Relationship between Climate Change in South China and Urbanization in the Pearl River Delta

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Workshop on Climate Change and Climate Prediction in the Pearl River Delta Region
December 15-16, 2008
Outline:

• Introduction
• Research objectives
• Data and the area of interest
• Methodology
• Results and discussion
• Conclusions
Variations of the Earth’s surface temperature over the last 140 years (source: Intergovernmental Panel on Climate Change (IPCC), 2001)
Introduction 2:

Potential climate changes impact

Temperature

Sea level rise

Precipitation

Impacts on...

Health
- Weather-related mortality
- Infectious diseases
- Air-quality respiratory illnesses

Agriculture
- Crop yields
- Irrigation demands

Forest
- Forest composition
- Geographic range of forest
- Forest health and productivity

Water resources
- Water supply
- Water quality
- Competition for water

Coastal areas
- Erosion of beaches
- Inundation of coastal lands
- Additional costs to protect coastal communities

Species and natural areas
- Loss of habitat and species
- Cryosphere: diminishing glaciers

Source: United States Environmental Protection Agency
The global surface temperature has increased around 0.6 °C since the late 19th century (IPCC, 2001);

Urbanization effect has a great impact on climate change (Collier, 2006; Kalnay & Cai, 2003);

South China, especially Guangdong Province, is a fast socio-economic developing and urbanized area in China.
Research Objectives

- Analysis of climate change characteristic in South China, including temperature, precipitation and relative humidity
- Investigation of the impact of urbanization on climate variation in South China
Area interested and Data

- Area:
  - Latitude: 21N~25N
  - Longitude: 111E~116E
  - 21 stations involved
Area interested and Data

- **Data**: from 1960 to 2005
  - Monthly average of daily Tmax, Tmin, precipitation, relative humidity
    (by: Chinese National Meteorological Center)
Methodologies

- Two non-parametric statistical methods
  
  **Sen slope**
  
  \[ b_{ij} = \frac{y_i - y_j}{x_i - x_j} \]

  Sen’s method is used for the estimation of trend. The slopes \( b_{ij} \) are first computed between each possible pair of datapoints \((x_i, y_i)\) and \((x_j, y_j)\).

  The trend estimate is then the median of all the pairwise slopes. (Sen, 1968)
Mann-Kendall test

\[
\tau = \frac{\text{concordant} - \text{discordant}}{\sqrt{\text{concordant} + \text{discordant} + \text{same}_X} \sqrt{\text{concordant} + \text{discordant} + \text{same}_Y}}
\]

Concordant is the number of pairs where the relative ordering of x and y are the same; discordant where they are the opposite; (Sen, 1968)
Comparison of parametric and non-parametric methods

- Nonparametric methods are based on relative ranks of data points; therefore, there are no data distribution requirement (Haan, 2002).
- Least squares estimation for linear models is notoriously non-robust to outliers. In the presence of any outliers, the estimates can be biased and inefficient.
Time series of annual average of Tmax anomalies from 1960 to 2005

All four stations show increasing trends. The trends in Guangzhou and Shenzhen are statistically significant. The minimum temperature occurs in 1984 for all four stations.
Time series of annual average of Tmin anomalies from 1960 to 2005

All of the increases are statistically significant at $\alpha = 5\%$
**Tmax Change from 1960 to 2005 and from 1984 to 2005**

From 1960 to 2005

Tmax $\uparrow$ 0.54 °C (0.117 °C/dec.)
≈ global rate (0.141 °C/dec.)

From 1984 to 2005

Tmax $\uparrow$ 1.44 °C (0.655 °C/dec.)
> global rate (0.287 °C/dec.)
Tmin Change from 1960 to 2005 and from 1984 to 2005

From 1960 to 2005

Tmin \(\uparrow\) 1.12 °C (0.243 °C/dec.)
≈ global rate (0.204 °C/dec.)

From 1984 to 2005

Tmin \(\uparrow\) 1.20 °C (0.545 °C/dec.)
> global rate (0.295 °C/dec.)
Tmean Change from 1960 to 2005 and from 1984 to 2005

From 1960 to 2005

From 1984 to 2005

\[ T_{\text{mean}} = \frac{(T_{\text{max}} + T_{\text{min}})}{2} \]

\[ T_{\text{mean}} \uparrow 0.82 \, ^\circ \text{C} \approx \text{global rate} \]

\[ T_{\text{mean}} \uparrow 1.32 \, ^\circ \text{C} > \text{global rate} \]
Comparison of regional and global Tmean change

<table>
<thead>
<tr>
<th></th>
<th>Tmean Change (°C)</th>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1960-2005</td>
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<td>Global land surface</td>
<td>0.87</td>
<td>0.67</td>
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<td>0.82</td>
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(Global data source: Hadley centre, UK)
### Comparison of regional and global Tmean change

#### Tmean Change (°C)

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(Global data source: Hadley centre, UK)
Time series of annual mean of DTR from 1960 to 2005

DTR (Diurnal Temperature Range) = Tmax - Tmin
DTR Change from 1960 to 2005 and from 1984 to 2005

Legend

<table>
<thead>
<tr>
<th>Change Value</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2.2 to -2.0</td>
<td>Dark Blue</td>
</tr>
<tr>
<td>-2.0 to -1.8</td>
<td>Light Blue</td>
</tr>
<tr>
<td>-1.8 to -1.6</td>
<td>Light Red</td>
</tr>
<tr>
<td>-1.6 to -1.4</td>
<td>Medium Blue</td>
</tr>
<tr>
<td>-1.4 to -1.2</td>
<td>Medium Red</td>
</tr>
<tr>
<td>-1.2 to -1.0</td>
<td>Dark Red</td>
</tr>
<tr>
<td>-1.0 to -0.8</td>
<td>Dark Orange</td>
</tr>
<tr>
<td>-0.8 to -0.6</td>
<td>Medium Orange</td>
</tr>
<tr>
<td>-0.6 to -0.4</td>
<td>Light Orange</td>
</tr>
<tr>
<td>-0.4 to -0.2</td>
<td>Light Yellow</td>
</tr>
<tr>
<td>-0.2 to 0.0</td>
<td>Light Green</td>
</tr>
<tr>
<td>0.0 to 0.2</td>
<td>Green</td>
</tr>
<tr>
<td>0.2 to 0.4</td>
<td>Yellow</td>
</tr>
<tr>
<td>0.4 to 0.6</td>
<td>Light Yellow</td>
</tr>
<tr>
<td>0.6 to 0.8</td>
<td>Light Green</td>
</tr>
<tr>
<td>0.8 to 1.0</td>
<td>Light Blue</td>
</tr>
<tr>
<td>1.0 to 1.2</td>
<td>Blue</td>
</tr>
</tbody>
</table>

From 1960 to 2005

From 1984 to 2005
Urban and other land-use changes accounted for at least half of the observed decrease in diurnal temperature range

(Kraganza et al. (2004). Diurnal temperature range as an index of global climate change during the twentieth century)
(Kalnay & Cai (2003). Impact of urbanization and land-use change on climate)

In US, urbanization decreases Tmax and increases Tmin, leading to decreased DTR

## Population and GDP development for part of the cities

<table>
<thead>
<tr>
<th>City</th>
<th>Population 1983</th>
<th>Population 2005</th>
<th>GDP (*100,000,000 Yuan) 1983</th>
<th>GDP (*100,000,000 Yuan) 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lianxian</td>
<td>432903</td>
<td>508129</td>
<td>0.74</td>
<td>37.89</td>
</tr>
<tr>
<td>Shaoguan</td>
<td>335581</td>
<td>907139</td>
<td>10.37</td>
<td>186.99</td>
</tr>
<tr>
<td>Fogang</td>
<td>239359</td>
<td>311357</td>
<td>0.28</td>
<td>31.19</td>
</tr>
<tr>
<td>Lianping</td>
<td>297917</td>
<td>378438</td>
<td>0.17</td>
<td>27.78</td>
</tr>
<tr>
<td>Guangping</td>
<td>454444</td>
<td>543646</td>
<td>0.60</td>
<td>33.99</td>
</tr>
<tr>
<td>Guangning</td>
<td>712952</td>
<td>728732</td>
<td>1.28</td>
<td>95.00</td>
</tr>
<tr>
<td>Gaoyao</td>
<td>563950</td>
<td>290515</td>
<td>1.36</td>
<td>51.32</td>
</tr>
<tr>
<td>Heyuan</td>
<td>587165</td>
<td>794295</td>
<td>1.00</td>
<td>269.68</td>
</tr>
<tr>
<td>Wuhua</td>
<td>878461</td>
<td>1252793</td>
<td>0.43</td>
<td>37.74</td>
</tr>
<tr>
<td>Luoding</td>
<td>789028</td>
<td>1106101</td>
<td>1.48</td>
<td>58.89</td>
</tr>
<tr>
<td>Taishan</td>
<td>945382</td>
<td>987514</td>
<td>2.93</td>
<td>109.49</td>
</tr>
<tr>
<td><strong>Guangzhou</strong></td>
<td><strong>3170029</strong></td>
<td><strong>6172839</strong></td>
<td><strong>108.87</strong></td>
<td><strong>4792.44</strong></td>
</tr>
<tr>
<td><strong>Shenzhen</strong></td>
<td><strong>481400</strong></td>
<td><strong>6068900</strong></td>
<td><strong>7.20</strong></td>
<td><strong>4950.91</strong></td>
</tr>
</tbody>
</table>

(Source: Guangdong Statistical Yearbook)
Development of Population, GDP & Built-up Area for slow-developing-city (SDC) and fast-developing-city (FDC)

Devel. rate=(V_{2005}-V_{1983})/V_{1983}

<table>
<thead>
<tr>
<th>Devel. Rate</th>
<th>Popu.</th>
<th>Built-up Area</th>
<th>GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDC</td>
<td>23.30%</td>
<td>247%</td>
<td>4950%</td>
</tr>
<tr>
<td>FDC</td>
<td>235.30%</td>
<td>662%</td>
<td>8294%</td>
</tr>
</tbody>
</table>

![Graphs showing population, GDP, and built-up area development over years for SDC and FDC.]
Urbanization Attribution for temperature change from 1961 to 2005

Tmax Anomaly

Year

SDC
FDC

Tmin Anomaly

Year

SDC
FDC

Tmin, 0.20 °C/dec.
FDC, 0.58 °C/dec.
Urbanization Attribution for temperature change from 1984 to 2005

Urban warming accounts for 58% of Tmin increase in FDC

Tmin
SDC, 0.46 °C/dec.
FDC, 1.09 °C/dec.
Time series of annual mean of precipitation from 1960 to 2005

All changes are not significant at statistical 5% level.
Precipitation Change from 1960 to 2005 and from 1984 to 2005

From 1960 to 2005

From 1984 to 2005
Urbanization Attribution for precipitation change from 1960 to 2005

From 1960 to 2005, precipitation increasing rate is 6.44mm/dec. in SDC; precipitation increasing rate is 33.35mm/dec. in FDC.
From 1984 to 2005, precipitation increasing rate is 15.88mm/dec. in SDC; precipitation increasing rate is 124.44mm/dec. in FDC
Time series of annual mean of relative humidity from 1960 to 2005

- Annual mean of relative humid in Lianxian
- Annual mean of relative humid in Shaoguan
- Annual mean of relative humid in Guangzhou
- Annual mean of relative humid in Shenzhen

All trends are decreasing, except Shaoguan.
Relative Humidity Change from 1960 to 2005 and from 1984 to 2005

From 1960 to 2005

From 1984 to 2005
From 1960 to 2005, relative humidity decreasing rate in SDC is 0.0049/decade; decreasing rate in FDC is 0.0147/decade.
Urbanization attribution for relative humidity change from 1984 to 2005

From 1984 to 2005, relative humidity decreasing rate in SDC is 0.0092/decade; decreasing rate in FDC is 0.0148/decade.
Conclusions

1. Climate change:
   - **Temperature**: Increase significantly in study region
     - 1960 to 2005 Tmean $\uparrow$ 0.178 °C/dec. $\approx$ global rate
     - 1984 to 2005 Tmean $\uparrow$ 0.287 °C/dec. $>$ global rate;
   - **Precipitation**: Overall, increased but not significant
   - **Relative humidity**: decreased significantly

2. Urbanization effect on climate change
   - **Temperature**:
     - 1960~2005 Tmin $\uparrow$ 0.38 °C/dec. more in FDC than in SDC
     - 1984~2005 Tmin $\uparrow$ 0.63 °C/dec. more in FDC than in SDC
   - **Precipitation**:
     - 1960~2005 Precipitation $\uparrow$ 26.91mm/dec. more in FDC than in SDC
     - 1984~2005 Precipitation $\uparrow$ 108.56mm/dec. more in FDC than in SDC
   - **Relative Humidity**:
     - 1960~2005 Relative humidity $\downarrow$ 0.0098/dec. more decrease in FDC
     - 1984~2005 Relative humidity $\downarrow$ 0.0056/dec. more decrease in FDC
Thank you!