GEE as tool for Water Resource Management

Case study : Zambezi Delta

Amit Singh

Suva, 30 November 2017

Presentation Outline

- Motivation
- Google Earth Engine and analysis
- Land surface change analysis with Aqua monitor
- Flood analysis with LandSat Water Mask
- Summary

Motivation

To assess the vulnerability of delta and coastal areas to CC and natural disasters

To better understand the impact of upstream economic and human activity

Contribute to achieve SDG's - about 7 goals relate to water, wetland and delta

Planetry scale change analysis platform for hazard identification

Why Google Earth Engine??

- It provides planetary scale analysis
- Powered by Google's cloud infrastructure including computing ability
- Aqua Monitor Tool and LandSat water mask tool (Deltares)
- Open source tool that analyses satellite data and visualises land and water changes around the globe
- shows at a 30-meter resolution where water is converted into land and vice versa.

Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Google Earth Engine: Planetary-scale geospatial analysis for everyone

Noel Gorelick [a,*], Matt Hancher [b], Mike Dixon [b], Simon Ilyushchenko [b], David Thau [b], Rebecca Moore [b]
[a] Google Switzerland, Brandschenkestrasse 110, Zurich 8002, Switzerland
[b] Google Inc., 1600 Amphitheater Parkway, Mountain View, CA, 94043, USA

ARTICLE INFO

Article history:
Received 9 July 2016
Received in revised form 5 June 2017
Accepted 27 June 2017
Available online xxxx

Keywords:
Cloud computing
Big data
Analysis
Platform
Data democratization

ABSTRACT

Google Earth Engine is a cloud-based platform for planetary-scale geospatial analysis that brings Google's massive computational capabilities to bear on a variety of high-impact societal issues including deforestation, drought, disaster, disease, food security, water management, climate monitoring and environmental protection. It is unique in the field as an integrated platform designed to empower not only traditional remote sensing scientists, but also a much wider audience that lacks the technical capacity needed to utilize traditional supercomputers or large-scale commodity cloud computing resources.

MENU
nature climate change

Commentary

Earth's surface water change over the past 30 years

Gennadii Donchyts, Fedor Baart, Hessel Winsemius, Noel Gorelick, Jaap Kwadijk & Nick van de Giesen

Earth's surface gained 115,000 km^2 of water and 173,000 km^2 of land over the past 30 years, including 20,135 km^2 of water and 33,700 km^2 of land in coastal areas. Here, we analyse the gains and losses through the Deltares Aqua Monitor – an open tool that detects land and water changes around the globe.

The Earth Engine Data Catalog

Landsat & Sentinel
10-30m, 14-day

MODIS
250m daily

Terra Bella
<1m daily–weekly

Terrain & Land Cover

Weather & Climate
NOAA NCEP, OMI, ...

... and many more, updating daily!

> 200 public datasets

> 4000 new images every day

> 5 million images

> 5 petabytes of data

What can Earth Engine do?

- Get an image

Pick your: projection, resolution, bands, bounding-box, visualization

What can Earth Engine do?

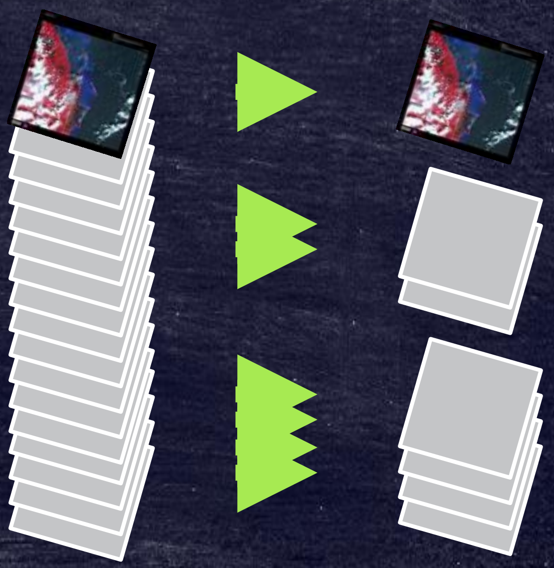
- Get an image
- Apply an algorithm to an image

Use library functions or script your own

What can Earth Engine do?

- Get an image
- Apply an algorithm to an image
- Filter a collection

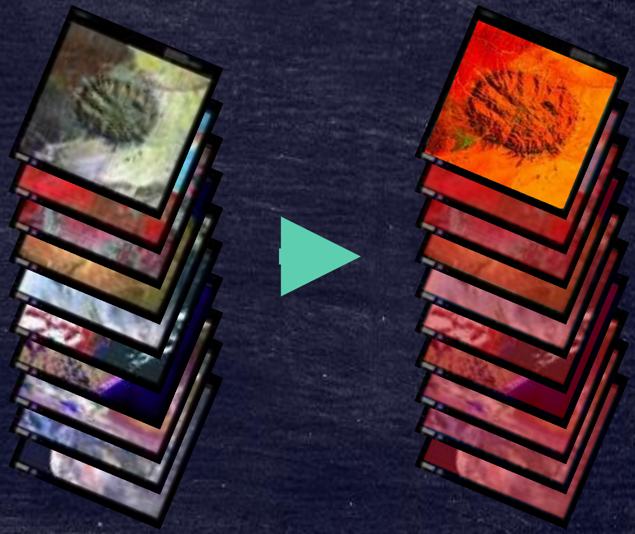
Time, Space & Metadata Search



What can Earth Engine do?

- Get an image
- Apply an algorithm to an image
- Filter a collection
- Map an algorithm over a collection

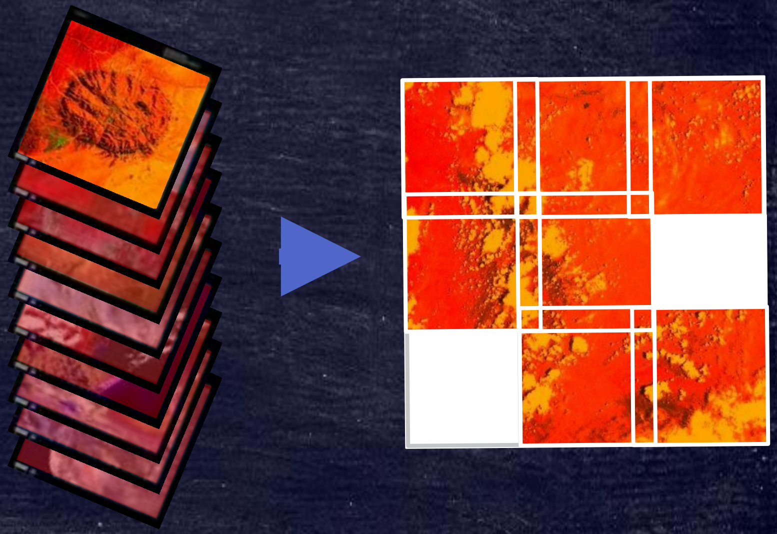
$N \rightarrow N$



What can Earth Engine do?

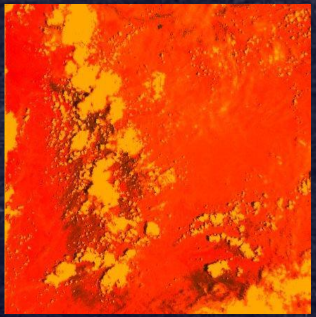
- Get an image
- Apply an algorithm to an image
- Filter a collection
- Map an algorithm over a collection
- Reduce a collection

$N \rightarrow 1$ or $N \rightarrow M$

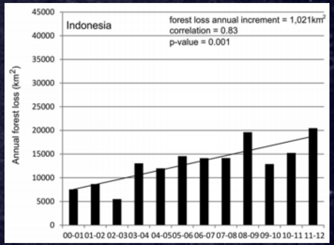


What can Earth Engine do?

- Get an image
- Apply an algorithm to an image
- Filter a collection
- Map an algorithm over a collection
- Reduce a collection
- Compute aggregate statistics



Gabon	1891	391	11898
Lithuania	1845	1226	40296
Cuba	1725	2271	68008
Mali	1694	0	1247103
Costa Rica	1653	382	11327
Czech Republic	1646	1331	46934
South Sudan	1635	38	460581
North Korea	1605	137	67695
Italy	1603	898	201331



Study Area

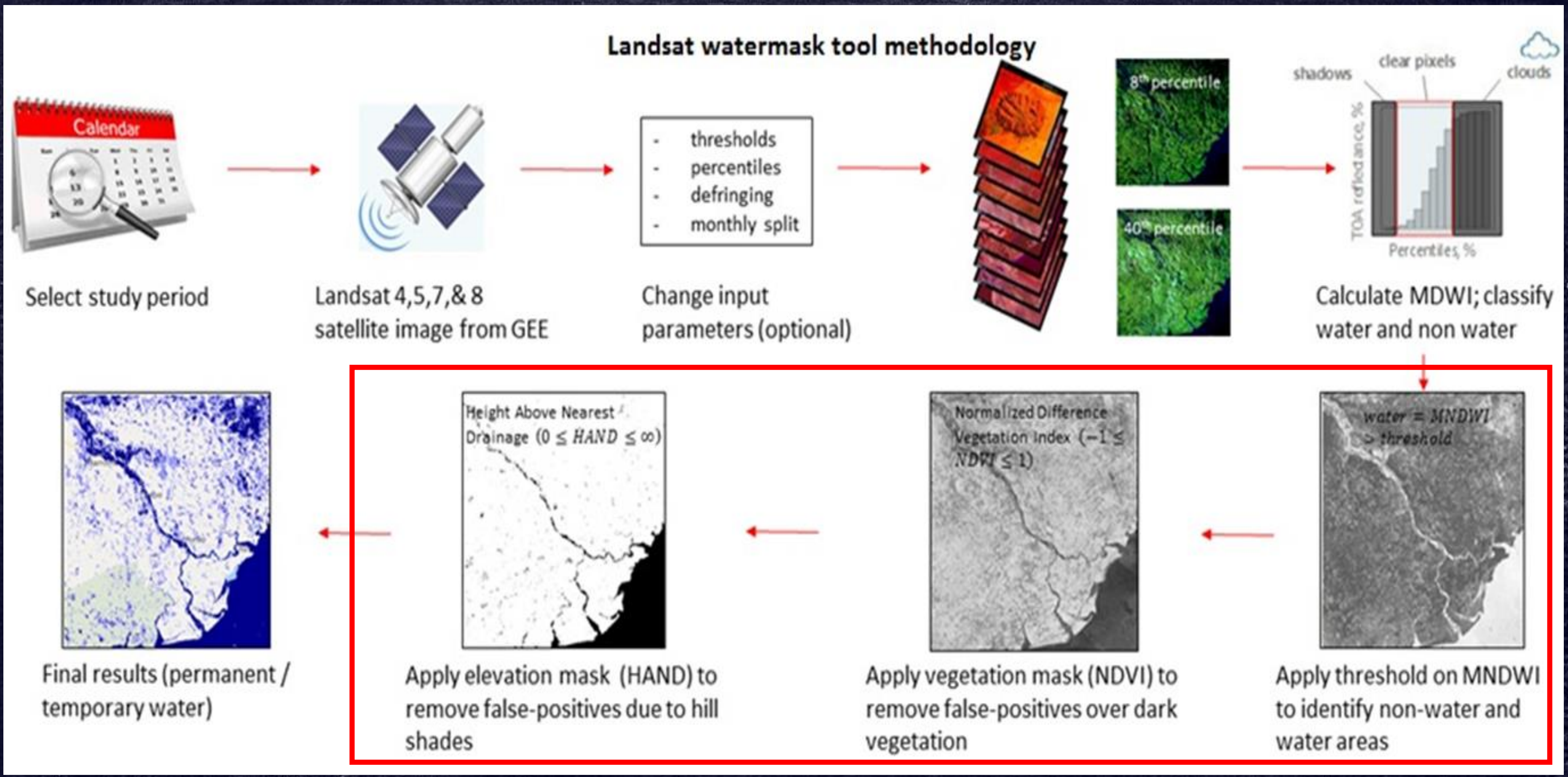
Zambezi river

- 4th largest river in the Africa
- Total basin area of 1,390,000 km^2 with av. discharge of 3400 m^3/s.
- Greatly regulated since 1960's
- Distinct dry (May-Oct) and wet (Nov – April) season.

Study area

- Lower Zambezi
- Marromeu of great ecological importance – RAMSAR site

GEE and Remote Sensing Analysis



- ✓ **Sensistivity analysis indicate max error of 11 % , associated with selection of water index threshold**

GEE and Earth Engine Code editor

```
var hand = ee.ImageCollection("users/gena/global-hand/hand-100"),
    countries = ee.FeatureCollection("ft:14Mx8qyeBtToqC0ozzjqG6xwiWaZd5lX0HoWaqlFH"),
    glcf = ee.ImageCollection("GLCF/GLS_WATER"),
    geometry = /* color: d63000 */ee.Geometry.MultiPoint();

function renderLandsatMosaic(options, dateIntervalIndex) {
  var percentile = options.percentile;
  var start = options.dateIntervals[dateIntervalIndex][0];
  var stop = options.dateIntervals[dateIntervalIndex][1];
  var sharpen = options.sharpen;
  var smoothen = options.smoothen;
  var filterCount = options.filterCount;

  var bands = ['swir1', 'nir', 'green'];
  var l8 = new ee.ImageCollection('LANDSAT/LC8_L1T_TOA').filterDate(start, stop).filterBounds(countries).select(['B6', 'B5', 'B3'], bar
  var l7 = new ee.ImageCollection('LANDSAT/LE7_L1T_TOA').filterDate(start, stop).filterBounds(countries).select(['B5', 'B4', 'B2'], bar
  var l5 = new ee.ImageCollection('LANDSAT/LT5_L1T_TOA').filterDate(start, stop).filterBounds(countries).select(['B5', 'B4', 'B2'], bar
  var l4 = new ee.ImageCollection('LANDSAT/LT4_L1T_TOA').filterDate(start, stop).filterBounds(countries).select(['B5', 'B4', 'B2'], bar

  var images = ee.ImageCollection(l8.merge(l7).merge(l5).merge(l4))

  //images = ee.ImageCollection(images.limit(100))
```

Image collation from different LandSat missions

```
// ======================================================== PARAMETERS AND SCRIPT

// start / stop times and averaging periods (in months)
var time0 = [ee.Date.fromYMD(2000, 4, 1), 8]; // [ee.Date.fromYMD(2000, 1, 1), 24];
var time1 = [ee.Date.fromYMD(2001, 1, 1), 7]; //[ee.Date.fromYMD(2015, 1, 1), 24];

// larger periods, more robust, slower, may contain less changes (used to compute results reported in the paper)
// var time0 = [ee.Date.fromYMD(1984, 1, 1), 240];
// var time1 = [ee.Date.fromYMD(2013, 1, 1), 48];

var options = {
  // intervals used for averaging and linear regression (the web site may use multiple intervals here)
  dateIntervals: [
    [time0[0], time0[0].advance(time0[1], 'month')],
    //[time0[0].advance(12, 'month'), time0[0].advance(time0[1]+12, 'month')],
    //[time1[0].advance(-12, 'month'), time1[0].advance(time1[1]-12, 'month')],
    [time1[0], ee.Date.fromYMD(2016, 5, 6)] // time1[0].advance(time1[1], 'month')
  ],

  percentile: 15,

  slopeThreshold: 0.025,
  slopeThresholdRatio: getWaterTrendChangeRatio(1984, 2015),

  slopeThresholdRefined: 0.015,

  //refine: true, // more expensive
  refine: false,
  refineFactor: 5,

  ndviFilter: 0.08, // the highest NDVI value for water
  //ndviFilter: -1,

  ndwiMinWater: -0.05, // minimum value of NDWI to assume as water
  ndwiMaxLand: 0.5, // maximum value of NDWI to assume as land

  filterCount: 10,
```

- Apply Normalized Difference Vegetation Index (NDVI)
- The Normalized Difference Water Index (NDWI)

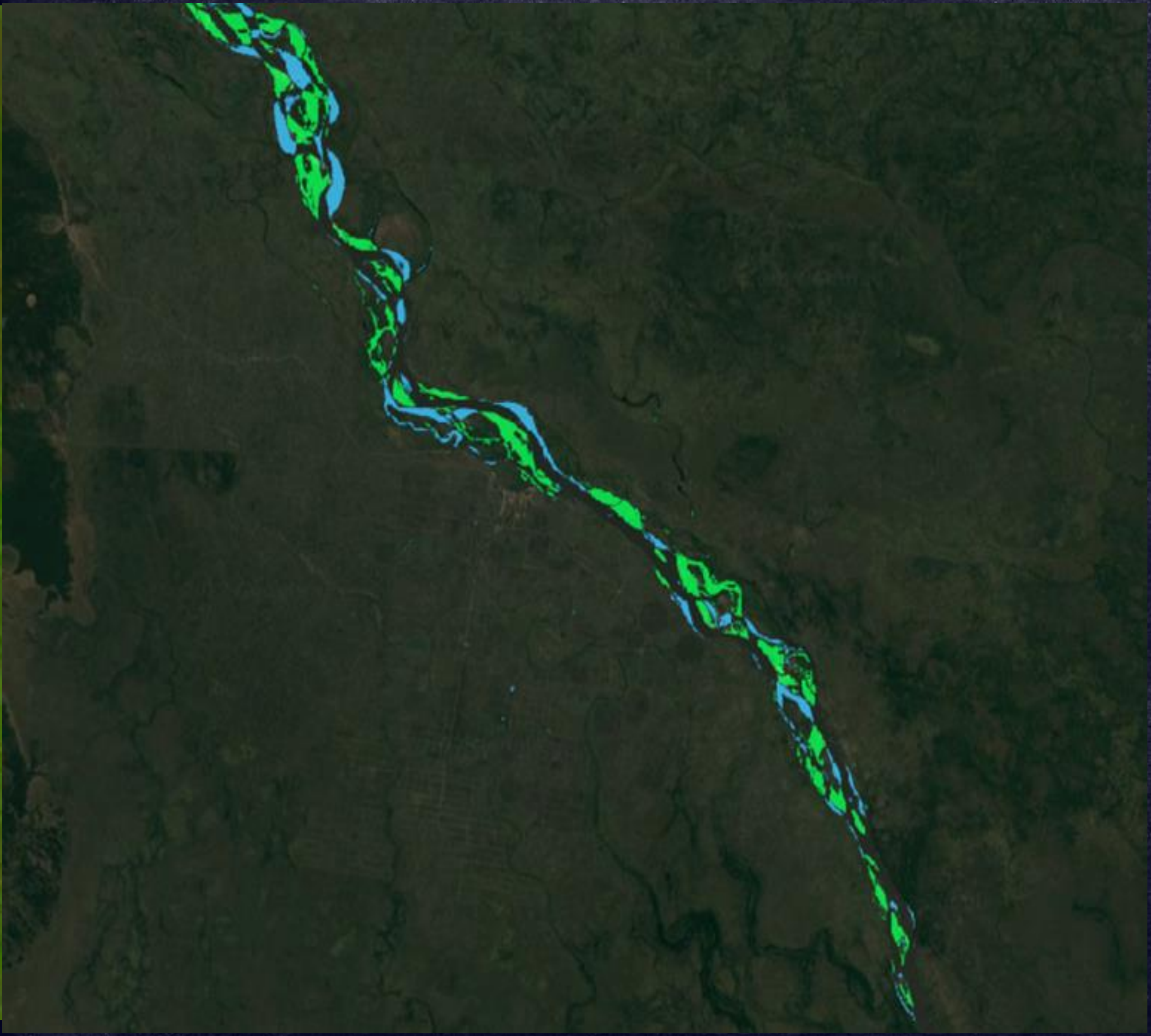
```
  // surface water change
  if(refine) {
    if(options.debug) {
      var maskBufferVis = maskBuffer.mask(maskBuffer).visualize({palette:['ffffff', '000000'], opacity:0.5})
      results.push(maskBufferVis);
    }

    var edgeWater = getEdge(mask.mask(scale.gt(0))).visualize({palette: '00d8ff'})
    var edgeLand = getEdge(mask.mask(scale.lt(0))).visualize({palette: '00ff00'})

    scale = scale.mask(maskRefined)

    var scaleRefined = scale.visualize({
      min: -slopeThreshold * slopeThresholdRatio,
      max: slopeThreshold * slopeThresholdRatio,
      palette: ['00ff00', '000000', '00d8ff'],
      opacity: showEdges ? 0.3 : 1.0
    })

    results.push(scaleRefined)

    if(showEdges) {
      results.push(edgeWater, edgeLand)
    }

  } else {
    scale = scale.mask(mask)

    var change = scale.visualize({
      min: -slopeThreshold * slopeThresholdRatio,
      max: slopeThreshold * slopeThresholdRatio,
      palette: ['00ff00', '000000', '00d8ff'],
    })

    results.push(change);
  }

  return {changeVis: ee.ImageCollection.fromImages(results).mosaic(), change: scale.toFloat()};
}

function computeAggregatedSurfaceWaterChangeArea(scale, options) {
  // add aggregated version of change
  var changeAggregatedWater = scale.gt(0).multiply(ee.Image.pixelArea())
```

Surface water change algorithm

```
Export.image.toDrive({
  image: trend1.changeVis,
  // description: ,
  folder: 'Earth Engine folder',
  fileNamePrefix: '1987_2015_waterchange',
  // dimensions: ,
  region: countries,
  scale: 100,
  // crs: ,
  // crsTransform:,
  // maxPixels:,
  // shardSize:,
  // fileDimensions:
});

/*
options.refine = false;
options.debugMapLayers = false;
var trend1 = renderWaterTrend(options)[0];
Map.addLayer(trend1.changeVis, {}, '1987 - 2015 (water change, no refine)', true)
*/
```

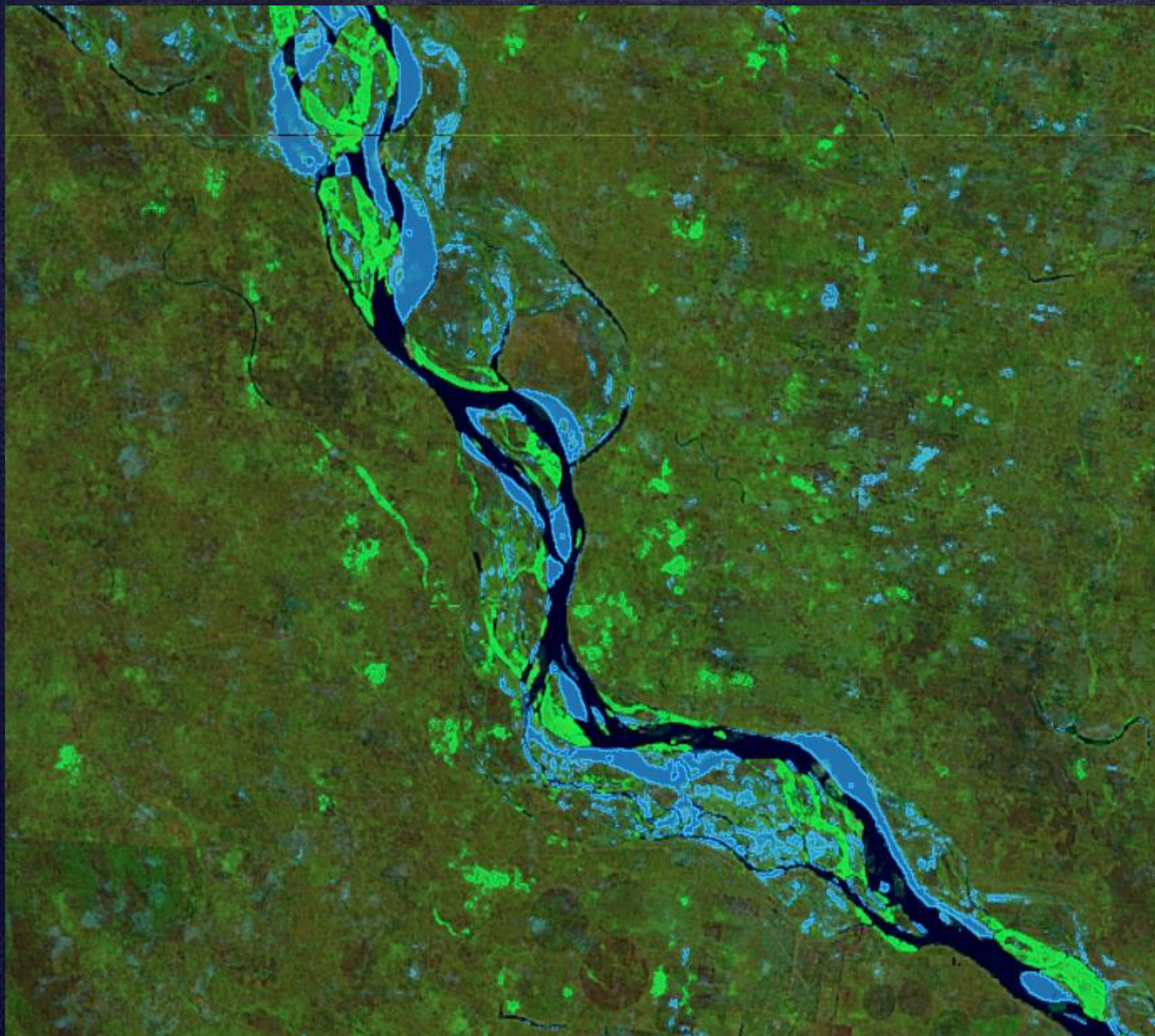
- Apply HAND
- Export image to drive

Changes in river morphology and surface 1995-2016



- Green and blue colors represent areas where surface water changes occurred during the last 20 years.
- Green pixels show where surface water has been turned into land (accretion, land reclamation, droughts).
- Blue pixels show where land has been changed into surface water (erosion, reservoir construction).

River morphology and River Dynamics



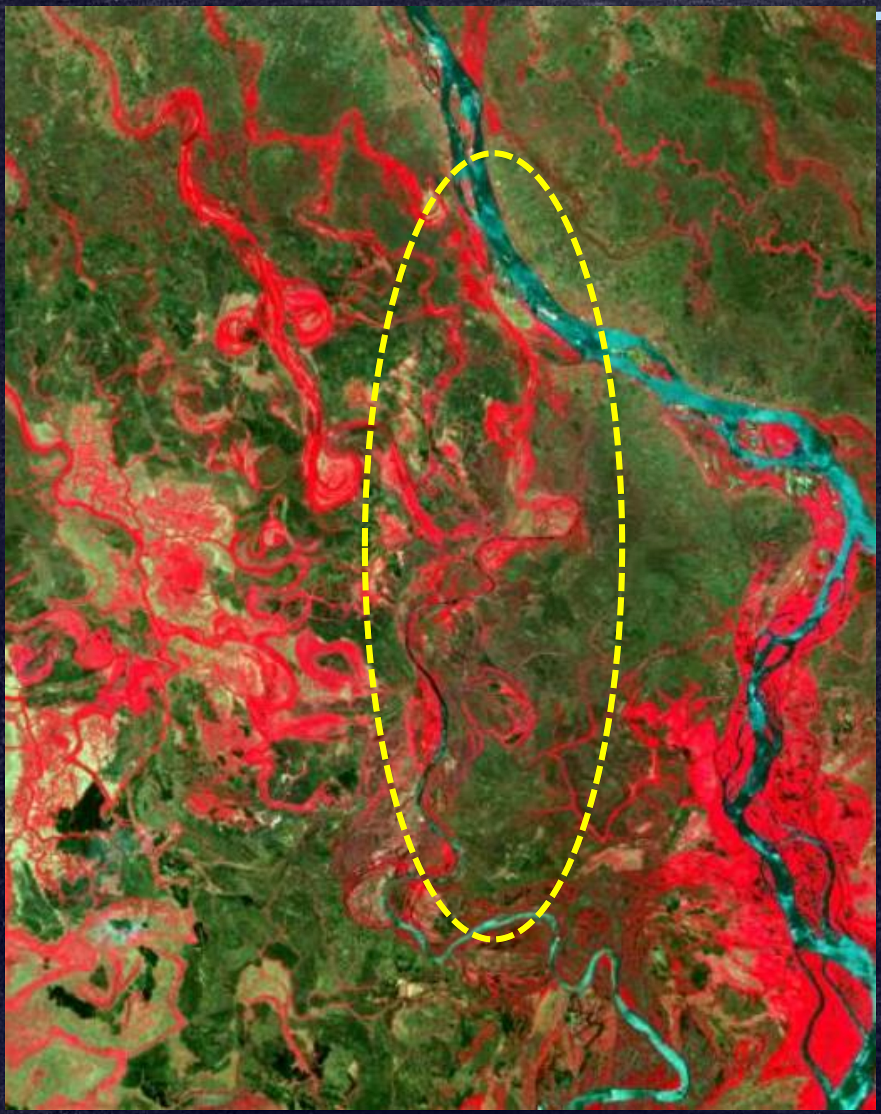
Changes analysis using images

- Fluvial process post river regulation
- Meandering

Sinuosity index

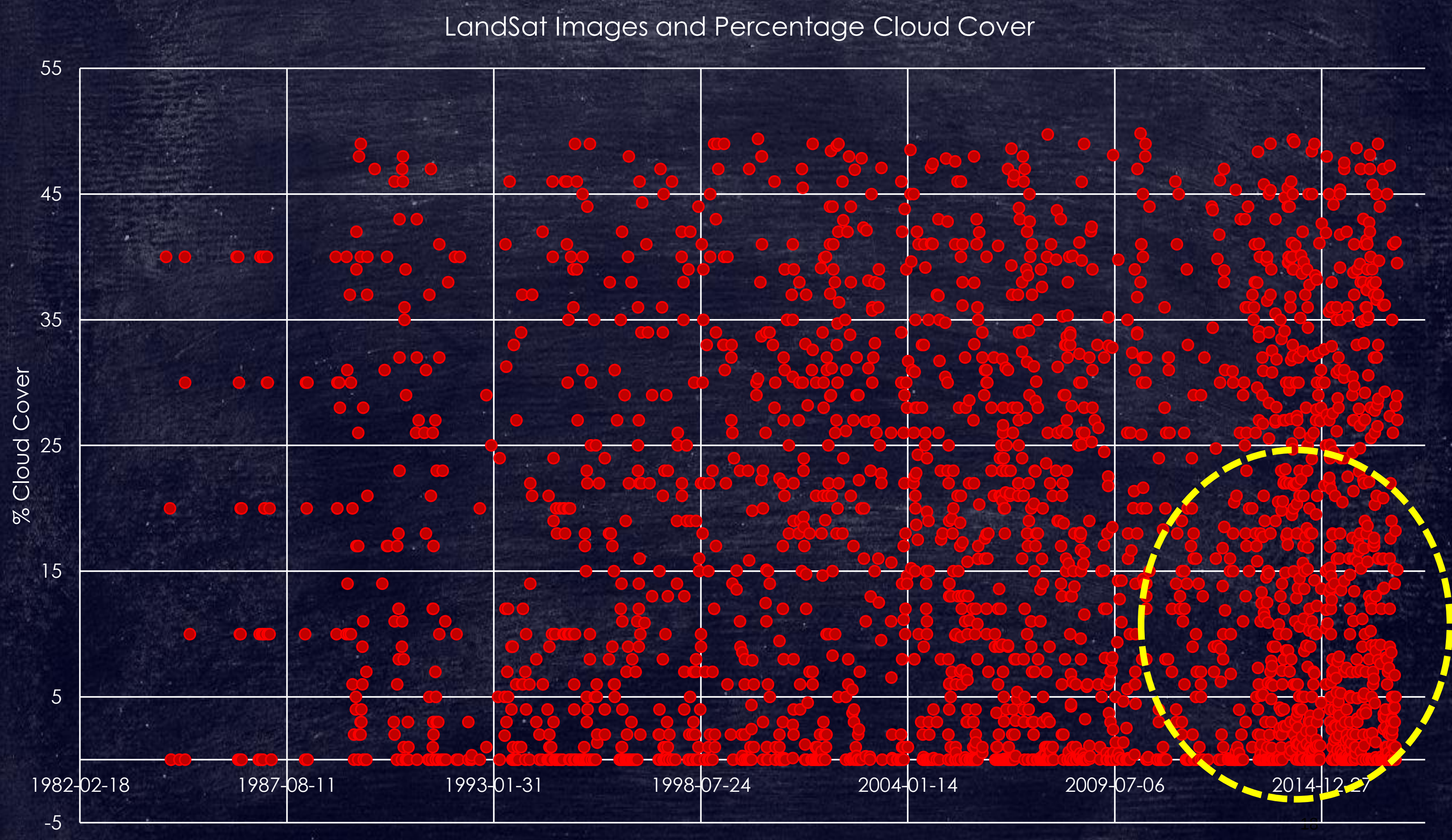
- Determining the sinuosity of the river

Changes in River Morphology – Disconnection of Secondary Channels

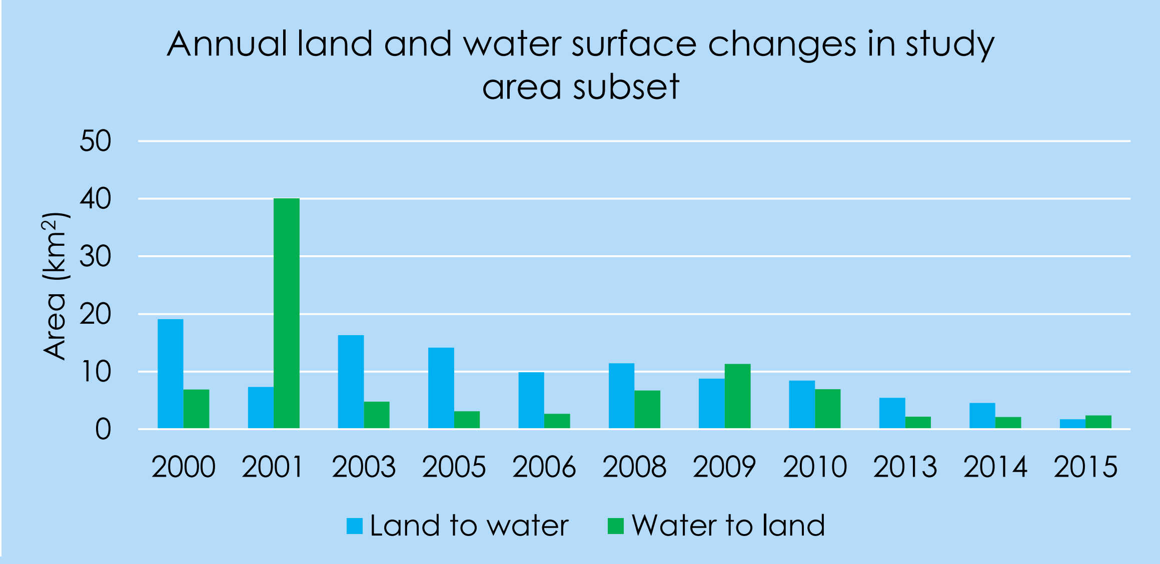


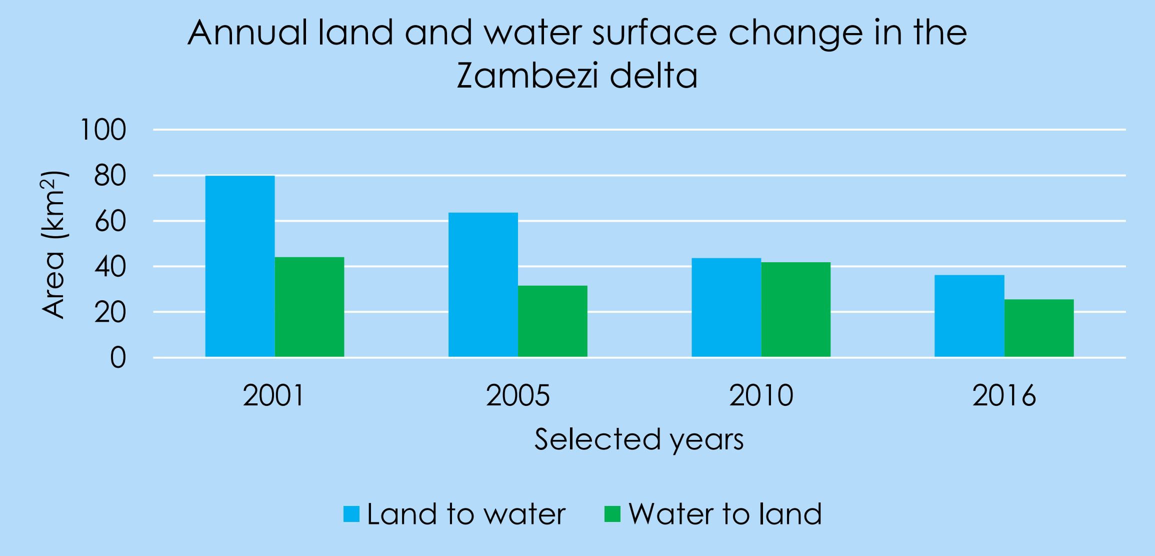
- Illustrates disconnection of Marromeu from Zambezi river
- Disconnection occured around 2003.
- Disconnected channels covered with vegetation
- Disconnection associated with reduction peak flows post regulation
- Shows distinct wet and dry season

LandSat Meta Data Analysis



Land and water surface change





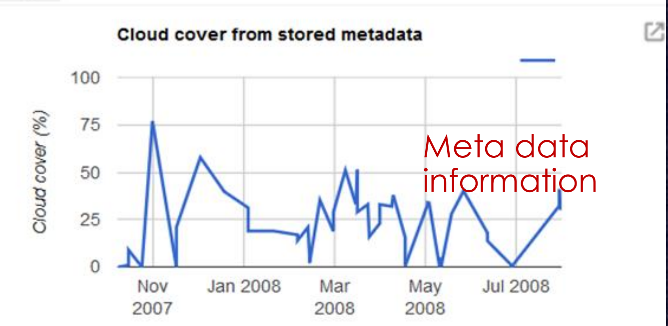
Annual changes study area subset

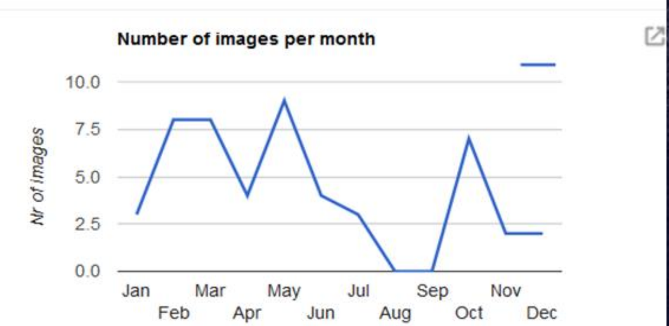
- surface changes from land to water tend to dominate except floods
- 2001 is highest with an approximately area 40 km^2
- Occurs mainly along channel banks and islands

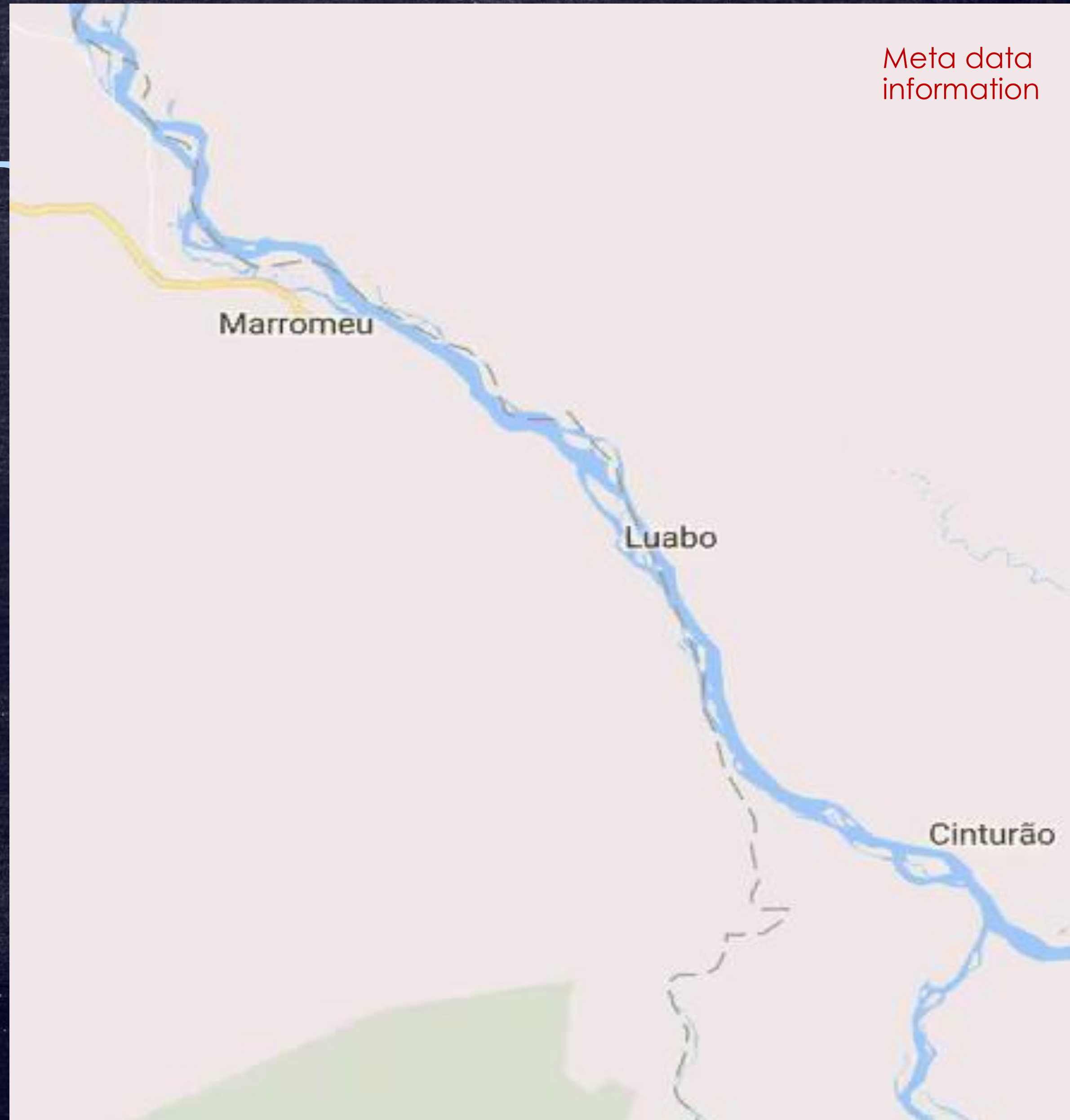
Flood Analysis using LandSat Data

```
// default values for input parameters
var default_startdate    = '2007-10-01';
var default_enddate      = '2008-07-30';
var default_timeslice    = 1;
var default_do_months    = false;
var default_pcnt_perm    = 40;
var default_pcnt_temp    = 8;
var default_water_thresh = 0.3;
var default_ndvi_thresh  = 0.4; //0.3
var default_hand_thresh  = 40;
var default_cloud_thresh = -1;
var default_defringe     = false;
var default_do_otsu      = false;

// default values for other controls
var default_quickscan_info = false;
var default_console_info   = false;
var default_area_calc      = false;
var default_cloudbust_test = false;
var default_prev_update    = false;
var default_otsu_inspector = false;

// default value for export resolution
var default_export_res = 30;

// minimum and maximum allowed values for dynamic MNDWI thresho
var min_mndwi_threshold = 0.0; //0.1;
var max_mndwi_threshold = 0.3; //0.4;
```

Script of change input parameters







Summary

- Big data at anyone's fingertips
- strong implications on monitoring and resource management capacities.
- Application for monitoring coastal erosion.
- Monitoring trans boundary impoundments
- Monitoring hazards and preparation

VINAKA VAKALEVU !!!