EXTREME WEATHER IMPACTS ON CITARUM CASCADE RESERVOIR OPERATION PATTERN 2011

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ABSTRAK

Realisasi Pola Operasi Waduk Kaskade Citarum Tahun 2011 menyimpang jauh dari rencananya, terutama pada bulan Januari – Maret 2011. Tinggi Muka Air Waduk Saguling, Cirata, dan Djuanda pada tanggal 9 April 2011 saat pelaksanaan Teknologi Modifikasi Cuaca (TMC) dihentikan masih jauh di bawah Pola kering, yaitu berturut-turut 3,36m, 4,81m, dan 7,32m. Dengan metode analisis deskriptif dapat diketahui penyebab terjadinya deviasi Pola operasi tersebut. Berdasarkan data hujan rata-rata DAS Citarum diketahui, bahwa curah hujan pada bulan Januari 2011 hanya 70mm, jauh lebih kecil dari curah hujan rata-rata pada bulan yang sama, yaitu 208 mm. Dampak curah hujan tersebut menyebabkan inflow *ke Waduk Saguling pada bulan Januari, Februari dan Maret 2011 berturut-turut 60,7 m³/s, 56,3 m³/s dan 67,8 m³/s, jauh di bawah* inflow *rata-rata pada bulan yang sama. Sedikitnya curah hujan atau* inflow *disebabkan oleh adanya anomali SST di perairan sekitar Pulau Jawa, sehingga mengakibatkan terjadi penurunan suhu muka laut yang berdampak pada sedikitnya penguapan. Kemudian, adanya sirkulasi monsun Asia – Australia dan ITCZ yang bergerak ke arah tenggara turut mempengaruhi dinamika atmosfer di wilayah perairan Indonesia. Pada kondisi tersebut dari bulan Januari sampai Maret 2011 di DAS Citarum khususnya mengalami musim kering.*

Kata kunci: *Pola Operasi, deviasi, inflow, dinamika atmosfer, pertumbuhan awan*

ABSTRACT

The actual operation pattern of Citarum Cascade Reservoir 2011 deviated from plan, particularly in January-March 2011. The water level in Saguling, Cirata and Djuanda reservoirs on 9 April, 2011 was far below the dry pattern, consecutively 3.36m, 4.81m and 7.32m, when implementation of the Weather Modification Technology (WMT) was stopped. With application of the descriptive analysis method it is possible to understand the cause of reservoir operation deviation. Based on Citarum average basin rainfall data is known that rainfall in January 2011 is only about 70mm, much smaller than the average basin rainfall in the same month, that is 208mm. Impact of this condition caused inflow into the Saguling reservoir in January, February and March 2011, respectively 60.7 m3/s, 56.3 m3/s and 67.8 m3/s, to be far below the average inflow of these same months. Scarcity of rainfall or inflow is caused by the SST anomaly in the waters around Java, decreasing sea surface temperature and causing not much evaporation. The existing Asia-Australia monsoon circulation and ITCZ moving southeast also influences the atmospheric dynamics in the Indonesian waters. With such conditions from January to March 2011, the Citarum watershed in particular was experiencing the dry season.

Keywords: *Operation Pattern, deviation, inflow, atmospheric dynamics, cloud development*

INTRODUCTION

For the last twenty-five years, inflow into the Citarum River has been normal, except for the year 1997 when impact of El Nino was felt throughout Indonesia causing extreme drought. In that year, dryness was experienced by the three reservoirs in the Citarum because the total reserve storage volume was used to meet the supply of raw water for drinking water, irrigation and electric power. At that time, water level in reservoir reached its lowest position and disturbed the irrigation water supply in the northern part of Java. Reservoirs found from upstream to downstream Citarum are in successive order, Saguling at elevation +643m mean sea level (msl), Cirata at +220m msl, and Djuanda at +107m msl. Up to present date, operation of these three reservoirs is following a single cascade system coordinated by a team of Sekretariat Pelaksana Koordinasi Tata Pengaturan Air/SPK-TPA Citarum (Citarum Water Management Board).

The Citarum cascade reservoir operation pattern is a yearly operation pattern and is to the present set up according to inflow data resulted by statistical analysis using Log Normal Type 3. Data used involve the main flow directly entering the Saguling reservoir; and local flow entering the reservoirs Cirata and Djuanda. Data observation started in 1986 and continues to the present. Whereas, the operation pattern comprises three patterns, namely the Normal, Wet and Dry pattern. In particular conditions, very dry and very wet patterns are added.

Apparently, during its operation in 2010, water level in the three reservoirs appears to be above the operation pattern, exceeding the wet pattern. Consequently, overflow was encountered at the Saguling reservoir from 12 March, 2010 to 6 April, 2010; at Djuanda reservoir on 12 March, 2010 to 23 April, 2010, and the Cirata reservoir was filled up to normal pool elevation. The overflow at Djuanda reservoir caused the Karawang area and surroundings to be inundated for a prolonged period.

Operation pattern of 2011 is the reverse pattern of 2010, with the Citarum Cascade Reservoir showing a drastic decrease of water level from January to March, 2011 due to very small inflow into the three reservoirs. The inflow entering the Saguling in January, February and March, 2011 had been only 60.7 m^3/s, 56.3 m^3/s and 67.8 m^3/s respectively. Because of the small inflow entering the three reservoirs, water level at each reservoir had reduced drastically until finally reaching a level below the dry pattern. On 9 April, 2011, water level in the Saguling, Cirata and Djuanda had reached respectively the elevation of 3.36m, 4.81m and 7.32m below the dry pattern.

This study aims to decide on the cause of water level decrease in the Citarum Cascade Reservoir from January to March, 2011 based on hydrological and climatological point of view. Impact of the small inflow into the Citarum Cascade Reservoir has caused the already designated operation pattern of 2011 to fail as reference of reservoir operation due to actual water level having deviated from the designed water level. Revision is to be made of the operation pattern of Citarum Cascade Reservoir of 2011 for the months April to December 2011 using the initial water level of 1 May, 2011.

LITERATURE REVIEW

According to *Ngo* (2006), in the past few years, many researchers had put forth the problem of ineffective reservoir operation using obsolete technology and very subjective management. Situations of too much water in the wet season and less water in the dry season have caused many problems in reservoir operation. Many reservoirs in Vietnam dry up in the dry season, but are prone to dam failure in the wet season. This case needs to be mentioned in order to emphasized on reservoir operation systems that have to adapt to global climate change or economic activities in the watershed. Each reservoir has adapted a different operation system considering each separate hydro-meteorological condition and the change of water demand from one area to another. Therefore, without accurate consideration, reservoir operation will be inefficient. Reservoir operation is a complex operation and involves many decisions, objectives, risks and uncertainties. Apart from that, different objectives of operation result a significant challenge for reservoir operators when making operational decisions. Commonly, reservoir operation is based on heuristic procedures, rule curves and subjective decision of the operator. These matters shall decide the general operation strategy for outflow appropriate with reservoir water level, hydrological condition and the annual water demand. In any case, operation patterns can not be instantly good, particularly in noting the actual change of condition. It would therefore be essential to decide the analytical and more systematic approach of reservoir operation, not only based on common probabilistic or stochastic analysis, but also on information and extreme hydrologic event prediction, and advanced computation methods in order to improve the reservoir efficiency to equal the demand of different users.

Reservoir condition in Indonesia are almost similar to reservoir conditions in Vietnam that often endure dryness in the dry season and excessive water in the rainy season. Such conditions often occur, particularly in small reservoirs. Different with the Citarum Cascade Reservoir when water level had reached a point below the normal condition in1997 caused by the El Nino. In 2010, the Citarum Cascade reservoirs contained excessive water the year long, contrary to conditions at the start of 2011 when dryness caused by weather anomaly was observed in the three reservoirs.

A study carried out by *L. Li* (2010), tried to deal with the future potential impact of climate to river discharge change and the performance of reservoir operation in the Prairie watershed, North America. Watershed hydrologic modeling and reservoir water dynamics in accordance with the dynamic process of generating river flow will be based on climatologic conditions and reservoir water dynamics to the reservoir operation pattern. Reliable effectiveness measures shall present the reservoir operation pattern to meet various requirements that are assumed constant for the period of 100 years ahead with study focus on structural understanding and behavior of water supply. Simulation results show that climate variation and climate change in future will have greater effect to peak elevation-flood event and excessive water resources. The real time reservoir operation pattern shall result high reliability in protection to drought and flood control.

Up to present time, the Citarum cascade reservoir pattern had not anticipated the occurrence of climate change, floods or drought (SPKTPA, 2011). During the months March–April, 2010, a significant inflow entered the reservoirs Saguling and Djuanda, whereas the Cirata reservoir was filled to normal pool capacity without leaving a space of free board. Such condition had been the first occurrence since 1988 when the three reservoirs started a simultaneous operation. On the contrary, a reversed condition occurred in the months of January to March, 2011 when a shortage of inflow was observed in the three reservoirs. Following this event, efforts of anticipating the impacts of climate change, particularly within the Citarum watershed, had been the concern of the authorities related with this issue.

Normal and extreme weather can be indicated by atmospheric dynamic conditions. According to BMKG/ Meteorological, Climatological and Geo-physical Agency (2011), atmospheric and sea dynamics can be monitored and forecasted based on 6 (six) natural phenomena, namely 3 (three) global phenomena and 3 (three) regional phenomena. Global phenomena include El Nino and La Nina, *Dipole Mode* and *Madden Julian Oscillation* (MJO), whereas the regional phenomena is related with the Asia-Australia monsoon circulation, Intertropical Convergence Zone (ITCZ) and Sea Surface Temperature in the Indonesian waters. These six natural phenomena which are generally used as the principle in regional weather forecasting and evaluation were also applied in the Citarum watershed.

METHODOLOGY

The operation pattern of Citarum Cascade Reservoir 2011 was made by simulation method using the RESOP (Reservoir Operation) model comprising three types for each reservoir, namely normal, wet and dry pattern (*SPKTPA*, 2011). Prediction of the inflow was done by statistical method involving the Log Normal Type 3 frequency distribution. This paper shall further discuss the drastic decrease of reservoir water level in January to March, 2011 from the hydrological and climatological point of interest. The quantitative analysis of the deviation of reservoir water level to the operation pattern of Citarum Cascade Reservoir 2011 had used the recorded rainfall data of the Citarum watershed from 1986 to March, 2011 and the inflow data from recordings of 1988 to March, 2011. Furthermore, qualitative explanation by atmospheric dynamics is given on the cause of the small amount of rainfall in the Citarum watershed during the months January to March, 2011.

RESULTS AND DISCUSSION

Each reservoir has an operation pattern used as guidelines for a one year reservoir operation. The setting up of a single reservoir operation pattern is certainly much easier than a cascade reservoir operation pattern for two or more reservoirs. In this case, references are made to the three reservoirs in the Citarum watershed, Saguling, Cirata and Djuanda. The reservoir operation pattern 2011 was based on the inflow prediction results of a normal, wet and dry year. A normal year is indicated by the 50% value of frequency distribution, a wet year on the average value between 90% and 60% frequency distribution , whereas a dry year is indicated by the average value of the frequency distribution between 10% and 40%. Results of the Citarum Cascade Reservoir Operation Pattern 2011 is depicted in Figure 1 and 3. The Citarum cascade reservoir operation pattern that was used to present time has indeed not considered the extreme weather changes as impact of the global warming. The operation pattern used to 2011 had only considered normal floods and dry conditions, based on time series data of less than 25-years recordings. More data may possibly illustrate the inflow condition for wet or dry conditions. These time series data may involve the data recorded during reservoir operation by assuming that these data are representing the actual inflow condition after Citarum cascade reservoir operation started. Going on the basis of inflow data of the Saguling and Cirata reservoirs, dry or El Nino conditions were encountered in 1997; whereas very wet conditions occurred in 2010. The question is whether conditions drier than the condition in 1997 or wetter than 2010 were encountered in the Citarum watershed before the three reservoirs were constructed.

Major floods occurred in February to March 2010, and extreme dry conditions in January to March, 2011. Impact of the very dry condition caused the water level in the three reservoirs to decrease drastically, far below the dry pattern. On 1 February, 2011, the Saguling water level showed a decrease of 6.75m, Cirata 3.74m, and Djuanda 1.23m, as shown in Fig 1 – Fig 3. To increase the water level of the three reservoirs the Weather Modification Technology (WMT) was carried out on 14 February, 2011. An evaluation of each ten days monitoring indicated that the inflow showed no significant increase, and on 9 April, 2011, WMT was stopped. According to *Petrus*, (**2009**), application of the WMT at end of the rainy season had shown better results compared to conditions at start of the rainy season. It will be difficult to ensure that WMT unsuccessful at start of the rainy season shall determine the atmospheric condition of a particular region in the transitional season. However, in this case study, failure of WMT was more influenced by weather anomaly as will be explained below.

On 9 April, 2011, water level in the three reservoirs was still below the dry pattern, i.e. Saguling 3.36m, Cirata 4.81m and Djuanda 7.32m. Rainfall observation in the Citarum watershed during the months January, February, and March, 2011 indicated respectively 70 mm, 115 mm and 156 mm, smaller than the average rainfall of same months, namely 208 mm, 197 mm and 236 mm. Data of inflow entering the Saguling reservoir showed that inflow of January, 2011 was not the least if compared with inflow of same months in 2003 and 2007. In January, 2003, inflow into the Saguling reservoir had been 57.1 m^3/s, but in February and March , 2003 the amount increased to 153 m^3/s and 108 m^3/s. In January, 2007, inflow into the Saguling reservoir indicated 54.1 m^3/s, but in February and March, 2007 had increased to 101 m^3/s and 98.8 m^3/s. Whereas, during January to March 2011, inflow into the Saguling had been small, namely 60.7 m^3/s, 56.3 m^3/s and 67.8 m^3/s respectively. These conditions caused the drastic decrease of water level in the three reservoirs. More details of the difference of inflow into the Saguling reservoir in 2003, 2007 and 2011 is shown in Table 1. In January, 2011, disruption of the Java-Bali inter-connection electrical service caused the hydro-powered electricity plants at Saguling and Cirata to use an excessive capacity of water for approximately one week. This condition were certainly contradictory with the operation pattern, but at that time the management of the Saguling and Cirata reservoirs had hoped that the discharged water would be replaced in February, 2011. Such is based on the general conditions when time series of inflow data for February and March are higher than the inflow of January.

Impacts of global warming are difficult to be predicted, for example in 2010, inflow into the Citarum had extremely increased to 10.3 billion m^3, much higher than the average inflow of 5.7 billion m^3, and on 12 March to 6 April, 2010 overflow happened at the Saguling, and on 12 March to 23 April, 2010 at Djuanda reservoir. At Cirata reservoir, water level reached normal pool elevation only without a freeboard space.

The drastic decrease of reservoir water level can be explained by the atmospheric dynamic phenomena, particularly as was encountered in the Citarum watershed from January to March, 2011. According to BMKG, a Sea Surface Temperature (SST) anomaly occurred in the Indonesian waters from January to April, 2011, particularly in the waters surrounding Java island. In January, 2011, sea surface temperature decreased between 0.5 to 1^o C , indicating the cold water temperature and the tendency of very little evaporation in the atmosphere disturbing the development of rain clouds. From February to April, 2011 Sea Surface Temperature surrounding Java island started to increase from 0 to 0.5^oC, but unfortunately not enough to increase the evaporation and therefore rain clouds were not formed. The increase of Sea Surface Temperature from January to April, 2011 is depicted in Figure 4 to Figure 7.

Table 1 Condition of Inflow (m^3/s) into the Saguling reservoir in the dry years 2003, 2007 and 2011

No.	Month	2003	2007	2011
1	January	57.1	54.1	**60.7**
2	February	153	101	**56.3**
3	March	108	98,8	**67.8**

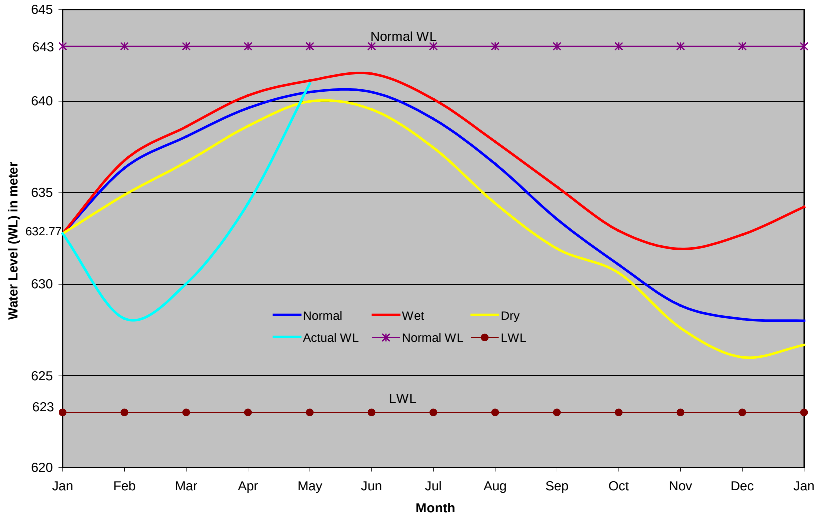

Figure 1 Operation pattern of the Saguling Reservoir, 2011

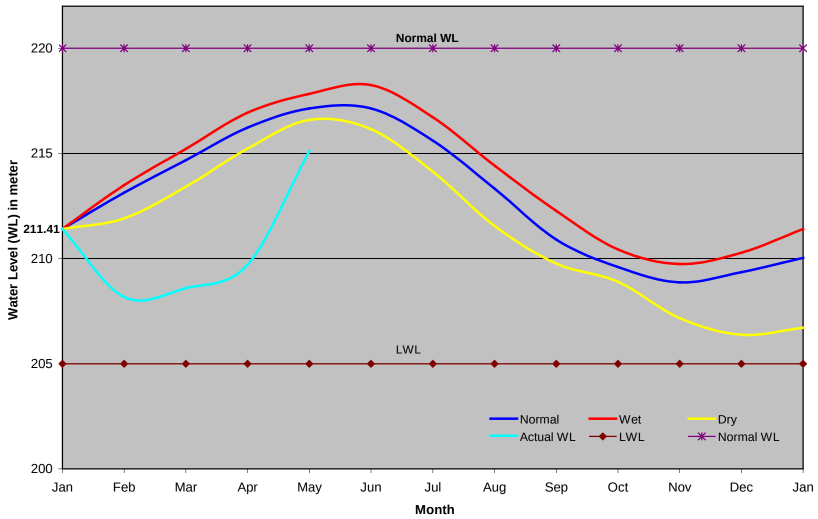

Figure 2 Operation pattern of the Cirata Reservoir, 2011

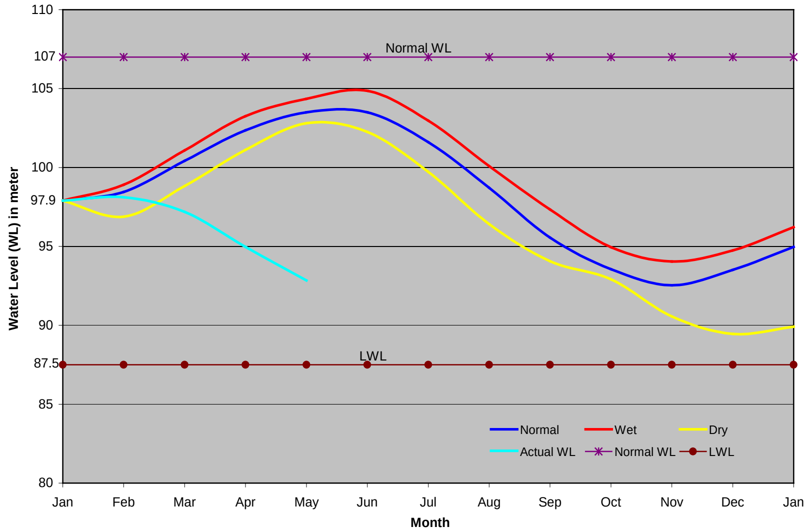

Figure 3 Operation pattern of the Djuanda Reservoir, 2011

In January 2011, Sea Surface Temperature in the Indonesian waters, particularly in the surroundings of West Java, started to become cold with an anomaly rate between -0.2 to -0.6, disrupting the development of clouds above West Java. Starting at the end of April, 2011, temperature in the waters surrounding West Java indicated a tendency to normal and particularly south of West Java, temperature started to increase.

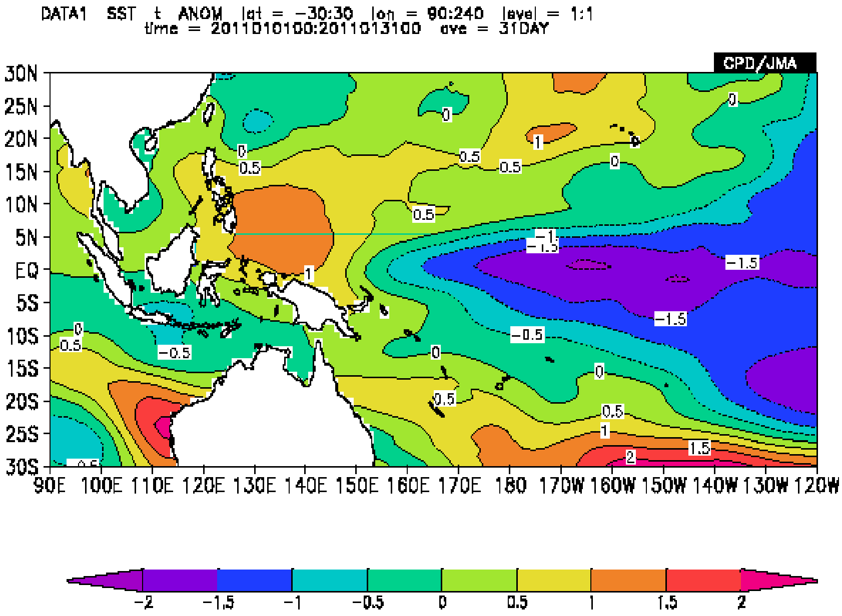

Figure 4 SST Anomaly, January 2011

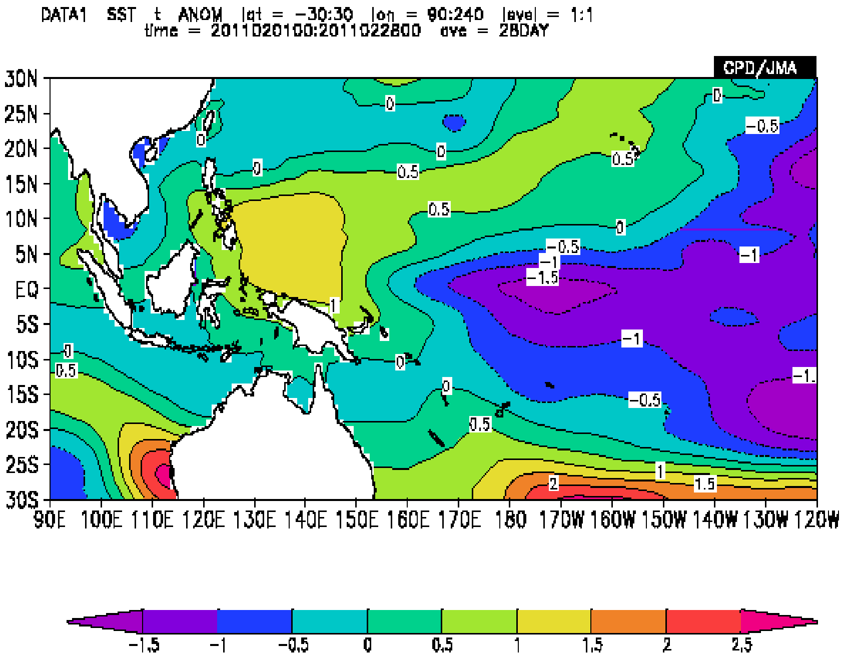

Figure 5 SST Anomaly, February 2011

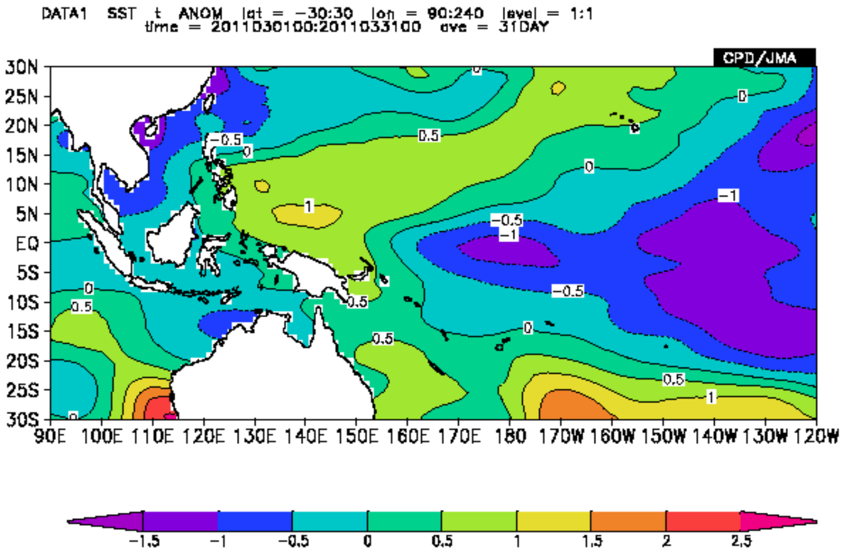

Figure 6 SST Anomaly, March 2011

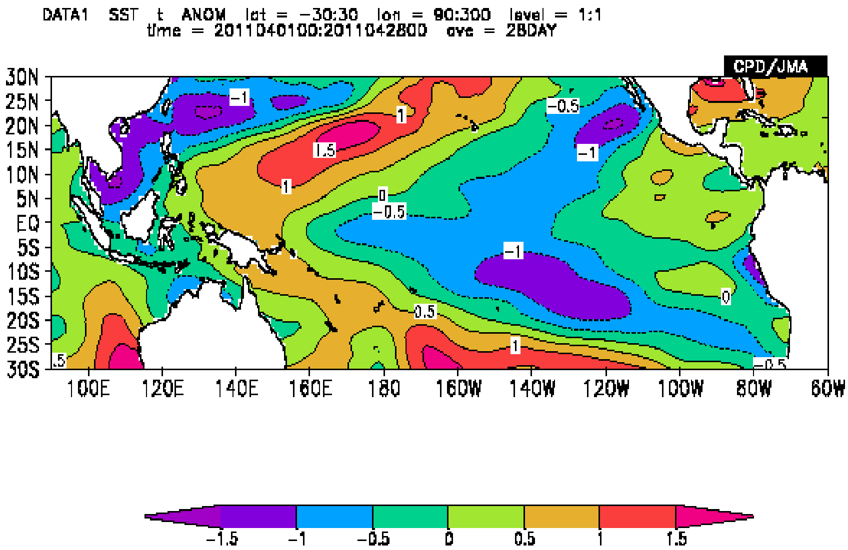

Figure 7 SST Anomaly, April 2011

In January, 2011, conditions at the equator in Central Pacific (Nino3-4) still show a moderate La Nina phenomena, namely -1 to -2; a phenomena that had appeared since June, 2010. In April 2011, La Nina became weaker showing the value of -0.5 to -1. From April to July, 2010 the Southern Oscillation Index (SOI) had been positive ranging between +2.0 to +3.3, increasing to +25 entering the month of January, 2011, and approximately +20 in April, 2011. These values are exceeding the limit of its influence (<+10 and >-10). These conditions indicate that during the event of La Nina, significant consideration is to be given to circulation activities of trade winds in Indonesia. Fluctuation of the SOI value is illustrated in Figure 8.

Whereas, the Dipole Mode Index (DMI) shows that a decrease of value had occurred in the last three months (- 0.4 in January, 2011 and -0.2 in March, 2011). These values are actually still neutral (+/- 0.4^{o}C), and indicate that the move of evaporation from the Indian Ocean east of Africa into the west region of Indonesia is still within the normal intensity. A better illustration, see Figure 9.

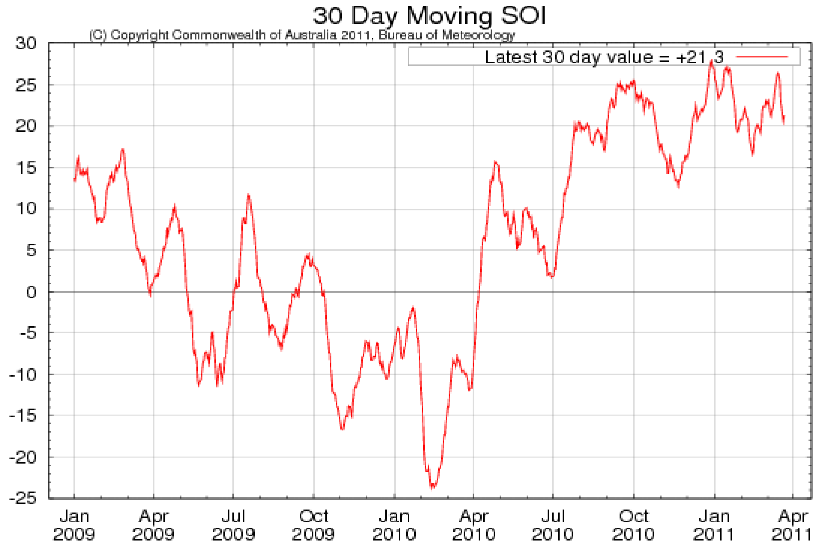

Figure 8 Fluctuation of SOI Value, January 2009 – April 2011

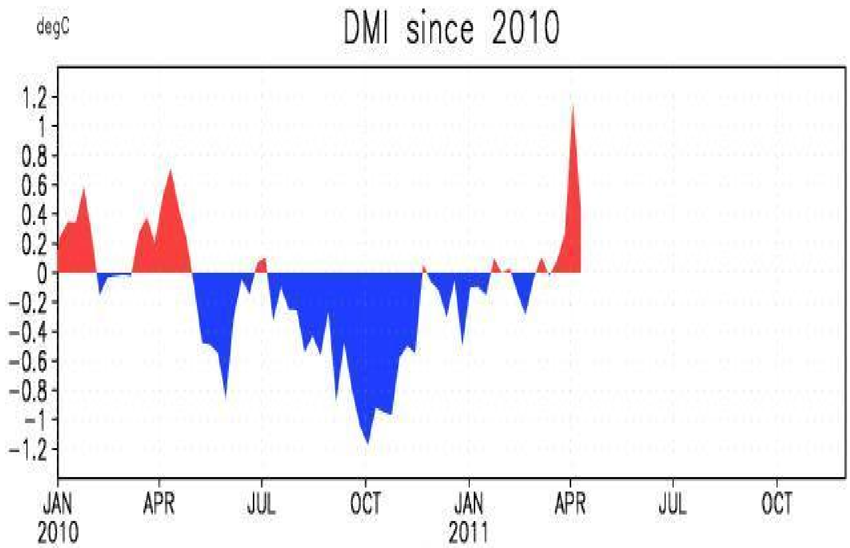

Figure 9 Fluctuation of DMI Value

The monitoring of **Madden Julian Oscillation** (MJO) activities, as related to the vertical movement on 28 April, 2011, had indicated an intensity in the Indian Ocean of 0.5 – 1, which gradually weakens. In Indonesia, such condition may indicate a normal situation not disrupted by the forming of rain clouds. MJO conditions in Indonesia are depicted in Figure 10.

The Asia-Australia monsoon circulation contributes to influence the atmospheric dynamics in the Indonesian waters. Until the end of August, 2010, in general monsoon circulation in Indonesia could be considered as normal, and the disturbances that occur during January to April, 2011 were usually caused by the low pressure patterns observed in the waters north of Aceh, whereas south of the equator, low pressure patterns were observed in the Indian Ocean southwest of Sumatera, south of Java and north of Australia. During WMT implementation carried out from mid February to the beginning of April, 2011, 3 (three) meteorological stations were set up at the Bandung Husein Sastranegara airport, Ciwidey and Cikalong Kulon (West Java) respectively. In general, wind at layers 3000 – 5000 feet, blows from the southwest to the northwest at 15 to 40 knots. These relatively strong winds disrupted the cloud development above the Citarum watershed. The Asia-Australia monsoon circulation, SST anomaly and others were not the only factors that influenced the success of WMT, but local weather such as upper wind, topographical conditions of Citarum watershed forming a basin surrounded by mountains and representing the wind ward that interacted in space at a rapid time contributed as well. Weather forecasting by BMKG before implementation of the WMT is therefore a substantial prerequisite (*Petrus*, 2009).

According to LAPAN in *Threwartha* and *Horn* (1968), ITCZ is the alignment or zone related with the cyclonic circulation center which is usually of lower pressure than the surrounding area and situated between two equatorial basins. The ITCZ is the point of wind convergence forming rain clouds in surrounding area and continuous rainfall. Energy requirement to maintain ITCZ is obtained from sea surface evaporation carried by lower troposheric wind convergence. From January to March, 2011, ITCZ moved into southeast direction where low pressure had concentrated north of Australia. Wind convergence forming rain clouds occurs in low pressured centers and surrounding areas so that rain clouds had also concentrated in Central Java to Nusa Tenggara. On the contrary, during these months, West Java has not been a point of wind convergence, and had in general formed upper and intermediate clouds. Figure 11 illustrates the normal wind pattern in Indonesia. With such wind pattern, in January, heavy rains are common on Java up through the islands in Nusa Tenggara. Apparently, in January 2011, an anomaly of wind pattern occurred in Indonesia (see Figure 12) affecting West Java and causing dryness. Rainfall rate of 1 January to 30 January, 2011 ranged only between 25 – 75 mm. This condition is complying with the average rainfall in the Citarum watershed of January, 2011 that is 70 mm, whereas average rainfall in February and March, 2011 was still below the average rainfall recorded since 1986. The satellite maps, Figure13 – Figure 15, confirmed the rainfall conditions in January, 2011. The atmospheric dynamics analysis indicated that the small inflow into the Citarum cascade reservoirs in January, 2011 was to greater extent caused by weather anomaly conditions.

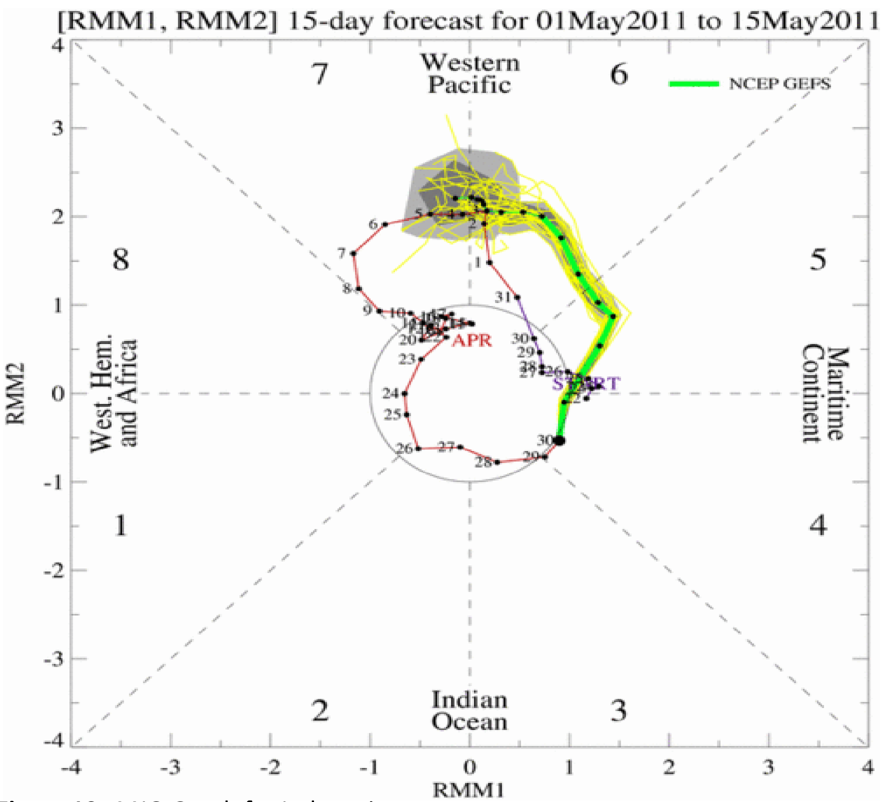

Figure 10 MJO Graph for Indonesia

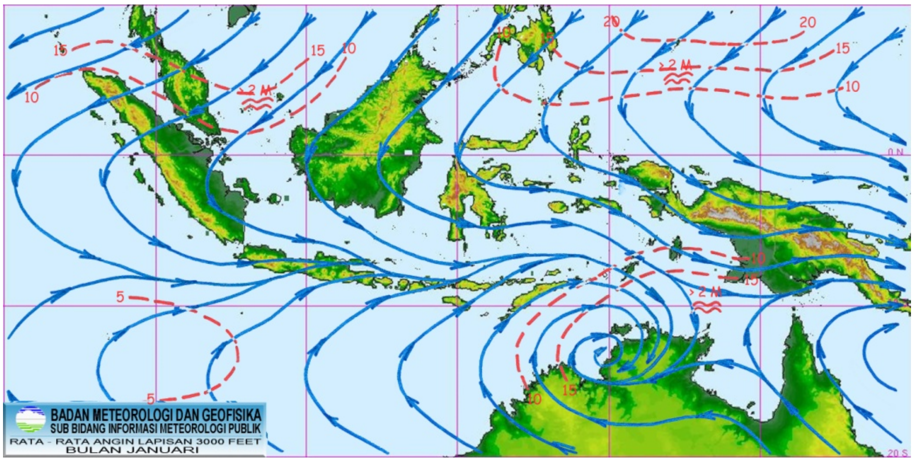

Figure 11 Normal Wind Pattern in Indonesia in January

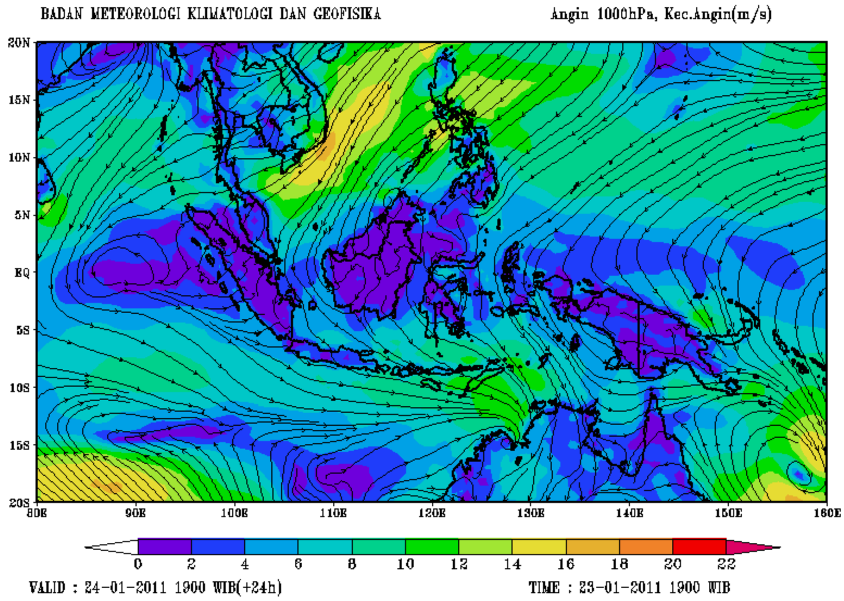

Figure 12 Actual Wind Pattern in January, 2011

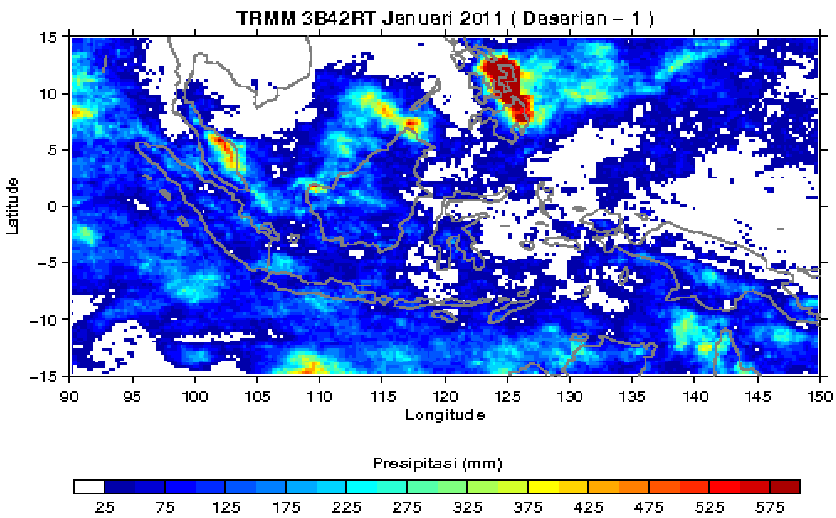

Figure 13 Satellite Map showing Rainfall of the 1 January – 10 January, 2011

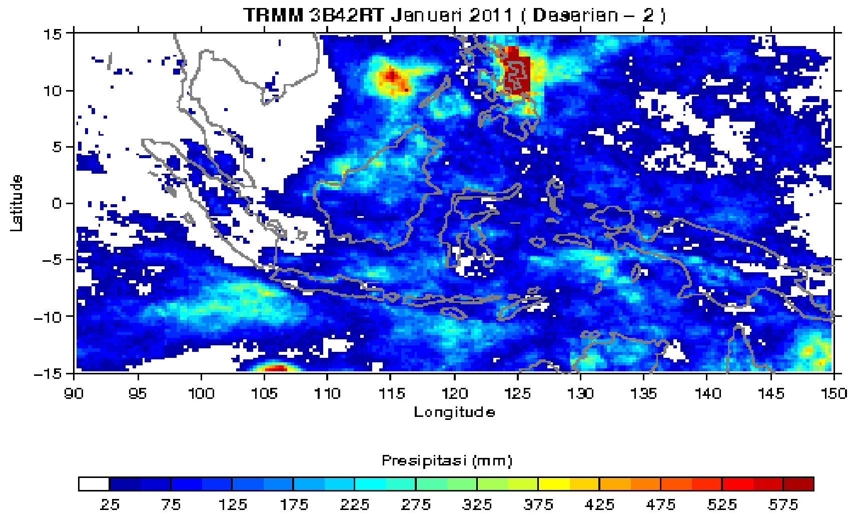

Figure 14 Satellite Map showing Rainfall of the 11 January – 20 January, 2011

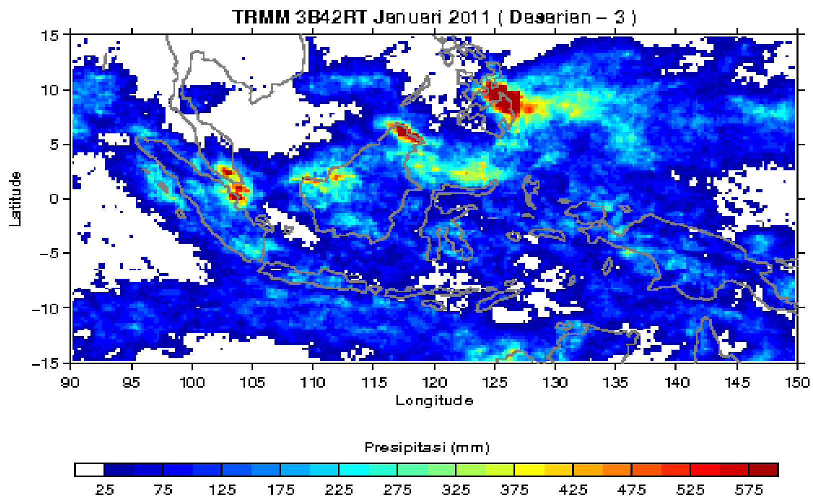

Figure 15 Satellite Map showing Rainfall of the 21 January – 31 January, 2011

The SST anomaly, SOI, DMI and some other conditions are accepted as being caused by the global warming effect. One of the factors considered as cause of global warming is the increase of carbon dioxide (CO_2) gas emission into the atmosphere showing the tendency of temperature increase. Following Bayong (2004), there are several theories on climate change , and one of them is the Carbon Dioxide theory. Carbon dioxide is one of the green house gasses, absorbing earth radiation at 4 – 5 micron wave length and greater than 14 micron particularly at the spectrum between 12 micron and 18 micron. The increase of carbon dioxide concentration shall increase the atmosphere temperature of earth surface and decrease the earth radiation lost in air.

Apparently, in a relatively short time, the Carbon dioxide theory was opposed by Chunaeni (2009) which proved that carbon dioxide analysis results did not significantly influence the change of air temperature, because actually there are still many other factors of great influence if related with the global warming issue. Thus, complexity of this atmospheric dynamic problem is influenced by many factors. Impact directly felt by human beings is the extreme climate change. An example is shown by the Citarum watershed; in 2010 when excessive water had occurred, whereas in 2011, same watershed experienced dryness. The actual reservoir operation pattern deviated from plan due to drastic changes, and similarly changes were encountered in agriculture with the significant change of planting pattern.

CONCLUSIONS AND RECOMMENDATIONS

The Citarum cascade reservoir operation pattern was made based on inflow data recorded from 1986 – 2010. The normal, wet and dry pattern are decided by prediction of inflow using the statistical method, LN Type 3.

From January 2011 – March 2011, actual inflow entering the Saguling reservoir had been far below the average inflow of same months, namely: 60.7 m^3/s, 56.3 m^3/s and 67.8 m^3/s respectively. The small inflow capacity is mainly due to the small average rainfall in the Citarum watershed in January, 2011, i.e. 70 mm, far below the average rainfall in the Citarum watershed for January of 208 mm.

Considering the sea and atmospheric dynamics, during the months January 2011 – March 2011, waters in the surroundings of Java experienced a SST anomaly which caused the decrease of sea surface temperature affecting small evaporation.

From January 2011 to March 2011, circulation of the Asia- Australia monsoon and shifting of ITCZ into southeast direction was observed causing a low pressure pattern north of Australia which consequently also influenced the atmospheric dynamics in the Indonesian waters. Impact of this condition is the high rainfall in Central Java, East Java up through the islands in Nusa Tenggara. On the contrary, the forming of clouds in West Java was very much disrupted by strong winds. In January, 2011, smallest rainfall rate was observed in the Citarum watershed since 1986, i.e. 70 mm, and in February – March 2011, rainfall was still below the average rainfall of 115 mm and 156 mm.

The dryness of January to March, 2011 in the Citarum watershed had caused small inflow into the Saguling, Cirata and Djuanda reservoirs, so that on 9 April, 2011, water level in these reservoirs had been below the dry pattern showing the level of 3.36 m, 4.81 m and Djuanda 7.32 m respectively. The effort to increase the water level of the three reservoirs through WMT was unsuccessful due to weather anomaly.

The deviation from planned into actual operation pattern 2011, requires a revision of operation pattern. The revised operation pattern may facilitate reservoir management in more realistic operation based on an equal sharing pattern.

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