Glossary of Forecast Verification Metrics

Bias

The difference between the mean of the forecasts and the mean of the observations. Could be expressed as a percentage of the mean observation. Also known as overall bias, systematic bias, or unconditional bias.
Relative Bias is computed as: RB = Mean Error / (observed mean).
Another relative measure is the Percent Bias:

$$PB = 100 \times \left[\sum_{i=1}^{n} \left(Fcst_i - Obs_i \right) / \sum_{i=1}^{n} \left(Obs_i \right) \right]$$

For categorical forecasts, bias (also known as frequency bias) is equal to the total number of events forecast divided by the total number of events observed. With the (2x2) **contingency table**, Bias = (a+b)/(a+c). Perfect score: 1.

Brier Score (BS)

The mean square error of probabilistic two-category forecasts where the observations are either 0 (no occurrence) or 1 (occurrence) and forecast probability may be arbitrarily distributed between occurrence and non-occurrence. BS=0 for perfect (single-valued) forecasts. BS=1 for forecasts that are always incorrect.

Brier Skill Score (BSS)

A **Skill Score** based on **BS** values. The most commonly used reference forecasts are persistence and climatology. Perfect score: 1.

Contingency Table

A two-dimensional table that gives the discrete joint distribution of forecasts and observations in terms of cell counts. For dichotomous categorical forecasts, having only two possible outcomes (Yes or No), the following (2x2) contingency table can be defined:

2x2 Contingency Table		Event Observed	
		Yes	**No**
Event Forecast	**Yes**	**a** (hits/true positives)	**b** (false alarms/false positives)
	No	**c** (misses/false negatives)	**d** (true negatives)

Continuous Ranked Probability Score (CRPS)

A measure of the integrated squared difference between the cumulative distribution function of the forecasts and the corresponding cumulative distribution function of the observations. It is an extension of the **Ranked Probability Score (RPS)** for continuous probability forecasts. It corresponds to the **Mean Absolute Error (MAE)** for single-valued forecasts. Perfect score: 0.

Continuous Ranked Probability Skill Score (CRPSS)

A **Skill Score** based on **CRPS** values. The most commonly used reference forecasts are persistence and climatology. Perfect score: 1.

Correlation Coefficient
A measure of the linear association between forecasts and observations independent of the mean and variance of the marginal distributions. Pearson Correlation Coefficient and Spearman Rank Correlation are the most widely used ones. Perfect score: 1.

Discrimination Diagram
A diagram plotting the conditional distributions of the forecasts. For binary events, this diagram plots the conditional distribution of the forecasts given that the event occurred, and the conditional distribution of the forecasts given that the even did not occur. Ideally, the two distributions are well separated from one another, becoming two distinct spikes for perfect forecasts.

False Alarm Ratio (FAR)
For categorical forecast, the number of false alarms divided by the total number of events forecast. A measure of reliability. With the (2x2) **contingency table**, FAR = b/(a+b). Not to be confused with the **Probability of False Detection (POFD)** (also called **False Alarm Rate**) (which is conditioned on observations rather than forecasts). Range: 0 to 1. Perfect score: 1.

Lead Time of Detection (LTD)
The average lead time of forecasts that correspond to hits in the contingency table.

Mean Absolute Error (MAE)
The average of the absolute differences between forecasts and observations. A more robust measure of forecast accuracy than Mean Square Error that is sensitive to large outlier forecast errors. It corresponds to the **Continuous Ranked Probability Score (CRPS)** for probabilistic forecasts. Perfect score: 0. Note: the overbar denotes the mean.

$$MAE = \overline{(|\ f - o\,|)}$$

Mean Absolute Error Skill Score (MAE-SS)
A **Skill Score** based on **MAE** values. The most commonly used reference forecasts are persistence and climatology. Perfect score: 1.

Mean Error (ME)
The average difference between forecasts and observations. Note: it is possible to get a perfect score if there are compensating errors. Perfect score: 0.

$$ME = \overline{(f - o)}$$

Probability Of Detection (POD) (or Hit Rate)
For categorical forecast, the number of hits divided by the total number of events observed. A measure of discrimination. For the (2x2) **contingency table**, POD = a/(a+c). Range: 0 to 1. Perfect score: 1.

Probability Of False Detection (POFD) (or False Alarm Rate)

For categorical forecast, the number of false alarms divided by the total number of events observed. A measure of discrimination. For the (2x2) **contingency table**, POFD = b/(b+d). Not to be confused with the **False Alarm Ratio (FAR)** (which is conditioned on forecasts rather than observations). Range: 0 to 1. Perfect score: 0.

Root Mean Square Error (RMSE)
The square root of the average of the squared differences between forecasts and observations. It puts a greater influence on large errors than smaller errors, which may be good if large errors are especially undesirable, but may also encourage conservative forecasting. Perfect score: 0.

$$RMSE = \sqrt{\overline{(f - o)^2}}$$

Ranked Probability Score (RPS)
The mean square error of probabilistic multi-category forecasts where observations are 1 (occurrence) for the observed category and 0 for all other categories and forecast probability may be arbitrarily distributed between all categories. By using cumulative probabilities, it takes into account the ordering of the categories. For two category forecasts, the RPS is the same as **Brier Score**. Perfect score: 0.

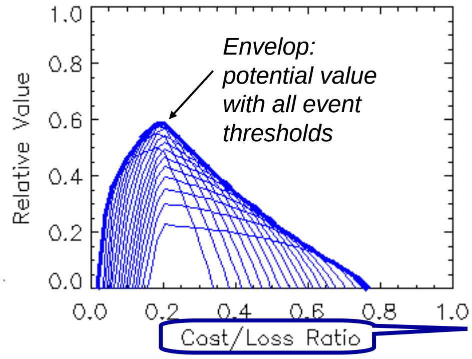
Ranked Probability Skill Score (RPSS)
A **Skill Score** based on **RPS** values. The most commonly used reference forecasts are persistence and climatology. Perfect score: 1.

Relative (or Receiver) Operating Characteristic (ROC)
A signal detection curve for binary forecasts obtained by plotting **POD** (y-axis) versus **POFD** (x-axis) to describe the forecast discrimination. There is one curve for each set of forecast-observed pairs and for a given event. The ROC curve for single-valued forecasts is defined as the curve from (0,0) to (POFD, POD) and to (1,1). For probabilistic forecasts, there are N increasing probability levels (binary classifiers) to turn the probabilistic forecast into a yes/no forecast; the ROC curve for probabilistic forecasts is defined as the curve from (0,0) to ($POFD_k$, POD_k) for each k^{th} probability level from 1 to N, and to finally (1,1). The ROC curves for single-valued forecasts and probabilistic forecasts for a given event can directly be inter-compared if plotted together. The 45 degree diagonal line indicates no skill. It is conditioned on the observations (given that Y occurred, what was the corresponding forecast?). It is a good companion to the **Reliability Diagram**, which is conditioned on the forecasts. Perfect: curve travels from bottom left to top left of the diagram, then across to top right of the diagram.

ROC Score
A summary score for binary forecasts derived from the **ROC** curve and its ROC Area (area below the ROC curve) for a given event to describe the forecast discrimination. ROC Score=2 x (ROC Area – 0.5). Perfect score: 1.

Relative Value (or Economic Value)
Skill score of expected expense using a Cost/Loss ratio, with climatology as a reference. The 2x2 expense matrix is defined for a given event with cost C for taking action based

on a forecast (the event being observed or not) and loss L for taking no action when the event actually occurred. The expense matrix is multiplied by the 2x2 contingency table to estimate the expense for the specified event. Perfect score: 1.
Since the Relative Value depends on the Cost/Loss ratio, it is plotted as a curve for Cost/Loss ratio varying from 0 to 1 for a given event. When considering a range of events, all the Relative Value curves are plotted together and the envelop of all the curves represents the potential economic value. For probabilistic forecasts, one needs to produce a curve for each probability threshold at which the forecast says the event will occur (similarly to the ROC curve with one point for each probability threshold). As for any skill score, if Relative Value is greater than zero, the forecast has more potential value than climatology; otherwise the forecast is worse than climatology.



Expense matrix for 1 event
cost **C** and loss **L** for taking action
based on a forecast

	Event	No event
Action	C	C
No Action	L	0

User picks his/her own Cost/Loss ratio

Reliability Diagram
A diagram in which the frequency of the observations, given the forecast probability, is plotted against the forecast probability, where the range of forecast probabilities is divided in to K bins. The sample size in each bin is often included as a histogram or values beside the data points. Perfectly reliable forecasts have points that lie on the 45 degree diagonal line. The deviation from the diagonal line gives the conditional bias. The Reliability Diagram is called the Attributes Diagram when the no-resolution line and the no-skill line with reference to climatology are included. It is conditioned on the forecasts (given that X was predicted, what was the outcome?). It is a good partner of the **ROC**, which is conditioned on the observations.

Root Mean Square Error Skill Score (RMSE-SS)
A **Skill Score** based on **RMSE** values. The most commonly used reference forecasts are persistence and climatology.

Sample Size
A numeration of the number of forecasts involved in the calculation of a metric appropriate to the type of forecast (e.g., categorical forecasts should numerate forecasts and observations by categories, etc.)

Skill Score
A measure of the relative improvement of the forecast over some (usually ‘low-skilled’) benchmark forecast. Skill score is associated with a given verification metric and a given

reference forecast. Commonly used reference forecasts include climatology, persistence, or output from an earlier version of the forecasting system. Perfect score: 1.

$$SS = \frac{Score(forecast) - Score(reference)}{Score(perfect) - Score(reference)}$$

Note: if the score of perfect forecast is equal to 0 (e.g., for MAE and CRPS), the skill score is computed as:

$$SS = 1 - \frac{Score(forecast)}{Score(reference)}$$

Talagrand Diagram (or Rank Histogram)
A plot of observed frequencies for k non-overlapping bins of equal probability for the forecast distribution. It measures how well the observed probability distribution is represented by the forecasts. For perfect forecasts, the rank histogram is flat since the observation is equally likely to fall between any two members. For U-shaped histogram, the ensemble spread is too small, most observations falling outside the extremes of the ensemble. For dome-shaped histogram, the ensemble spread is too large, most observations falling near the center of the ensemble. For asymmetric histogram, the model has a bias to one side.

Uncertainty
The degree of variability in the observations. Most simply measured by the variance of the observations. Important aspect in the performance of a forecasting system, over which the forecaster has no control.

On-line References

http://www.bom.gov.au/bmrc/wefor/staff/eee/verif/verif_web_page.html
http://www.swpc.noaa.gov/forecast_verification/Glossary.html