ENSO Impact to the Hydrological Drought in Lombok Island, Indonesia

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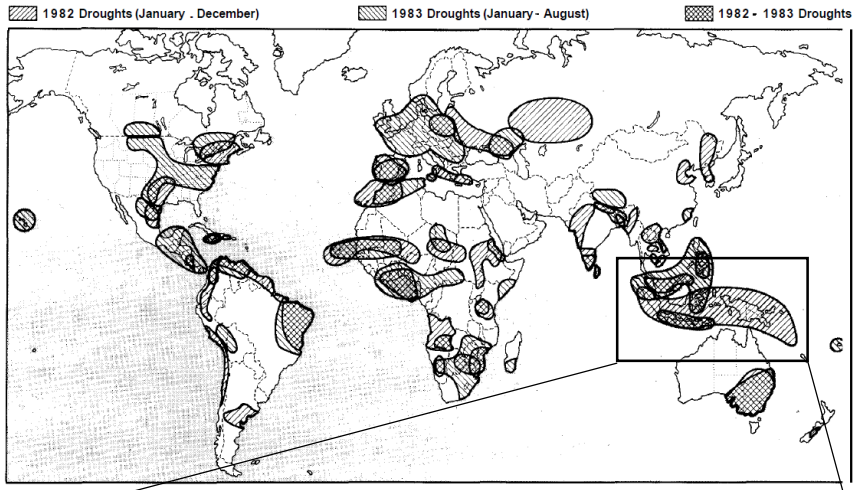
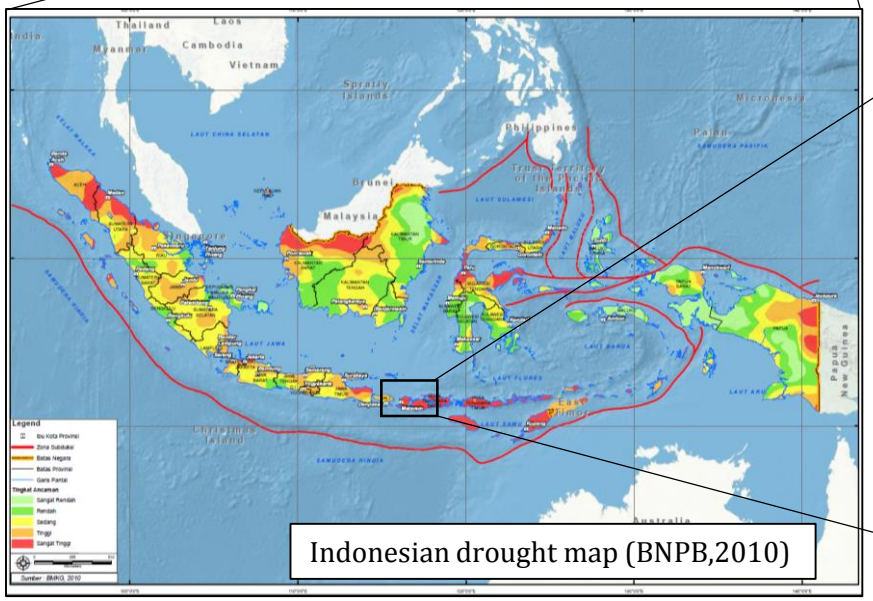
Background

- Drought occurs in high as well as low rainfall areas (Wilhite and Glantz 1985)

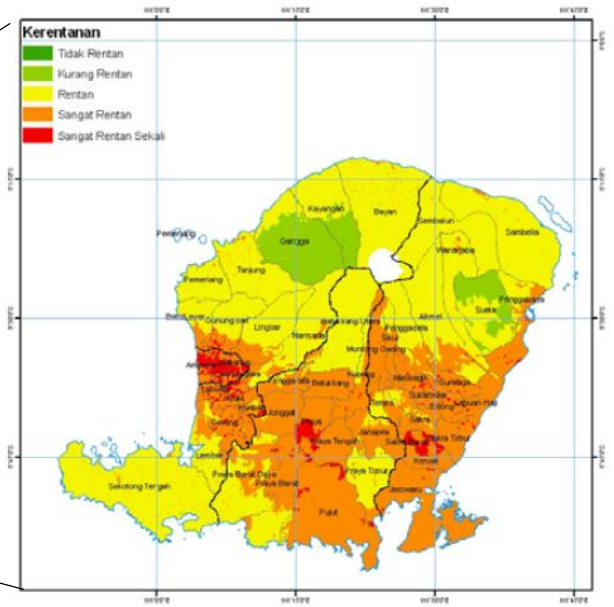


The occurrence of drought, January, 1982 to August, 1983 (Wilhite and Glantz 1985)



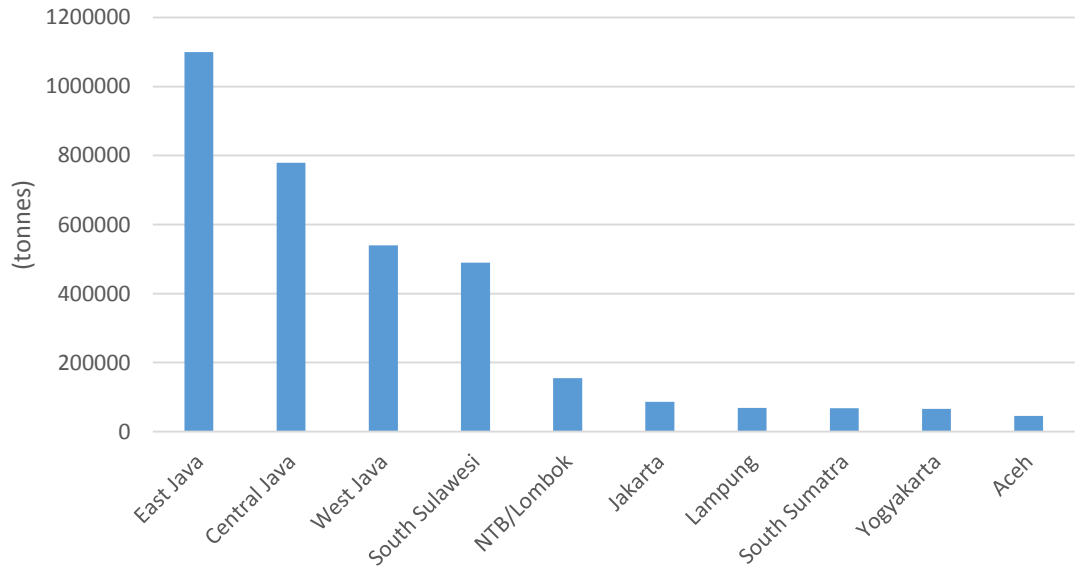
Indonesian drought map (BNPB,2010)

Vulnerability map of water sector of Lombok Island (Suroso, Hadi et al. 2009)



Background

- Lombok Island is one of the 10 biggest rice producers in Indonesia
- There is a necessity to study cause and impact of drought to prepare a good mitigation plan of drought in the Island



Background

- Drought occurrences in the future is likely increasing due to climate change
- In Indonesia, climate change has increase the number and severity of natural disaster, such as typhoons, droughts, forest fires, and floods (Measey 2010)
- In Lombok Island, the effect of climate change has been already felt by the increasing of vulnerability of water sector (Suroso, Hadi et al. 2009)

Background

- Mishra and Singh (2010) stated that the droughts around the globe are related to large-scale climate condition.
- Understanding the relationship between climate indices and drought will be useful for any drought prediction.
- El Nino worsen the drought condition
- The 1997 El Nino drought affected approximately 426.000 hectares of rice in Indonesia (Measey 2010)
- Climate change increase the frequency of El Nino Southern Oscillation (ENSO) event (Suroso, Hadi et al. 2009)
- The increasing trend of ENSO frequency will worsen the future drought
- In this study, we focus on impact of ENSO to hydrological drought in Lombok Island
- Hydrological drought is a period of inadequate surface and subsurface water resources for established water uses of a given water resources management system (Wilhite and Glantz 1985).

Problem Statement

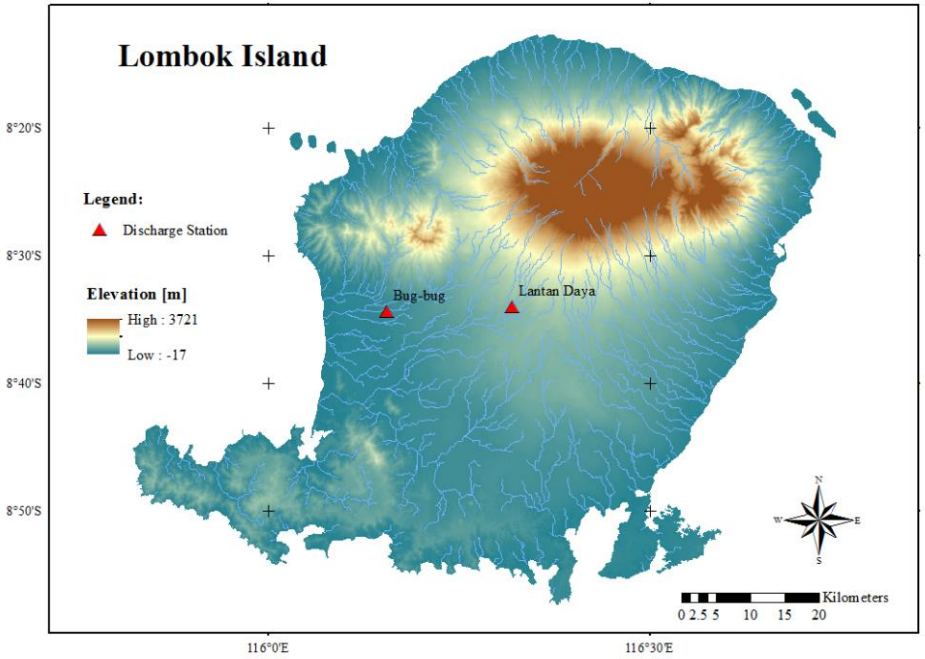
- Is drought getting more severe?
- Is there any direct correlation between ENSO and hydrological drought event?
- Is it possible to use ENSO index for drought prediction in Lombok Island?

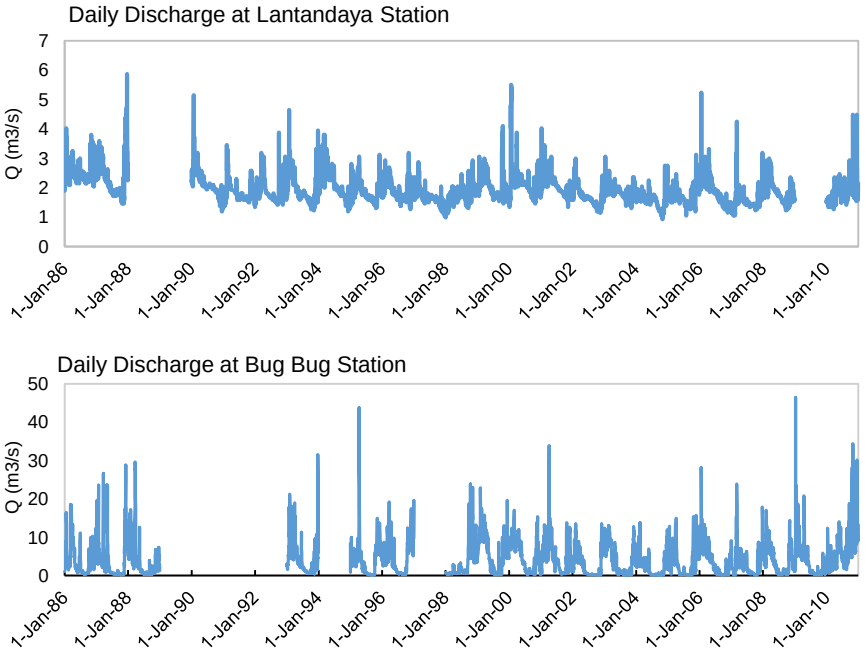
Objectives

- To understand the historical trend of drought in Lombok Island
- To investigate the ENSO - hydrological drought correlation
- To assess the lag correlation between ENSO and hydrological drought

Data and method

- Data used:
  - Daily discharge data from Lantandaya and Bug Bug Station
  - The data was collected from River Basin Organization of West Nusa Tenggara
  - Data period:
    - Lantandaya 22 years (1986-2010), missing data 1988-1989 & 2009
    - Bug Bug 19 years (1986-2010), missing data 1989-1992,1994 & 1997





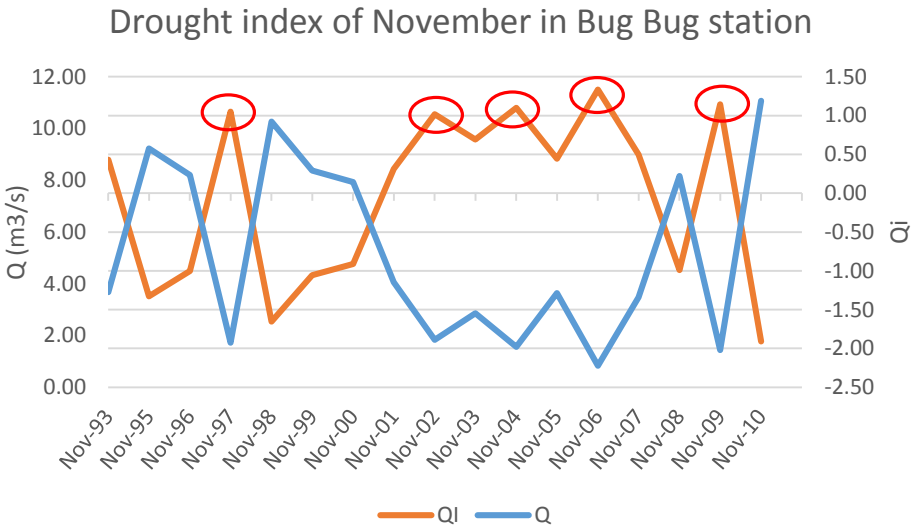
Data and method

- Hydrological drought event is defined by using discharge index

$$Qi = \frac{\overline{Q} - Q}{\sigma}$$

Where
Q_i = discharge index
$\bar{Q}$ = monthly average discharge
Q = monthly discharge in a particular year
σ = standard deviation

Q_i	Classification
< -1	wet/high events
-1 ~ 1	normal
> 1	dry/low events (drought)

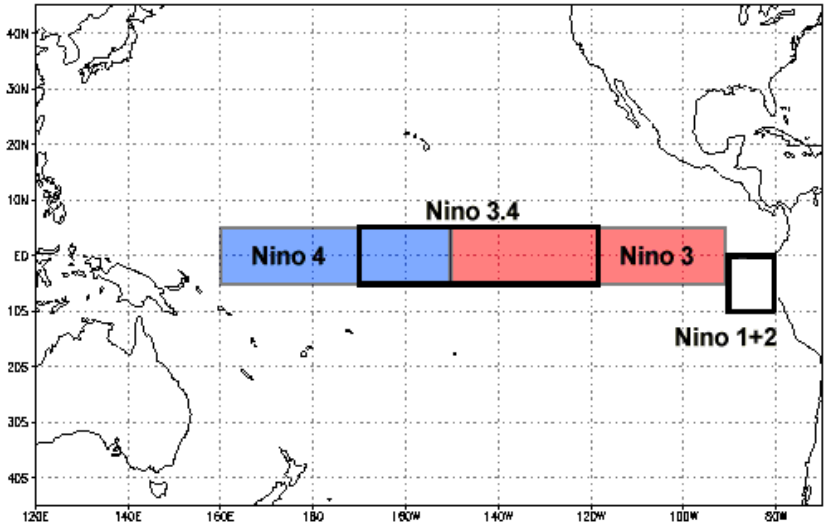


Data and method

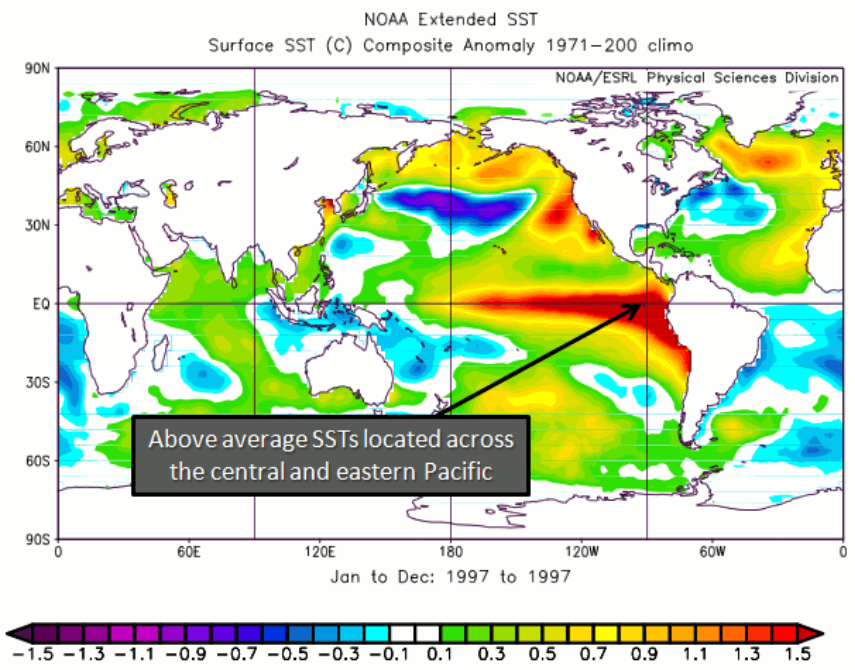
ENSO (El Nino Southern Oscillation)

- Is a naturally occurring phenomenon that involves fluctuating ocean temperatures in the equatorial Pacific
- It is a single climate phenomenon that periodically fluctuates between three phases: Neutral, La Niña (cold) or El Niño (warm)

The various "Niño regions" where sea surface temperatures are monitored to determine the current ENSO phase (warm or cold)



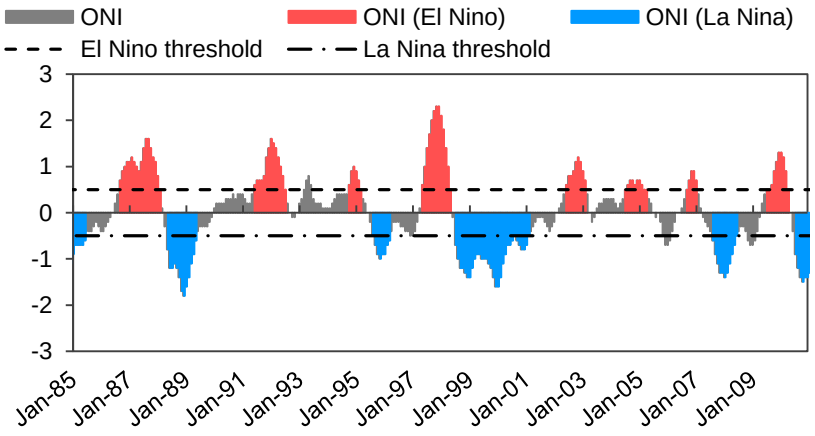
Source: https://www.ncdc.noaa.gov/teleconnections/enso/indicators/sst.php



https://climate.ncsu.edu/climate/patterns/ENSO.html

Data and method

- The ENSO indices:
  - Oceanic Nino Index (ONI) → 3 months running mean of Extended Reconstructed Sea Surface Temperature (ERSST).v4 SST anomalies in the Nino 3.4 region (5˚N-5˚S, 120˚-170˚W)
  - Nino3.4 → monthly SST in the Nino 3.4 region (5˚N-5˚S, 120˚-170˚W)
- The drought-ENSO correlation is investigated by using simple correlation

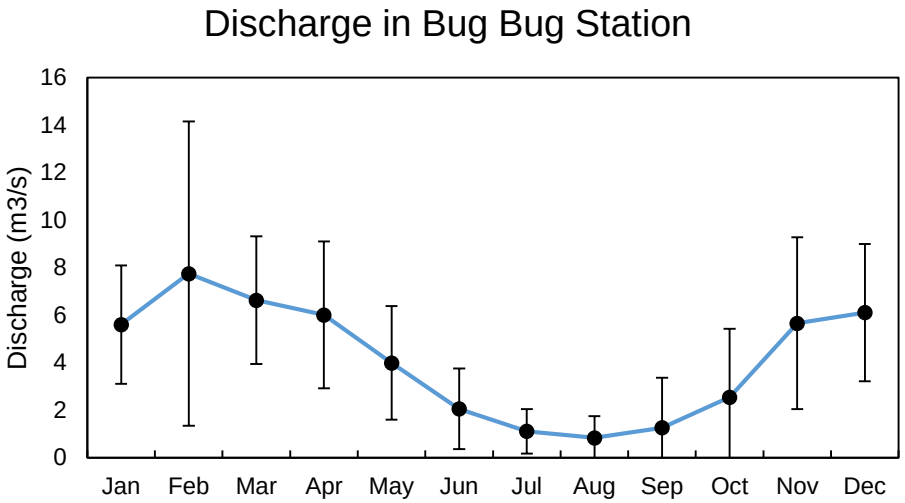


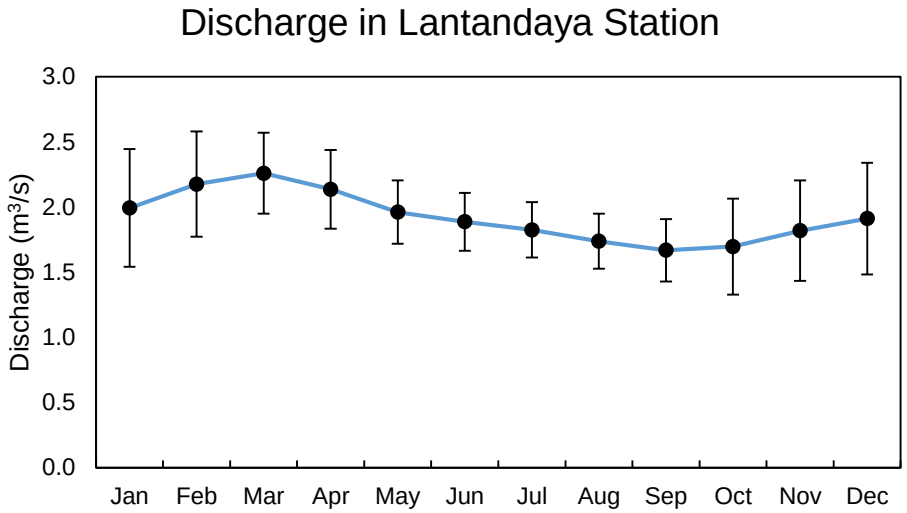
ENSO Classification based on ONI

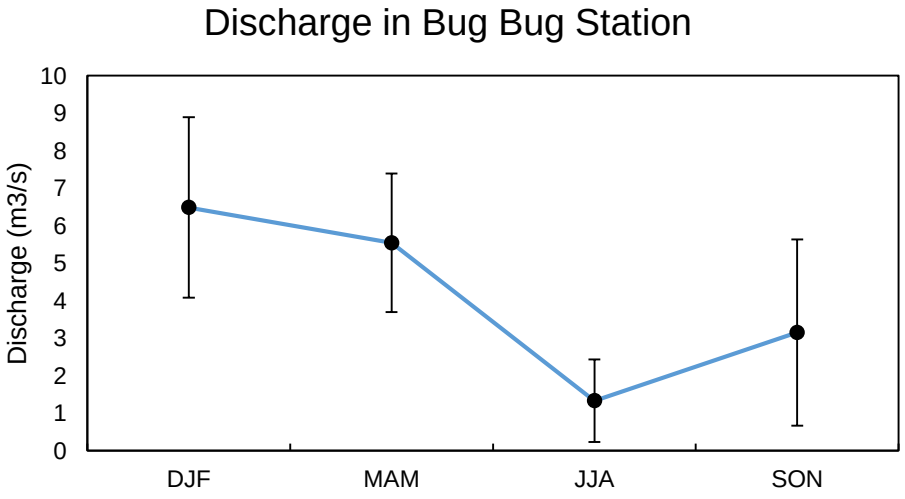
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1980	0.6	0.5	0.3	0.4	0.5	0.5	0.3	0.2	0	0.1	0.1	0
1981	-0.2	-0.4	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.2	-0.1	-0.1	0
1982	0	0.1	0.2	0.5	0.6	0.7	0.8	1.0	1.5	1.9	2.1	2.1
1983	2.1	1.8	1.5	1.2	1.0	0.7	0.3	0	-0.3	-0.6	-0.8	-0.8
1984	-0.5	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3
1986	-0.4	-0.4	-0.3	-0.2	-0.1	0	0.2	0.4	0.7	0.9	1.0	1.1
1987	1.1	1.2	1.1	1.0	0.9	1.1	1.4	1.6	1.6	1.4	1.2	1.1
1988	0.8	0.5	0.1	-0.3	-0.8	-1.2	-1.2	-1.1	-1.2	-1.4	-1.7	-1.8
1989	-1.6	-1.4	-1.1	-0.9	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.1
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1990	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4
1991	0.4	0.3	0.2	0.2	0.4	0.6	0.7	0.7	0.7	0.8	1.2	1.4
1992	1.6	1.5	1.4	1.2	1.0	0.8	0.5	0.2	0	-0.1	-0.1	0
1993	0.2	0.3	0.5	0.7	0.8	0.6	0.3	0.2	0.2	0.2	0.1	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.6	0.9	1.0
1995	0.9	0.7	0.5	0.3	0.2	0	-0.2	-0.5	-0.7	-0.9	-1.0	-0.9
1996	-0.9	-0.7	-0.6	-0.4	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5
1997	-0.5	-0.4	-0.2	0.1	0.6	1.0	1.4	1.7	2.0	2.2	2.3	2.3
1998	2.1	1.8	1.4	1.0	0.5	-0.1	-0.7	-1.0	-1.2	-1.2	-1.3	-1.4
1999	-1.4	-1.2	-1.0	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.2	-1.4	-1.6
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.6	-1.4	-1.1	-0.9	-0.7	-0.7	-0.6	-0.5	-0.6	-0.7	-0.8	-0.8
2001	-0.7	-0.5	-0.4	-0.3	-0.2	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.3
2002	-0.2	0.0	0.1	0.2	0.4	0.6	0.8	0.8	0.9	1.1	1.2	1.1
2003	0.9	0.7	0.4	0	-0.2	-0.1	0.1	0.2	0.2	0.3	0.3	0.3
2004	0.3	0.3	0.2	0.1	0.2	0.3	0.5	0.6	0.7	0.7	0.6	0.7
2005	0.7	0.6	0.5	0.5	0.3	0.2	0	-0.1	0	-0.2	-0.5	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.0	0.1	0.3	0.5	0.7	0.9	0.9
2007	0.7	0.4	0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.1	-1.3	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.4	-0.3	-0.3	-0.4	-0.6	-0.7
2009	-0.7	-0.6	-0.4	-0.1	0.2	0.4	0.5	0.5	0.6	0.9	1.1	1.3
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2010	1.3	1.2	0.9	0.5	0.0	-0.4	-0.9	-1.2	-1.4	-1.5	-1.4	-1.4
2011	-1.3	-1.0	-0.7	-0.5	-0.4	-0.3	-0.3	-0.6	-0.8	-0.9	-1.0	-0.9
2012	-0.7	-0.5	-0.4	-0.4	-0.3	-0.1	0.1	0.3	0.3	0.3	0.1	-0.2
2013	-0.4	-0.4	-0.3	-0.2	-0.2	-0.2	-0.3	-0.3	-0.2	-0.3	-0.3	-0.3
2014	-0.5	-0.5	-0.4	-0.2	-0.1	0.0	-0.1	0.0	0.1	0.4	0.5	0.6
2015	0.6	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.7	2.0	2.2	2.3
2016	2.2	2.0	1.6	1.1	0.6	0.1	-0.3	-0.6	-0.8	-0.8	-0.8	

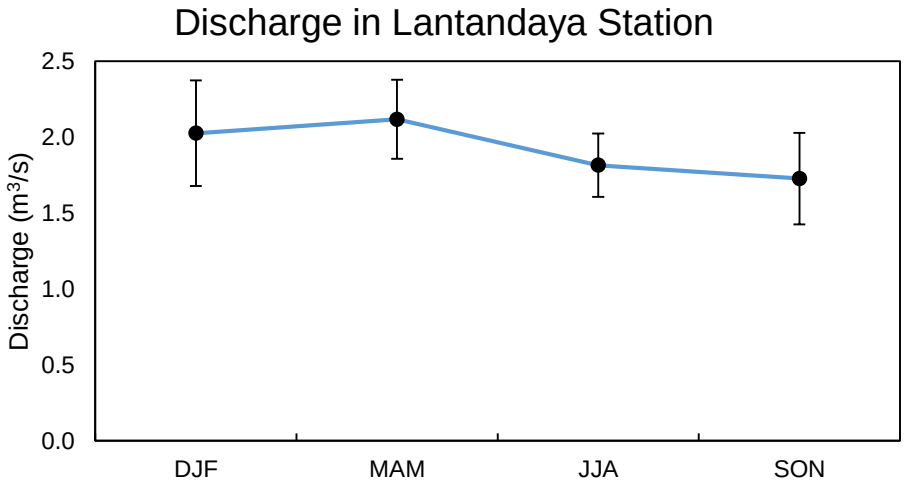
http://www.cpc.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Streamflow climatology



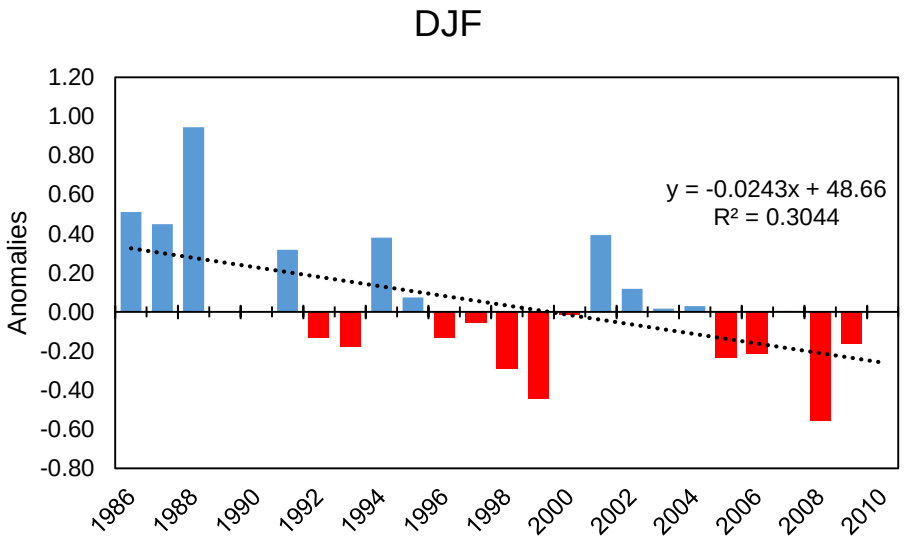


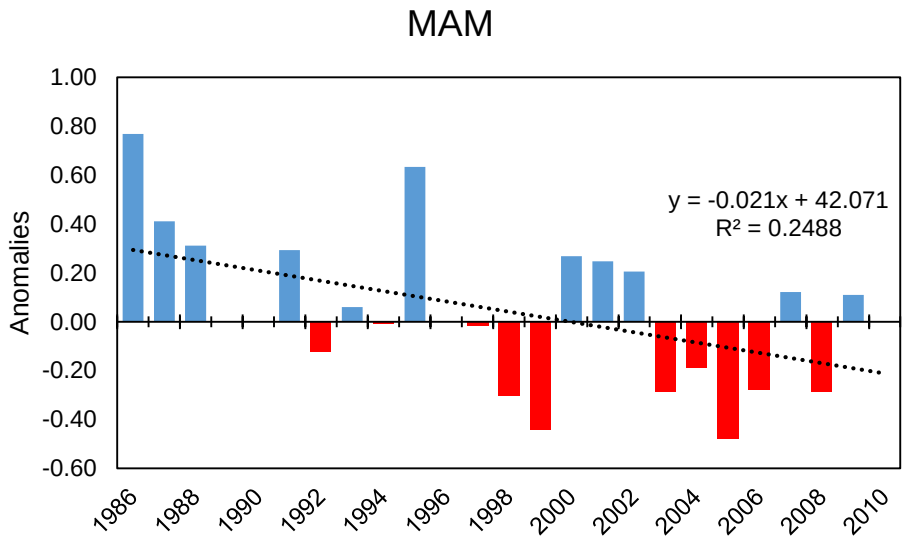


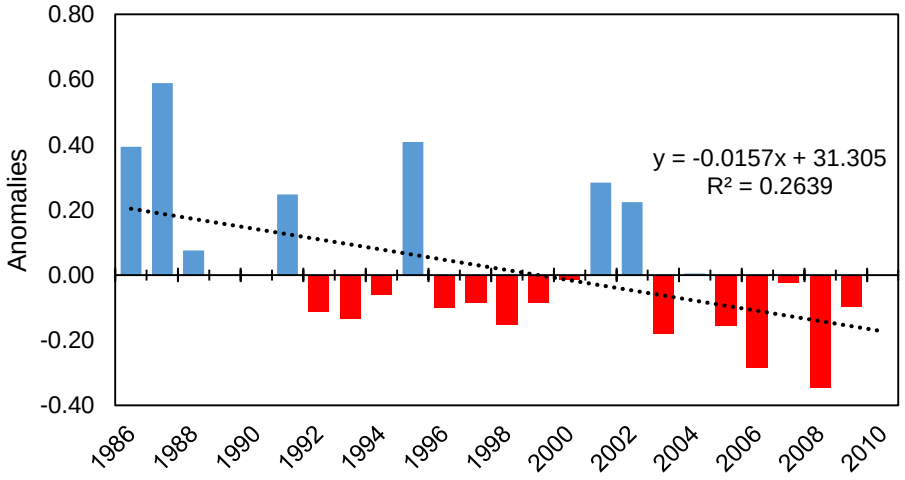


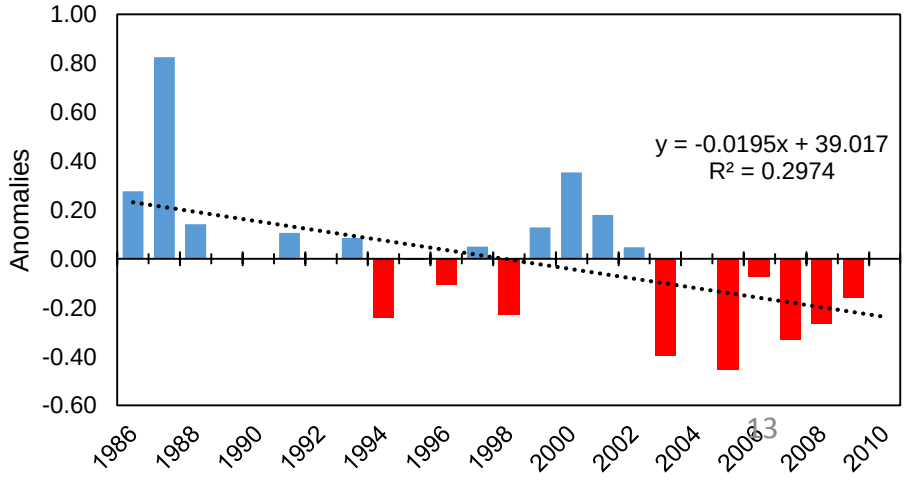
Seasonal anomalies trend of discharge (Lantandaya station)

- We used the anomalies trend to investigate the drought trend

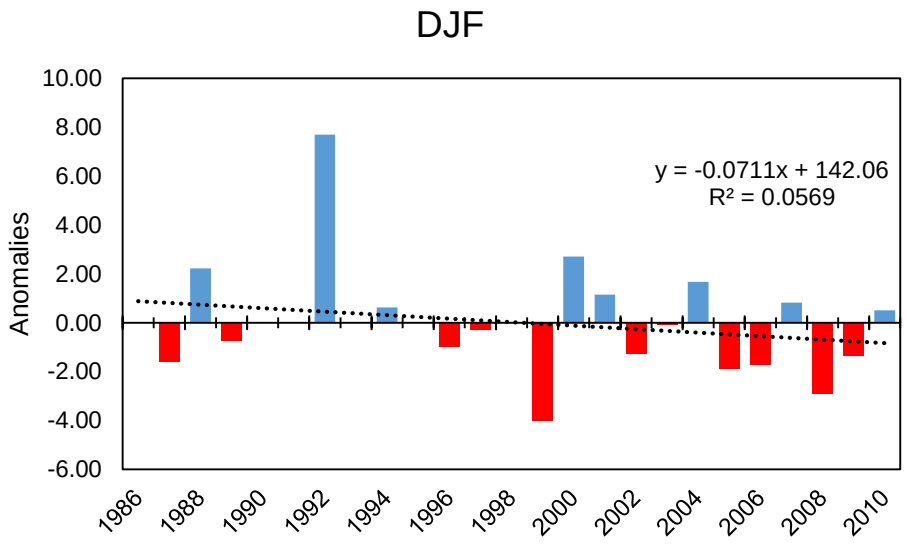


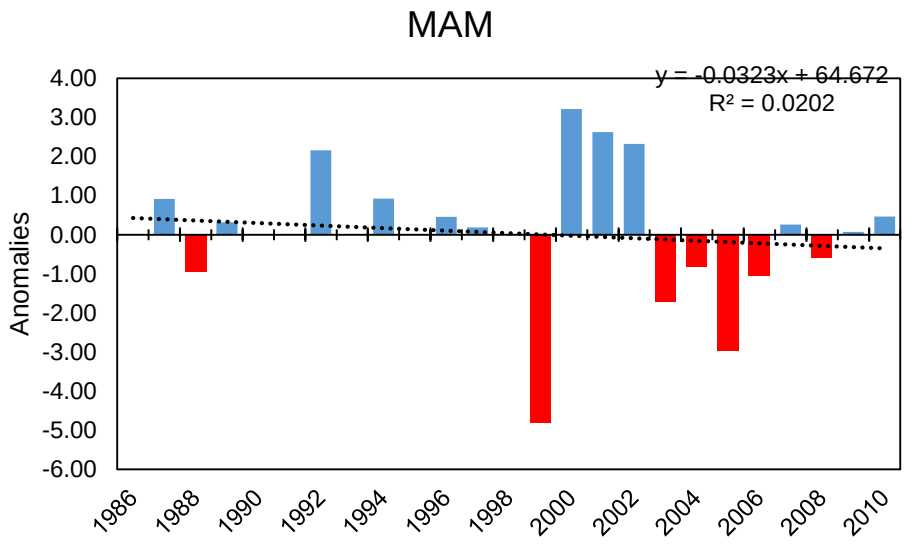


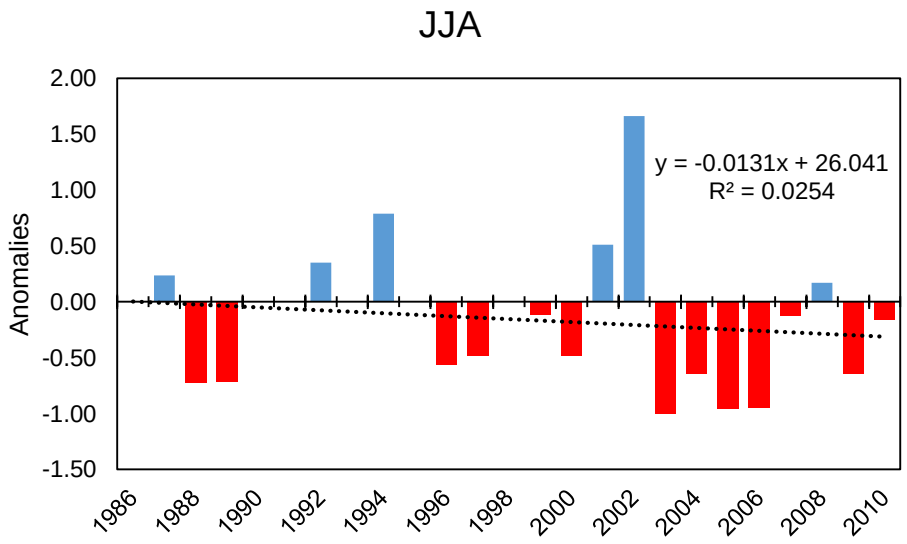


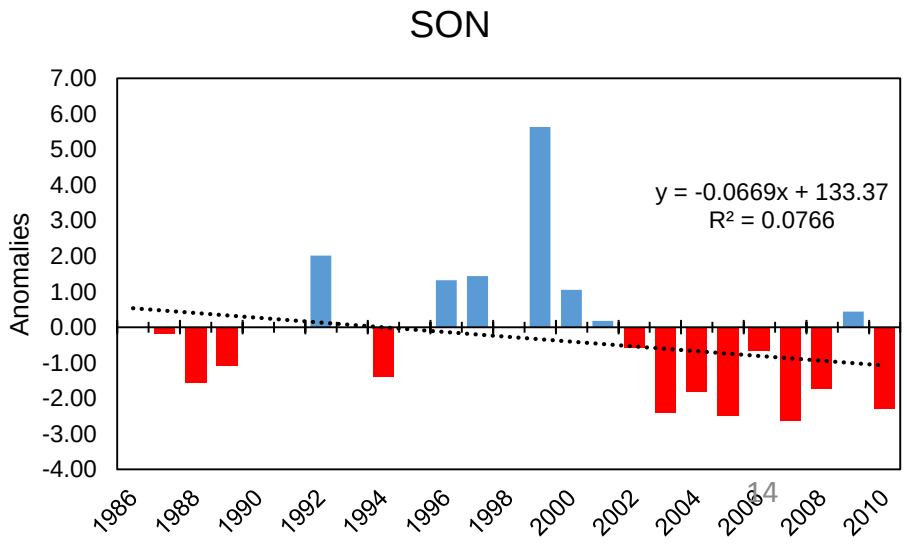


Seasonal anomalies trend of discharge (Bug Bug station)

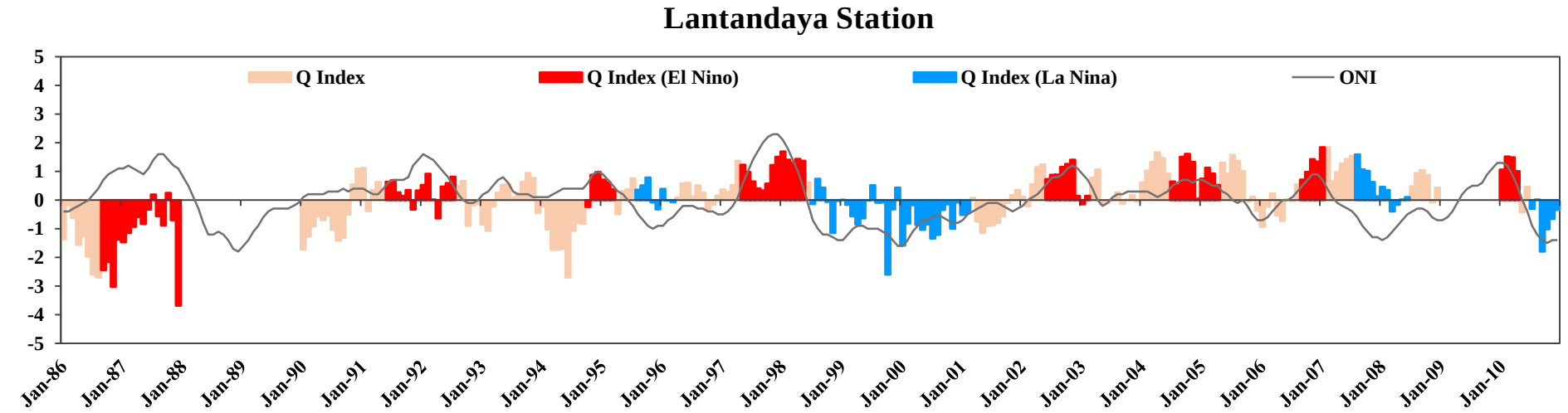


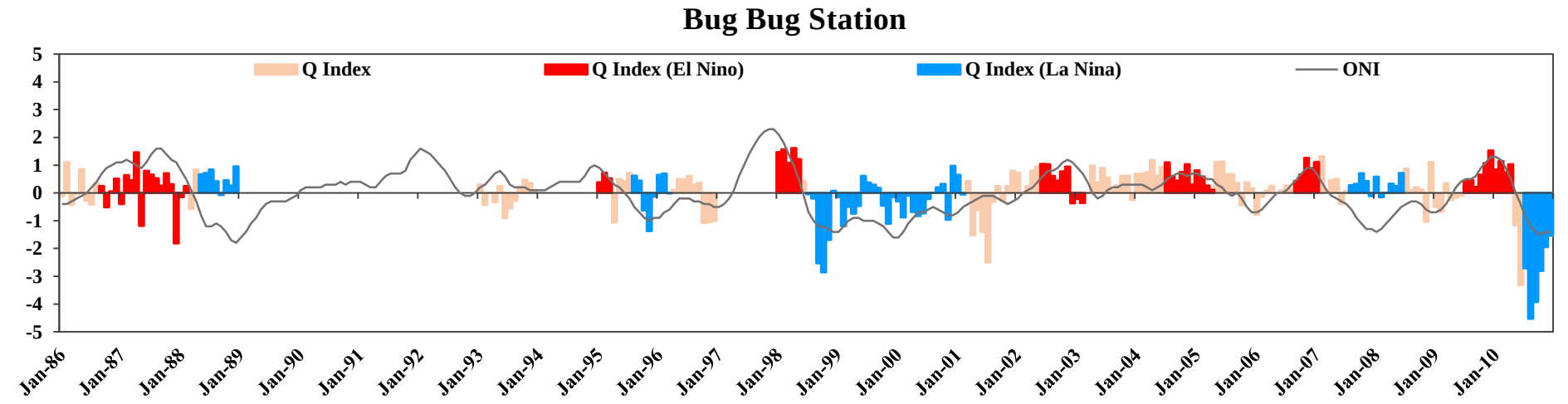




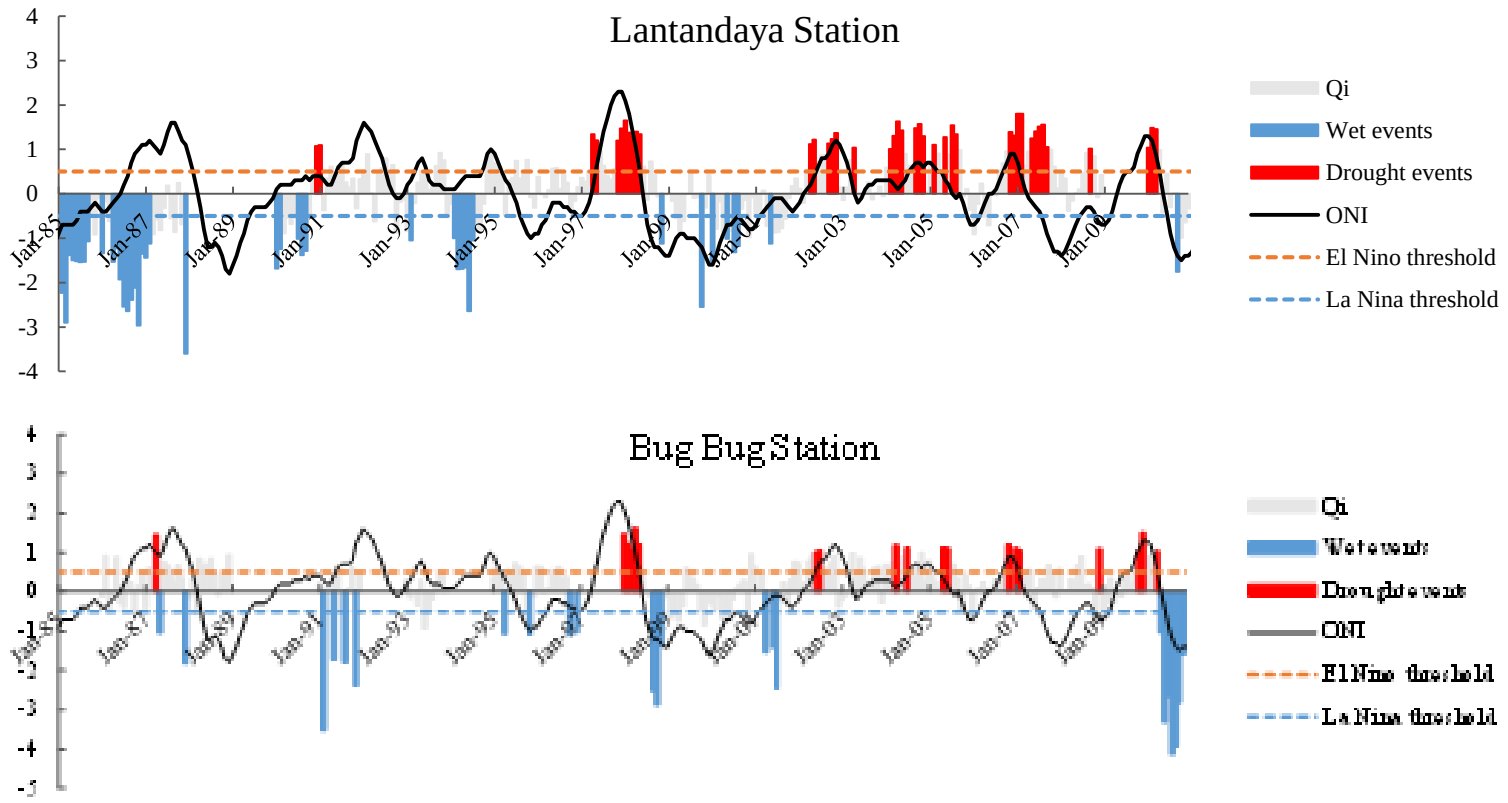


Drought vs ENSO





Drought vs ENSO



Drought vs ENSO frequency

The frequency of drought related El Nino was tested by using chi square test of independence

Example:

SON

Data: contingency table

	El Nino	Non-El Nino	Total
Drought	8	4	12
Non-drought	15	42	57
All	23	46	69

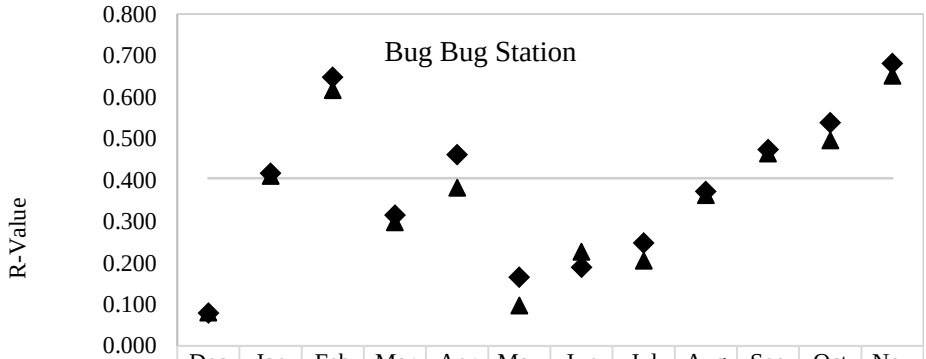
X^2 7.263 statistically significant

Season	Bug Bug	Lantandaya
DJF		
MAM		
JJA		
SON		

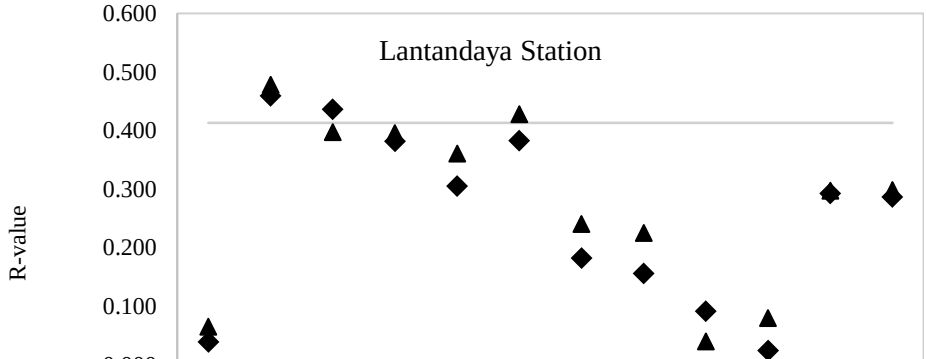
Note

	statistically not significant
	statistically significant

Monthly correlation

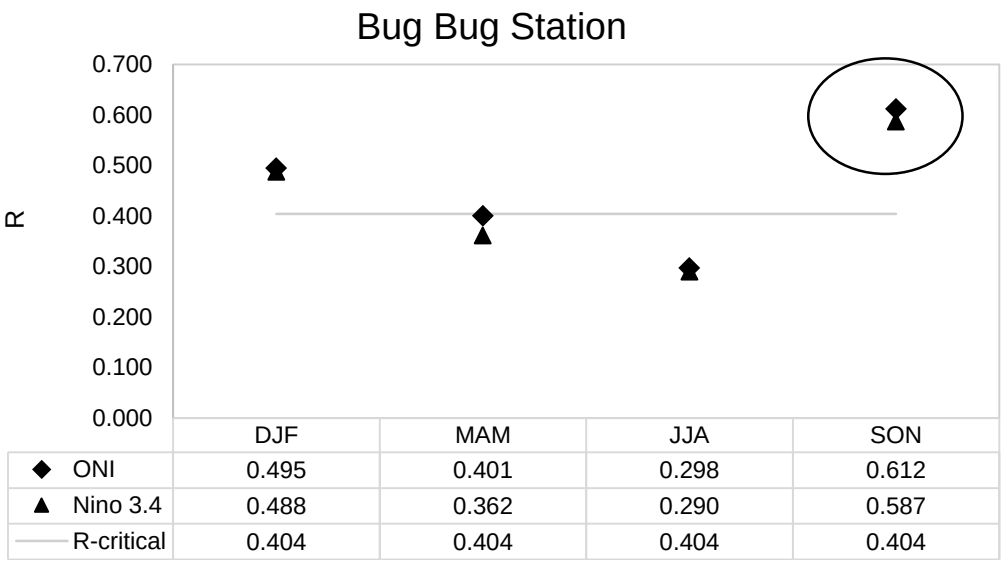


	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
◆ ONI	0.079	0.416	0.648	0.315	0.461	0.166	0.189	0.248	0.372	0.473	0.538	0.681
▲ Nino 3.4	0.080	0.410	0.617	0.297	0.381	0.097	0.227	0.205	0.363	0.463	0.495	0.651
R-critical	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404



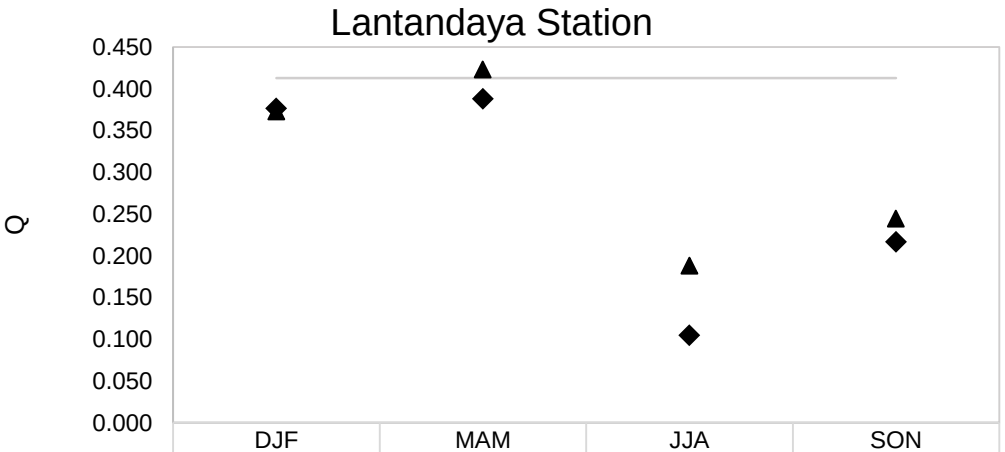
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
◆ ONI	0.039	0.459	0.436	0.382	0.305	0.382	0.182	0.156	0.091	0.025	0.292	0.287
▲ Nino 3.4	0.065	0.478	0.397	0.395	0.360	0.428	0.240	0.225	0.040	0.080	0.297	0.298
R-critical	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413	0.413

Seasonal correlation



	DJF	MAM	JJA	SON
ONI	0.495	0.401	0.298	0.612
Nino 3.4	0.488	0.362	0.290	0.587
R-critical	0.404	0.404	0.404	0.404

- The strongest correlation is seen during SON season.
- Some previous research of rainfall-ENSO correlation in Indonesia found out the highest correlation of rainfall and ENSO happens during dry season (JJA) (Hendon 2003)(Haylock and McBride 2001)(Kirono, Butler et al. 2015)
- The results shows possibility of lag correlation of discharge and ENSO



	DJF	MAM	JJA	SON
ONI	0.377	0.388	0.105	0.217
Nino 3.4	0.373	0.423	0.188	0.245
R-critical	0.413	0.413	0.413	0.413

Unclear correlation of ENSO and discharge:

- the location of the discharge in the upstream may give significant impact to the river discharge which may be strongly affected by
  - Orographic rainfall
  - Groundwater that is affected by land use type which is typically forest and there is natural reservoir in the mountain

Lag-correlation between ENSO and discharge in Bug Bug station

Nino3.4 - Qi lag correlation (R)

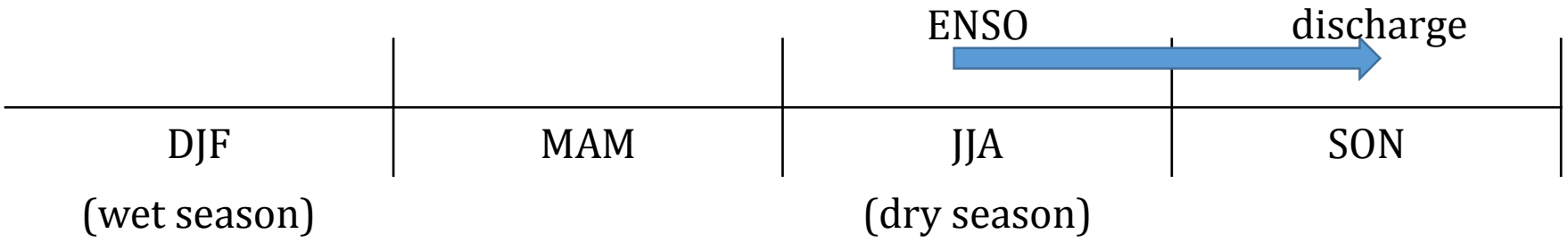
Time lag of Nino3.4 (months prior to)	Rainfall Season			
	DJF	MAM	JJA	SON
9	-.058	.413 *	-.014	.548 *
6	-.176	.405 *	.299	-.280
3	-.257	.021	-.136	***.539*** *
0	.549 *	.559 *	.316	***.595*** *

*significant at 95%

ONI - Qi lag correlation (R)

Time lag of ONI (months prior to)	Rainfall Season			
	DJF	MAM	JJA	SON
9	-.109	.432 *	.012	.561 *
6	-.200	.443 *	.281	-.207
3	-.265	.055	-.097	***.541*** *
0	.524 *	.597 *	.305	***.633*** *

*significant at 95%



Conclusions

- The trend of drought in Lombok Island is increasing.
- The ENSO impact to discharge in Bug Bug station is more significant than in Lantandaya station.
- The strongest ENSO-discharge correlation in Bug Bug station happens during SON season and the weakest one happens during JJA season.
- There is a lag correlation between JJA ENSO and SON Discharge in Lantandaya Station.

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Thank you so much for your kind attention…