<table>
<thead>
<tr>
<th>Title</th>
<th>Quantification of variability change in Terrestrial Hydrological Processes over the Pearl River Basin in South China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Niu, J; Chen, J</td>
</tr>
<tr>
<td>Citation</td>
<td>The PRAGMA 20th Workshop cum HKU Centennial IT Conference on Grid Applications and Research collaboration (PRAGMA20), Computer Centre, The University of Hong Kong, Hong Kong, China, 2-4 March 2011.</td>
</tr>
<tr>
<td>Issued Date</td>
<td>2011</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/10722/140746">http://hdl.handle.net/10722/140746</a></td>
</tr>
<tr>
<td>Rights</td>
<td>This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.</td>
</tr>
</tbody>
</table>
Quantification of Variability Change in Terrestrial Hydrological Processes over the Pearl River Basin in South China

Jun NIU and Ji CHEN

Department of Civil Engineering
The University of Hong Kong
Mar. 3, 2011
The Pearl River basin

- Total basin area 453,690 km²
- Average Annual precipitation 1477mm
- Four river systems: West River, North River, East River, Pearl River Delta
- Annual runoff generation 0.74 million m³/km²
- \( (Q_{\text{wet}}/Q_{\text{dry}})_{\text{max}} = 6\sim7 \) (inter-annual)
- \( Q_{\text{Apr-Sep}} \approx 80\% Q_{\text{annual}} \)
10 sub-basins for the Pearl River basin

- Comparable basin area;
- Available observation data;
- Discriminative geographic features.
Flood events in the Pearl River basin

**Whole Basin Floods:** 1968.6-8, 1994.6, 2005.6

**The East River Floods:** 1959.6, 1966.6, 1979.7

**The North River Flood:** 1982.5


**The Nanpan&Beipan Floods:** 1991.7

**The Zuoyu Floods:** 1986.7, 2001.7

**The Liujiang Flood:** 1996.7

---

**Jun. 2005**

**Wuzhou, Guangxi Province:**

**Peak Flood Level:** 26.75m

**Return Period:**
- 100 years for West River
- 10 years for North River
- 20 years for East River

**Population affected:** 12.6 million

**Economic loss:** 13.6 billion RMB
## Drought condition in the Pearl River basin

### Distribution of drought frequency in China

![Map of China showing drought frequency](http://disg.eq-igl.ac.cn)

**Drought Disaster Area of Pearl River Basin**

<table>
<thead>
<tr>
<th>Year</th>
<th>Pearl River</th>
<th>West River</th>
<th>North River</th>
<th>East River</th>
<th>Pearl River Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963</td>
<td>2216.11</td>
<td>1621.63</td>
<td>183.05</td>
<td>137.31</td>
<td>274.11</td>
</tr>
<tr>
<td>1977</td>
<td>1691.81</td>
<td>1044.21</td>
<td>166.55</td>
<td>125.29</td>
<td>355.77</td>
</tr>
<tr>
<td>1956</td>
<td>1543.84</td>
<td>1126.07</td>
<td>97.85</td>
<td>59.42</td>
<td>260.49</td>
</tr>
<tr>
<td>1960</td>
<td>1254.99</td>
<td>815.21</td>
<td>41.07</td>
<td>45.17</td>
<td>353.53</td>
</tr>
<tr>
<td>1955</td>
<td>820.26</td>
<td>497.69</td>
<td>150.00</td>
<td>60.56</td>
<td>112.25</td>
</tr>
<tr>
<td>1957</td>
<td>775.61</td>
<td>648.17</td>
<td>26.25</td>
<td>20.65</td>
<td>80.54</td>
</tr>
<tr>
<td>1954</td>
<td>684.41</td>
<td>550.91</td>
<td>83.83</td>
<td>5.89</td>
<td>43.78</td>
</tr>
</tbody>
</table>


**The severest drought event:**

1963

**Other drought events:**

The VIC-NL model represents surface and subsurface hydrologic processes on a spatially distributed (grid cell) basis.

Energy and water balance terms are computed independently for each coverage class (vegetation and bare soil) present in the model.

Processes governing the flux and storage of water and heat in each cell-sized system of vegetation and soil structure include:
- Evaporation from the soil layers (E)
- Evapotranspiration (E_t)
- Canopy interception evaporation (E_c)
- Latent heat flux (L)
- Sensible heat flux (S)
- Longwave radiation (R_L)
- Shortwave radiation (R_S)
- Ground heat flux (G)
- Infiltration (i)
- Percolation (Q)
- Runoff (R)
- Baseflow (B)
## Validation of streamflow simulation

<table>
<thead>
<tr>
<th>Station</th>
<th>Number of months*</th>
<th>Mean(O) (mm/mon)</th>
<th>Mean(S) (mm/mon)</th>
<th>RB</th>
<th>RRMSE</th>
<th>NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhedong</td>
<td>360</td>
<td>46.14</td>
<td>45.02</td>
<td>-0.02</td>
<td>0.59</td>
<td>0.72</td>
</tr>
<tr>
<td>Baise</td>
<td>355</td>
<td>32.65</td>
<td>36.43</td>
<td>0.12</td>
<td>0.52</td>
<td>0.78</td>
</tr>
<tr>
<td>Nanning</td>
<td>372</td>
<td>43.34</td>
<td>54.56</td>
<td>0.26</td>
<td>0.45</td>
<td>0.80</td>
</tr>
<tr>
<td>Liuzhou</td>
<td>360</td>
<td>71.24</td>
<td>64.91</td>
<td>-0.09</td>
<td>0.32</td>
<td>0.90</td>
</tr>
<tr>
<td>Wuzhou</td>
<td>264</td>
<td>51.53</td>
<td>53.21</td>
<td>0.03</td>
<td>0.23</td>
<td>0.93</td>
</tr>
<tr>
<td>Gaoyao</td>
<td>212</td>
<td>54.35</td>
<td>56.64</td>
<td>0.04</td>
<td>0.16</td>
<td>0.96</td>
</tr>
<tr>
<td>Shijiao</td>
<td>240</td>
<td>96.13</td>
<td>81.90</td>
<td>-0.18</td>
<td>0.32</td>
<td>0.85</td>
</tr>
<tr>
<td>Boluo</td>
<td>420</td>
<td>77.35</td>
<td>77.17</td>
<td>-0.01</td>
<td>0.52</td>
<td>0.56</td>
</tr>
<tr>
<td>Xinfengjiang</td>
<td>84</td>
<td>76.03</td>
<td>71.77</td>
<td>-0.06</td>
<td>0.39</td>
<td>0.85</td>
</tr>
<tr>
<td>Longchuan</td>
<td>252</td>
<td>77.28</td>
<td>61.29</td>
<td>-0.21</td>
<td>0.41</td>
<td>0.82</td>
</tr>
</tbody>
</table>

* Number of available monthly flow observations in the period of 1952-1988.
Spectral analysis: Fourier transform & Wavelet transform

\[ F(\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t} dt \]

Constituent sinusoids of different frequencies

\[ C(\text{scale, position}) = \int_{-\infty}^{\infty} f(t)\psi(\text{scale, position}, t) dt \]

Constituent wavelets of different scales and positions

- Low scale  \( a \)  ➔ Compressed wavelet ➔ Rapidly changing details ➔ High frequency  \( \omega \)
- High scale  \( a \)  ➔ Stretched wavelet ➔ Slowly changing coarse features ➔ Low frequency  \( \omega \)

Reference: Wikipedia & MATLAB
Example: wavelet transform of annual precipitation

\[
\psi(x) = \frac{2}{\sqrt{3}} \pi^{-1/4} (1 - x^2) e^{-x^2/2}
\]

<table>
<thead>
<tr>
<th>Year</th>
<th>Anomaly (mm)</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50s</td>
<td>-16.09</td>
<td>-1.08</td>
</tr>
<tr>
<td>60s</td>
<td>-7.48</td>
<td>-0.50</td>
</tr>
<tr>
<td>70s</td>
<td>+22.61</td>
<td>+1.52</td>
</tr>
<tr>
<td>80s</td>
<td>-41.78</td>
<td>-2.81</td>
</tr>
<tr>
<td>90s</td>
<td>+42.75</td>
<td>+2.87</td>
</tr>
</tbody>
</table>

Annual precipitation decadal anomalies in the Pearl River basin during 1951-2000

- Whole basin floods: 1968, 1994
- The severest drought: 1963
Variability transfer in East River

Local spectrum

Global spectrum

Precipitation

Streamflow

Soil moisture

VIC model
Northeastern Region
(e.g., Guihe River)

[Map of the Northeastern Region showing the Guihe River and surrounding rivers and elevation levels.]

[Graphs showing global wavelet power for precipitation, streamflow, and soil moisture.]
Middle Region
(e.g., Hongshui River)

- Precipitation
- Streamflow
- Soil moisture
Southern Region
(e.g., WR Lower Reach)

Precipitation

Streamflow

Soil moisture
Multi-scale wavelet power ratio

Wavelet power ratio vs. period (years)

Hongshui River

Guihe River

Youjiang River

WR Lower Reach

Streamflow / Precipitation
Soil moisture / Precipitation
Variability relationships

- The streamflow variability can be reflected by the precipitation variability at long timescales (longer than 2-year periods for most of the subbasins in the Pearl River basin).

- The soil moisture variability can reflect even longer timescales of precipitation variability than the streamflow, and may further extend precipitation variability at much longer timescales due to the terrestrial system memory for precipitation variability.

- The above variability relationships vary for different subbasins, which can be partly attributed to their geographic characteristics.
Thank you!