Introduction of Seasonal Forecast Guidance

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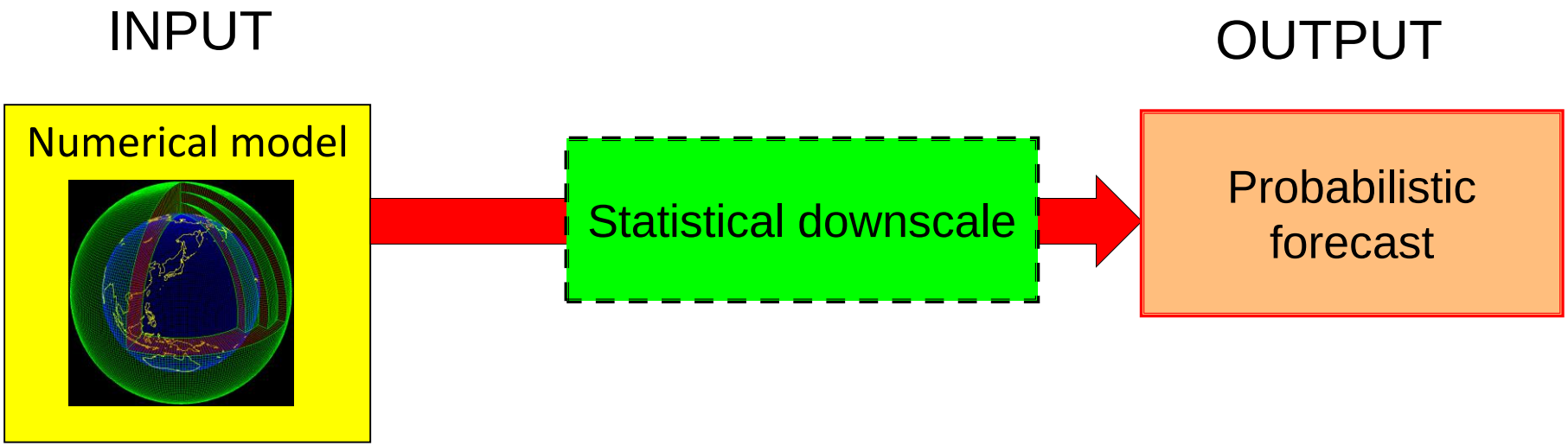
Outline

- Outline of Guidance
  - Objective of Guidance
  - MOS Technique
  - Regression Model
  - Estimation of Probability
- Predictors for Seasonal Forecast
- Verification
  - Verification Score

Outline of Guidance

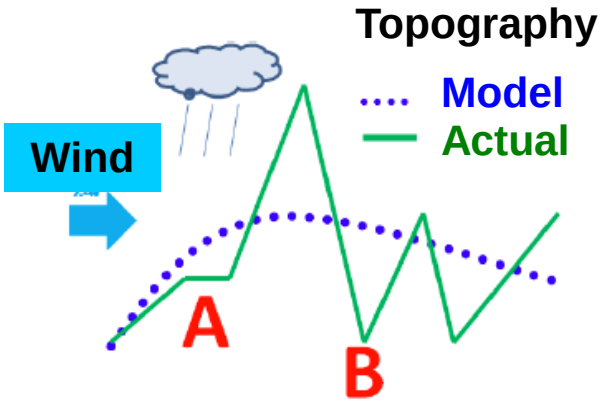
Guidance



- "Guidance" is an application 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 effect of sub-grid scale topography
  - Model does not necessarily reproduce effect of local topography due to limited resolution.
- 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, compared with the direct model output.

Principle of Guidance – MOS Technique

MOS (Model Output Statistics):

To derive statistical relationship between observation and model forecast from past cases, and apply it to the real-time forecast

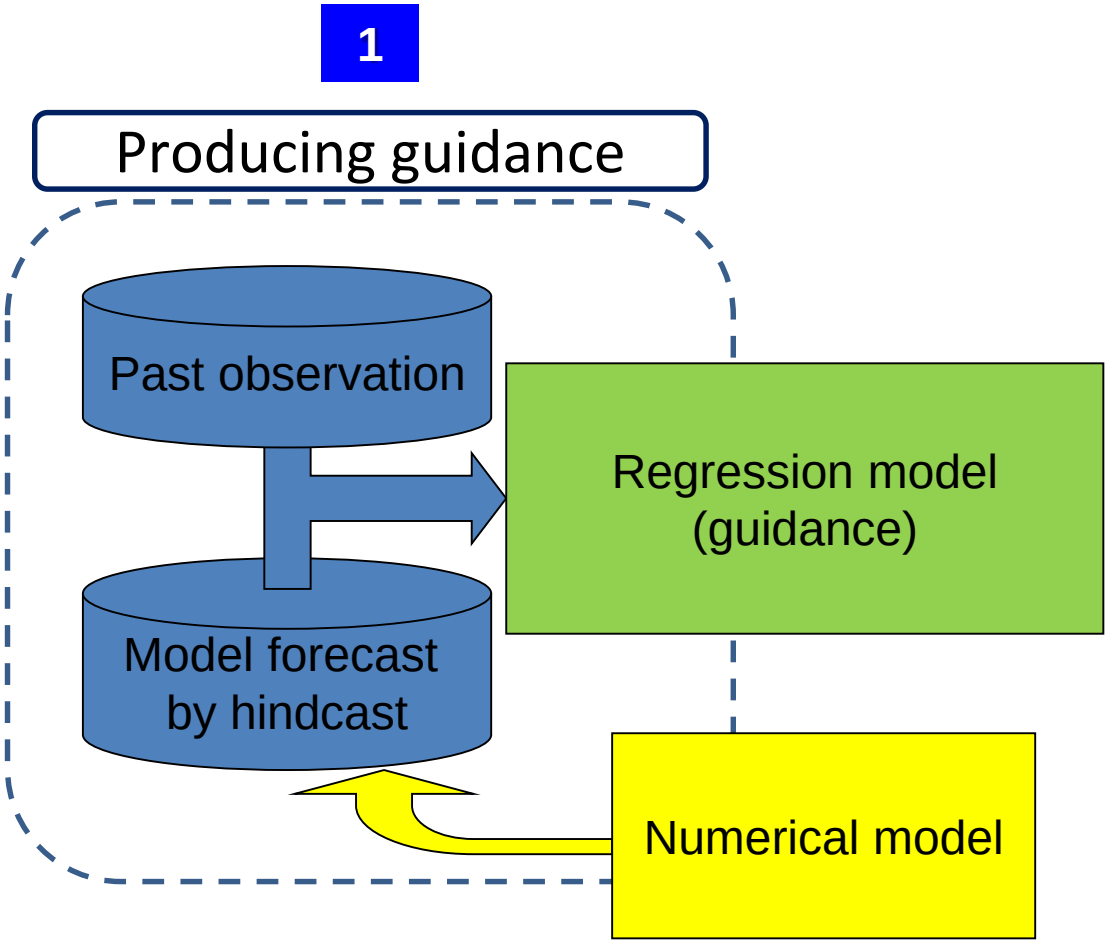
- Two types of the time series data are needed in order to produce guidance.
  - 1. Past observation (i.e., Predictands)
  - 2. Past model forecast by hindcast (i.e., Predictors)

Prepared by users

On ITACS

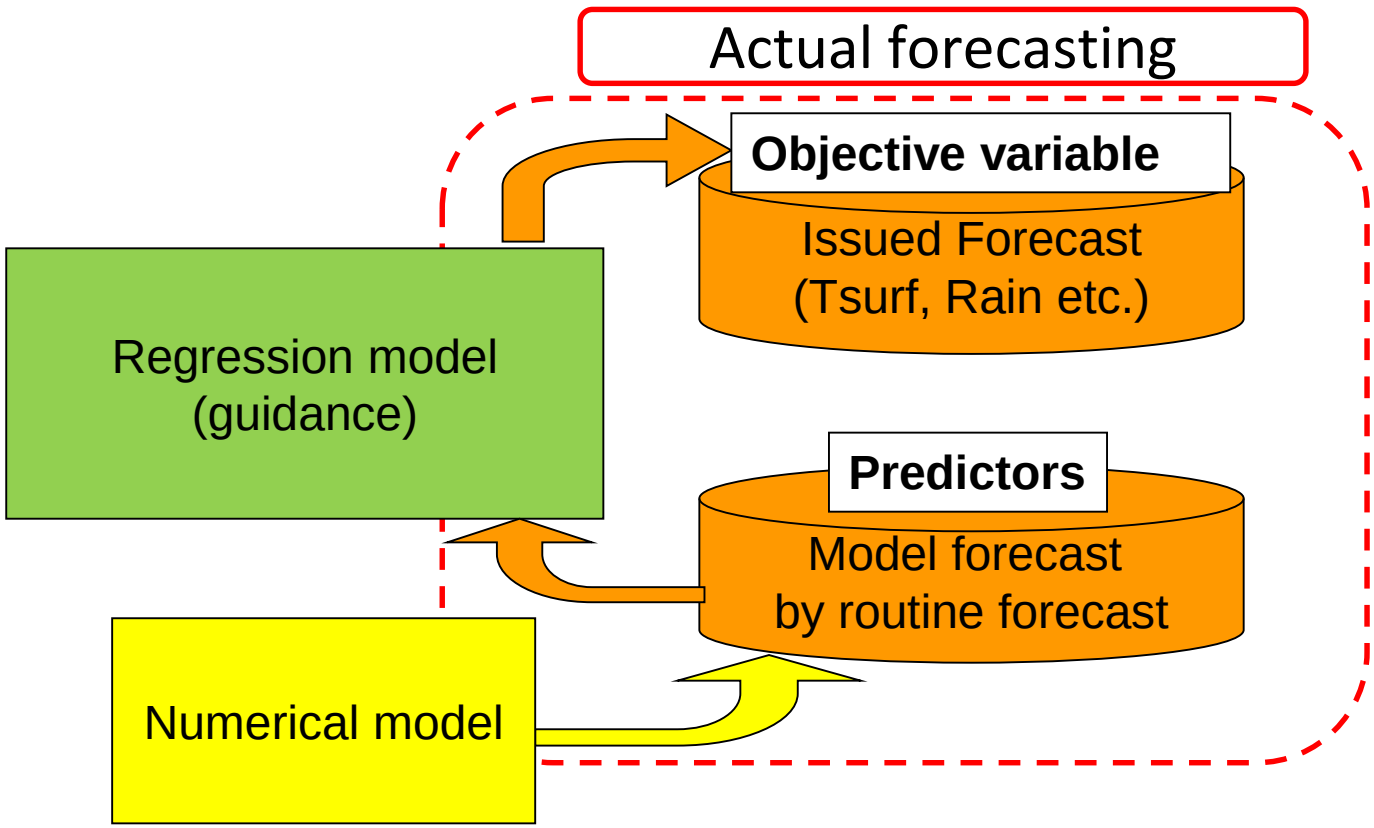
Concept of MOS Technique (1)

- **Statistical relationship** is estimated 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 objective variable



Single Regression

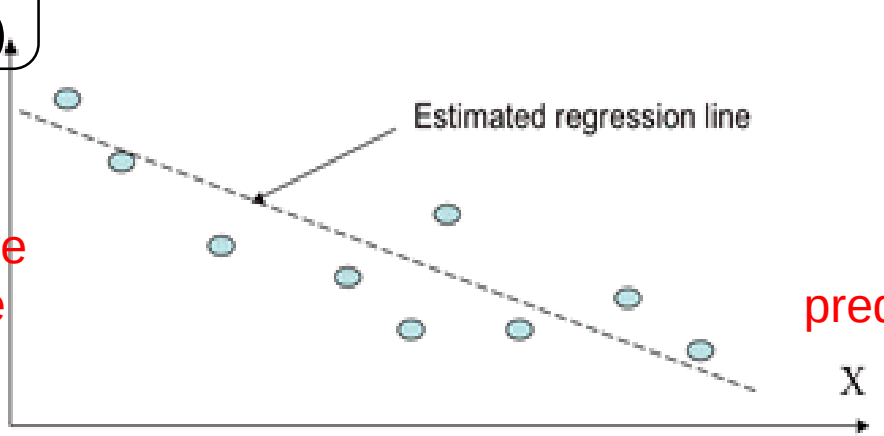
- Single regression is the relationship between **one explanatory variable** (predictors) and **objective variable** (ex. temp. rainfall).
- Single regression model is written as

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

Y: predictand X: predictor
a: regression coefficient b: constant,
ε: error term

Predictand (e.g., temp., precipitation)

Predictor (i.e., model output)



objective variable

predictors

Multiple Regression

- More than one predictors are employed in multiple regression.
- It is assumed that the objective variable is the sum of a linear combination of predictors.

Example: **two** predictors

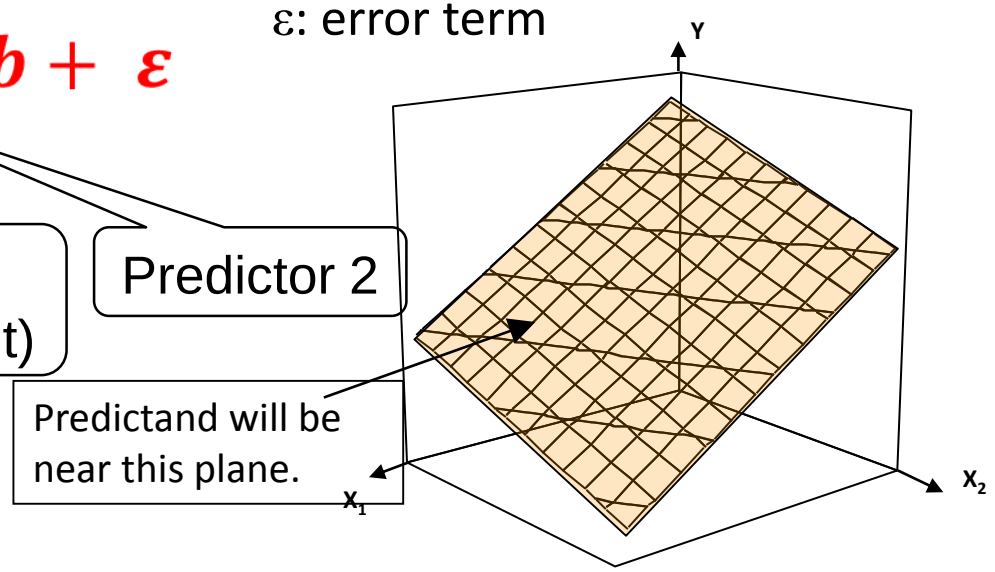
a_1, a_2: regression coefficient
b: constant
ε: error term

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

Predictand (e.g., temp., precipitation)

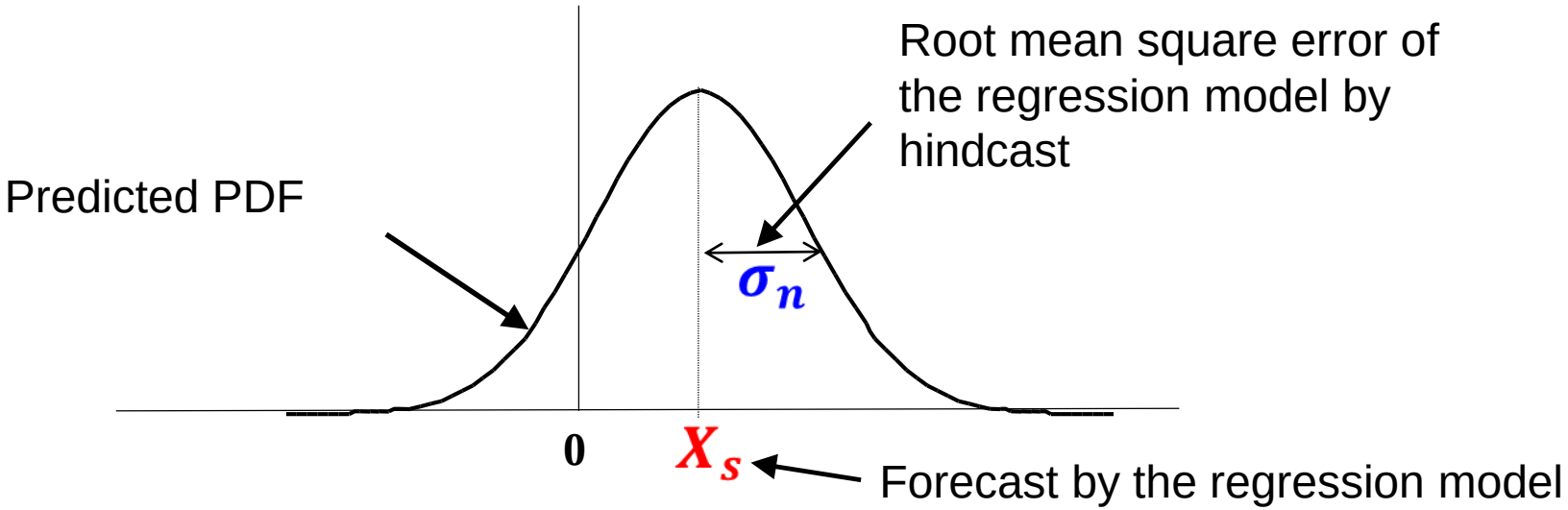
Predictor 1 (i.e., model output)

Predictor 2



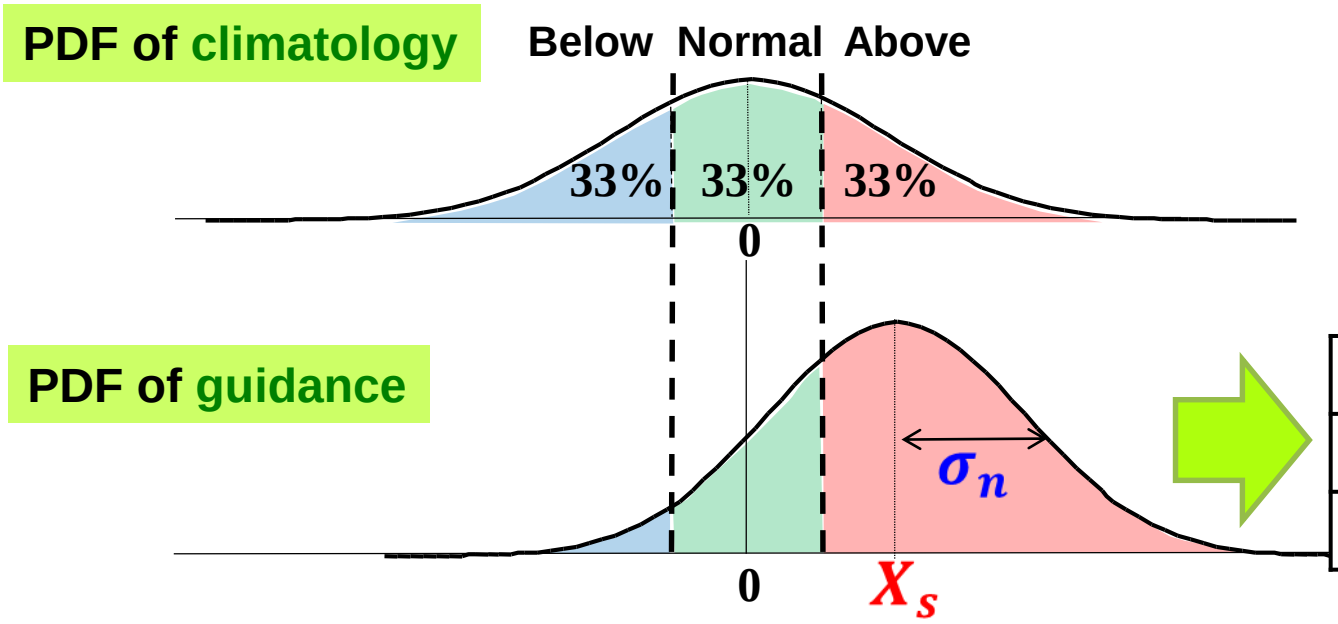
From Regression Model to Probability

- Probability Density Function (PDF) is assumed to be a **normal distribution.**
  - **Mean (x_s):** Prediction value by the regression model
  - **Standard deviation (σ_n):** RMSE of the regression model.



Estimation of Probability for 3-category

- The threshold values for 3 categories are determined from the past observation (1981 to 2010).
- Probability for each category (below-, near-, above-normal) is calculated by PDF and the threshold values.



Issued Forecast		
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,

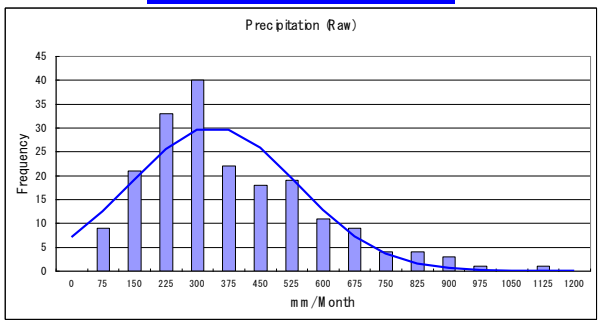
- As for precipitation, its distribution does not represent a normal distribution, and it's usually approximated by a gamma distribution.

- In order to create guidance, precipitation data need to be normalized.

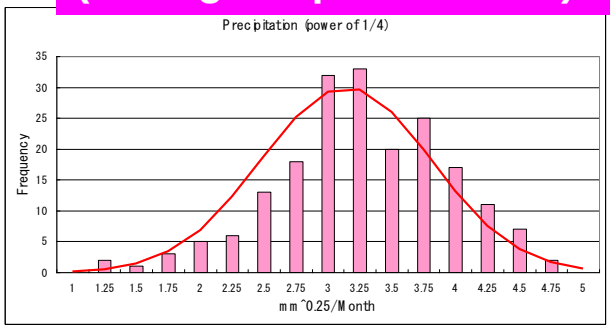
- Power of 1/4 for precipitation ($RAIN^{1/4}$) is approximated by a normal distribution.

Ex. Precipitation over Japan

(Row value)



(Taking the power of 1/4)



Predictors for Seasonal Forecast

Selection of Predictors

In this seminar, you will select 1-3 indices as predictors to make guidance at your forecast point.

Indices	Variables	Areas
NINO3 SST	SST	(150W-90W, 5S-5N)
NINOWEST SST	SST	(130E-150E, EQ-15N)
IOBW SST	SST	(40E-100E, 20S-20N)
WIO SST	SST	(40E-70E, EQ-20N)
EIO SST	SST	(70E-100E, EQ-20N)
IOBW RAIN	RAIN	(40E-100E, 20S-20N)
WIO RAIN	RAIN	(40E-70E, EQ-20N)
EIO RAIN	RAIN	(70E-100E, EQ-20N)
SAMOI RAIN	RAIN	(80E-105E, 5N-25N) + (107.5E-140E, 5N-20N)
WNP RAIN	RAIN	(110E-160E, 10N-20N)
SEAsia RAIN	RAIN	(115E-140E, 10N-20N)
MC RAIN	RAIN	(110E-135E, 5S-5N)
DL RAIN	RAIN	(170E-170W, 5S-5N)
Z500 Z2030	500hPa Height	(0-360, 20N-30N)
Z500 Z3040	500hPa Height	(0-360, 30N-40N)
Z500 Z4050	500hPa Height	(0-360, 40N-50N)
Z500 Z5060	500hPa Height	(0-360, 50N-60N)
THICKMID (THMD)	Thickness Middle	(0-360, 30N-50N, 300hPa-850hPa)
THICKNH (THEX)	Thickness extratropics	(0-360, 30N-90N, 300hPa-850hPa)
THICKTRO (THTR)	Thickness tropics	(0-360, 25S-25N, 100hPa-850hPa)
NINO3.4SST	SST	(170W-120W, 5S-5N)

SST

RAIN

Z500

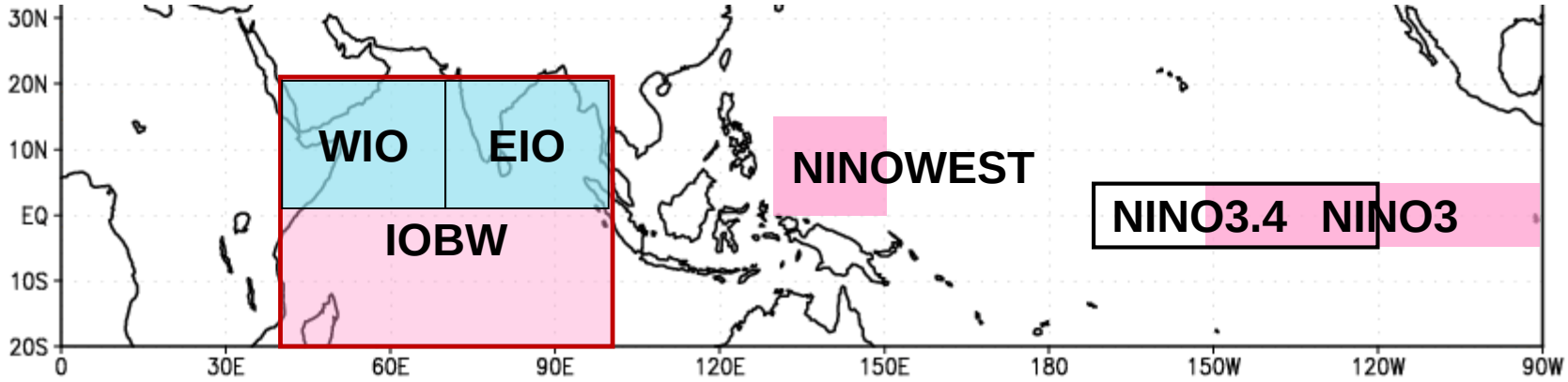
Thickness

SST

Hindcast and prediction data of each predictor are available on TCC website

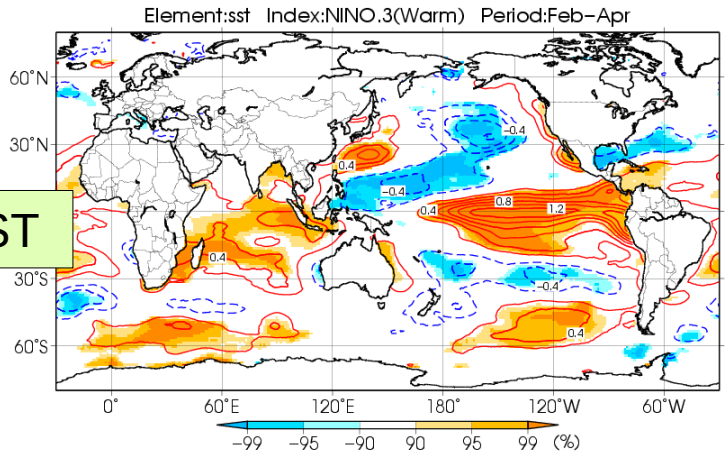
Predictors – SST

- These indices are associated with SST variabilities in the tropics such as ENSO, IOBW.



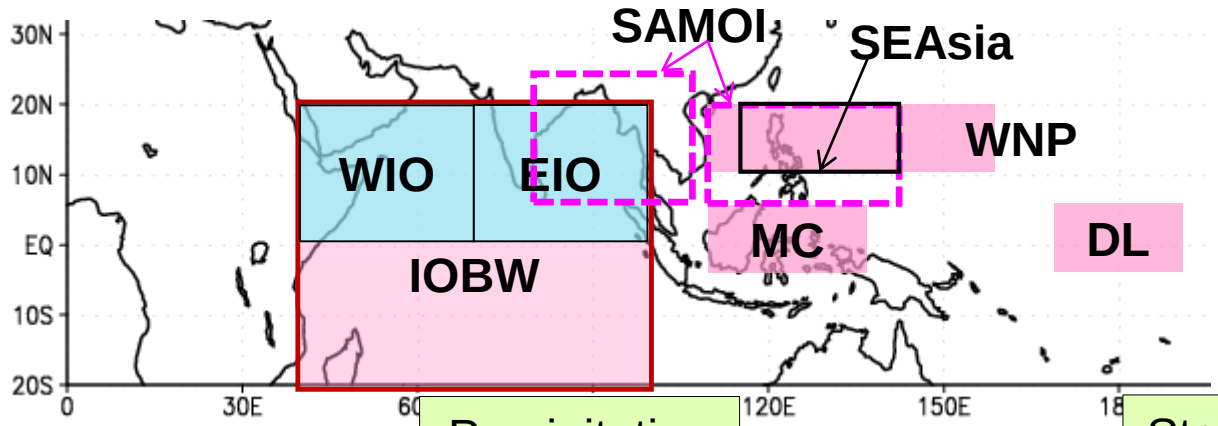
Composite maps for El Nino (FMA)

SST



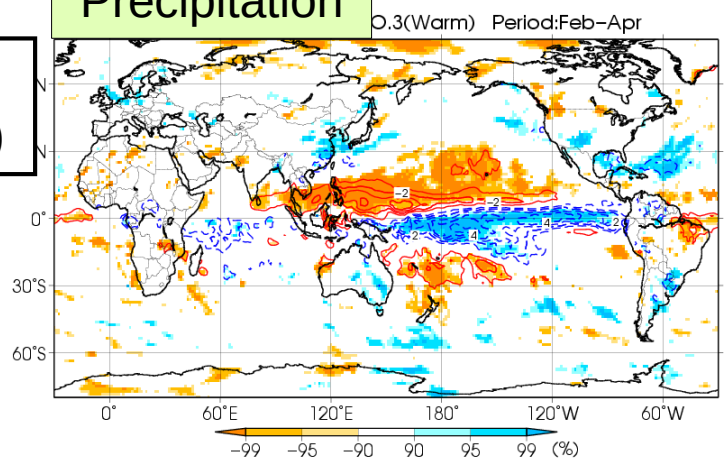
Predictors – Rain

- These are associated with convective activity in the tropics, which affects the climate in mid-latitude as well as tropics.

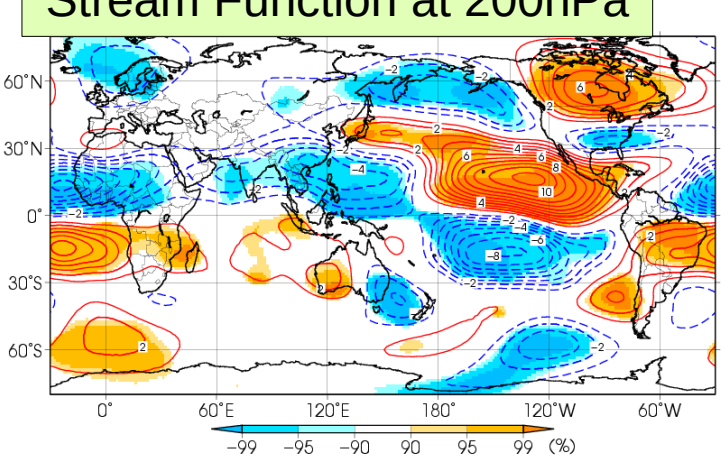


Composite maps for El Nino (FMA)

Precipitation

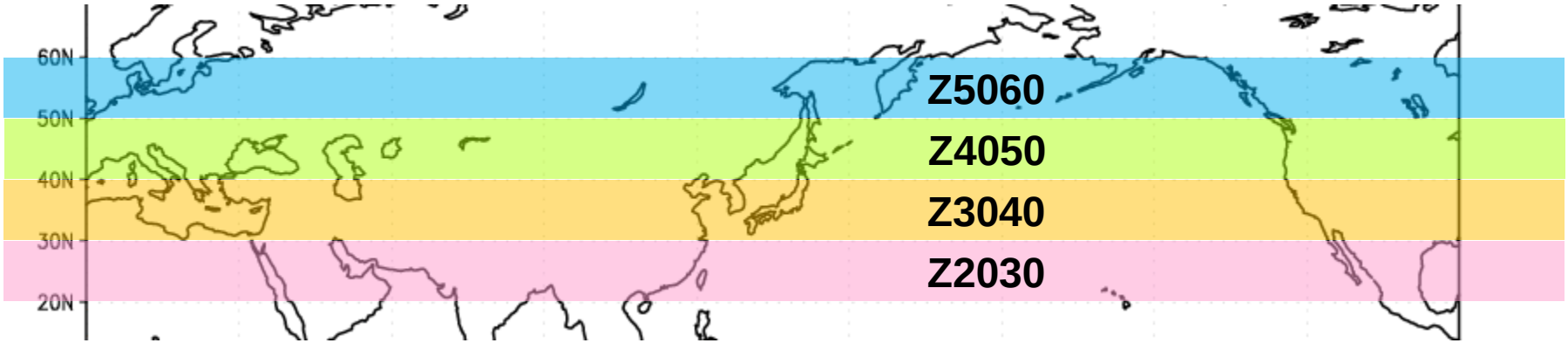


Stream Function at 200hPa



Predictors – Z500

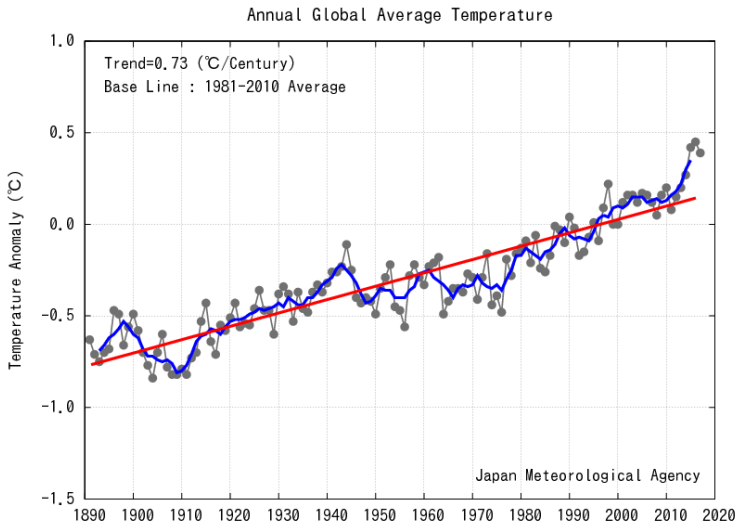
- These indices represent zonal-mean 500-hPa height (Z500) over mid-latitude bands.
- These are associated with atmospheric circulation over mid-latitude.



Predictors – Thickness

- Thickness are defined as zonal mean difference of Z300 and Z850 (for tropics Z100 and Z850).
- These correspond to zonal mean temperature anomalies in the troposphere over mid-latitudes, extratropics, and tropics.
- These also show the signal of global warming.

THICKMID (THMD)	Mid-latitude	30-50N, 300-850hPa
THICKNH (THEX)	Extratropics	30-90N, 300-850hPa
THICKTRO (THTR)	Tropics	25S-25N, 100-850hPa



Verification

Verification for Deterministic Forecast

- Root Mean Square Error (RMSE)

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

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

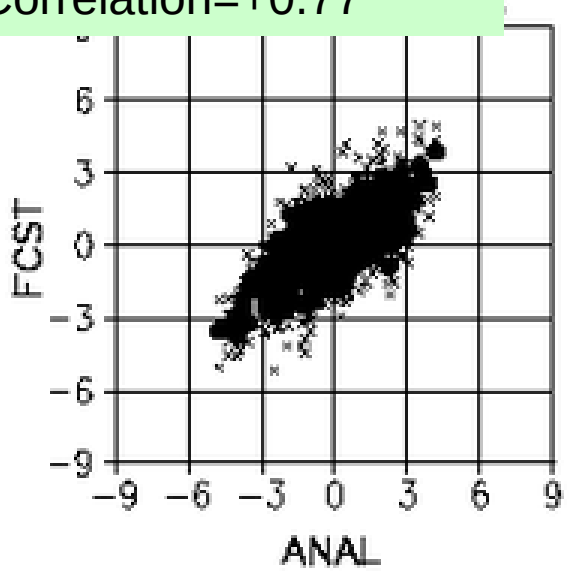
Perfect score: 0

- Anomaly Correlation Coefficient (ACC)

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

Range: -1 to 1.
Perfect score: 1

Correlation=+0.77

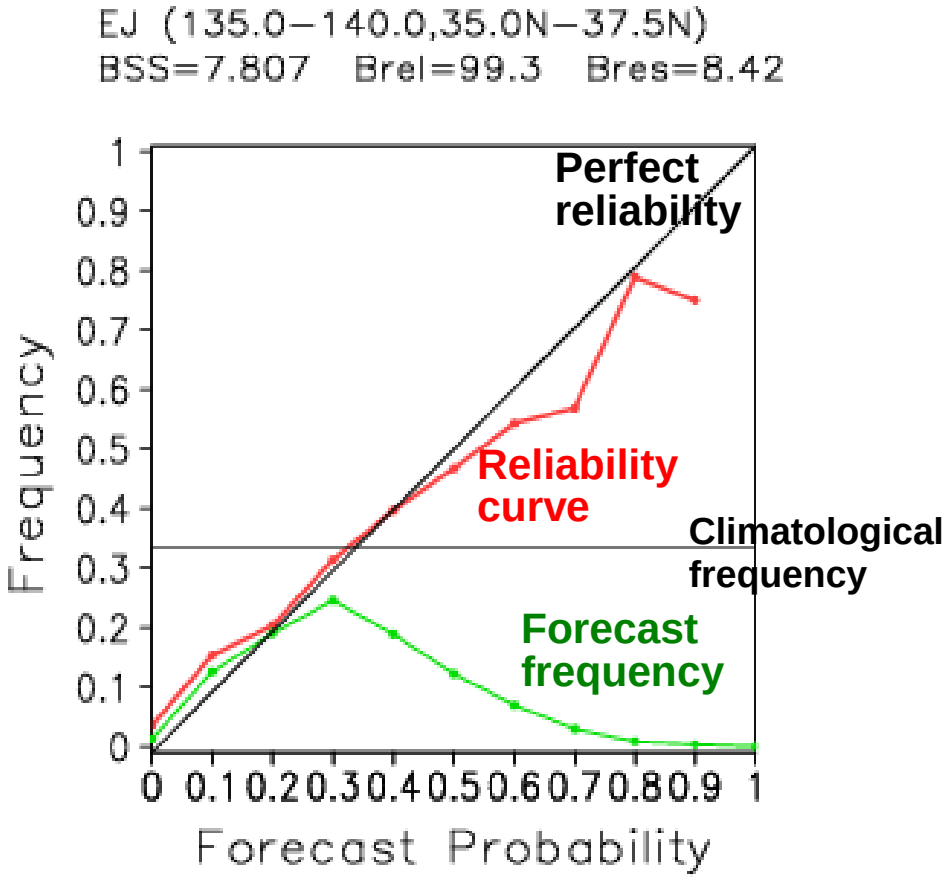


Reliability Diagram

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

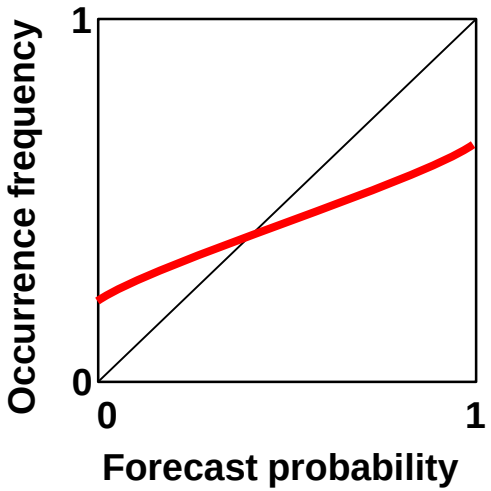
Probabilistic forecast becomes better the more the reliability curve fit to 45° line (perfect reliability).

- Green line denotes forecast frequency (sharpness diagram);
  - •If most of the forecast probabilities are near the climatological frequency = unsharp
  - •If probabilities near 0 and 1 (100%) are often used = sharp

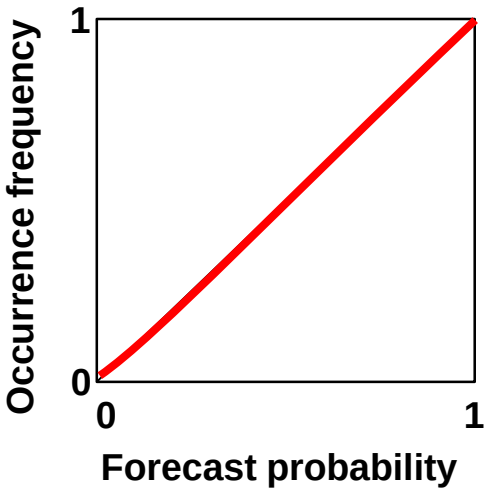


Over/under Confidence

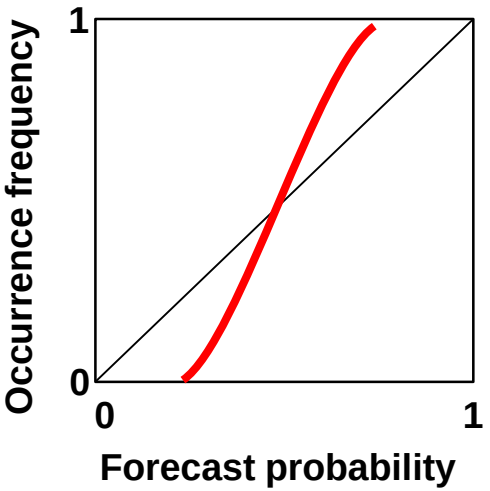
Over confidence



Perfect reliability



Under confidence

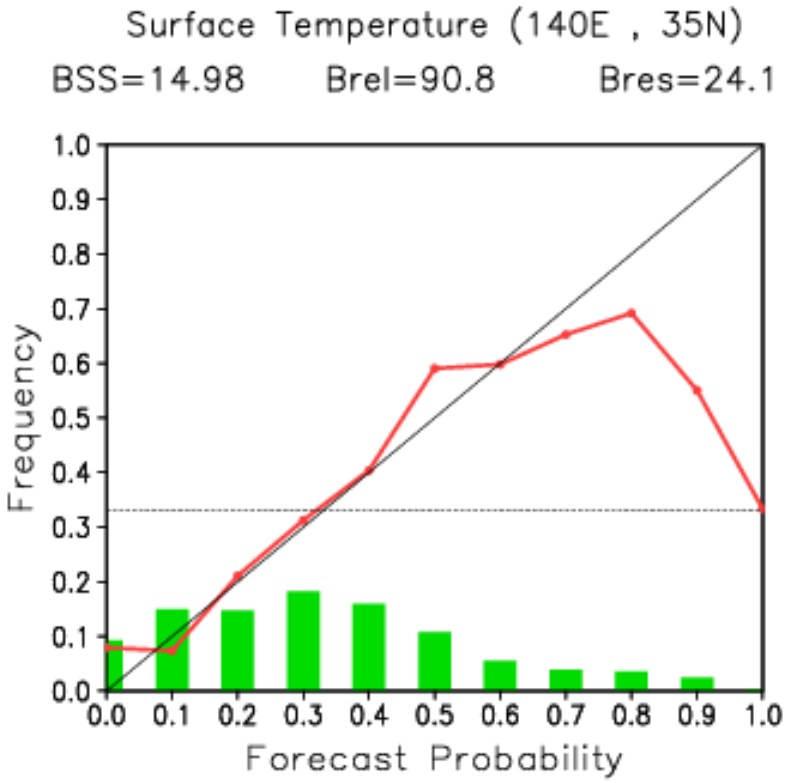


- ✓ Predicted probabilities are overestimated as compared with actual

- ✓ Predicted probabilities are underestimated as compared with 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 60%

Brier 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)

Forecast (Below, Near, Above): (0.1, 0.3, 0.6)

Observation: Above normal (0, 0, 1)

BS: $\{(0.1-0)^2+(0.3-0)^2+(0.6-1)^2\}/2 = 0.13$

Brier Skill Score (BSS)

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

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

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

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

Exercise for Making Guidance (Tomorrow)

- Step 1: Prepare 3-month mean (Feb.-Apr.) temperature and precipitation observation data for 1981-2010.
- Step 2: Select appropriate predictor(s) and make a regression model at your forecast point for Feb.-Apr.
- Step 3: Verify the forecast skill of the guidance.
- Step 4: Calculate the guidance for Feb.-Apr. 2018 with your regression model.