



# Concept of numerical guidance



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Climate Prediction Division of  
Japan Meteorological Agency (JMA)*

# Outline

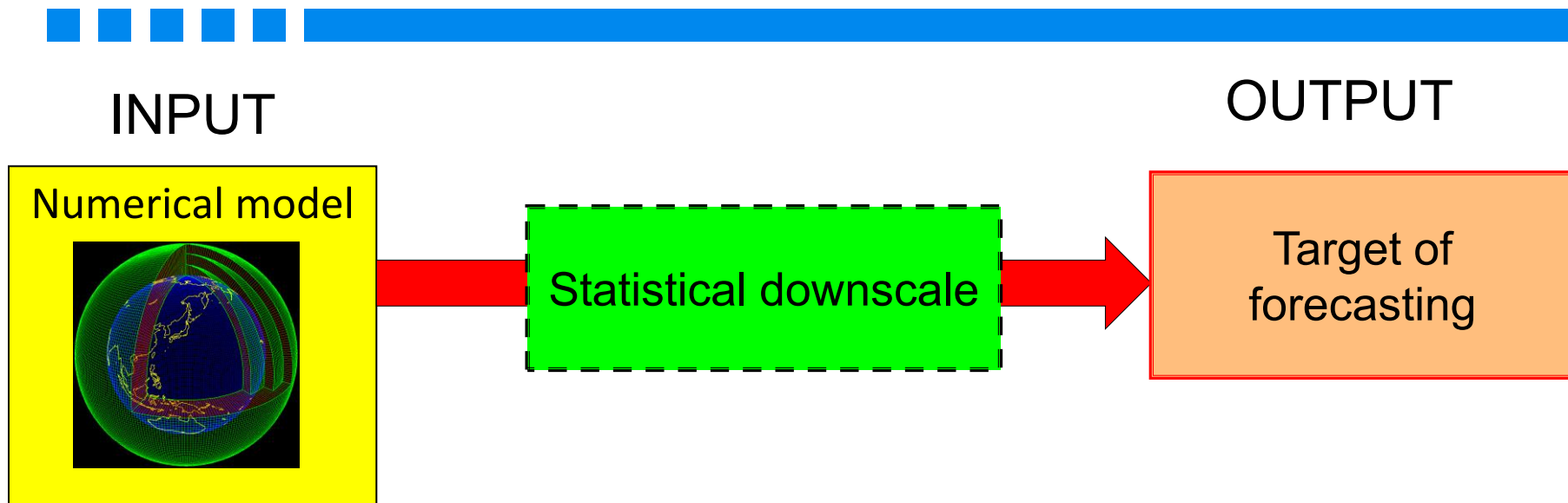
- Basic concept of the guidance
  - Objective of Guidance
  - MOS Technique
  - Regression Model
  - Estimation of Probability
- Verification
  - Verification Score



# Basic concept of the guidance



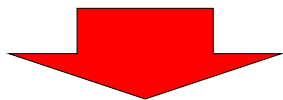
# Guidance



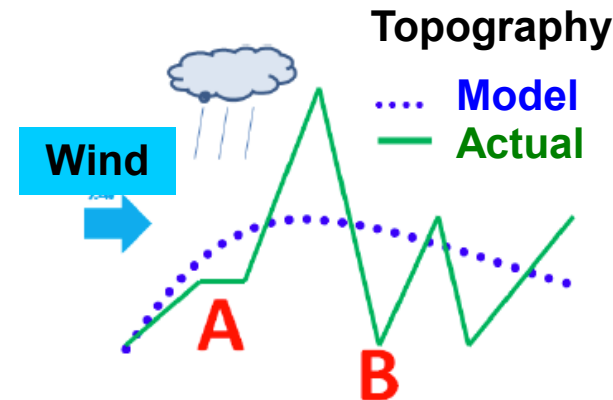
- “**Guidance**” is an application tool to translate model output values into target of forecasting.
- Principle of guidance is **based on statistical relationship** using model forecasts and observation data for past cases.

# Role of Guidance

- To extract the effects of sub-grid scale topography
  - Model may not enough reproduce the effects of local topography due to limited resolution, while a guidance enable to consider from the large-scale field.
- To reduce imperfection of the model, such as systematic error (bias error)
- To estimate degree of uncertainty, considering prediction skill



“Guidance” enable to improve prediction skill from the direct model output.



- A: Upwind side
  - Model may underestimate precipitation
- B: Bottom of the valley
  - Model may have warming bias

# Principle of Guidance – MOS Technique

## MOS (Model Output Statistics):

Forecast value is derived by **statistical relationship** between observation and model forecast from past cases, and **applied** this relationship **to the real-time forecast**.

➤ Two types of the time series data are necessary in order to produce guidance.

- 1. **Past observation**  
(Variable to be predicted; **Predictand**)
- 2. **Past model forecast by hindcast** (**Predictor**)

Prepared by users  
(Thank you for preparing!!!)

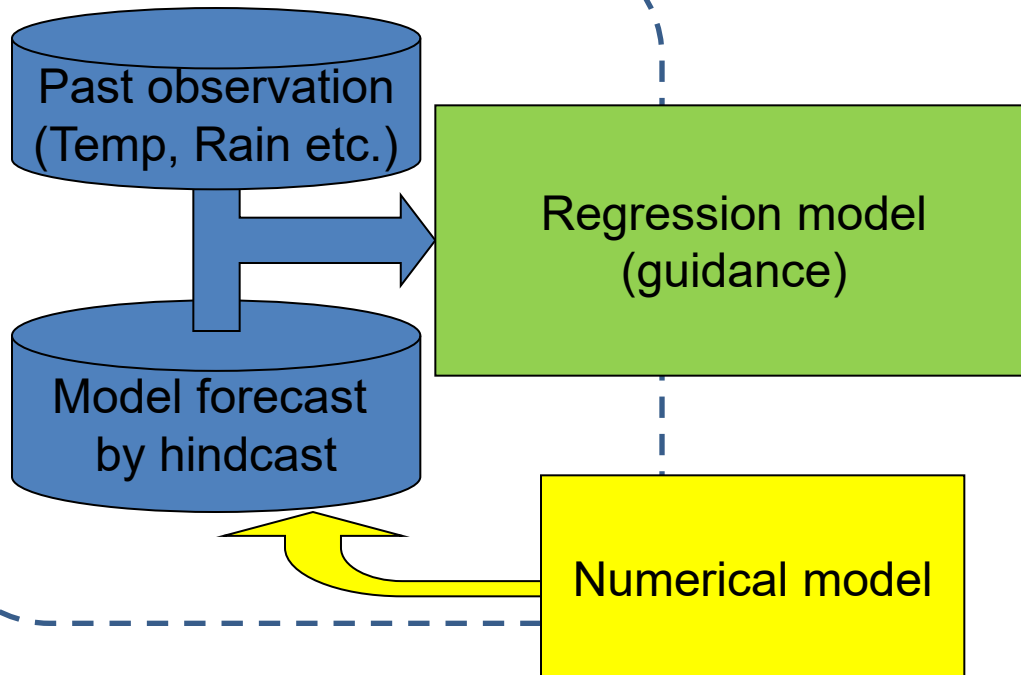
Included in the guidance tool

# Concept of MOS Technique (1)

- **Statistical relationship** is estimated by the regression model using observation and model forecast for past cases.

1

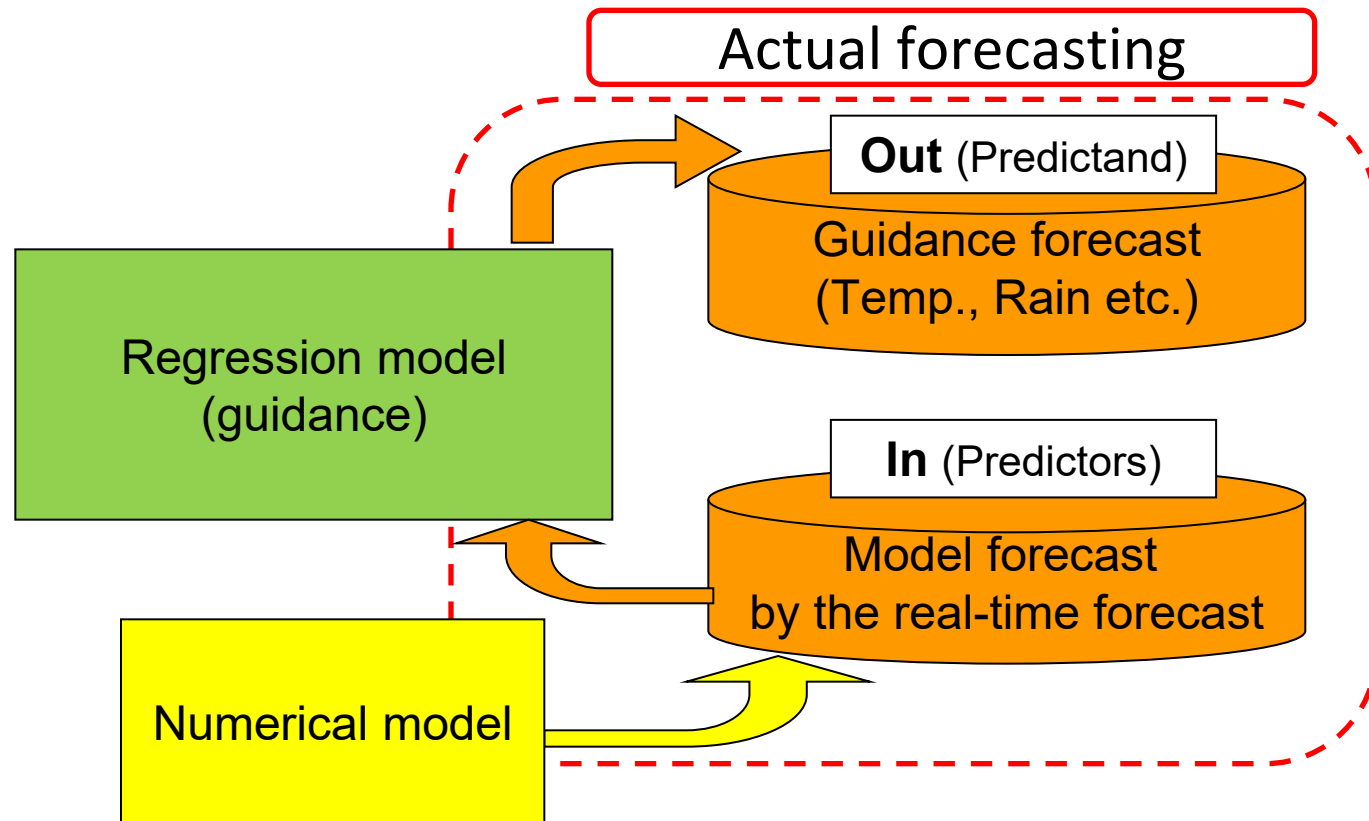
Producing guidance



# Concept of MOS Technique (2)

- In the real-time forecast, model results are **applied to the statistical relationship** to obtain guidance result.

2

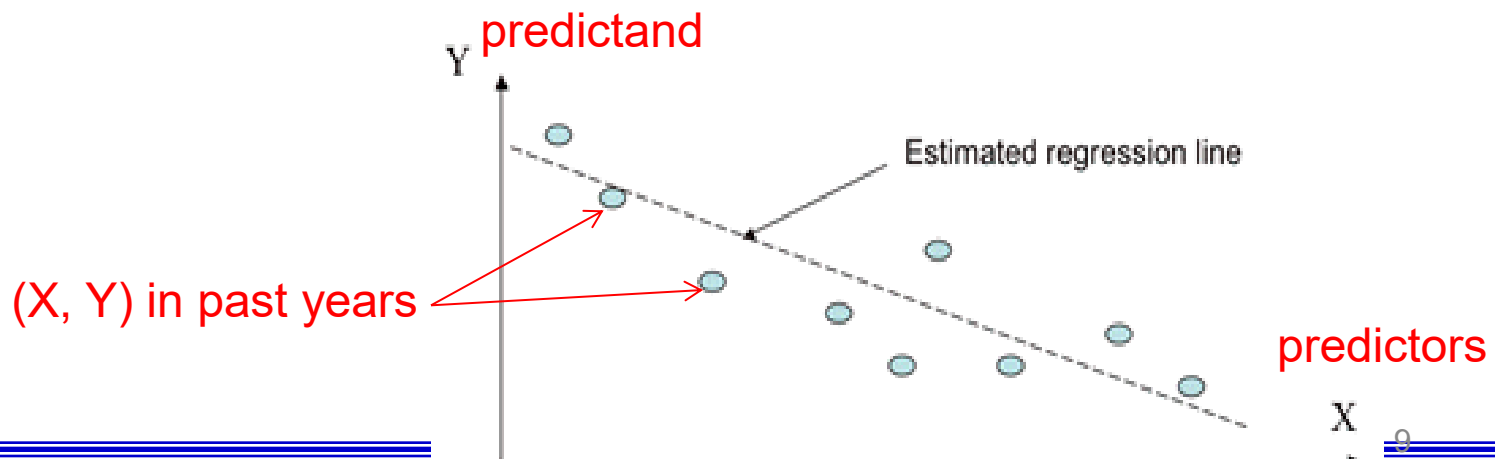


# Single Regression

- “**Single regression**” is the relationship between **one explanatory predictor** and **variable to be predicted** (predictand, ex., temp. rainfall).
- Single regression model is written as

$$Y = aX + b + \varepsilon$$

Y: predictand    X: predictor  
a: regression coefficient    b: constant,  
 $\varepsilon$ : error term



# Multiple Regression

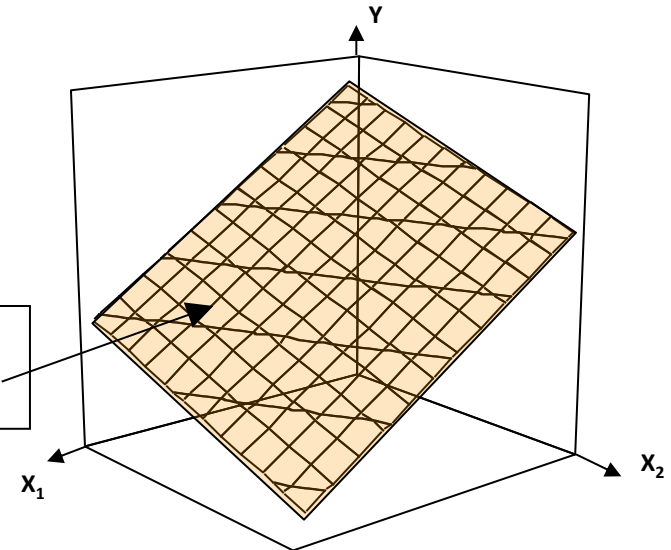
- **“Multiple Regression”** is **more than one predictors** are employed.
  - It is assumed that the predictand is the **sum of a linear combination** of predictors.

Example: **two** predictors

$$Y = a_1X_1 + a_2X_2 + b + \varepsilon$$

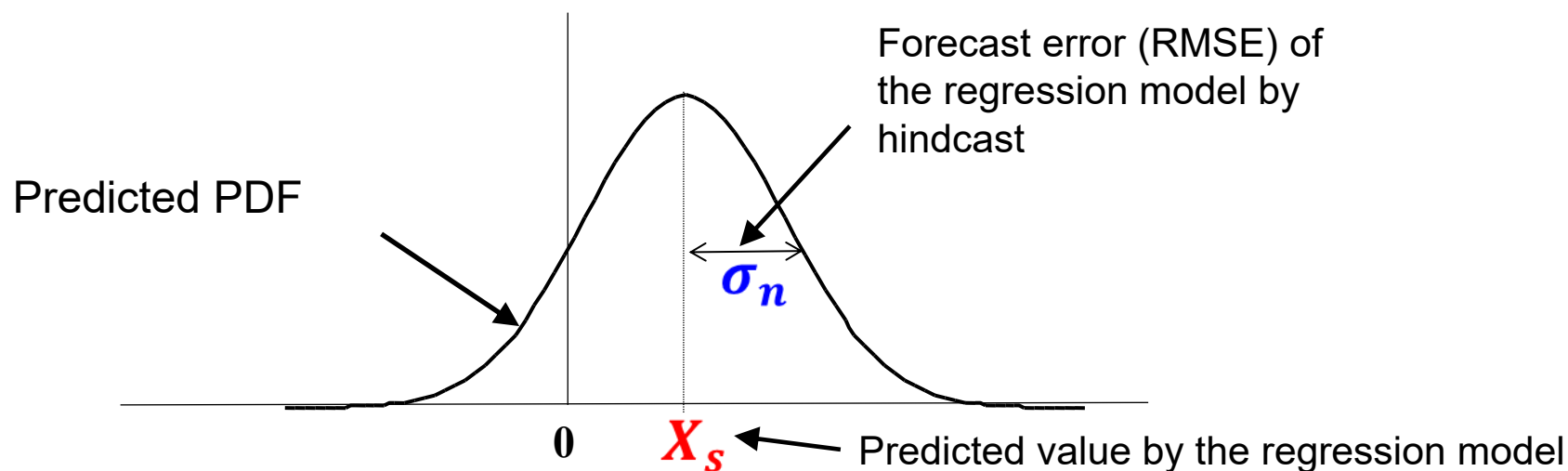
$a_1, a_2$ : regression coefficient  
 $b$ : constant  
 $\varepsilon$ : error term

Predictand will be near this plane.



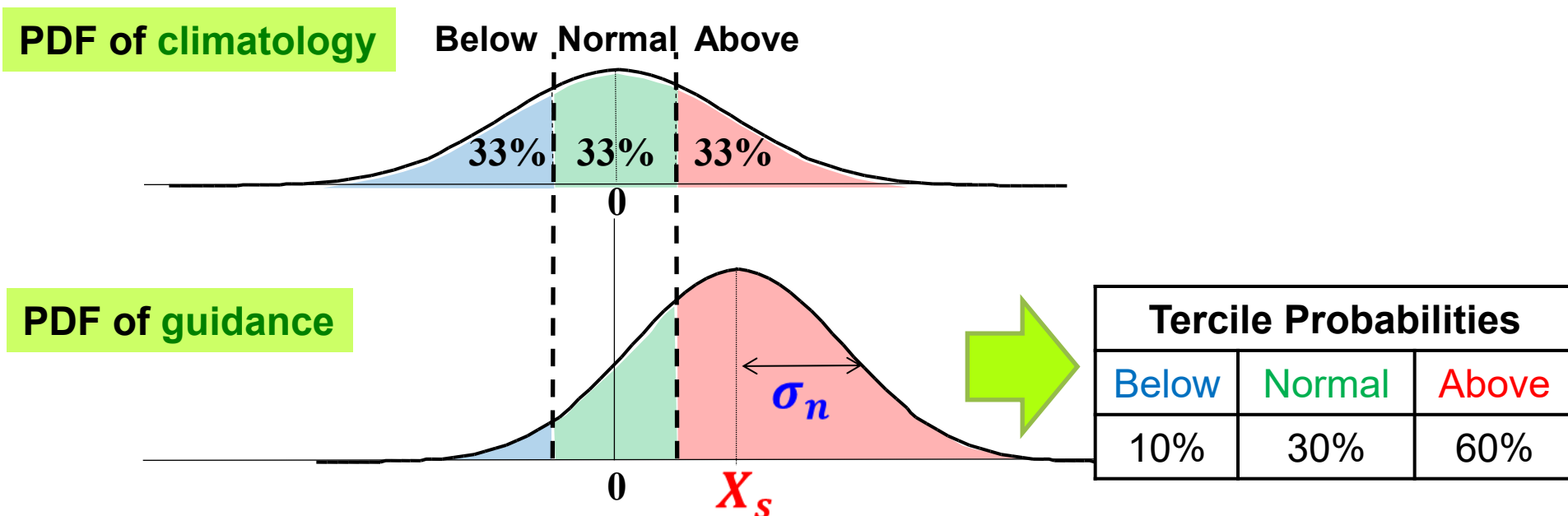
# Translation to PDF in the regression model

- Probabilistic forecast is essential for seasonal prediction.
- In the guidance tool, Probability Density Function (PDF) is assumed to be a normal distribution.
  - **Mean ( $x_s$ )**: prediction value by the regression model
  - **Standard deviation ( $\sigma_n$ )**: error of the regression model, which is assumed to be forecast error (RMSE) of the regression model using hindcast.



# Estimation of Tercile probability with regression model

- The threshold values for tercile categories (below-, near-, above-normal) determined from the past observation. (ex. 1991 to 2020, depending on the setting by user)
- Probability for each tercile category is calculated by PDF of guidance and the threshold values for tercile categories.



# Normalization of Precipitation Data

- **Normal distribution** is assumed in the regression model.
- As for temperature, its distribution is generally approximated by a normal distribution.

Meanwhile,

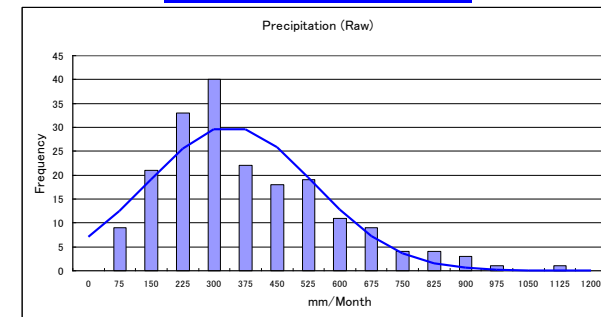
- As for precipitation, its distribution does not represent a normal distribution, and it's generally approximated by a gamma distribution.
- In order to create guidance, precipitation data need to be normalized.



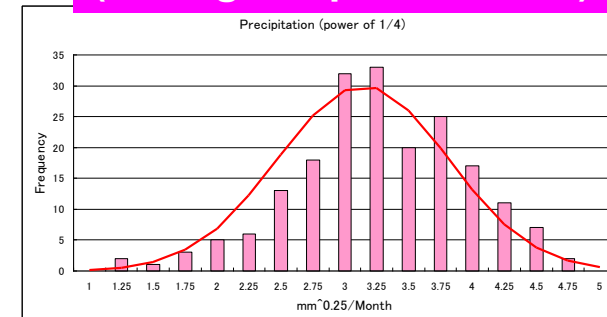
- Power of 1/4 for precipitation ( $\text{RAIN}^{1/4}$ ) is approximated by a normal distribution.

Ex. Precipitation over Japan

(Raw value)



(Taking the power of 1/4)



◆ The guidance tool automatically enable to consider this normalization.



# Verification



# Verification scores for Deterministic Forecast

## ● Root Mean Square Error (RMSE)

- representing absolute magnitude of the forecast
- **Perfect score: 0**

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (F_i - O_i)^2}$$

$F_i$ : Forecast,       $O_i$ : Observation  
 $C_i$ : Climatology,     $N$ : Sample size

## ● Anomaly Correlation Coefficient (ACC)

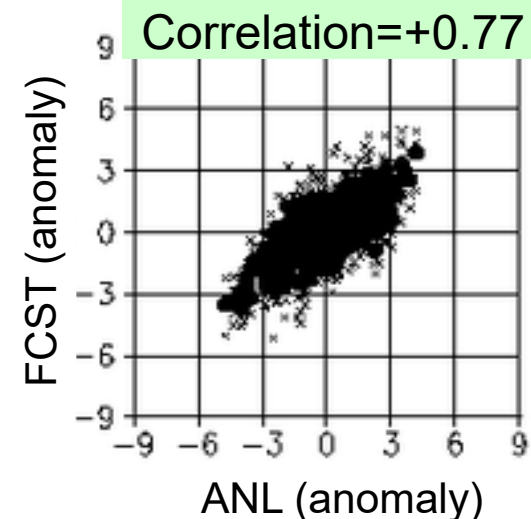
- representing correlation between anomalies of forecasts and those of the **reference**

1: Perfect score

0.31: 95% significance level of t-test (30 samples)

0: No signal

$$ACC = \frac{\sum_{i=1}^N (F_i - C_i)(O_i - C_i)}{\sqrt{\sum_{i=1}^N (F_i - C_i)^2} \sqrt{\sum_{i=1}^N (O_i - C_i)^2}}$$

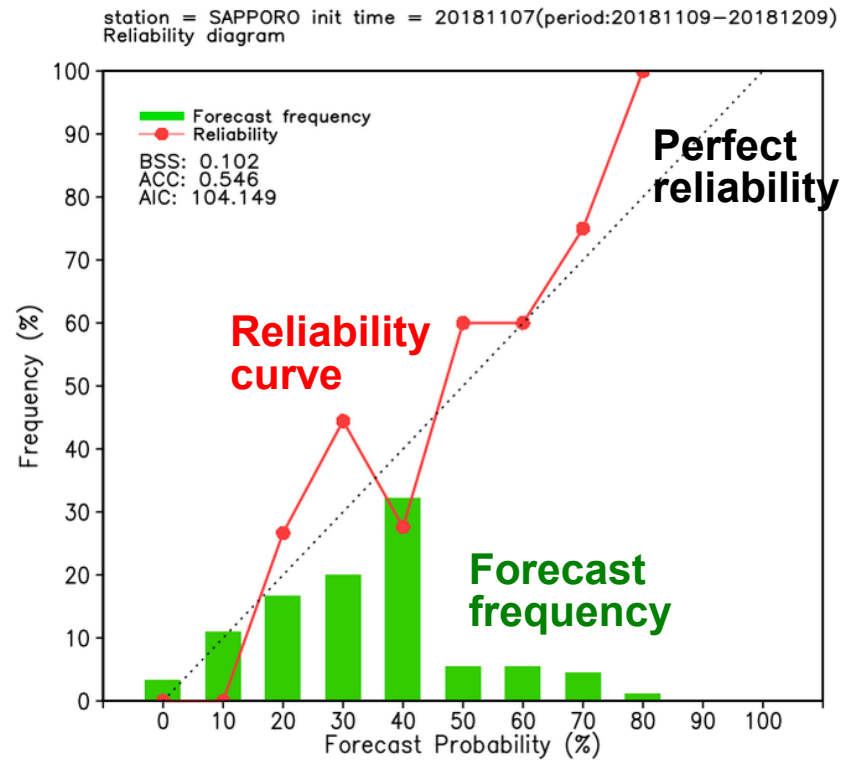


# Reliability Diagram

- **Red line (reliability curve);**
  - plotted the observed frequency (Y-axis) against the forecast probability (X-axis)

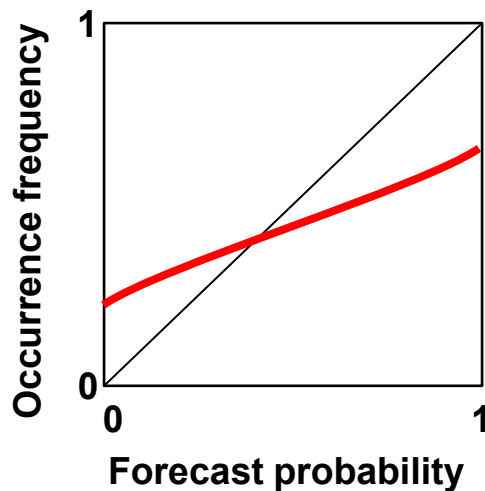
Probabilistic forecast becomes better the more the reliability curve fit to 45° line (perfect reliability).

- **Green bars denote forecast frequency (sharpness diagram);**
  - If most of the forecast probabilities are near the climatological frequency (33%) => **unsharp**
  - If probabilities near 0% or 100% are often calculated => **sharp**

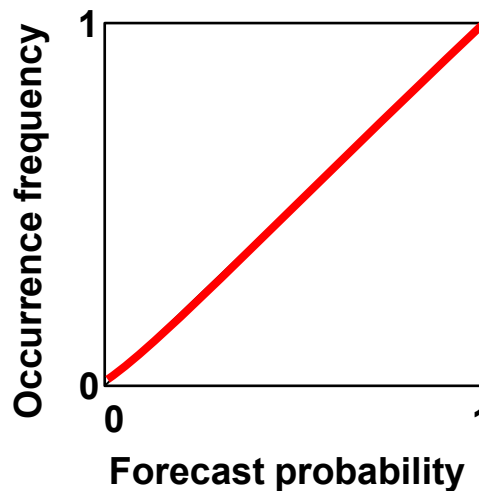


# Over/under Confidence

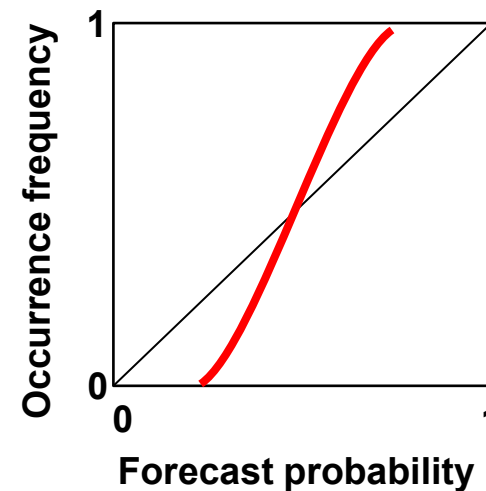
**Over confidence**



**Perfect reliability**



**Under confidence**



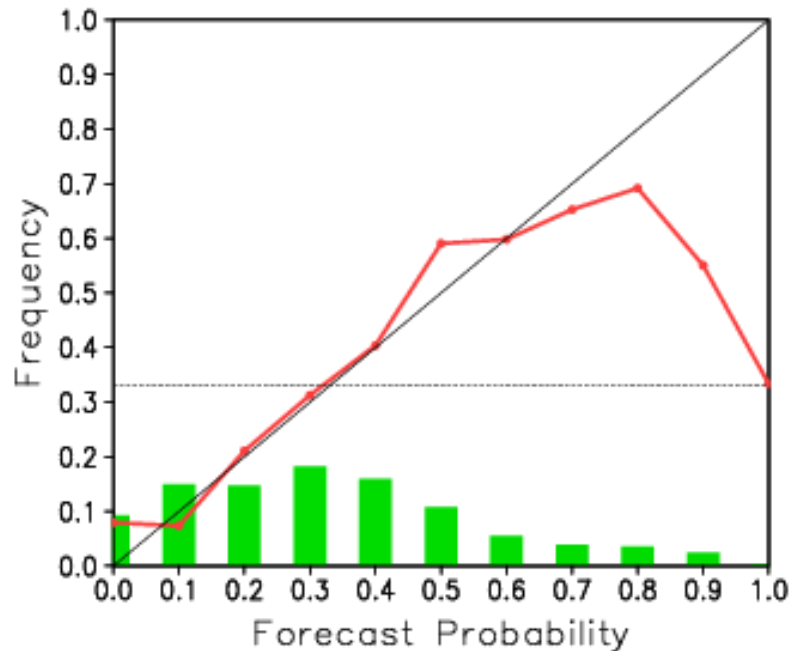
- ✓ Predicted probabilities are **overestimated** as compared with the actual

- ✓ Predicted probabilities are **underestimated** as compared with the actual

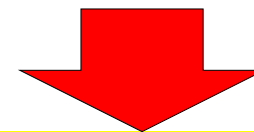
## Example

Surface Temperature (140E , 35N)

BSS=14.98    Brel=90.8    Bres=24.1



- The forecast is generally reliable for below 60%, while over-confident over 70%.



- ✓ Maximum probability should be suppressed under about 60%

- In actual, reliability curve may not such smooth “curve”.
- If so, the forecaster should moderate the probabilities, taking account of the other information, such as the verification scores (e.g., ACC, BSS).

# Brier (skill) Score (BS)

□ **Brier score** is mean squared error of the probability forecasts.

$$BS = \frac{1}{2N} \sum_{i=1}^N \sum_{m=1}^3 (p_i^m - o_i^m)^2$$

$p_i^m$  : forecast probability

$o_i^m$  : observed occurrence(0 or 1)

$N$  : forecast frequency

$m$  : category

- Range: 0 to 1
- Smaller score indicates better forecast (Perfect score: 0)

□ **Brier skill score** is skill relative to a reference forecast (usually climatology).

$$BSS = 1 - \frac{BS}{BS_{reference}}$$

- Perfect score: 1
- $BSS > 0$ ; better than the climatological forecast.
- $BSS = 0$ ; climate forecast
- $BSS < 0$ ; worse than the climatological forecast.

$$BSr = \frac{1}{3}$$