Climate Changes in Taiwan

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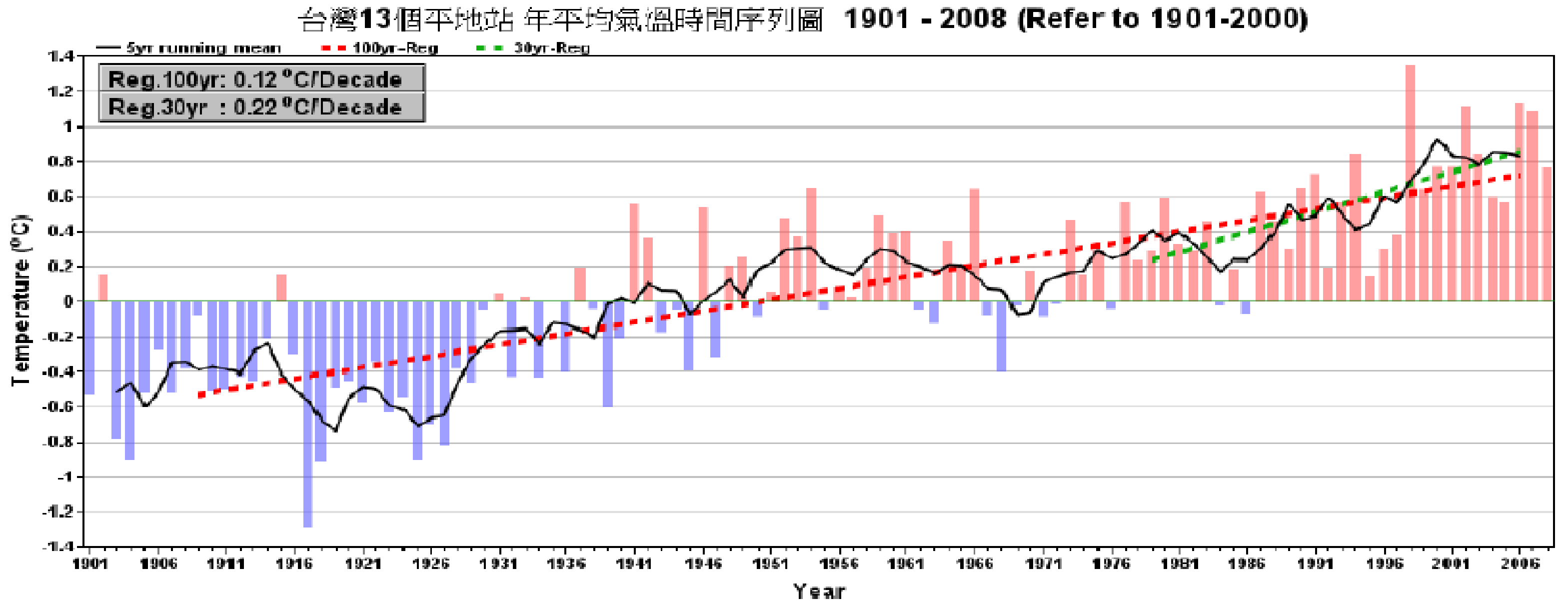


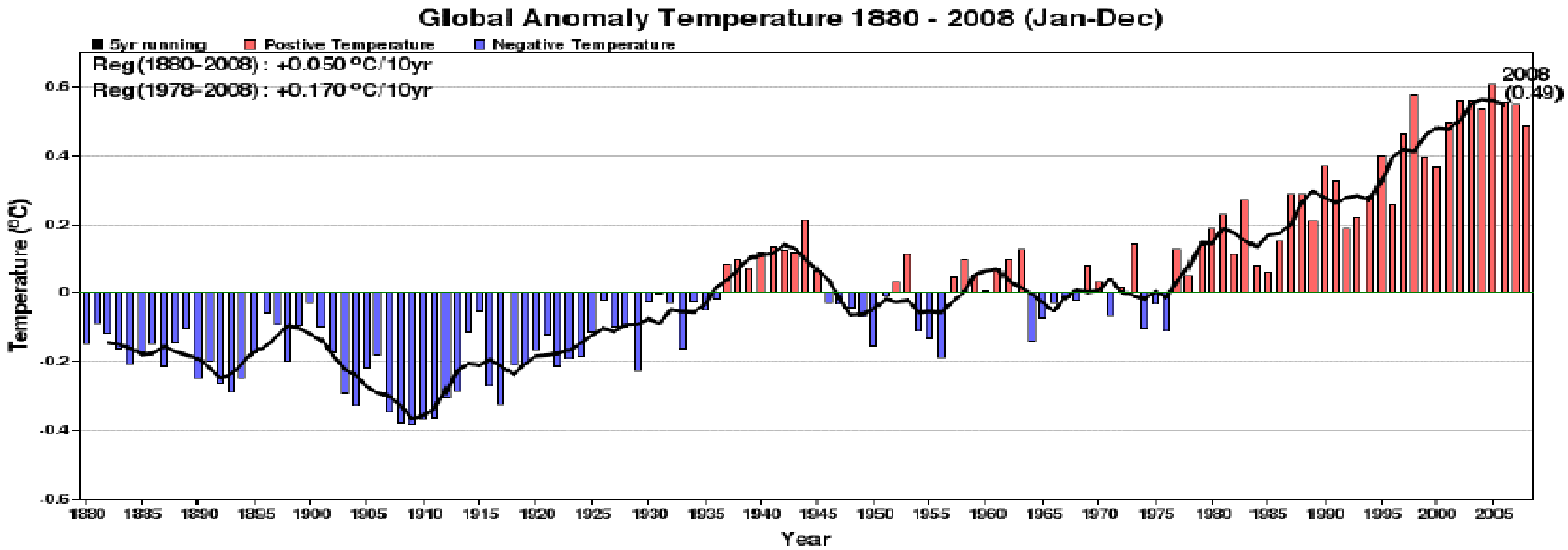
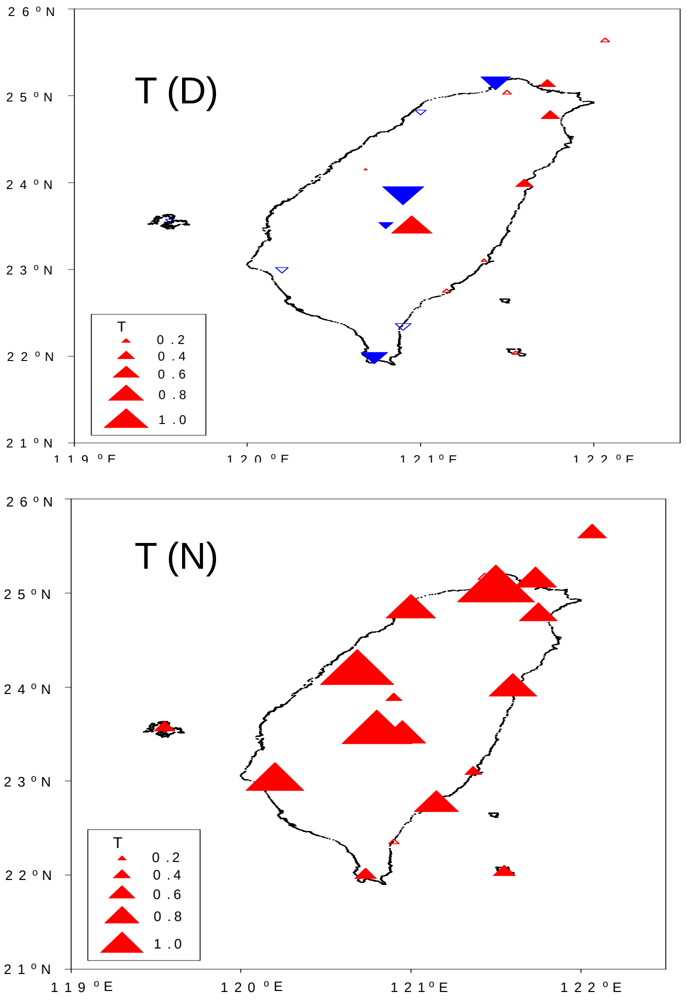


圖 1. 1880-2008 年全球溫度距平之時間序列圖，圖中紅色/藍色長條分別表示正距平/負距平溫度，5 年滑動平均為黑色實線，圖左上數值分別為百年及近 30 年之上升趨勢值，單位為˚C/10 年。註：氣候平均值為使用 1901 至 2000 年的 100 年平均值做為參考。

Climate Changes in Taiwan during 20th Century

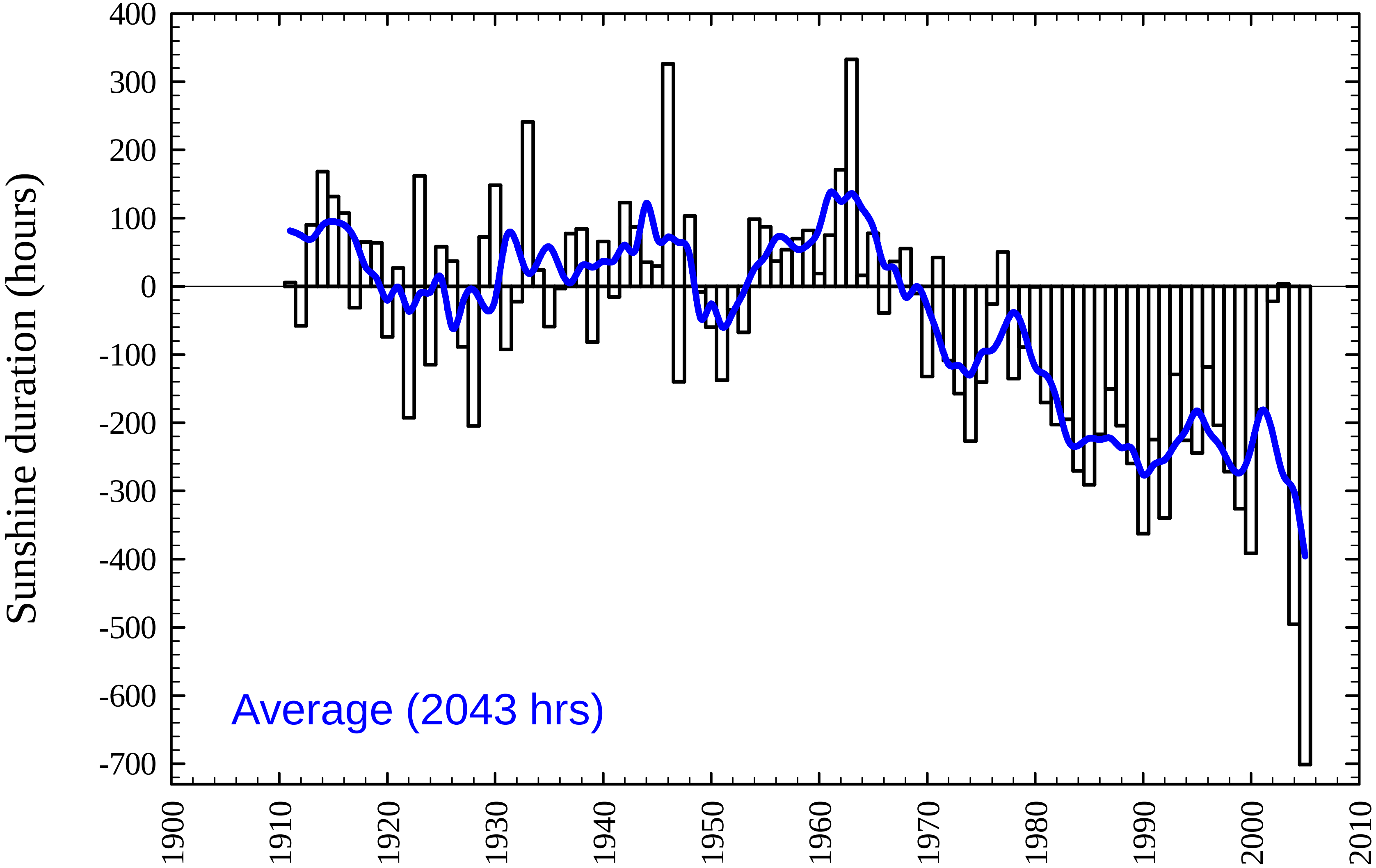
- The average temperature in Taiwan increased by about 1.1C vs. 0.6C in average global temperature. The major reason for the larger increase is the urban heat island effect.
- Since 1961 most temperature increase occurred at night, there was little change in daytime temperature.
- There has been a ~13% decrease in sunshine hours since 1970, probably due to anthropogenic emissions of aerosols.
- There has been a factor of 2 drop in the occurrence of RH > 85% since 1970, probably as a result of land use change such as the urban heat island effect.
- The most serious change was a ~30% increase in precipitation intensity since 1961, due to an increase in very heavy precipitation and decreases in light/moderate precipitation. The cause of the increase is now identified to be global warming.

Linear trends of daytime & nighttime temperature in Taiwan (1961-2005)



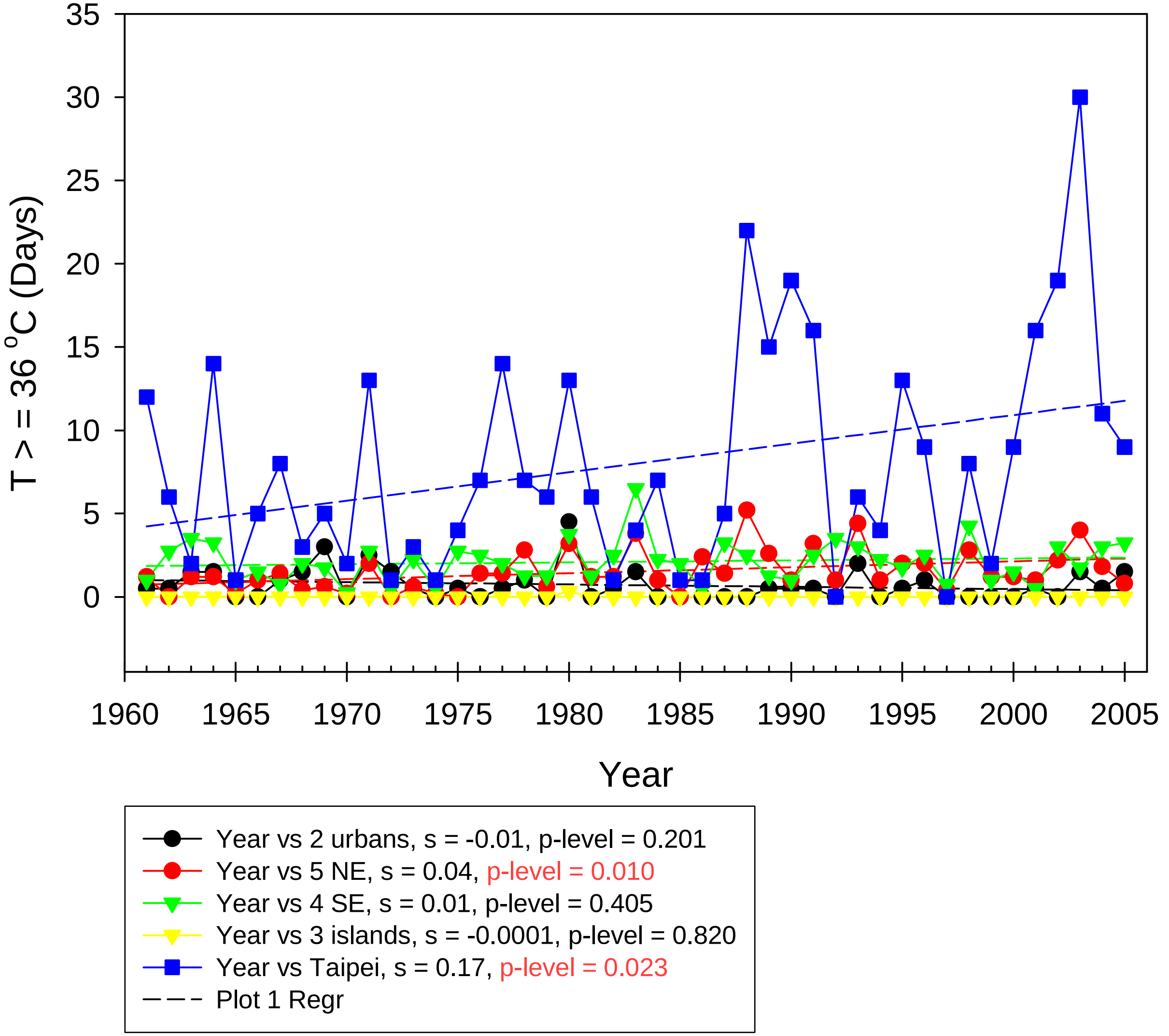
Blue is decreasing trend, red is increasing trend

Direct sunshine hours have decreased by ~15% since 1970 (updated from Liu et al. 2002)



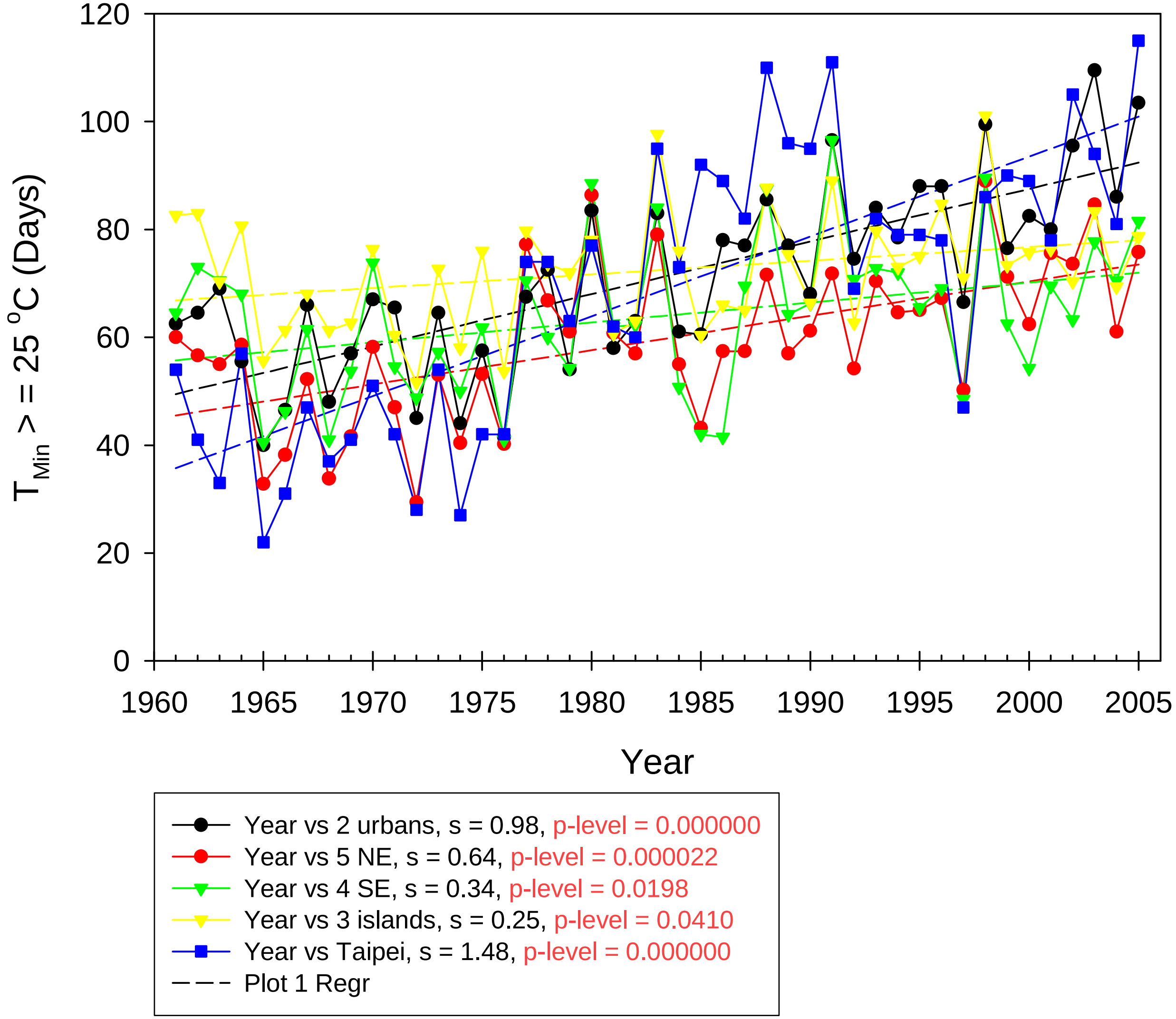
Extreme Climate/weather

- **Extreme climate changes, such as heat waves, severe storms and droughts, have been observed to increase significantly over most regions of the world in the last few decades.**
- **But extreme climate events are very difficult to predict. Therefore, IPCC2007 has been very conservative in projecting/predicting future changes in extreme climate events.**



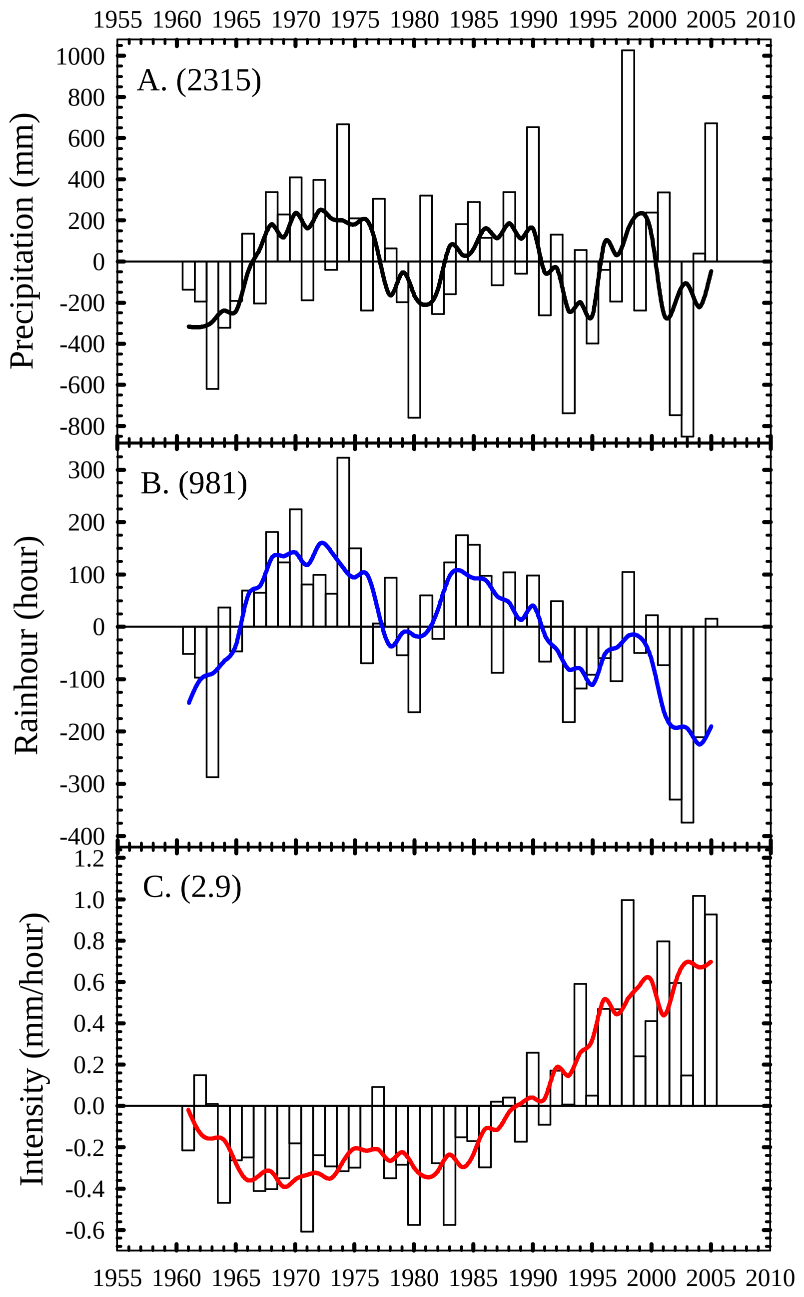
35
30
25
20
15
10
5
0
T > = 36 °C (Days)
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year
Year vs 2 urbans, s = -0.01, p-level = 0.201
Year vs 5 NE, s = 0.04, p-level = 0.010
Year vs 4 SE, s = 0.01, p-level = 0.405
Year vs 3 islands, s = -0.0001, p-level = 0.820
Year vs Taipei, s = 0.17, p-level = 0.023
Plot 1 Regr

"Tropical" nights, or nights requiring air conditioning



Extreme Precipitation Events

- Increases in very heavy precipitation, and sometimes with decreases in light precipitation have been reported in recent years over most land areas (e.g. Karl & Knight, 1998; Goswami et al., 2006) as well as the tropical oceans (Lau and Wu, 2007).
- Increases in heavy precipitation can lead to more and worse floods and mudslides.
- Light and moderate precipitation is a critical source of soil moisture. Since light and moderate precipitation events frequently occur in different seasons from those of heavy precipitation, their decrease poses a serious threat to the drought problem.



Updated from
Liu et al. (2002)

Hsu & Chen (2002) also noticed the loss of light rain.

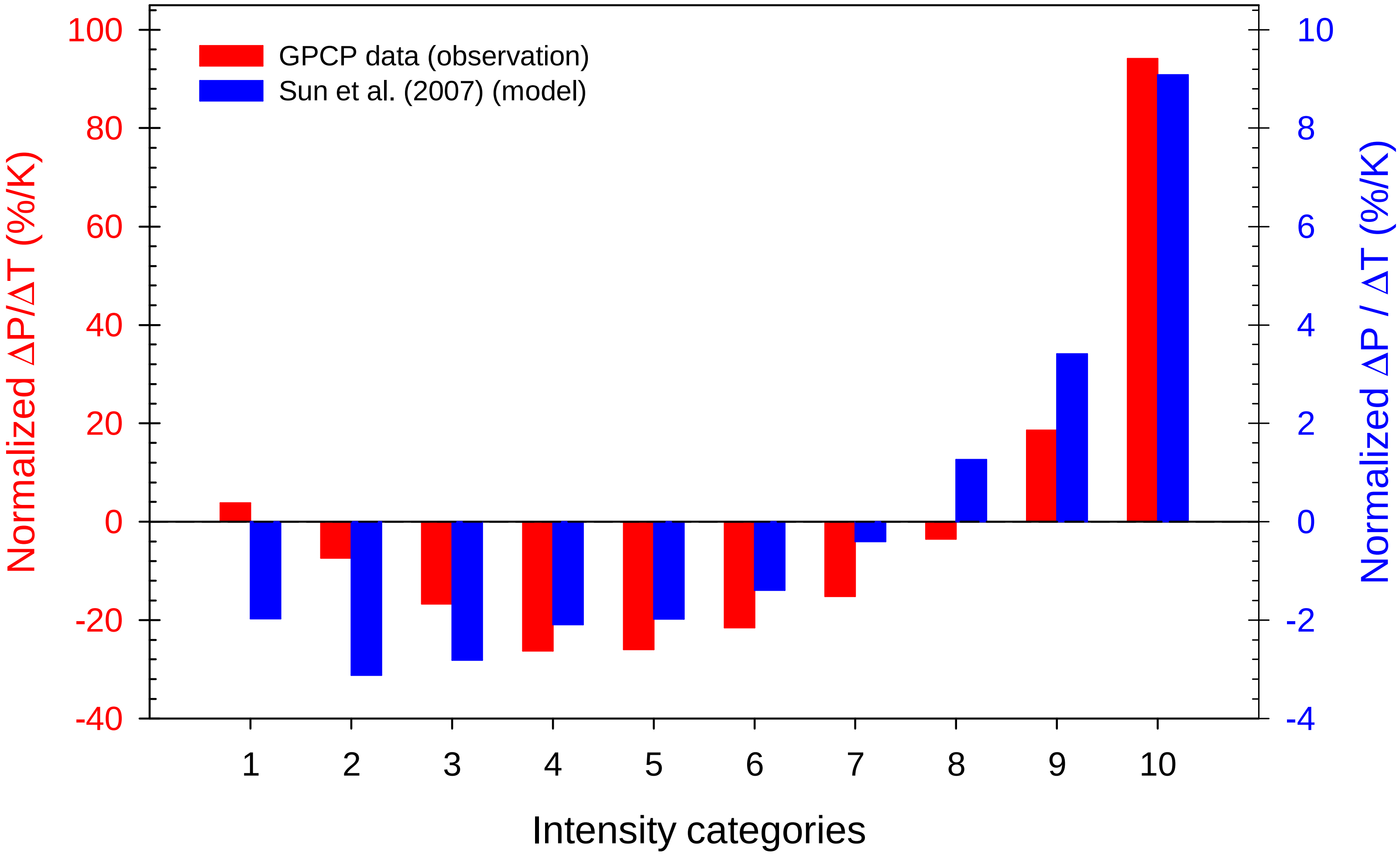
In theory, how should precipitation intensity change in a warming globe?

- Trenberth et al. (2003) hypothesized that the precipitation intensity should increase at about the same rate as atmospheric moisture, i.e. about 7%/K according to the Clausius-Clapeyron equation, because precipitation rates from storms were determined by low-level moisture convergence.
- Furthermore, they argued that the increase of heavy rainfalls could even exceed the moisture increase because additional latent heat released from the increased water vapor could feed back and invigorate the storms.
- Since large storms in the tropics are a major process transporting heat from the boundary layer to the upper troposphere, the invigorated storms can increase the stability of the atmosphere, thereby suppressing light and moderate precipitation.
- However, quantitatively the hypothesis was not corroborated by results from an ensemble of 17 current climate models which shows a global mean increase in precipitation intensity to be only ~2%/K (Sun et al., 2007).

Changes in precipitation intensity derived from observations

- By using an analysis focusing on the interannual variability rather than the long-term trend, Liu et al. (GRL, 2009) were able to determine a statistically significant relationship between precipitation extremes and global temperature.

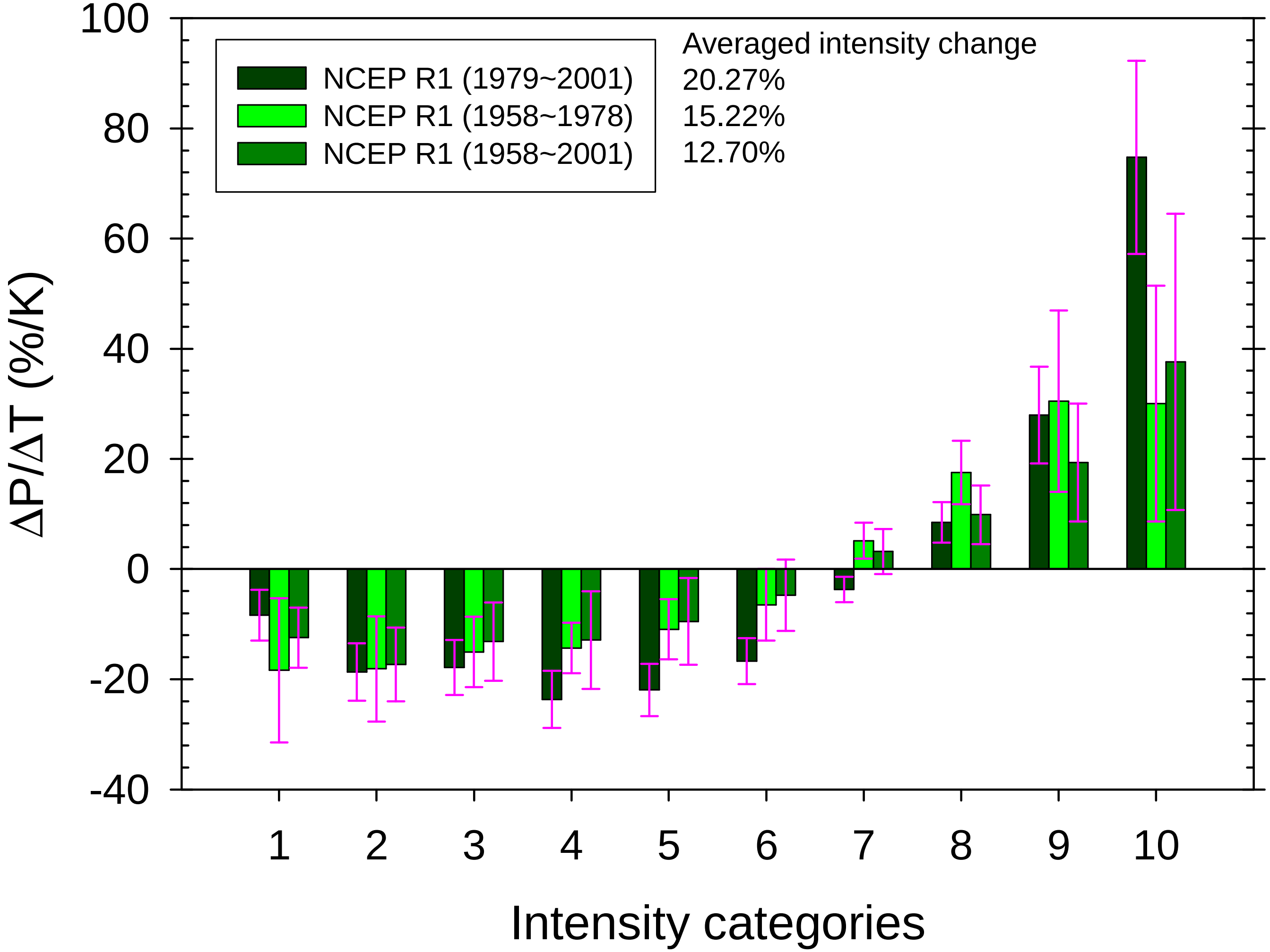
Average precipitation intensity increases by 23% for GPCP data.
Only 2% for the ensemble of 17 current climate models.



From Liu et al. (2009)

- The above results show that the risk of floods and droughts were severely underestimated by the climate models of IPCC2007.
- These findings have been independently substantiated by changes in extreme precipitation derived from the reanalysis by operational weather forecast models of ECMWF (European Center Medium-range Weather Forecast) and NCEP (National Center for Environmental Prediction, USA).

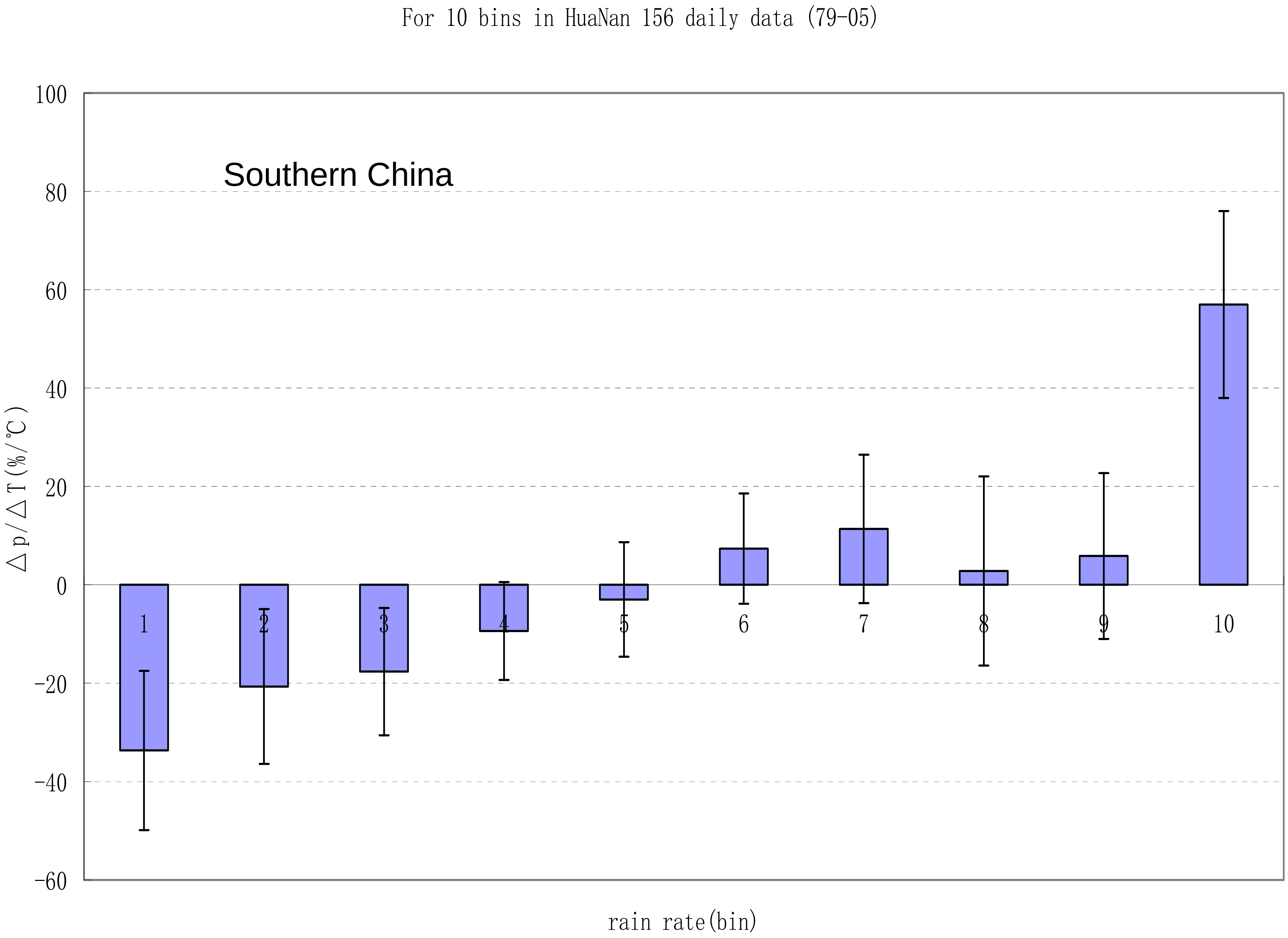
NCEP Reanalysis (daily data)



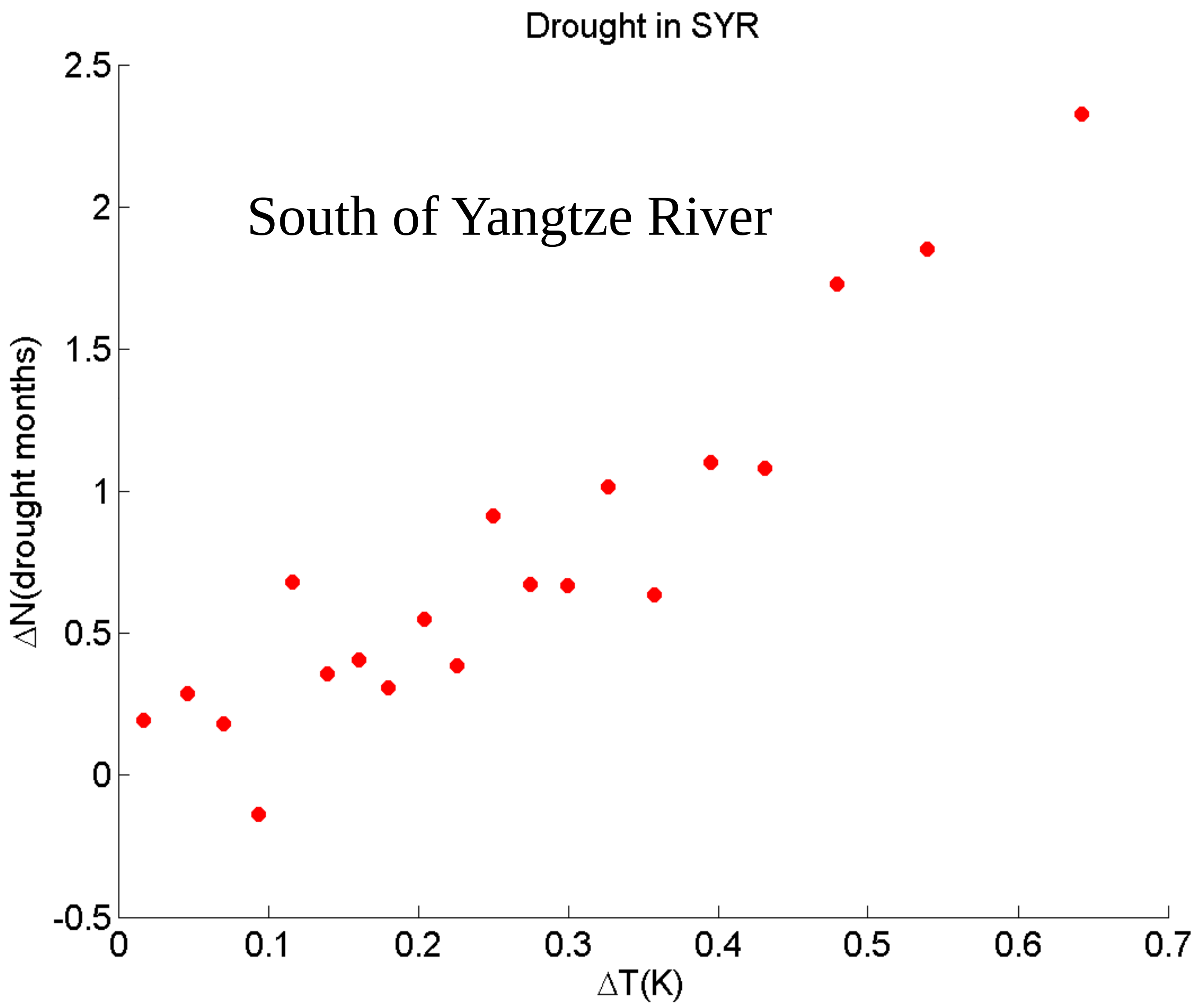
Note: ΔT is from 2m air temperature of NCEP R1

How does the change in precipitation intensity link to the occurrence of floods and droughts?

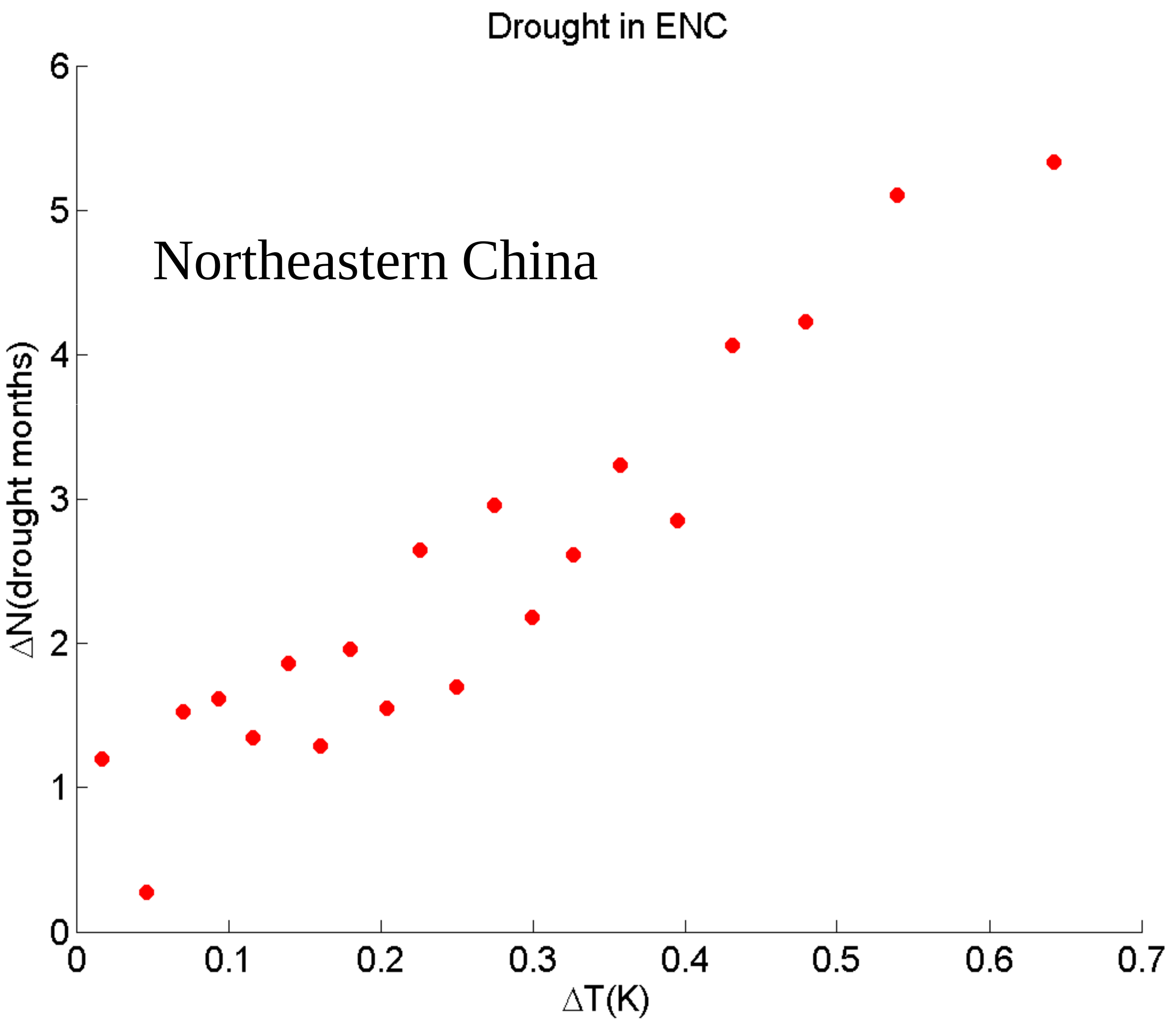
- We use Mainland China as an example.
- NCAR (National Center of Atmospheric Research, USA) has developed a global index for floods and droughts


For 10 bins in HuaNan 156 daily data (79-05)
Southern China
100
80
60
40
20
0
-20
-40
-60
△p/△T(%/℃)
1
2
3
4
5
6
7
8
9
10
rain rate(bin)

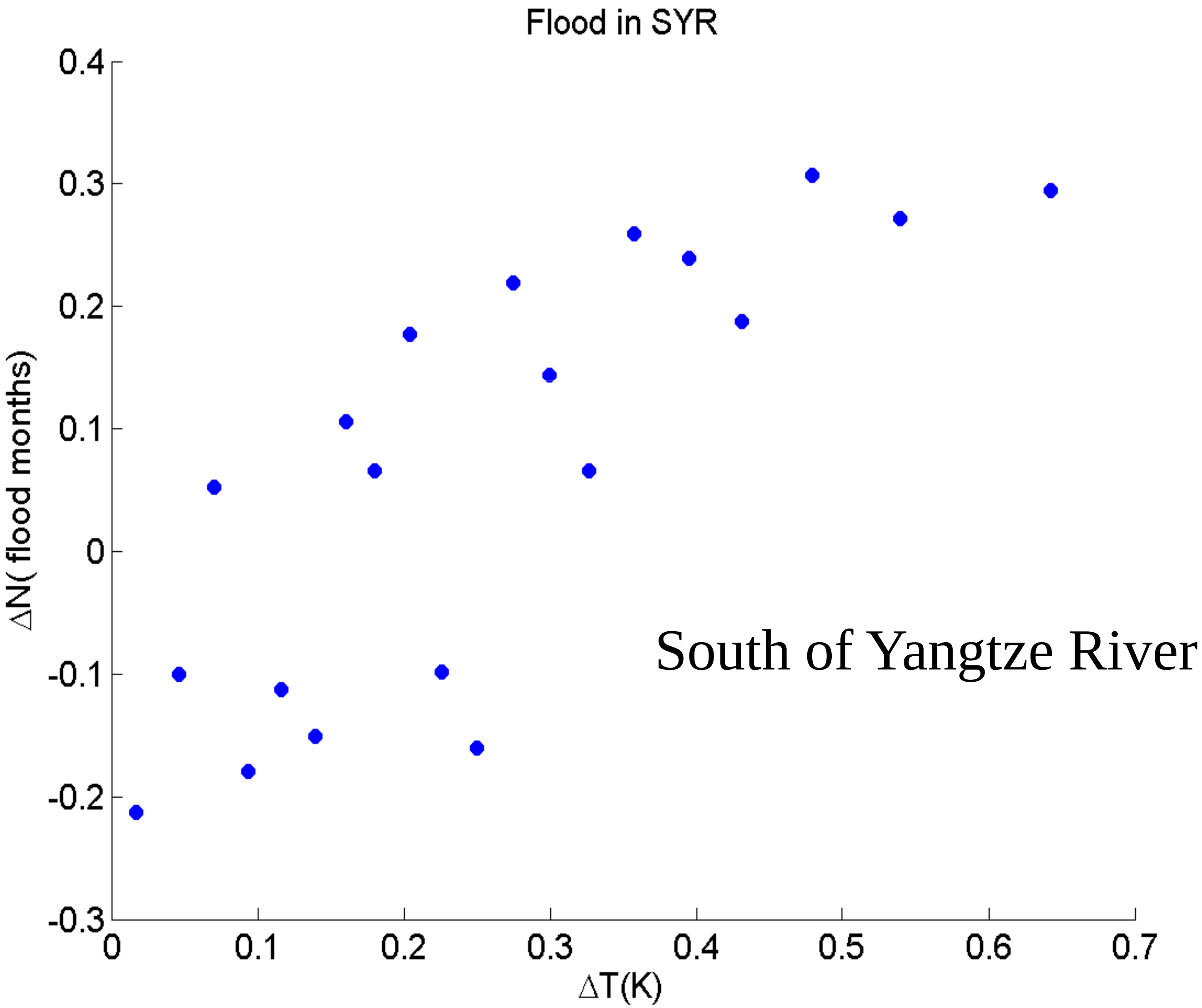
Change in annual number of drought-months (ΔN) plotted as a function of increase in global average temperature (ΔT)



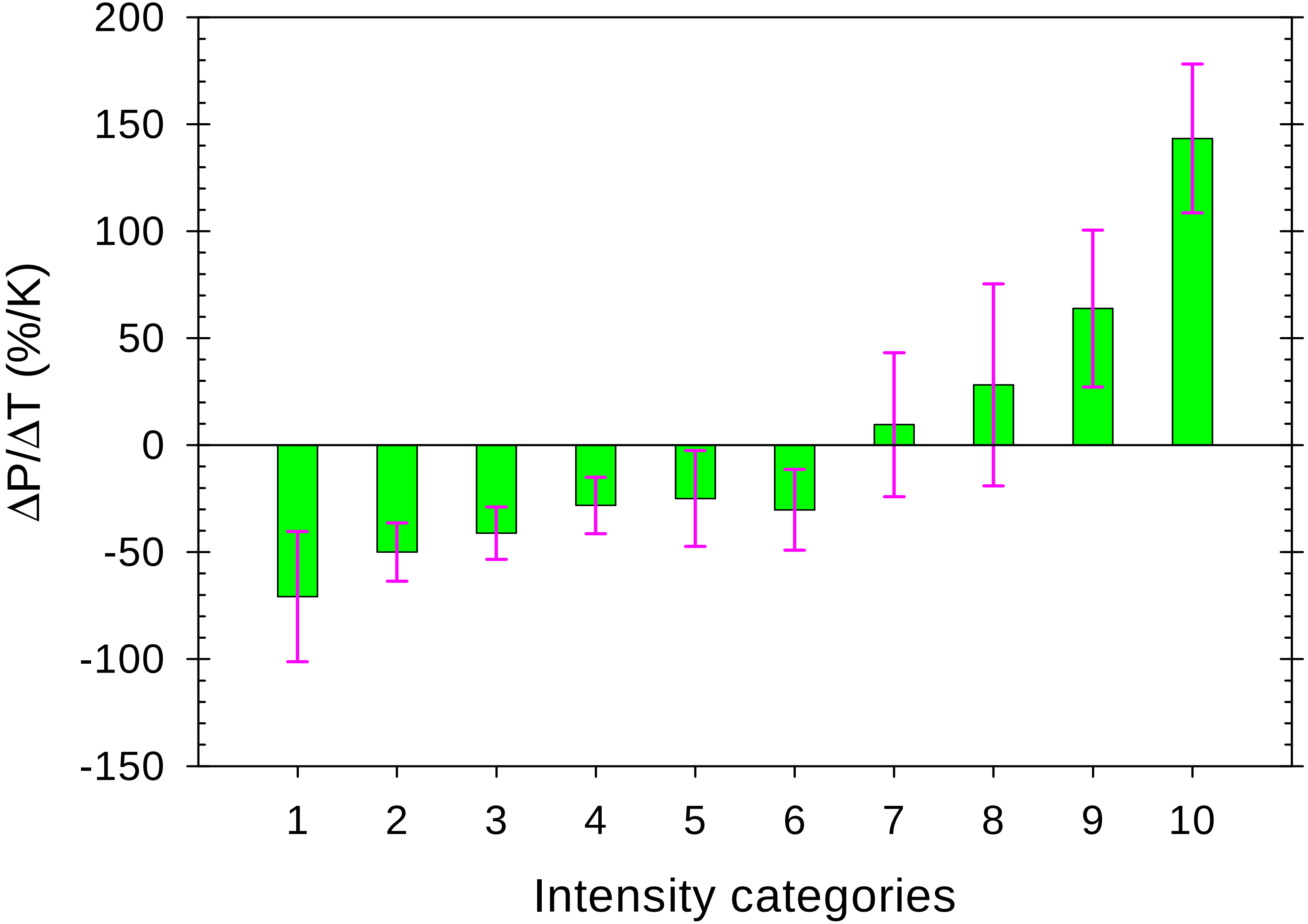
Change in annual number of drought-months (ΔN) plotted as a function of increase in global average temperature (ΔT)

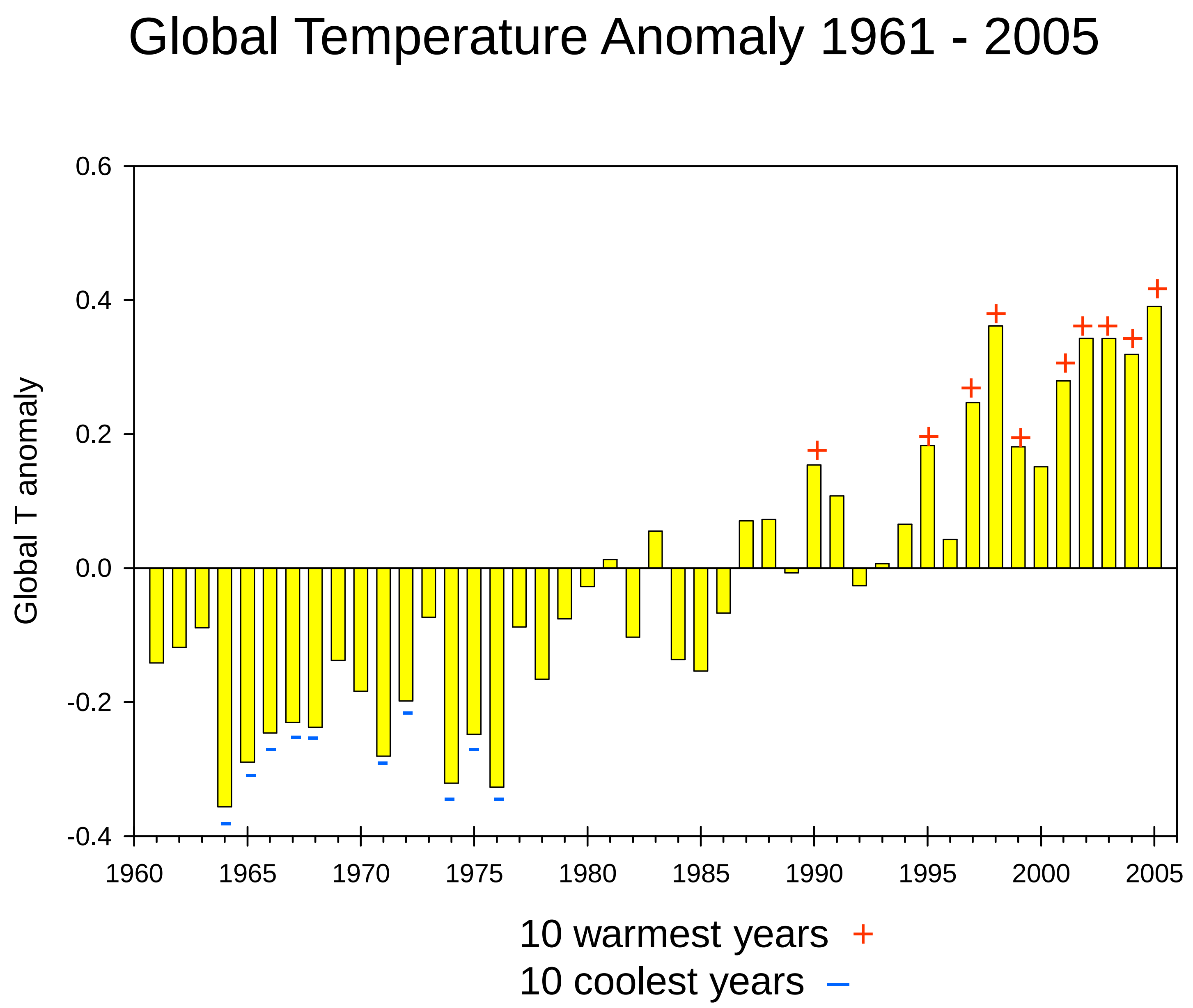


Change in annual number of flood-months (ΔN) plotted as a function of increase in global average temperature (ΔT)

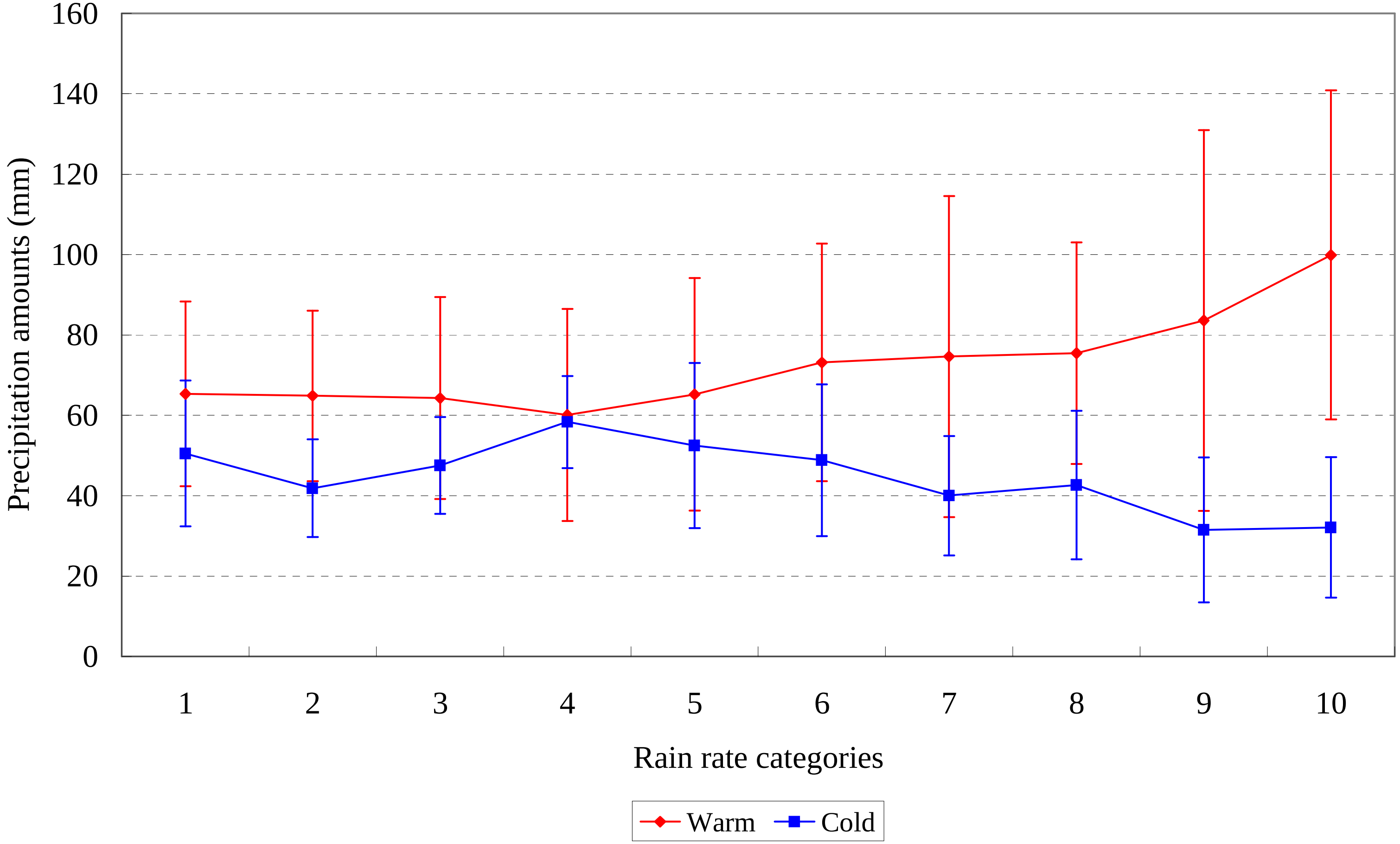


Changes in Taiwan's rain intensity for each degree warming in global temperature



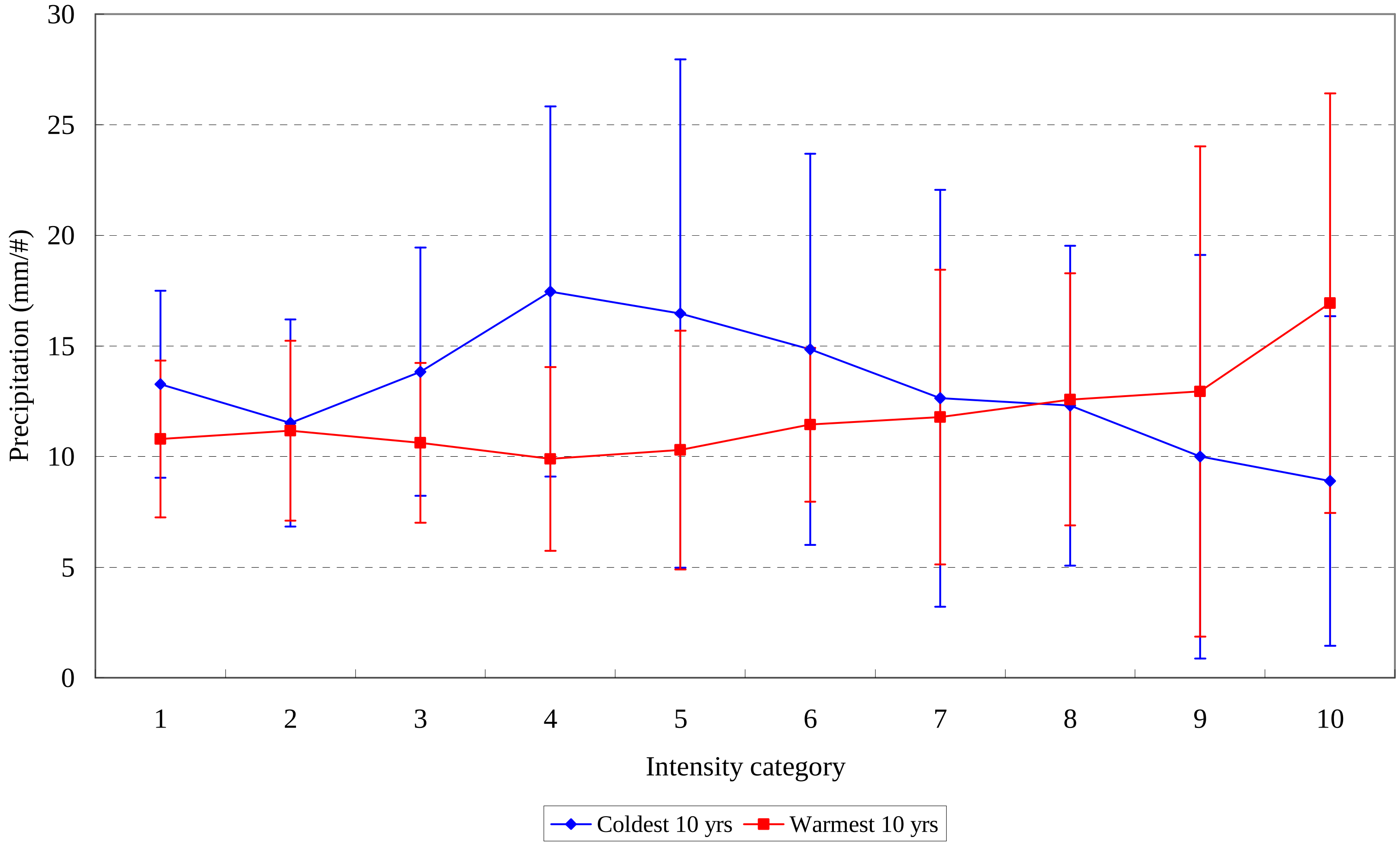

Global Temperature Anomaly 1961 - 2005
Global T anomaly
0.6
0.4
0.2
0.0
-0.2
-0.4
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
10 warmest years +
10 coolest years –

Rain intensity of typhoons landed in Taiwan
15 CWB stations (in mm/hr)
Warm years: 728.2 mm , # = 5.9
Cold years: 445.9 mm, # = 3.3



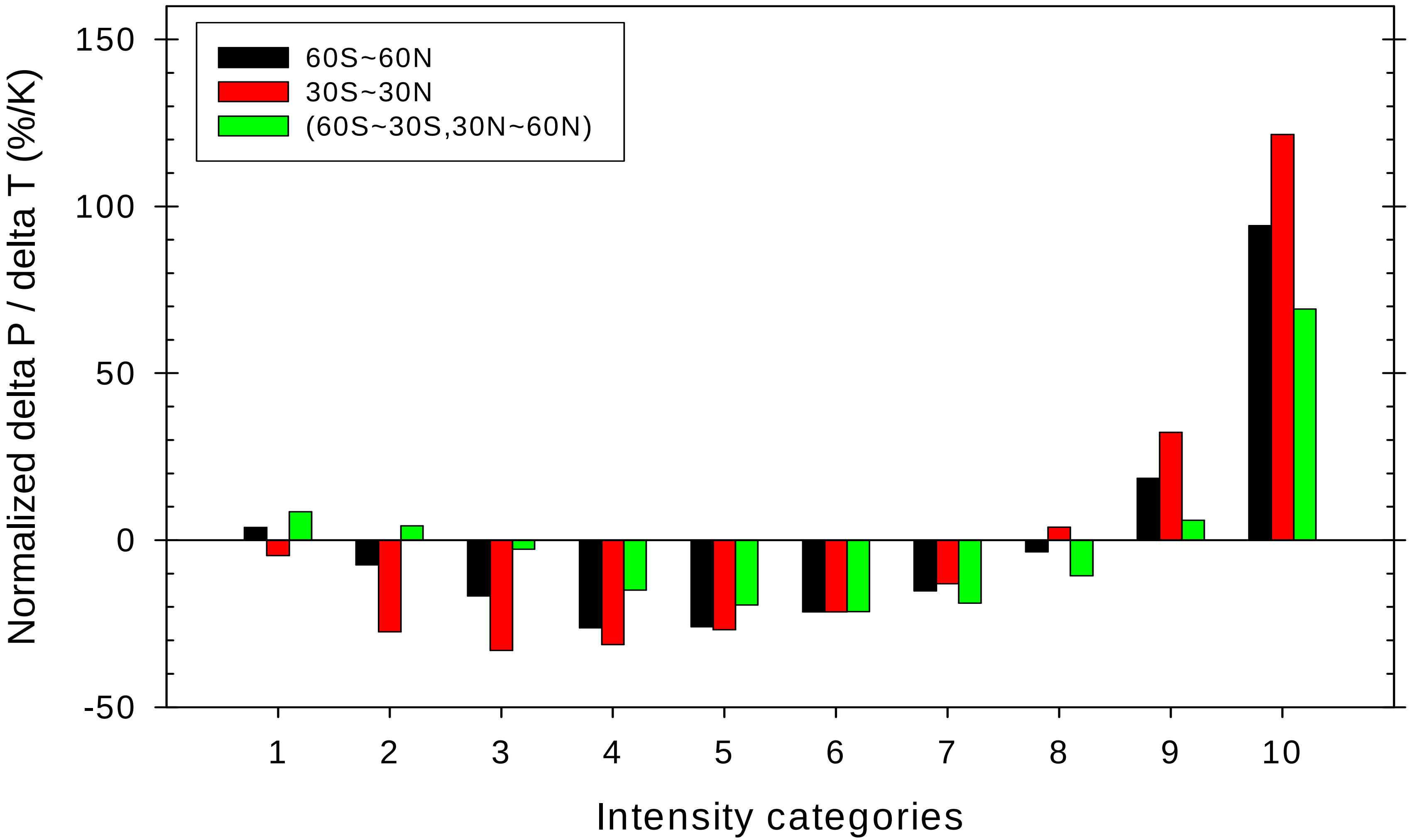
	1	2	3	4	5	6	7	8	9	10
P-values	0.2670	0.0474	0.1905	0.8921	0.4279	0.1341	0.0826	0.0382	0.0326	0.0029

15 CWB stations (in mm/hr)
Composite according to global T
Typhoon



Precipitation amounts of each category of each year normalized by its typhoon numbers

GPCP data, latitudinal variation



Conclusions

- Global warming has already caused alarming increases in the occurrence of droughts and floods in most areas in the world, often by more than a factor of 2.
- At low latitudes (30S – 30N), the increase is about twice as large as mid latitudes.
- Another round of similar changes are predicted by 2035.
- Because reduction of greenhouse gases will take a long time (>50 years because the anthropogenic CO2 lifetime is ~100 years), adaptation strategies such as flood control, water resource policy and land use plans must be developed and implemented quickly.

Thank you for your attention!