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ASSESSMENT OF ENSO BASED PREDICTIVE SYSTEMS IN INDONESIA

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ABSTRACT

The use of Seasonal Climate Forecasting (SCF) in risk management decisions in the developing countries such Indonesia, which are most vulnerable to the impacts of climate variability and climate change, has not been widely applied yet. The major limitations are; the limited national capacity for climate monitoring and forecasting; low levels of awareness among decision makers to the local and regional impact of climate variability (e.g. ENSO); and lack of effective policy responses to climate variability and climate change. The specific objectives of this study are, for each main climate regions of the Indonesia, analyse the relationship of seasonal rainfall with key ENSO based predictors and determine the most "robust" predictive system(s) for each these region. To use FLOWCAST software to undertake three methods of investigation. Results of regression and contingency table analyses show that the synchronous associations between SOI, NINO 3.4, SST and Indonesia rainfall are significantly stronger in all climate zones for 2 seasonal periods selected (May – October and November – April) in Monsoonal and Local Type. The strength of this relationship also corresponded to high forecasting skill (LEPS) being found especially in Monsoonal and Local Climate Type of Indonesia, with the influences effecting Monsoonal.

Keywords: *Seasonal Climate Forecasting, Predictor, ENSO, LEPS.*

ABSTRAK

Penggunaan Model Prakiraan Iklim (SCF) di negara-negara berkembang seperti Indonesia, yang paling rentan terhadap dampak variabilitas iklim dan perubahan iklim, belum banyak diaplikasikan. Keterbatasan utama adalah; kapasitas nasional yang terbatas untuk pemantauan iklim dan prakiraan; rendahnya tingkat kesadaran para pengambil keputusan dengan dampak lokal dan regional dari variabilitas iklim (misalnya ENSO); dan kurangnya respon kebijakan yang efektif terhadap variabilitas iklim dan perubahan iklim. Tujuan khusus dari penelitian ini adalah, untuk menganalisis hubungan curah hujan musiman dengan prediksi berdasarkan ENSO kunci dan menentukan yang paling "kuat" sistem prediktif (s) untuk masing-masing daerah tersebut. Penggunaan software FLOWCAST dengan tiga metode penyelidikan. Hasil regresi dan analisis tabel kontingensi menunjukkan bahwa hubungan antara SOI, Nino 3.4, SST dan Indonesia curah hujan secara signifikan lebih kuat di semua zona iklim selama 2 periode musiman yang dipilih (Mei - Oktober dan November-April) di wilayah hujan dengan tipe monsunal dan lokal. Kekuatan hubungan ini juga berhubungan dengan keterampilan peramalan tinggi (Leps) yang ditemukan terutama di daerah type monsunal dan lokal, yang mempengaruhi crah hujan musiman.

kata kunci: Seasonal Climate Forecasting, Predictor, ENSO,LEPS..

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INTRODUCTION

The general circulation of the atmosphere, caused by uneven heating of the Earth's surface, is the driving force behind Indonesia's weather and climate. Indonesia climate drivers such as the El Niño-Southern Oscillation (ENSO) El nino/ La nina, the Indian Ocean Dipole (IOD), Monsoon and Sea Surface Temperature (SST), are some phenomenon which will influence the variability of climate in Indonesia (Harijono et al. 2008). El Nino and the Southern Oscillation (ENSO) are air–sea interactions occurring at centered in the equatorial Pacific Ocean which changes in tropical convection associated the global atmospheric circulation (Alexander et al. 2002). The SOI is an index used to quantify the strength of an ENSO event. It is calculated from the difference between the sea level pressure (SLP) at Tahiti and Darwin (Troup, 1965). Monsoons are the seasonal shift of winds created by the great annual temperature variation that occurs over large land areas in contrast with associated (Walker, 1924; Cane, M. 2000). Ocean surfaces Large-scale meridional heat transport in the Indian Ocean modulates the north Indian Ocean SST on seasonal time-scales and can possibly be involved in inter annual variability of the Asian monsoon by affecting the heat content and SST anomalies (Meehl et al. 2003). The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere climate mode in the tropical Indian Ocean. During a positive IOD event SST is anomalously warm in western Indian Ocean while it is colder than normal in the east (Saji et al. 1999; Yamagata et al. 2004).

Temporal changes in climate at small scales tend to be predictable seasons occur consistently from year to year. However, changes may occur when oceanic currents and movement of air masses are disrupted. The best-known example of this phenomenon is the El Niño-Southern Oscillation. During an El Niño event, the trade winds decrease, and the surface currents follow suit, rather than pooling in the western Pacific, warm water covers much of the ocean surface in the eastern tropics. Base on the scientific background it will be interesting to use ENSO Index and SST as a predictor for Seasonal Climate Forecast such as rainfall, then determine what the most "robust" predictive system(s) for Indonesia and also expand analysed the onset and retreat monsoon in Indonesia.

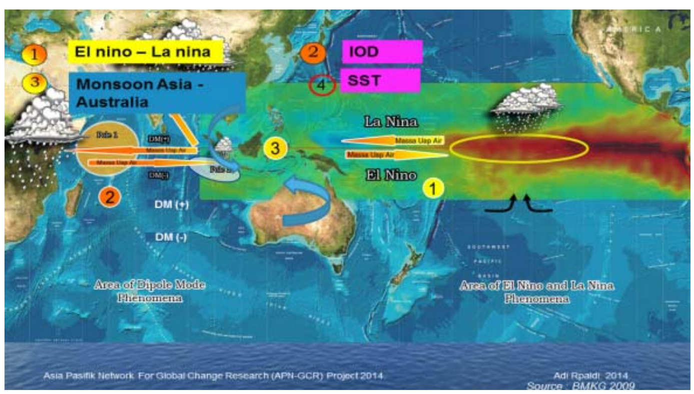

Figure 1. The Driver Climate of Indonesia (Harijono, 2008).

Split by the equator, Indonesia predominantly has a tropical climate. There are two seasons in this country – the wet and the dry seasons, and there are three dominant rainfall regions in Indonesia: the monsoon, equatorial and local types (Aldrian and Susanto 2003). The first rainfall region, the monsoon, has one peak in the rainy season. The wet season occurs between November to April while the dry season lasts from May to October. The second region, equatorial, has two wet season peaks that occur in March and October. The local region has rainfall distribution in contrast to the monsoon type (see the map belows).

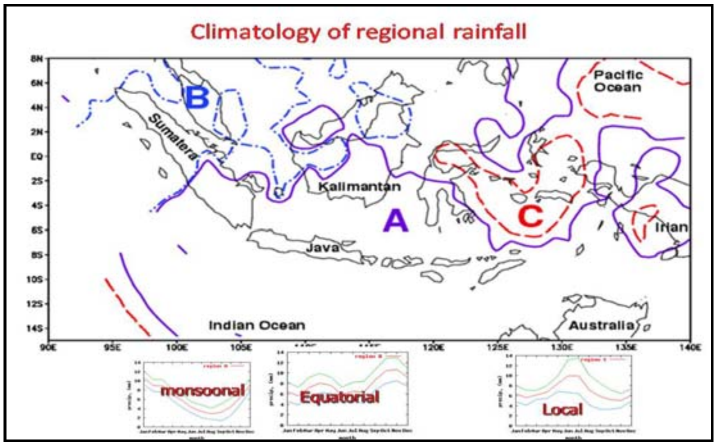

Figure 2. The Rainfall Type in Indonesia (Aldrian and Susanto, 2003)

Indonesia which located 6° N to 11 °S and 95 - 141 °E, are the archipelago countries which has a tropical climate which varies from area to area. The eastern monsoon brings the driest weather (June to September), while the western monsoon brings the main rains (December to March). Rainstorms can occur all year. Indonesia experiences very warm, sometimes humid weather throughout the year, especially along the coastal areas. The climate varies with the location of east-west stretch between islands and the elevation within the island. The wet seasons generally from November to April for Monsoon type region, June to August for Local climate type and 2 time peaks wet season for Equatorial Climate Type April and October with the mean annual rainfall exhibiting a wide variation (ranging from 700 to 2,500 mm).

METHODOLOGY

The methodology used in this investigation follows that of a recently completed validation study conducted across 3 regional rainfall type in Indonesia. Station selection base on climate regional type for each of the three distinct climate zones of Indonesia : Monsoonal Climate Type, Equatorial Climate Type and Local Climate type (Aldrian and Susanto, 2003) with length of data record about 50 years long period. Validation and analysis across additional key predictors (e.g. NINO3.4 and a range of SSTs) study for Indonesia has investigate seasonal rainfall variability and its relationship with ENSO-based predictive systems, and identify suitable skilled climate predictors for operational.

1. **Synchronous correlations** - to investigate what concurrent relationship exist between key ENSO drivers (NINO3.4, SOI & SSTs) and rainfall for select periods of the year based on seasonal forecast.
2. **LEPS score** - to calculate summary measures of skill for selected predictors (NINO3.4, SOI & SSTs) to determine predictive systems which are robust in terms of spatial and temporal consistency and nominate preferred predictive system/s that could be used operationally to forecast rainfall and identify the range of lead-times that forecasts can be made.
3. **Normalized Weighted Tercile Hindcast** - to compare the relative success between various predictors and predictands when performing a tercile forecast for a select predictor-period and predictands-period.

   Based on the seasonality in rainfall for these climate type, a six month “wet” season and six month “dry” season was defined. Using FlowCAst, regression analysis was used to investigate the concurrent trend and synchronous correlations which exist between key ENSO based predictor SOI, NINO 3.4, SST1-9 and predefined rainfall periods. To simplify the comparison between predictors a star rating was also assigned. LEPS skill score analysis and tercile hindcasting was then used to quantify and compare the robustness of main predictive systems, based on spatial and temporal consistency throughout the year and the range of lead-times that forecasts can be reliable made.

Synchronous rainfall correlation

Synchronous relationship analysis was conducted using the FLOWCAST "Analyze Relationship/ Regression Analysis" feature. Both the trend in regression analysis (positive or negative) between each climate driver and rainfall/inflow station and correlation value was recorded. For ease of interpretation the correlation value was then converted to a star-scale rating (1 star for each 0.1 of correlation), with 1 star representing poorly correlated and 5 stars or more representing highly correlated.

Rating for all stations and predictors were then tabulated for comparative purpose and to provide an "estimate" of potential forecast skill, both on an individual station level and at a climate region level base on the average for stations used which were located within each climate region.

4. **LEPS Skill Score**

Assessment of forecasting skill was undertaken using the "Skill Test" function within FLOWCAST. A range of ENSO-based statistical forecast systems were tested for each station to calculate a LEPS score for:

- 12 starting periods throughout the year,
- 3 lead times (0,1 & 2 months)
- 3 predictor –averaging period (1,2 & 3 month SST based systems & 2,3 & 4 month SOI based systems)

To enable a crude comparison of relative skill between alternative ENSO-based systems, the arithmetic average for each county and each climate region was calculated.

5. **Normalised Weighted Tercile Hindcast Analysis**

Weighted assessment of how successful a forecast strategy was for a specified predictor period and predictand period which has been normalized by years of data available and weighted based on consistency of the tercile forecast between predicted and observed.

DATA COLLATION AND INTERPRETATION

A specify number of meteorological stations from each of the three climate regions type was selected based on completed and longest data availabilities.

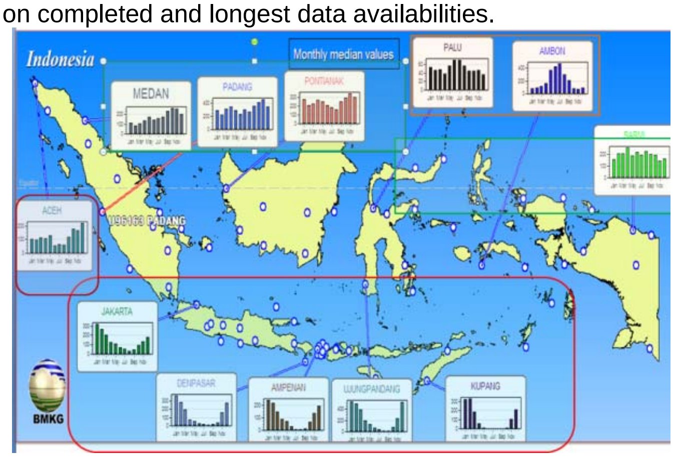

Figure 3. Meterological station used within the 3 main climate regions of Indonesia (red cycle, green cycle and, brown cycle) Monsoon, Equatorial and Local Climate Type.

Based on the general seasonality in rainfall for Indonesia, annual rainfall was split into 2 periods, May to October (Dry Season) for Monsoon Type but contrast or opposite for Local Climate Type (November to April), and then almost no dry season for Equatorial Type the rainfall always high every month (> 100 mm/month) the lowest rainfall on June and February. The Rainy Season, November to April for Monsoon Climate Type, June to August for Local Climate Type and 2 times peaks Apr and October for Equatorial Climate Type.

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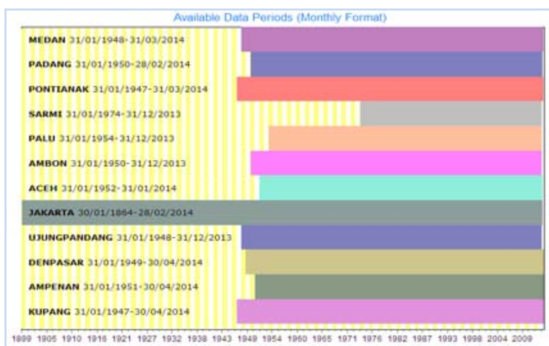
Look at the Table for selected station for analyse 3 Regional Climate Type in Indonesia.

Table 1. Meteorological station used within the 3 main climate regions of Indonesia

Climate Region Type	Specify station	Lon	Lat	Wet season	Dry Season
1. Monsoonal	Aceh	5.52 N	95.42 E	Nov-Apr	May-Oct
	Jakarta	6.16 S	107.22 E	Nov-Apr	May-Oct
	Denpasar	9.15 S	115.16 E	Nov-Apr	May-Oct
	Ampenan	8.52 S	116.07 E	Nov-Apr	May-Oct
	Ujung Pandang	5.06 S	119.55 E	Nov-Apr	May-Oct
	Kupang	10.16 S	124.07 E	Nov-Apr	May-Oct
2. Equatorial	Medan	3.57 N	99.07 E	Apr&Oct	Nov-Feb
	Padang	1.27 S	100.34 E	Apr&Oct	Nov-Feb
	Pontianak	0.01 S	109.37 E	Apr&Oct	Nov-Feb
	Sarmi	2.2 S	139.13 E	Apr&Oct	Nov-Feb
3. Local	Palu	1.07 S	120.13 E	May-Oct	Nov-apr
	Ambon	4.09 S	128.07 E	May-Oct	Nov-apr

The rainfall data availability for each of meteorological station with length of data record more than 50 years long period, which mostly was starting from 1950. The longest period is Jakarta which starting from 1864, and the shortest is Sarmi (Papua) whith starting from 1974.

Table 2. Periodical Data viability for 3 Region Climate type



Median of Rainfall for Each of Climate Type in Indonesia based on (1950-2014) period divide into 3 main category (Monsoonal, Equatorial and Local) Climate type.

Table 3. Periodical Data viability for Monsoonal Climate type

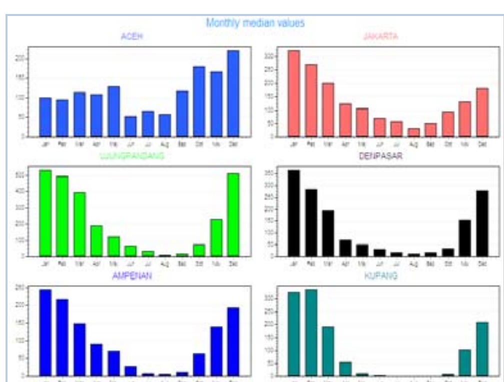


Table 4. Periodical Data viability for Local Equatorial Climate type

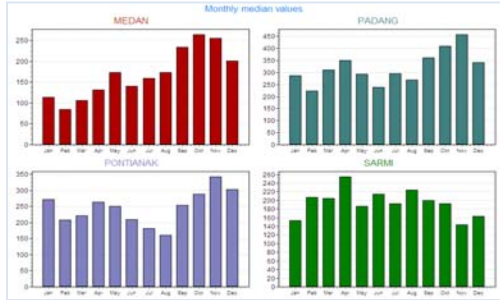
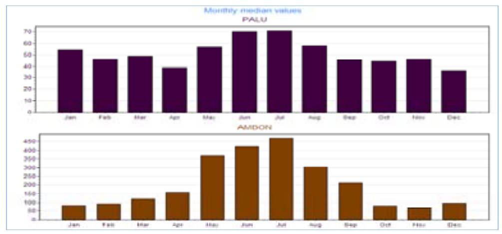


Table 5. Periodical Data viability for Local Climate type



The first rainfall region, the monsoon (Aceh, Jakarta, Ujung Pandang, Denpasar, Amenan and Kupang) has one peak in the rainy season. The wet season occurs between November to April while the dry season lasts from May to October. The second region, equatorial (Medan, Padang, Pontianak and Sarmi Papua) has two wet season peaks that occur in April and October. The 3rd is Local Climate region (Ambon and Palu) has rainfall distribution in contrast to the monsoon type, The wet season occurs between May to October while the dry season lasts from November to April.

Synchronous rainfall correlation

Preliminary synchronous relationship analysis was conducted using the SCOPIC "Analyse Relationship/Regression Analysis" feature. Both the trend in regression analysis (positive or negative) between SOI and rainfall, and correlation value was recorded. This will be later expanded to all main climate predictors (i.e. NINO 3.4, SOI and SSTs) and quartile periods throughout the year. For ease of interpretation the correlation value found was converted to a star-scale rating (1 star for each 0.1 of correlation), with 1 star representing poorly (weak) correlated and 5 stars or greater representing significant correlation (strong).

Rating for all stations and predictors were then tabulated for comparative purpose and to provide an "estimate" of potential forecast skill, at a climate region level based on the average for all stations located within each climate region (**Error! Reference source not found.** &Table). The combination of all individual synchronous relationships between predictands and predictors for 6 month periods for all stations selected across the 3 climate type is shown in **Error! Reference source not found.**-12.

Table 6. Synchronous associations (trend and correlation) between SOI and Indonesian rainfall for the period May – October for each climate zone

Climate Region Type	Specify station	Relationship	Correlation	May-Oct Star Rating
1. Monsoonal	Aceh	+ive	0.04	
	Jakarta	+ive	0.49	☆☆☆☆☆
	Denpasar	+ive	0.6	☆☆☆☆☆☆
	Ampenan	+ive	0.68	☆☆☆☆☆☆☆
	Ujung Pandang	+ive	0.54	☆☆☆☆☆
	Kupang	+ive	0.29	☆☆☆
2. Equatorial	Medan	+ ive	0.18	☆
	Padang	+ ive	0.27	☆☆☆
	Pontianak	+ ive	0.28	☆☆☆
	Sarmi	+ ive	0.32	☆☆☆
3. Local	Palu	+ve	0.5	☆☆☆☆☆
	Ambon	+ive	0.43	☆☆☆☆

Table 7. Synchronous associations (trend and correlation) between NINO 3.4 and Indonesian rainfall for the period May – October for each climate zone

Table 8. Synchronous associations (trend and correlation) between SSt 1-9 and Indonesian rainfall for the period May – October for each climate zone.

Table 9. Synchronous associations (trend and correlation) between SOI and Indonesian rainfall for the period November-April for each climate zone

Table 10. Synchronous associations (trend and correlation) between NINO 3.4 and Indonesian rainfall for the period November-April for each climate zone

Table 11. Synchronous associations (trend and correlation) between SSt 1-9 and Indonesian rainfall for the period November-April for each climate zone

Contingency tables and regression analysis show that the synchronous relationship between seasonal rainfall and SOI, Nino 3.4 and SST for the **Monsoonal and Local climate type** is **strong to very strong in the May – October (Dry Season) for Monsoonal type and Wet Season for Local Climate type.** The trend in relationship was found to be consistently positive for stations in Monsoonal and Equatorial, but consistently negative in Local climate type, this result because the peak season of Local Climate contras with the Monsoon climate type. SOI had a positive relationship with higher SOI leading to increased rainfall (high air pressure in Eastern Pacific - La Nino conditions) and NINO3.4 having a negative relationship with higher NINO3.4 leading to reduced rainfall, warm waters in Eastern Pacific- El Nino conditions (Troup, 1965).

During the period **November to April** (Rainy Season for Monsoonal type but dry season for Local Climate type. For some stations, in all three of the climate zones, this trend was reversed. It's also important at this point to note that difference in strength of relationship do exist between stations/locations and conclusions drawn above is based on the averaging of 2-4 stations in each climate region a high degree of variability exists between station correlations, especially for **Monsoonal climate type (Denpasar and Ujung Pandang) two station have very strong correlation for whole of predictor (SOI, Nino 3.4 and SST1-9)** (refer to **Error! Reference source not found.**). For **Equatorial Climate type has weaker relationship with SOI, Nino 3.4 , SSTs** and rainfall for two rainfall station (Padang and Sarmi). The reasoning behind the weaker relationship for whole stations at Equatorial climate type because the equatorial belt is a low pressure area. The tropical air masses from both the hemisphere are brought by the trade winds and they meet here which results in the formation of what is called Inter-Tropical Convergence Zone (Tjasyono, 2007). These air masses are warm and humid, the absolute humidity is constantly higher owing to the high temperature coupled with abundant moisture and have favourable lapse rates up to great heights. Therefore convection starts on a large scale leading to large cloud formations resulting in heavy rains during most part of the year. The others reasoning in part could be due to the geographic and orographic effects of the stations, and length of period data of predictor.

It's important to note that although SOI and NINO 3.4 displays a strong correlation than SST, direct comparison of these results is hindered by the limited availability of SST data (only starting in 1982, compared to SOI which in all situation predates available rainfall records). It is also important to consider within each climate type, difference in strength of relationship do exist between stations/locations and conclusion drawn above is based on the averaging of 4 stations in each climate region (Refer to **Error! Reference source not found.** for individual station results), of which some have varying lengths of records .

LEPS Skill Scores

LEPS (Linear Error in Probability Space) skill score tests can identify forecast "signals" highlighting the times of the year when a forecast will be most reliable, and the corresponding envelope of lead times that will maintain forecast reliability. Assessment of forecasting skill was undertaken using the "Skill Test" function within SCOPIC. A range of ENSO-based statistical forecast systems were tested for each station to calculate a LEPS score for 3 months rainfall with:

- 12 starting periods throughout the year,
- 3 lead times (0,1 & 2 months), and
- 3 predictor –averaging period (1,2 & 3 month for SST & Nino3.4 based systems , &

2,3 & 4 month SOI based systems).

To enable a crude comparison of relative skill between alternative ENSO-based systems the arithmetic average for each predictor for each climate region was also calculate. As shown in

this was achieved by taking the average of all skills score for all 12 start periods, 3 lead times (0-2 months) and 3 predictor periods for each ENSO-based system investigated (Nino3.4, SOI and SSTs).

Results of LEPS skill scores for individual stations and the range of starting periods, lead times, predictors and predictor periods can be seen in **Error! Reference source not found.**.

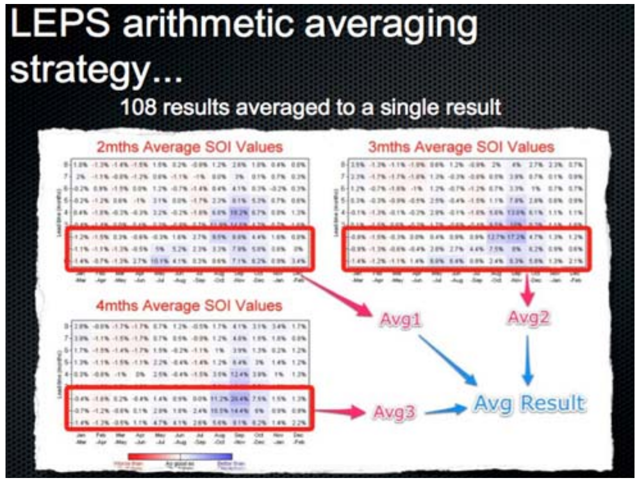
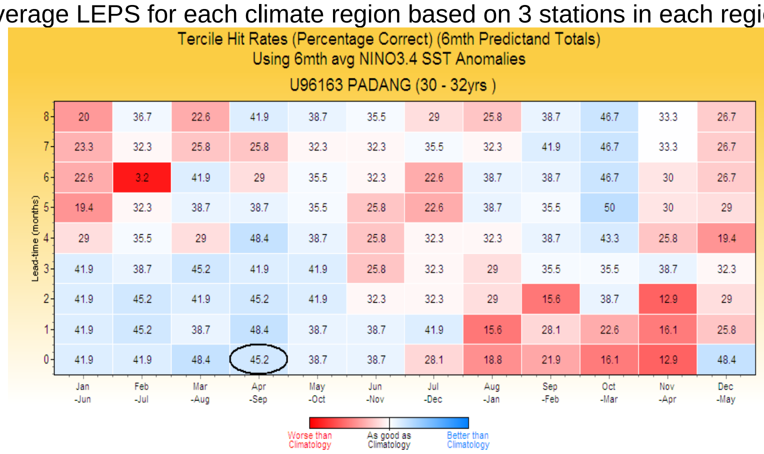


Figure 4. Method used to derive annual average LEPS value.

Significant average annual skill for individual stations located in, and collectively for 3 Climate regions (Table 1 and Table 2) were found. However, further investigation of the temporal distribution of this skill (**Error! Reference source not found.**) shows significant seasonality in skills using either NINO3.4 or SOI. It is important to consider that although a strong to very strong relationship was also found for the same locations and periods using synchronous correlation, both analyses are undertaken using different lead-times, and that high correlation does not necessarily imply high forecast skill if the predictor does not explain the variability in local rainfall.

Table 1. Average annual LEPS for each station based for a range of predictors

Table 2. Average LEPS for each climate region based on 3 stations in each region.



Lead-time (months)	Jan -Jun	Feb -Jul	Mar -Aug	Apr -Sep	May -Oct	Jun -Nov	Jul -Dec	Aug -Jan	Sep -Feb	Oct -Mar	Nov -Apr	Dec -May
8	20	36.7	22.6	41.9	38.7	35.5	29	25.8	38.7	46.7	33.3	26.7
7	23.3	32.3	25.8	25.8	32.3	32.3	35.5	32.3	41.9	46.7	33.3	26.7
6	22.6	3.2	41.9	29	35.5	32.3	22.6	38.7	38.7	46.7	30	26.7
5	19.4	32.3	38.7	38.7	35.5	25.8	22.6	38.7	35.5	50	30	29
4	29	35.5	29	48.4	38.7	25.8	32.3	32.3	38.7	43.3	25.8	19.4
3	41.9	38.7	45.2	41.9	41.9	25.8	32.3	29	35.5	35.5	38.7	32.3
2	41.9	45.2	41.9	45.2	41.9	32.3	32.3	29	15.6	38.7	12.9	29
1	41.9	45.2	38.7	48.4	38.7	38.7	41.9	15.6	28.1	22.6	16.1	25.8
0	41.9	41.9	48.4	45.2	38.7	38.7	28.1	18.8	21.9	16.1	12.9	48.4

Figure 5. LEPS skill table for individual stations

A common result found is the greater skill in forecasting stream flow (which accounts for catchment scale rainfall) verses individual rainfall stations, even when located within the catchment. This was the case in terms of Angat Dam with high skill in LEPS arithmetic average for Angat Dam Inflow, but little to no skill found for Science Garden rainfall station.

Normalised Weighted Tercile Hindcast Analysis

This analysis in SCOPIC historically tests on a year-by-year basis, how successful a three category forecasting strategy would have been for a specified predictor-period and predictands -period. On a year-by-year basis forecasts are denoted as one of three results.

- Consistent (predicted coincides with observed tercile category),
- Near Consistent (predicted and observed differ by one category)
- Inconsistent (predicted and observed differ by two categories).

To reflect the significant of a correct tercile forecast, verses a near consistent forecast or the penalty associated with an inconsistent forecast, weightings were assigned to each year based on the following to derive a weighted hindcast score.

Number of Consistent years	x 3
Number of Near Consistent years	x 1
Number of Inconsistent years	x -3

Weighted scores were then divided by the total number of years of forecasts to normalize scores and enable comparison of weighted results across station with differences in record length (Refer to **Error! Reference source not found.**).

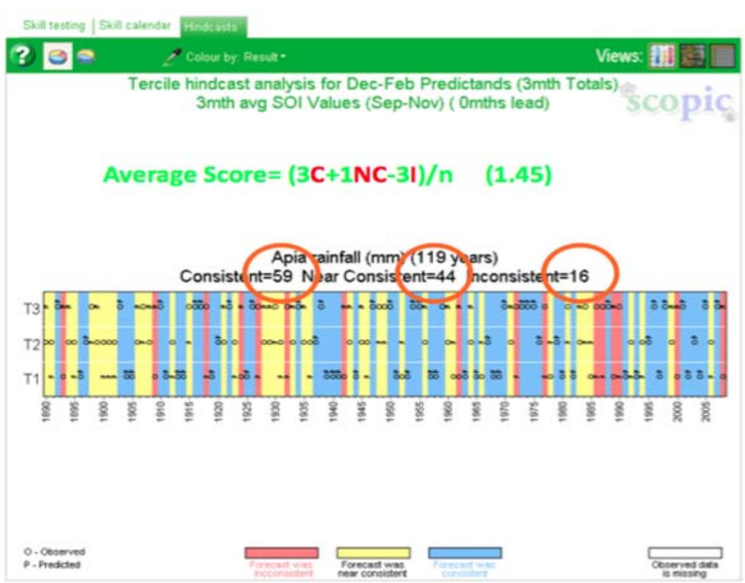


Figure 8. Tercile hindacast showing normalised weighted scoring system.

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Table 14 shows the normalised weighted tercile hindcast analysis for each stations individually and as an averaged based on each climate region. Although not as strong or high as that relationship and skill found for synchronous correlations or LEPS score, individual stations show significant differences in hindcast score. In addition to this, some stations located in Monsoonal and Local Climate type exhibit good hindcast results for the "dry" season (May – October) and rainy season (November – April), but do not for Equatorial climate have weaker tercile hindcast all the year (November – April). It is assumed at this stage, orographic influences and prevailing winds may play a role and as the predictor period is limited to 1-4 moths and rainfall periods reduced to quarterly periods throughout the year, even greater robustness and skill in tercile hindcast should be achieved.

Table 14. Six months tercile hindcast (based on assigned score weighting and normalised for years)

CONCLUSION

1. Base on the synchronous relationship analysis using the SCOPIC "analyse relationship/regression analysis'' show that :The synchronous associations between SOI, Nino 3.4 and SST anomali, in Indonesia rainfall are significantly stronger in 2 climate type (Monsoonal and Local) for both seasonal periods selected (May – October) Dry Season and (November – April) Rainy Season.
2. The strength of this relationship also corresponded to high forecasting skill (LEPS) being found especially in Monsoonal and Equator Climate type of Indonesia.
3. SOI (Southern Oscilation Index) is the most robust predictor for Seasonal Climate Forecast for Monsoonal and Equator climate type.
4. Although not as strong or high as that relationship and skill found for synchronous correlations or LEPS score, individual stations show significant differences in hindcast score.
5. Some stations located in the Monsoonal and Local exhibit good hind cast results for the "dry" season (May – October) and for rainy season (November – April)., but do not for Equatorial type, even greater robustness and skill in tercile hind cast should be achieved
6. The reasoning behind the weaker relationship for whole stations at Equatorial climate type because the equatorial belt is a low pressure area. The tropical air masses from both the hemisphere are brought by the trade winds and they meet here which results in the formation of what is called Inter-Tropical Convergence Zone.
7. Predictability in both the onset/start , retreat/finish and duration of the monsoon for selected stations (Ampenan) Monsoon type on average the onset of monsoons about 1st of October. In La Niña years, 50% of the time the monsoon is only delayed by 17days or less, where as this compares to more than 42 days in El Niño years. A similar situation occurs in monsoon length with El Niño years showing shorter length in monsoon compared to La Nina years.
8. SCOPIC are very useful software for SCF and Drought analysis for 3 Main Rainfall region in Indonesia.

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