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Estimation of Water Volume Variations for large-scale Lake Based on Multi-source Satellite Data

Tongji University
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2018.07

Contents

BACKGROUND

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Issues

- Shortage of water resources
- Water pollution
- Drought and flood disasters
- ……

How to **accurately** and **rapidly** monitor the change of water resources has become an important research field.

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Water resources	Water surface area	Water surface height	Water volume
Traditional method	• Field measurement	• Field measurement	• Combine field-measured data with accurate terrain data
Disadvantages	1. Low accuracy 2. Low automation	1. Time-consuming 2. Labor-intensive 3. High-cost	1. Difficult to acquire terrain data 2. Impractical 3. Hard to do a long time series analysis
Improvements	• Multi-spectral imagery • Machine learning	• Multi-mission altimetry data	• Multi-source remote sensing data • Long-term analysis • Driving force analysis

Water body extraction → Water level change calculation → Water volume variation estimation

BACKGROUND

Study area

Lake Victoria

- 0°20′N/3°0′S ~ 31°40′E/35°53′E
- Largest freshwater lake in Africa and second largest in the world
- Approximately 68600km^2
- Shared with Tanzania, Uganda and Kenya

Data

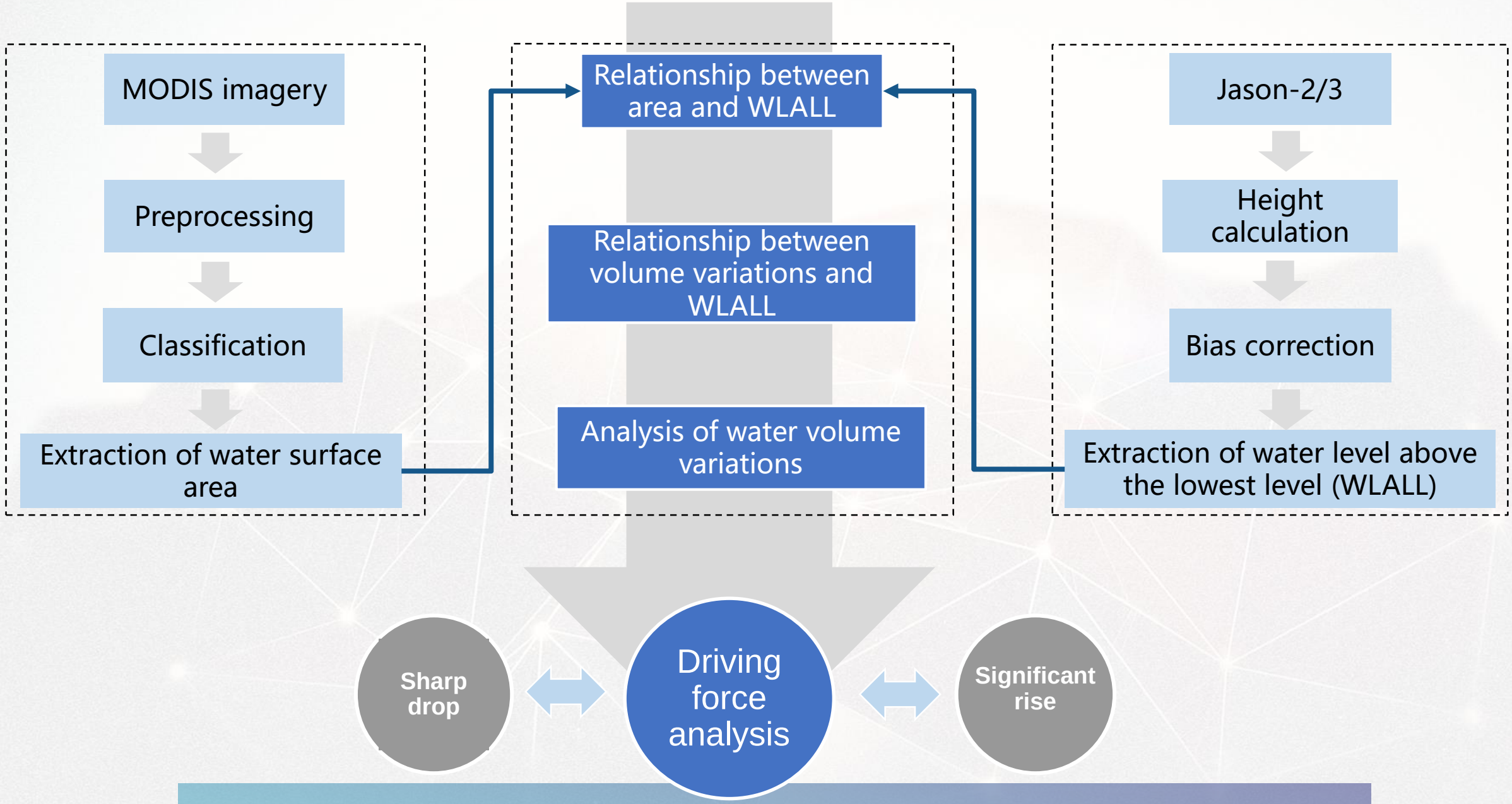
Multi-spectral imagery

- MODIS/ 500m, 2012-2017

Multi-mission altimetry data

- Jason-2, 2012-2016
- Jason-3, 2016-2017

BACKGROUND


MODIS imagery
Preprocessing
Classification
Extraction of water surface area
Relationship between area and WLALL
Relationship between volume variations and WLALL
Analysis of water volume variations
Jason-2/3
Height calculation
Bias correction
Extraction of water level above the lowest level (WLALL)
Sharp drop
Driving force analysis
Significant rise

Contents

AREA EXTRACTION OF LAKE SURFACE

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Machine learning

Support vector machine (SVM)

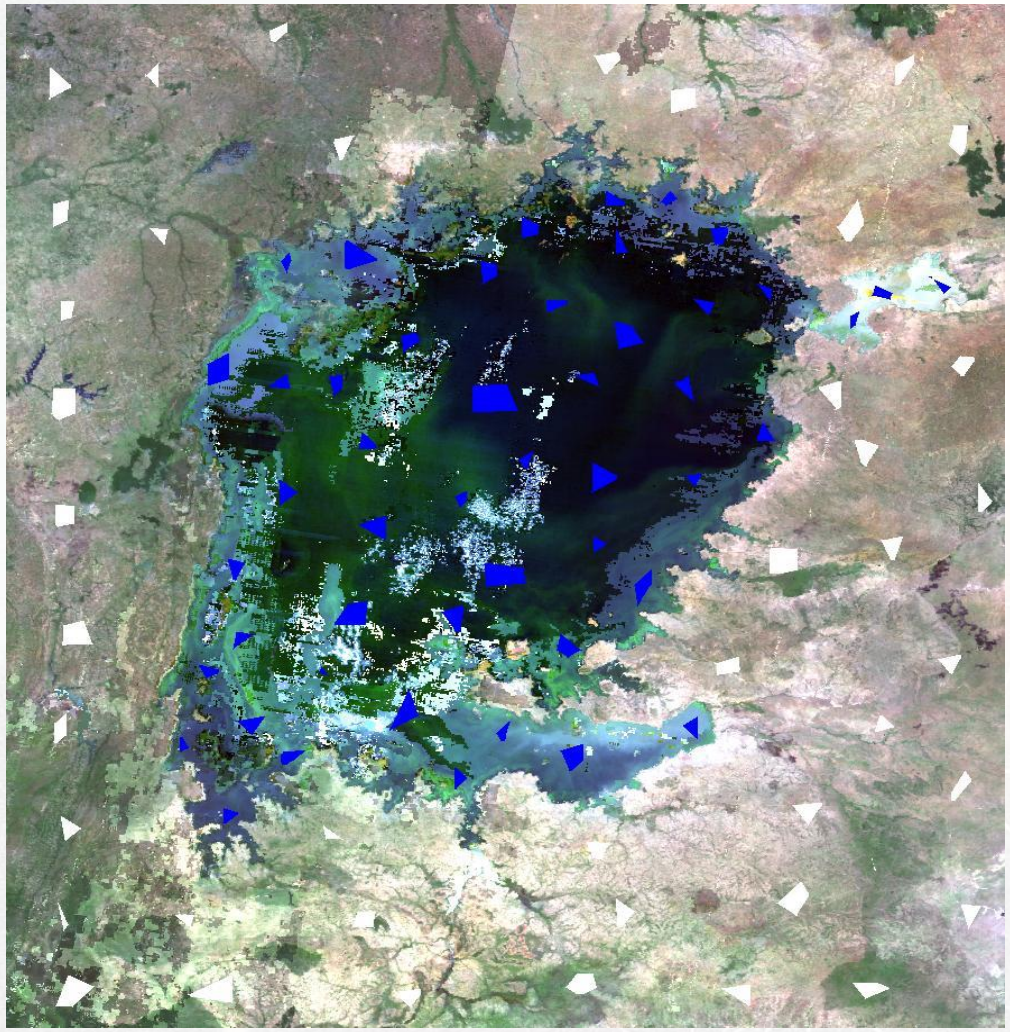
Kernel trick

Radial basis function (RBF)

Classifier

- Minimum Distance
- Maximum likelihood
- Neural Network

AREA EXTRACTION OF LAKE SURFACE



February 2, 2012

Method	Overall Acc. /%	Kappa Coefficient
Minimum Distance	98.89	0.9777
Maximum likelihood	99.73	0.9945
Neural Network	99.70	0.9941
SVM	99.83	0.9966

AREA EXTRACTION OF LAKE SURFACE

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	2012	2013	2014	2015	2016	2017	Total
Jan		2	1				3
Feb	1	1	1	1	1		5
Mar	2			2	1		5
Apr	1						1
May	2	2	1	1		1	7
Jun		1				1	2
Jul				2	1		3
Aug		1		2	1		4
Sep				1			1
Oct		1	1				2
Nov	1						1
Dec		1	1		1		3
Total	7	9	5	9	5	2	37

AREA EXTRACTION OF LAKE SURFACE

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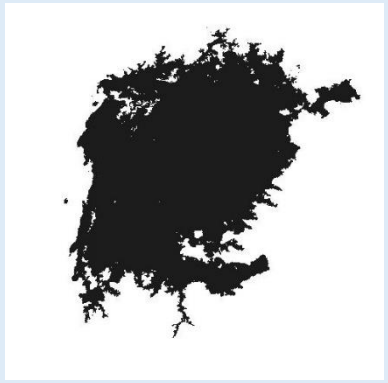
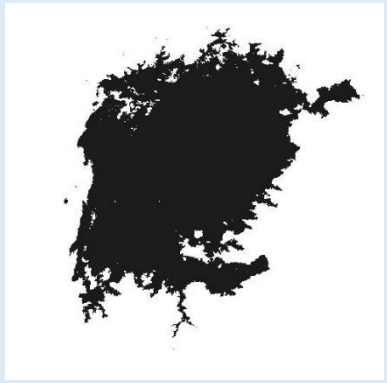
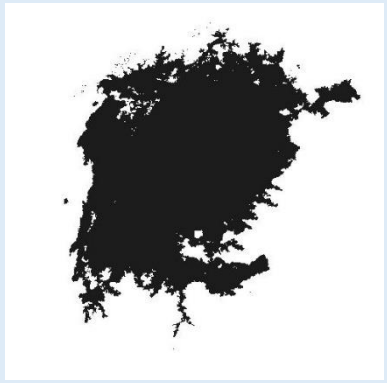
Maximum



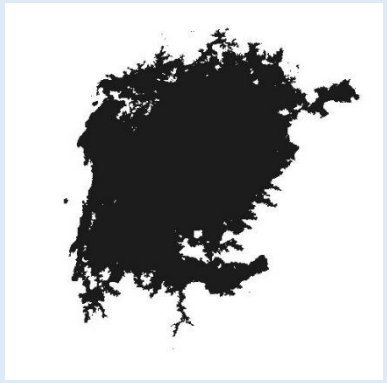
2012



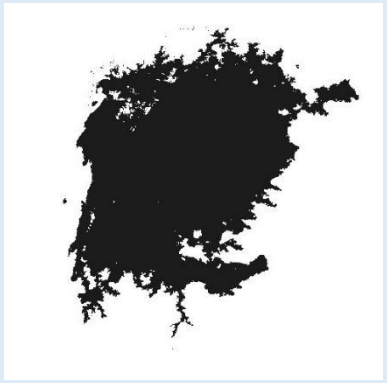
2013



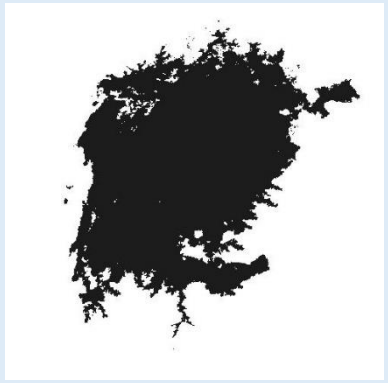
2014



2015

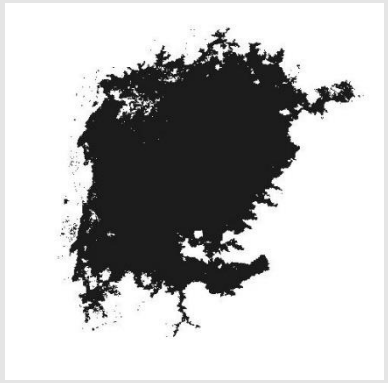


2016

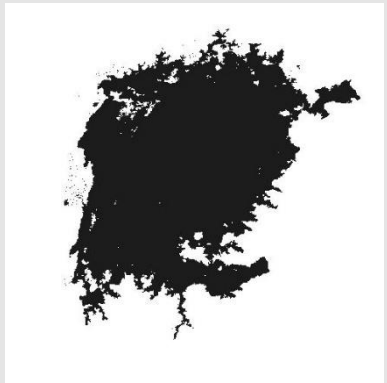


2017

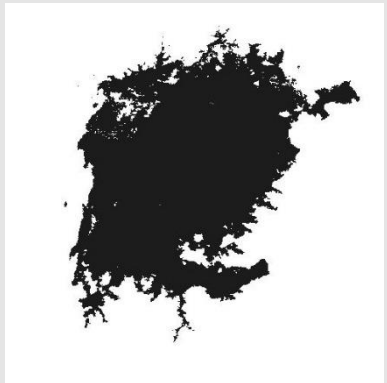
Minimum



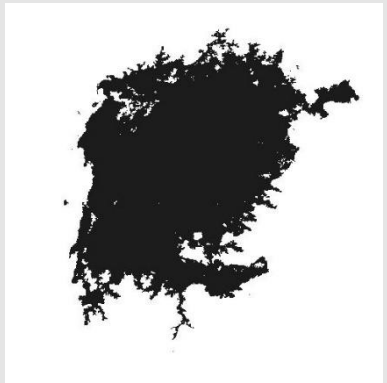
2012



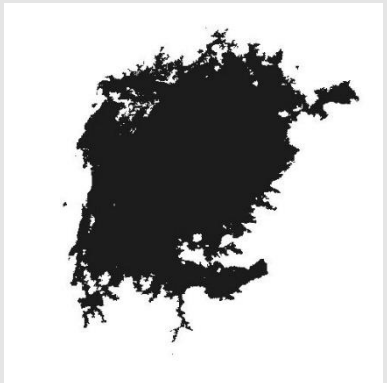
2013



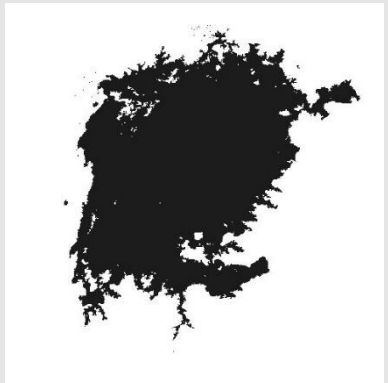
2014



2015

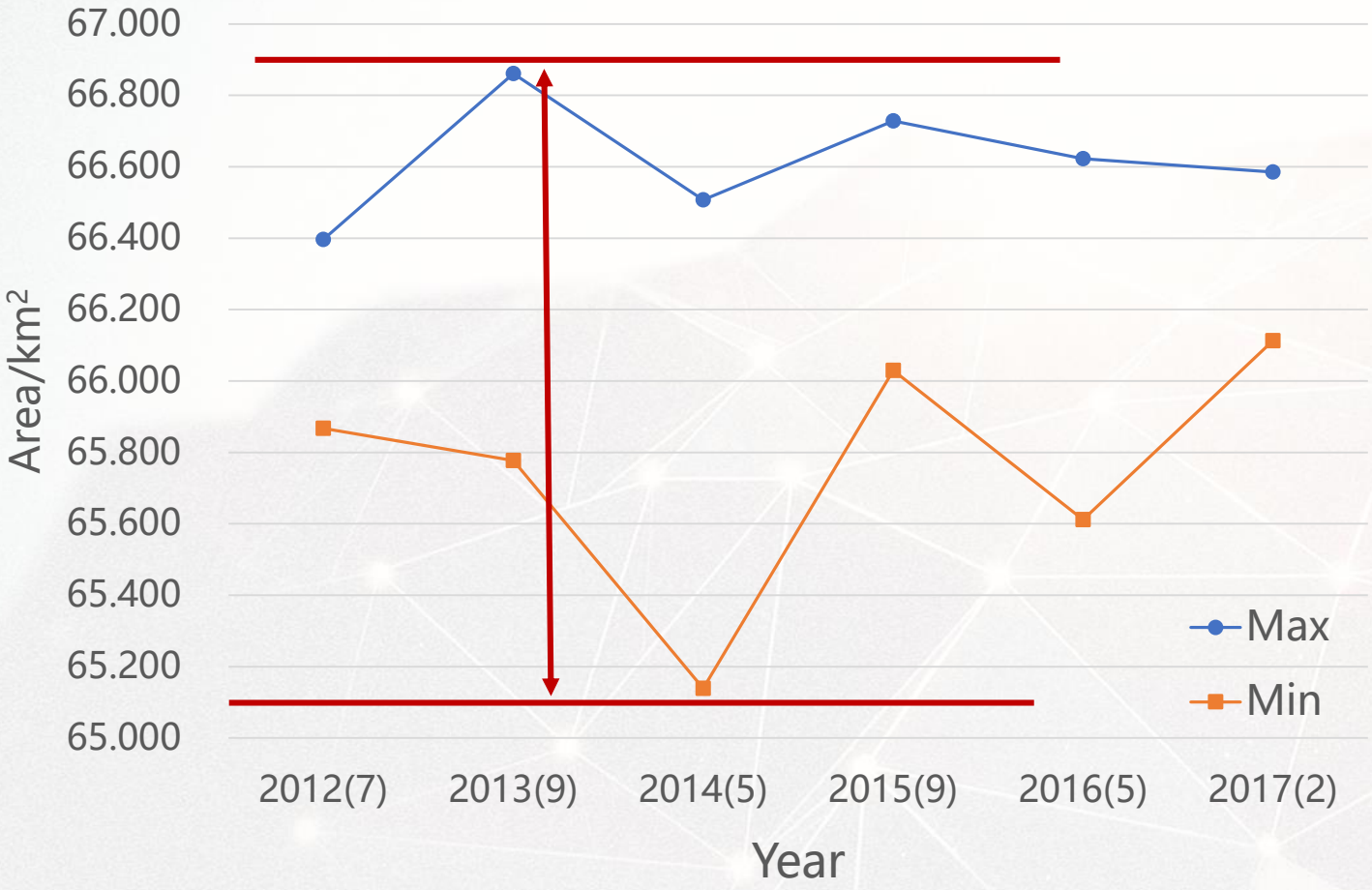


2016



2017

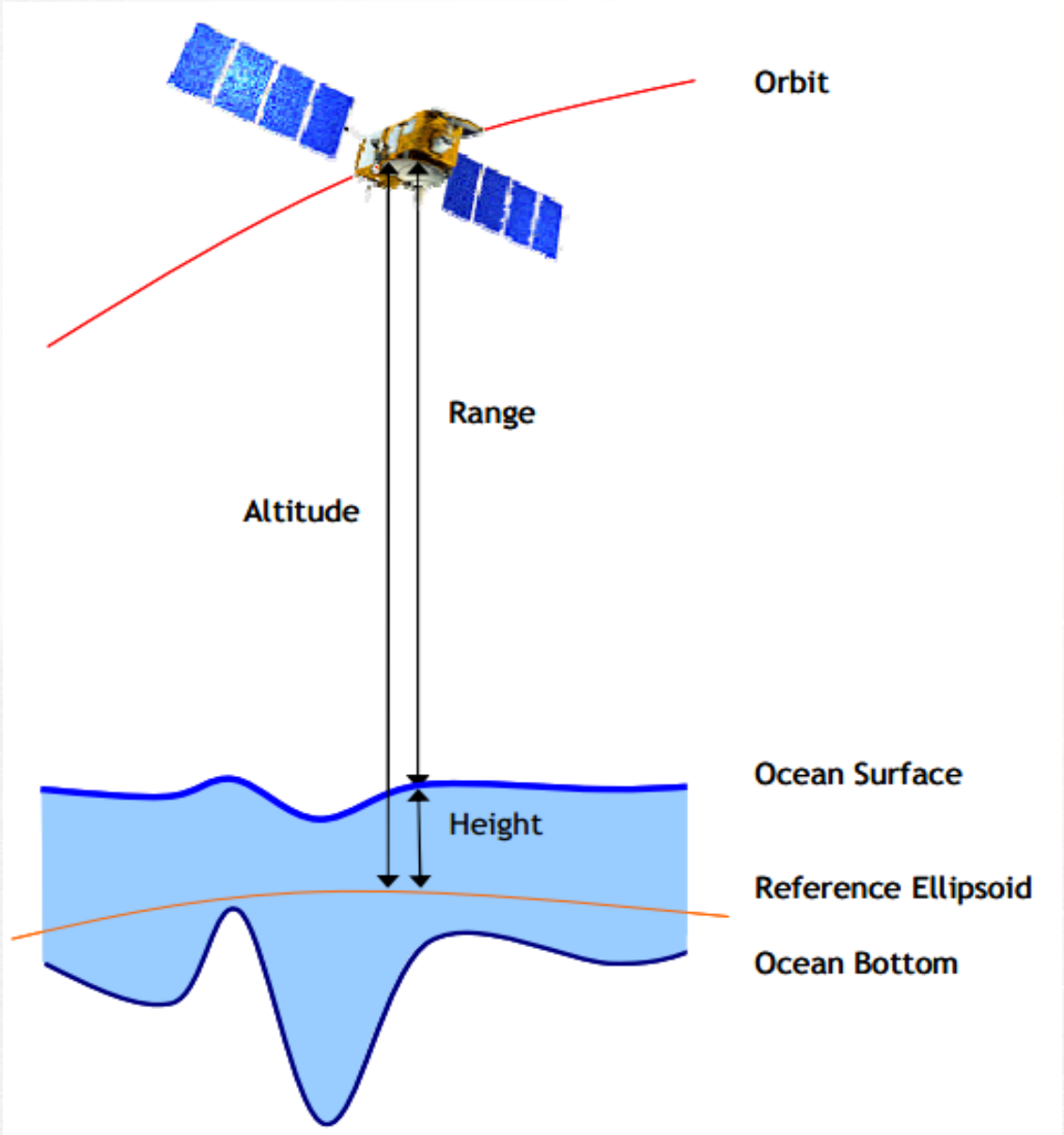
AREA EXTRACTION OF LAKE SURFACE



	Area/km²	Date
Maximum	66,861.25	2013-08-21
Minimum	65,139.00	2014-10-08
Maximum Variation	1,722.25	

Contents

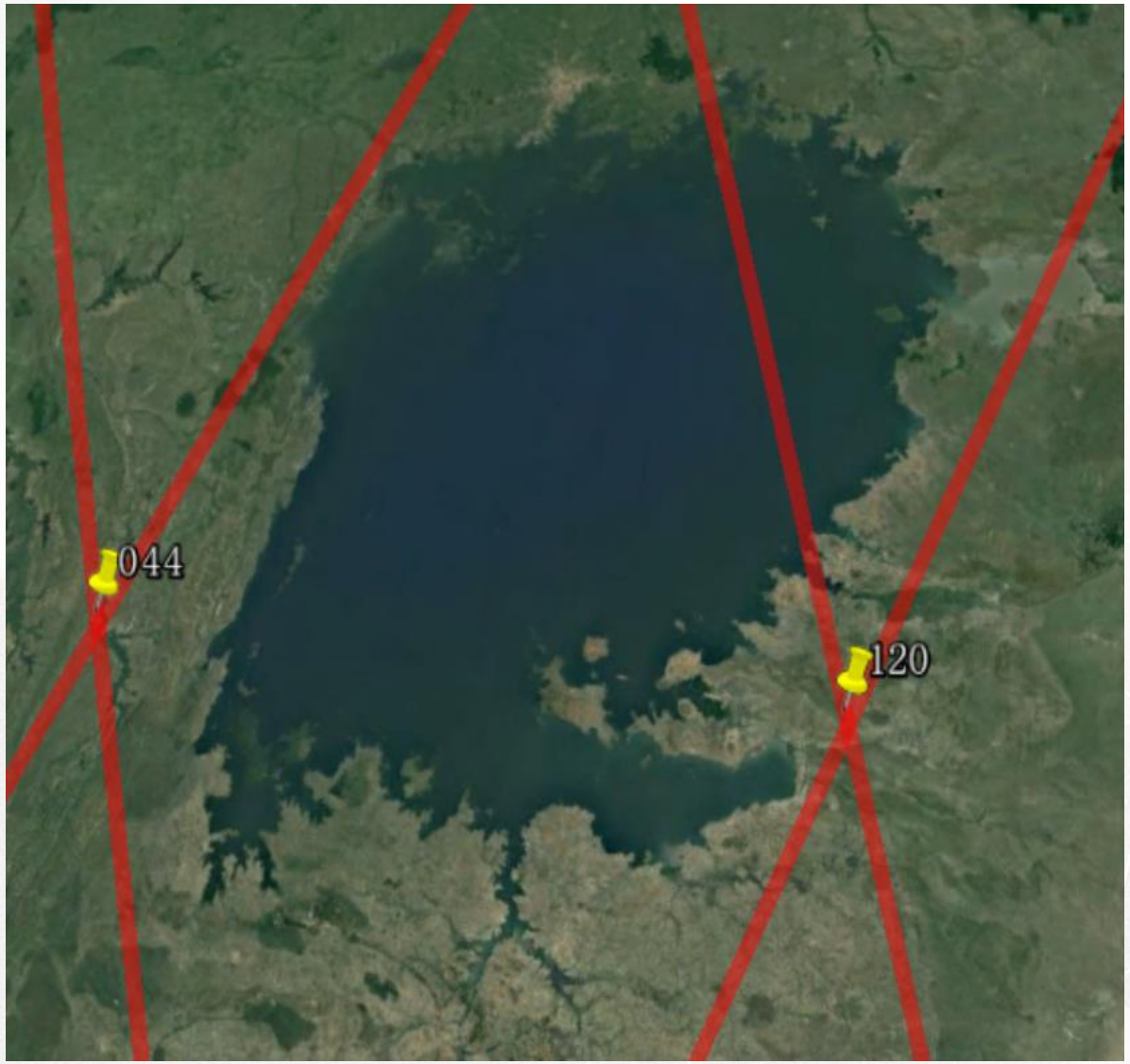
HEIGHT EXTRACTION OF LAKE SURFACE



$$H = R_{alt} - R - \Delta R$$

$$\Delta R = Wet + Dry + Iono + Sea + Set + Pol$$

HEIGHT EXTRACTION OF LAKE SURFACE



Before Feb, 2016
Jason-2

↓

Cross-analysis of Jason-2 and Jason-3 during the overlap period

↓

Bias correction

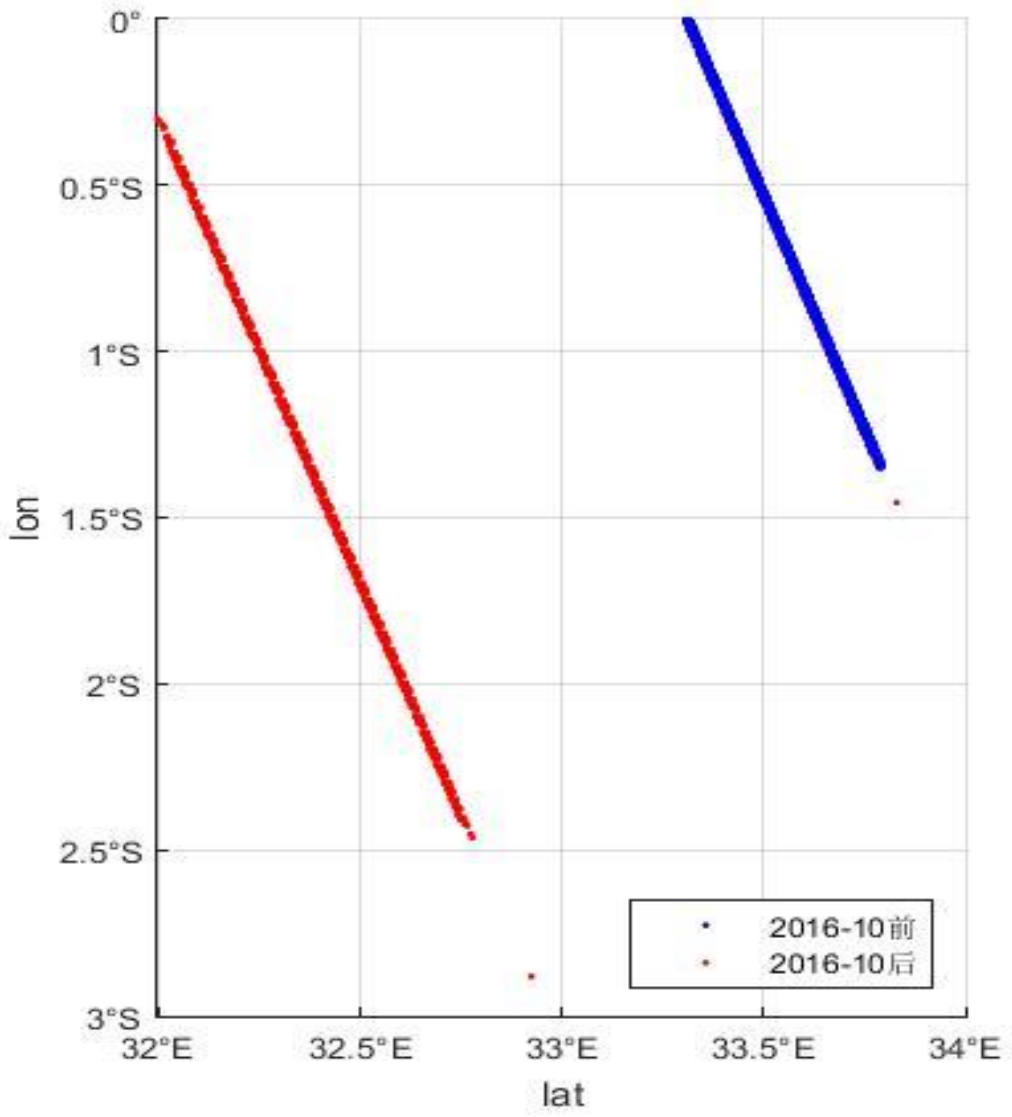
↓

After Mar, 2016
Jason-3

↓

Height change analysis

HEIGHT EXTRACTION OF LAKE SURFACE



Before Feb, 2016
Jason-2

Cross-analysis of Jason-2 and Jason-3 during the overlap period

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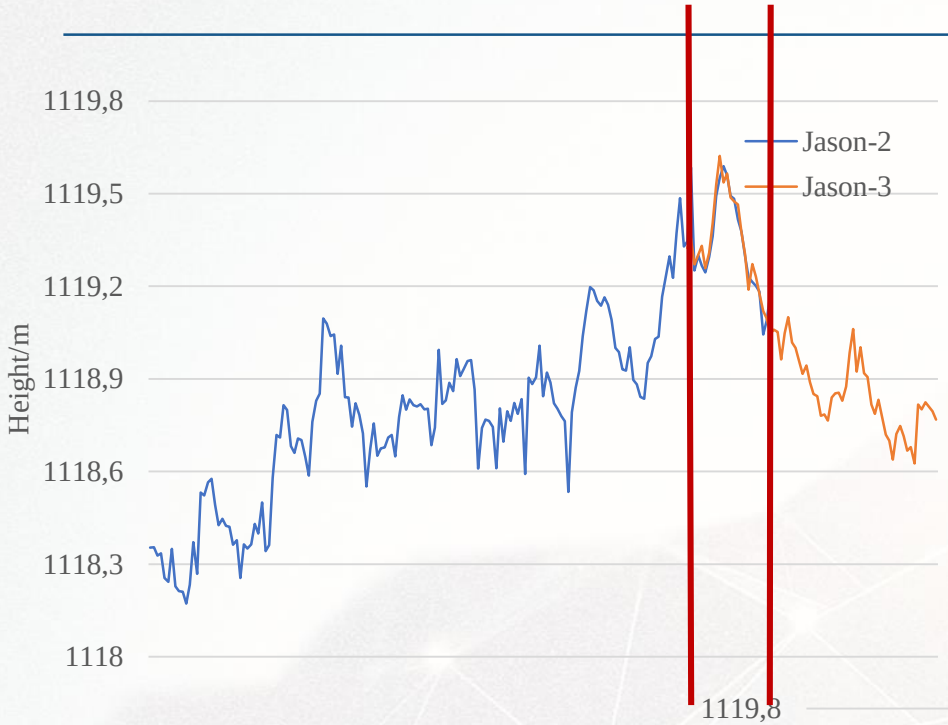
After Mar, 2016
Jason-3

Height change analysis

HEIGHT EXTRACTION OF LAKE SURFACE



Before eliminating the system bias

After eliminating the system bias

Before Feb, 2016
Jason-2

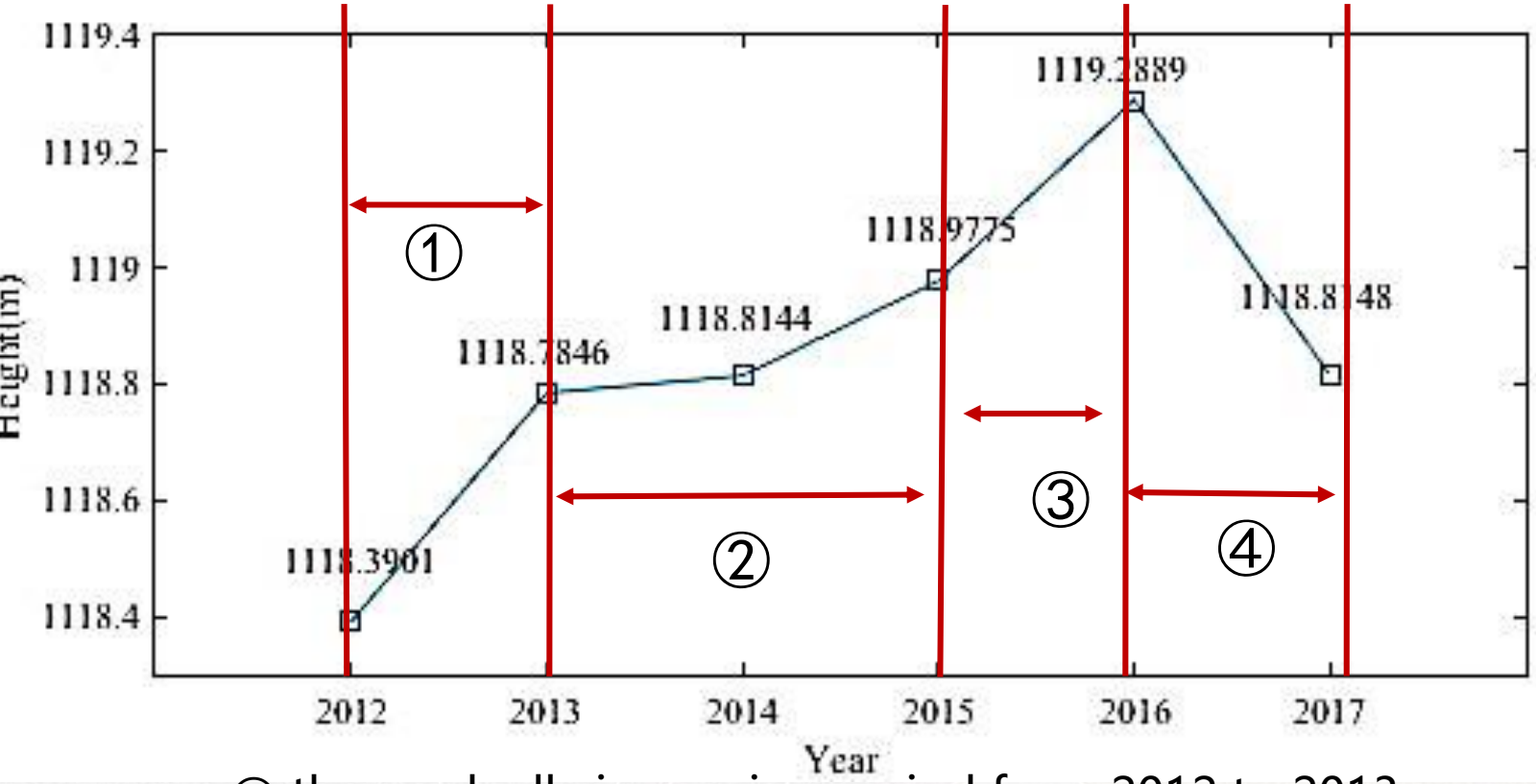
Cross-analysis of Jason-2 and Jason-3 during the overlap period

Bias correction

After Mar, 2016
Jason-3

Height change analysis

HEIGHT EXTRACTION OF LAKE SURFACE



① the gradually increasing period from 2012 to 2013

② the relatively stable period from 2013 to 2015

③ the significantly increasing period from 2015 to 2016

④ the significantly decreasing period from 2016 to 2017

Before Feb, 2016
Jason-2

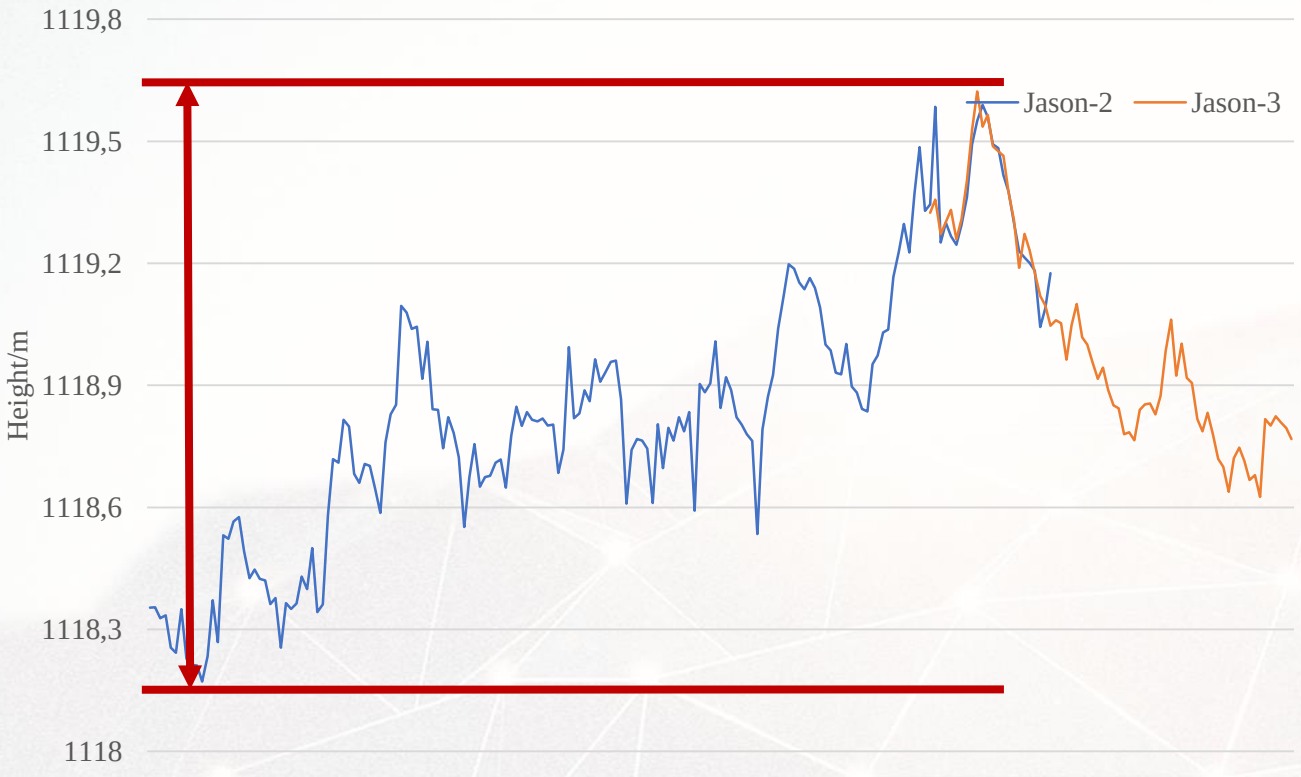
Cross-analysis of Jason-2 and Jason-3 during the overlap period

Bias correction

After Mar, 2016
Jason-3

Height change analysis

HEIGHT EXTRACTION OF LAKE SURFACE



	Height/m	Cycle	Date
Maximum	1119.6228	Jason-3 Cycle 009	2016-05-11
Minimum	1118.1717	Jason-2 Cycle 139	2012-04-15
Maximum Variation	1.4511		

Before Feb, 2016
Jason-2

↓

Cross-analysis of Jason-2 and Jason-3 during the overlap period

↓

Bias correction

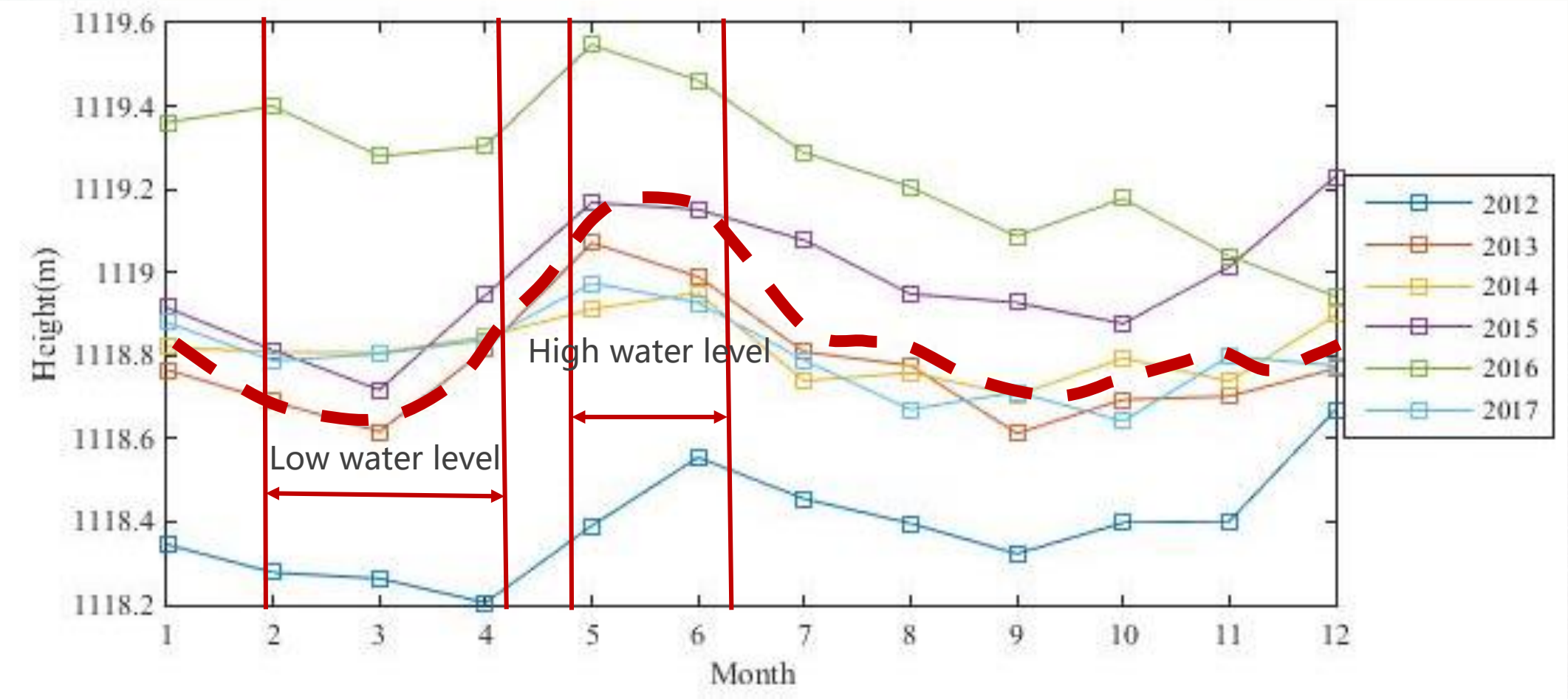
↓

After Mar, 2016
Jason-3

↓

Height change analysis

HEIGHT EXTRACTION OF LAKE SURFACE



Intra-annual change of water surface height

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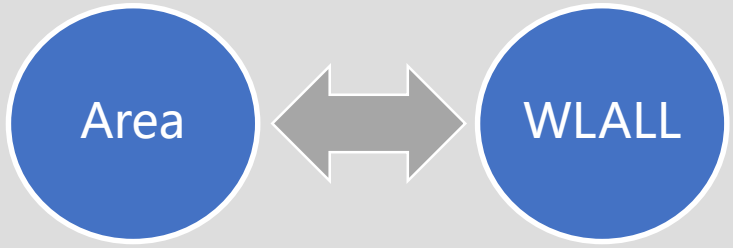
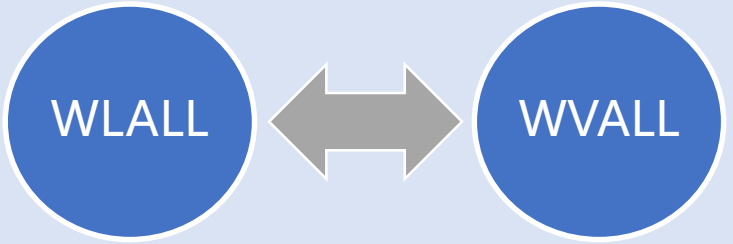
ESTIMATION OF WATER VOLUME VARIATIONS

WLALL Water level above the lowest level ⟺ **WVALL** Water volume above the lowest level



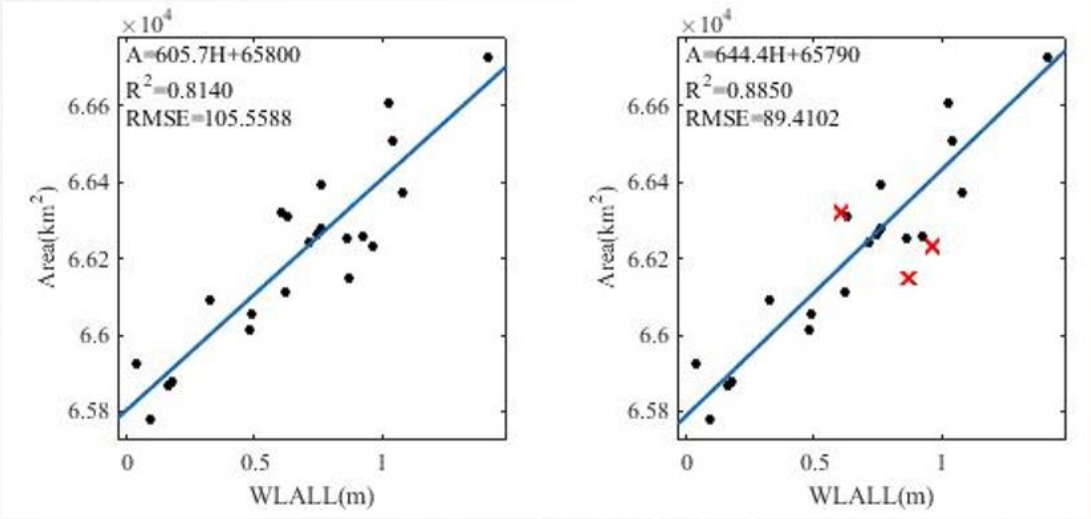
$$A = f(H)$$

- 25 pairs of water area and WLALL with similar observation dates (interval ≤ 1d) were selected.
- 22 pairs were randomly selected for establishing the relationship model, and the rest 3 pairs were used to evaluate the model accuracy.

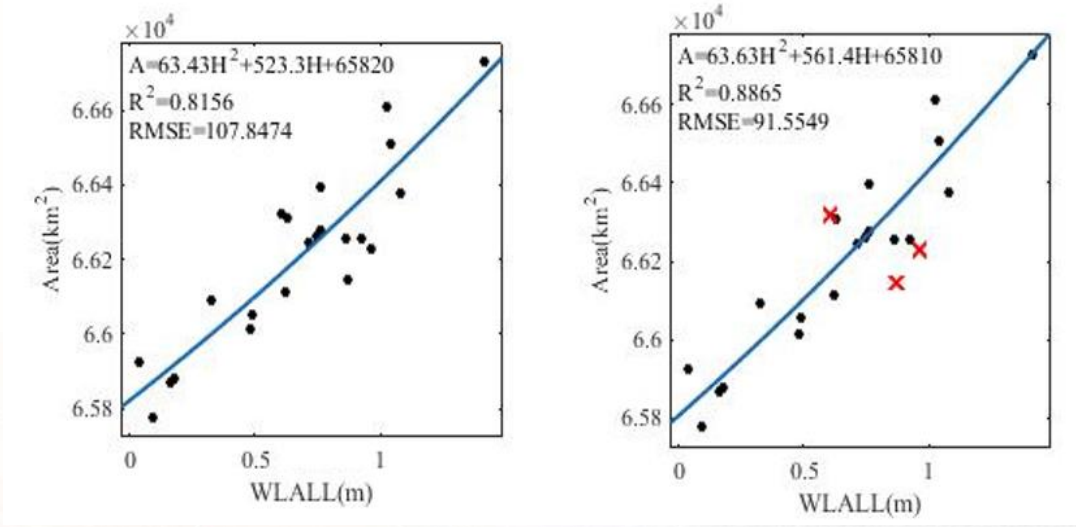


$$V = \int AdH = \int f(H)dH$$

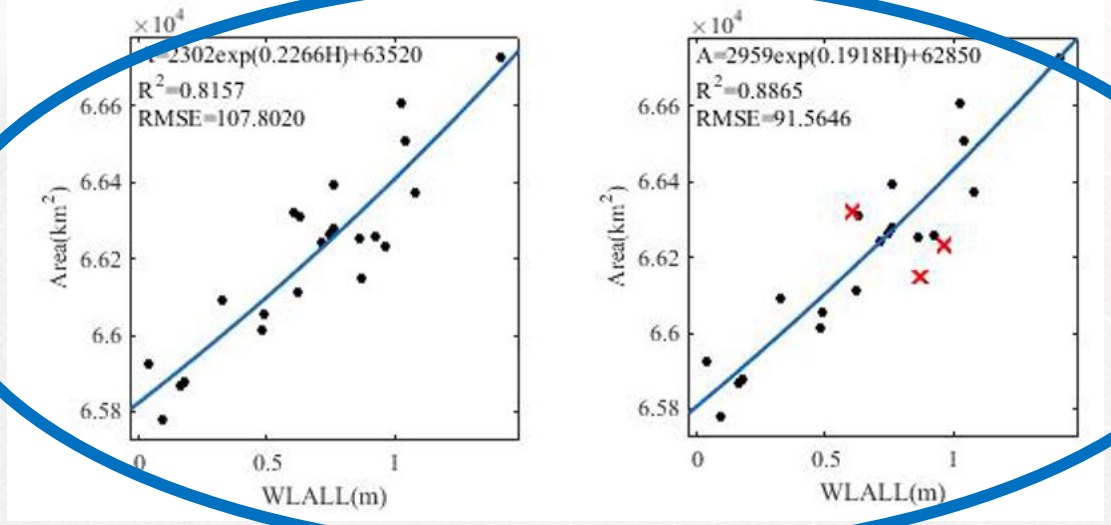
ESTIMATION OF WATER VOLUME VARIATIONS



Linear



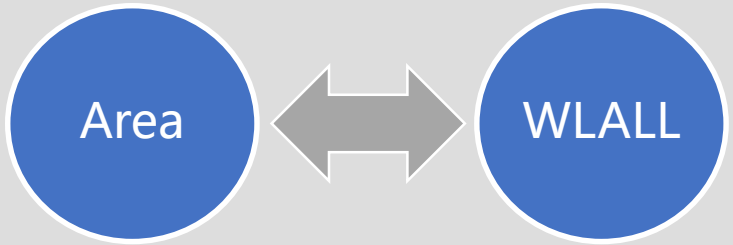
Polynomial



Exponential

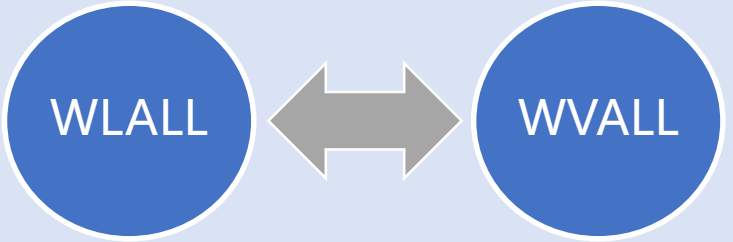
Regression	R^2		R^2
Linear	0.8140	Excluding outliers	0.8850
Polynomial	0.8156		0.8865
Exponential	0.8157		0.8865

ESTIMATION OF WATER VOLUME VARIATIONS



$$A = f(H) = ae^{bH} + c = 2959e^{0.1918H} + 62850$$

	Date	MODIS-derived area /km²	WLALL/m	Relationship-derived area /km²	Absolute error /km²	Relative error /%
1	2013/10/12	66141.75	0.4792	66093.85	47.90	**0.07**
2	2016/8/8	66656.25	1.0426	66464.02	192.23	**0.29**
3	2016/12/15	66404.25	0.7858	66290.33	113.92	**0.17**



$$V = \int f(H)dH = \frac{a}{b}e^{bH} + cH + d$$
$$= 15427.5287e^{0.1918H} + 62850H - 15427.5287$$

ESTIMATION OF WATER VOLUME VARIATIONS

① the gradually increasing period from 2012 to 2013

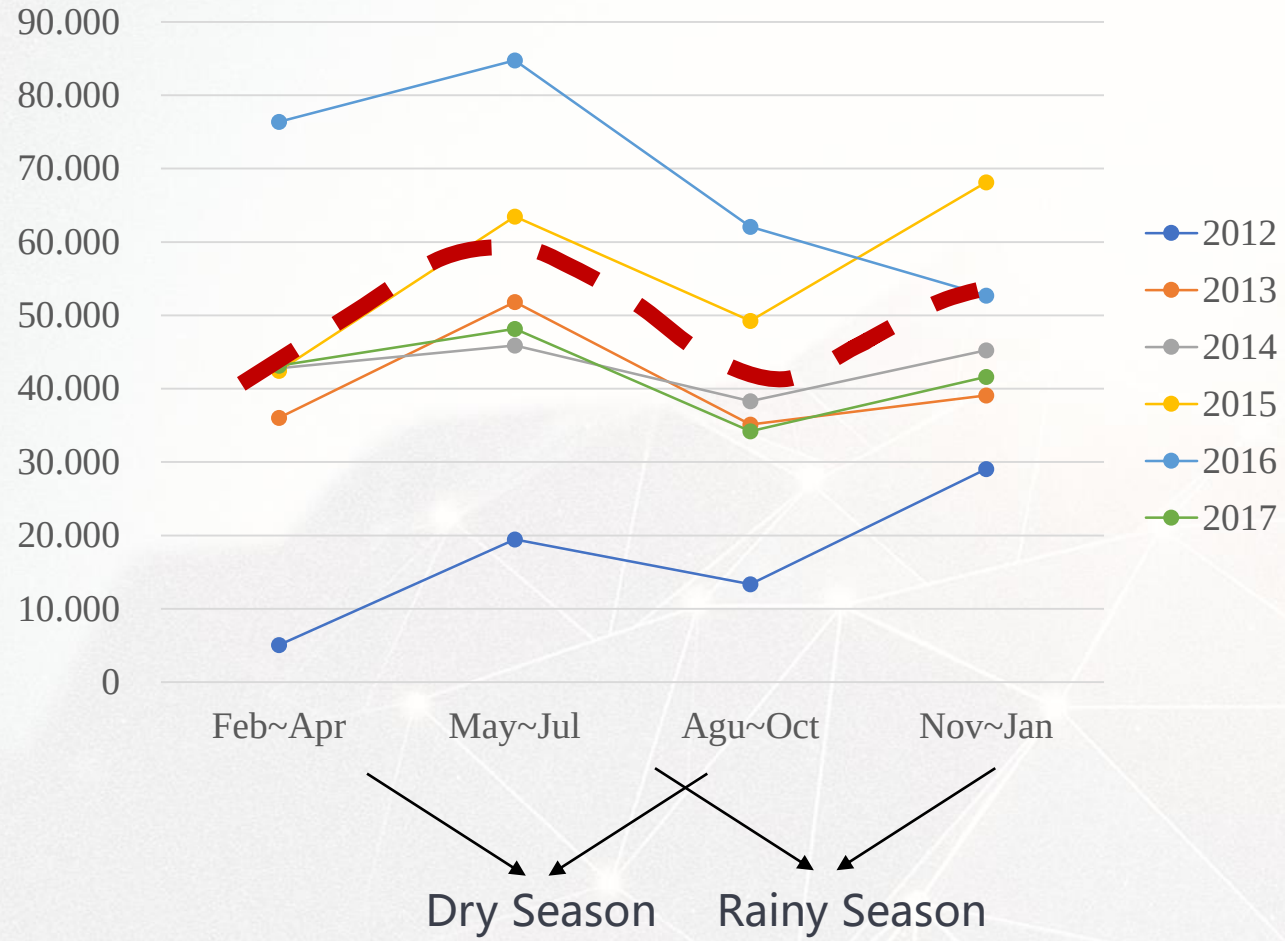
② the relatively stable period from 2013 to 2015

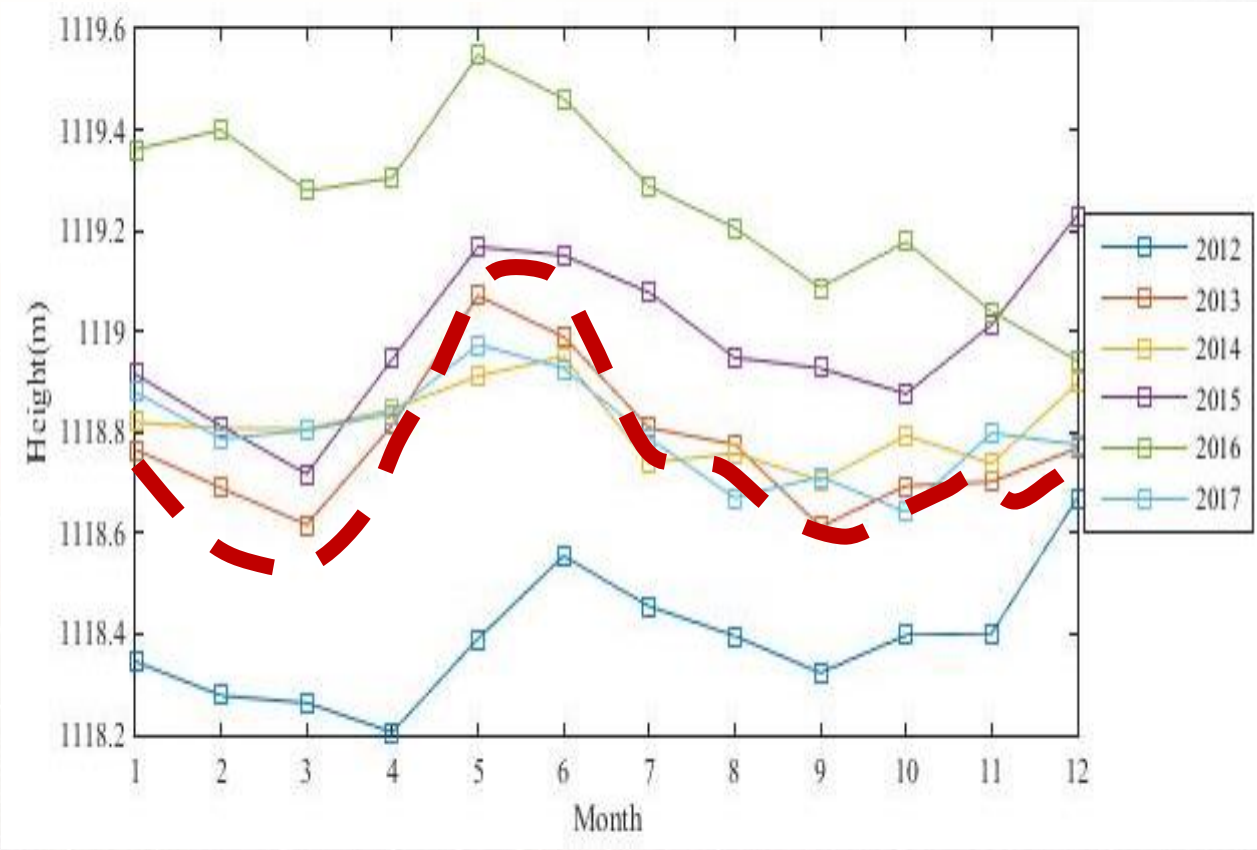
③ the significantly increasing period from 2015 to 2016

④ the significantly decreasing period from 2016 to 2017

	WVALL/m³	Date
Maximum	93,736.64	2016-05-11
Minimum	0	2012-04-15

ESTIMATION OF WATER VOLUME VARIATIONS





ESTIMATION OF WATER VOLUME VARIATIONS

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Climatic conditions

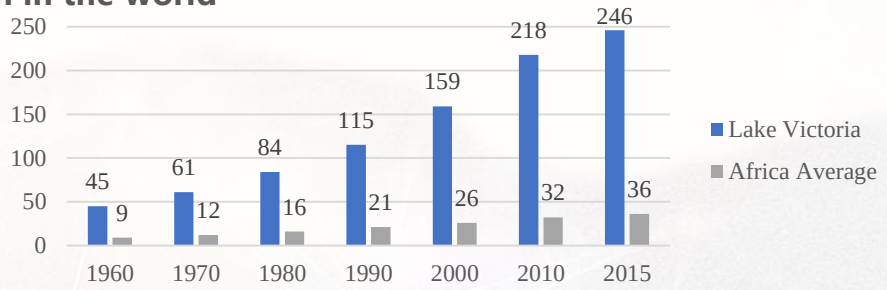
Have great influence on water volume variations of Lake Victoria

Rainfall is the main reason of water volume variations

Location is located on the equator great fluctuation in precipitation

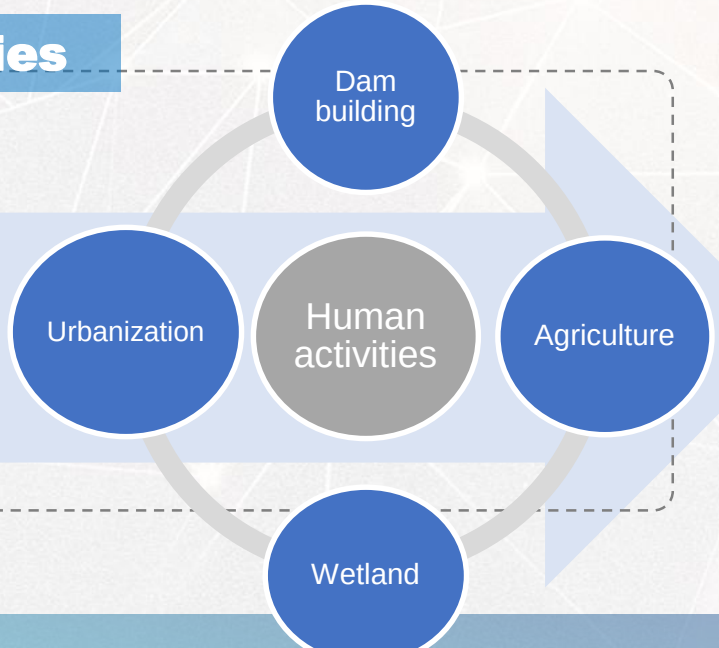
Population growth

Has experienced rapid population growth
the area around the lake is the most densely populated rural region in the world



Human activities

Human activities will play an important role in land use/ cover change around Lake Victoria



Driving force analysis

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CONCLUSIONS AND FUTURE WORKS

In our research		Future work
MODIS Jason-2/3	Data	Landsat ENVISAT Gravity data Hydrological data
Conventional SVM	Area extraction of water surface	Unmixing technology
Altimetry data	Height extraction of water surface	Gravity data and hydrological data to validate
2012-2017	Estimation of water volume variations	Much longer time series

Thank You!

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