Concept of numerical guidance

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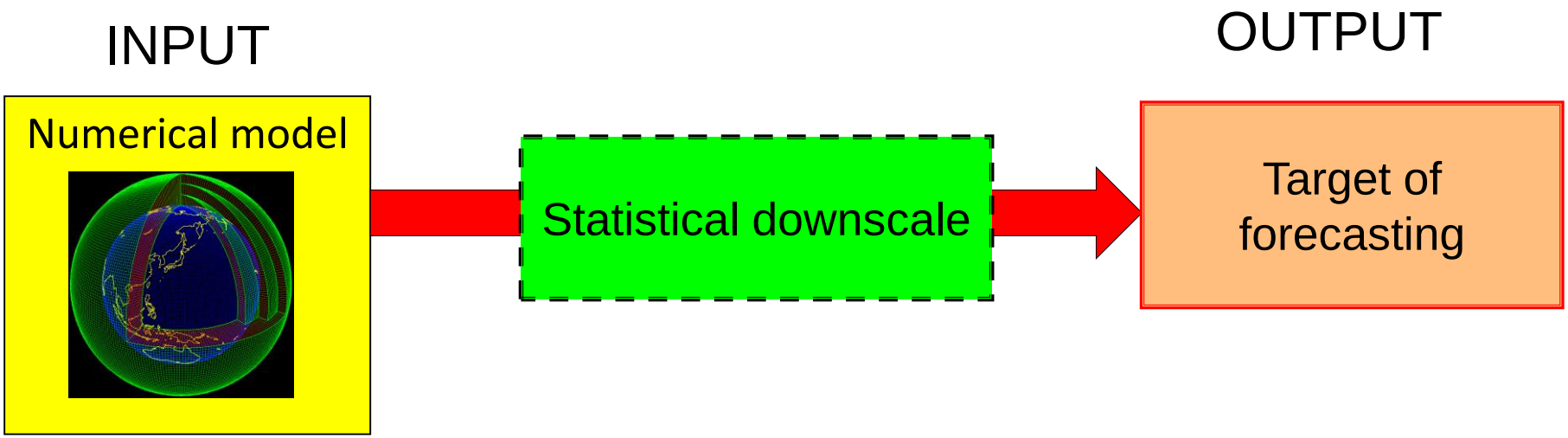
Outline

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

Basic concept of the guidance

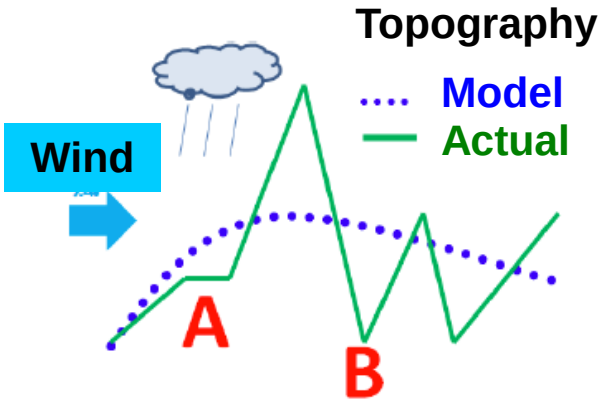
Guidance



- "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



A: Upwind side
- ➢Model may underestimate precipitation

B: Bottom of the valley
- ➢Model may have warming bias

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

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.

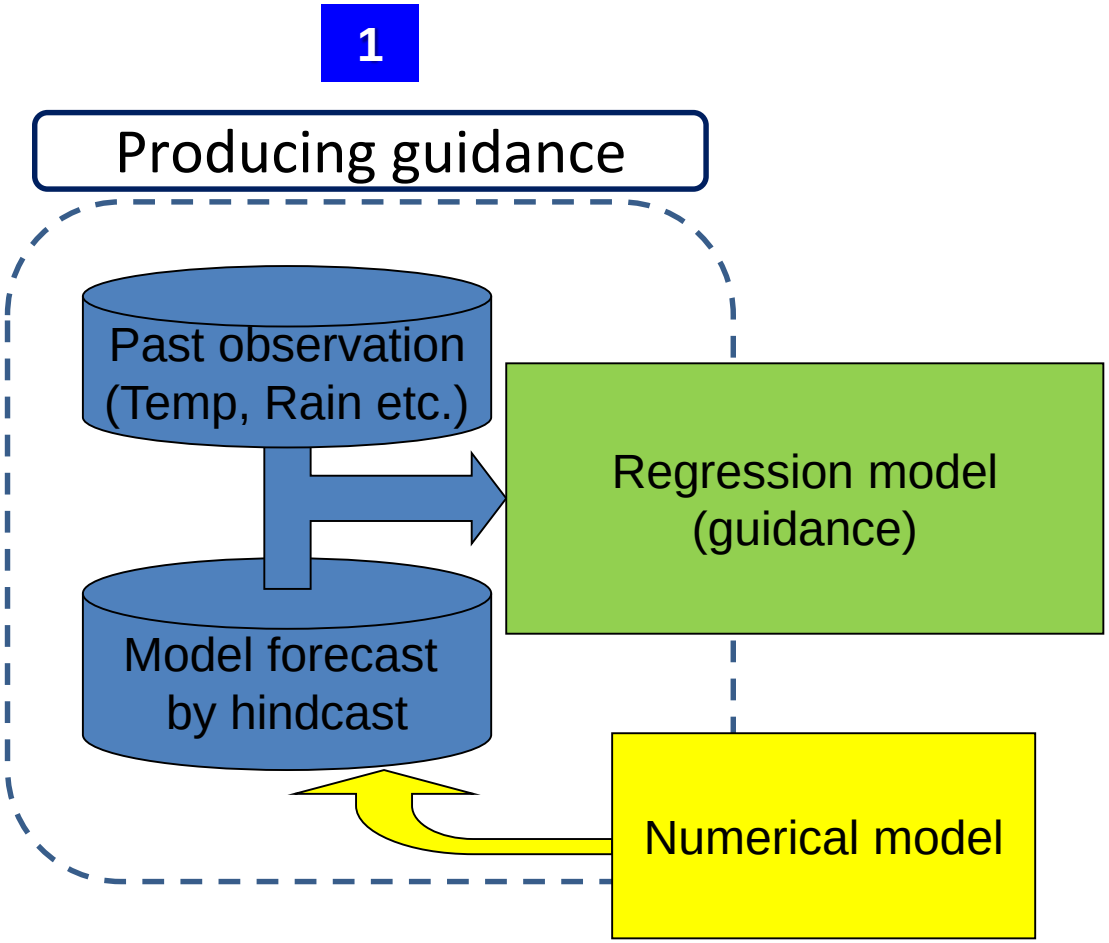
- Two types of the time series data are necessary in order to produce guidance.
  - 1. Past observation
    (Variable to be predicted; Predictand)
  - 2. Past model forecast by hindcast (Predictor)

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

Included in the guidance tool

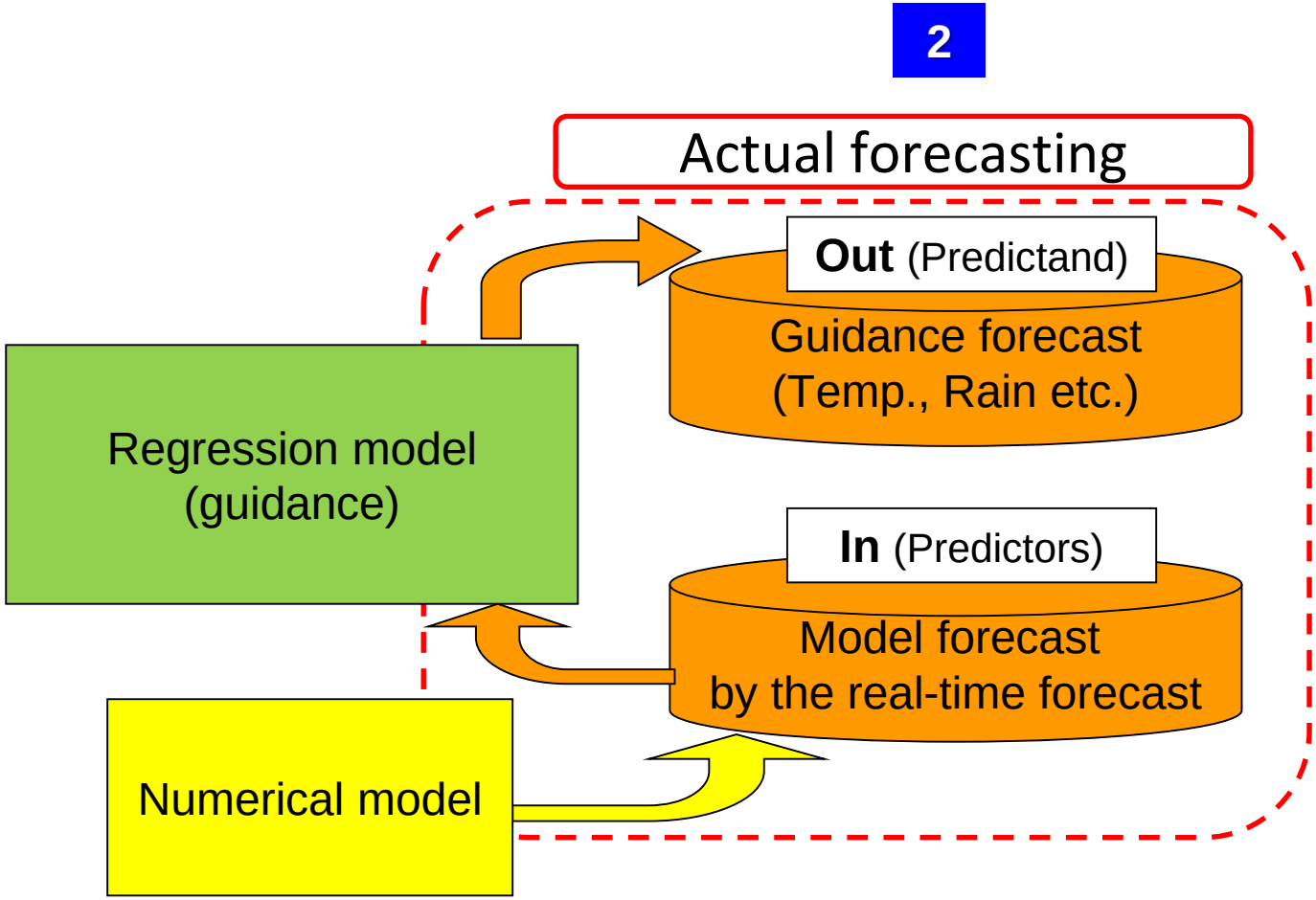
Concept of MOS Technique (1)

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



Concept of MOS Technique (2)

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

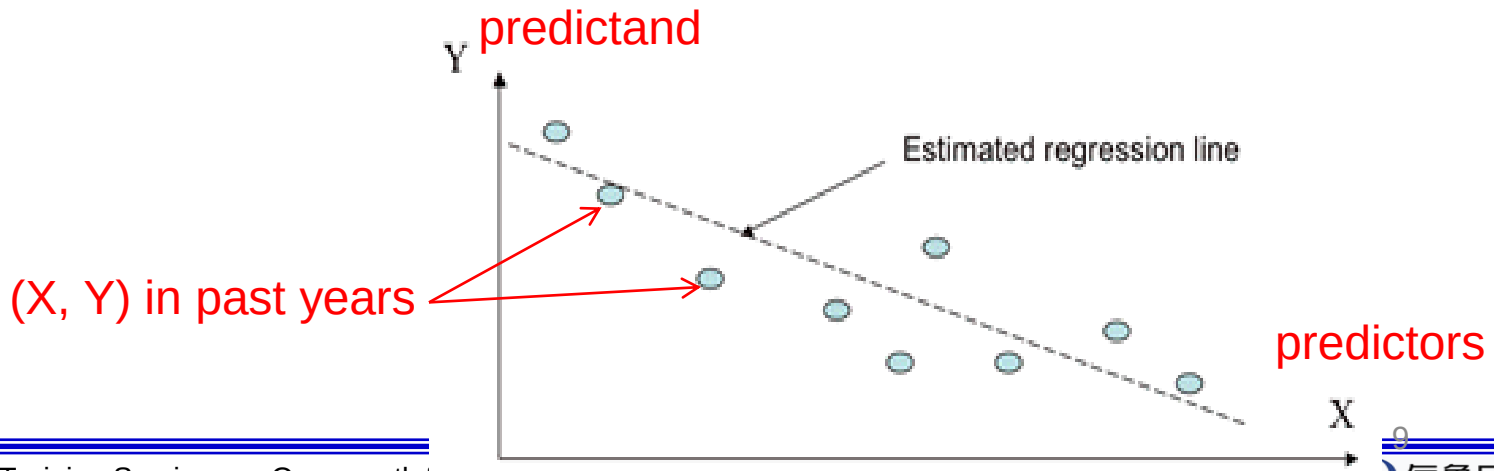


Single Regression

- "**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,
ε: error term



Multiple Regression

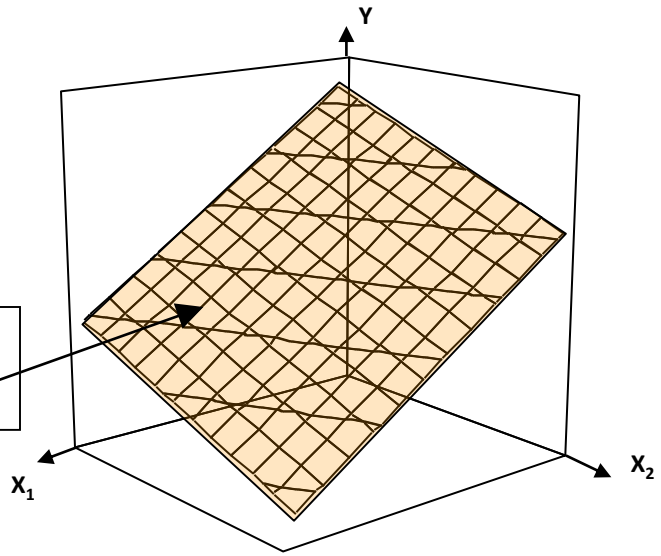
- **"Multiple Regression"** is **more than one** predictors are employed.
  - It is assumed that the predictand is the sum of a linear combination of predictors.

Example: **two** predictors

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

a_1, a_2: regression coefficient
b: constant
ε: error term

Predictand will be near this plane.

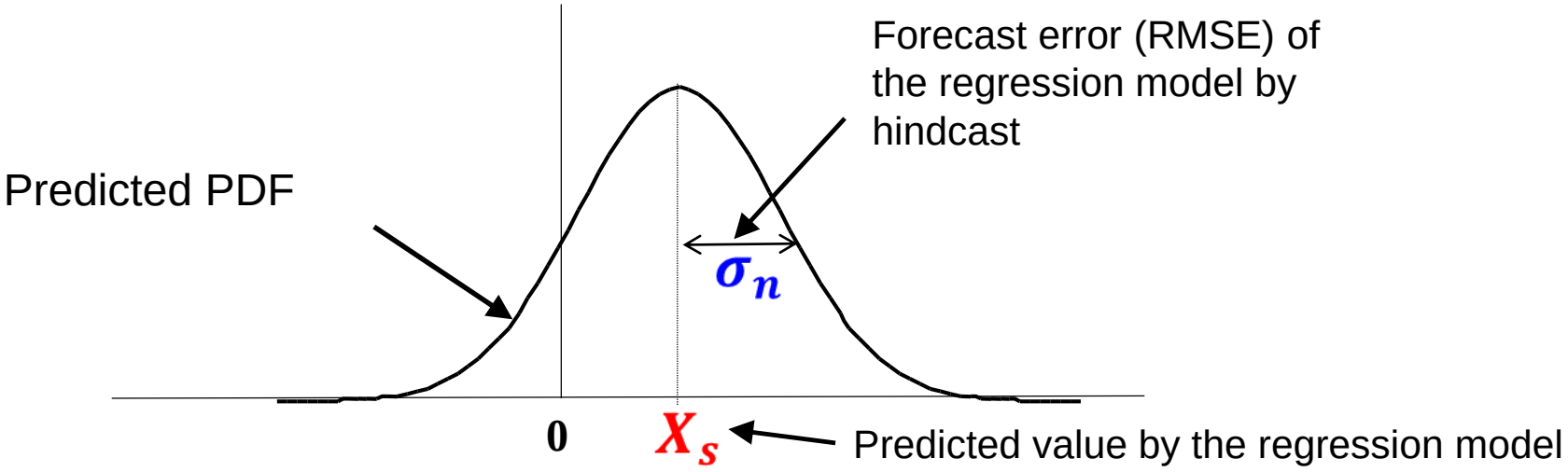


Translation to PDF in the regression model

- Probabilistic forecast is essential for seasonal prediction.

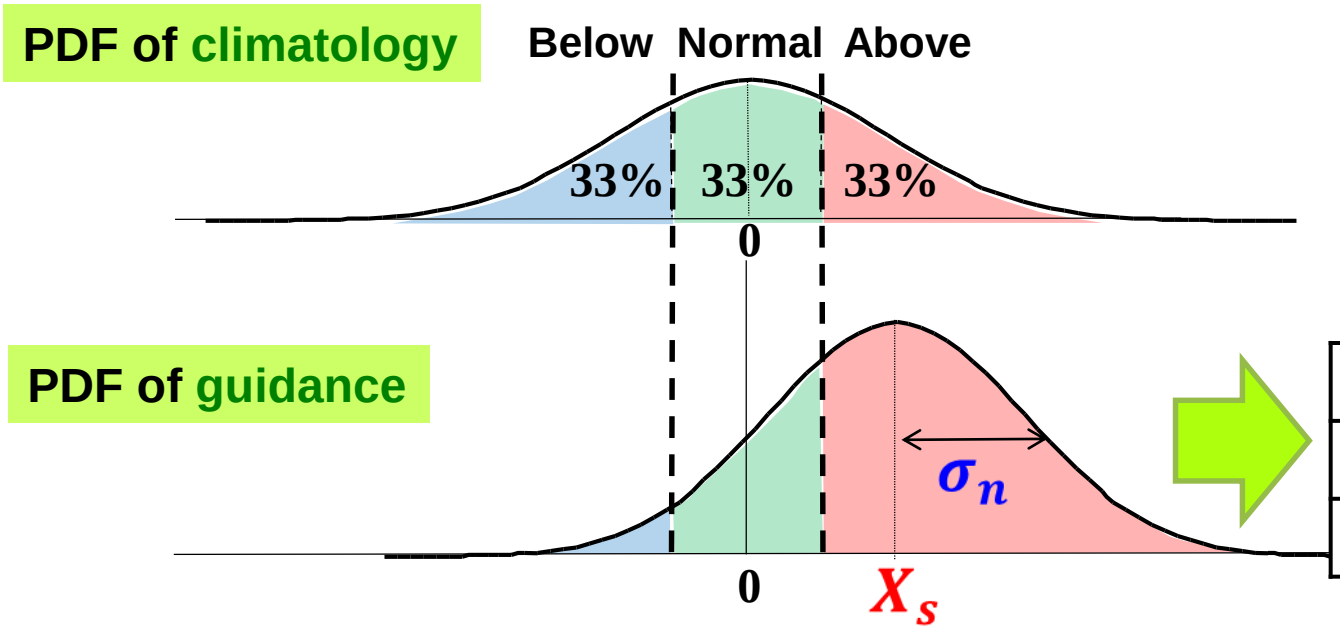
➢ In the guidance tool, Probability Density Function (PDF) is assumed to be a **normal distribution.**

- **Mean (x_s)**: prediction value by the regression model
- **Standard deviation (σ_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.



Tercile Probabilities		
Below	Normal	Above
10%	30%	60%

Normalization of Precipitation Data

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

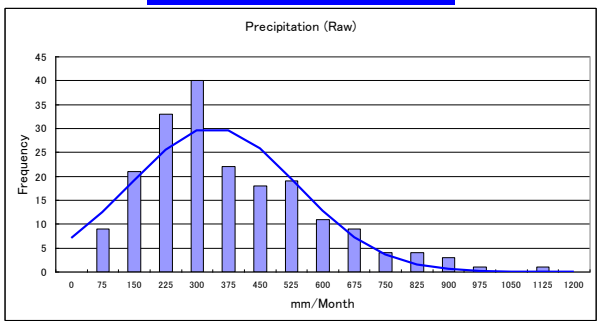
Meanwhile,

- 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.

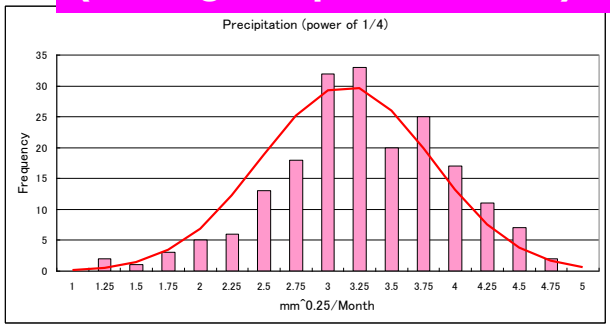
- Power of 1/4 for precipitation ($RAIN^{1/4}$) is approximated by a normal distribution.

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

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

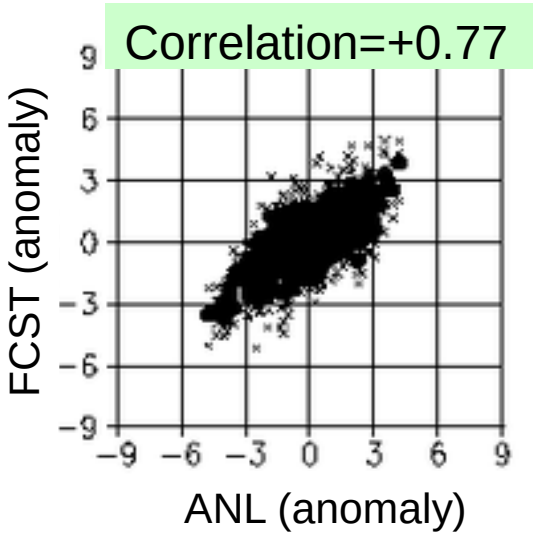
F_i: Forecast, *O_i: Observation*
C_i: Climatology, *N: Sample size*

● 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

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

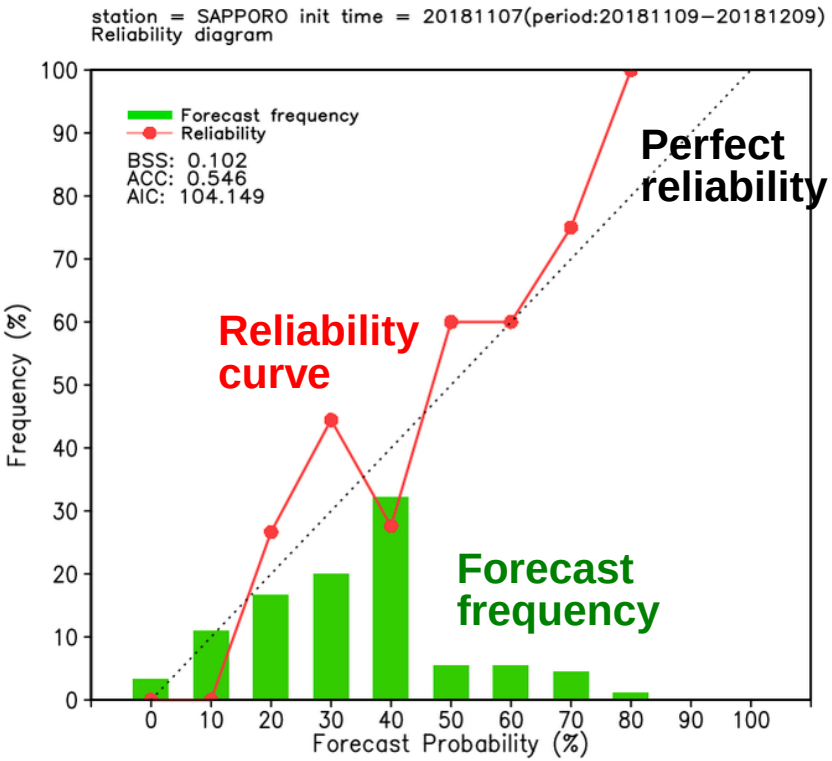


Reliability Diagram

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

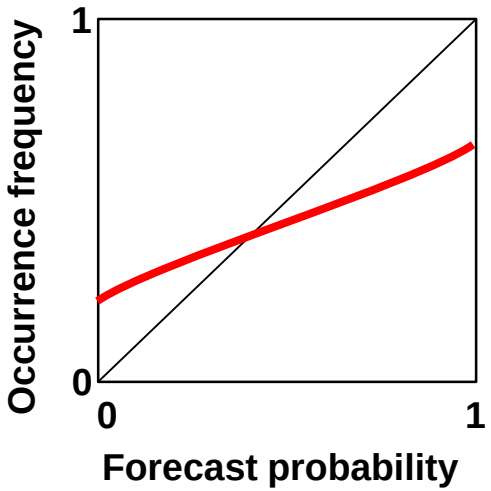
Probabilistic forecast becomes better the more the reliability curve fit to 45° line (perfect reliability).

- 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**

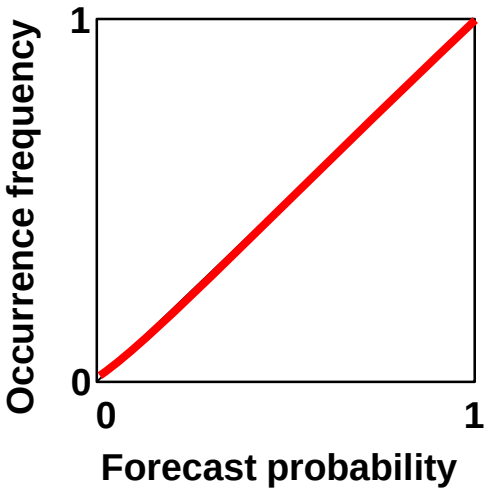


Over/under Confidence

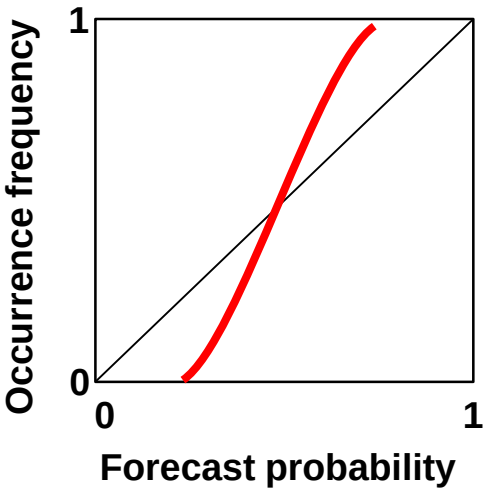
Over confidence



Perfect reliability



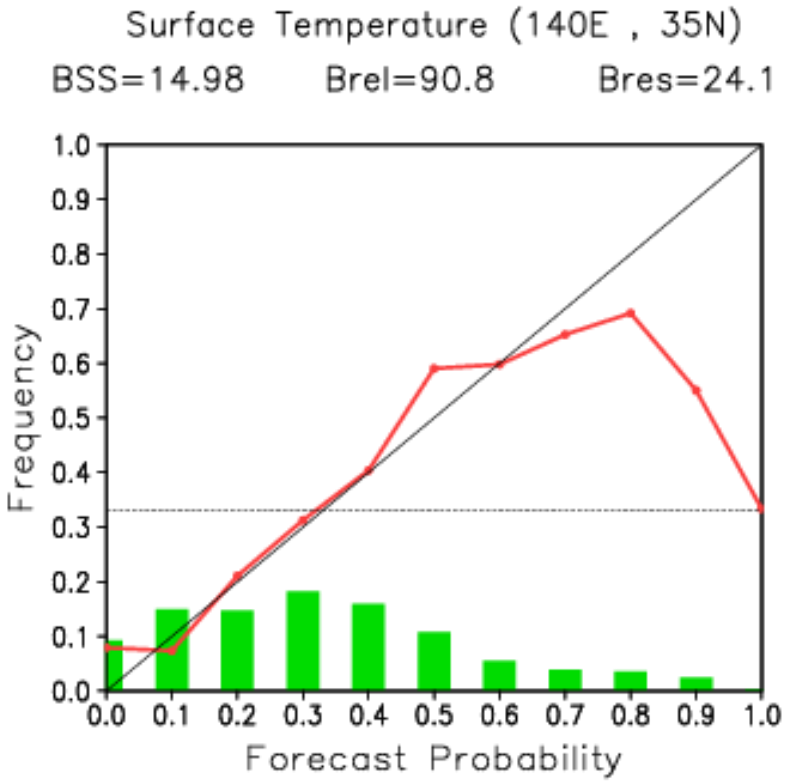
Under confidence



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

Interpretation of Reliability Diagram

Example



- 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.

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