Programma STM - Short Term Mobility (Anno 2015), authorized with Prot. AMMCNT Num. 24220 of 09/04/2015

Final Report of Activities

carried out during the STM period at NIGLAS-CAS

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Project Title

Integrated assessment of water quality threats in Lake Taihu area by satellite data

In the context of the Short Term Mobility program for 2015, I have been visiting scientist in Nanjing Institute of Geography and Limnology (NIGLAS), Chinese Academy of Sciences (CAS), Nanjing for a period of 2 weeks (May 25th, June 7th, 2015).

During the visiting period, research activities under the title " Integrated assessment of water quality threats in Lake Taihu area by satellite data" have been carried out jointly by me and NIGLAS laboratory of Lake Remote Sensing, led by professor Hongtao Duan.

The technical and scientific work and results derived through such activities are described in this final report.

Rationale of the proposal

Water quality is strongly affected by anthropic activities and their influences on the land, and human health is as well dependent upon the availability of clean water. Thus, the assessment of aquatic resources is one important focus area for interdisciplinary environmental studies. Remote Sensing and Earth Observation can now deliver a wide range of information on spatio-temporal evolution of environmental dynamics both in the water and the land domain, and is therefore the most relevant and potentially effective candidate tool for monitoring complex ecosystems such as in the case of transition environments and coastal areas. Eastern China big lakes are located in one of the most densely anthropized area of the world (Jiangsu, Anhui and Shanghai provinces), populated by more than 150 million of people and featuring massive industrial and agricultural activities; this area is an ideal test case for the approach proposed.

During 2013, I have been visiting scientist in NIGLAS - Lake Remote Sensing lab, under the supervision of Hongtao Duan (June-August 2013, Candidature di Scambio Libero CNR-CAS). The main output of the

activities carried out during the visiting was published in Villa et al. (2015), which focuses on the analysis of environmental stressors of Taihu, covering one decade (2000-2010). This STM project proposal aims to further advance Taihu area integrated satellite monitoring, by covering the last two decades (1990 onwards), and by including into the analysis additional environmental features not yet considered and connected to water quality threats and algal blooming: hydrology (e.g. water level, inflowing river regimes), meteorology (e.g. winds, precipitation time series), and possibly sediment biogeochemistry.

Objectives

- Reconstructing the spatial and temporal dynamics of water quality parameters in Lake Taihu focusing on algal blooming phenomena and mapping coastal and watershed processes (anthropic and natural), using satellite data covering the last two decades.
- Delivering a framework for interpreting the effects of land cover/use evolution on water quality of Lake Taihu, which integrates remote sensing products and in situ data (nutrients loading, climatic and hydrological conditions).

Study Area

Eastern China lakes region, along the course of the lower Yangtze River, is currently one of the most densely populated areas in the world, and therefore subject to anthropogenic pressures on the environment. More than 150 million people live here (an average of around 600 per km2), in Anhui, Jiangsu and Shanghai provinces, and a remarkable part of national GDP is produced in this region both from massive industrial installments and agricultural plantations.

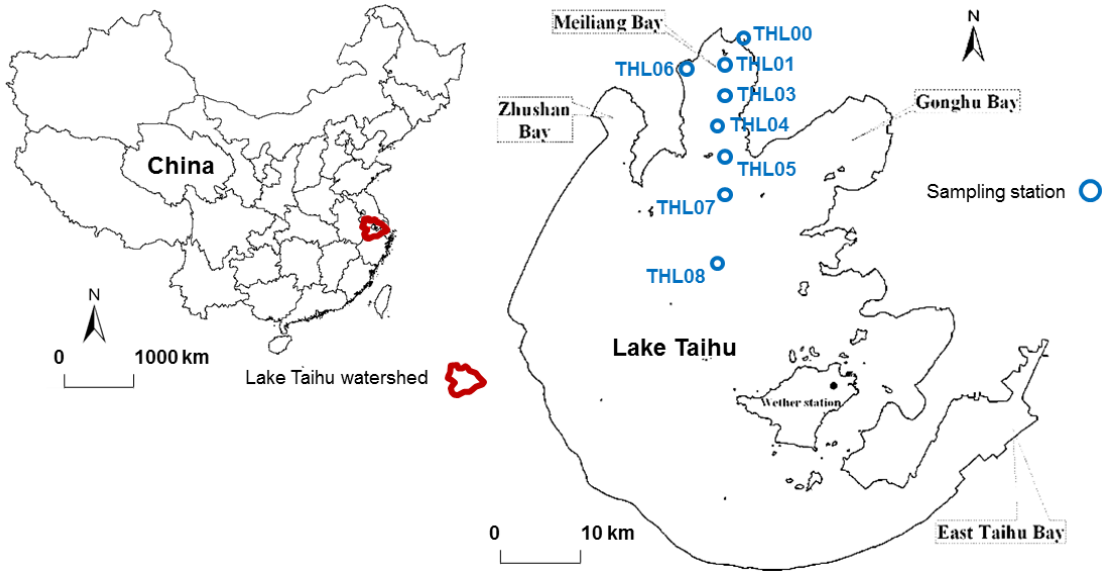

Figure 1 - Study area, Lake Taihu highlighting the position of the sampling station for in situ dataset

This context is reflecting into environmental pressures on remaining natural ecosystems which has been almost unprecedented due to the rapid growth of urbanization phenomena in the area, starting the early '80s. In particular, since the area is one of the richest in surface water resources in China (with big and small lake bodies as well as the Yangtze River course and its delta), freshwater ecosystems in the area are suffering from pollution and chronic eutrophication issues for decades. Among those water bodies, Lake Taihu (Jiangsu) is the largest and most endangered one, suffering from huge nutrients loads, water scarcity, and eutrophic conditions, bringing to massive anoxia and algal blooming episodes. Those issues deeply affect not only flora and fauna ecosystems, but also human activities, since the population (more than 100 million in the watershed area) relies on water resources for agriculture, fishing, fish farming and aquaculture, as well as drinking water supplies (e.g. the extraordinary blooming event of 2007 led to drinking water shortage affecting more than 1 million people in Wuxi city).

An integrated assessment and identification of water quality stressors in this study area is therefore needed in order to understand interactions and relations between land use and human activities and water quality deterioration, with the final goal of managing and possibly reduce the driving forces behind those water quality threats.

Materials and methods

In Villa et al. (2015), we used an integrated watershed approach, based on remote sensing, to gather information about the environmental dynamics of a Lake Taihu, and we finally identified two distinct temporal patterns of algal bloom events, with an associated change in land use and environmental conditions. Prior to 2006, algal bloom initiation date was linked to land cover, in particular to winter crops productivity and the subsequent nutrient loading into the lake. After 2007, there was an inversion in this relationship between land cover and algal bloom dynamics, suggesting that nutrient saturation had occurred and other environmental factors, such as temperature and winter crops seasonality, became more important. After 2008, the situation seems to have returned to pre-2006 conditions with less intense bloom events up to 2013 (Figure 2).

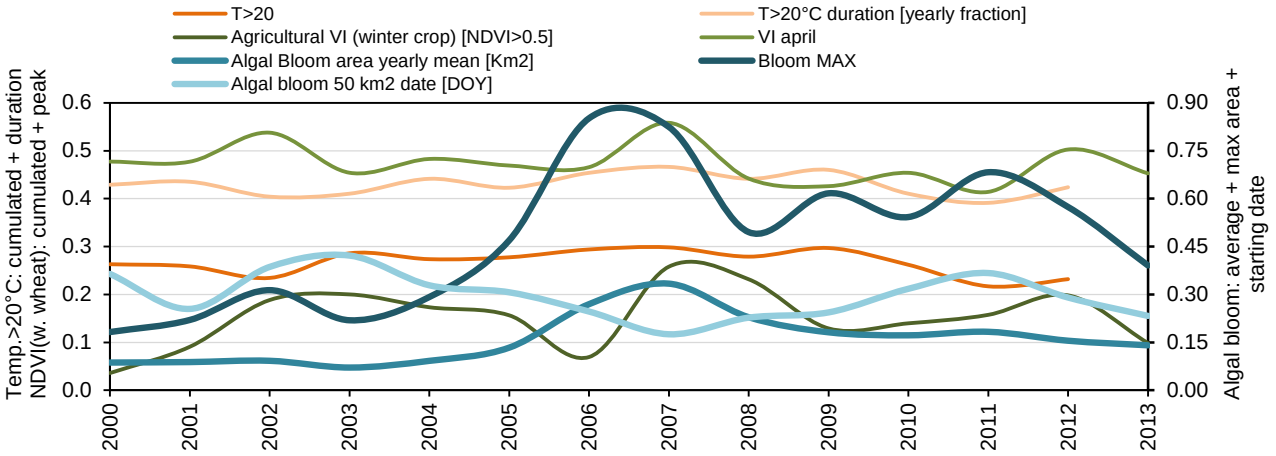

Figure 2 - Yearly variations of environmental features of Lake Taihu area covering 14 years (2000-2013), derived from monthly profiles: duration of hot season (T >20°C), Nitrogen (TN) accumulation during the winter-spring season (from January to April), Algal bloom areal extent (yearly average, mapped from MODIS), Agricultural vegetation productivity for winter crops at peak of season (cumulated NDVI>0.5 in February-May range, from MODIS), Algal bloom starting date (lake area covered by algae >50 km2, derived from MODIS). Figure adapted from Villa et al. (2015).

During the visiting period of STM 2015, we have worked on enlarging this analysis extending the multitemporal series back to the '90s and adding some additional potential stressor into the framework.
For this aim, new data were collected and merged together with the dataset used in Villa et al. (2015):

- Air Temperature (1986-2012, from Xishan Island weather station)
- Water temperature, TN, TP, Chl-a, TSM, pH, Conductivity (1991-2010, collected by Taihu Laboratory for Lake Ecosystem Research (TLLER), in 8 sampling stations shown in Figure 1)
- Water level (1990-2000, from Wuxi CMCC station; 2000-2011 from HYDROWEB satellite altimetry database)
- Precipitation (1990-2000, from Wuxi CMCC station; 2000-2014 from TRMM monthly satellite products)
- Land Cover, crop phenology and productivity, algal blooming areal extension and starting date (1992-1998, derived from Landsat 3 MSS multispectral data; 1994-1995, derived from AVHRR decadal NDVI time series; 2000-2013 derived from MODIS 250m NDVI series)
- Sediment biogeochemistry (1900-2010, from the data published by Huang et al. (2015))

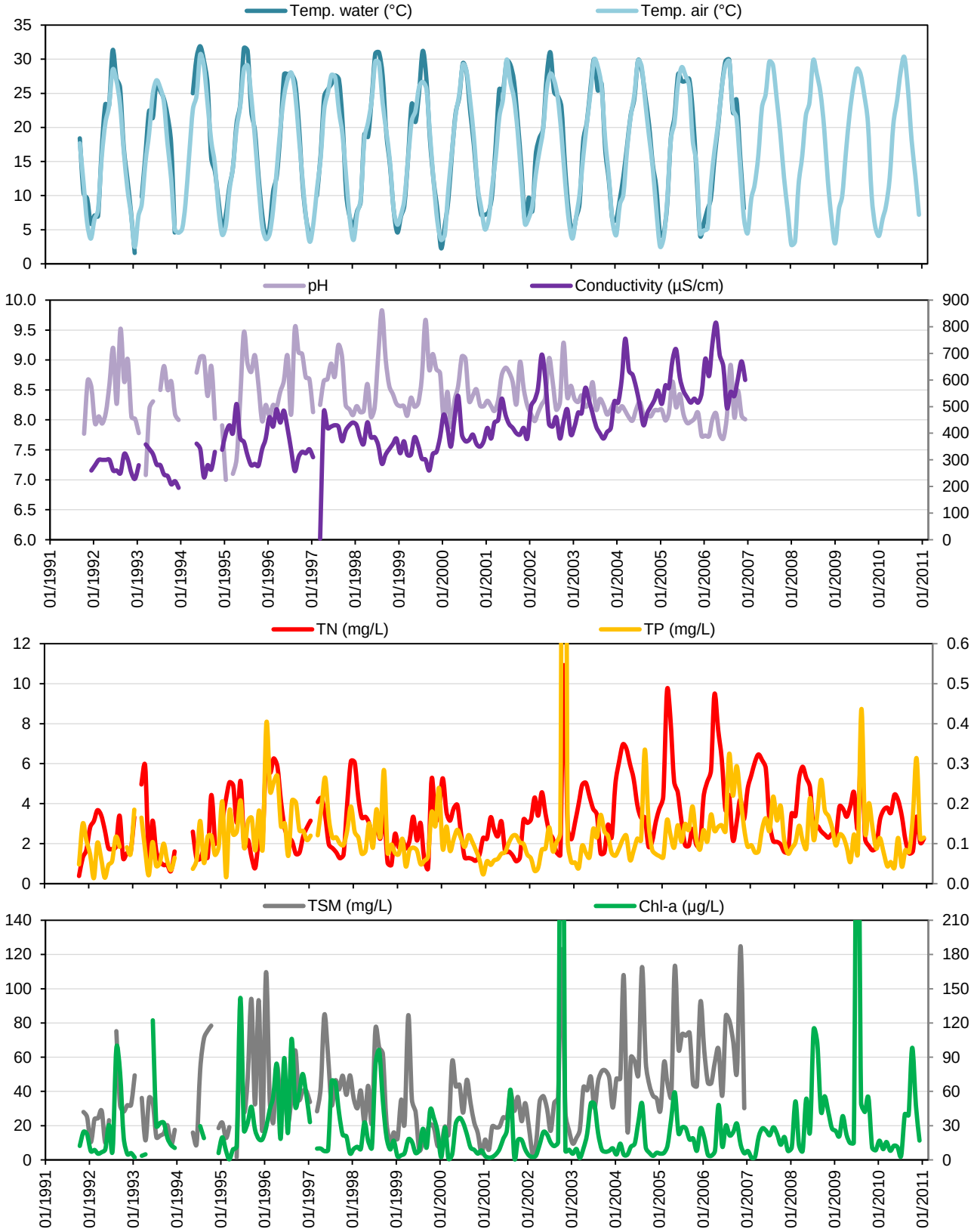

Figure 3 – Monthly profiles of biophysical and biochemical parameters sampled in THL03 station (Meiliang Bay, Northern part of Taihu), covering the period October 1991-December 2010: air and water temperature, conductivity and pH, dissolved nutrients (TN and TP), suspended matter (TSM) and chlorophyll-a concentration

Some examples of monthly data for relevant bioparameters are displayed in Figure 3. The study focused on a subset of the lake centered on Meiliang bay and its surrounding regions (up to 40-50 km radius), as Huang et al. (2015) have done in their recent work.
Multitemporal annual synthetic features for each stressor were derived and their correlation with algal blooming timing and intensity was assessed for identifying the interactions and dynamics between environmental factor analyzed and the occurrence of severe algal blooms. The preliminary results demonstrated how remote sensing can be a very effective tool for monitoring watershed dynamics in space and time, especially in conjunction with in situ data.

Seminars held

- *Crop monitoring using optical and SAR multi-temporal data: case studies in Northern Italy* (held at, Nanjing Agricultural University, on May 29th, 2015, for the National Engineering and Technology Center for Information Agriculture research group)
- *A rule-based approach for mapping macrophyte communities using multi-temporal aquatic vegetation indices* (held at NIGLAS, on June 4th, 2015, for Lake Remote Sensing Research Group)

References framework

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Date: 24/07/2015 *Signature*