Satellite data and hydrological model to assess water quantity and quality in the Yangtze river basin, ID 10664

Third year activity

Marco Mancini¹; Jiren Li²; Chiara Corbari¹ Antonio Di Trapani; Jinfeng Xin²; Jianli Zhang²; Xingnan Zhang³; Yuanhao Fang³; Bob Su⁴

1 Politecnico di Milano, Milano, Italy
2 China Institute of Water Resources and Hydropower Research, Beijing, China
3 Hohai University, Naijing, China
4 University of Twente, Twente, The Netherlands
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<th>WP4: Water Quality</th>
<th>WP5: Small cases study</th>
<th>WP6: Link with other Dragon3 projects</th>
<th>WP7: Deliverables</th>
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<td>WP4.2: Reservoir water quality from satellite</td>
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PAPERS
• Corbari, C., Mancini, M., Li, J., Su, Z., (2015), Can satellite land surface temperature data be used similarly to ground discharge measurements for distributed hydrological model calibration?, Hydrological sciences journal, 60 (1-2), 202-217

STUDENT EXCHANGE
• PhD student (Yuanhao Fang) from Hoai University (Nanjing) joined the group of Politecnico di Milano (Italy)

MASTER/PHD THESIS
• One master thesis defended in December 2014
• On going PhD thesis started in October 2014
Objectives and motivation

**Objectives:**

1) **Calibration at pixel wise of soil hydraulic** and vegetation parameters for a distributed energy-water balance model based on **land surface temperature MODIS** which is complementary to **discharge traditional calibration**
2) **lake area and water level dynamics using satellite altimetry** and visible **MERIS** data to calibrate **FEST-EWB** hydrological water balance model:
3) **Water quality parameters** from satellite along the Yangtze river

**Scientific motivation:**
1) Increasing fluxes control points to improve the mass balance accuracy for large basin area;
2) Improving the understanding of the relationship between LST and SM;
3) Improving the synergic use of hydrologic modelling and Remote Sensing data for real time water management: flood forecast and parsimonious irrigation systems.

**PROJECT RESULTS:**

- **hydrological model calibrated with the support of LST remote sensing**
- **soil moisture & evapotranspiration** estimates from remote sensing & hydrological model
- **Discharges** estimates from hydrological model → three gorges dam simulation and lakes dynamics
- **Turbidity maps from MODIS** and correlation with Yangtze hydrological regimes.
Objective: internal calibration of a distributed hydrological water balance model using satellite land surface temperature images

Is it reasonable to use evaporation flux “measures” similarly to discharge measurements?

J. Dooge (1986), internal variables.

Corbari & Mancini, 2014 (JHM)
Corbari et al., 2014, (HSJ)

Distributed hydrological model FEST-EWB - by POLIMI


[Sources: Mancini phd 90; Montaldo et al., 2007; Rabuffetti et al., 2008; Corbari et al., 2009; Ravazzani et al., 2011; Corbari et al., 2011]
Case study: Yangtze river basin

- Area: 2005500 km²
- Main length river: 2400 km
- Average Discharge: 13242 m³/s
- Cumulated annual rainfall: 816 mm

The forcing dataset used in this study was developed by Data Assimilation and Modeling Center for Tibetan Multi-spheres, Institute of Tibetan Plateau Research, Chinese Academy of Sciences.

METEOROLOGICAL FORCINGS
- 3 hours data, 5° x 5°
- Air temperature
- Rainfall
- Air relative humidity
- Incoming shortwave radiation
- Wind speed

Model pixel resolution 5 x 5 km
Land cover MERIS- ESA GLOB COVER 2009

ALBEDO, LAI, NDVI, vegetation fraction (MODIS and MERIS)

Land surface temperature
1. MODIS/Terra LST daily L3 global; \( \Delta X = 1 \) km; Number of images: 183

LAKES AREA: Three gorges dam, Poyang, Dongting, Taihu: from MERIS

Lakes water level: ALTIMETER: Topex/Poseidon, Jason-1 e 2 (revisiting time 10 days, track distance 350 km), ENVISAT (revisiting time 35 days, track distance 70 km): LEGOS database

(Creataux et al., 2011 advances in space research)
Hydrological model calibration with distributed information: satellite images of land surface temperature (LST)

Traditional calibration on point measurements (observed discharge, local soil moisture or evapotranspiration)

\[ \Delta Q = \text{Min}(Q_{\text{obs}} - Q_{\text{sim}}) \]

Pixel to pixel calibration on satellite LST

\[ \Delta T(.) = \text{Min}(\text{RET}(.) - LST(.)) \]

Not calibrated

![Not calibrated](image)

Calibrated

![Calibrated](image)

Each pixel is multiplied by a common factor which depends on discharge differences

Soil parameters: same spatial distribution

Not calibrated

![Not calibrated](image)

Calibrated

![Calibrated](image)

Each pixel is multiplied by a local factor which depends on the temperature matrix differences

Soil parameters: increased spatial variability

Corbari & Mancini, 2014 (JHM)
Corbari et al., 2014, (HSJ)
Surface parameters calibration pixel by pixel through minimising LST differences for FEST hydro model

Histograms are computed for the same number of pixels (e.g. if MODIS is covered with clouds also FEST-EWB is clouded)

FEST-EWB model can help in creating complete long time series of LST data

<table>
<thead>
<tr>
<th></th>
<th>Mean absolute difference (pixel-by-pixel) Over 183 images</th>
<th>Standard deviation of Mean difference</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before calibration</td>
<td>7.1 °C</td>
<td>10.3 °C</td>
<td>11 °C</td>
</tr>
<tr>
<td>After calibration</td>
<td>3.2 °C</td>
<td>4.2 °C</td>
<td>4.1 °C</td>
</tr>
</tbody>
</table>
FEST-EWB model: parameters calibration pixel by pixel through LST images: Ksat example

Soil hydraulic parameters: literature values from the FAO global soil type map (Harmonized World Soil Database, FAO, 2009)

- Saturated hydraulic conductivity
- Brooks-corey index
- Saturated soil moisture
- Wilting point and field capacity
- Soil depth
- Bubbling pressure

Before calibration

Ksat example

<table>
<thead>
<tr>
<th>[m/s]</th>
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<tbody>
<tr>
<td>0.0000000000</td>
</tr>
<tr>
<td>0.0000000001</td>
</tr>
<tr>
<td>0.0000000002</td>
</tr>
<tr>
<td>0.0000000003</td>
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<tr>
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<td>0.0000000006</td>
</tr>
<tr>
<td>0.0000000007</td>
</tr>
<tr>
<td>0.0000000008</td>
</tr>
<tr>
<td>0.0000000009</td>
</tr>
</tbody>
</table>

Ks=5.2*10^-4

After calibration

Ks=1.1*10^-7
Ks=5.2*10^-6

Increased spatial variability (remaining within valid values)
SIMULATED LST, LE Fluxes and SOIL MOISTURE (2003-2005)

LST (°C)

SM (-)

LE (W/m²)
Regulation policy: keeping a fix water level into the lake

I Stage of filling: 01/06/2003 – 01/10/2006

II Stage: 01/10/2006 – 01/11/2008

III Stage: 01/11/2008

Hydraulic head: 113 m

Power installed capacity GW: 18,200

Yearly average electricity generation: TWh 80

Observed data (provided by Z. Su)

FEST-EWB 2003-2006

\[ Q_s(t) - Q_{in}(t) = \frac{d}{dt} V(t) \]

\[ Q_{in}(t) = Q_{in}(t,V(t)) \]
Subsurface Discharge CALIBRATION downstream the Three Gorges Dam

Yichang discharge station

<table>
<thead>
<tr>
<th></th>
<th>R.E. % on volumes discharge</th>
<th>Nash index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non calibrated</td>
<td>-27.9</td>
<td>0.34</td>
</tr>
<tr>
<td>Calibrated</td>
<td>-7.3</td>
<td>0.6</td>
</tr>
</tbody>
</table>

High differences between discharges during monsoon and dry periods

area dynamic: FEST-EWB changes considering DEM

Area calibration against MERIS data

FEST-EWB (5km x 5km) vs MERIS (300m x 300m)

15-05-2006

1/10/2006

Mean area between 2003-2009

WATER level: satellite altimeter

LEGOS: Topex/Poseidon, Jason-1 e 2 (revisiting time 10 days, track distance 350 km), ENVISAT (revisiting time 35 days, track distance 70 km)

Error [%] -3.58
Dongting lake: area dynamic and water level satellite data and FEST-EWB modelling

Mean area between 2003-2009

**area dynamic**

![Graph showing area dynamic](image)

**WATER level: satellite altimeter**

![Graph showing water level](image)

LEGOS Topex/Poseidon, Jason-1 e 2 (revisiting time 10 days, track distance 350 km), ENVISAT (revisiting time 35 days, track distance 70 km)

<table>
<thead>
<tr>
<th>Error (%)</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.58</td>
<td>3.57</td>
</tr>
</tbody>
</table>

J.-F. Cretaux et al., 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 47 (2011) 1497-1507
Poyang lake: Simulated evaporation (LE) and water surface temperature LST

**MERIS visible**

**FEST-EWB LST**

**FEST-EWB LE**

During summer, monsoon season → bigger area, low LST, high evapotranspiration

During dry winter → small area, high evaporation

2 August 2005

19 December 2003

18 July 2003 – 12:00

10 November 2003 – 12:00

LE (W m⁻²)

LST (°C)
Subsurface Discharge CALIBRATION downstream the lakes at different gauge stations

**Hankou**

<table>
<thead>
<tr>
<th>Error [%]</th>
<th>Nash Sutcliffe index [-]</th>
</tr>
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<tbody>
<tr>
<td>17,0</td>
<td>0,221</td>
</tr>
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</table>

**Jiujiang**

<table>
<thead>
<tr>
<th>Error [%]</th>
<th>Nash Sutcliffe index [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>32,3</td>
<td>0,336</td>
</tr>
</tbody>
</table>

**Datong**

<table>
<thead>
<tr>
<th>Error [%]</th>
<th>Nash Sutcliffe index [-]</th>
</tr>
</thead>
<tbody>
<tr>
<td>34,4</td>
<td>0,39</td>
</tr>
</tbody>
</table>

Subsurface Discharge CALIBRATION downstream the lakes at different gauge stations
Flow duration curves at Yichang for water resources management for hydropower and agricultural potential use for river cross section of interest.
Water mask extraction: to delete pixels with both land and water

Only water

25m

250m

NTU = 1203.9 * R_{rs}(645nm)^{1.087}

(Chen et al., 2007)

Yichang discharge station

Turbidity

During 2006

DOY 96

DOY 135

DOY 254

DOY 275

Water quality: turbidity maps from MODIS data along the Yangtze river

1 - 25

25 - 45

45 - 65

65 - 85

85 - 100
Water quality: low correlation between MODIS turbidity and 2006 hydrological data

FIRST results

Satellite turbidity data time series are affected by cloud cover
Synergy between REMOTE SENSING and distributed Hydrological hydraulic model is a powerful tool in water resource engineering to assess water resources availability also when there is a lack of ground data:

The implemented satellite based distributed hydrologic–hydraulic model on the entire Yangtze basin is now a powerful framework for possible water engineering applications?
Many thanks!

Nanjing, Yangtze River, 23 May 2014