TWENTY YEARS OF MONITORING OF LARGEST CHINESE MONSOON LAKES BASED ON ENVISAT AND JASON ALTIMETRY MISSION

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ABSTRACT

Dongting Lake and Poyang Lake are the largest lakes in China and contribute to flood control in Yangze basin. These lakes have the specific behaviour of monsoon lakes, with very large and rapid level variations. All the altimetric data of ENVISAT nominal mission have been processed these lakes. Topex/Poseidon and JASON2 data have also been analysed over Dongting Lake.

These altimetric measurements have been validated using in situ water level data. Poyang Lake surface variations are monitored since 2000 within the framework of the ESA MOST DRAGON programs, using time series of medium and high resolution optical images. A strong correlation of these surfaces with altimetric water level is demonstrated for various sub-basins. Finally, water levels and surface are coherent with gauge station measurements.

1. STUDY AREA

Since the beginning of the 90‟, satellite altimetry missions allow an accurate and continuous monitoring of large lakes and inlands seas [1].

Figure 1: Yangze River basin

Within the complex watershed of Yangtze (Chang Jiang) basin (Fig. 1), Poyang Lake, the biggest lake in China, and Dongting Lake are regularly flooded, in a region in which is living one third of PRC population and is growing nearly half of China‟s crop production. These lakes are considered as hydrological keys components in flood control and reduction for the middle Yangtze basin. These lakes have specific behaviour of monsoon lakes, presenting very important level variations during transition between dry and wet seasons. The surfaces vary in a ratio being about 1 to 4. During dry season, Dongting and Poyang lakes can be reduced to a relative narrow river with connected small lakes.

2. WATER LEVEL WITH ALTIMETRY

2.1. Data

We have used data from the American and French space missions Topex/Poseidon (T/P) on its nominal orbit (1992 - 2002) and intermediate (2002 – 2006) and Jason 2 (2008 – going on).
We have also used data from ENVISAT (2002- 2010). We use the high frequency radar measurements, a 10 Hz rate for T/P and 20 Hz for ENVISAT and Jason2.
Only few tracks are available for each lake. Concerning Poyang Lake we analyse ENVISAT tracks 163 and 980, and T/P interim orbit 153
Concerning Dongting Lake for ENVISAT tracks 694 and 879 are available. For T/P and J2 only track 12 can be used.

The software used has been developed at LEGOS for continental water studies [2]. The selection of data to be processed (definition of the virtual station) is made by a geographical study of the water body and satellite track. The water height is a mean along the selected part of the track of the 20 Hz (or 10 Hz for T/P) elementary values H :

$$H = \text{range} - \text{altitude} - \Sigma(\text{corrections}) - \text{geoid} \qquad (1)$$

The range is computed using ICE1 algorithm. Corrections taken into account are:

- ionosphere correction from GIM_Ku model,
- wet and dry troposphere correction computed from the ECMWF fields,

The geoid is EGM08 from GRACE mission.

2.2. results for Poyang Lake

Fig. 2 is presenting satellite tracks above Poyang Lake. T/P provide 3 years of data along the outlet channel, with a 35 km long path. For ENVISAT mission, best results are get using a 3 km long path for track 163 and a 10 km path for track 980.In this figure are also tagged in situ water level measurement stations, from North to South Hukou,Xingzi, Poyang City, Duchang and Kangshan.

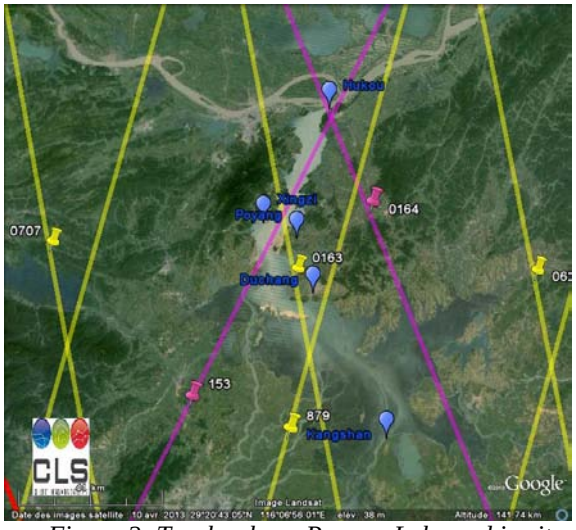

Figure 2 :Tracks above Poyang Lake and in situ stations

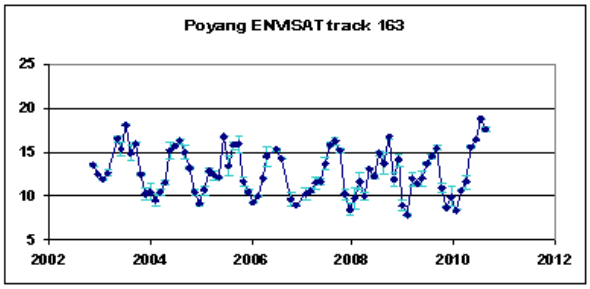

Figure 3: ENVISAT track 163

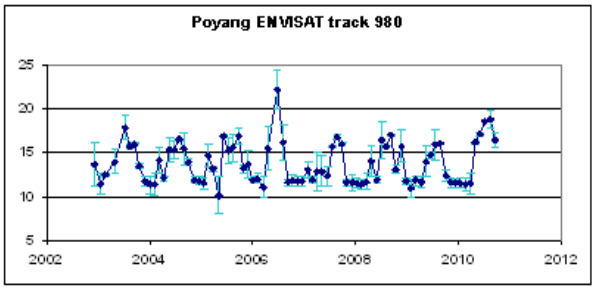

Figure 4 : ENVISAT track 980

Results from track 980 are of lower quality than results from track 163. We have not been able to identify the reason for this discrepancy. On track 163 ENVISAT is flying from South to North while it is flying from North to South for track 980, this could have some impact on the radar behaviour.

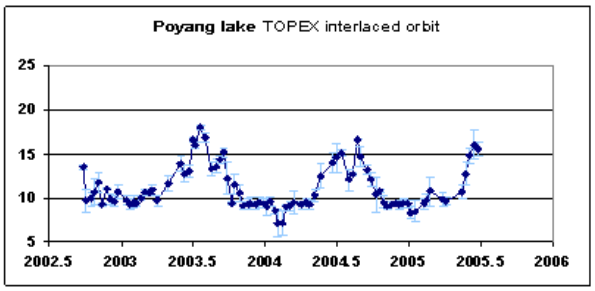

Figure5 : T/P track 153 intermediate orbit

T/P (and J2) unfortunately, does not fly over Poyang Lake. But during the short period of the "intermediate orbit" measurements were available above the outlet channel. Water levels from T/P are lower than water level from ENVISAT.

2.3. results for Dongting Lake

Fig. 6 is presenting satellite tracks above Dongting Lake.

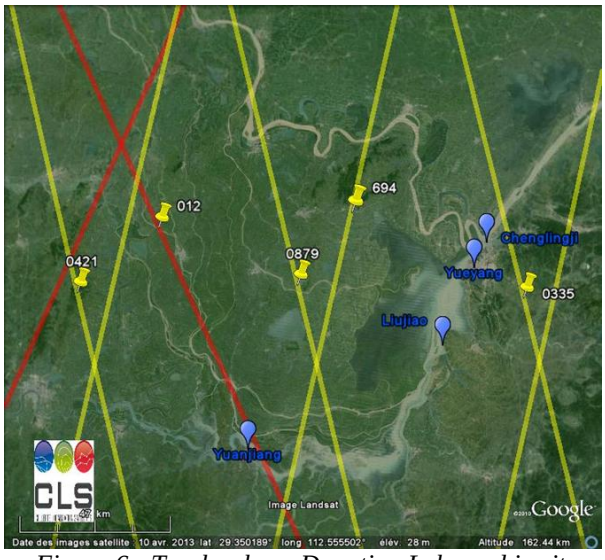

Figure 6 : Tracks above Dongting Lake and in situ stations

Tracks 12 (T/P and J2) and ENVISAT 694 and 879 lay in 23 km. The selected segments are all of them 9 km long.

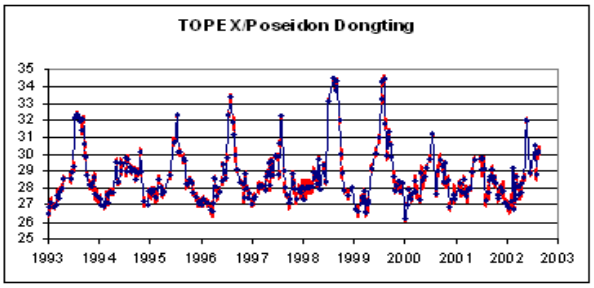

Figure 7 : Dongting Lake water level measured by T/P

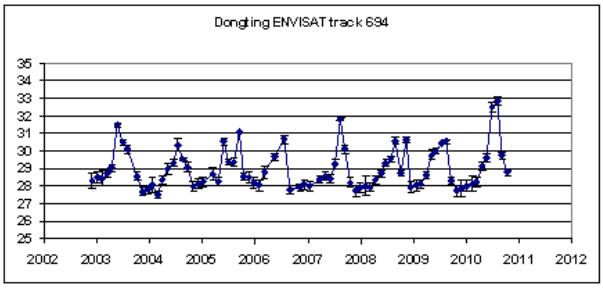

Figure8 : Dongting Lake water level measured by ENVISAT track 694

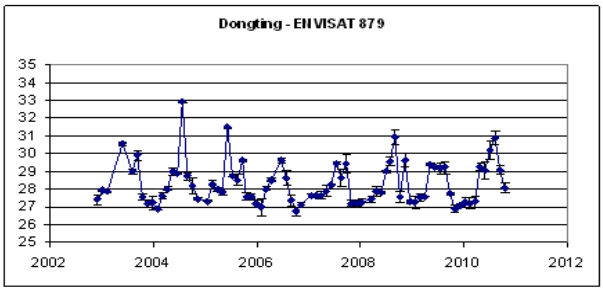

Figure 9 : Dongting Lake water level measured by ENVISAT track 879

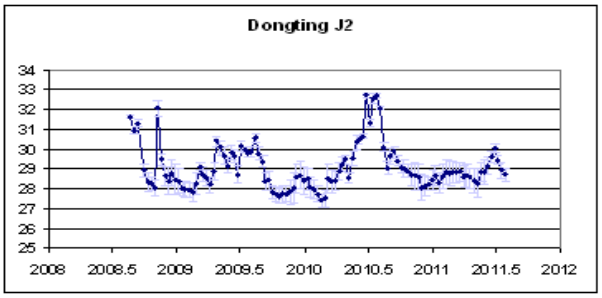

Figure 10 : Dongting Lake water level measured by J2

3. VALIDATION

3.1. In situ water measurements

3.1.1. Poyang Lake

Several limnimetric stations are available around Poyang Lake. Fig.11 displays the observed levels.

We can observe that Hukou (northern part of the outlet) and Xingzi (southern part of the outlet) give the same values. Unfortunately, we cannot decide if these two stations are at the same altitude or if corrections are applied to fit them altogether and by the way, no conclusion is possible regarding the lower values of T/P mesurements in Poyang Lake.

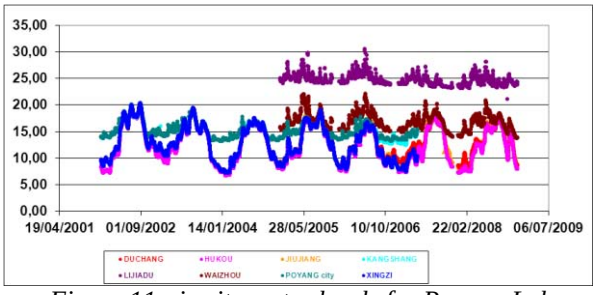

Figure 11 : in situ water levels for Poyang Lake

Fig. 12 is comparing ENVISAT water level from track 163 to Xingzi water levels, this station being the most representative of the lake level (private communication Pr. Lai). The two curves are fitting well but we have to keep in mind that no geodetic information is available to validate this.

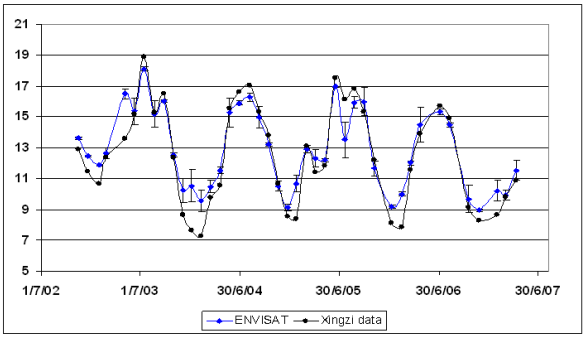

Figure 12 : Comparing water level from ENVISAT track 163 and Xingzi station.

3.1.2. Dongting Lake

Several stations are available around Dongting Lake. Chenlingjing offers a very long serie but unfortunately it is to far from satellite tracks. The most interesting station from a geographical point of view is Yuangjiang for which we have only a short set of data.
Comparing with ENVISAT results (Fig. 13) shows a weak correlation.

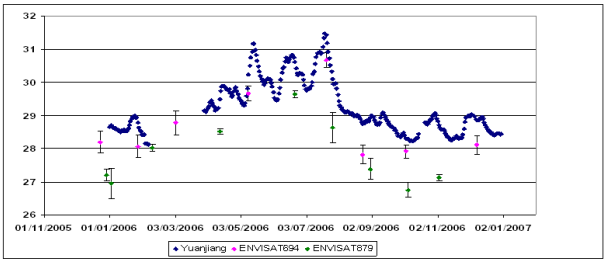

Figure 13 : comparing ENVISAT water level with Yuanjiang station

3.1.3. Discussion for in situ stations :

The in situ data we have analyzed are generally of very good quality, especially for Poyang Lake stations Hukou and Xingzi.
Some stations are not really useful because measurements are missing because of no water in dry season (Duchang and Kangshan stations). The major problem remains the lack of geodetic reference for these stations. In this condition, we are not able to process an absolute validations of the water levels computed with altimetry

3.2. Surfaces with spaceborn measurements

Within the framework of the ESA MOST DRAGON programs, [3] an extent time series of medium and high resolution satellite data, both optical such as MERIS and MODIS, large swath Deimos, HJ1A-B, ALOS AVNIR, and SAR, such as ASAR ENVISAT, Cosmo-Skymed, have been collected over Poyang Lake.
Detailed informations are in [4], [5], [6].
Water surface extents (Fig. 14) have been derived on a averaged 10 days basis since 2000. Despite a time sampling relatively different for images and water height acquisition, and by the way a rare acquisition of the two parameters on a single date, numerous similarities can be observed between Fig. 14 and Fig. 3.

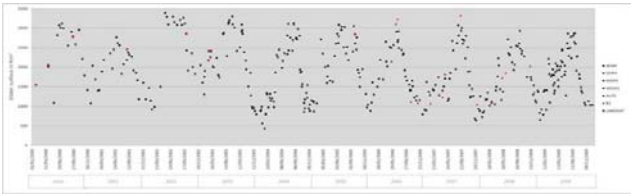

Figure 14 : 13 years of Poyang Lake surface extends

They present the same peaks and weak values which correspond to the dynamic of monsoon lakes : low water level and extent during the dry season (November to April) and high water level and extent from June to August.
The correlation between the two series, water height measurements with altimetry and watered surfaces with space imaging, is very high, with a R2 of 0.8228 (Fig. 15).

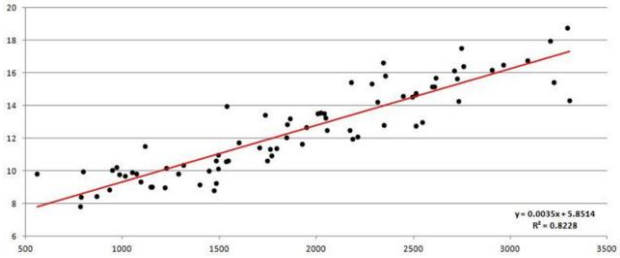

Figure 15 : relationship between surfaces and water heights

An attempt was done to take into account sub system division within the Poyang Lake depressions (Fig. 16). The analysis between water height and water surface behavior was done over eight hydrological sub basins derived from recent field works. We considere here only three important sub basins, being main basin (violet contour), outlet channel (red contour); Kangshan polder (green contour).
The correlations between the watered surfaces of each sub basins and the water level have been computed.
In the central part of the lake, a good correlation is observed.

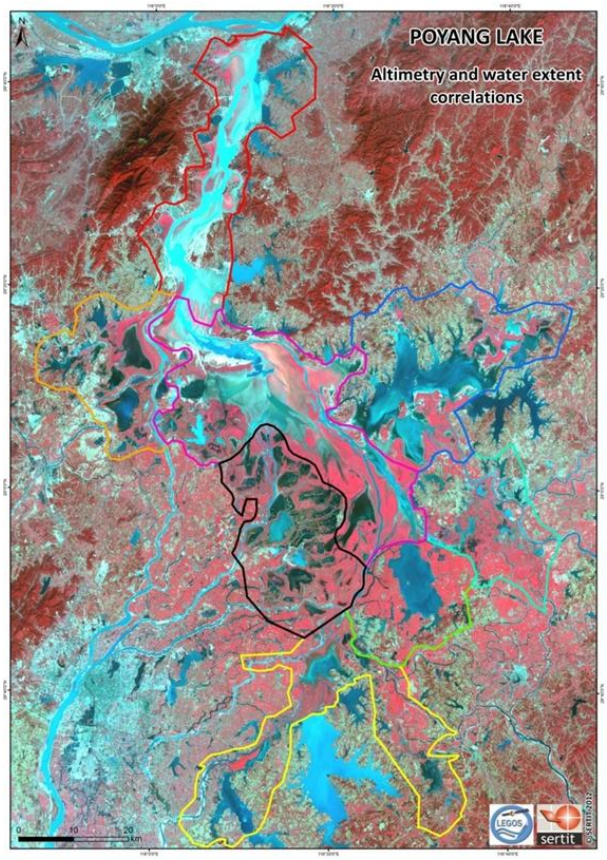

Figure 16 : Sub basins definitions

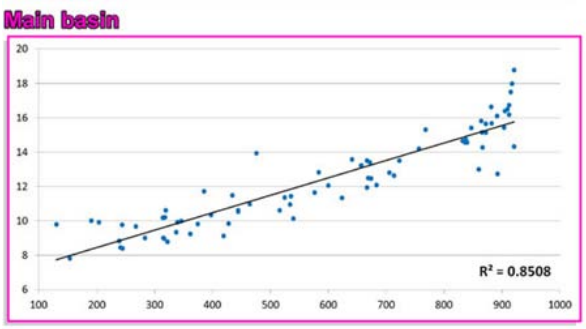

Figure 17 : correlations in the main basin

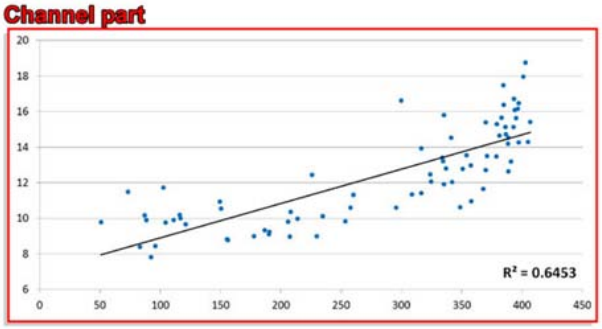

Figure 18 : outlet channel

The central part of the lake and the channel part present a some sort of locking surfaces, heights continue to increase (red and orange blocks) whereas the water extend is blocked.

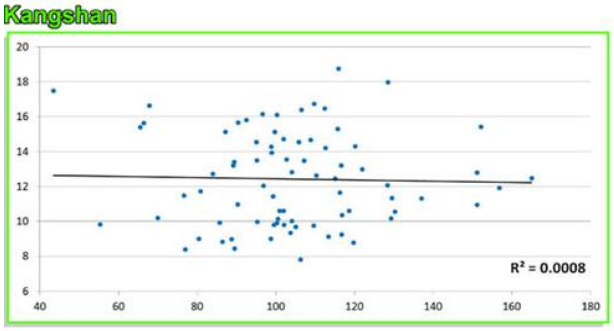

Figure 19 : Kangshan Lake

Southern part of the lake, i.e. Kangshan Polder, do not present any correlation between surface and water height. This is normal, as the water level in these areas is fully control by gates and dams management.

Full study can be found in [7].

4. CONCLUSION

This work in presenting the first detailed exploitation of all historical data, Topex/Poseidon, ENVISAT and JASON2, still flying.
A rich database has been created, including altimetry, in situ measurements, images.

As a main result, we demonstrate that water level from altimetry over Poyang and Dongting lakes are coherent with in situ measurements and optical surfaces.
Unfortunately, an absolute validation of altimetry would need field campaign for geodetic reference of the in situ stations.
These 20 years of data will be enhanced with the analysis of AltiKa data.

Knowledge of monsoon lakes will be improved in a short delay with Sentinel3 and a longer perspective with JASON CS and SWOT.

5. REFERENCES

[1] Calmant S., Seyler F. and Cretaux J.F.,2008 Monitoring continental surface waters by satellite altimetry, Survey in Geophysics, special issue on „Hydrology from Space" 29, 247-269, 2008.

[2] J.-F. Crétaux, W. Jelinski, S. Calmant, A. Kouraev, V. Vuglinski, M. Bergé-Nguyen, M.-C. Gennero, F. Nino, R. Abarca Del Rio, A. Cazenave, P. Maisongrande, 2011, SOLS: A lake database to monitor in the Near Real Time water level and storage variations from remote sensing data, Advances in Space Research, Volume 47, Issue 9, 3 May 2011, Pages 1497-1507

[3] Desnos, Y-L., Bergquist, K., Li, Z., 2004. The Dragon programme: ESA and China cooperate in earth observation. E.S.A bulletin (E.S.A. bull.) ISSN 0376-4265 European Space Agency bulletin 2004, no119: 22-28.

[4] Andreoli R., Yesou H., Li J., Desnos Y-L., Shifeng H., De Fraipont P., 2009 : Poyang Hu (Jiangxi Province, P.R. of China) Area Variations between January 2004 and June 2006 Using ENVISAT Low and Medium Resolution Time Series, Geographic Information Sciences Vol. 13, No 1-2, 24-35.

[5] Yésou H., Huber C., Lai X., Averty S., Li J., Daillet S., Bergé-Nguyen M., Chen X., Huang S., Burnham J., Crétaux J.F., Marie T., Li J. Andreoli R. and Uribe C., 2011, Nine years of water resources monitoring over the middle reaches of the Yangtze River, with ENVISAT, MODIS, Beijing-1 time series, Altimetric data and field measurements ; Lakes & Reservoirs : Research and Management 16 : 231-247

[6] Huber C., Li Jiren, Daillet S., Chen Xiaoling , Lai Xijun, Crétaux JF, Zhang Wei, Uribe C., Stuber M. Huang Shifeng, Averty S., Burnham J. and Yésou H. , 2012. Twelve year of water resource monitoring over the Yangtze middle reaches exploiting DRAGON time series and field measurements. Proceedings of DRAGON 2 final results, SP ESA 704.

[7] Daillet S., Huber C., Li J., Lai X., Chen X., Huang S., Yésou H., Crétaux J-F ., Gennero M-C.,, Uribe C. (in review) Large monsoon lakes monitoring in China exploiting ENVISAT, Topex/Poseidon and JASON altimetry mission: yearly variations and global trends for Poyang and Dongting lakes (P.R. China) , JSTARS