PERSISTENT WATER, TEMPORARY WATER, PARTIAL WATER MAPPING USING MODIS DATA 2008

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ABSTRACT: Water is always one of the most important classes on global land use/land cover mapping. Paddy, Mangrove and Wetland are also important classes of land use/land cover maps that are difficult to extract directly from remote sensing data. These three classes include water or partial water in some periods of a year cycle. It means that the three classes are related significantly to temporary water and partial water. Currently, in the six known existing global land cover maps including IGBP DISCover, Univ. of Maryland, MODIS Land Cover, GLC2000, Globcover, GLCNMO, there are no map that includes temporary water and partial water. One of the newest global water maps is MOD44W - MODIS Water Mask (2009) that also does not include temporary water and partial water. Therefore, objective of this study is to map persistent water, temporary water and partial water in global scale using multi-temporal satellite data. 23 periods of MODIS 2008 data, 500m resolution, processed by Center for Remote Sensing (CEReS), Chiba University were used. MODIS tasseled cap coefficients developed by Lobser and Cohen (2007) were used to calculate Wetness, Brightness and Greenness indexes. The TC-Wetness, TC-Brightness and TC-Greenness images were compared with color composites of MODIS 2008 data (RGB: 621) to set threshold values for making TCW-water map, TCBr-water map and TCGr-water map, respectively. Snow information was also extracted from the three MODIS tasseled cap indexes. The TCW-water, TCBr-water and TCGr-water maps and snow information of 23 periods of MODIS 2008 data were combined together in one combination model to map persistent water, temporary water and partial water. Our preliminary results show that a high quality Persistent Water map can be made and Temporary Map, Partial Water maps may provide some useful information for extracting Paddy, Mangrove and Wetland from other types of land cover.

1. INTRODUCTION

Water is an important class of land use/land cover map, in global mapping projects, water class is always required. Persistent water extracted by this study will be one class of Land Cover, Land Use and Vegetation mapping in Global Mapping project. This project is supported by The Ministry of Construction of Japan (present Ministry of Land, Infrastructure and Transport) for contribution to global environmental conservation from mapping sector, in response to "Agenda21" adopted at the "Earth Summit" in 1992 (ISCGM 2011). In global land cover mapping, Wetland, Mangrove and Paddy are always difficult classes to be extracted directly from remote sensing data. All of the three classes include water or partial water in the whole year or some periods of a year cycle. It means that the three classes are related significantly to temporary water and partial water. Currently, in the six known existing global land cover maps including IGBP DISCover (Loveland et al. 2000), Univ. of Maryland (Hansen et al. 2000), MODIS Land Cover (Boston University 2009), GLC2000 (IES 2010), GLOBCover (ESA 2011) and GLCNMO (Tateishi et al. 2011), there are no map that includes temporary water and partial water. One of the newest global water maps is MODIS Water Mask - MOD44W (Carroll et al. 2009) that also does not include temporary water and partial water. In this study, MODIS 2008 data, 16-day composite, 500 m resolution, processed by CEReS, Chiba University (Hoan et al. 2011) were used. The MODIS 2008 data covers whole the earth nearly two times per month. It is very good data for monitoring phenology of land cover objects. Therefore, objective of this study is to map persistent water for the Global Mapping project, and to map temporary water and partial water for extracting the land cover objects that include a part of water like Wetland, Paddy, Mangrove and so on.

The tasseled cap transformation (TCT) provides a mechanism for data volume reduction with minimal information loss and its spectral features can be directly associated with the important physical parameters of the land surface. Therefore, the TCT of Thematic Mapper (Landsat-TM) imagery has been widely applied for ecological monitoring and environmental change detection (Zhang et al. 2002). TC-Wetness index, one index of TCT, derived from Landsat-TM image, was concluded that it is better than other water indexes for water mapping (Ouma and Tateishi

2006). For MODIS data, currently, two coefficient systems for the tasseled cap transformation have been developed by Zhang et al. (2002) and Lobser and Cohen (2007). This study uses the coefficients developed by Lobser and Cohen (2007) for water mapping because it is newer than the coefficients developed by Zhang et al. (2002). The comparison between them has not yet done.

2. METHODOLOGY

Three main MODIS TCT indexes developed by Lobser and Cohen (2007) are used for water mapping including Wetness, Brightness and Greenness. The formulas to calculate the indexes are as following:

TC-Wetness = 0.1147*b1+0.2489*b2+0.2408*b3+0.3132*b4-0.3122*b5-0.6416*b6-0.5087*b7

TC-Brightness = 0.4395*b1+0.5945*b2+0.2460*b3+0.3918*b4+0.3506*b5+0.2136*b6+0.2678*b7

TC-Greenness = -0.4064*b1+0.5129*b2-0.2744*b3-0.2893*b4+0.4882*b5-0.0036*b6-0.4169*b7

Figure 1 is a flowchart of water mapping methodology.

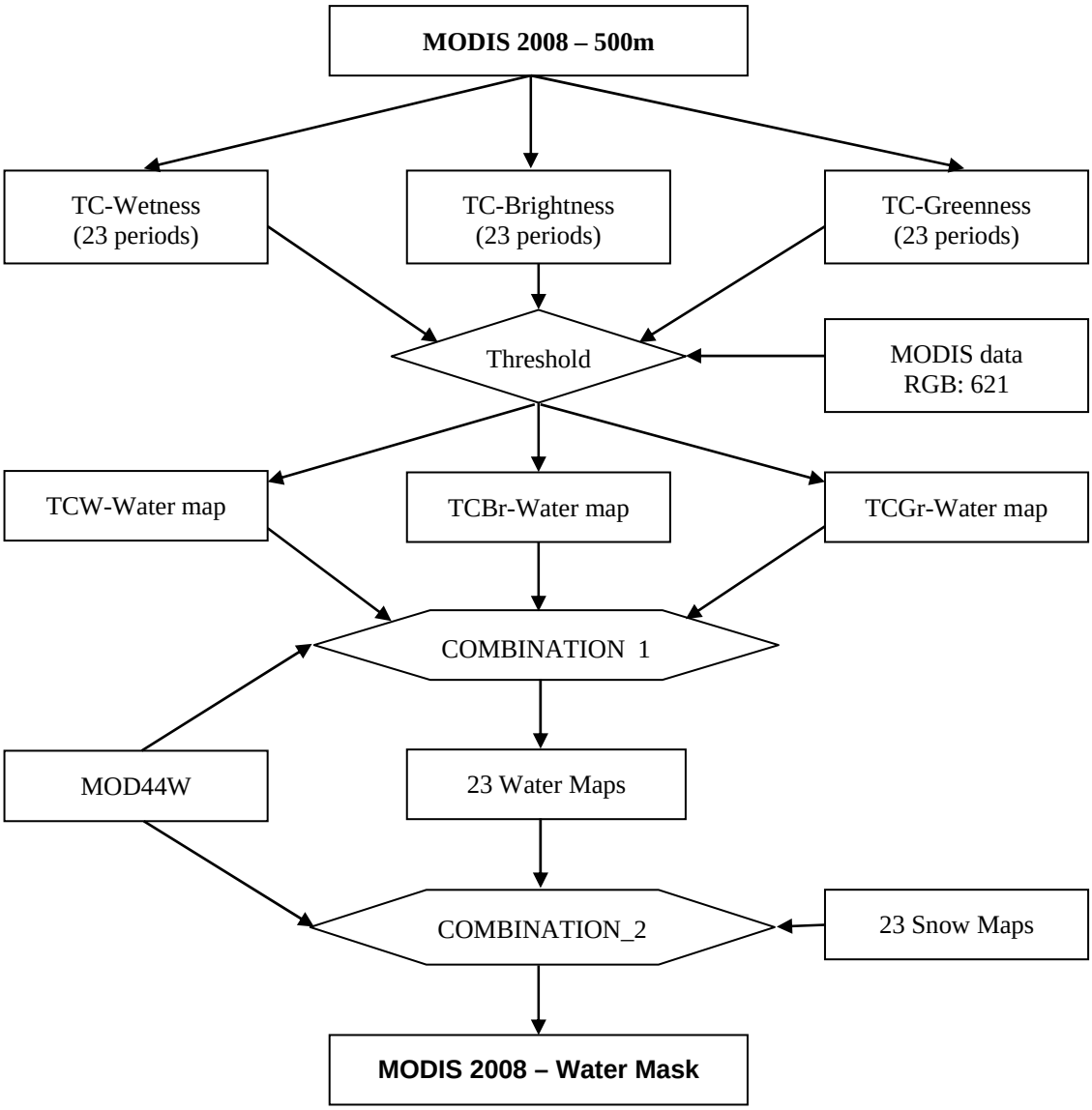


Figure 1. Flowchart of Water Mapping Methodology

Where, TCW is tasseled cap Wetness, TCBr is tasseled cap Brightness, TCGr is tasseled cap Greenness.

The first, TC-Wetness, TC-Brightness and TC-Greenness indexes were calculated from MODIS 2008 data for each of 23 periods. Then, the TC-Wetness, TC-Brightness and TC-Greenness were compared with color composite of MODIS data (RGB: 621) to set threshold values for making TCW-Water map, TCBr-Water map and TCGr-Water map, respectively. The obtained threshold values for Persistent Water mapping are as following:

TC-Wetness	> -200	=>	it is water in TCW-Water map
TC-Brightness	< 3800	=>	it is water in TCBr-Water map
TC-Greenness	< 600	=>	it is water in TCGr-Water map

Following is explanation of the methodology for Persistent Water mapping. Parameters for Temporary Water and Partial Water mapping have not yet finished.

COMBINATION_1 uses only AND condition. It means that "IF(AND(TC-Wetness > -200, TC-Brightness < 3800, TC-Greenness < 600)) = 1 THEN Water_Map = water".

MOD44W was also used to improve the water map. If it is water in MOD44W, some partial water will be set to Water in result map. It means: "IF(AND(MOD44W = Water, TC-Wetness > -500, TC-Brightness < 4500, TC-Greenness < 1000)) = 1 THEN Water_Map = water".

23 Snow Maps were also obtained from the three TCT indexes of MODIS 2008 data. Snow has very high values of TC-Wetness and TC-Brightness indexes. So they are easy to be separated from others. The parameters to extract Snow from others are: "IF(AND(TC-Wetness > -500, TC-Brightness >= 4500, TC-Greenness < 1000)) = 1 THEN Snow_Map = Snow".

Processing in COMBINATION_2 includes:

- If (number of water periods >=16 (>8 months)), that is Persistent Water
- If (number of water periods + number of snow periods) > 22, and number of water periods >= 4 (>2months), that is Persistent Water. Because some regions that are near the northern pole have only 4 for 5 snow-free periods of MODIS 2008 data in a year cycle and some salt lakes look like snow in almost periods of MODIS data
- If (MOD44W = Water and number of water periods >= 10 (>5 months)), that is Persistent Water. This function is to set small lakes and small rivers to Water and to reduce noises from MODIS 2008 data.

3. PRELIMINARY RESULTS AND DISCUSSIONS

Global MODIS 2008 is very large data. The image size of only Eurasian continent is 21597 rows and 45816 columns. Total volume of Eurasian continent is more than 300 GB for 23 periods, 7 bands (Hoan et al. 2011). Processing for the whole continent or global data is time consuming work. To experiment the methodology, MODIS 2008 data of South and South-East part covering from Philippines to Afghanistan of Eurasian continent were subsetted as shown in figure 2.

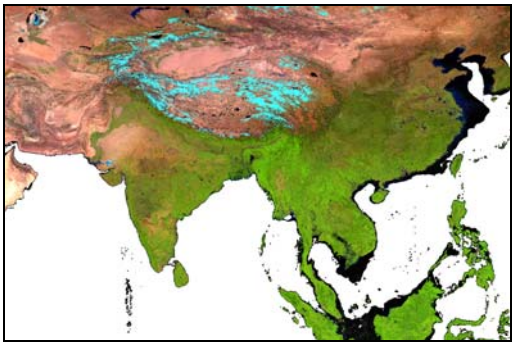


Figure 2. Experiment Area

Up to this time, MODIS 2008 – Water Mask (Persistent Water map) has been done for the experiment area. Final maps of Temporary Water and Partial Water have not yet finished. However, some analyses already have been done as presented in figures 3, 4 and 5 below.

Figure 3 shows that Water1 (Persistent Water) and Water2 (Water with some periods covered by snow) have higher TC-Wetness values than others. TC-Wetness values of Mangrove and Partial Water are similar together. Temporary

Water (around Tonle Sap Lake, Cambodia) includes Partial Water in some periods of a year cycle; other periods are covered by vegetation (figure 4d). Evergreen Broadleaf Forest and Cropland have a lower TC-Wetness value. TC-Wetness value of Paddy is higher than that of Cropland a little and similar with that of Partial Water in one (or two) period (in June) of a year cycle.

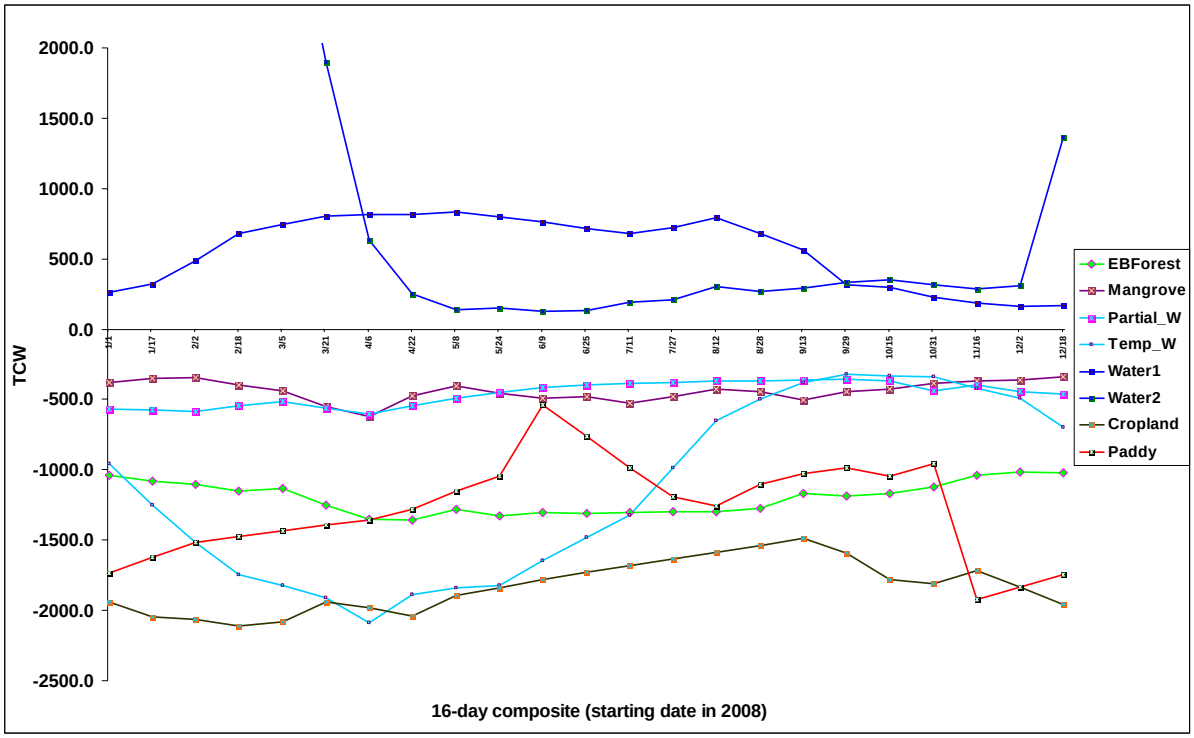


Figure 3. Phenology of Some Main Land Cover Objects by TCW index

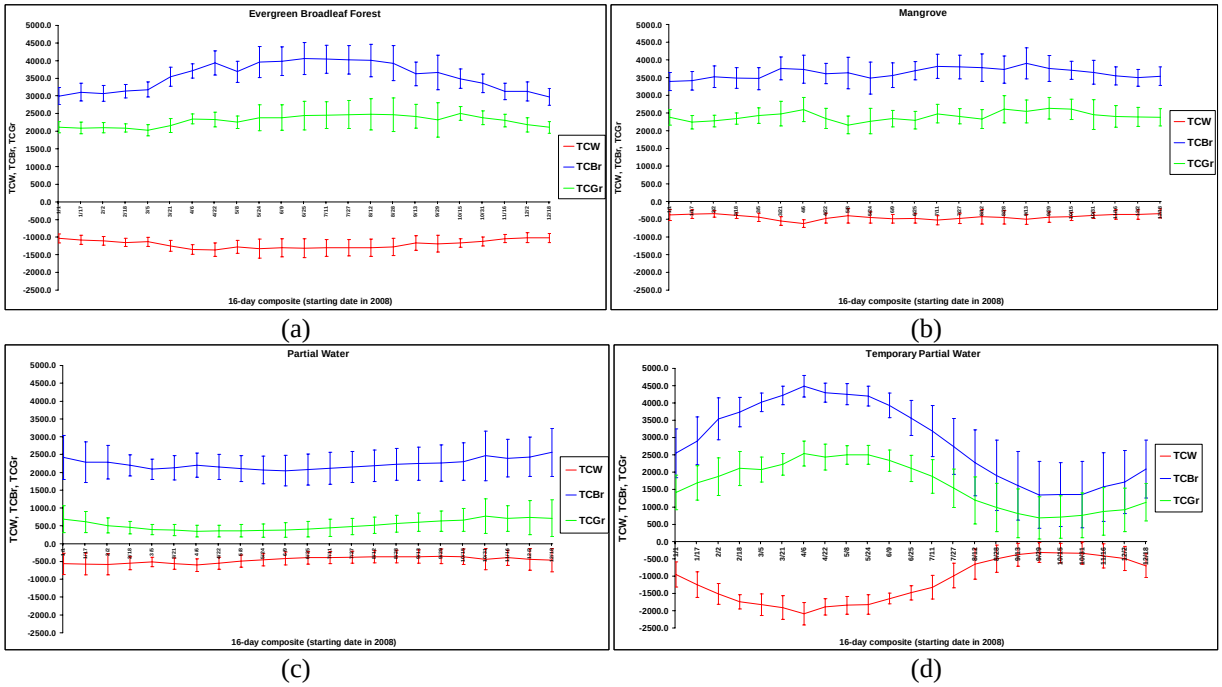
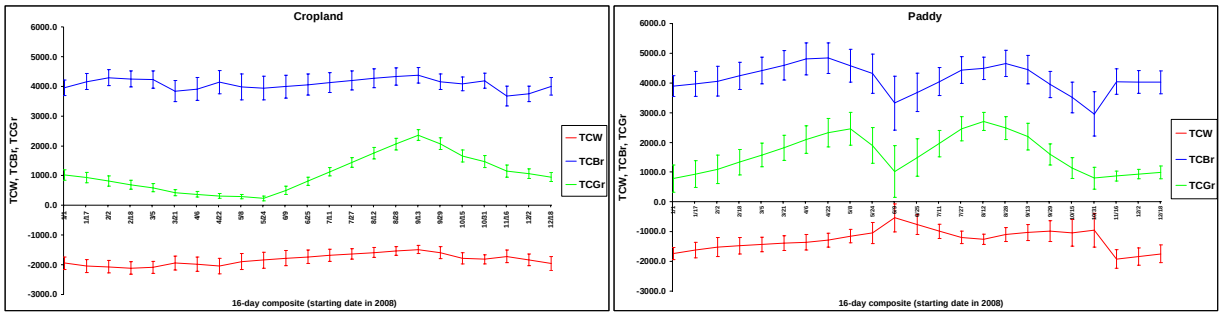


Figure 4. Difference between: (a) Evergreen Broadleaf Forest, (b) Mangrove, (c) Partial Water and (d) Temporary-Partial Water using TCW, TCBr and TCGr Indexes

Figure 4 shows that Evergreen Broadleaf Forest (figure 4a), Mangrove (figure 4b), Partial Water (figure 4c) and Temporary-Partial Water (figure 4d) can be separated together by using analysis of phenology of TC-Wetness, TC-Greenness and TC-Brightness indexes. In this case, TC-Wetness and TC-Greenness are more effective than TC-Brightness. However, TC-Brightness is very important to extract Snow from Water and others.



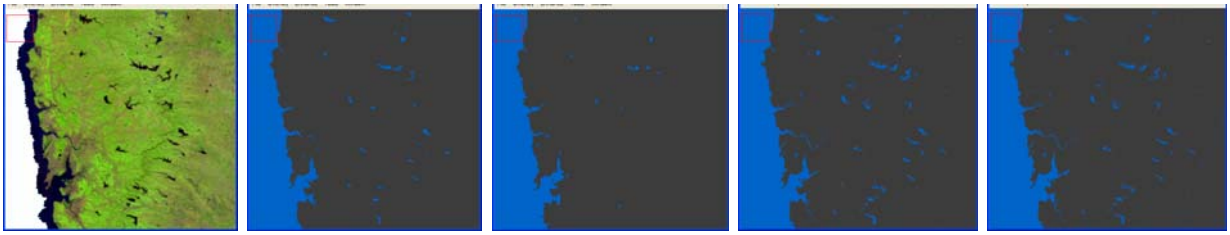
(a) (b)

Figure 5. Difference between: (a) Cropland and (b) Paddy using TCW, TCBr and TCGr Indexes

Cropland and Paddy are always very difficult to separate together. In figure 5, TC-Wetness of Paddy (5b) is higher than that of Cropland (5a) a little. Especially, TC-Wetness of Paddy of one (or two) period is similar with TC-Wetness of partial water and the time of the periods is the same as the time of TC-Greenness reduction. In our plan, two-dimension function of TCW and TCGr will be used to separate between Cropland and Paddy.

The preliminary analysis results as above show that Persistent Water, Temporary Water and Partial Water mapping is possible by combination of TC-Wetness, TC-Greenness and TC-Brightness from MODIS 2008 data. These maps may provide some useful information for extracting Paddy, Mangrove and Wetland from other types of land cover.

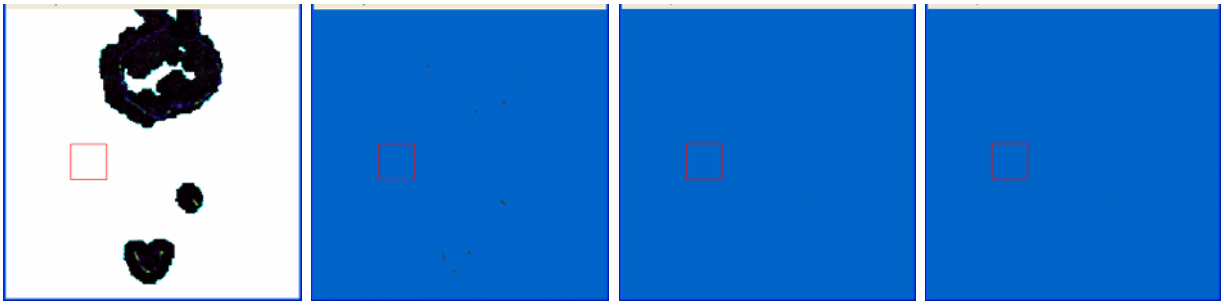
Currently, GLOBCover and MOD44W are two of the newest global maps. GLCNMO 2003 is our older product. So, the first product of this study, Persistent Water, MODIS 2008 – Water Mask, will be compared with water class of GLCNMO 2003, GLOBCover, MOD44W and color composite of MODIS 2008 data to have an imagine. In figures 6, 7 and 8 below, water is blue color and other is grey color.



MODIS (20081015) | MODIS 2008 – Water Mask | GLCNMO 2003 | GLOBCOVER | MOD44W

Figure 6. Comparison of MODIS data (RGB: 621), MODIS 2008 – Water Mask, GLCNMO2003, GLOBCOVER and MOD44W in some small lakes.

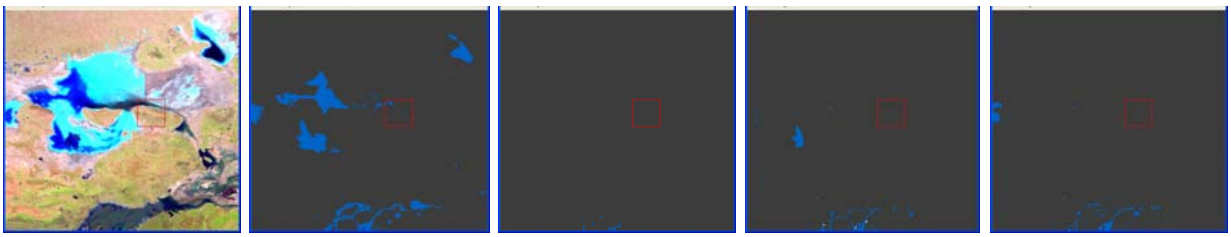
In figure 6, small lakes are appeared in MODIS 2008 – Water Mask but not all. Many small lakes are disappeared in GLCNMO 2003. GLOBCOVER and MOD44W look like better than MODIS 2008 – Water Mask, because they have higher resolution (300m and 250m, respectively)



MODIS (20081015) | MODIS 2008 – Water Mask | GLOBCOVER | MOD44W

Figure 7. Comparison of MODIS data (RGB: 621), MODIS 2008 – Water Mask, GLOBCOVER and MOD44W in some small islands.

Figure 7 shows some small islands of Maldives. They are appeared in color composite of MODIS data and MODIS 2008 - Water Mask. However they are not appeared in GLOBCOVER and MOD44W at all. In this case, MODIS 2008 - Water Mask is better than others.



MODIS (20081015) | MODIS 2008 – Water Mask | GLCNMO 2003 | GLOBCOVER | MOD44W

Figure 8. Comparison of MODIS data (RGB: 621), MODIS 2008 – Water Mask, GLCNMO2003, GLOBCOVER and MOD44W in some salt lakes.

Figure 8 shows an example of salt lakes. Comparing with color composite of MODIS data, water in GLCNMO 2003, GLOBCOVER and MOD44W maps are too small. MODIS 2008 - Water Mask looks better than others.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

Arino, O., Gross, D., Ranera, F., Bourg, L., Leroy, M., Bicheron, P., Latham, J., Gregorio, A. D., Brockman, C., Witt, R., Defourny, P., Vancutsem, C., Herold, M., Sambale, J., Achard, F., Durieux, L., Plummer, S., Weber, J., 2007. GlobCover: ESA service for Global Land Cover from MERIS. Geoscience and Remote Sensing Symposium (IGARSS), 23-28 July 2007, pp. 2412 – 2415.

Boston University, 2009. The homepage of the MODIS Land Cover and Land Cover Dynamics project. MODIS Land Cover Group. Available online at: http://www-modis.bu.edu/landcover/index.html (accessed 29 Aug. 2011)

Carroll, M.L., Townshend, J.R., DiMiceli, C.M., Noojipady, P., and Sohlberg, R.A., 2009. A new global raster water mask at 250 m resolution. International Journal of Digital Earth, Vol. 2, No. 4, December 2009, pp. 291-308.

Carroll, M., DiMiceli, C., Townshend, J., Noojipady, P., Sohlberg, R., 2009.. UMD Global 250 meter Land Water Mask User Guide. Available online at: http://www.landcover.org/library/guide/techguide_watermask.pdf (accessed 29 Aug. 2011)

ESA, 2011. ESA GlobCover Project page. Available online at: http://www.gofc-gold.uni-jena.de/sites/globcover.php (accessed 28 Aug. 2011)

HANSEN. M. C., DEFRIES, R. S., TOWNSHEND, J. R. G. and SOHLBERG, R., 2000. Global land cover classification at 1 km spatial resolution using a classification tree approach. International Journal of Remote Sensing, 2000, Vol. 21, No. 6 & 7, 1331–1364.

Hoan, N. T., Tateishi, R., Al-Bilbisi, H., 2011. Global MODIS 2008 data - User's Manual. Published by CEReS, Chiba University, Feb. 2011.

IES (Institute for Environment and Sustainability), 2010. Global Land Cover 2000. Available online at: http://ies.jrc.ec.europa.eu/our-activities/global-support/Global Land Cover 2000.mht (accessed 18 Aug. 2011)

ISCGM (International Steering Committee for Global Mapping) 2011. Global Mapping Homepage. Available online at: http://www.iscgm.org/cgi-bin/fswiki/wiki.cgi (accessed 29 Aug. 2011)

LOBSER, S.E. and COHEN, W.B., 2007. MODIS tasseled cap: land cover characteristics expressed through transformed MODIS data. International Journal of Remote Sensing, Vol. 28, No. 22, 20 November 2007, pp. 5097-5101.

LOVELAND, T. R., REED, B. C., BROWN, J. F., OHLEN, D. O., ZHU, Z., YANG, L. and MERCHANT, J. W., 2000. Development of a global land cover characteristics database and IGBP DISCover from 1 km AVHRR data. International Journal of Remote Sensing, 2000, vol. 21, no. 6 & 7, 1303–1330.

Ouma, Y. O., Tateishi, R., 2006. A water index for rapid mapping of shoreline changes of five East African Rift Valley lakes: an empirical analysis using Landsat TM and ETM+ data. International Journal of Remote Sensing, Vol. 27, No. 15, 10 August 2006, pp. 3153–3181.

Tateishi, R., Uriyangqai, B., Al-Bilbisi, H., Ghar, M. A., Tsendayush, J., Kobayashi, T., Kasimu, A., Hoan, N. T., Shalaby, A., Alsaaideh, B., Tsevengee, E., Gegentana, Sato, H. P., 2011. Production of global land cover data – GLCNMO. International Journal of Digital Earth, Vol. 4, No. 1, Janurary 2011, pp. 22-49.

Zhang, X., Schaaf, C. B., Friedl, M. A., Strahler, A. H., Gao, F., and Hodges, J. C. F., 2002. MODIS Tasseled Cap Transformation and its Utility. Geoscience and Remote Sensing Symposium (IGARSS), 24-28 June 2002, vol.2, pp. 1063 – 1065.