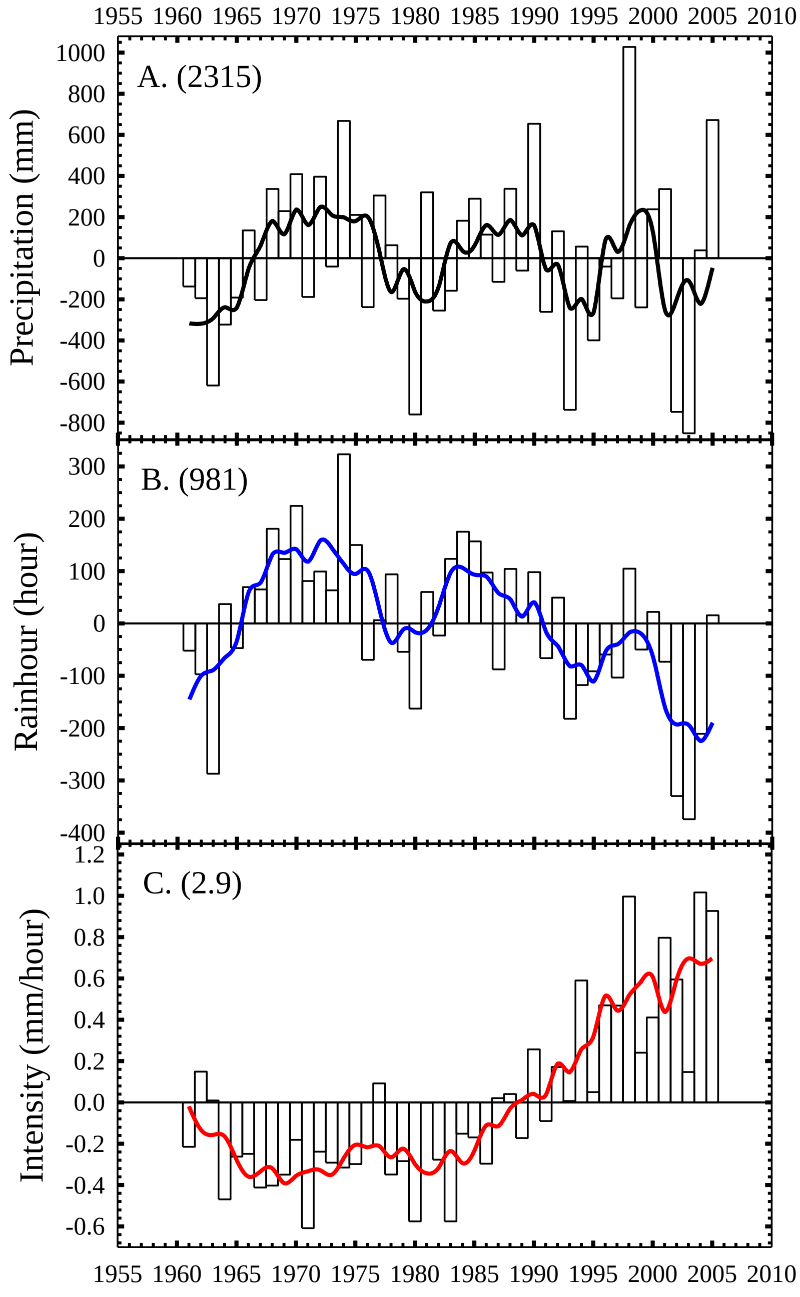
Precipitation extremes in a warming globe: comparison of observations to climate models and weather models

Shaw C Liu[1], Congbin Fu[2,3], C-J Shiu[1], J-P Chen[4], and Futing Wu[2]
[1] Research Center for Environmental Changes, Academia Sinica, Taipei
[2] Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing
[3] College of Atmospheric Science, Nanjing University, Nanjing
[4] Department of Atmospheric Sciences, National Taiwan University, Taipei

2010 International Workshop of TCCIP Project on Climate Change
Taipei
Nov. 1-3, 2010

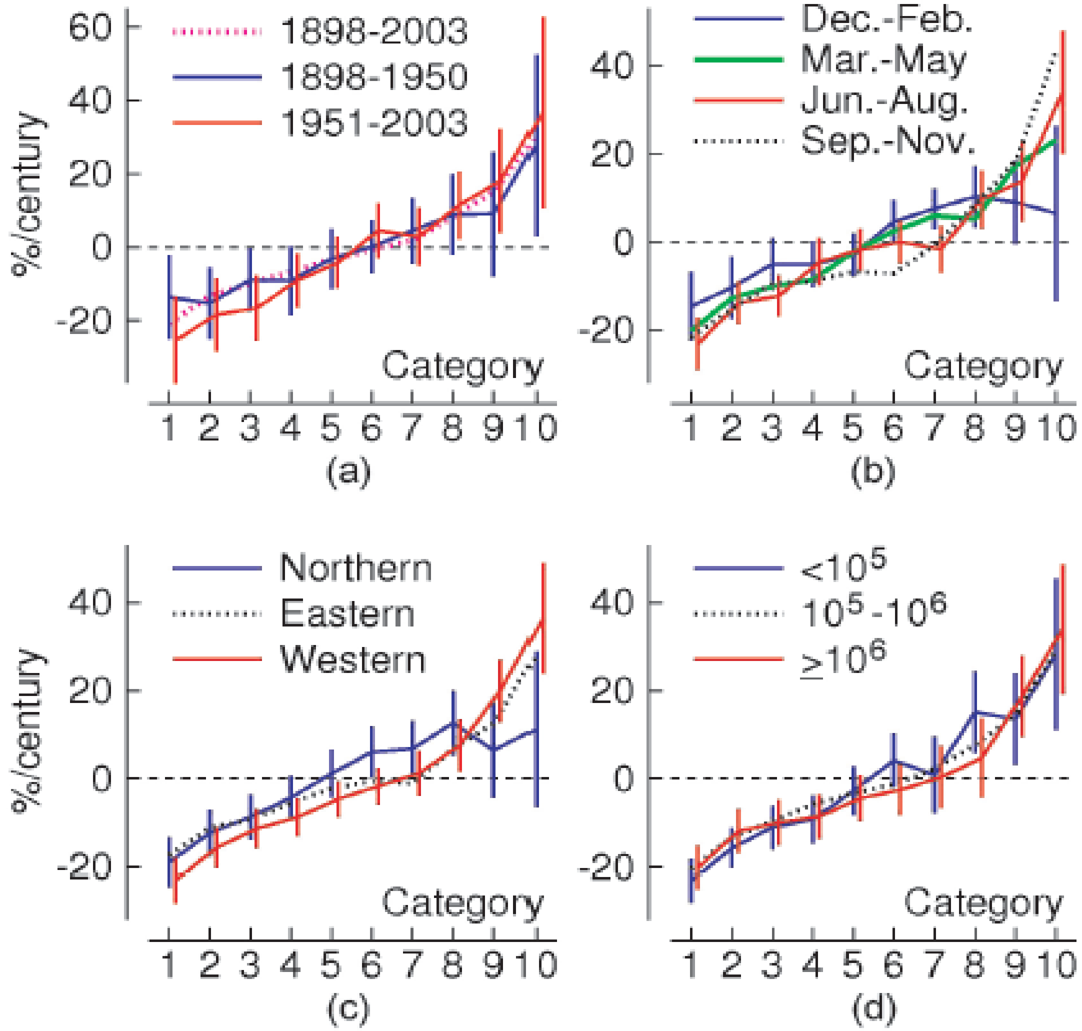
- Increases in very heavy precipitation, and sometimes with decreases in light precipitation have been reported in recent years over most land areas (e.g. Karl & Knight, 1998; Fujibe et al., 2005) as well as the tropical oceans (Lau and Wu, 2007).



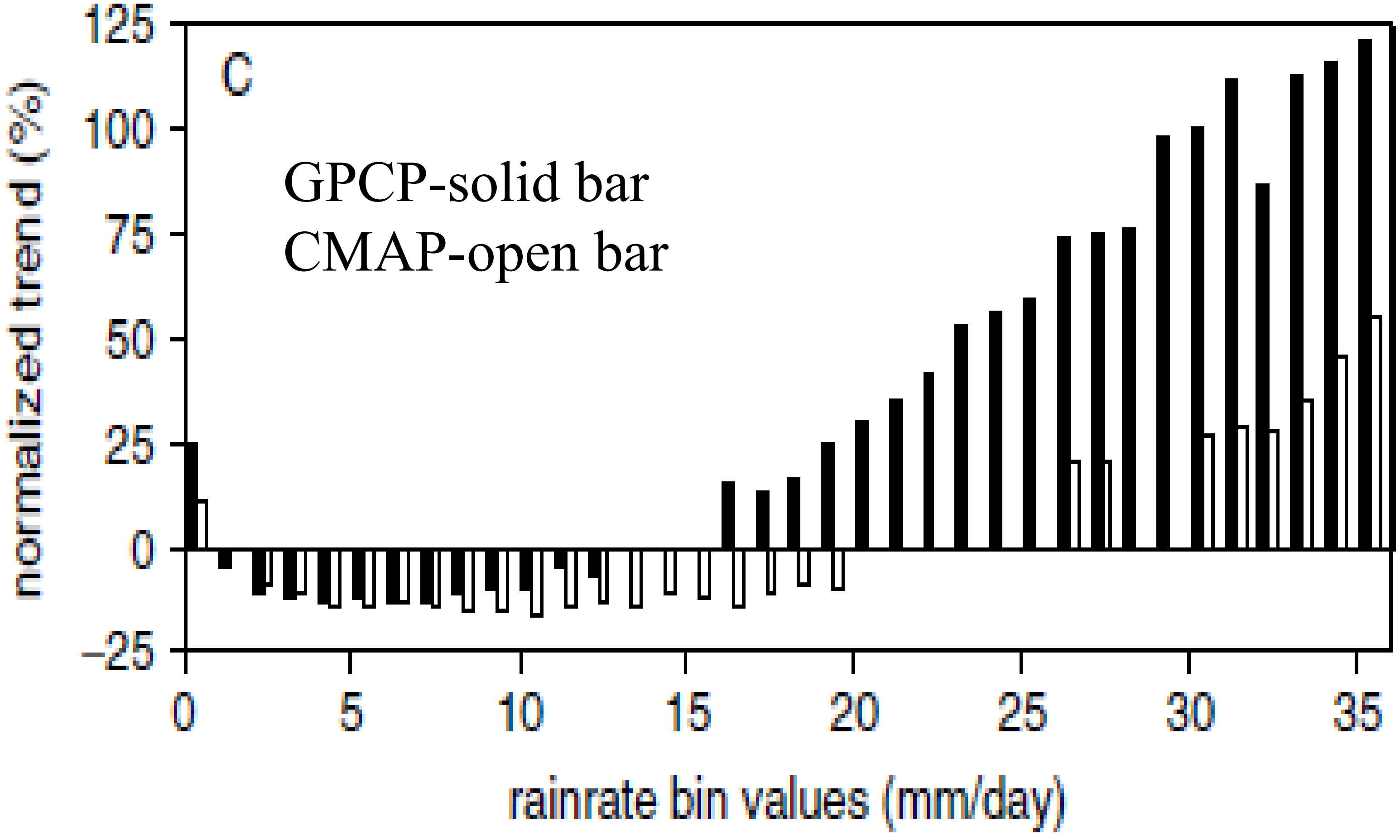
Updated from Liu et al. (2002)

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

Linear trends of precipitations (in mm/4 hours) at different intensities in Japan, (a) for 3 time periods, (b) for 4 seasons, (c) for 3 regions, and (d) for 3 urban population ranges. (Fujibe et al., 2005)



From Lau and Wu (2007)



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.
- 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.

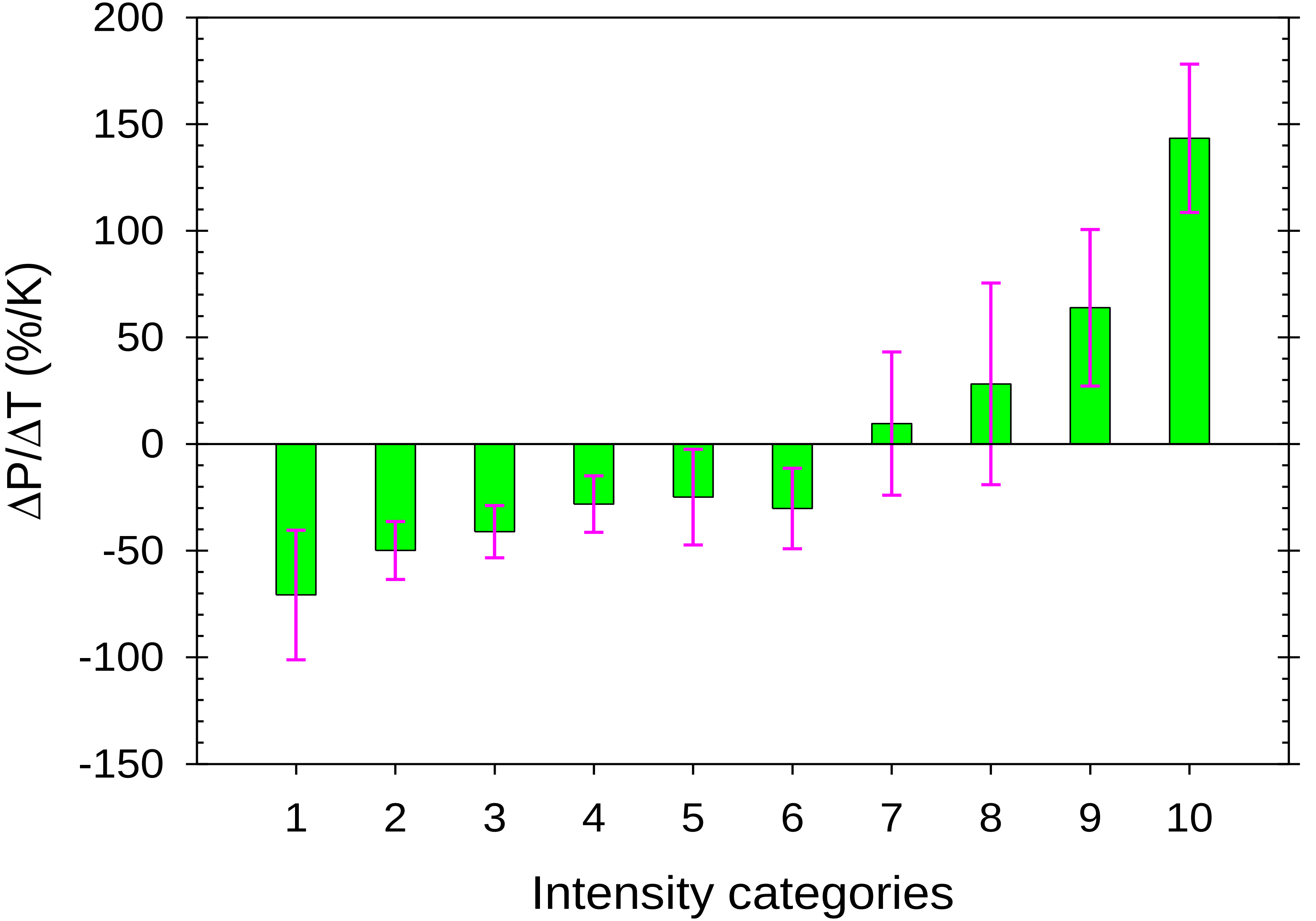
AR3 Climate Models: 2 %/K

- However, quantitatively the hypothesis of Trenberth et al. (2003) 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 about 2 %/K (Sun et al., 2007).

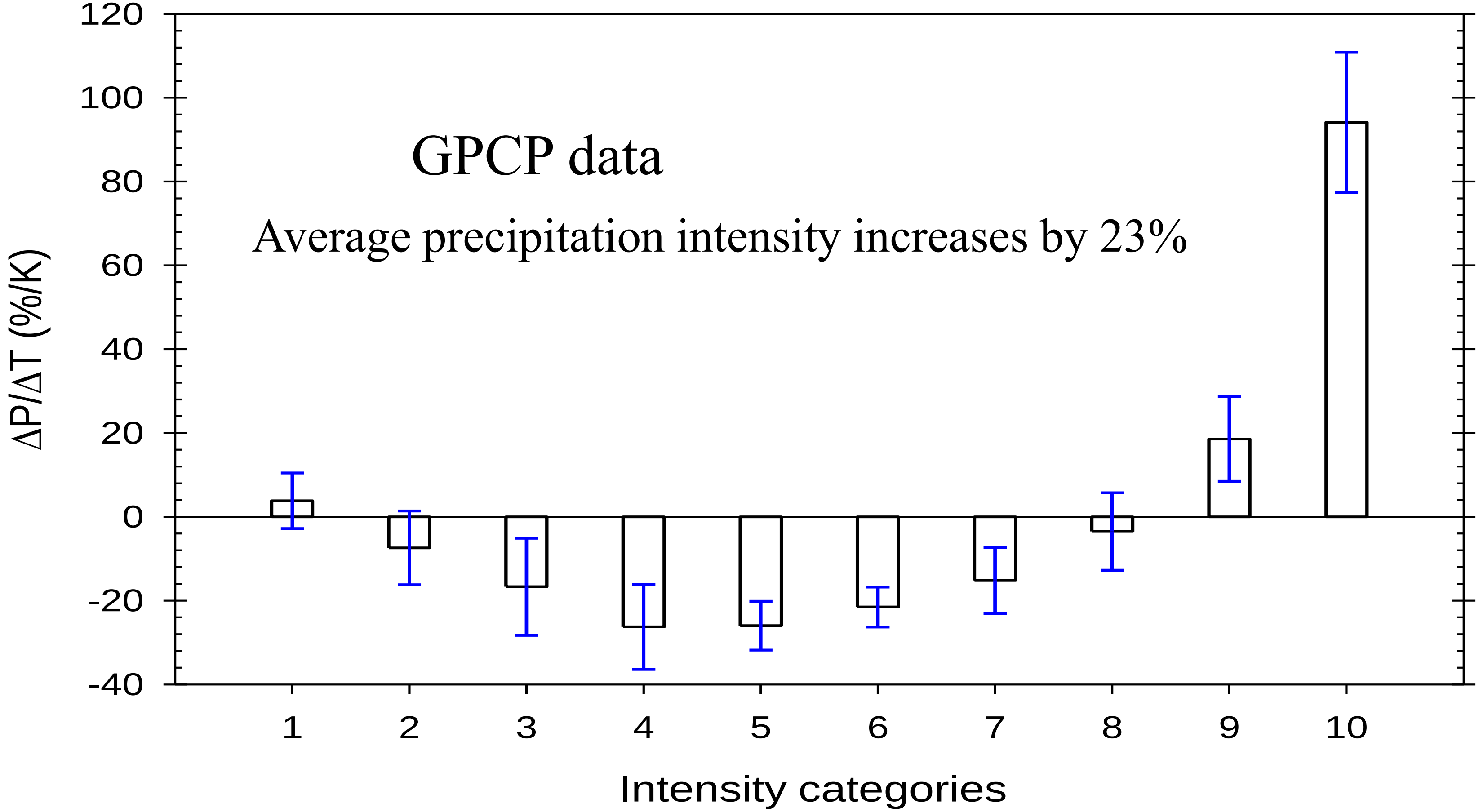
Changes in precipitation intensity derived from observations

- 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 global precipitation extremes and temperature.

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

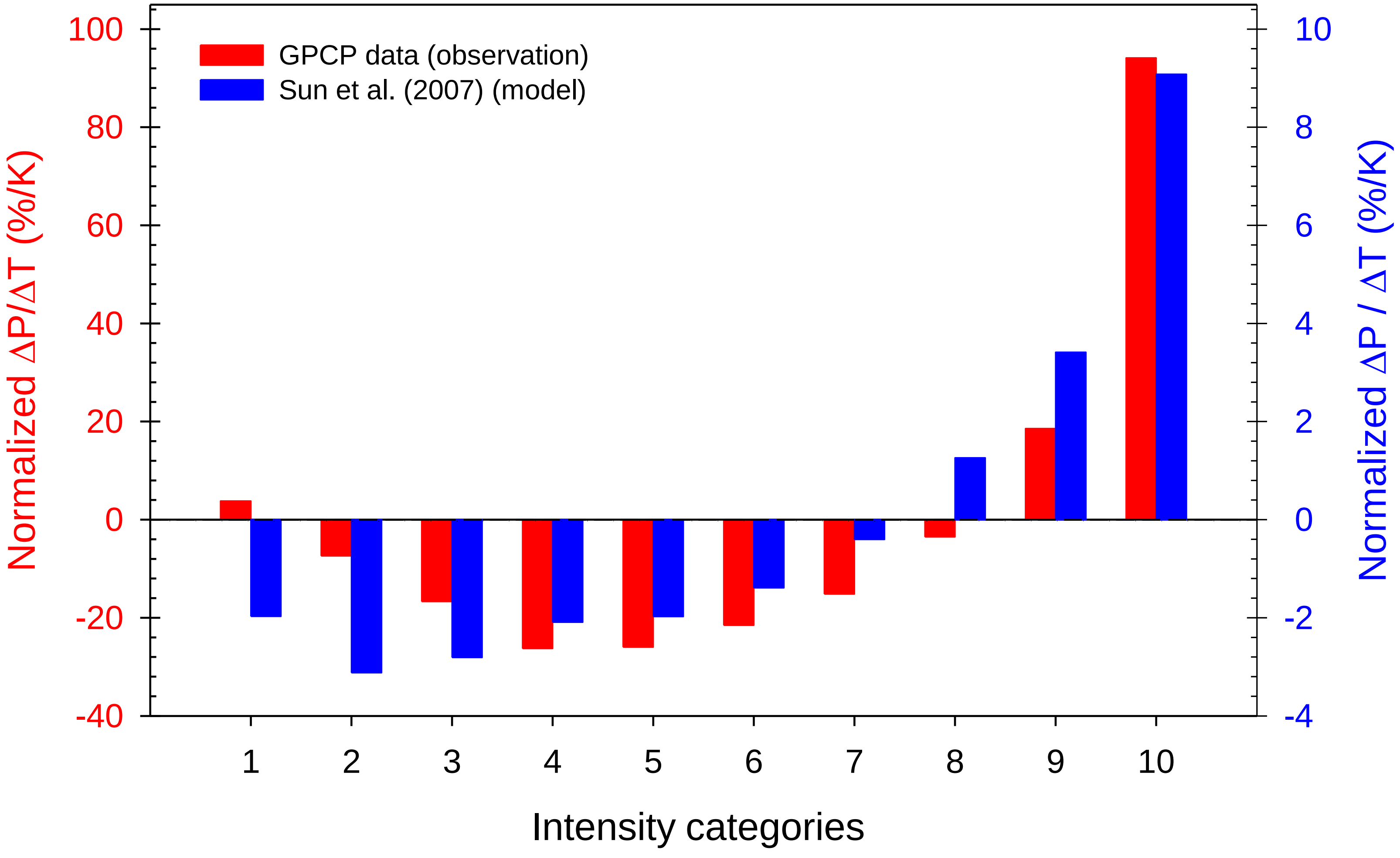


From Liu et al. (GRL, 2009)



ΔP/ΔTc for all 10 bins of precipitation intensity. Open bars denote values of ΔP/ΔTc. The vertical line on top of each open bar denotes the 2 standard deviation.

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



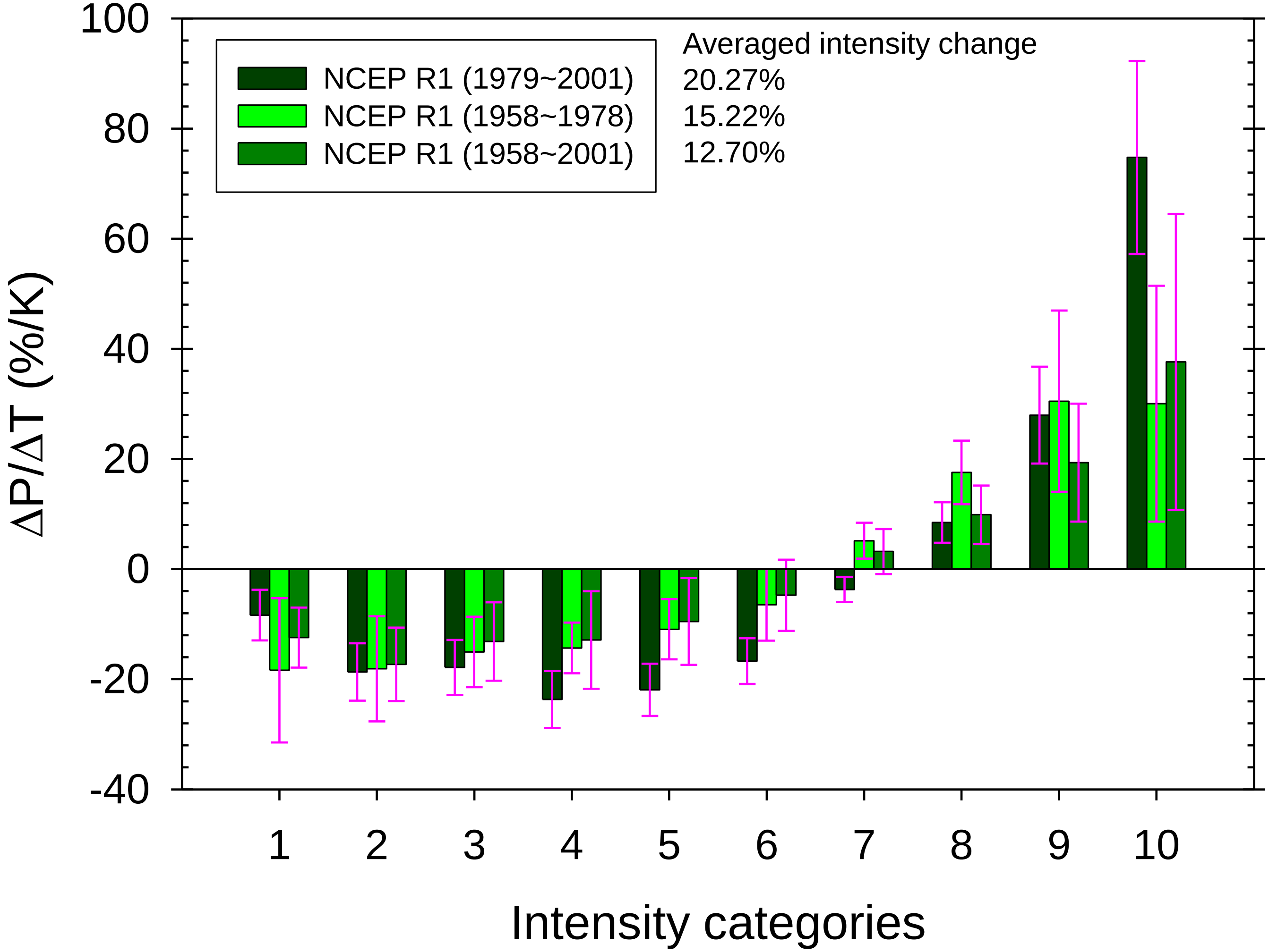
From Liu et al. (2009)

Concerns about the GPCP data

- **The short length of time: 1979-2007.**
- **The coarse temporal and spatial resolutions: 2.5^o x 2.5^o, 5-day average.**
- **Different satellite data sets, each with different bias, calibrations, and drifts in the accuracy of measurements.**

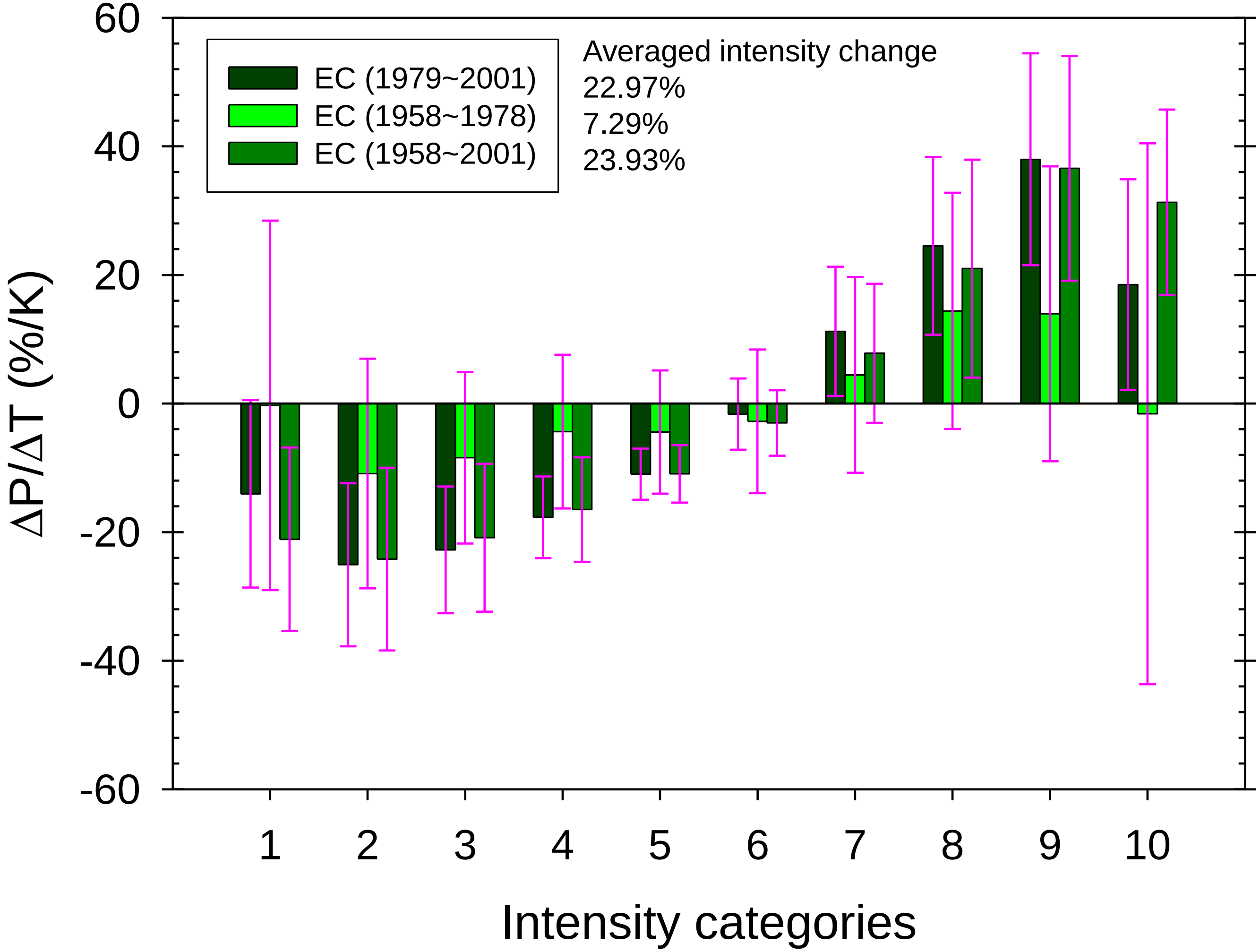
So we check GPCP values against results of reanalyses from operational weather forecast models of NCEP (R1, 2^{o}x2^o) and ECMWF (ERA-40, 1^{o}x1^o). This check is an independent evaluation of the GPCP results as the precipitation from the reanalysis is a diagnostic quantity. In fact, observed precipitation is not used in the data assimilation of the reanalysis.

NCEP Reanalysis (daily data)



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

EC Reanalysis (daily data)

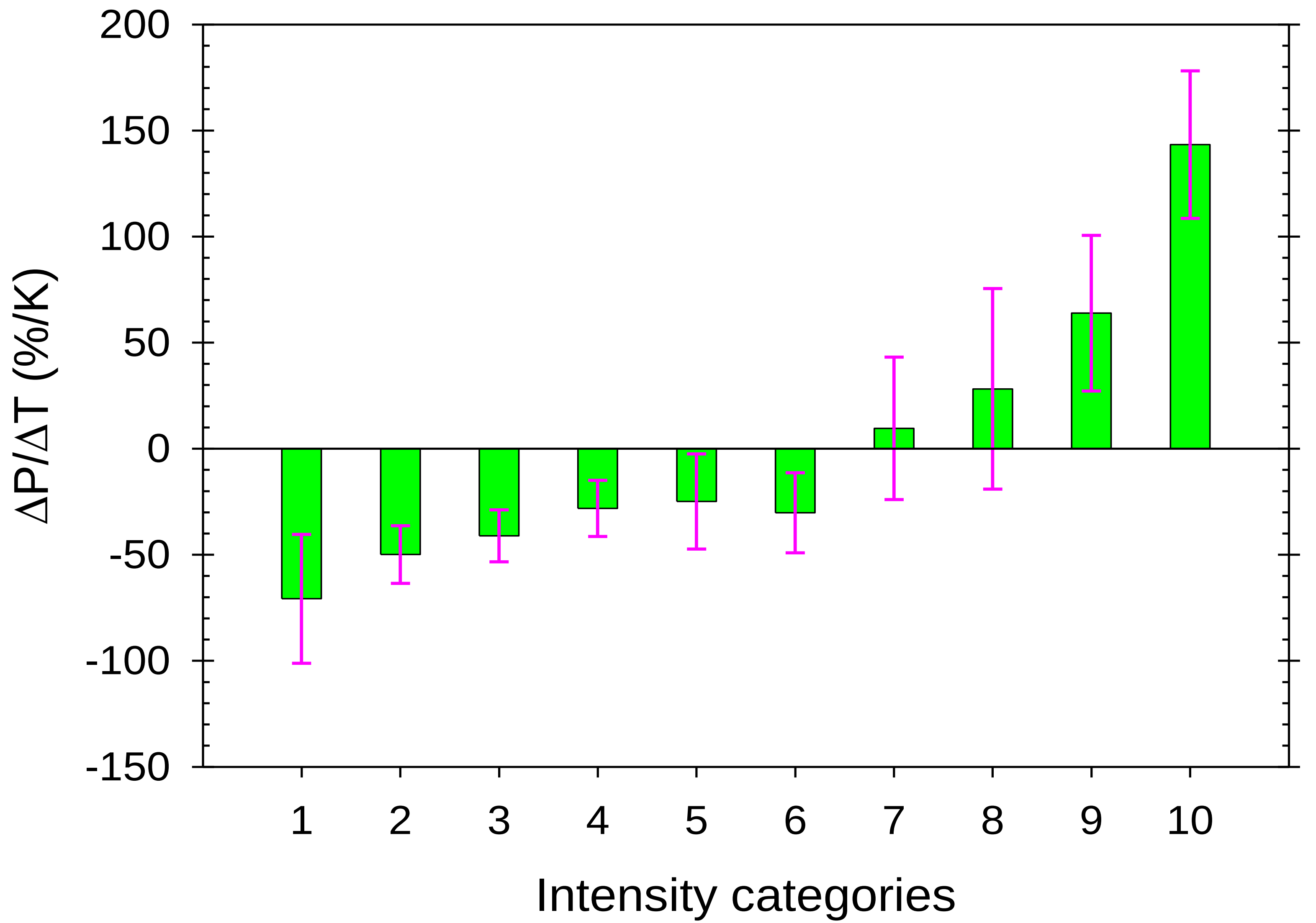


Note: ΔT is from 2m air temperature of EC

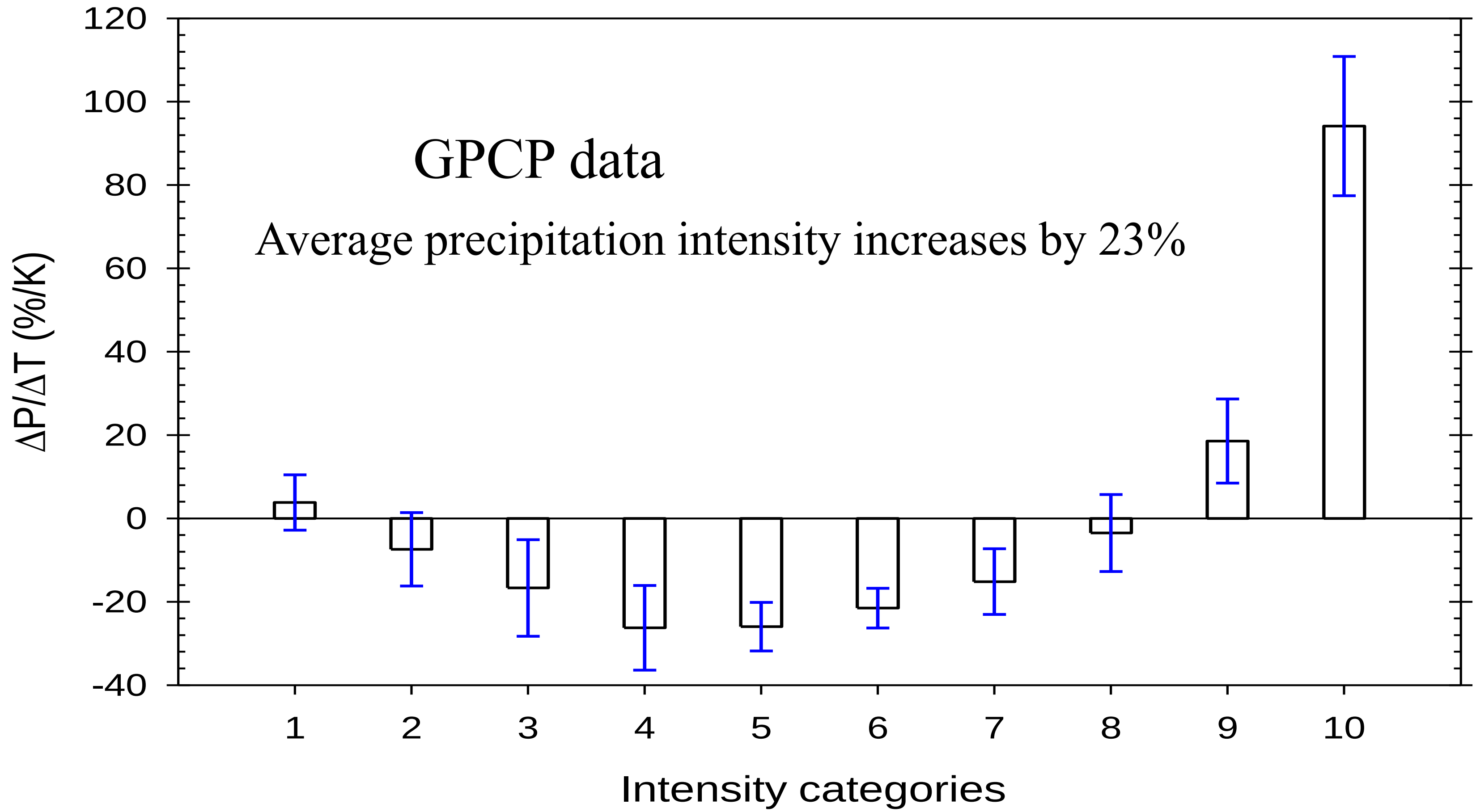
- The temperature dependence of global precipitation intensity derived from GPCP agrees very well with results of reanalyses by NCEP and ECMWF. The agreement strongly suggests that the large increase in precipitation intensity with global temperature derived from the GPCP data is more credible than those calculated by current (~2007) climate models.
- The reason that climate models underestimate the increase in precipitation intensity by a factor of 10 is obviously due to a shortcoming in their deep convection schemes. How would this shortcoming affect the water vapor and cloud feedbacks in the climate models is a serious concern.

Thank you for your attention!

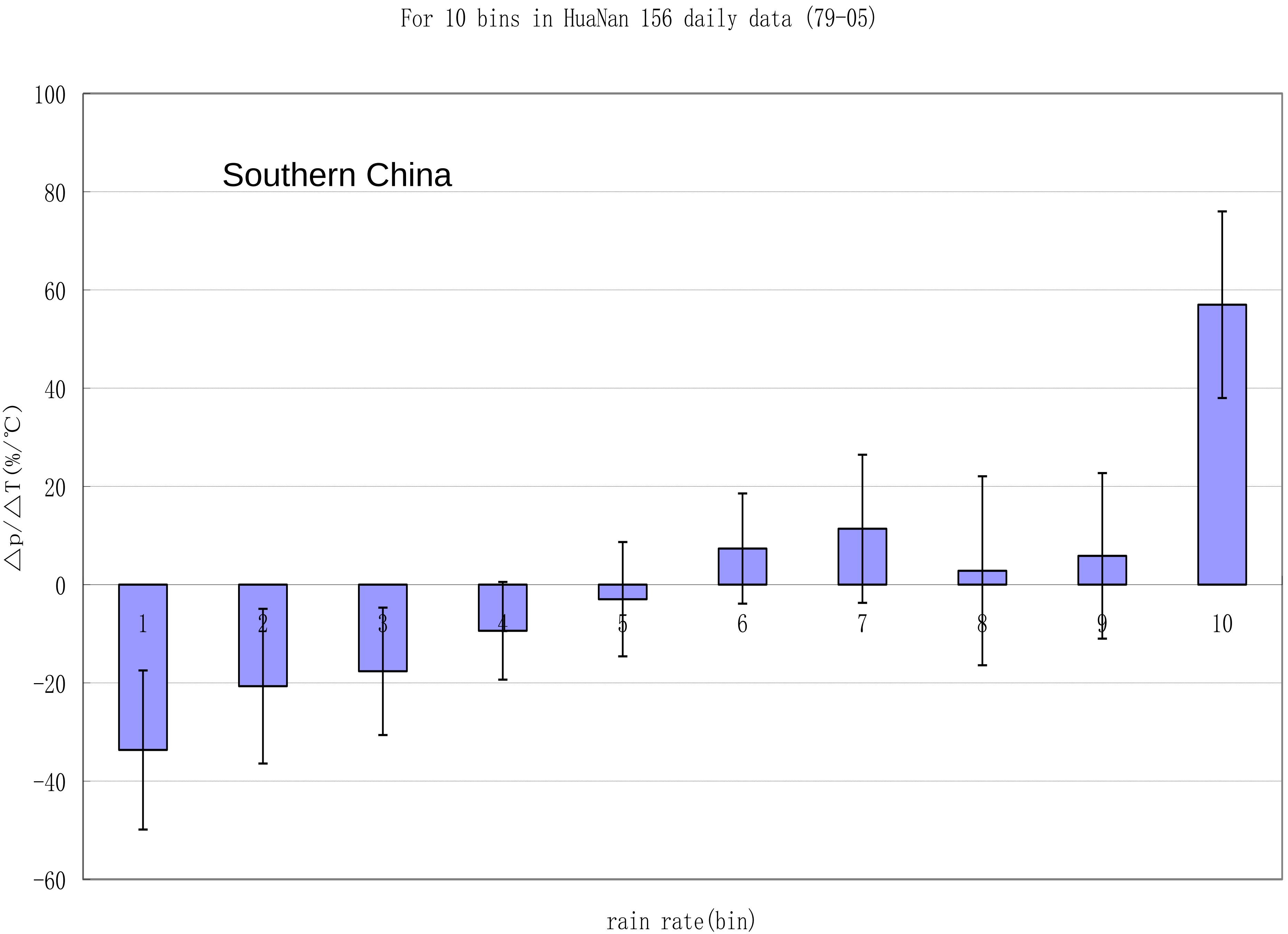
Changes in Taiwan’s rain intensity for each degree warming in global temperature



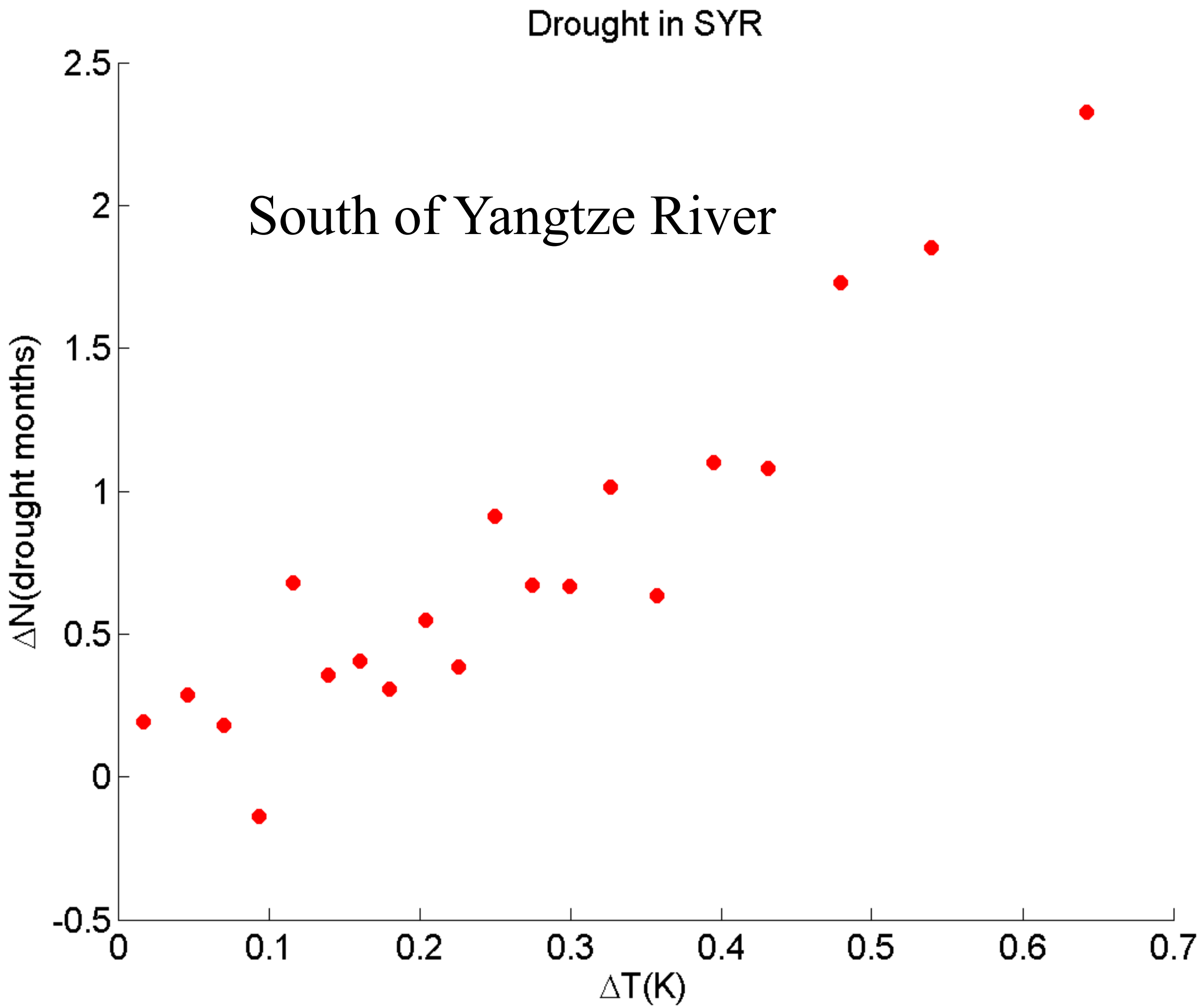
From Liu et al. (GRL, 2009)



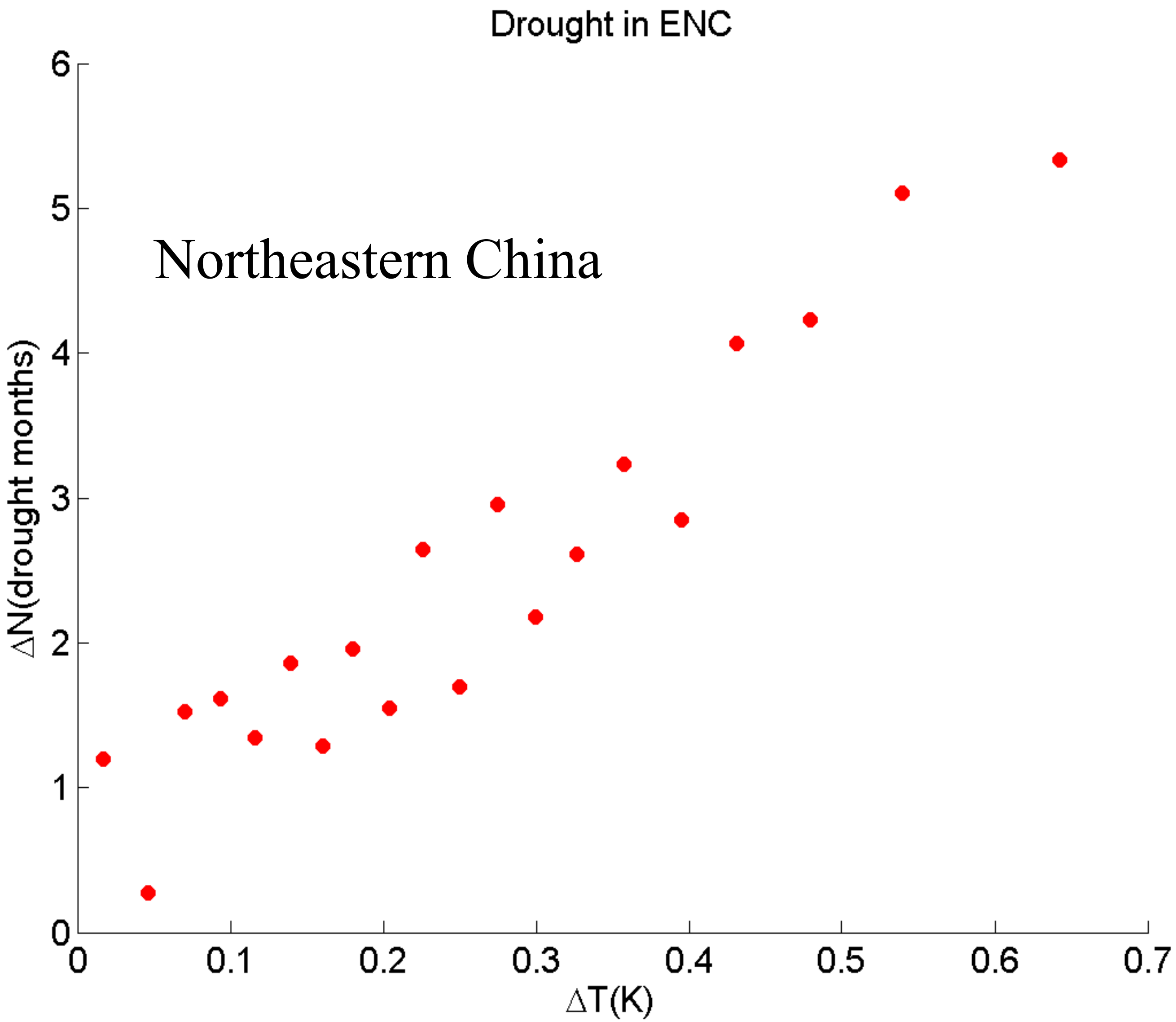
ΔP/ΔTc for all 10 bins of precipitation intensity. Open bars denote values of ΔP/ΔTc. The vertical line on top of each open bar denotes the 2 standard deviation.


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)

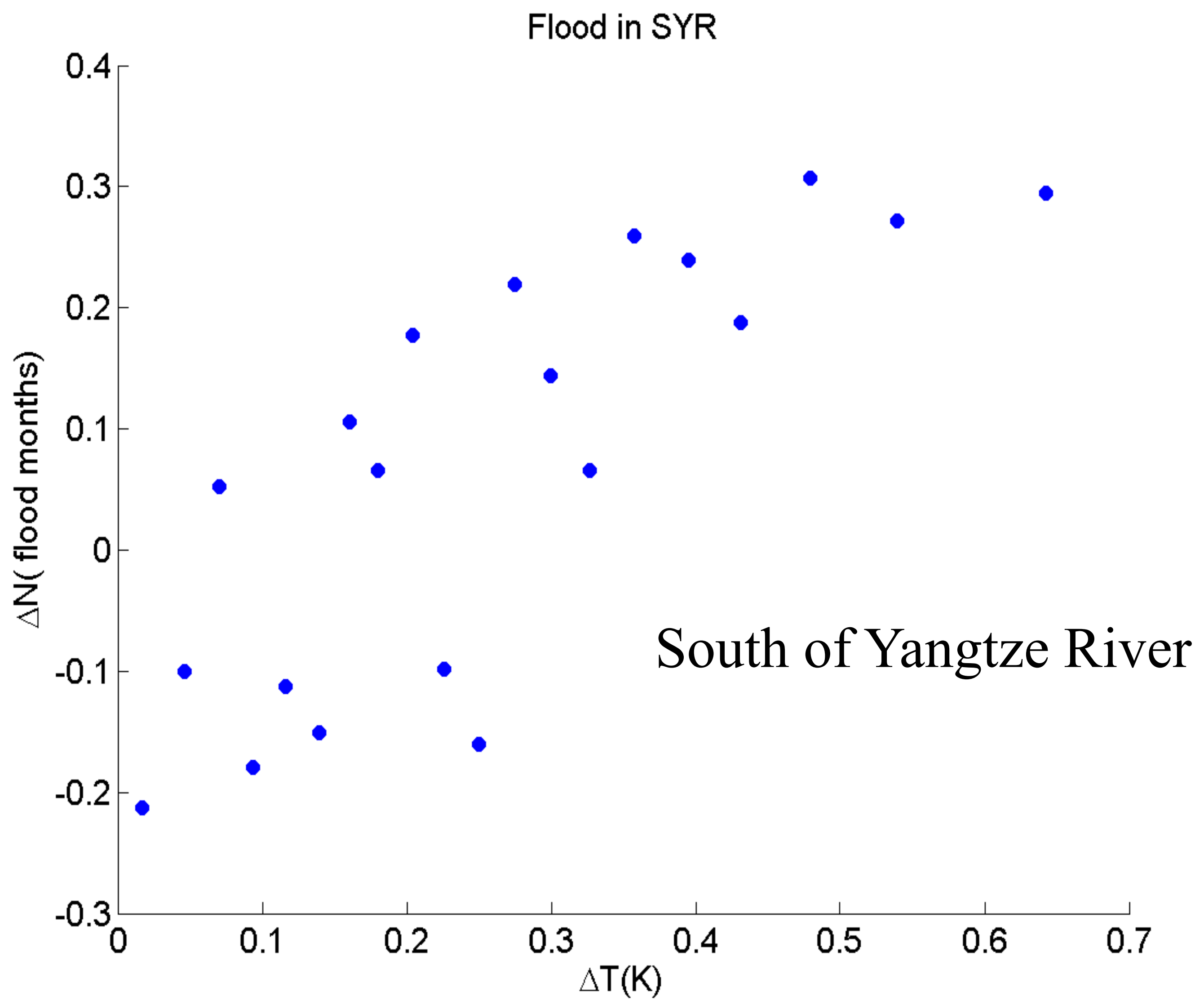
Change in annual number of drought-months (ΔN) plotted as a function of increase in global average temperature (ΔT)



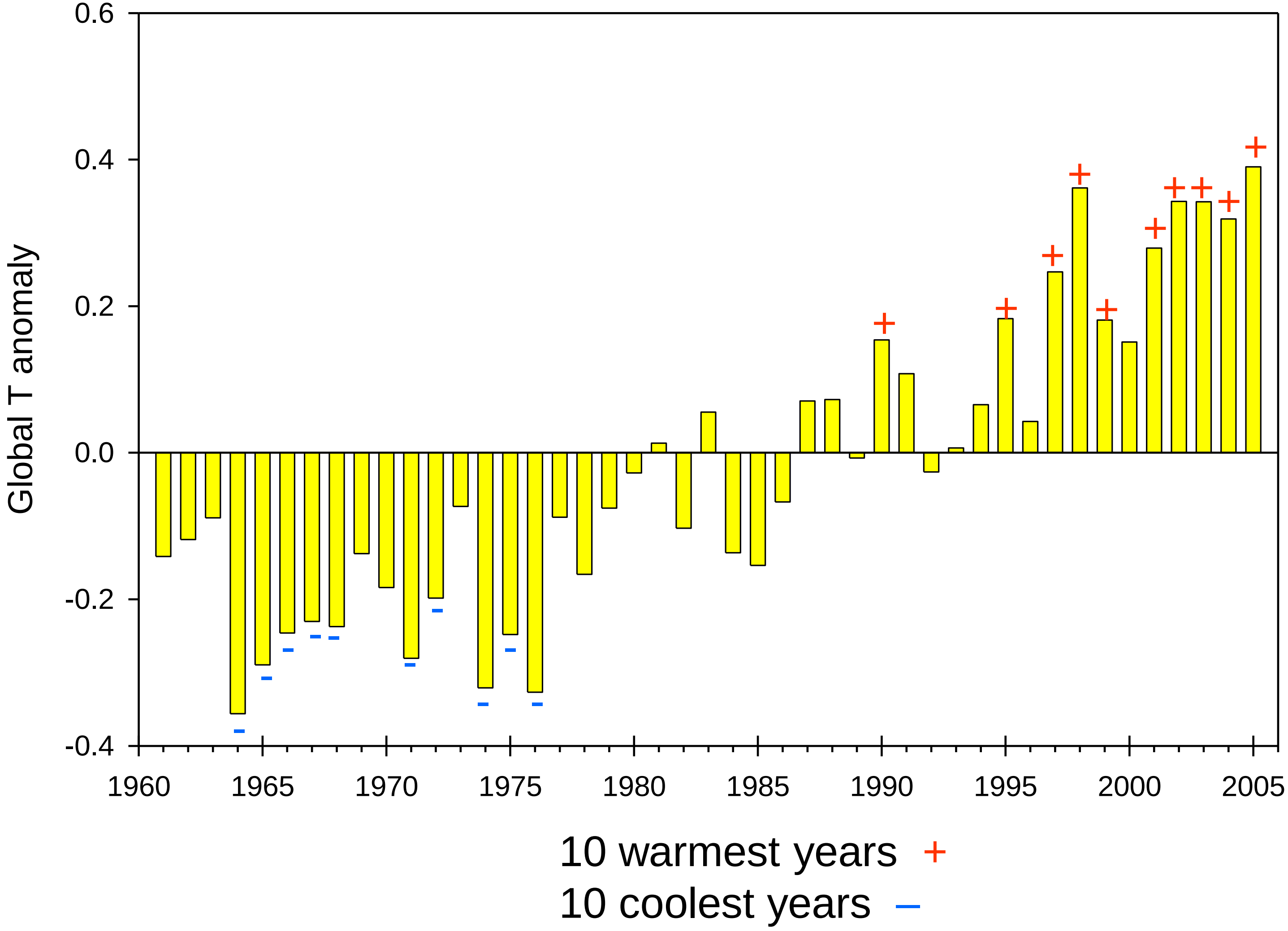
Change in annual number of drought-months (ΔN) plotted as a function of increase in global average temperature (ΔT)



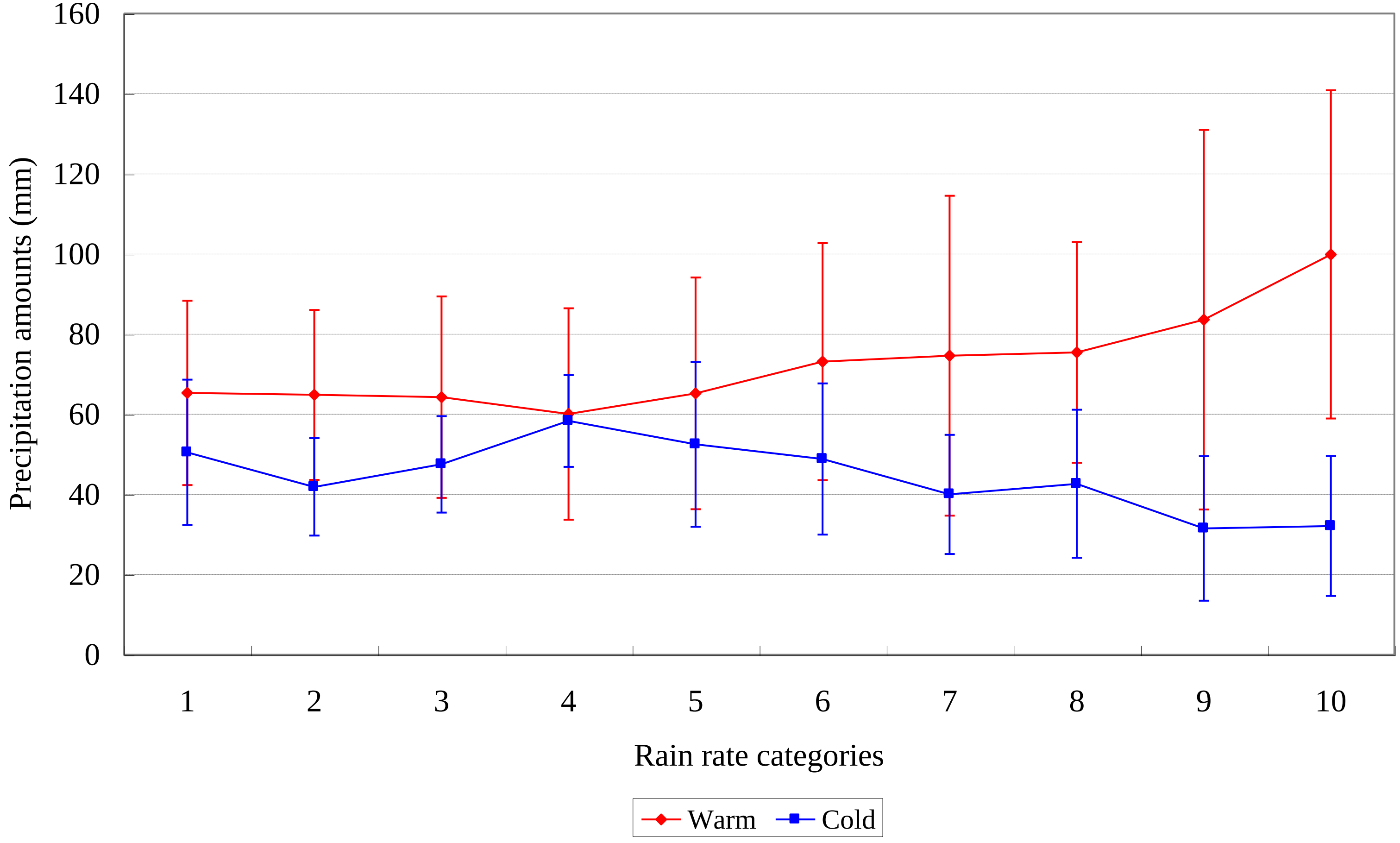
Change in annual number of flood-months (ΔN) plotted as a function of increase in global average temperature (ΔT)



Global Temperature Anomaly 1961 - 2005

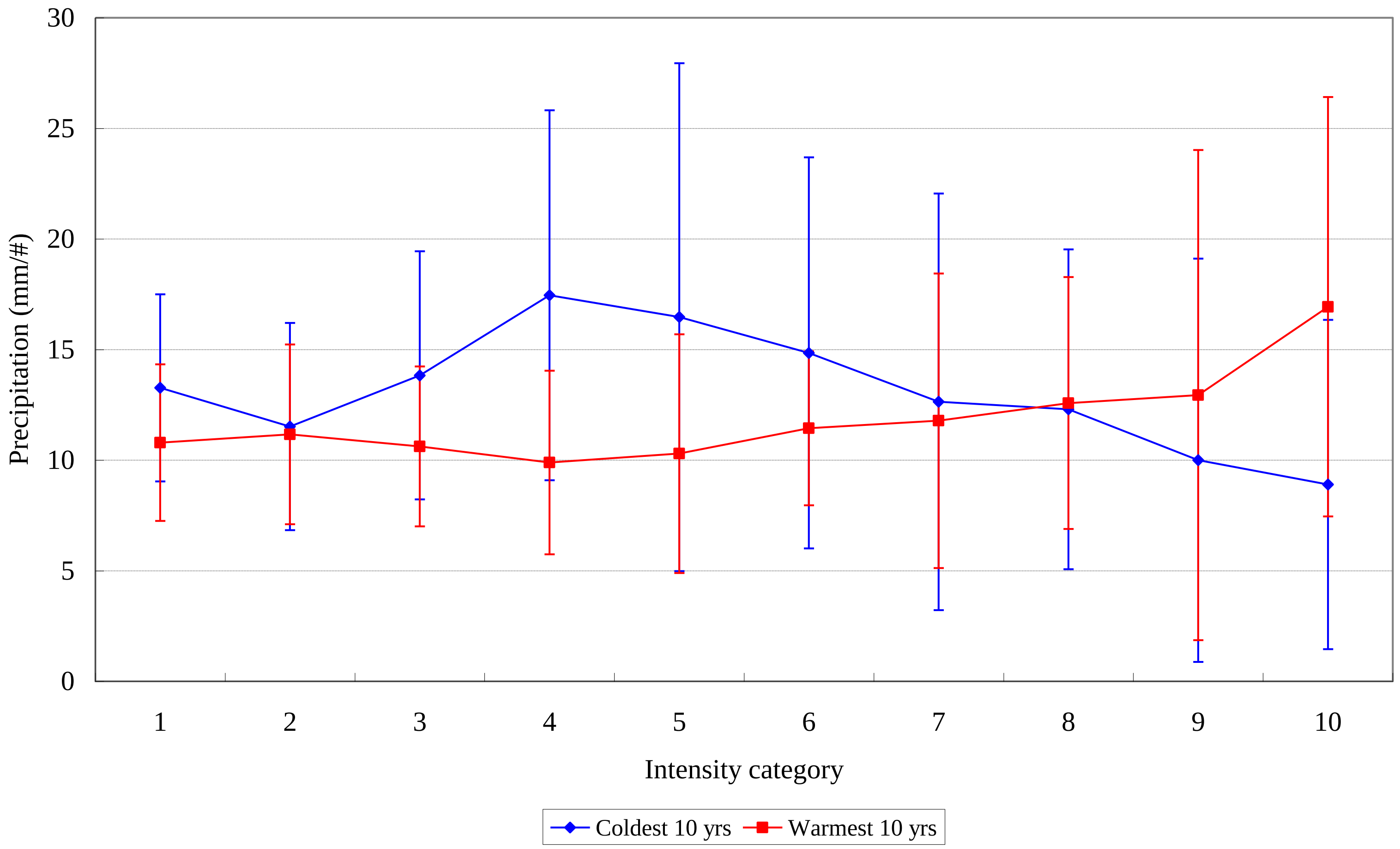


Rain intensity of typhoons landed in Taiwan
15 CWB stations (in mm/hr)
Warm years: 728.2 mm , # = 5.9
Cold years: 445.9 mm, # = 3.3



	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

Changes in Bin 10 (top 10%) as a function of changes in global temperature

(Precipitation data from 15 Taiwan stations in 1961-2005)