Probabilistic Forecast Systems Overview

Expert Meeting on the Application of Probabilistic Forecasting

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Probabilistic Forecast System

I focus on probabilistic forecast systems, which are designed to estimate the uncertainty of a NWP forecast and used to produce the application of probabilistic forecasting.

Item on the agenda

Hop! **Step!!** **Jump!!!**

Developer

Harthy-san →

Forecaster

Harthy-san →

End user

Guiney-san Mylne-san Mylne-san

Probabilistic Forecast System

Why Probabilistic Forecast ?

Basic premise

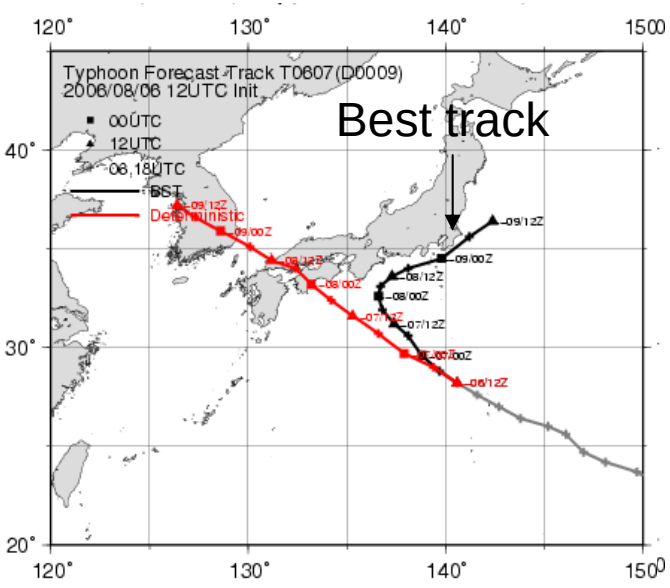
inherently chaotic behaviour of the atmosphere

Small errors in the initial conditions of a NWP model can lead to large errors in the forecast, and a NWP model itself is not perfect.

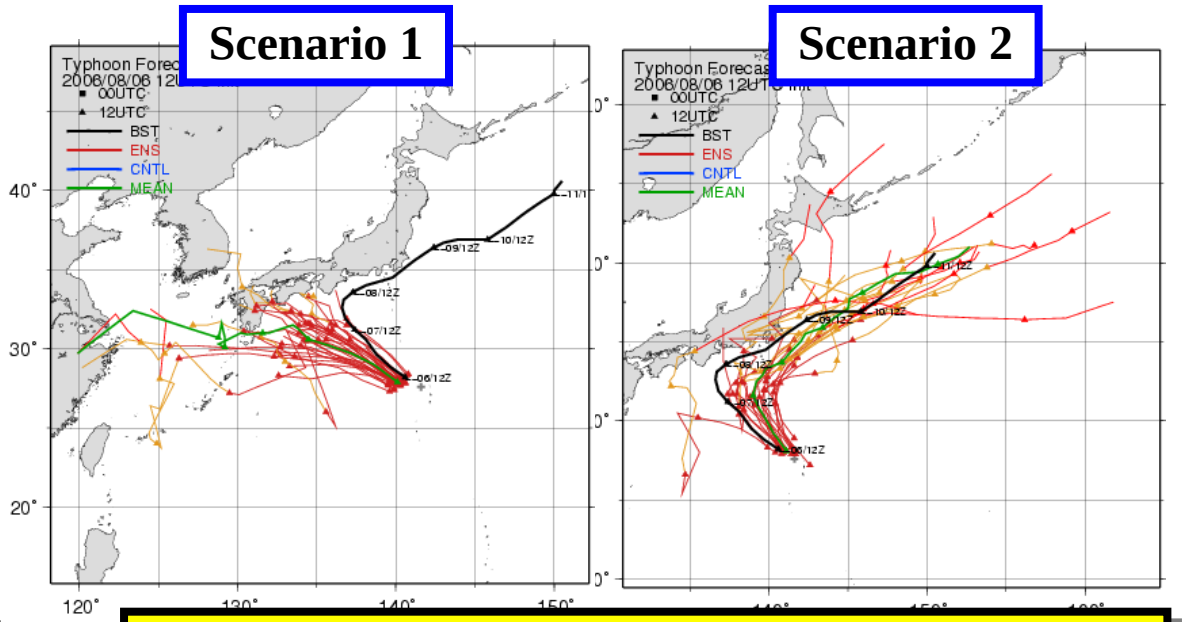
Ways of coping

The state of the atmosphere should be dealt with in a probabilistic way

Why Probabilistic Forecast ?
- case study : typhoon MARIA-



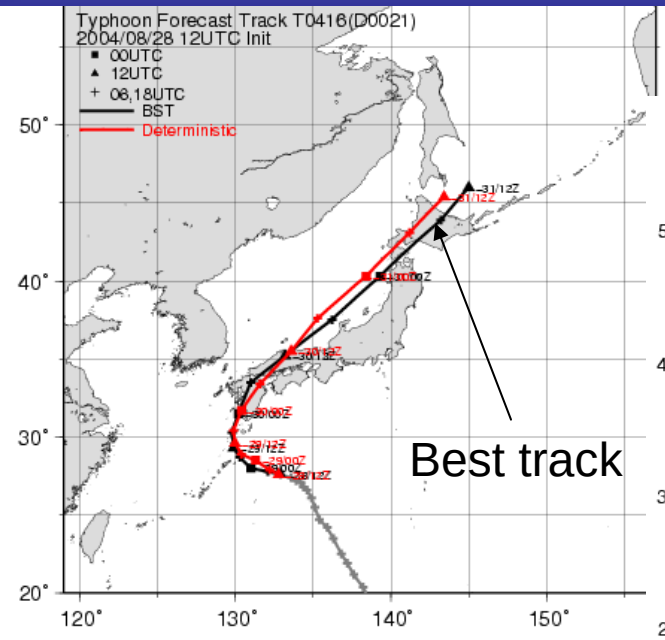
Deterministic forecast (red line)
Initial: 2006.08.06 12UTC

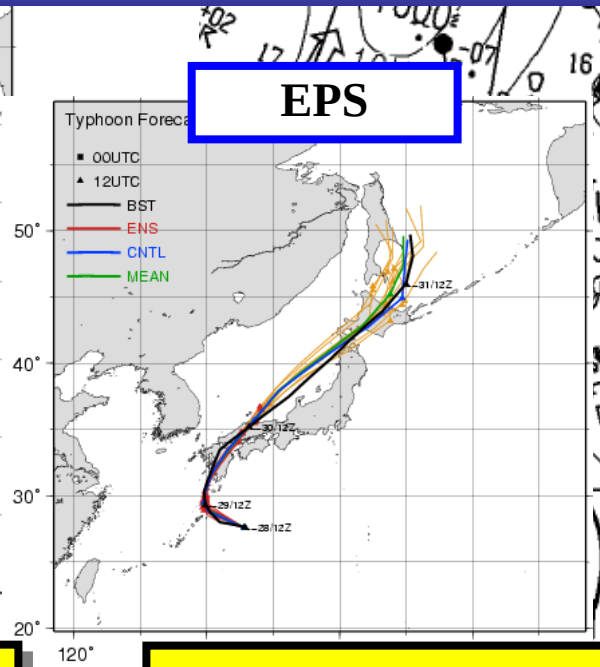


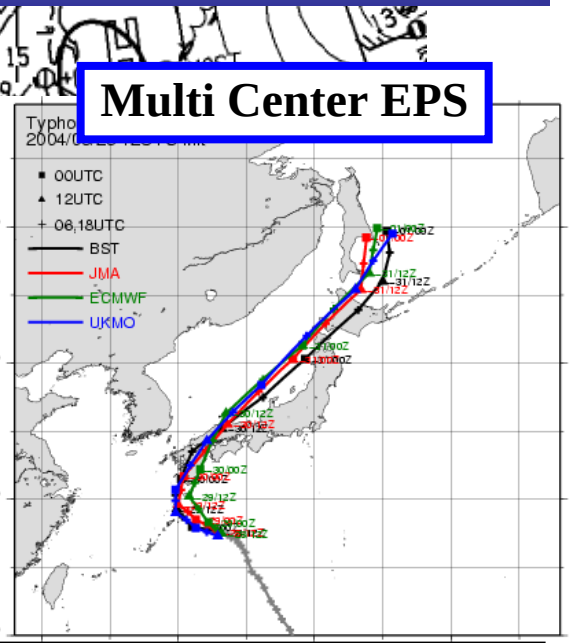
Example of probabilistic forecast
Two scenarios (see green line) suggested

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.

Why Probabilistic Forecast ?
- case study : typhoon CHABA-







Deterministic forecast (red line)
Initial: 2004.08.28 12UTC

Example of probabilistic forecast.
Conceivable scenario is only one!

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.

How to bring out forecast uncertainties -1-

Dramatis Personae

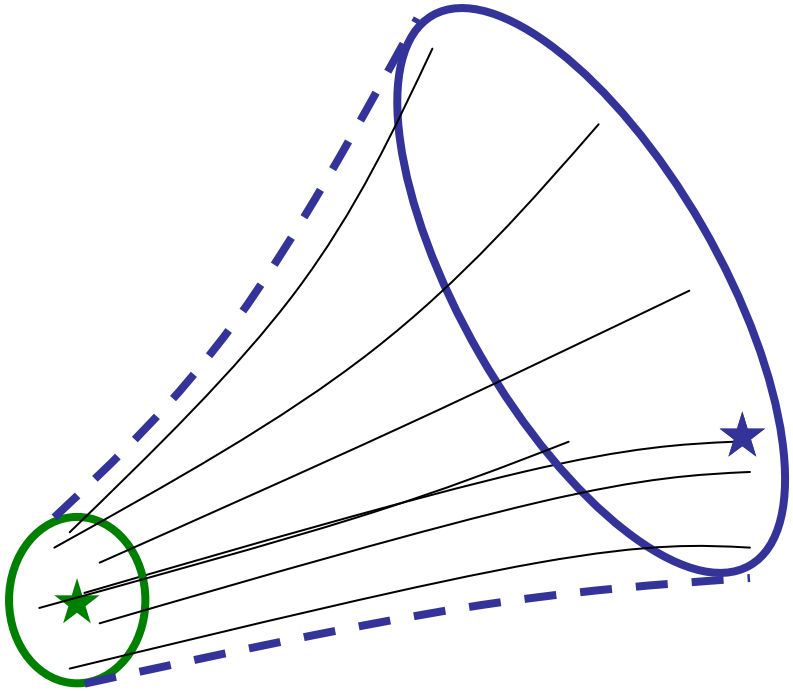
★ Analysis field

Uncertainty of Analysis field

★ Deterministic forecast

Forecast Uncertainty

Ensemble member



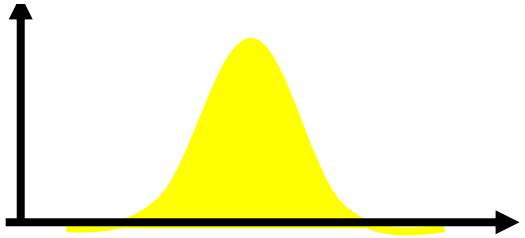
T=t0

T=t1

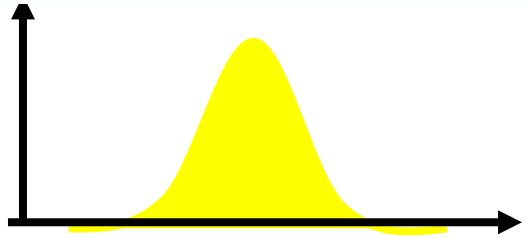
How to bring out forecast uncertainties -2-

PDF (Probability Density Function)

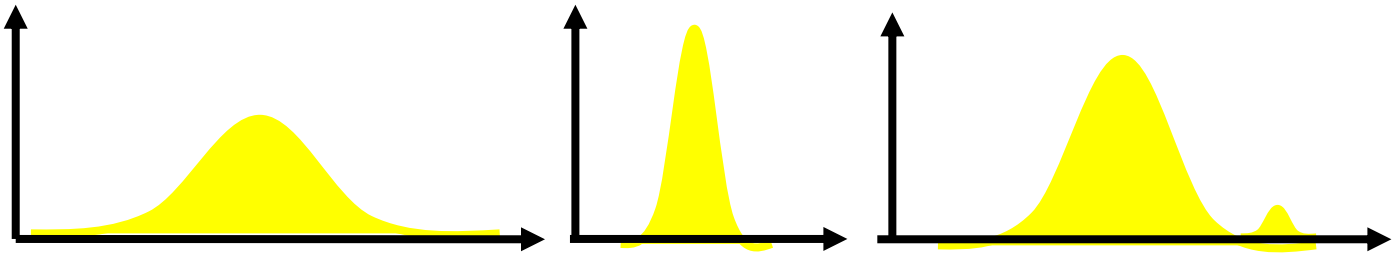
We know



Climatological distribution

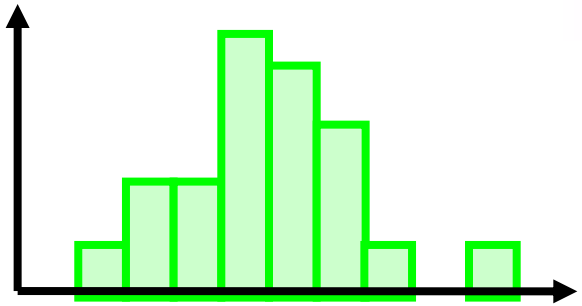


Distribution of NWP model's climatology

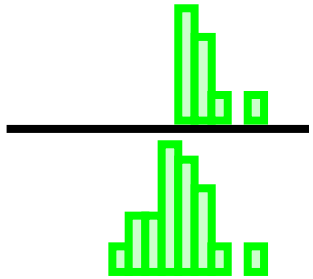


EPS provides the information of forecast uncertainties directly as a form of PDF, which changes day by day, initial by initial, region by region and variable by variable.

In actuality, EPS estimates the PDF with the limited number of forecasts called ensemble size.



Forecast Probability =



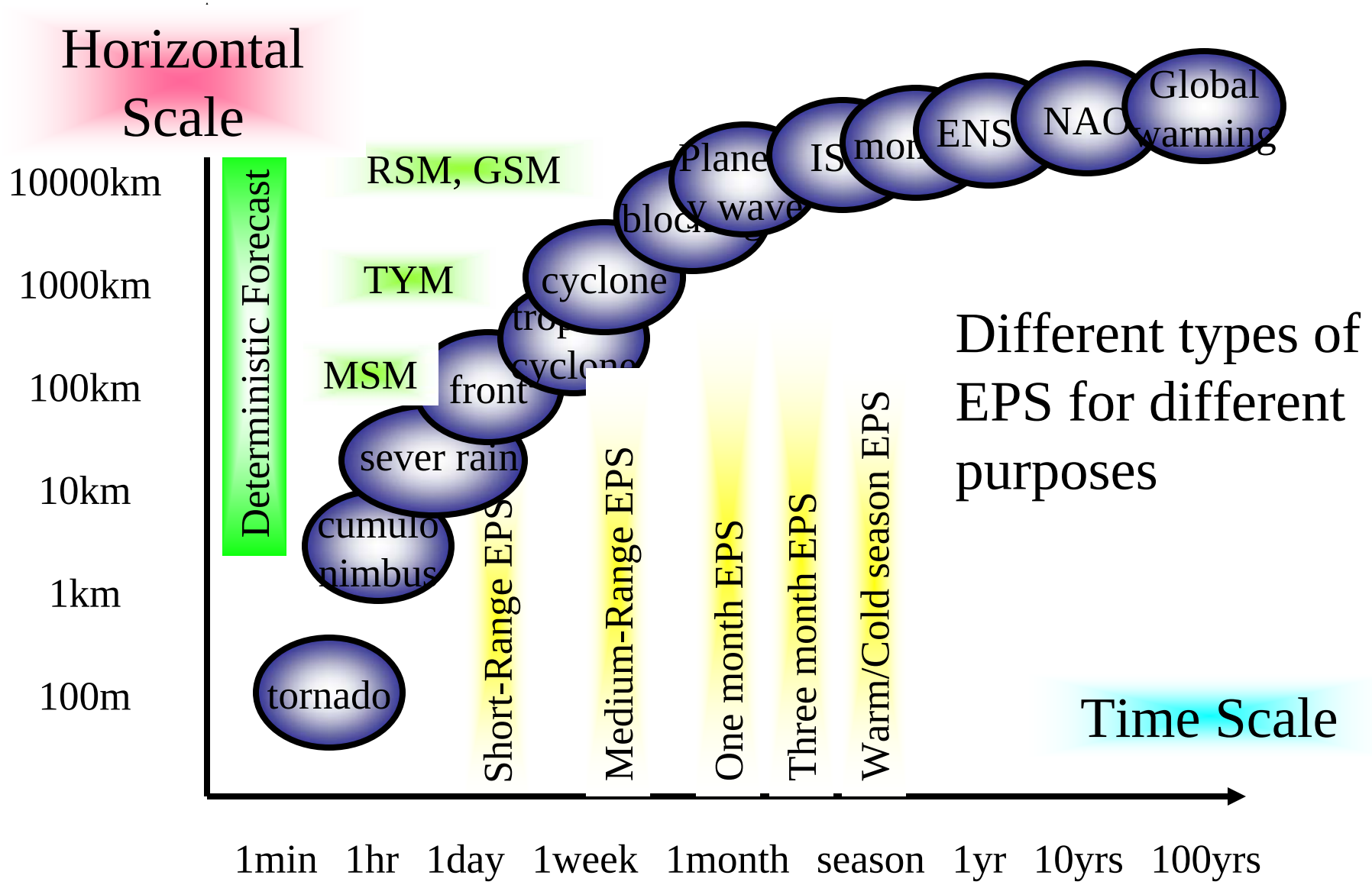
Ensemble Prediction System

Ensemble Prediction System (EPS) is an only way to directly provide the uncertainties of a numerical weather prediction. Using the outcomes of EPS, we can estimate the probability of a particular event by counting the proportion of ensemble members which forecast that event to occur.

The different types of EPS

- EPS by perturbing initial conditions
  - ✓ BGM method, SV method, ETKF, etc.
- EPS considering the imperfection of a NWP model
  - ✓ Stochastic physics method, multi-parameterization method, etc.
- EPS considering the uncertainty of boundary conditions of a NWP model or considering a changing external forcing.
  - ✓ SST (Sea Surface Temperature) ensemble, CO_2 ensemble, etc.
- Multi Center EPS
  - ✓Collecting a number of deterministic forecasts or ensemble forecasts and comprising a EPS

Different types of EPS for different purposes



Statistical Approach

Statistical methods like kalman filtering and neural network also make it possible to produce probabilistic information.

Multiple regression method

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

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%	Daytime High Osaka 33° C
Tomorrow 14 September	RAIN AT TIMES	00-06 30% 06-12 40% 12-18 50% 18-24 30%	Morning Low / Daytime High Osaka 23° C / 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.

Verification of Probabilistic Forecast System

Verification is an essential part of probabilistic forecast systems. Correct and accurate use of probability forecasts means that, given a large sample, on average and event will occur at the same frequency as the forecast probability.

The verification of probabilistic forecast

$$\text{Brier Score} = \frac{1}{N}\sum_{i=1}^{N}(p_i - a_i)^2$$

N: the number of samples

pi: forecast probability

(ex. 0, 0.1, 0.2 …..0.9, 1)

ai: observation (1 or 0)

"Brier Score = 0" means a perfect forecast.

Decompositing brier score (Murphy 1973), we can get 3 terms; reliability term, resolution term and uncertainty term.

- Reliability term tests whether the forecast system has the correct statistical properties.
- Resolution term shows the impact obtained by issuing case-dependent probability forecasts.
- Uncertainty term represent the Brier Score one would obtain when only the climatological frequency is available.

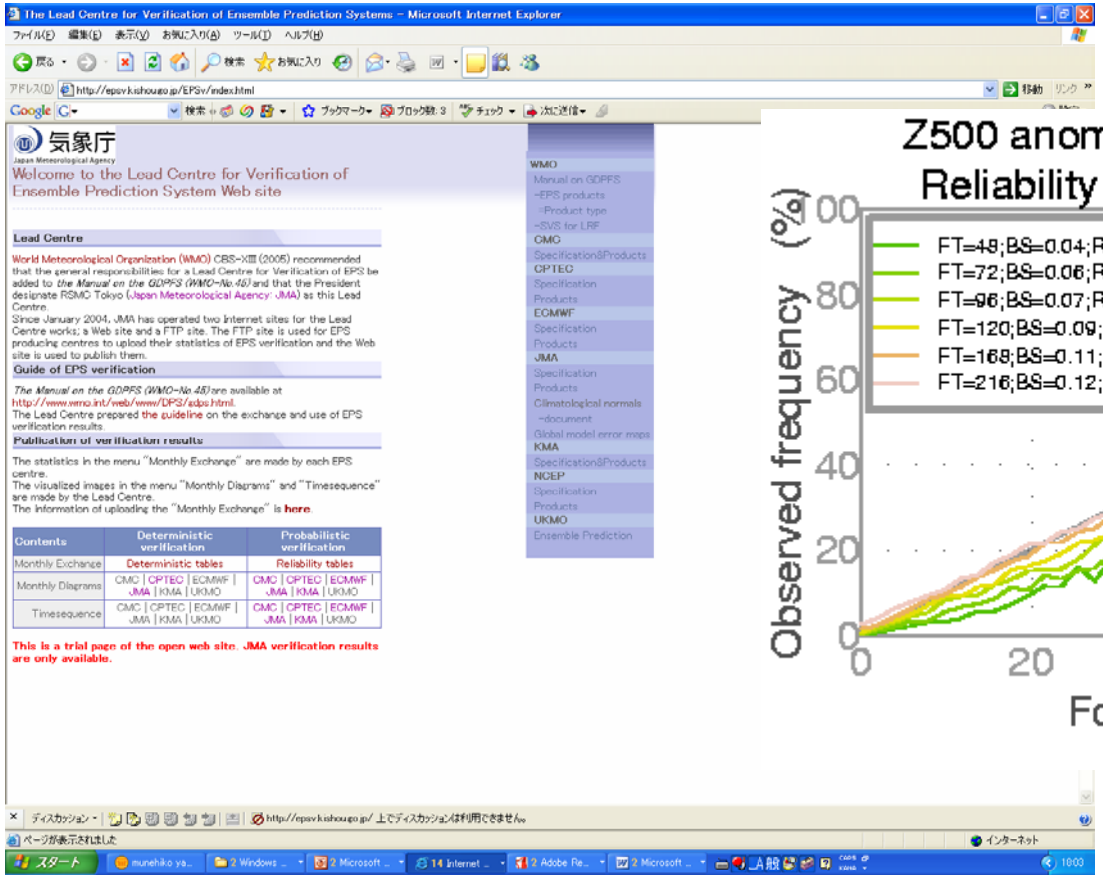
Verification of EPS

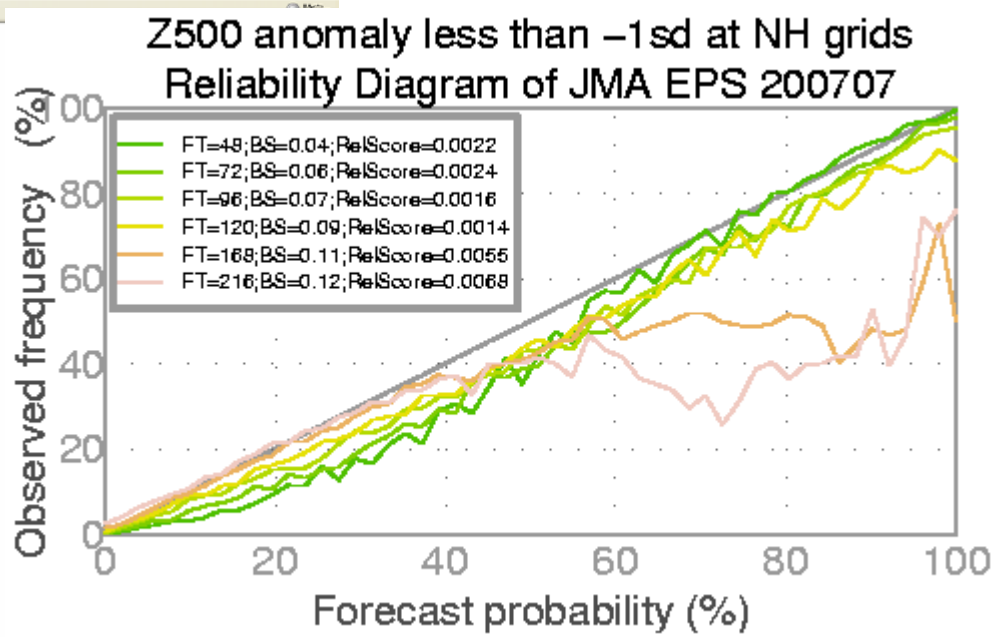
The verification of EPS

- Evaluation of spread and skill of ensemble mean
- Talagrand Diagram
- Reliability Diagram
- ROC & Cost-Loss Analysis
- Brier Skill Score

EPS Verification Program - medium range -

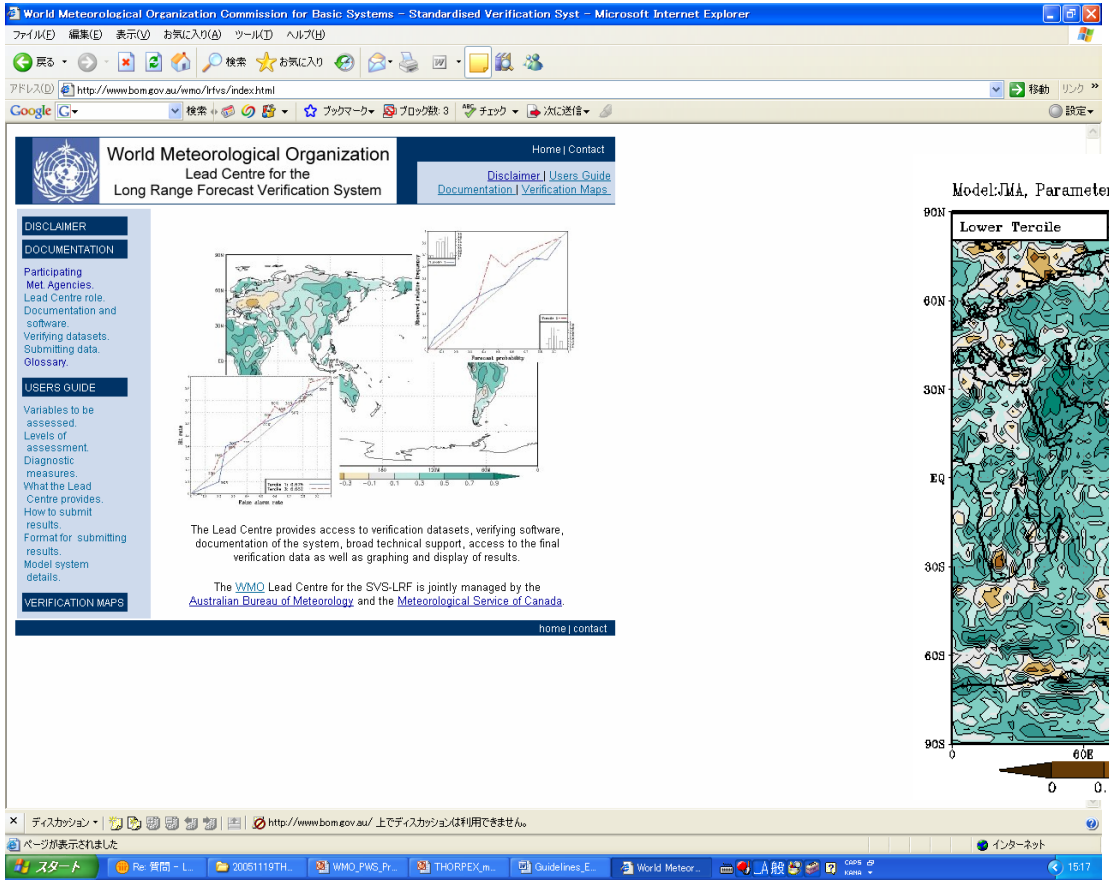
World Meteorological Organization (WMO) CBS-XIII (2005) recommended that the general responsibilities for a Lead Centre for Verification of EPS be added to *the Manual on the global data processing system (GDPFS) (WMO-No.45; available at http://www.wmo.int/web/www/DPS/gdps.html)* and that the President designate RSMC Tokyo (Japan Meteorological Agency; JMA) as the Lead Center.

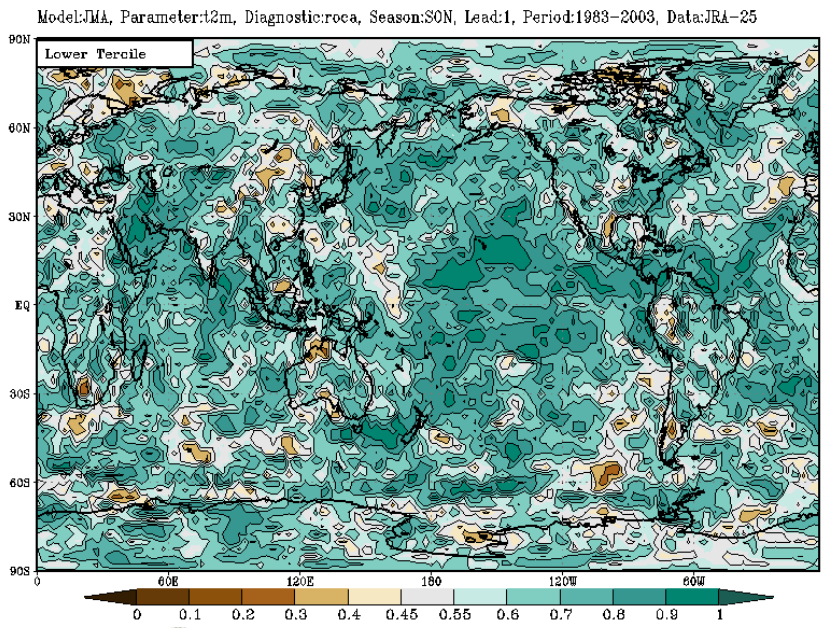




EPS Verification Program - seasonal forecast -

Based on the definition in the WMO Manual on the Global Data-Processing System, the Lead Centre, Australian Bureau of Meteorology and Meteorological Service of Canada, facilitates the exchange of seasonal and longer range forecast verification results, as specified in the Standardised Verification System (SVS) for Long Range Forecasts (LRF).





For further improvements of probabilistic forecast systems

NAEFS - operational use of multi-center ensemble -

Multi-center grand ensemble system called NAEFS (The North American Ensemble Forcast System) has been operating since March 2006. This is an international collaboration project in which the US, Canada and Mexico participate.

http://www.emc.ncep.noaa.gov/gmb/ens/NAEFS.html

RESEARCH

THORPEX Interactive Grand Global Ensemble (TIGGE)

Transfers New methods

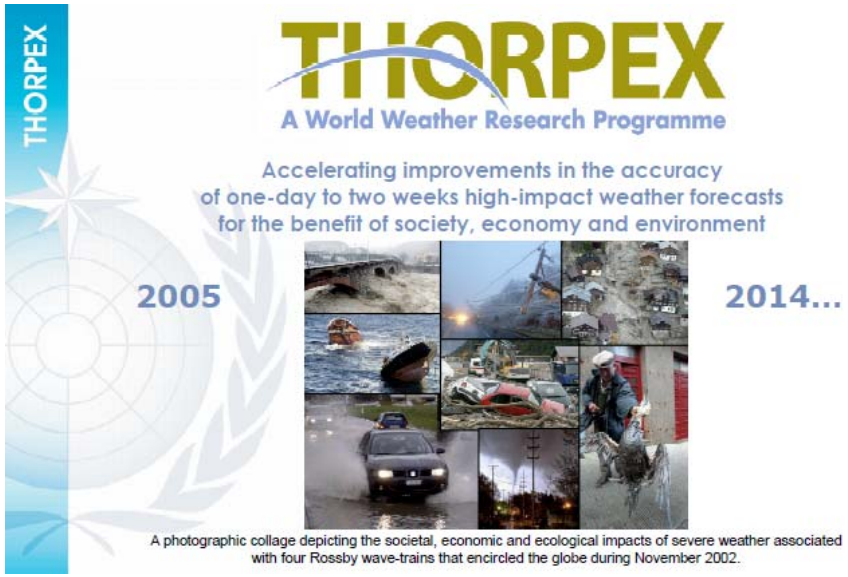
Articulates operational needs

North American Ensemble Forecast System (NAEFS)

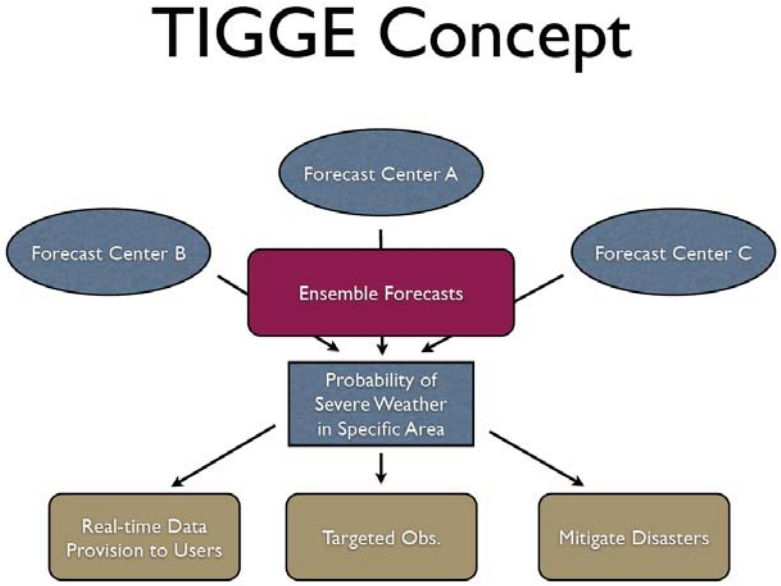
OPERATIONS

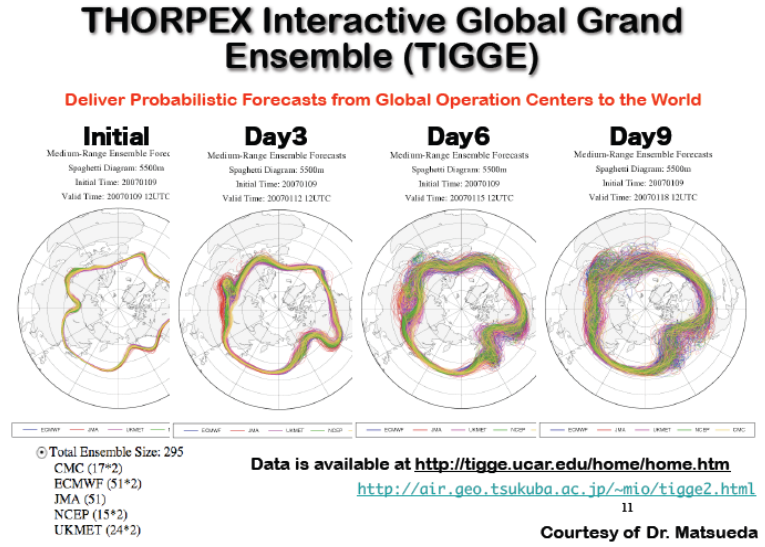
THORPEX & TIGGE - research activities -

THORPEX aims at improvements in the accuracy of one-day to two weeks high-impact weather forecasts for the benefit of society, economy and environment.



http://www.wmo.ch/pages/prog/arep/thorpex/index_en.html

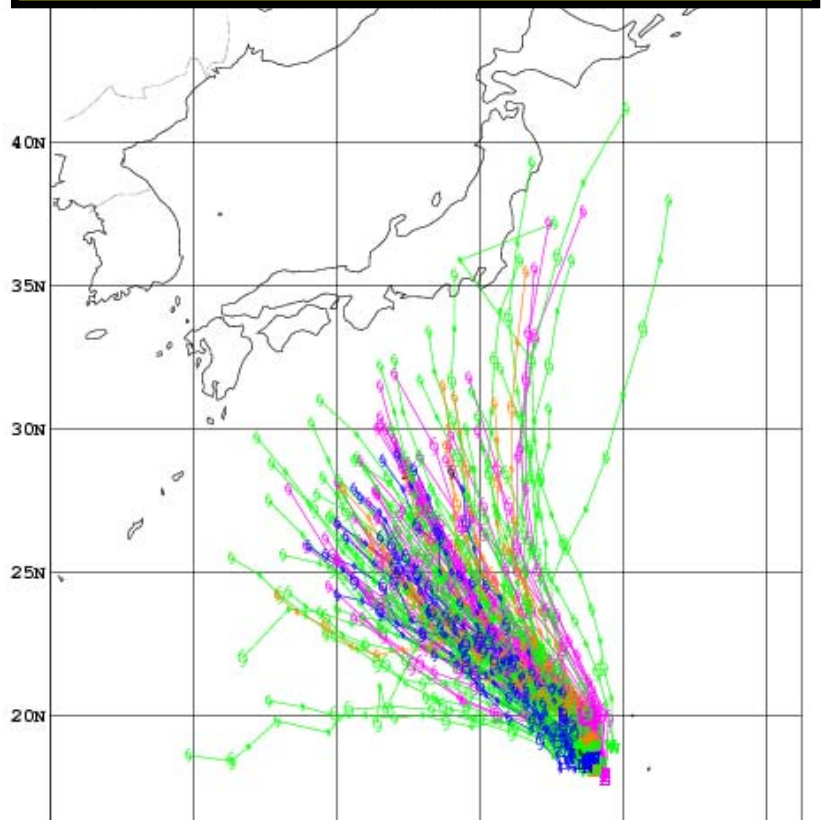




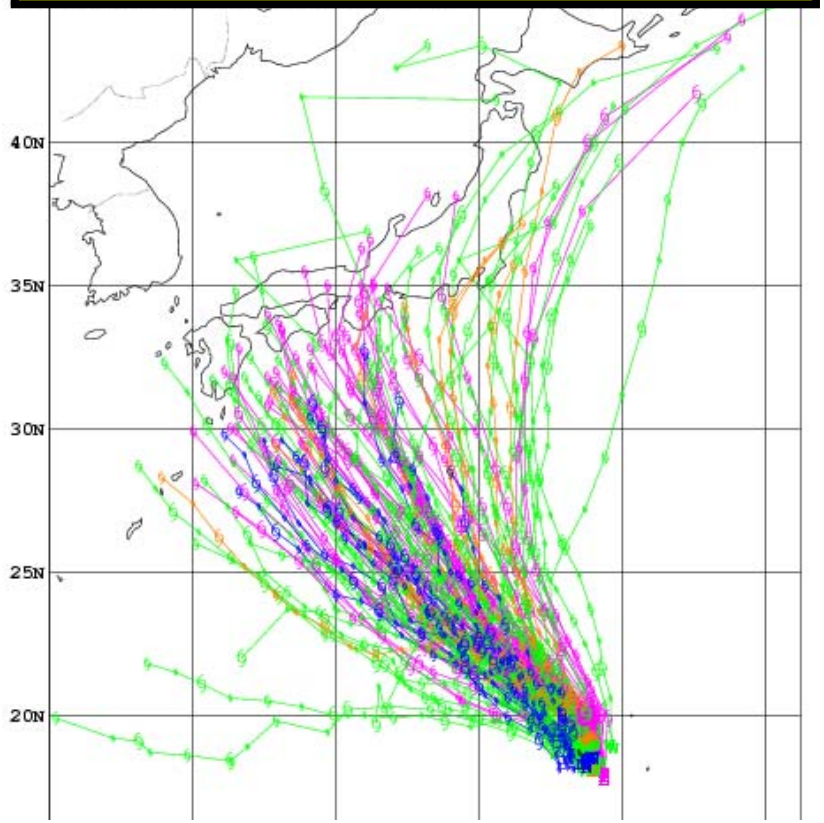
Multi Center Grand Ensemble

Initial date: 2007.07.29 12UTC Typhoon name : USAGI

T+72 hours



T+96 hours

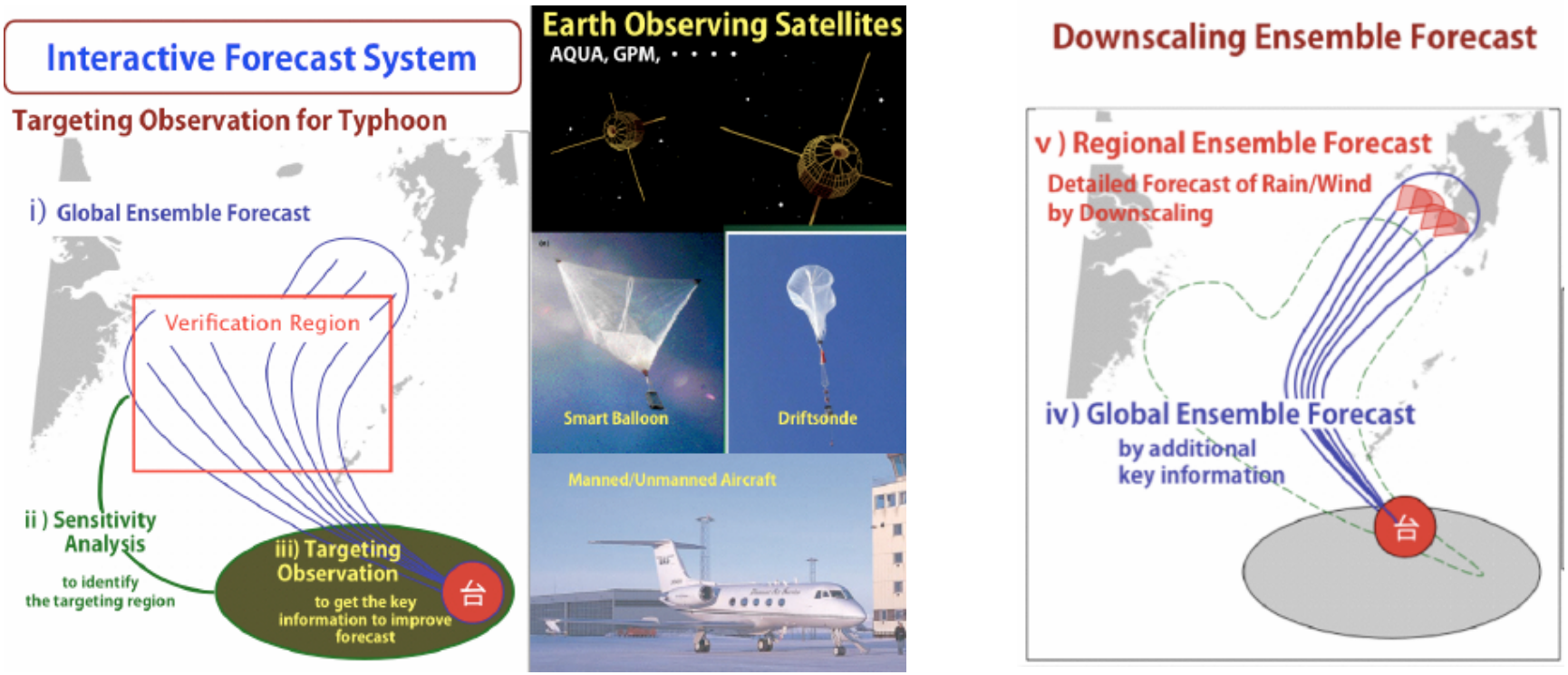


Green(51) : JMA Medium-Range EPS **Pink**(51) : ECMWF EPS

Orange(11) : JMA Typhoon EPS (semi-operation) **Blue**(14) : NCEP EPS

T-PARC

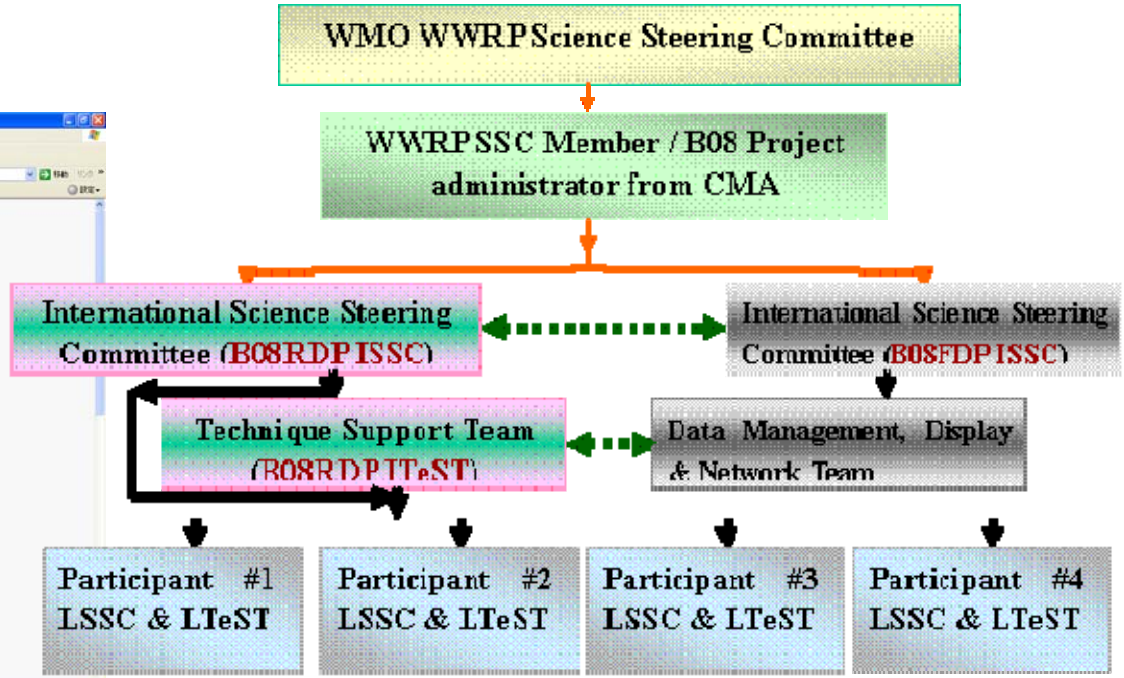
THORPEX Pacific Asian Regional Campaign (T-PARC) is a research activity aimed to improve the forecast skill of severe weather events. Predictability study, which is closely related to the concept of a probabilistic forecast, is one of the main purposes in T-PARC.



By additional observation data, T-PARC tries to reduce the uncertainties of a forecast and to improve the accuracy of a probabilistic forecast.

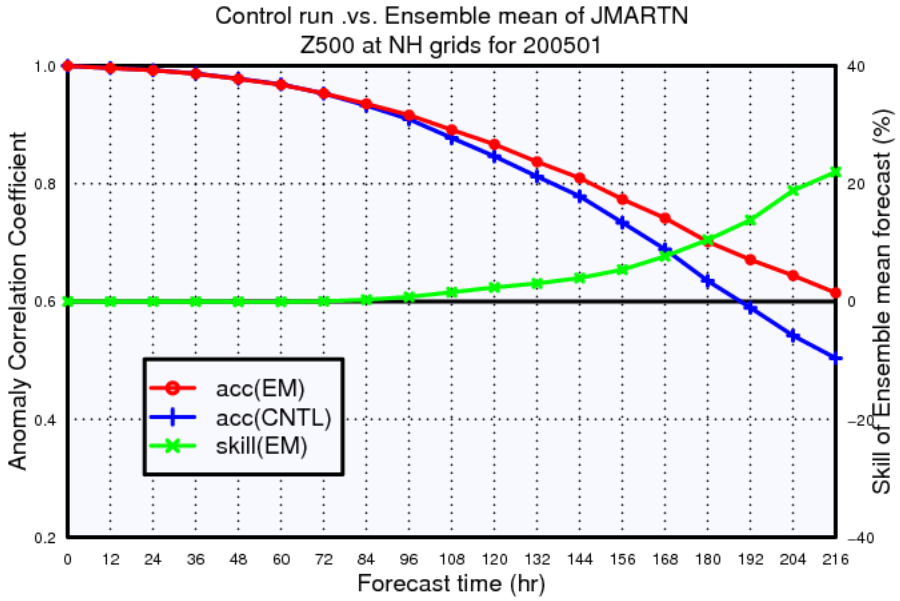
WWRP B08RDP

B08RDP stands for Beijing 2008 Olympics Mesoscale Ensemble Prediction Research and Development Project. It's designed to contribute to the better understanding and forecasting of high impact weather events, mainly rainfall and wind, in summer season in Beijing. The goals of this RDP project are to understand meso-scale high resolution (about 5 kilometres) and short range (6-36 hours) ensemble prediction, and setup state-of-the-arts EP systems during the Games and to demonstrate the social and economic benefits of the weather service.

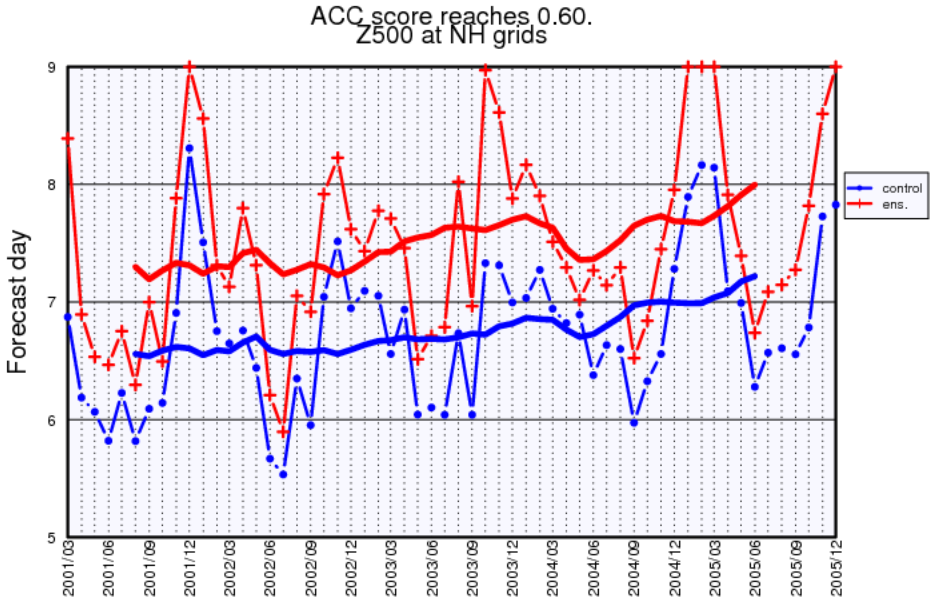


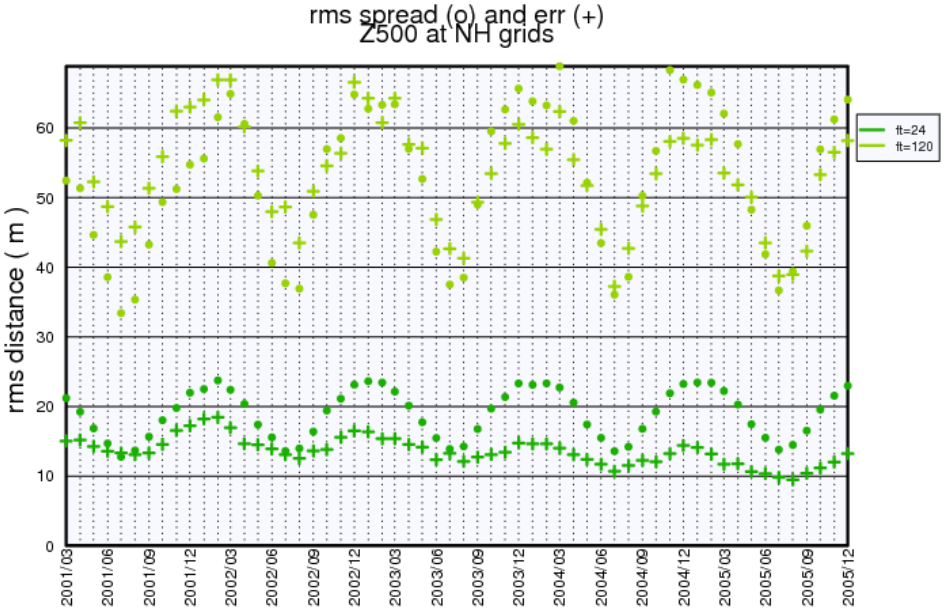
Thank you for your listening

Evaluation of spread and skill of ensemble mean



Anomaly correlation of ensemble mean forecast is more than 0.6 over the forecast period of 9 days (above left). Forecast period in which anomaly correlation is over 0.6 is about one day longer in ensemble mean forecast than control run (below left). The relationship between ensemble spread and RMSE of ensemble mean forecast (right below).





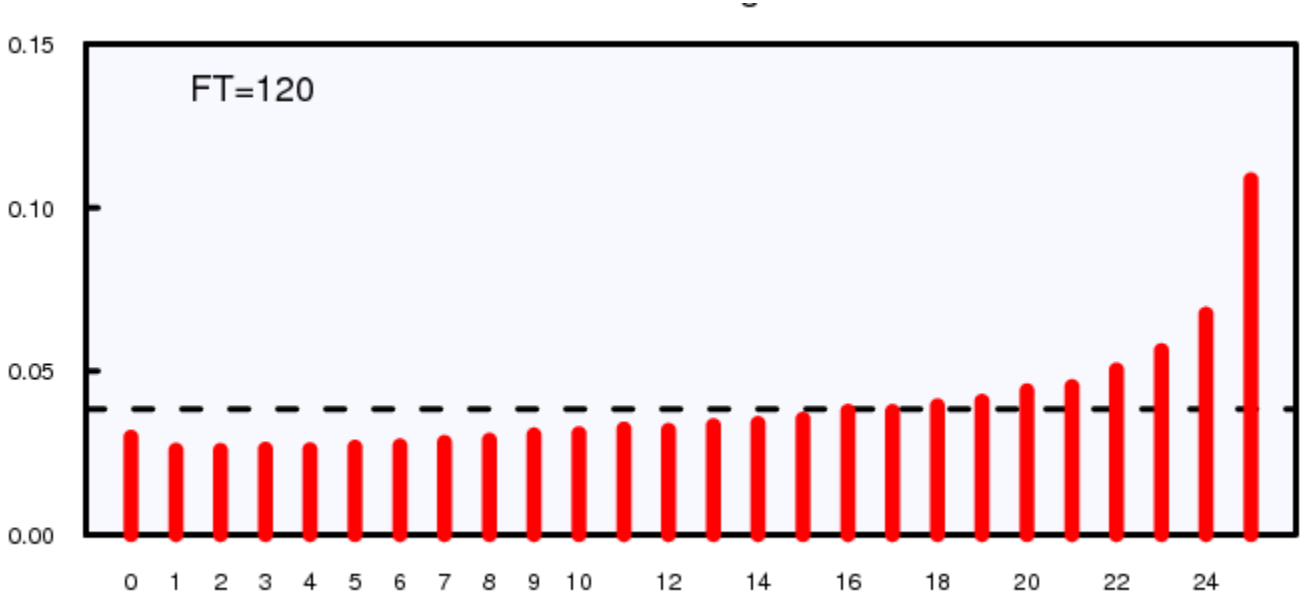
Talagrand Diagram

Talagrand diagram is useful when verifying whether or not the size of ensemble spread is appropriate and estimating a bias of a NWP model.

The size of spread is appropriate → flat

The size of spread is small → concave The size of spread is large → convex

J-shape or L shape → suggesting a bias of a NWP model

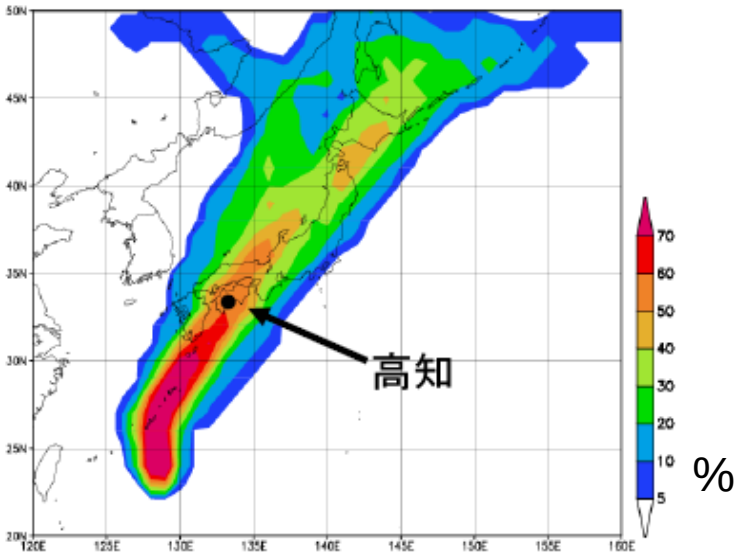


Talagrand diagram for 5-day forecast by JMA medium-range EPS.

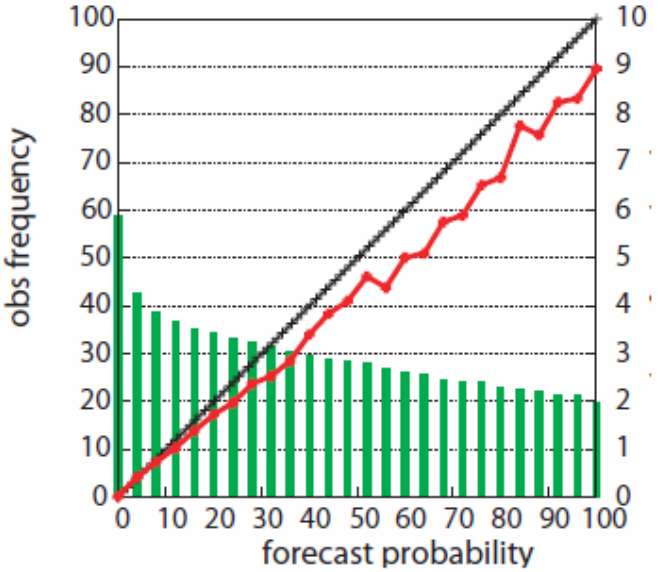
Verification element is T850. Verification area is Japan. Verification period is July 2007

Reliability Diagram

Correct and accurate use of probability forecasts means that, given a large sample, on average an event will occur at the same frequency as the forecast probability. Reliability diagram is useful when verifying the accuracy of forecast probability.



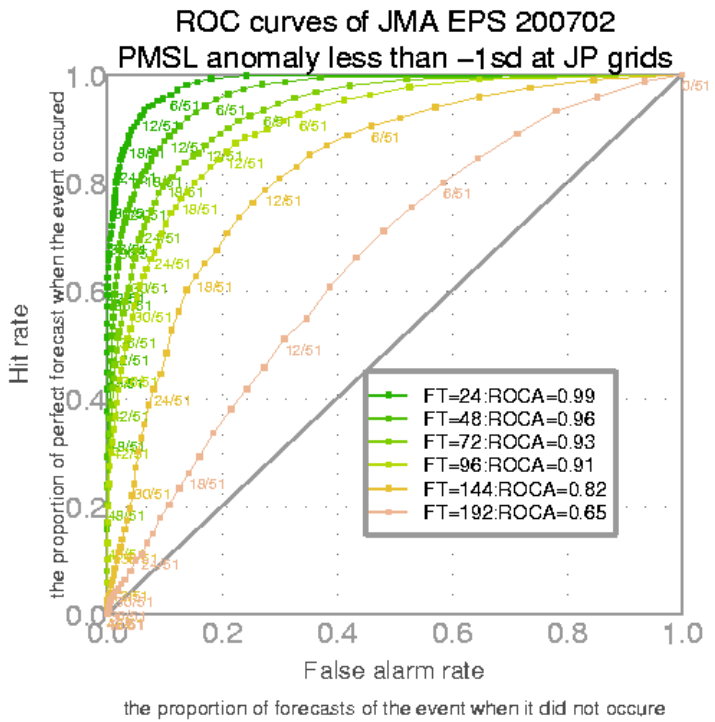
Typhoon strike probability map, which gives the probability of typhoon striking over the next 5 days.



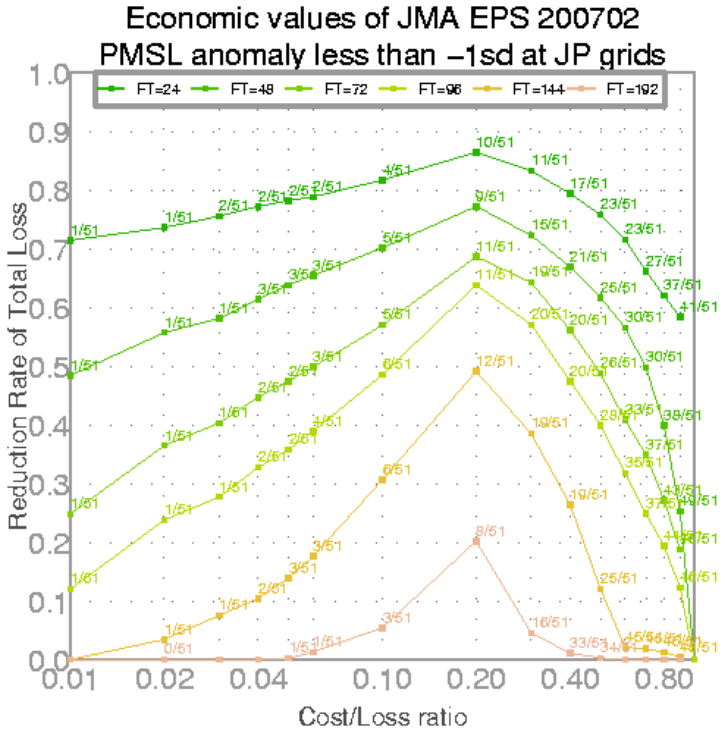
Reliability diagram of typhoon strike probability. Verification period is 2004.

ROC & Cost-Loss analysis

Optimal use of forecasts can be facilitated by examining the Relative Operating Characteristic (ROC) curve, and economic value can be estimated with simple tools such as the Cost/Loss model. Although analyses such as these are a good starting point, in practice the detailed applications will have to be worked out with individual users or user communities.



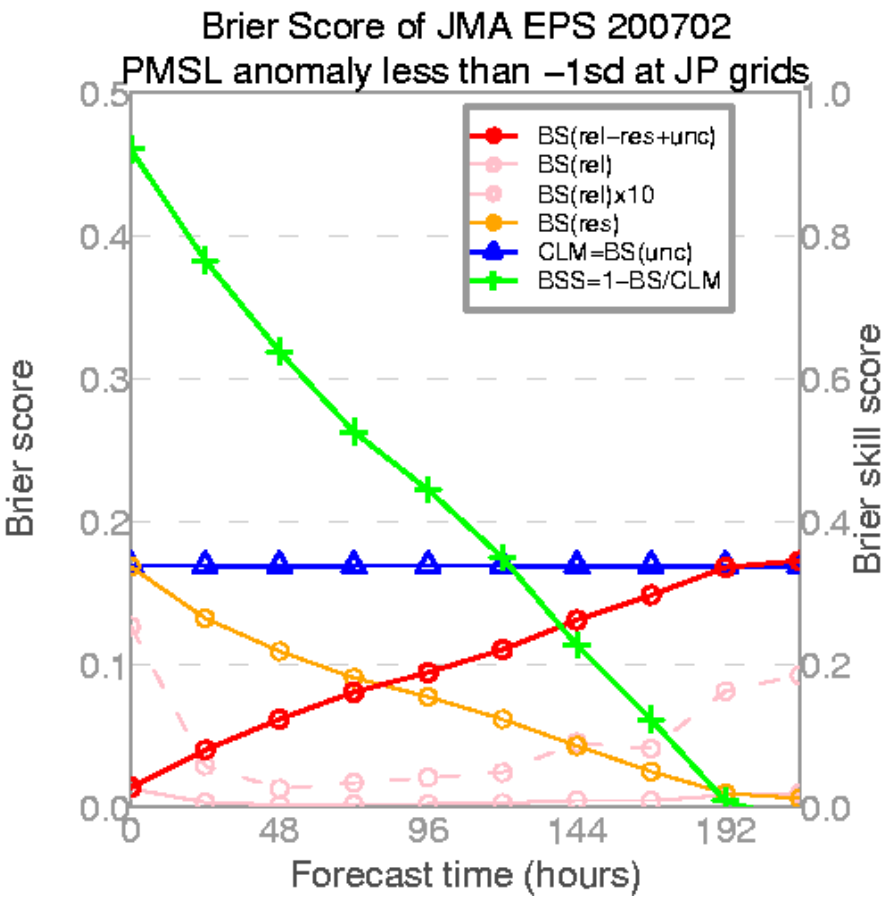
Roc curves by JMA medium-range EPS. Verification element is the probability that PMSL anomaly is less than 1 standard deviation. Verification period is Feb. 2007, and area is Japan.



The result of Cost-Loss analysis.

Brier Skill Score

Skill score gives an easy understanding on the value of a probabilistic forecasts.



Brier Skill Score (green line) by JMA medium-range EPS. Verification element is the probability that PMSL anomaly is less than 1 standard deviation. Verification period is Feb. 2007, and area is Japan.

Brier Skill Score : **green**

Brier Score of a probabilistic forecast : **red**

Brier Score of climatorogical forecast : **blue**