

由HHT探討台灣地溫變化的特性

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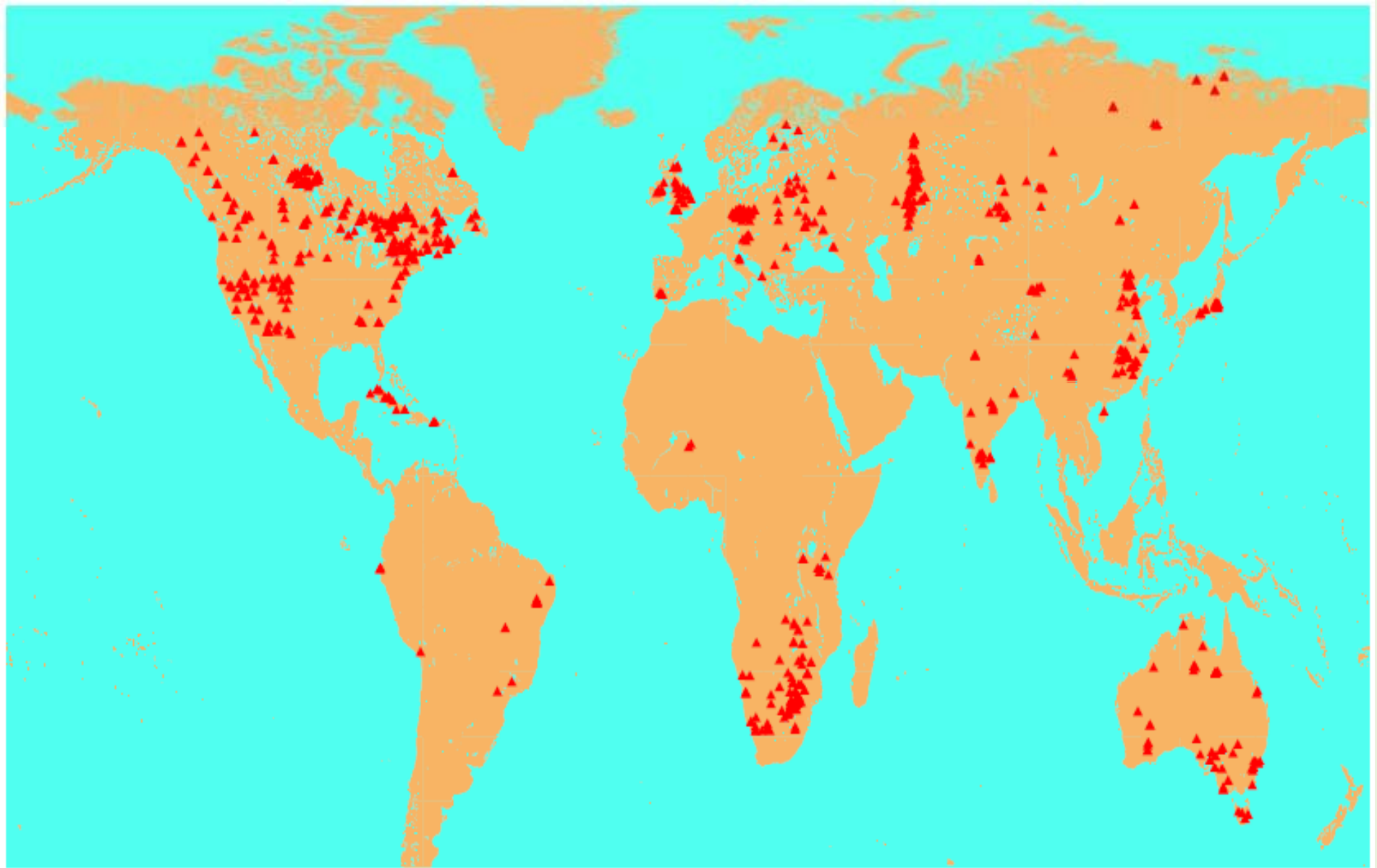
在全球暖化的大背景下，包括熱環境在內的氣候環境已經發生了明顯變化。

但目前大多數熱環境研究只是側重於對環境系統中大氣熱狀態的研究，往往忽略了大氣與其他環境系統組成部分，特別是與地下土壤、水和岩石的相互作用，缺乏區域熱環境分析。

地溫變化是熱環境變化的一個重要組成部分，由於土壤和岩石的導熱性較空氣對流要差得多，地溫變化比氣溫變化更為持久和顯著。

綜合氣象觀測、衛星遙感和地溫資料開展包括大氣、土壤、地下水和淺層岩石在內的熱環境系統研究是今後熱環境研究的一個重要發展方向。

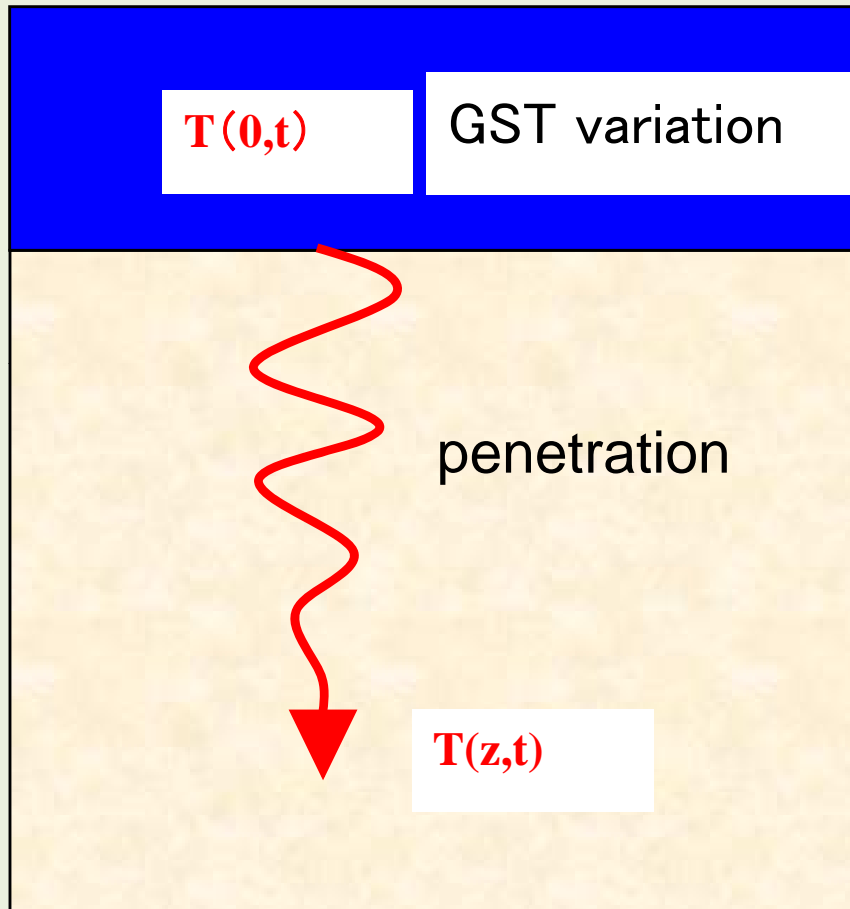
另一個具發展前景的研究方向是經由對熱環境系統的深入認識，進一步探討城市熱環境變化對經濟社會發展和居住健康的影響，對於在全球氣候暖化的節能減排，更具有特殊的意義。



Locations of the borehole sites (~950) of the global database of subsurface temperatures for climate reconstruction. Currently, Taiwan is absent in the database.

<http://www.ncdc.noaa.gov/paleo/borehole/borehole.html>

Penetration of surface temperature variation into subsurface

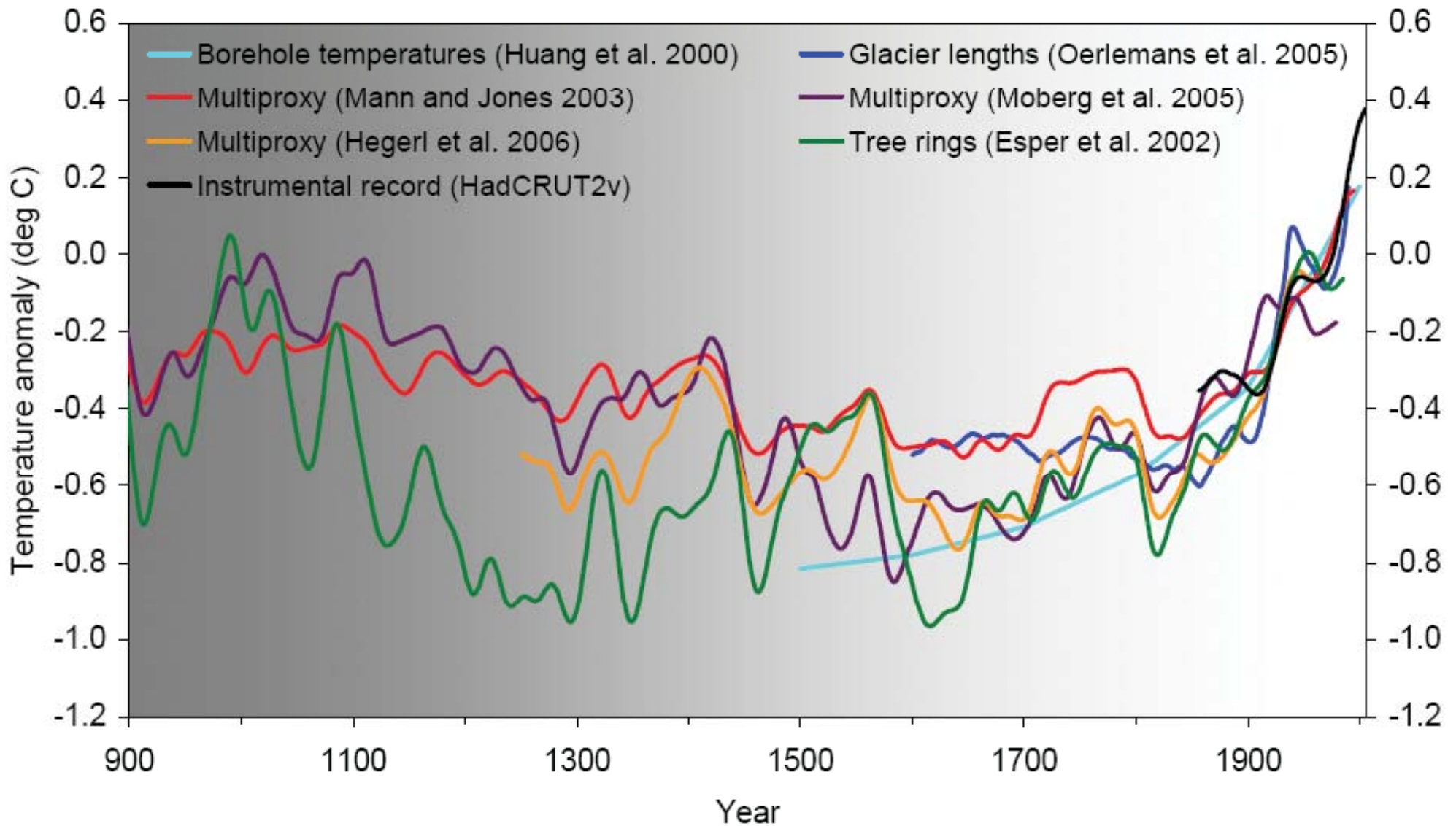


Thermal diffusion

$$\frac{\partial T}{\partial t} = \kappa \frac{\partial^2 T}{\partial z^2}$$

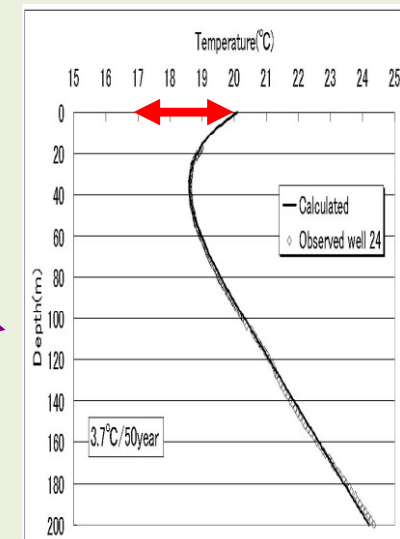
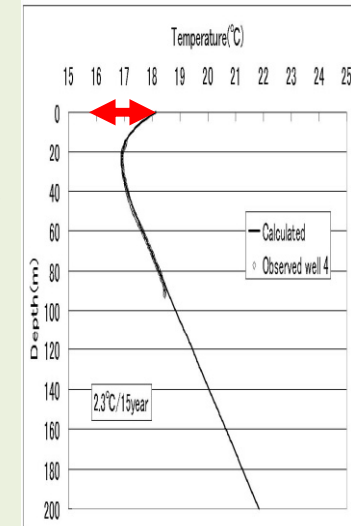
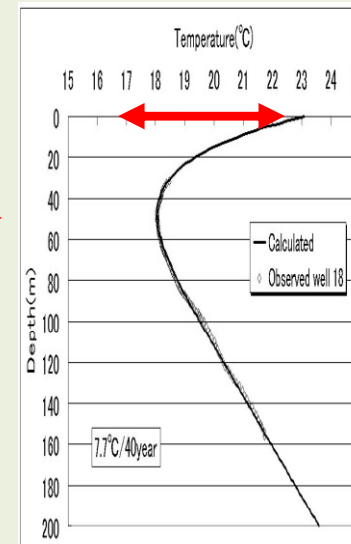
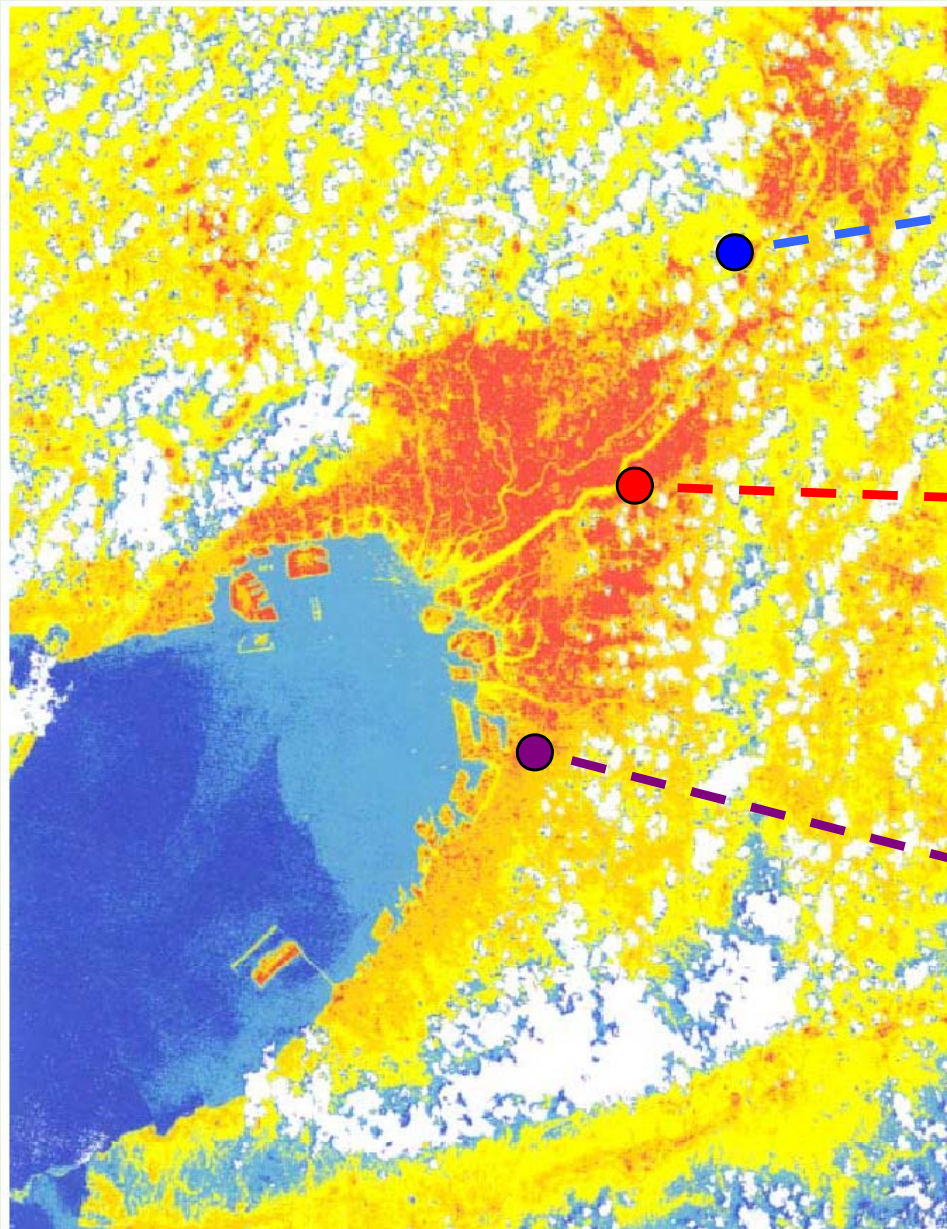
κ : thermal diffusivity

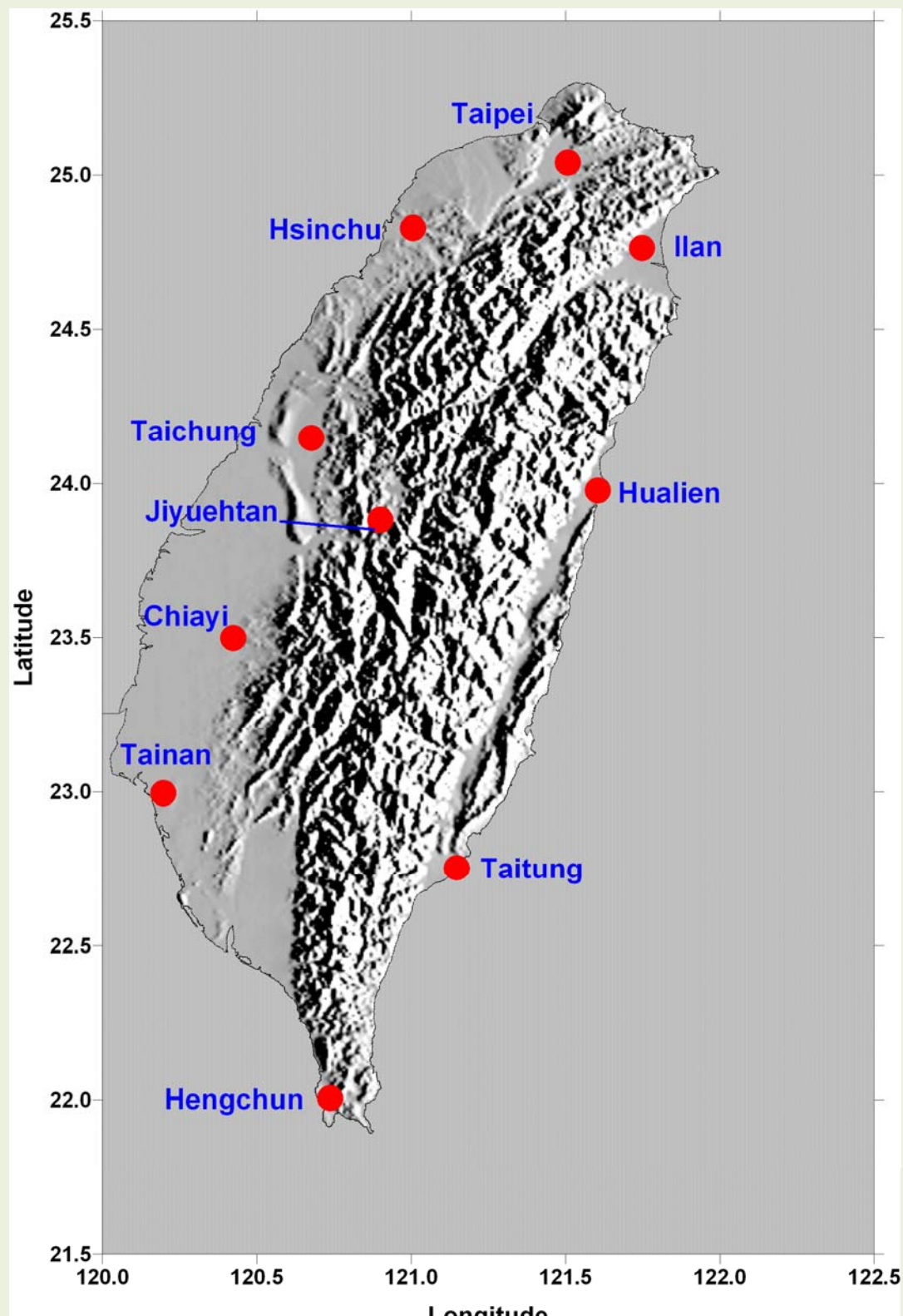
Information on the past
has been recorded in the subsurface.



Comparison of selected reconstructions to instrumental record. The figure is taken from National Research Council (2006, Figure S1).

Effect of heat island around Osaka

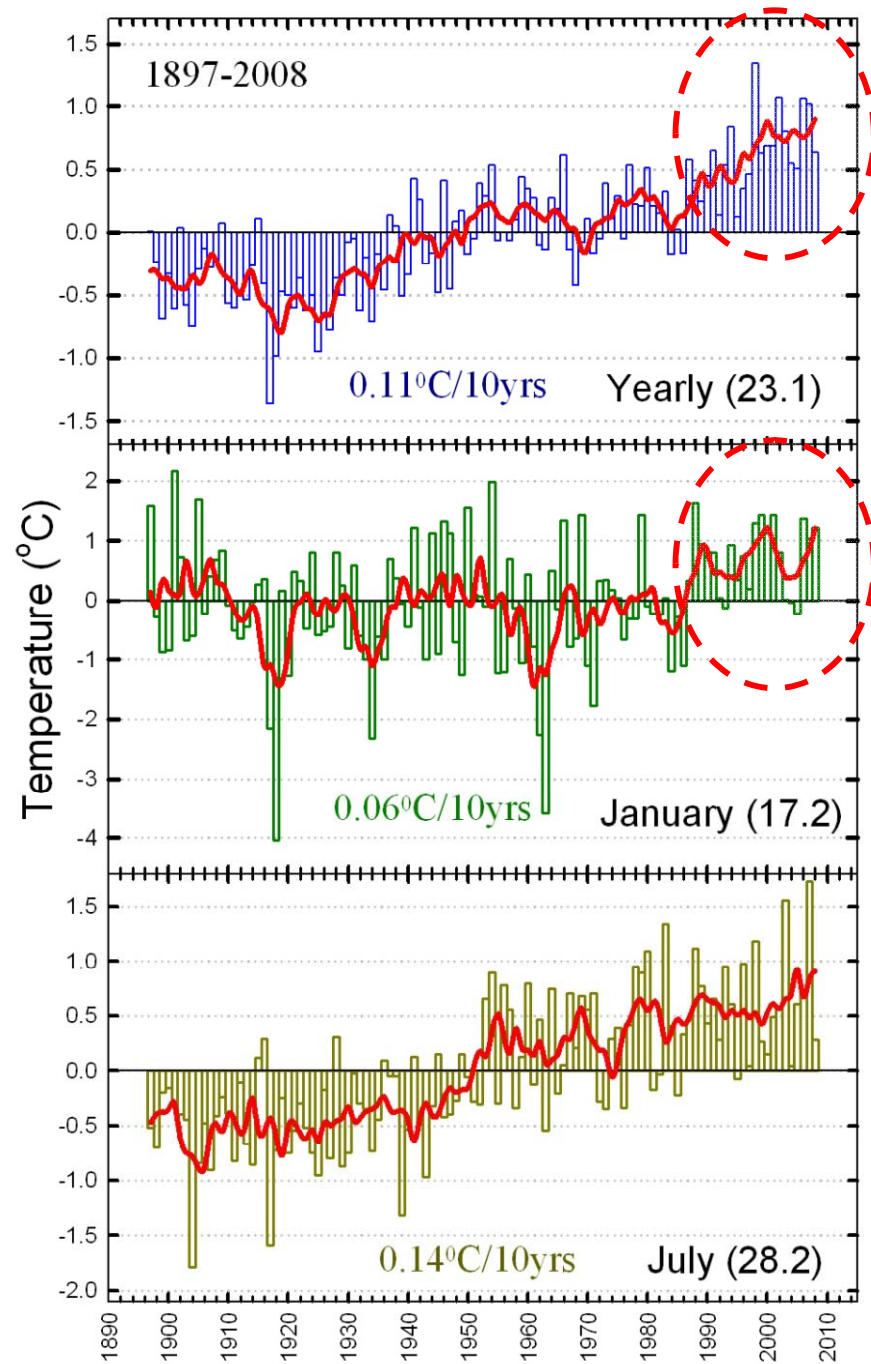




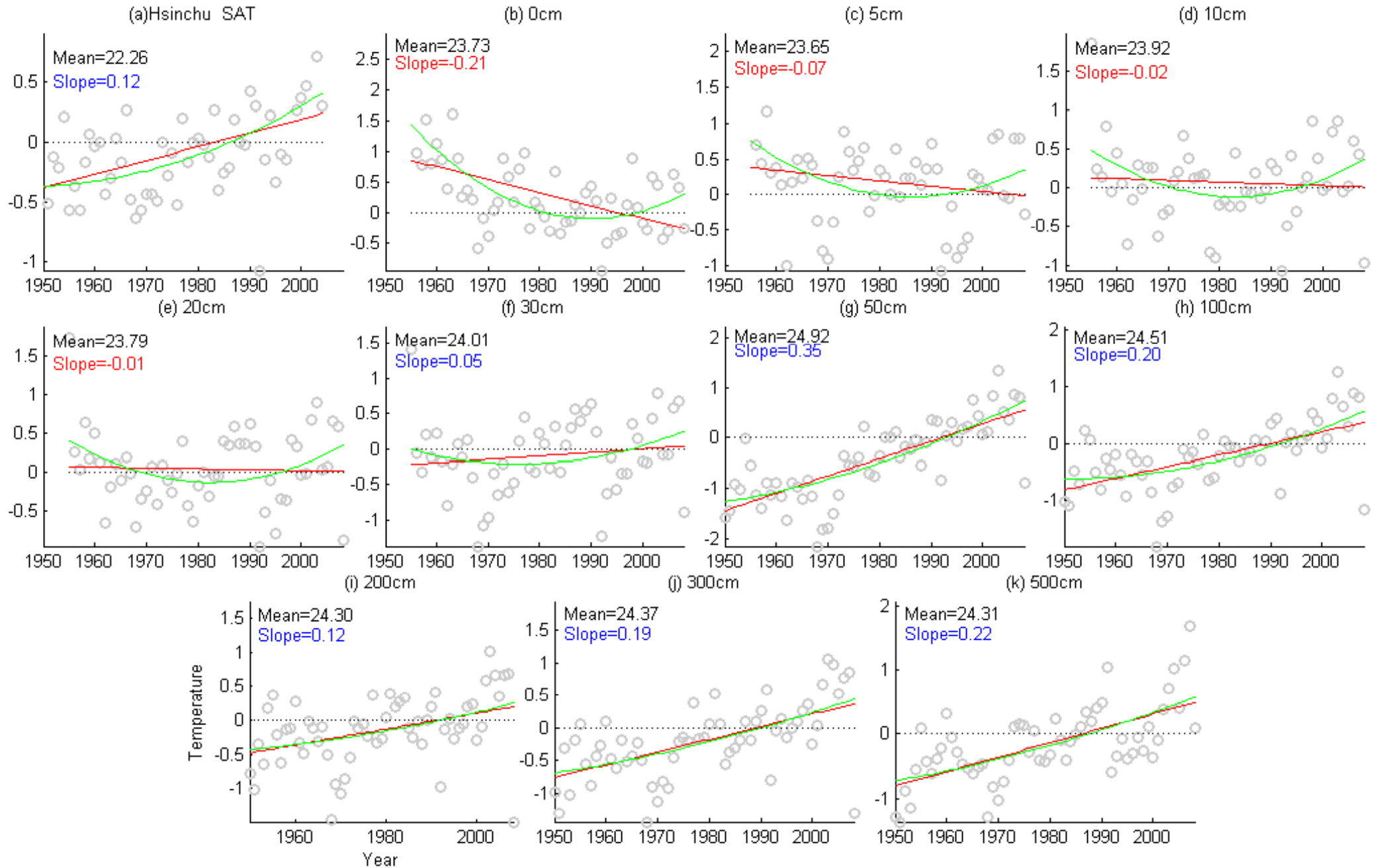
Locations of selected stations in this study with subsurface temperature records observed by Central Weather Bureau since 1900.

Data Continuity

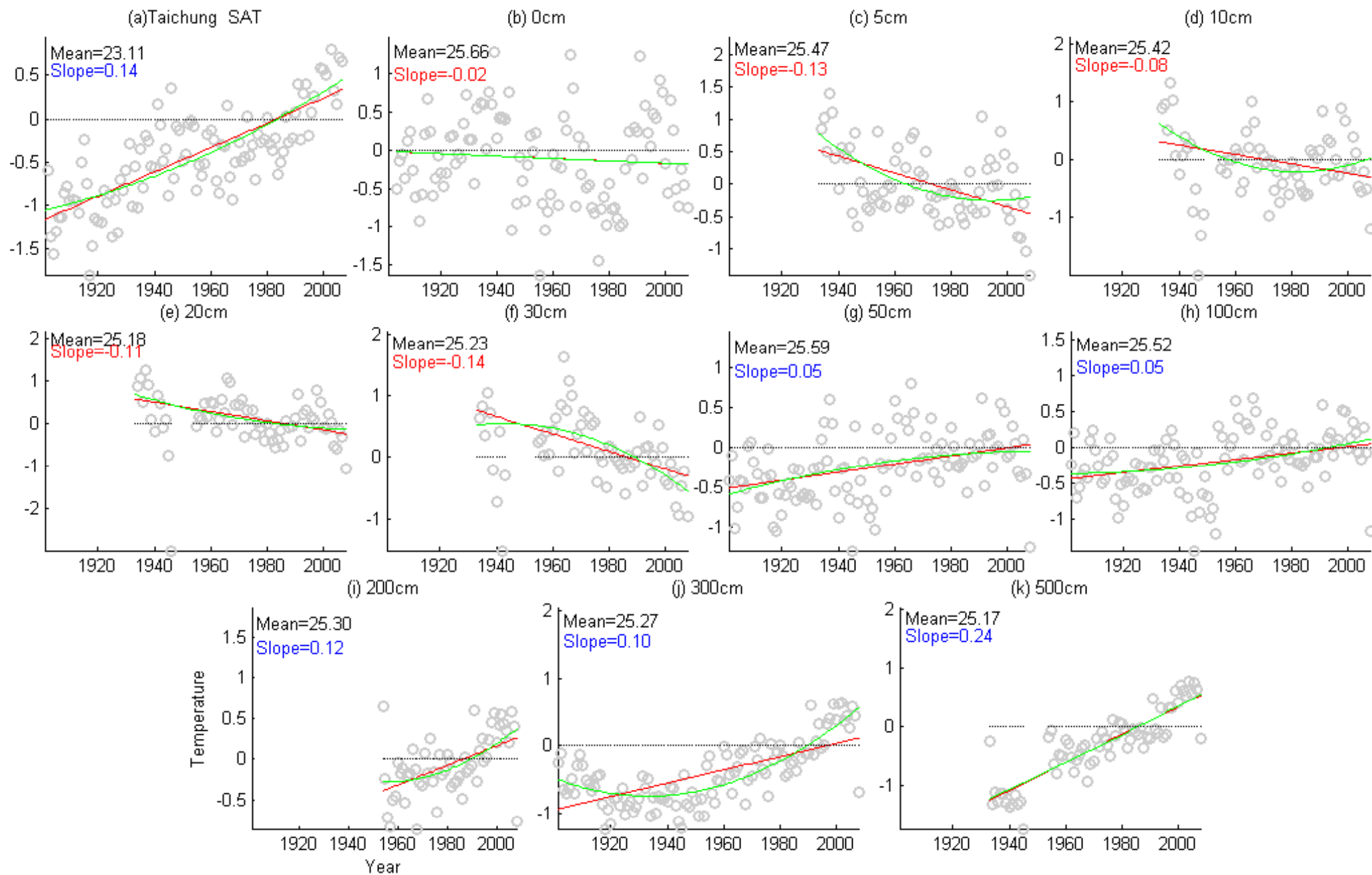
| Stations | Long. | Lat. | Periods | 0cm | 5cm | 10cm | 20cm | 30cm | 50cm | 100cm | 200cm | 300cm | 500cm (%) |
|-----------|--------|-------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-----------|
| Taipei | 121.51 | 25.04 | 1930-1996 | 99.4 | 99.6 | 99.4 | 99.4 | 72.6 | 99.6 | 99.6 | 99.5 | 97.2 | 91.0 |
| Hsinchu | 121.01 | 24.83 | 1939- | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.7 | 99.6 |
| Taichung | 120.68 | 24.15 | 1901- | 99.5 | 99.9 | 93.9 | 89.4 | 85.9 | 99.9 | 99.9 | 100.0 | 99.9 | 88.4 |
| Jiyuehtan | 120.9 | 23.88 | 1950- | 98.8 | 98.8 | 98.8 | 92.2 | 98.3 | 98.9 | 98.9 | 98.9 | 98.0 | 98.0 |
| Chiayi | 120.42 | 23.5 | 1968- | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 |
| Tainan | 120.2 | 23 | 1900-2001 | 99.9 | 99.8 | 95.3 | 89.7 | 88.2 | 96.0 | 96.0 | 100.0 | 96.0 | 92.7 |
| Hengchun | 120.74 | 22.01 | 1900- | 98.6 | 98.3 | 96.8 | 74.4 | 72.6 | 99.4 | 99.4 | 99.2 | 99.4 | 99.2 |
| Taitung | 121.15 | 22.75 | 1902- | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 98.0 | 100.0 | 96.4 | 97.2 |
| Hualien | 121.61 | 23.98 | 1922- | 100.0 | 99.9 | 99.9 | 99.9 | 99.8 | 99.8 | 99.2 | 99.9 | 99.9 | 100.0 |
| Ilan | 121.75 | 24.77 | 1936- | 99.3 | 99.9 | 100.0 | 98.8 | 97.8 | 83.1 | 83.1 | 82.6 | 82.6 | 83.1 |



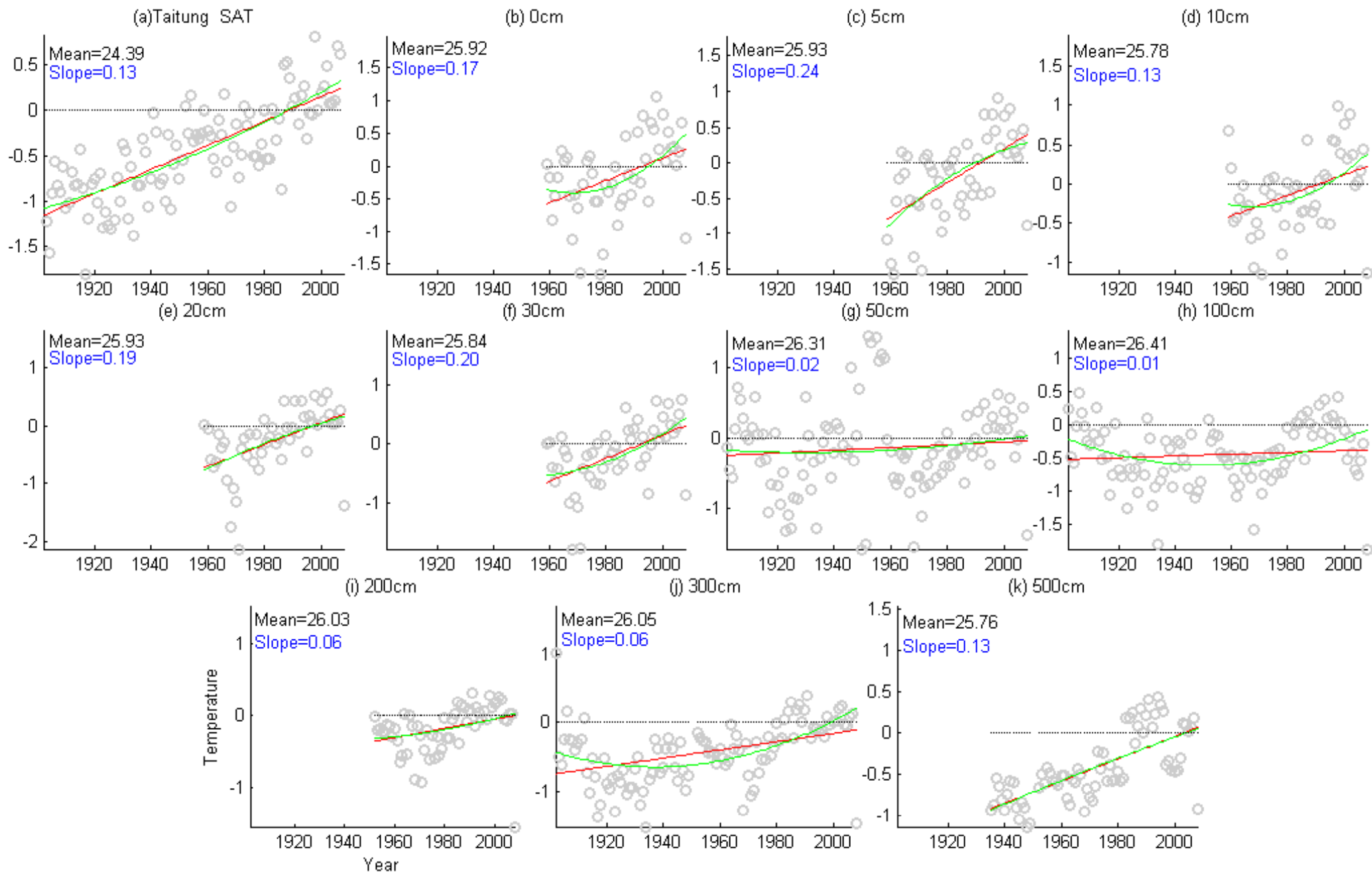
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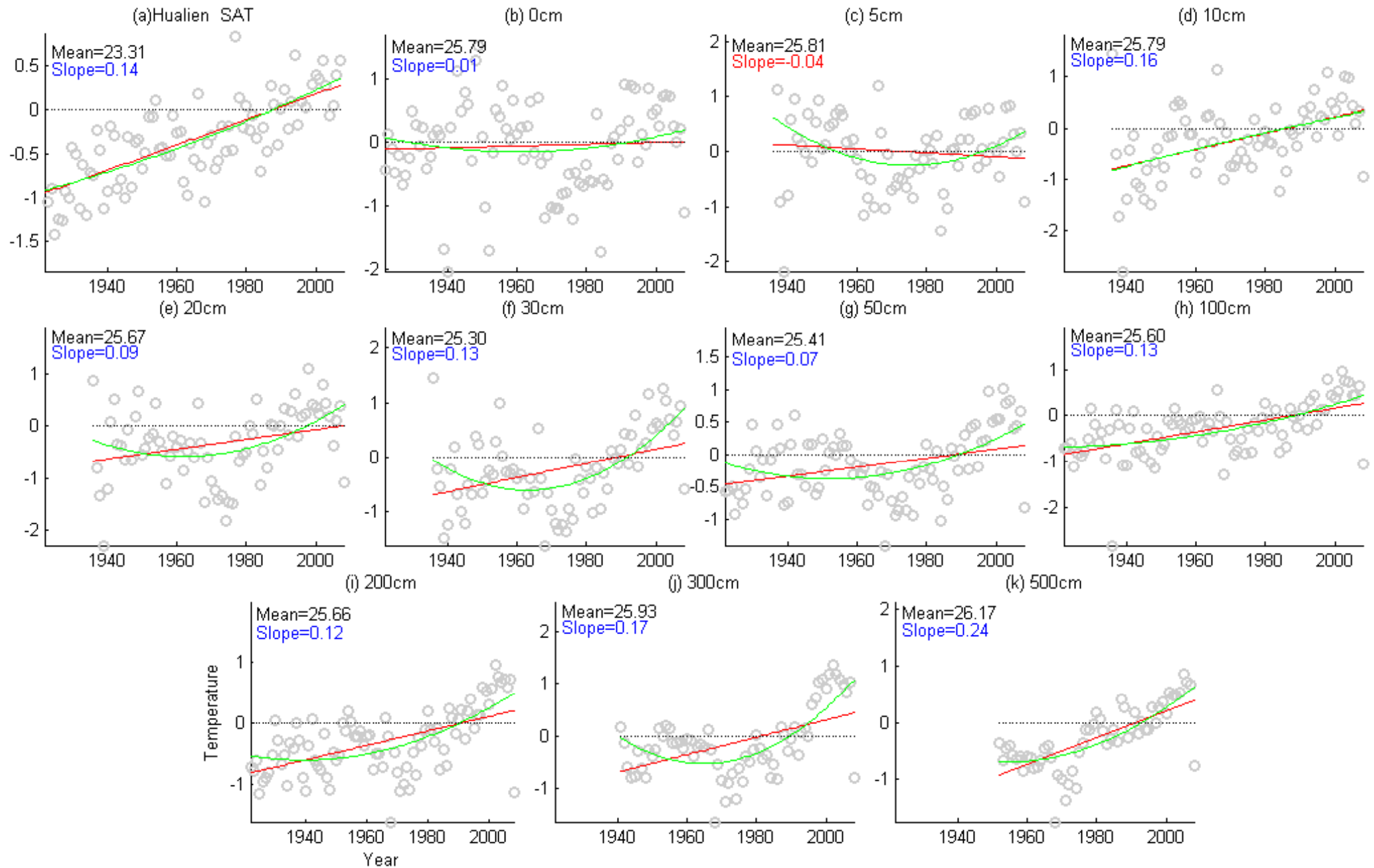
台中



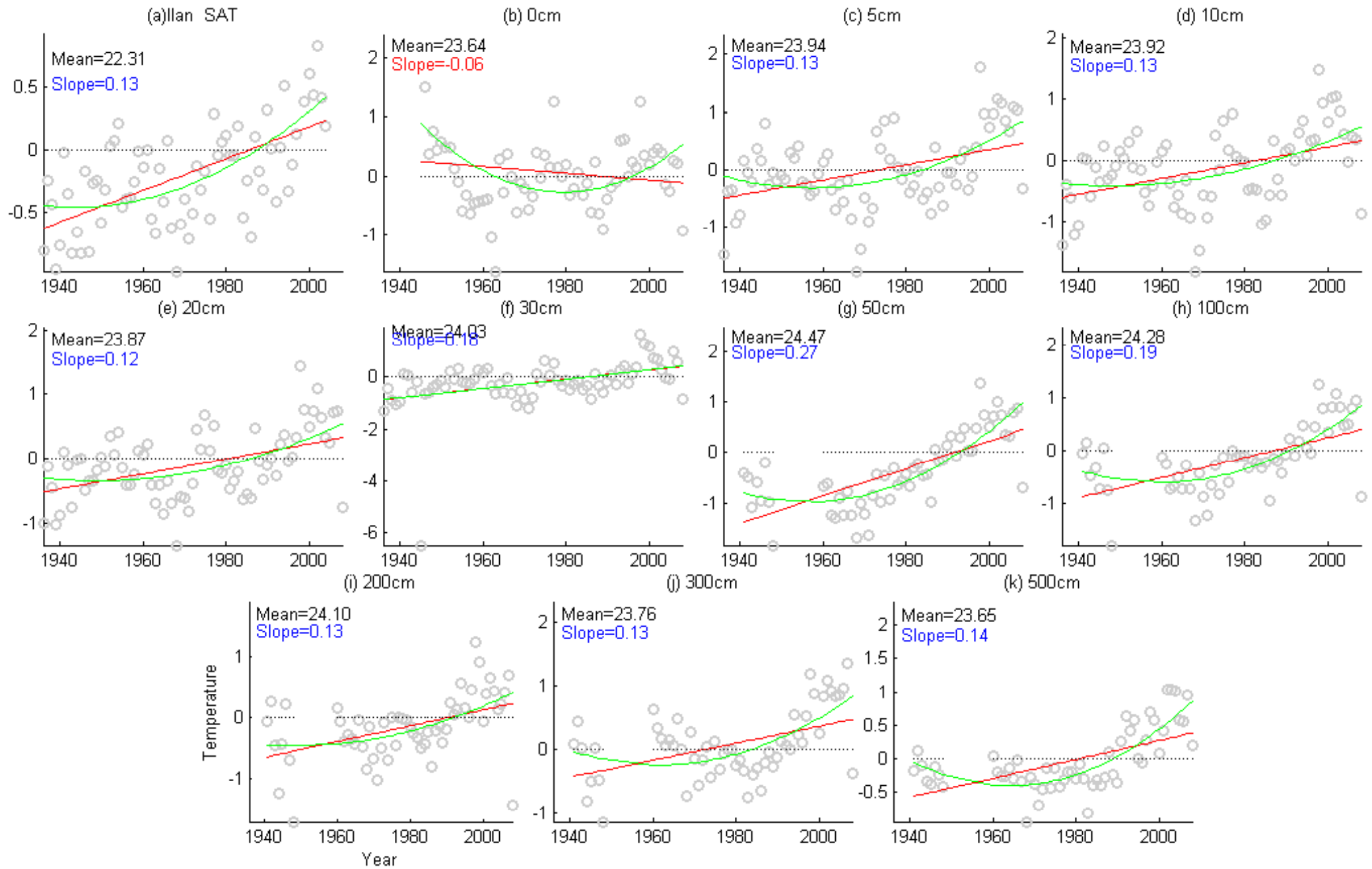
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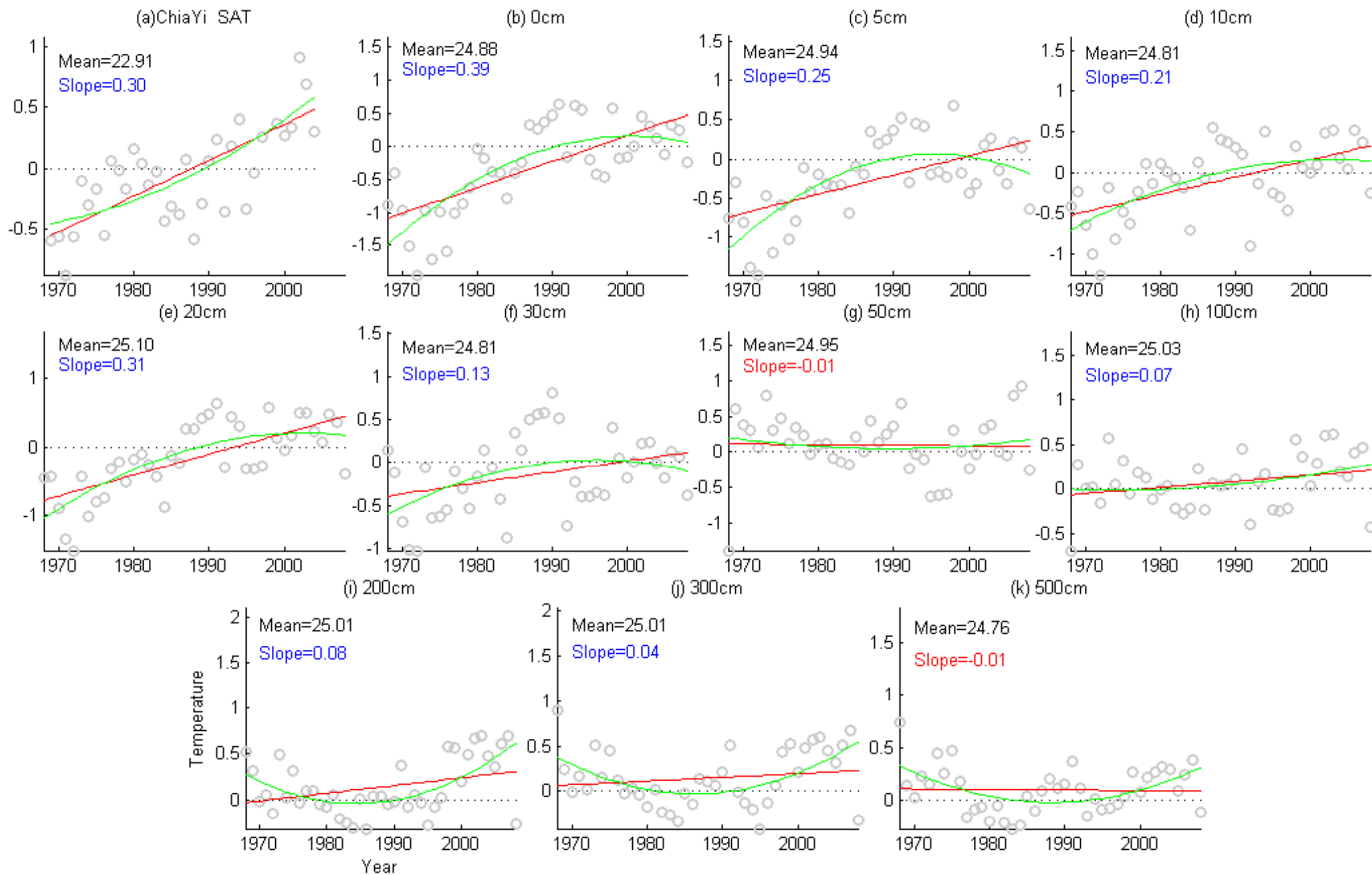
花蓮



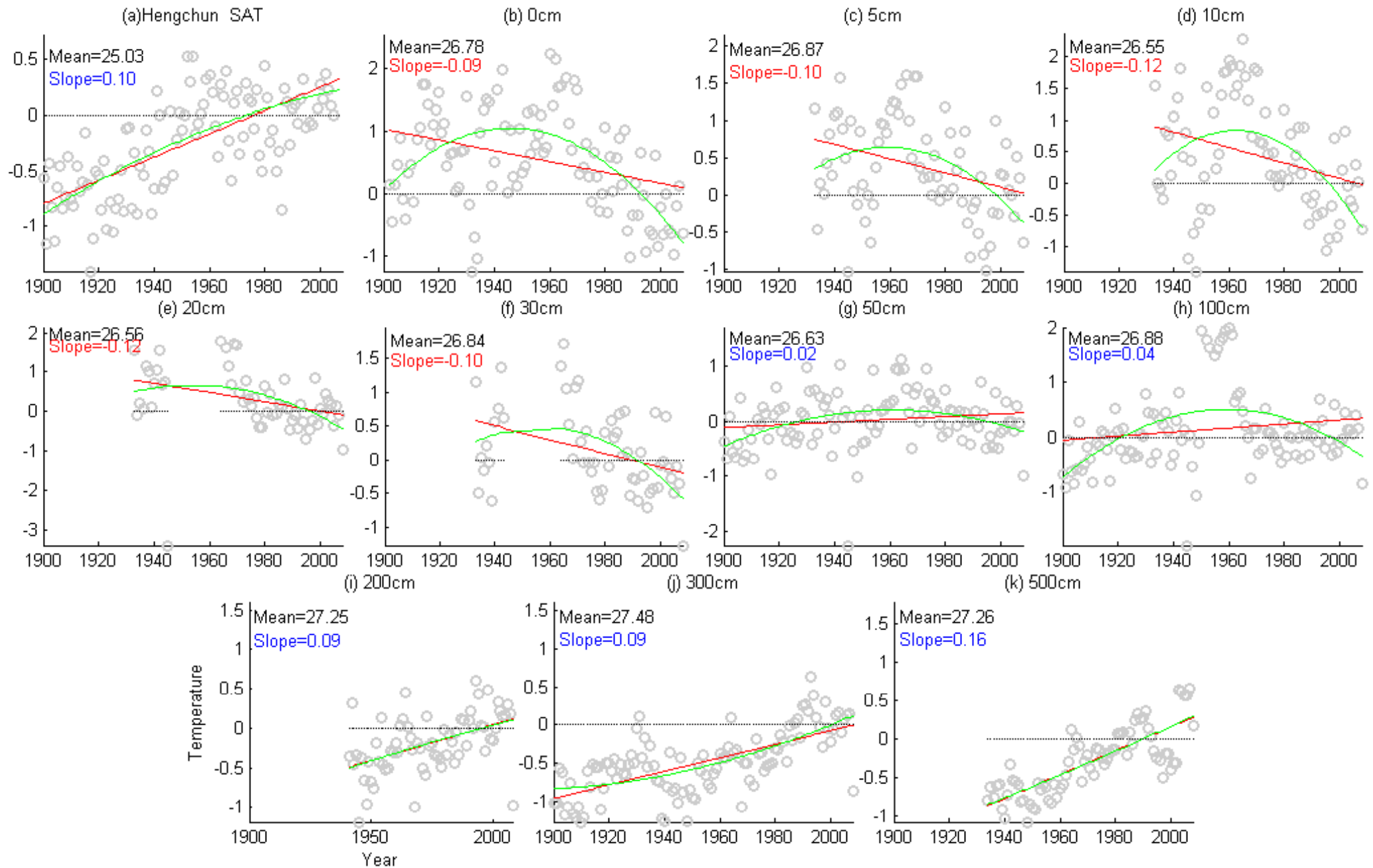
宜蘭



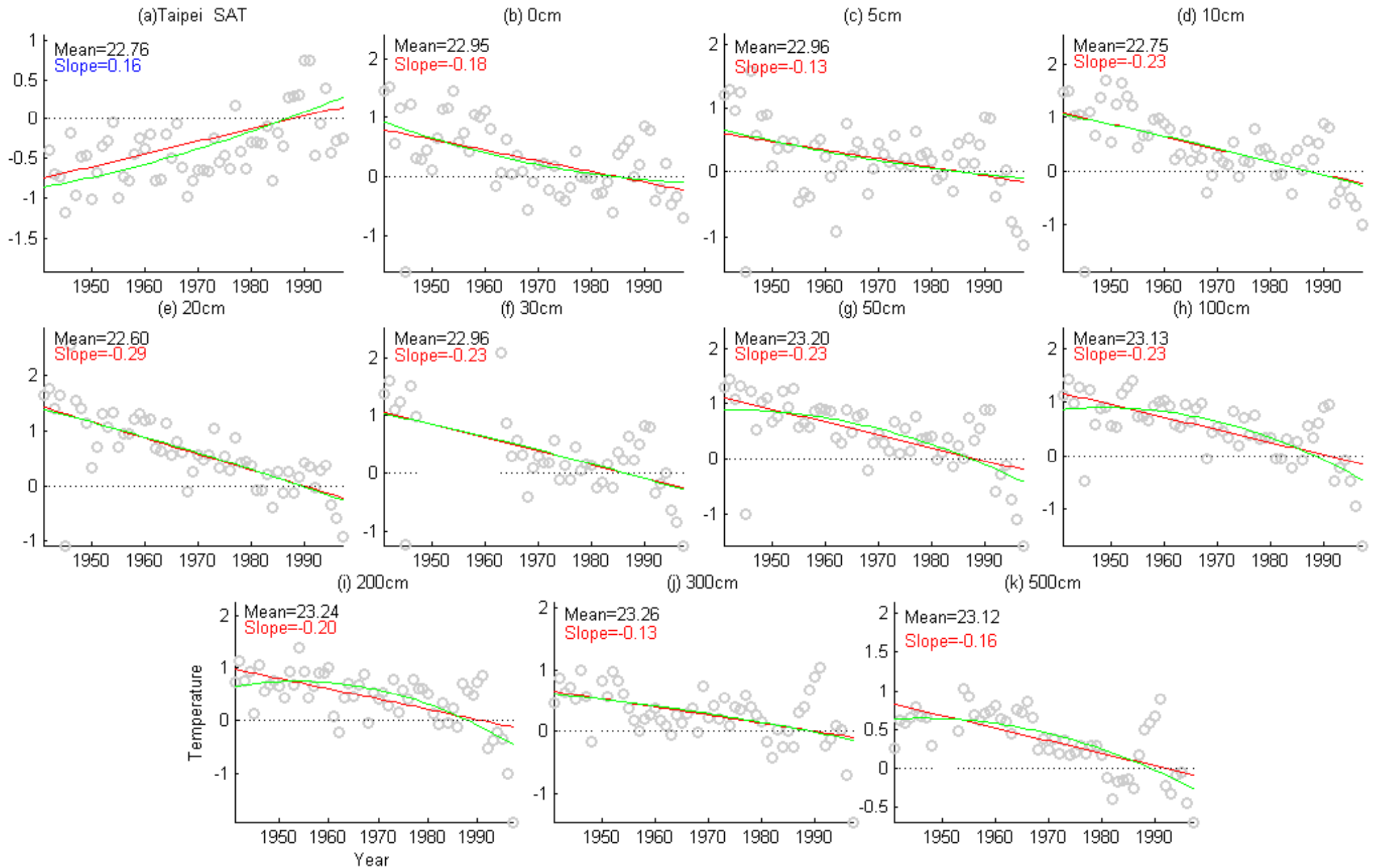
嘉義



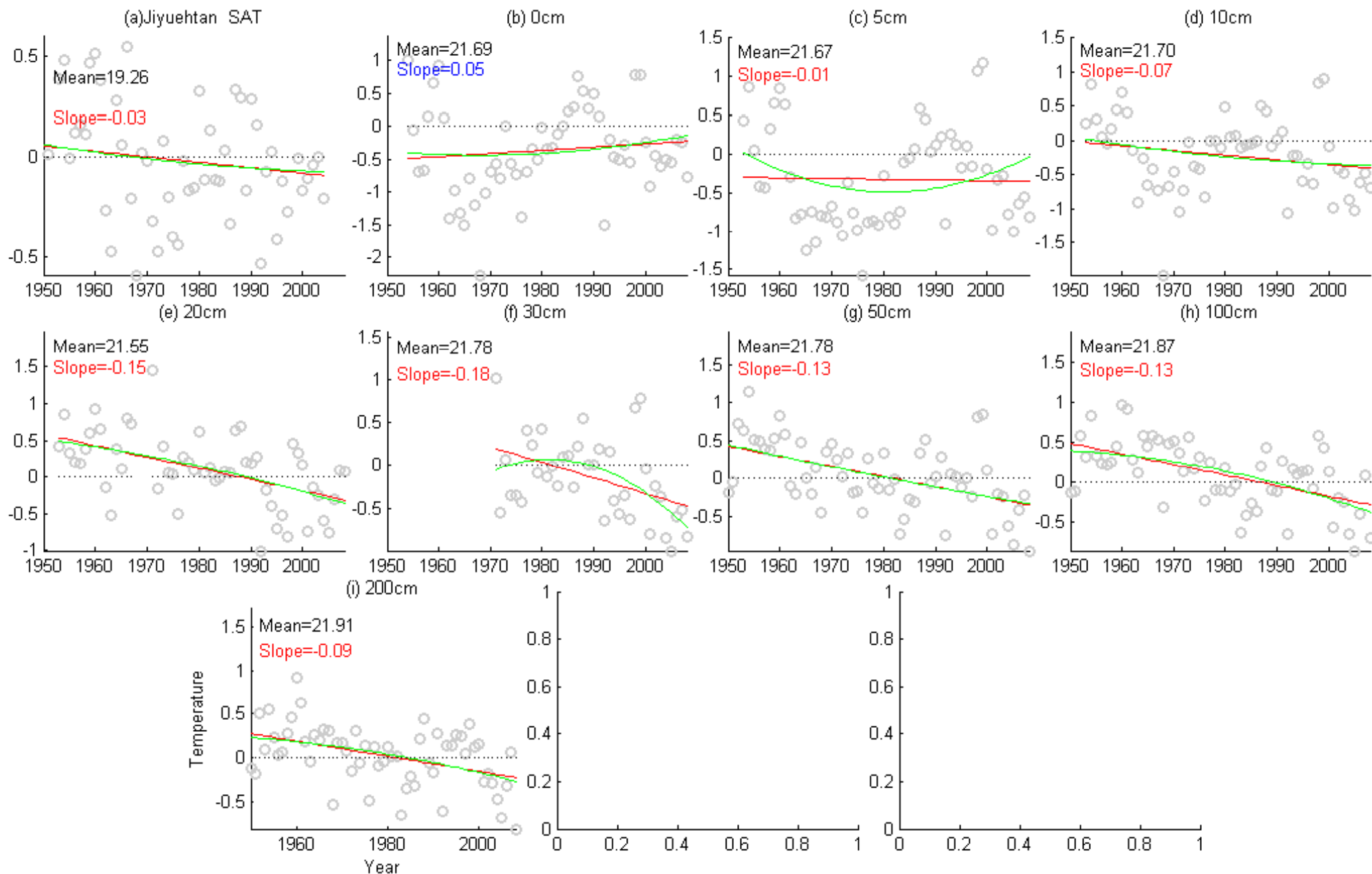
恆春



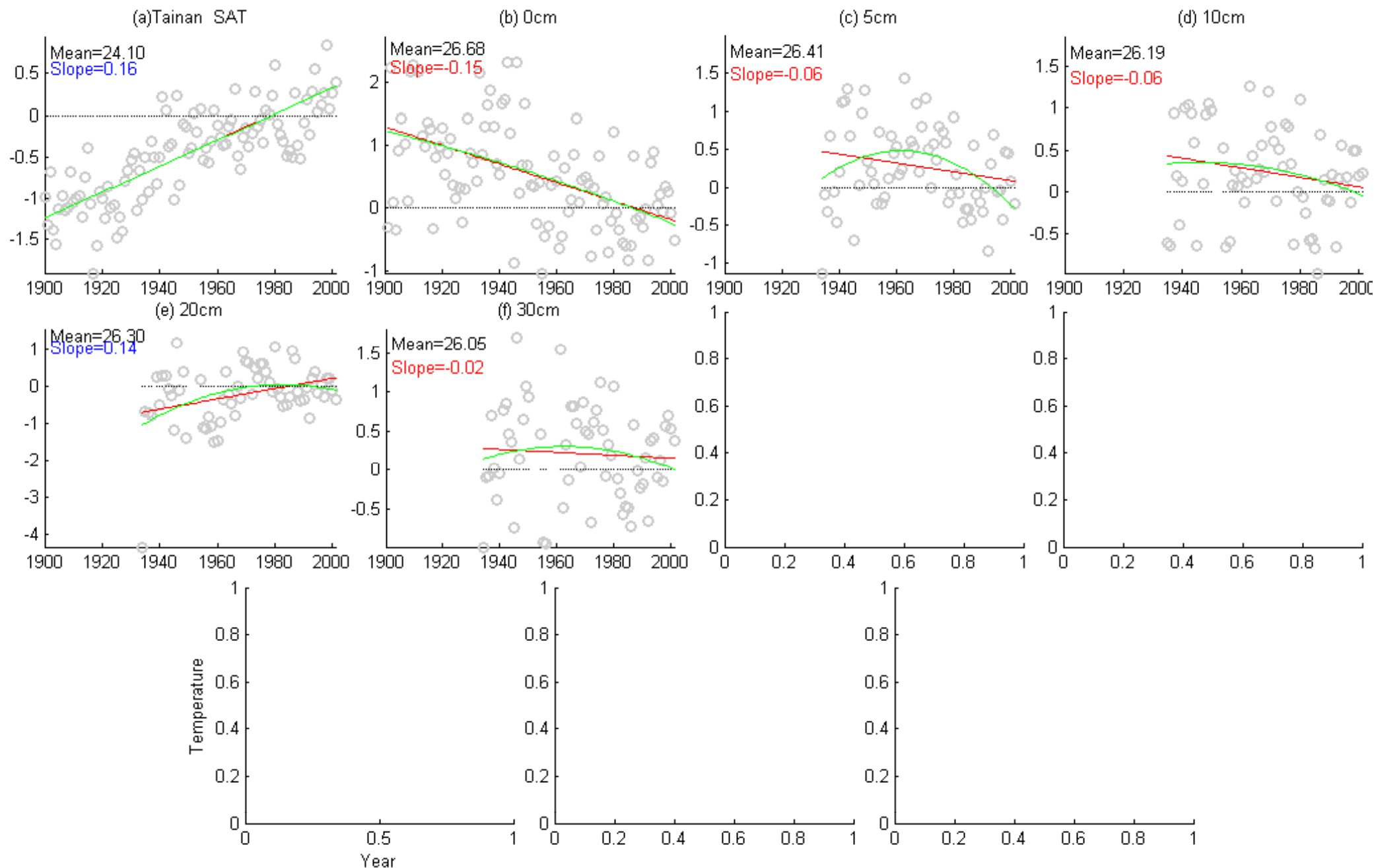
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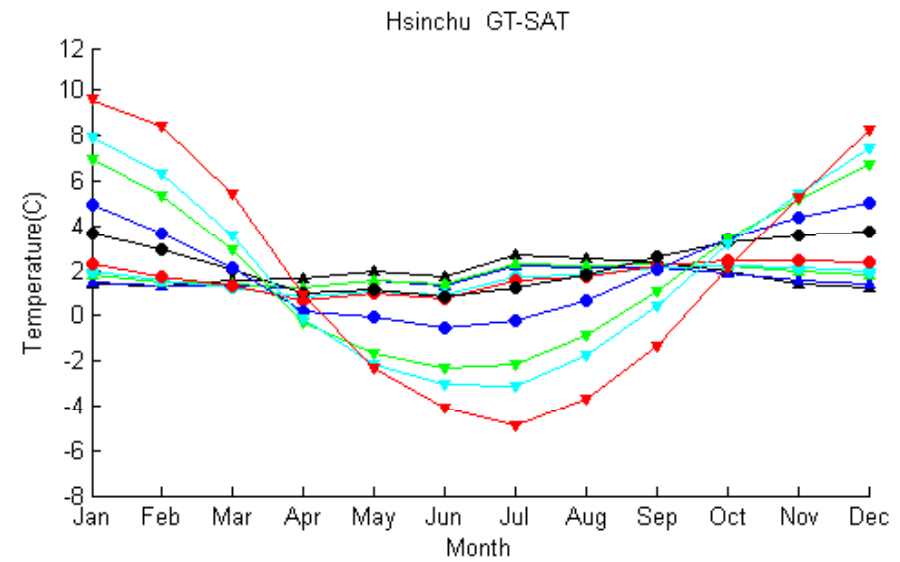
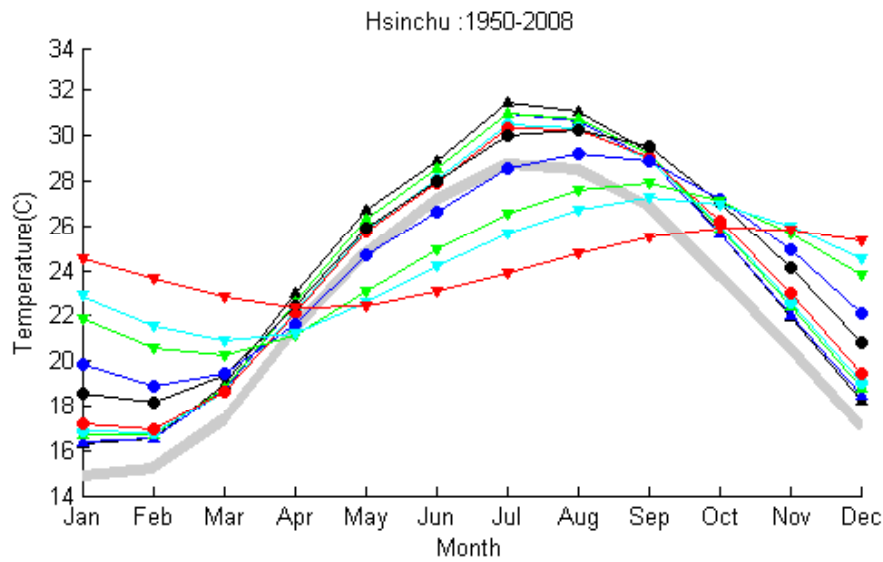
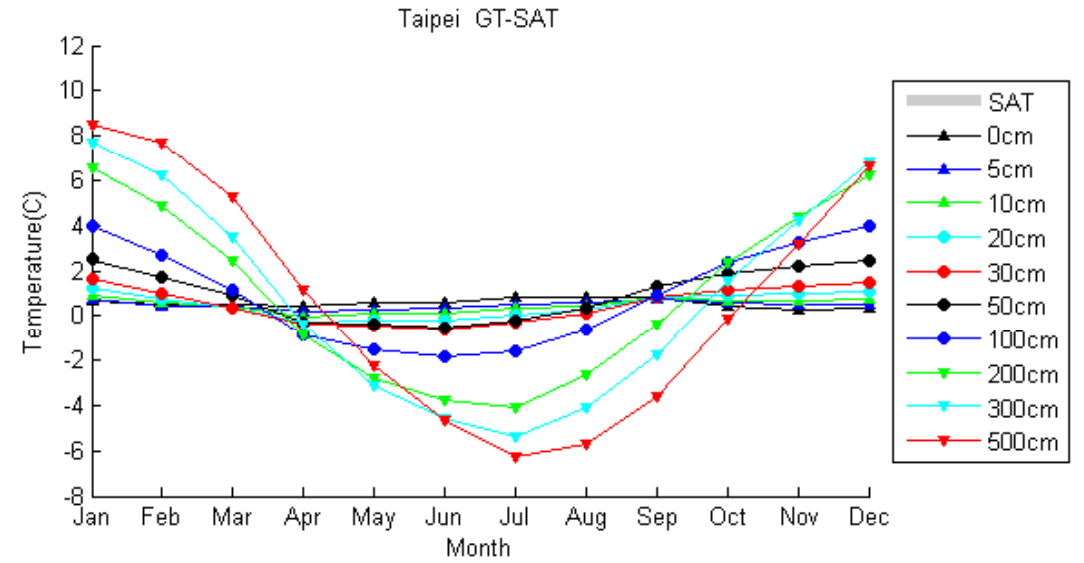
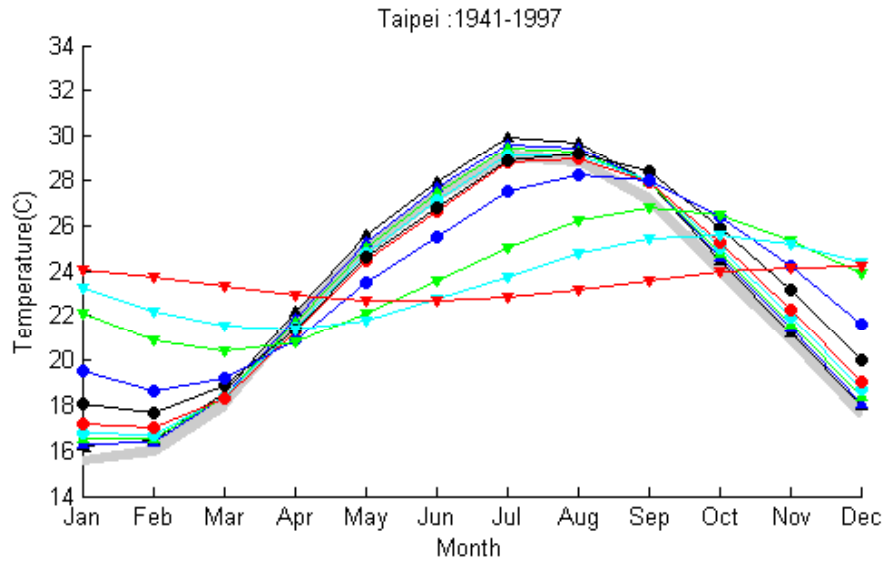
日月潭

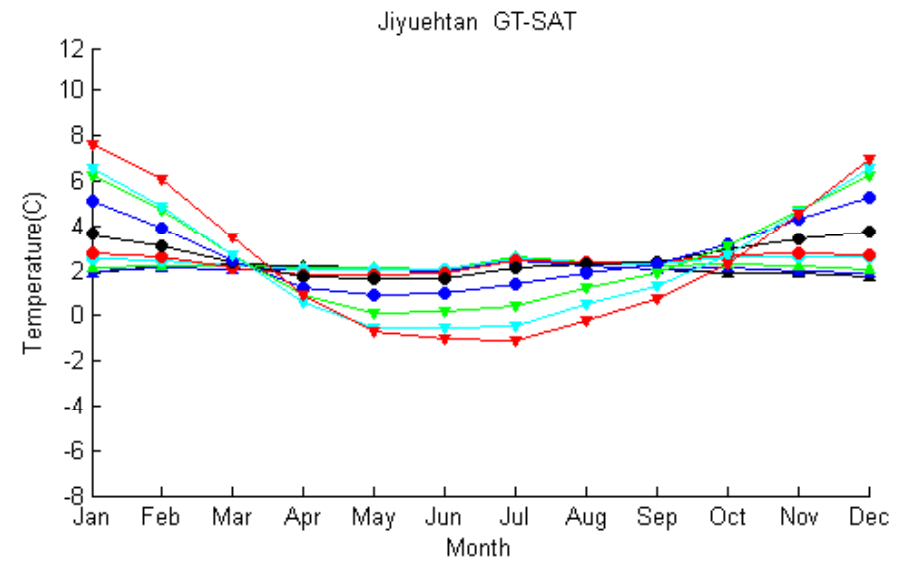
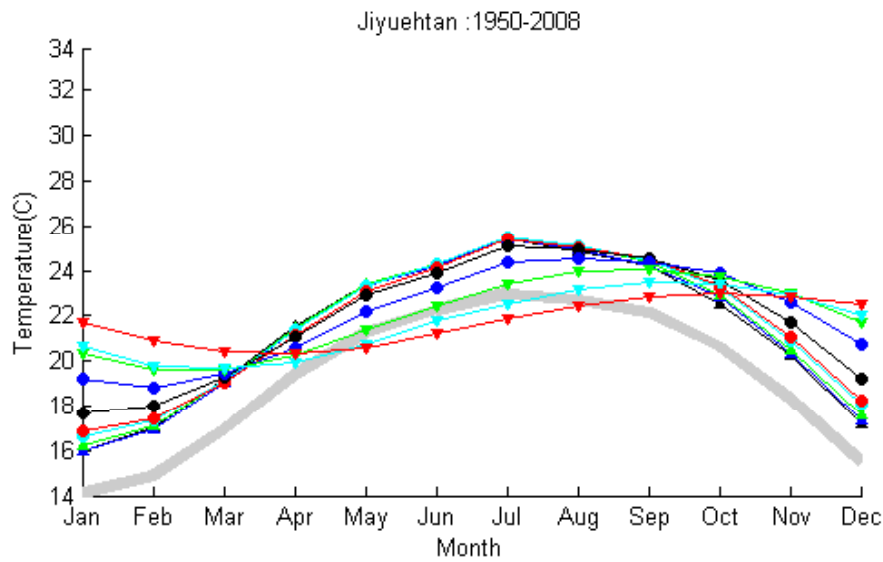
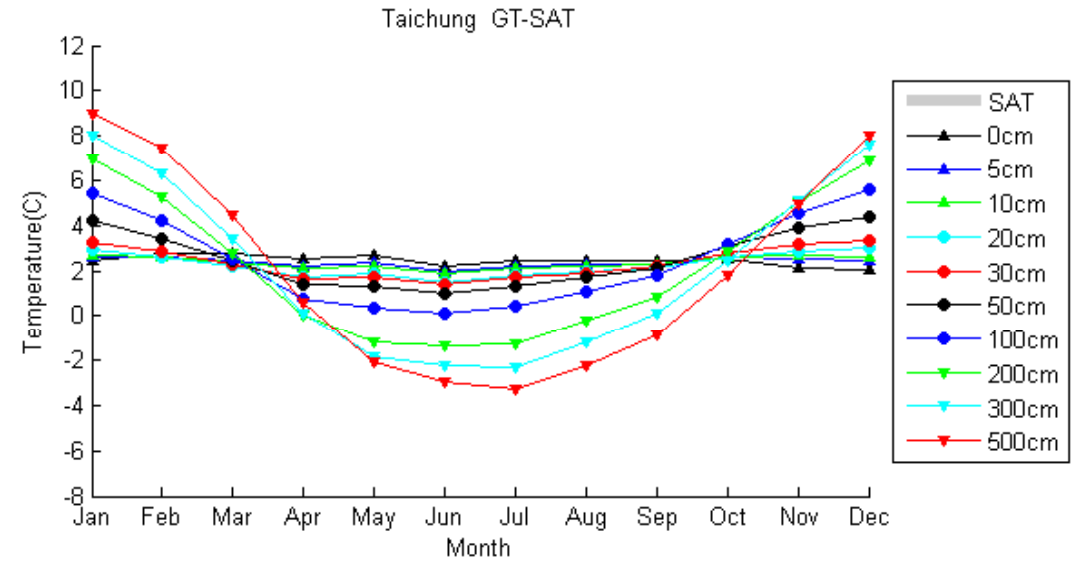
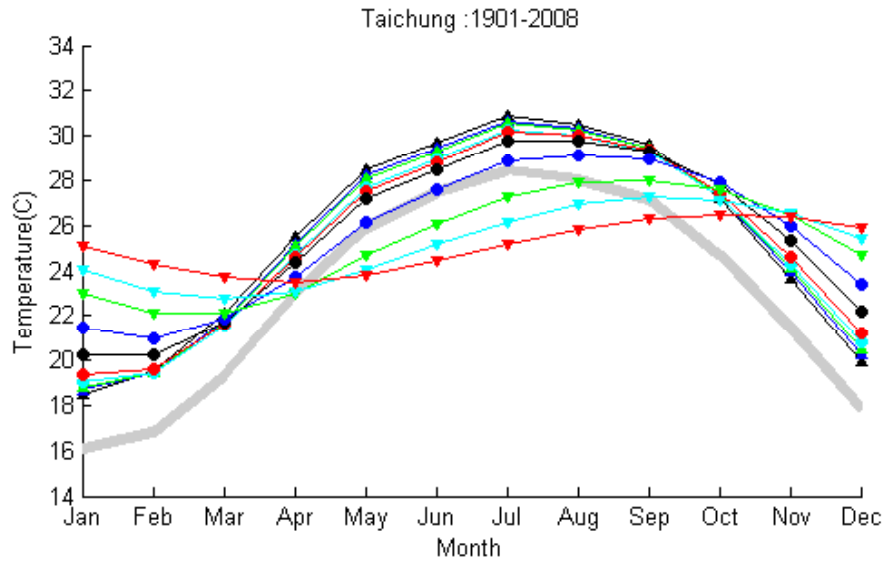


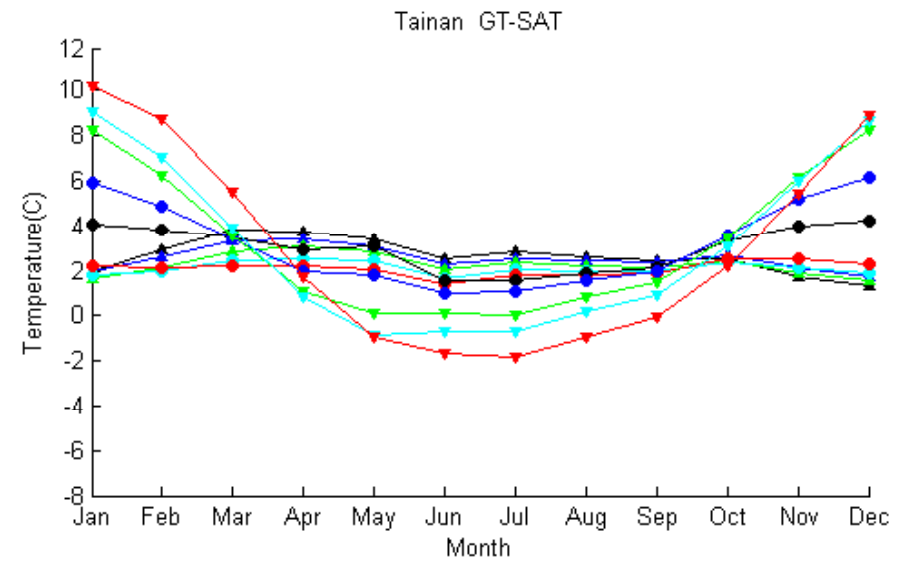
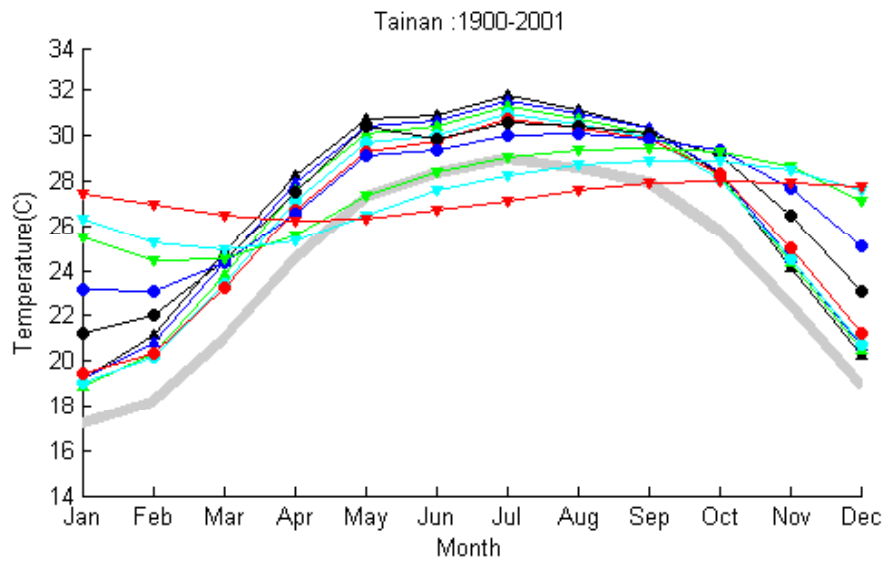
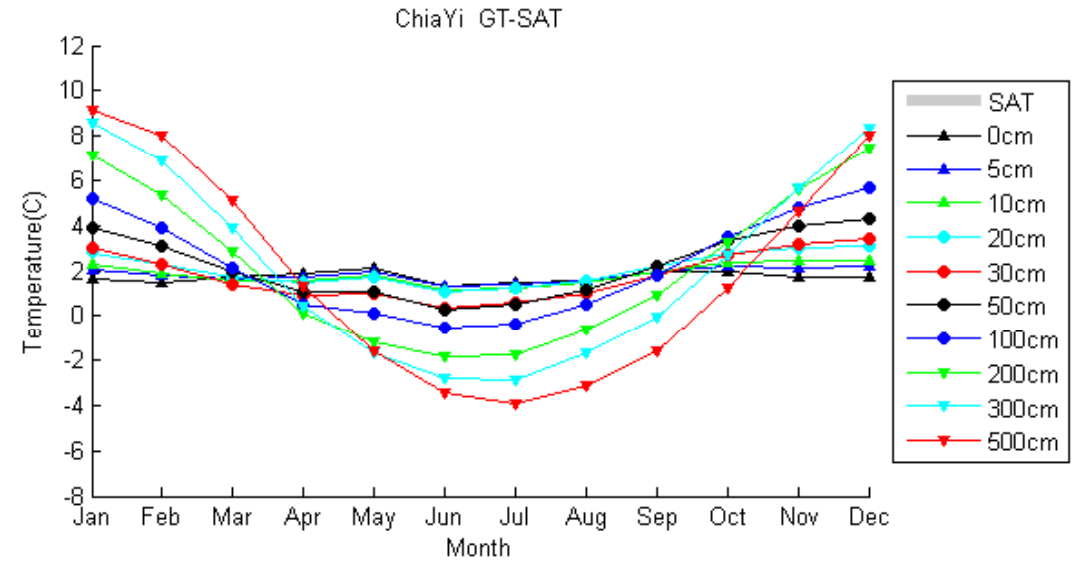
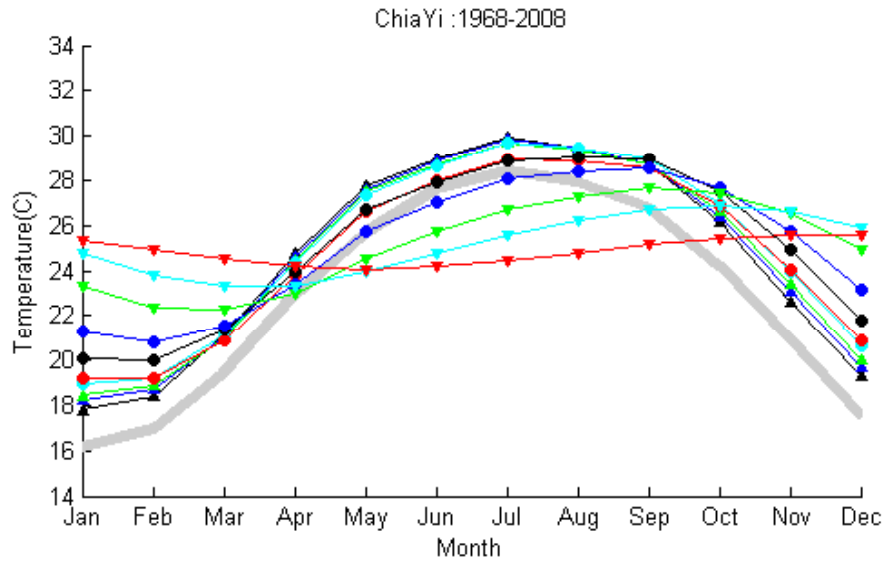
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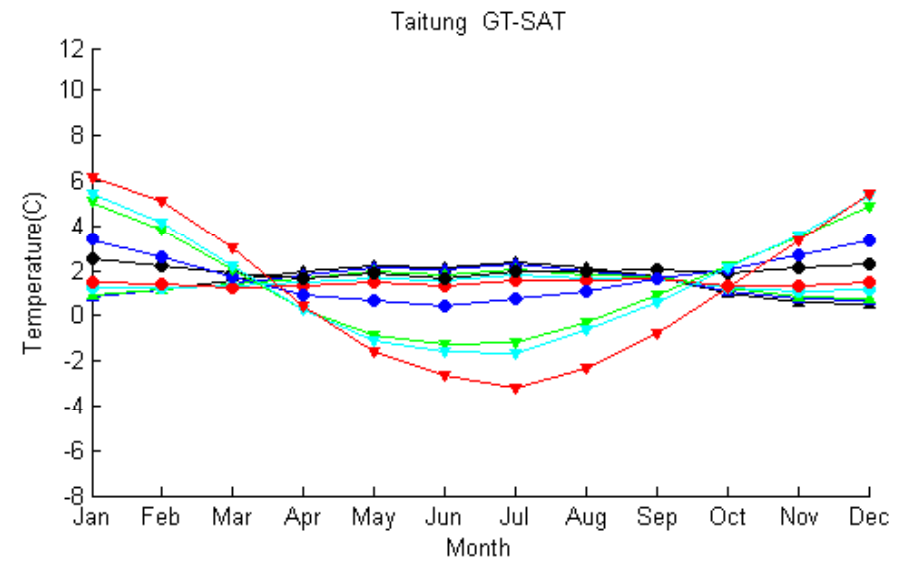
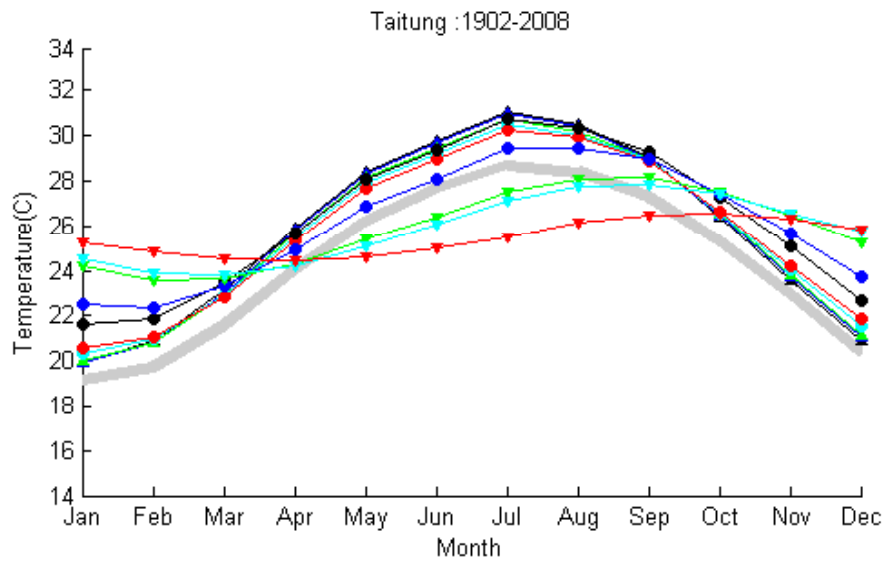
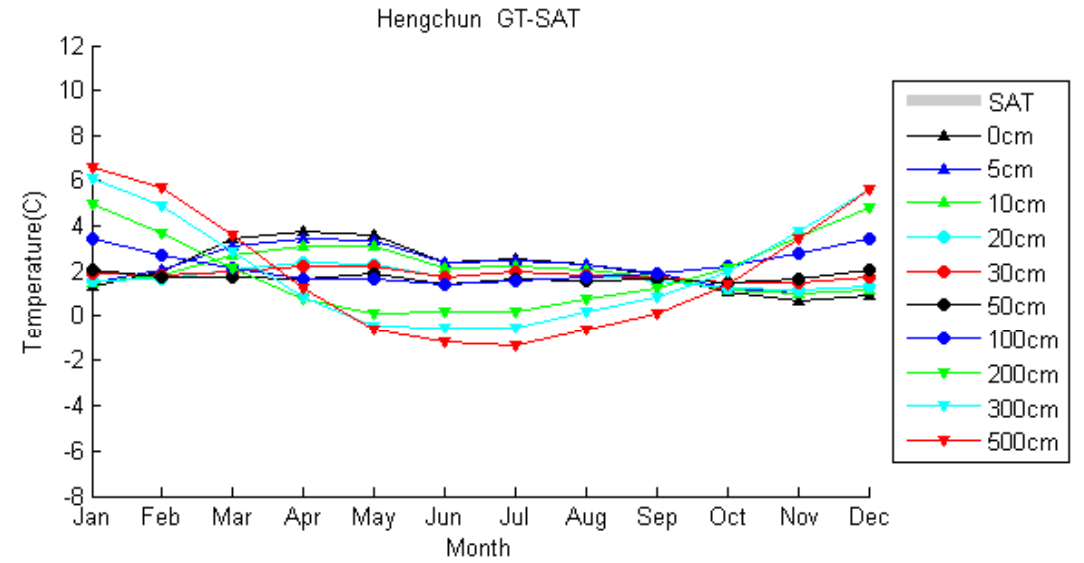
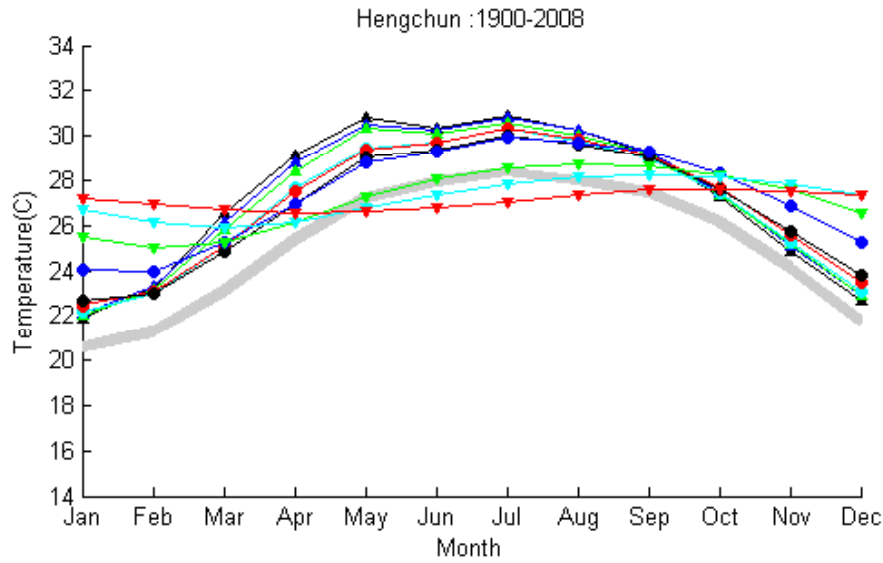


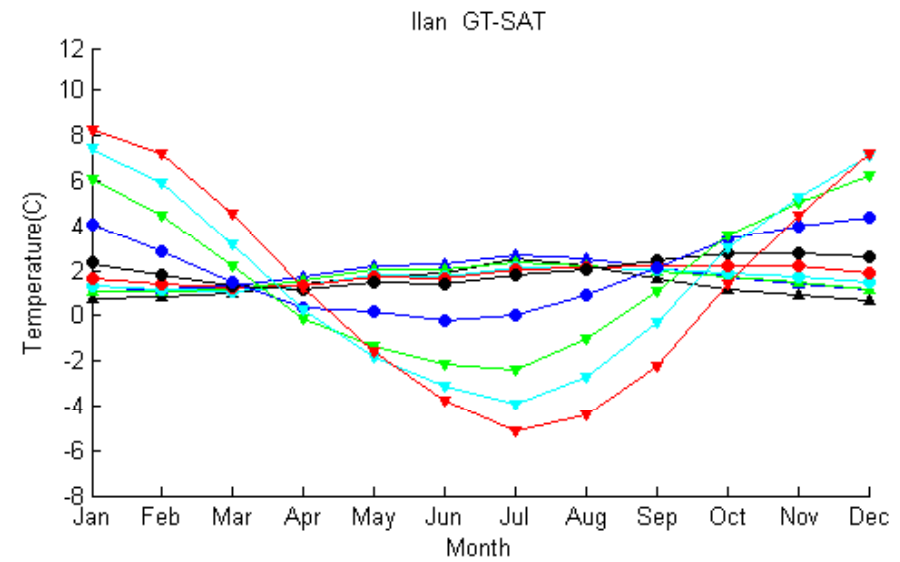
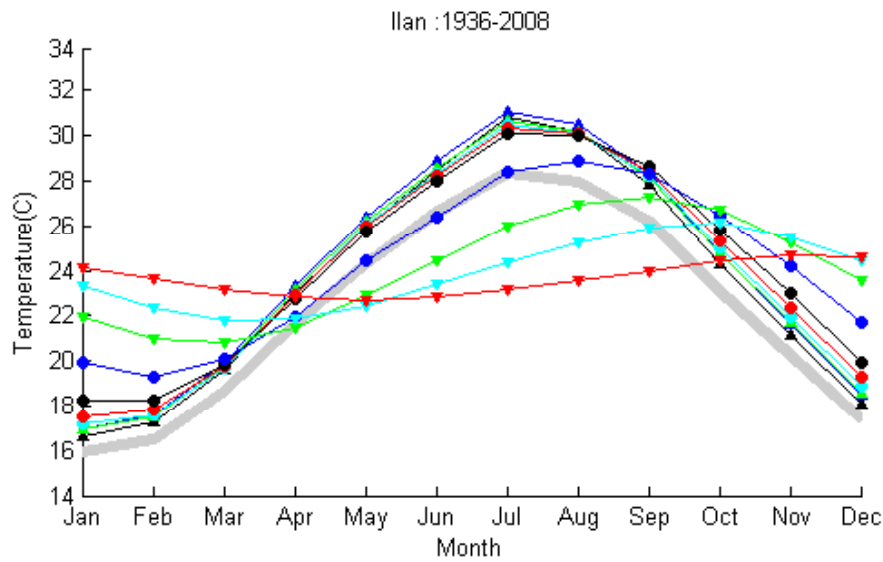
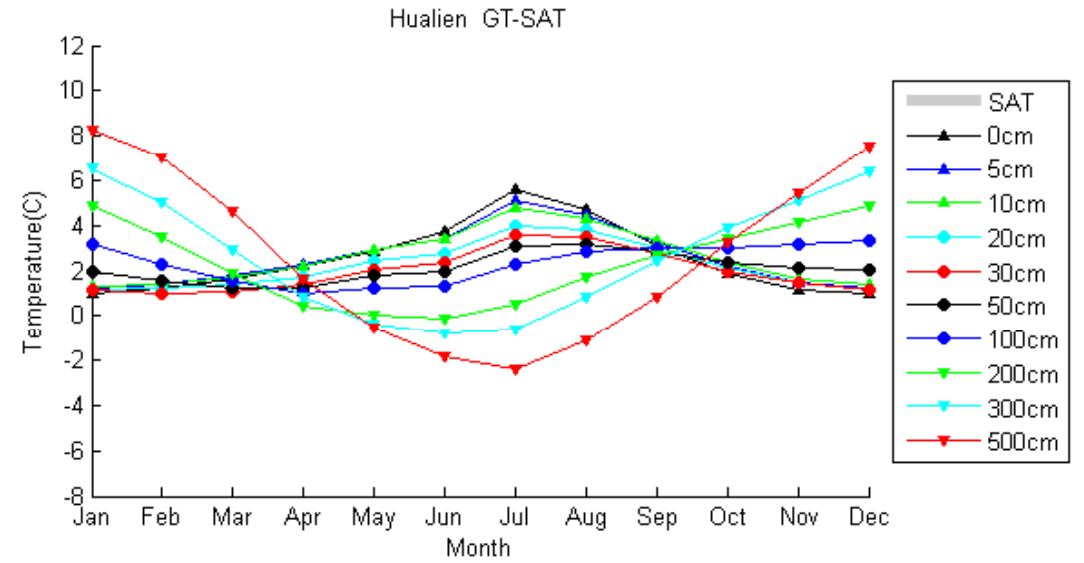
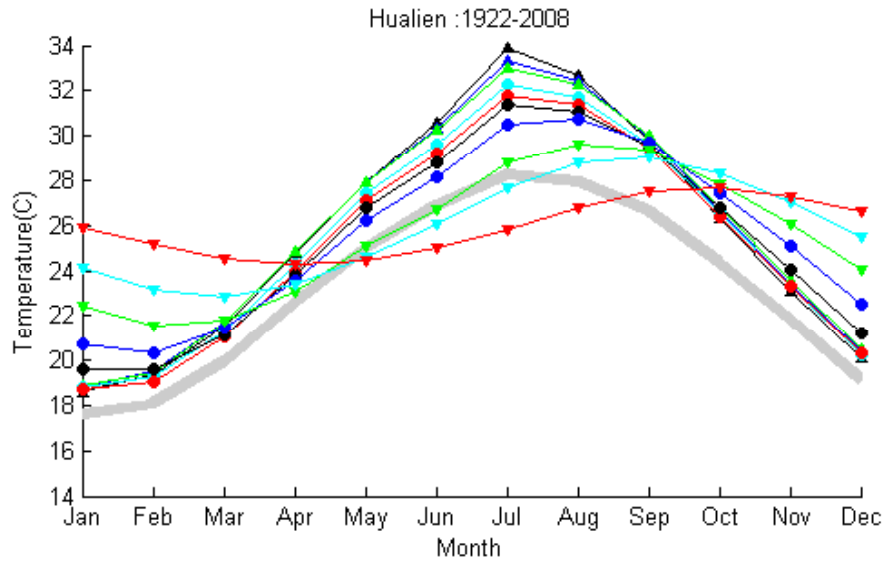
| | SAT | | 0cm | | 5cm | | 10cm | | 20cm | | 30cm | |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|--------------|-----------|
| Stations | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 |
| Taipei | 0.115 | 0.402 ↑ | -0.269 | -0.109 | -0.138 | -0.475 | -0.247 | -0.437 | -0.262 | -0.252 | -0.263 | -0.418 |
| Hsinchu | 0.071 | 0.289 | -0.562 | 0.051 | -0.261 | 0.014 | -0.322 | 0.125 | -0.334 | 0.049 | -0.177 | -0.018 |
| Taichung | 0.119 | 0.438 | -0.055 | 0.139 | -0.227 | -0.161 | -0.195 | -0.030 | -0.125 | -0.022 | -0.062 | -0.211 |
| Jiyuehtan | -0.067 | -0.059 | -0.276 | -0.216 | -0.541 | -0.103 | -0.262 | -0.313 | -0.104 | -0.218 | 0.067 | -0.289 |
| Chiayi | 0.697 | 0.352 ↓ | 0.367 | 0.116 | 0.445 | 0.031 | 0.548 | 0.090 | 0.453 | 0.164 | 0.033 | -0.025 |
| Tainan | 0.172 | 0.382 | -0.147 | 0.087 | 0.082 | 0.019 | 0.026 | 0.215 | 0.288 | -0.090 | 0.087 | 0.272 |
| Hengchun | 0.132 | 0.232 | 0.066 | -0.371 | 0.080 | -0.129 | 0.144 | -0.276 | 0.011 | -0.130 | -0.030 | -0.278 |
| Taitung | 0.119 | 0.247 | -0.301 | 0.236 | 0.256 | 0.196 | -0.142 | 0.160 | 0.001 | 0.045 | -0.047 | 0.141 |
| Hualien | 0.135 | 0.265 | -0.087 | 0.293 | -0.224 | 0.167 | 0.164 | 0.281 | -0.150 | 0.176 | -0.130 | 0.470 |
| Ilan | 0.082 | 0.323 | -0.271 | 0.141 | 0.049 | 0.530 | 0.072 | 0.405 | 0.067 | 0.373 | 0.194 | 0.368 |
| T% | 70% | 90% | 10% | 50% | 20% | 30% | 30% | 50% | 20% | 30% | 10% | 40% |
| | 50cm | | 100cm | | 200cm | | 300cm | | 500cm | | each station | |
| Stations | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | 1900-1980 | 1980-2008 | D% | I% |
| Taipei | -0.187 | -0.707 | -0.153 | -0.581 | -0.092 | -0.733 | -0.101 | -0.217 | -0.112 | -0.090 | 80% | 0% |
| Hsinchu | 0.168 | 0.285 | 0.040 | 0.230 | 0.049 | 0.051 | 0.151 | 0.189 | 0.188 | 0.269 | 0% | 70% |
| Taichung | 0.073 | -0.064 | 0.049 | 0.026 | 0.064 | 0.198 | 0.047 | 0.250 | 0.254 | 0.308 | 20% | 50% |
| Jiyuehtan | -0.189 | -0.137 | -0.083 | -0.093 | -0.103 | -0.091 | | | | | 27% | 27% |
| Chiayi | 0.279 | 0.053 | 0.172 | 0.144 | -0.268 | 0.261 | -0.444 | 0.222 | -0.446 | 0.128 | 50% | 30% |
| Tainan | | | | | | | | | | | 0% | 30% |
| Hengchun | 0.090 | -0.115 | 0.137 | 0.034 | 0.066 | 0.065 | 0.050 | 0.043 | 0.153 | 0.092 | 70% | 0 |
| Taitung | -0.007 | 0.067 | -0.051 | -0.244 | -0.099 | -0.032 | 0.007 | -0.082 | 0.080 | -0.043 | 10% | 30% |
| Hualien | -0.040 | 0.343 | 0.087 | 0.267 | 0.028 | 0.293 | -0.104 | 0.564 | 0.054 | 0.217 | 0% | 100% |
| Ilan | 0.004 | 0.434 | 0.007 | 0.399 | 0.054 | 0.256 | 0.032 | 0.542 | -0.047 | 0.466 | 0% | 100% |
| T% | 22% | 33% | 22% | 44% | 0% | 44% | 13% | 63% | 27% | 63% | 0% | 100% |



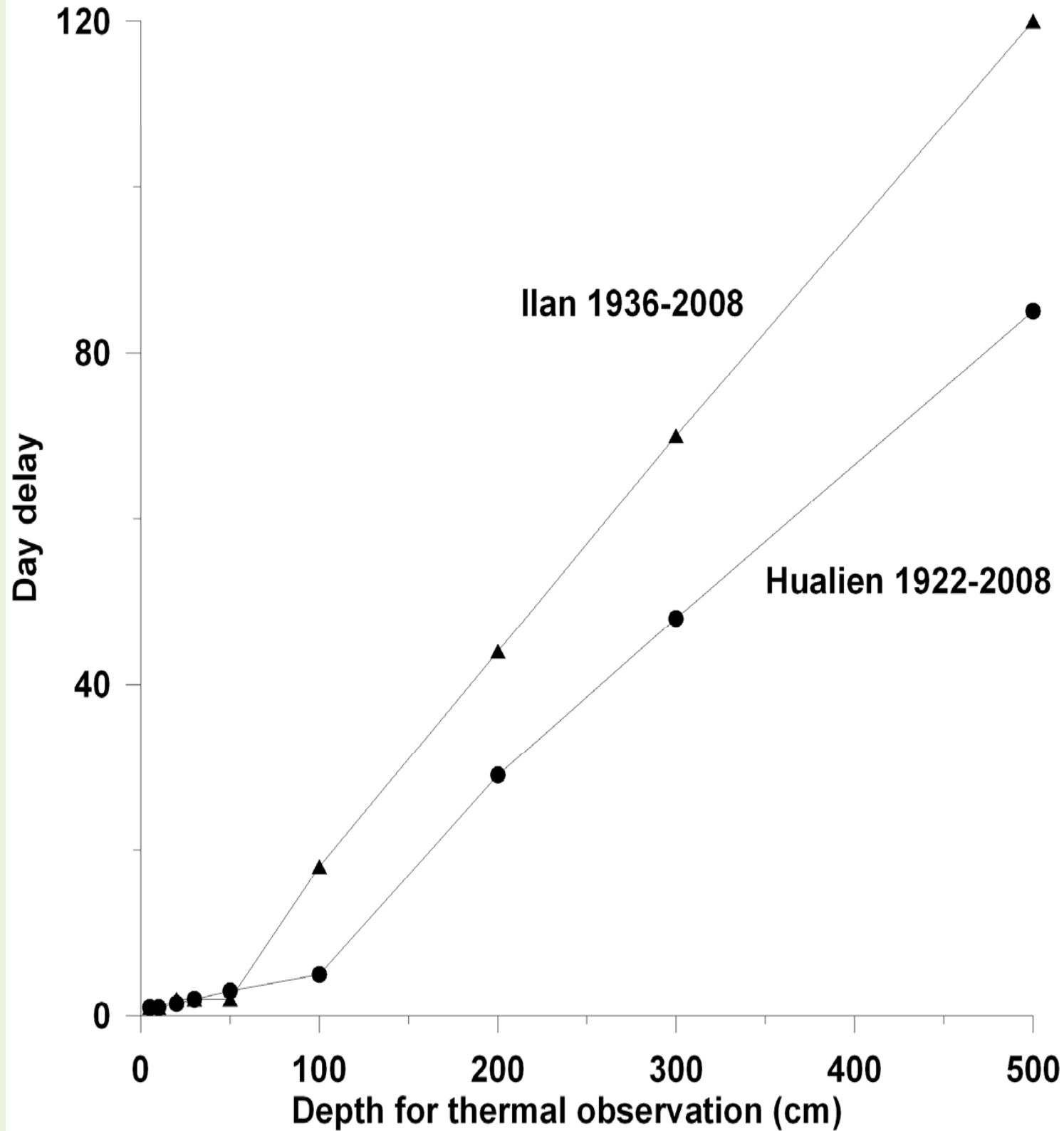






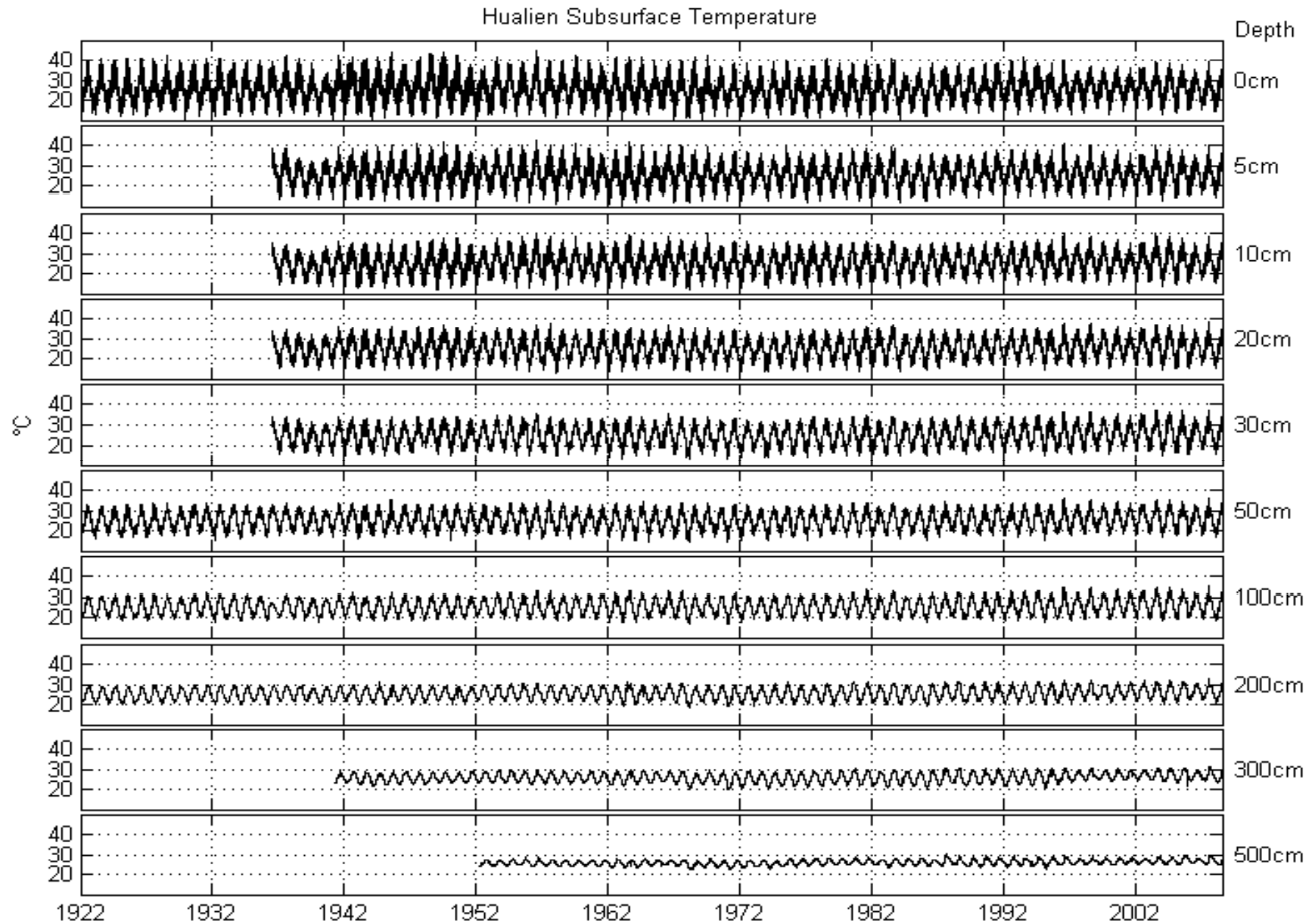


淺層地溫的季節性變化大致同步，7月為溫度最高的月份；深層地溫有明顯滯後現象，並且具有區域性差異。



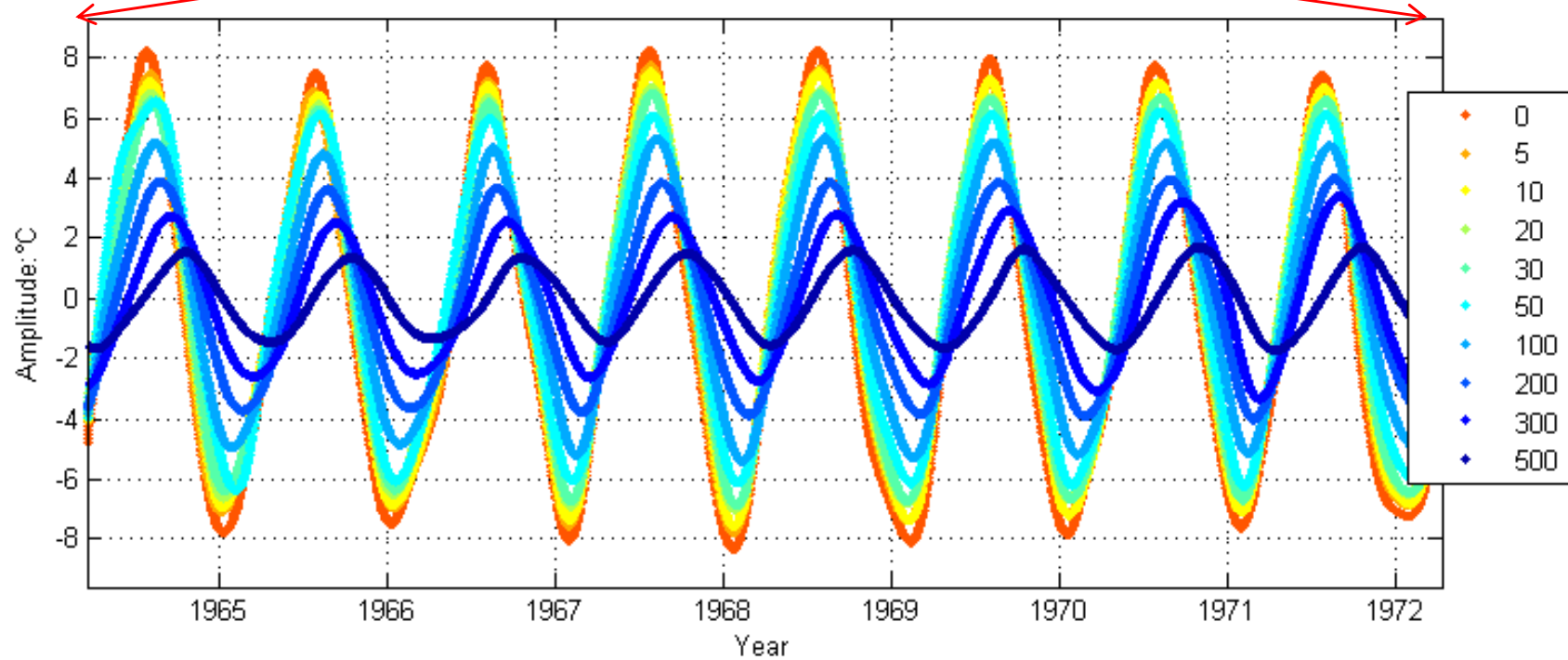
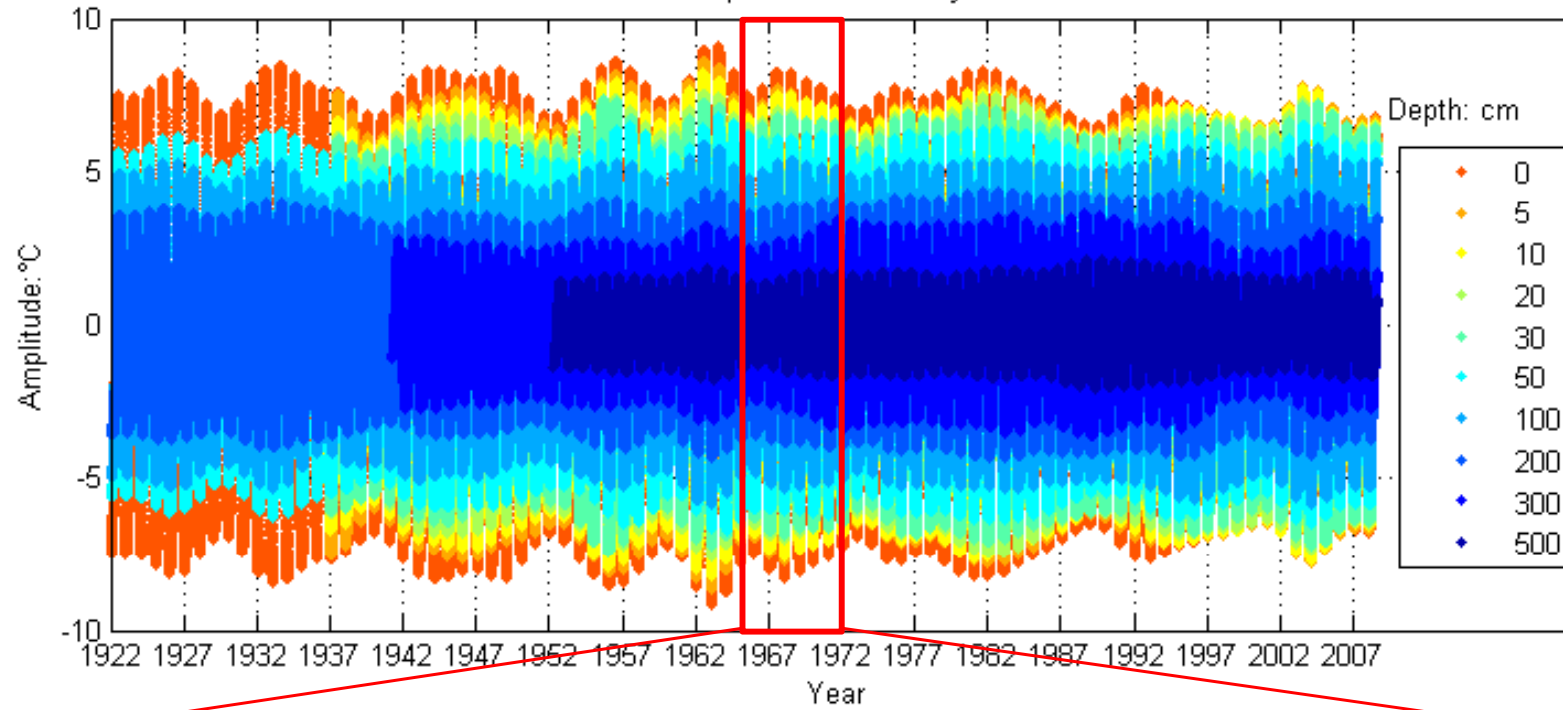
Time shifts VS Observation depths

| Satation | 5cm | 10cm | 20cm | 30cm | 50cm | 100cm | 200cm | 300cm | 500cm |
|-----------|-----|------|------|------|------|-------|-------|-------|-------|
| Taipei | 1 | 1 | 2 | 2 | 3 | 21 | 52.5 | 74.5 | 134 |
| Hsinchu | 1 | 1 | 2 | 2 | 3 | 15 | 41 | 53.5 | 91 |
| Taichung | 1 | 1 | 2 | 2 | 3 | 12 | 40 | 58 | 83 |
| Jiyuehtan | 1 | 1 | 2 | 2 | 3 | 18.5 | 43 | 54 | 82 |
| Chiayi | 1 | 1 | 2 | 2 | 3 | 23 | 45 | 72 | 120 |
| Tainan | 1 | 1 | 2 | 2 | 2 | 13 | 47 | 68.5 | 104 |
| Hengchun | 1 | 1 | 2 | 2 | 3 | 7 | 43.5 | 69 | 116.5 |
| Taitung | 1 | 1 | 2 | 2 | 2 | 5 | 42 | 55 | 85 |
| Hualien | 1 | 1 | 1.5 | 2 | 3 | 5 | 29 | 48 | 85 |
| Ilan | 1 | 1 | 2 | 2 | 2 | 18 | 44 | 70 | 120 |

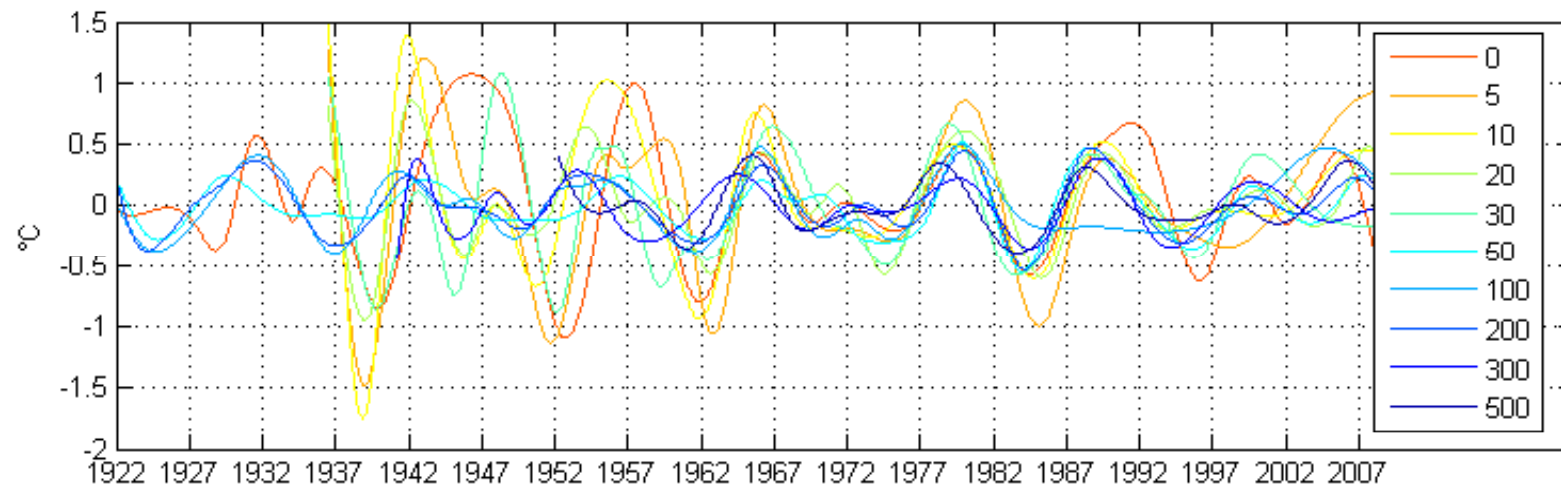


Subsurface temperature time series from the Hualien meteorological station of Central Weather Bureau.

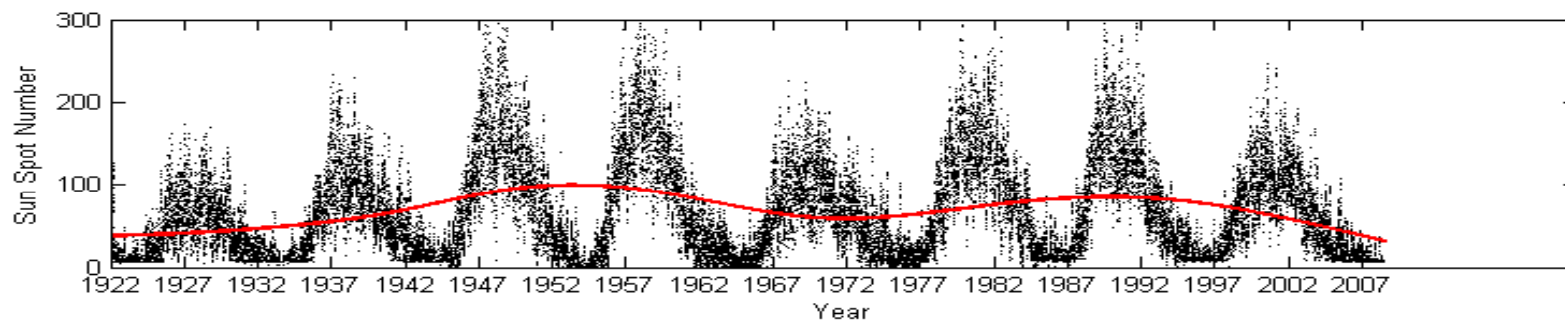
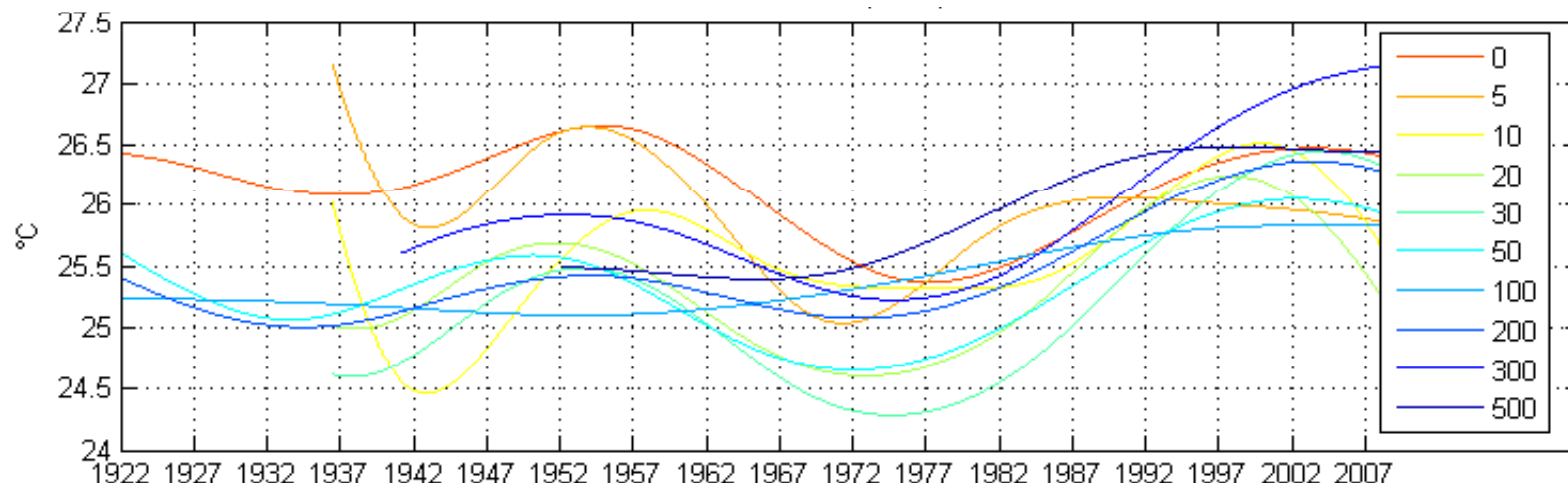
IMF period: 1 year



Sum IMF11 and IMF12



Sum IMF14 15 and DC term



Summary

- Investigation of the relatively shallow subsurface temperature database (0 - 500 cm) enhances the analysis of the air-ground temperature interaction and allow a better assessment of regional climate variability at island-wide scales.
- The surface temperature signals propagate to the depth of 5-meter in about 3 months in Taiwan.
- The phase shift reaches to the maximum and minimum in April and October, respectively, within a depth of 1-meter, and show opposite pattern for deeper temperature profiles.
- The instantaneous amplitude of 1-year period IMF and combinations of specific IMFs show that the subsurface temperatures record the signal of solar activities on the earth climate.