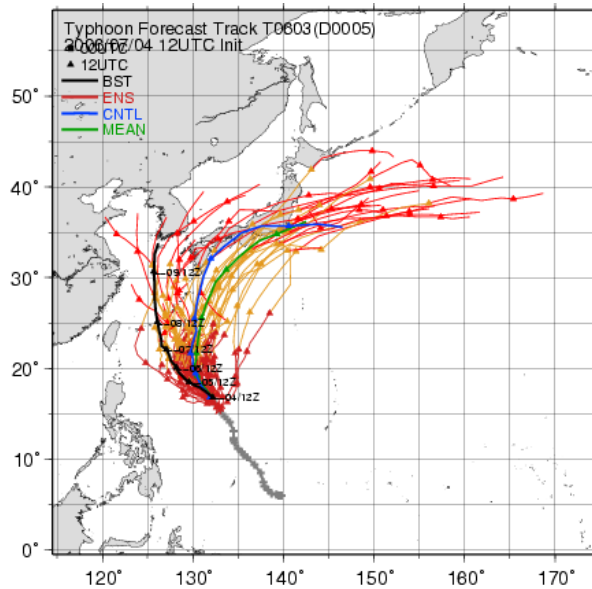
We can say “the uncertainty of the track forecast is relatively small”



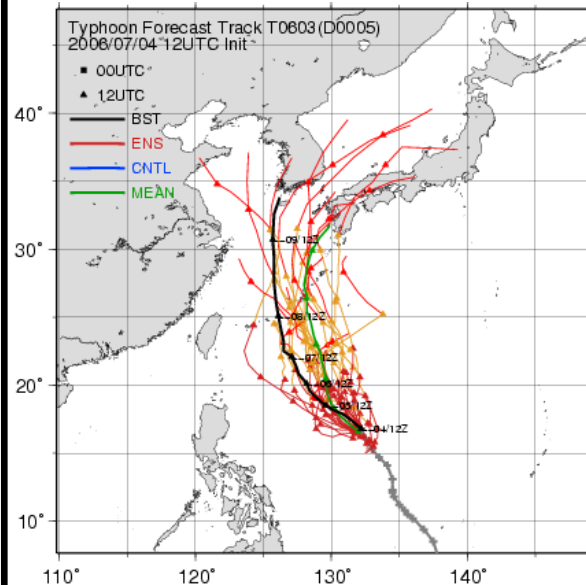
Case Study : The analyzed number of cluster is 2

2006年7月4日 T0603

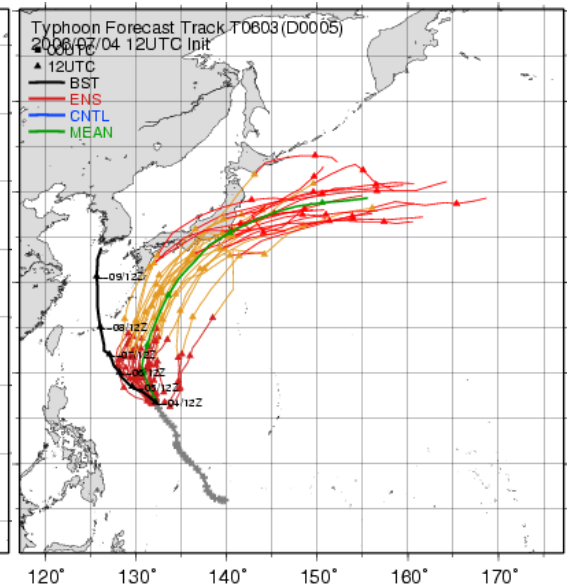
All ensemble members



1st Cluster



2nd cluster



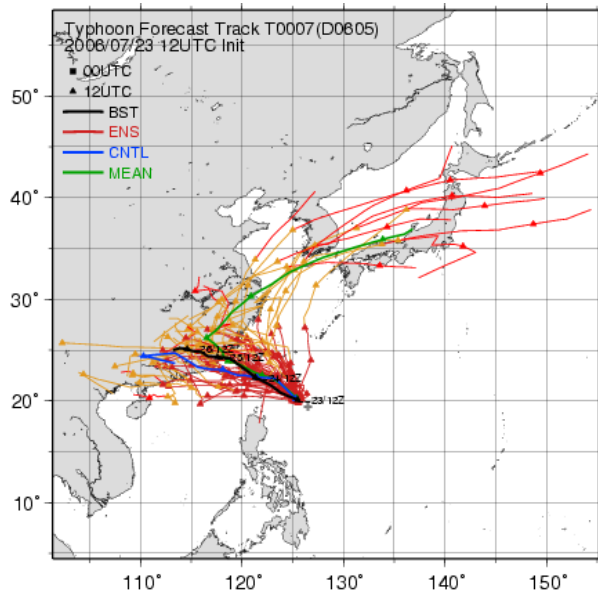
The 1st cluster was correct

By clustering, we can identify 2 scenarios, going into the Sea of Japan and going toward Tokyo area.

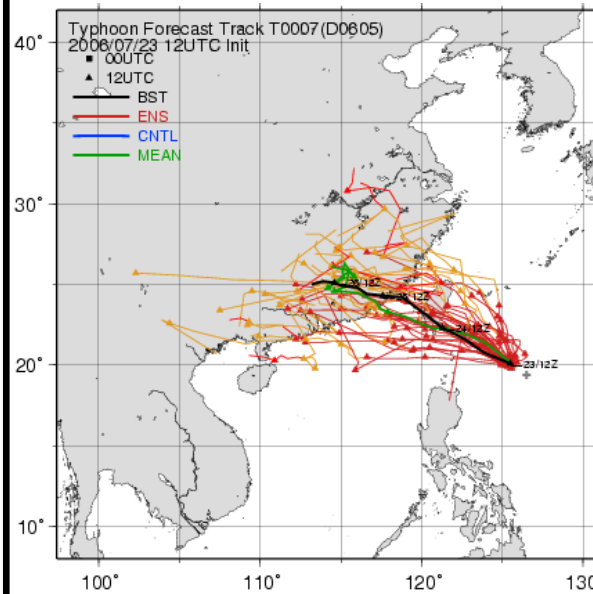
Case Study : The analyzed number of cluster is **2**

2006年7月23日 T0605

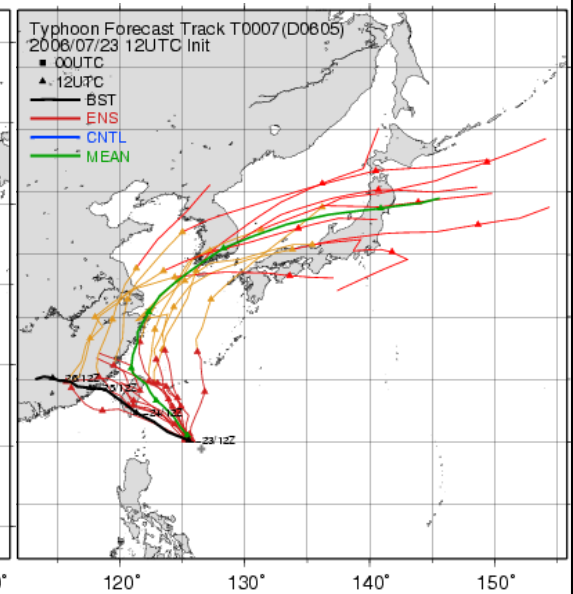
All ensemble members



1 s t Cluster



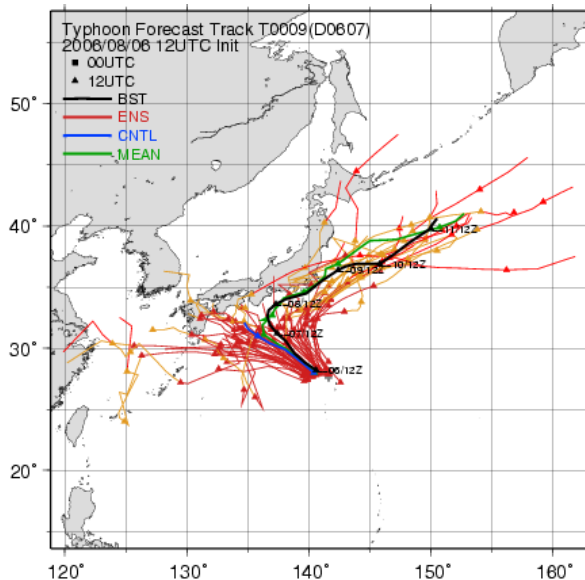
2nd cluster



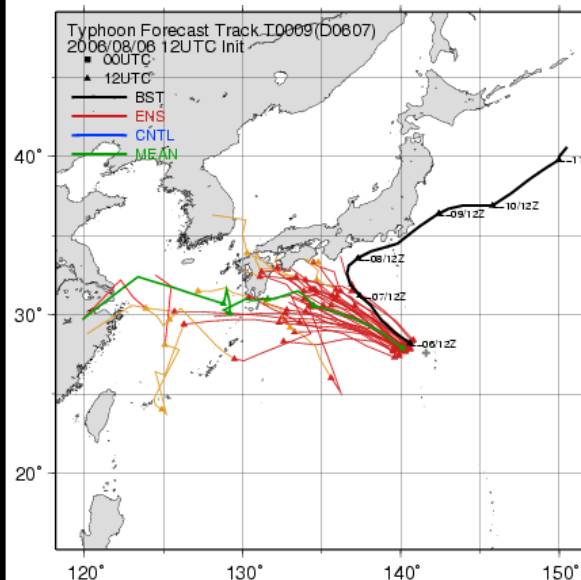
Case Study : The analyzed number of cluster is **2**

2006年8月6日 T0607

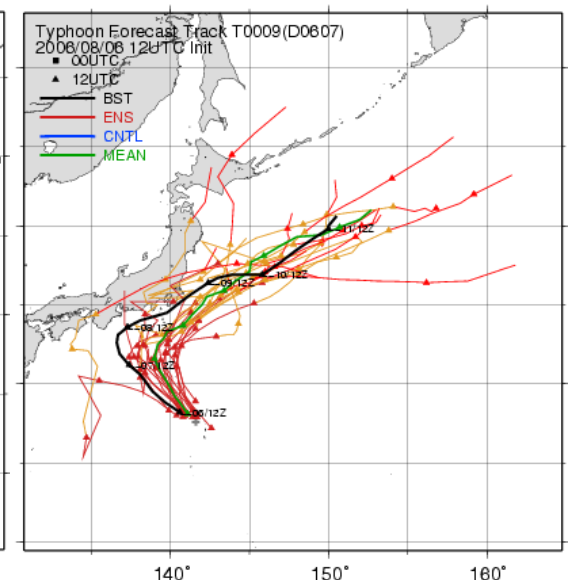
All ensemble members



1st Cluster



2nd cluster



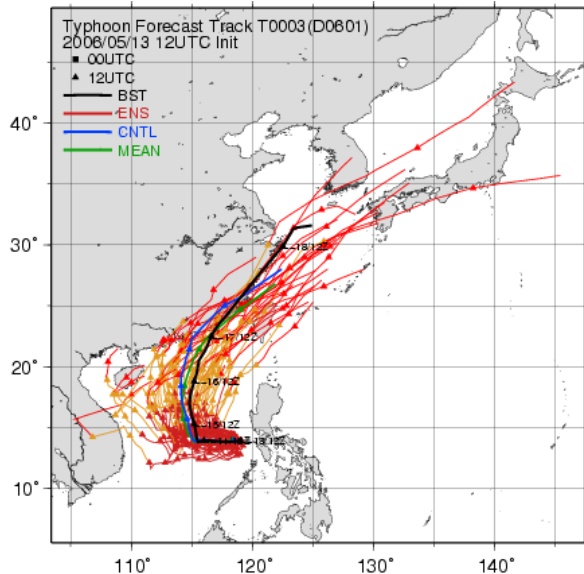
The 2nd cluster was correct

Even if the best likely solution, or deterministic forecast, goes wrong, several other scenarios presented help people act accordingly, and in some cases they can prepare for the anticipated damage well in advance.

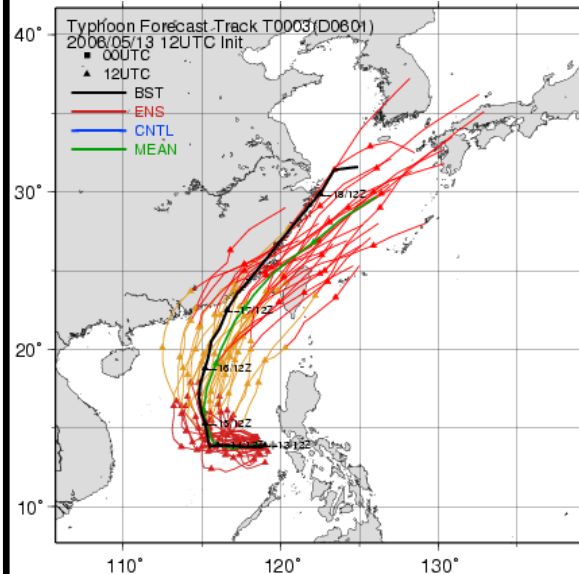
Case Study : The analyzed number of cluster is **3**

2006年5月13日 T0601

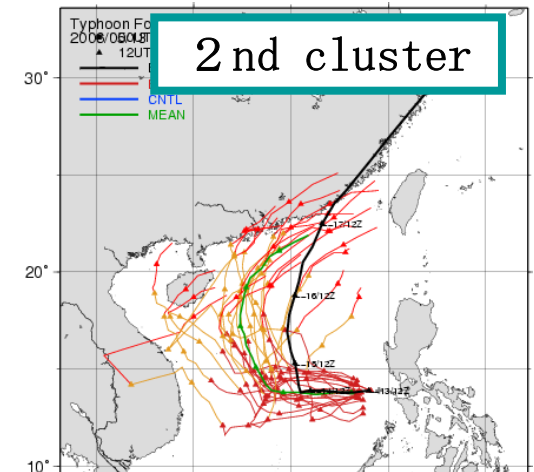
All ensemble members



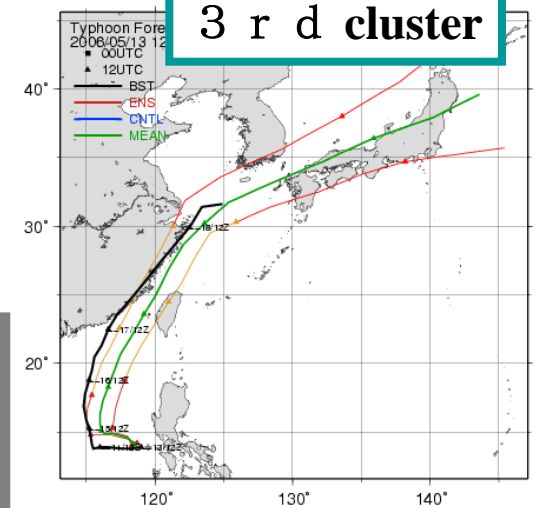
1 s t cluster



2 n d cluster



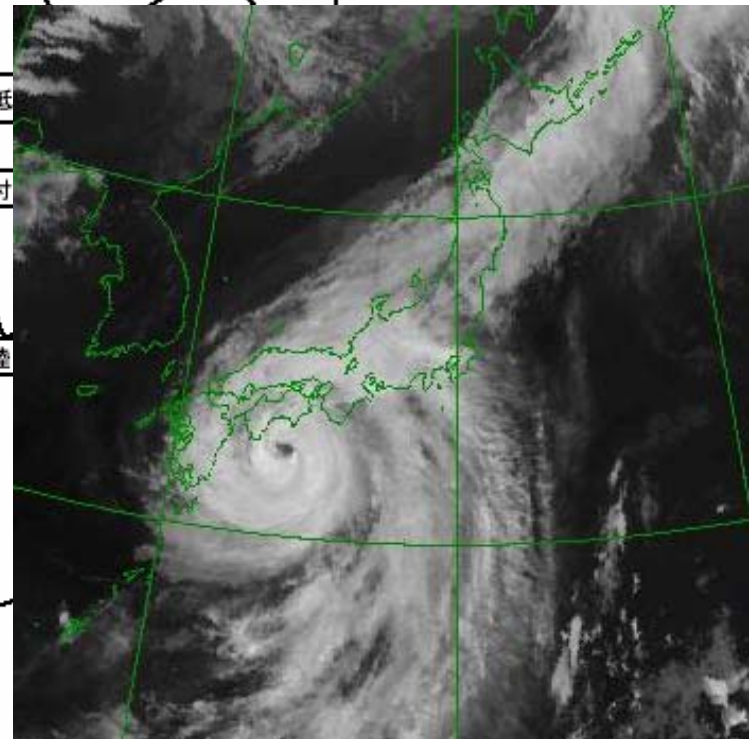
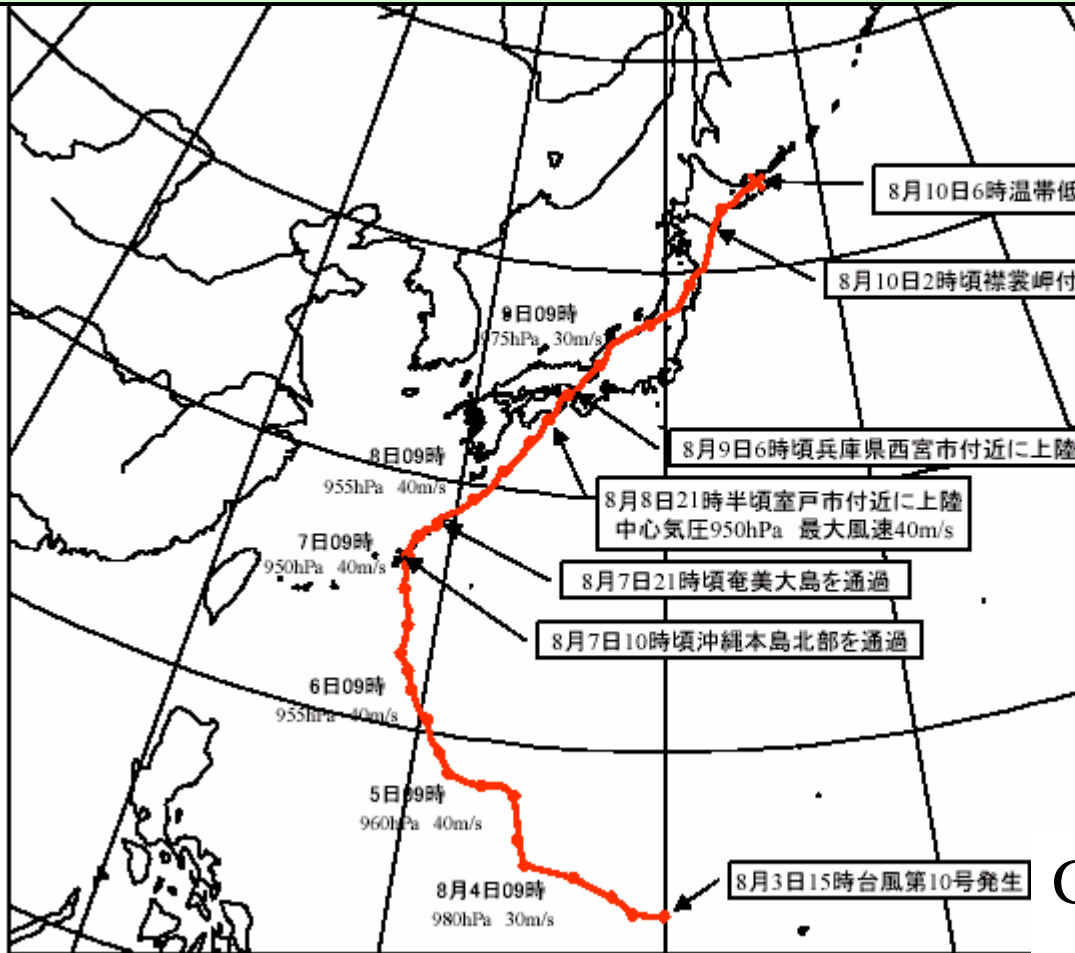
3 r d cluster



Considering not only the direction but also the speed, the cluster analysis method suggested 3 scenarios.

Case study - Typhoon Etau (T0310)

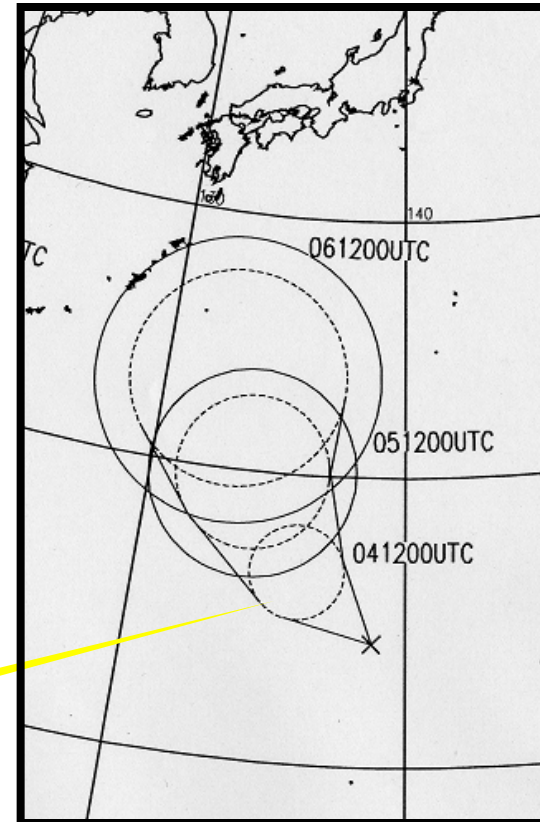
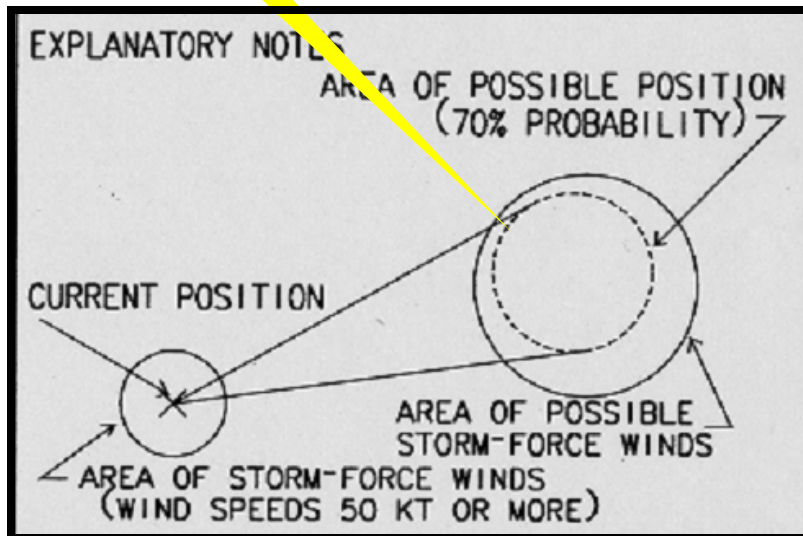
Red line indicates the observed track of T0310.



GOES 9 Infrared Satellite Image
at 09 UTC 8 August 2003

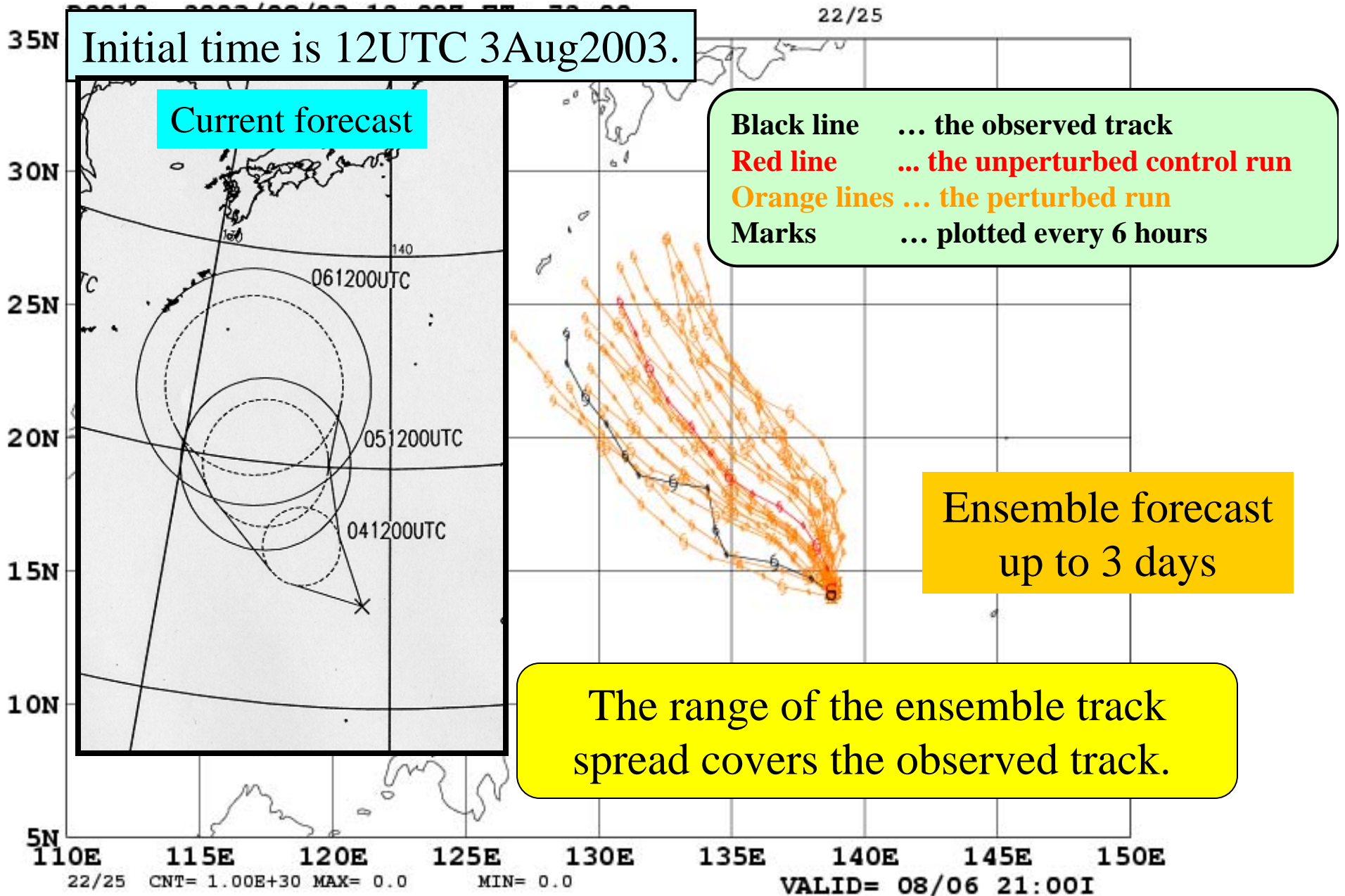
JMA issues the typhoon forecast

JMA currently issues the information on a geographical **circle** in which a typhoon center will reach with 70% probability.

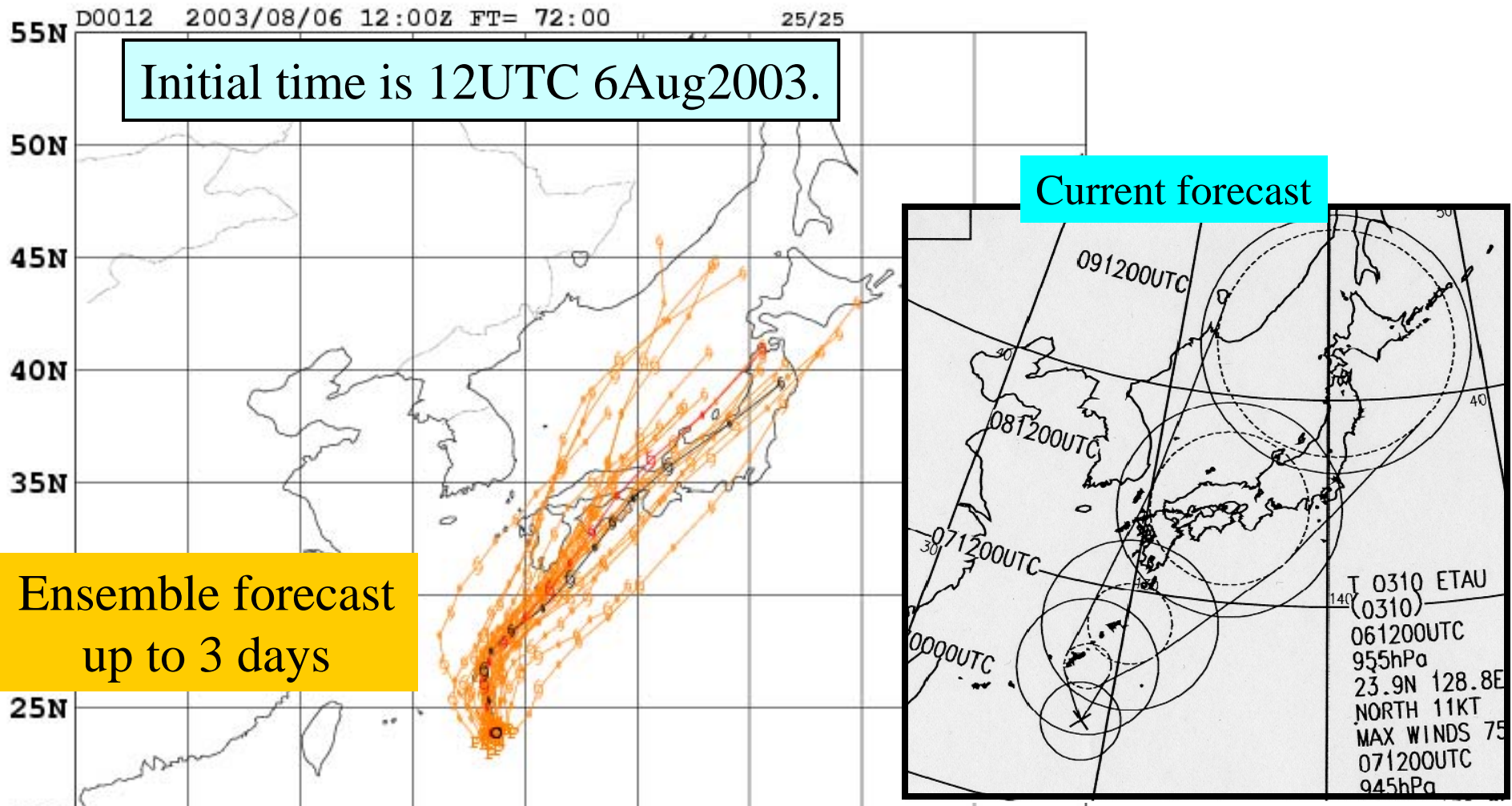


The **radius** of the forecast circle depends on the statistics of the past forecast results but **not on the characteristic of individual typhoon.**

typhoon track forecasts of Etau in the early stage



Typhoon track forecasts of Etau just before recurvature



The spread was small enough to indicate high reliability. The probability of landfall of the typhoon on western Japan was very high.

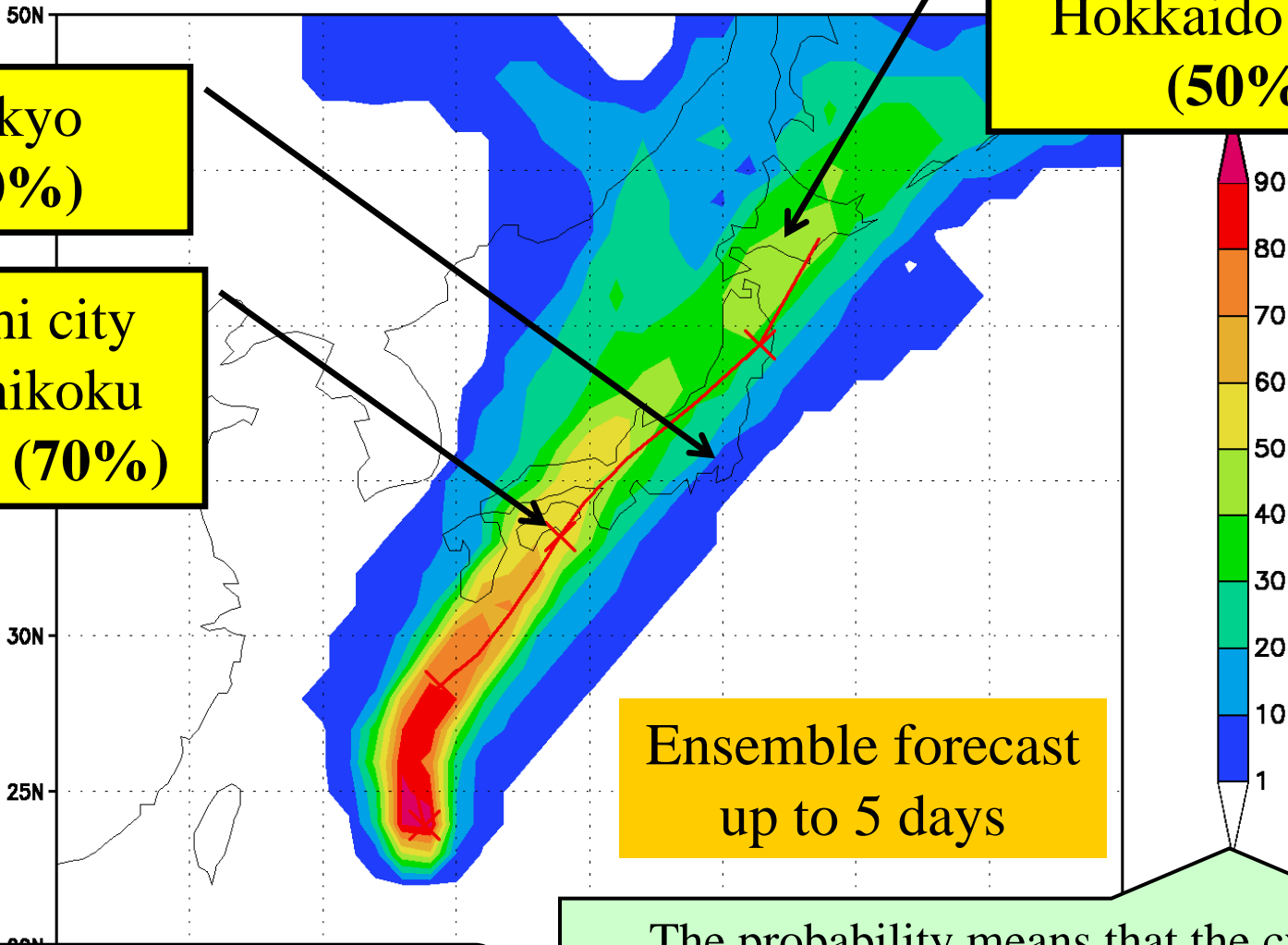
Strike probability of Etau

Initial time is 12UTC6Aug2003.

Tokyo
(10%)

Kochi city
of Shikoku
island (70%)

Hidaka of
Hokkaido island
(50%)

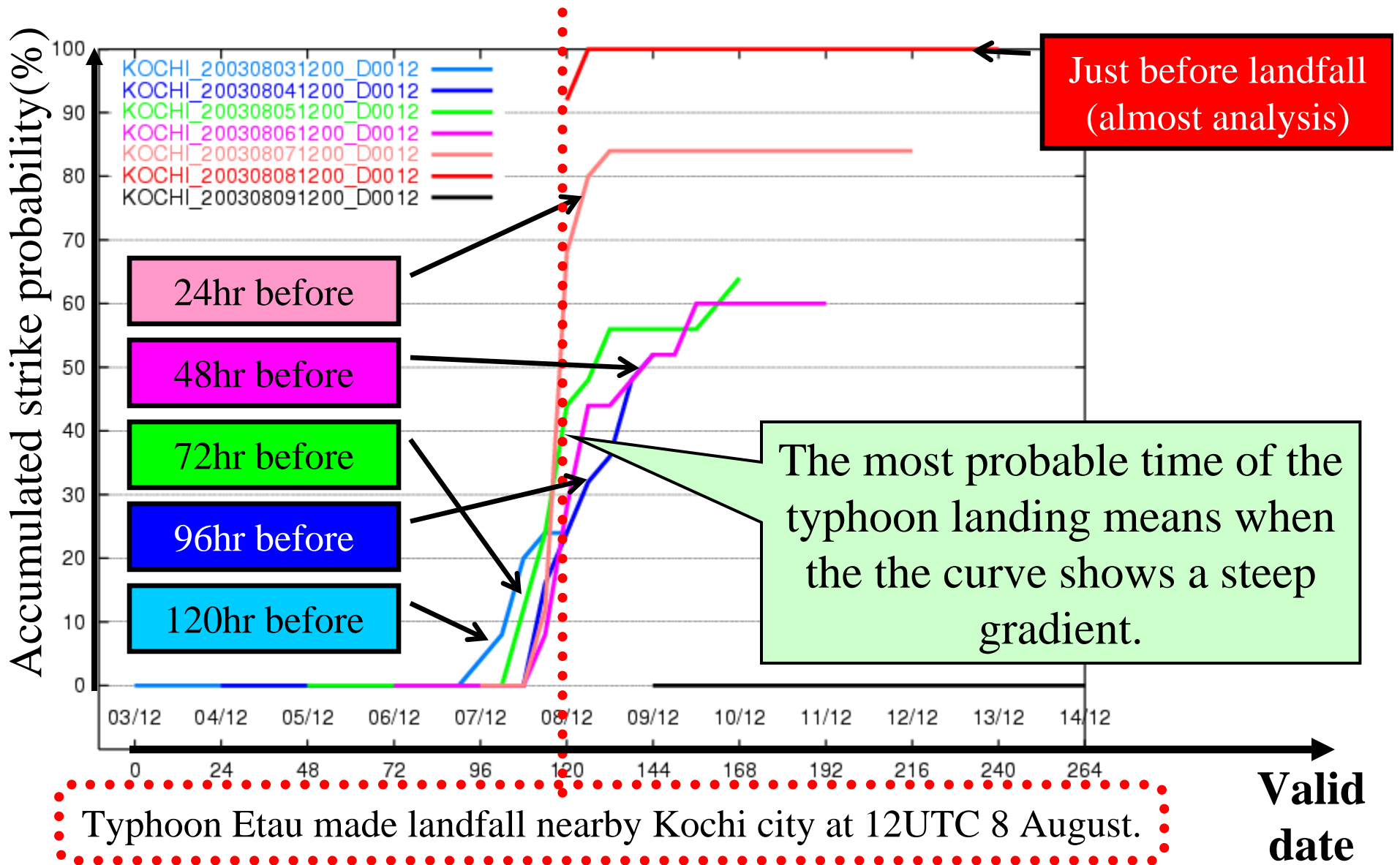


Ensemble forecast
up to 5 days

Red line ... the observed track
X marks ... plotted every 24 hours

The probability means that the cyclone
will pass within a 120km (about 65nm) radius
during the next 120 hours.

Point strike probability at Kochi city



Verification of strike probability forecast

The reliability diagram for strike probability forecast that typhoon centers will pass within 120km from the verification points during the first 120 hours. The data used for verification are 174 forecasts for 37 Tropical cyclones over the responsible area of the RSMC Tokyo Typhoon Center in the year of 2002.

