Winter & Power Trends in Korea

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A R T I C L E   I N F O

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Heating Energy Demand
Peak Power Consumption
Energy Policy

A B S T R A C T

Every year the peak value of power consumption occurs in summer, but from 2009 to 2015 winter peak power consumption is pretty close or even outshoot the summer peak load. This rise in peak load in winter is attributed to a more winter which leads to more energy demand for heating purposes.
It is postulated by some studies that Extreme cold weather is related to Arctic Amplification, which is a consequence of Global Warming. So, extreme cold is expected to reoccur and hence adequate policy measures should be taken to curb this menace, as the lower income strata is likely to be affected more by this sharp fall in winter temperature.

1. Introduction

There has been a warming trend throughout the world and this trend is also very clear in the case of Korea (see Fig. 3). But in recent years Northern Hemisphere has been experiencing extreme cold waves. These have a climatic as well as a sociological and economical effect on people living in Northern Hemisphere, specifically mid-latitudes and South Korea is one of them.

Arctic Warming, also known as, Arctic Amplification has been a major consequence of Global Warming. Due to higher temperature sea ice melted. Ice reflects 90% of sunlight whereas sea water absorbs 80%, thus leading to warmer sea and hence further reducing the formation of ice. Due to this cyclic phenomenon Arctic has warmed 2 times more than the global average.

Decrease in temperature difference between Arctic and mid-latitudes has led to change in circulation

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patterns in the atmosphere. Number of studies present that the recent extreme cold conditions in mid-latitudes is closely related to it.

Why does it matter?

Heating accounts for 70% of the total power consumption in winter in South Korea, therefore any change in heating trends directly impacts energy consumption patterns.

If cold is extreme, then more power will be consumed in heating hence more energy will be consumed. Also, the most affected would be the ones with little means. People with resources may have other sources to provide them with energy or fulfil their heating demands.

So, we should take into consideration the high uncertainty regarding variable future seasonal climate extremes.

2. Methodology & Results

Climate varies across geographical regions; therefore, our observation stations range from mountains to plains to coastal regions so as to get a proper idea of the variation of climate across the country. There are 66 weather observation stations in Korea.

Out of them 22 stations are either below 35° latitude or are island regions and hence are of not much interest, so we exclude them. We also exclude overly adjacent cities in the same province so as to not be biased.

At the end we have 8 cities in plains,7 in mountain regions and 7 in coastal regions (see Fig 1).

We are interested in extreme winter conditions; hence we collect daily minimum temperature of all the 22 stations from *KMA Database*.

We have collected the data for peak power consumption from *Korean Power Exchange (KPX)*.

KPX which is in control of operation of south Korea's electricity and power system has collected peak load data from 1993. But it was only annual peak data. It started collecting daily peak data from 2003 onwards.

1997 is the year of East Asian Financial Crisis and was a turning point for South Korea, and hence is taken as a basis for analyzing economic and social changes. So, we analyze peak power load of summer from 1997-2015 (extended to 2020) and winter from 2003-2015 (extended to 2020).[1]

Also, we have taken a different parameter to measure the extent of cold felt by people of Korea by analyzing heat sales percentage in January[2] by *Korea District Heating Corporation (KDHC)*, which holds more than 50% of the market share.

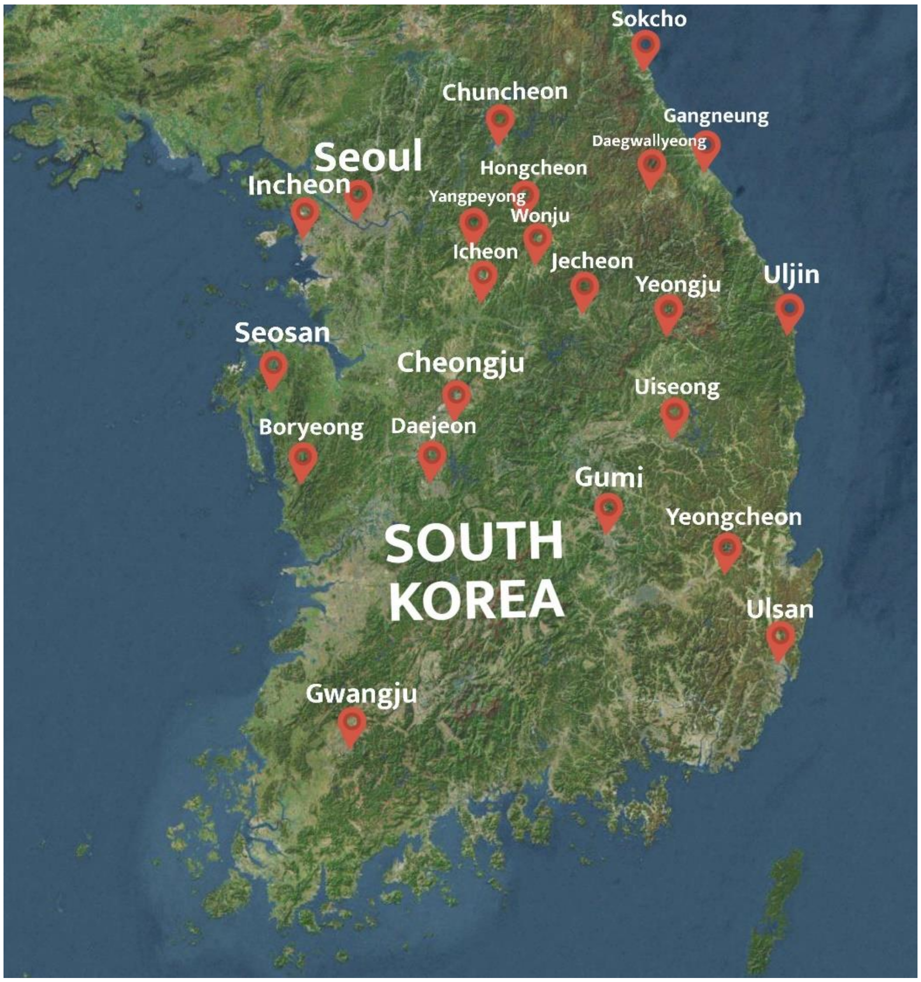

Fig 1: The 22 Observation Stations

[1] From 1997-2002 annual peak power load is taken to be that of summers as it is the natural choice since, from 2003-2009 summer peak load is greater than that of winter.

[2] January is the coldest month of the year and hence percentage of heat sales in January correlates to extremity of winter in that year.

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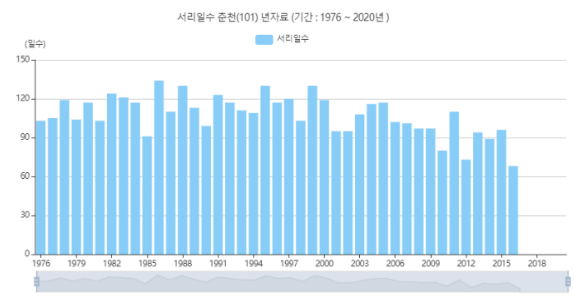
The World Meteorological Organization presents **27 indices** to study the weather phenomena in extreme cases.

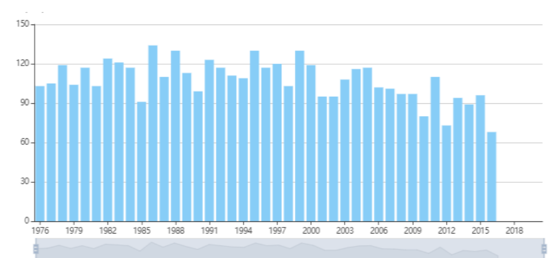
Following are some of the indices related to extreme winter condiions:

1. Frost days- The days with daily minimum temperature < 0*C
2. Average daily temperature in winter
3. Cool days- %of days with daily maximum temperature < 10th Percentile
4. Cold spell duration- Annual number of days with at least six consecutive days when the daily minimum temperature < 10th Percentile

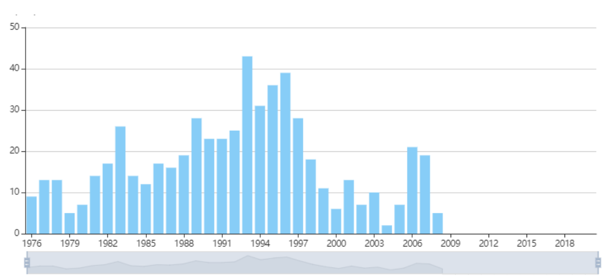
Cheongju



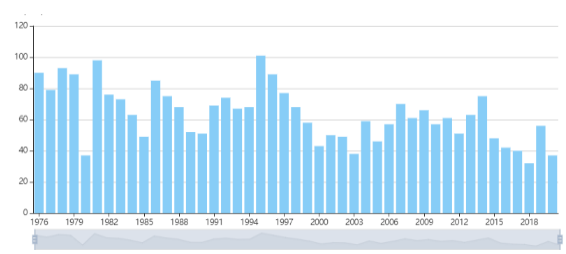
Chuncheon



Gangneung



Gwang



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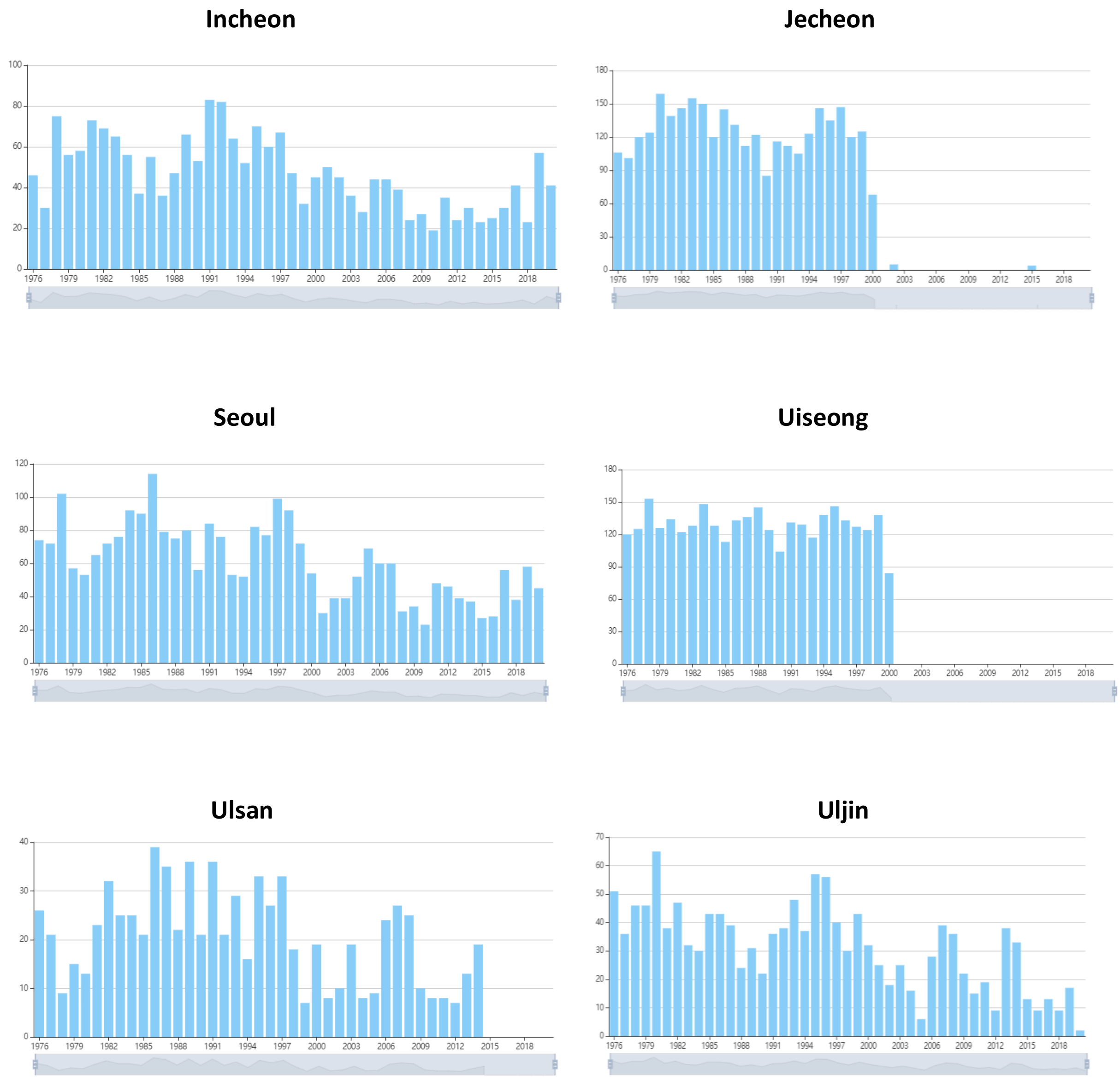

Fig.2 : Number of frost days (1976-2020)#

The graphs show that the number of frost days has decreased for the 10 stations

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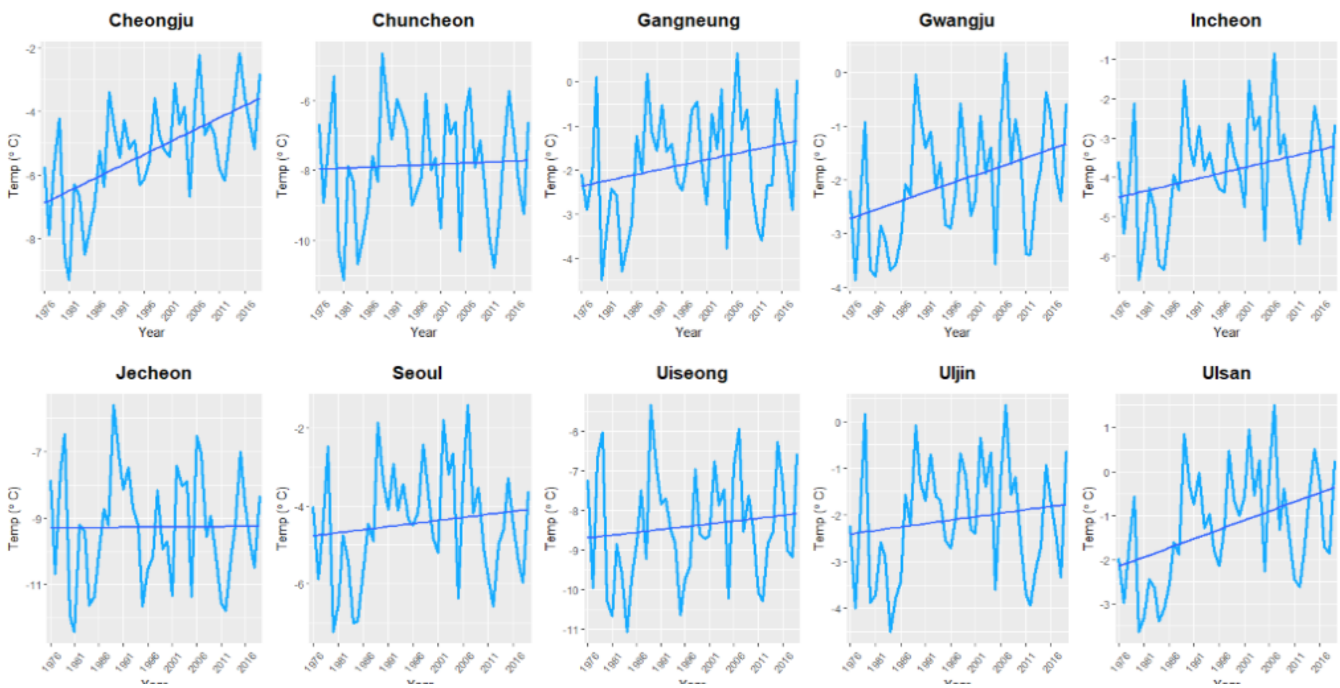

Fig.3: Annual Average of Daily Minimum Temperature in Winter

The graphs show decreasing trends in case of all the cities indicating warming effects clearly.

The decreasing trend in number of frost days and the increasing trend in the average daily minimum temperatures points to the fact that winters in Korea have become less cold over time, which is partly explained by global warming.

A study by Lee and Heo reported that **the number of cool days and the cold spell duration has also followed decreasing trends.**

But a study by Jeon and Cho in 2015 shown the increasing frequency of cold waves during clod waves during 2004 to 2014.

This suggests we should look for some different index to model the extreme cold events in Korea.

We turn to Quantile Regression to model the data.

What is Quantile Regression?

We are interested in explaining a specific quantile of a variable y in terms of another variable x. (In this case, the 10th quantile of the daily minimum temperature is to be explained in terms of the year).

More specifically, **we want to find a line that passes through (or is closest to) all the τ -th quantiles of y given x.**

The usual least squares deviation is not suitable for this, as it weighs the opposite end of the quantile we are studying very highly, which is undesirable, especially when we are considering a low or high quantile. Instead, we look at an extension of least absolute deviation, in the sense that we change the weights of error terms in both ends of the quantile under study to give them equal weightage.

$$Min\frac{1}{n}\Big[\sum_{y_i \geq \beta X_i} \tau|y_i - \beta X_i| + \sum_{y_i < \beta X_i} (1-\tau)|y_i - \beta X_i|\Big]$$

We are searching for a β(slope) that minimizes this value.

An added advantage of this is that the quantile regression has more flexible assumptions on the distribution of the variables. For example, we don't need to assume that the variance of the y given x is constant, an assumption of the usual linear regression.

All of these are reasons why quantile regression in perfect for studying the trends in extreme weather conditions.

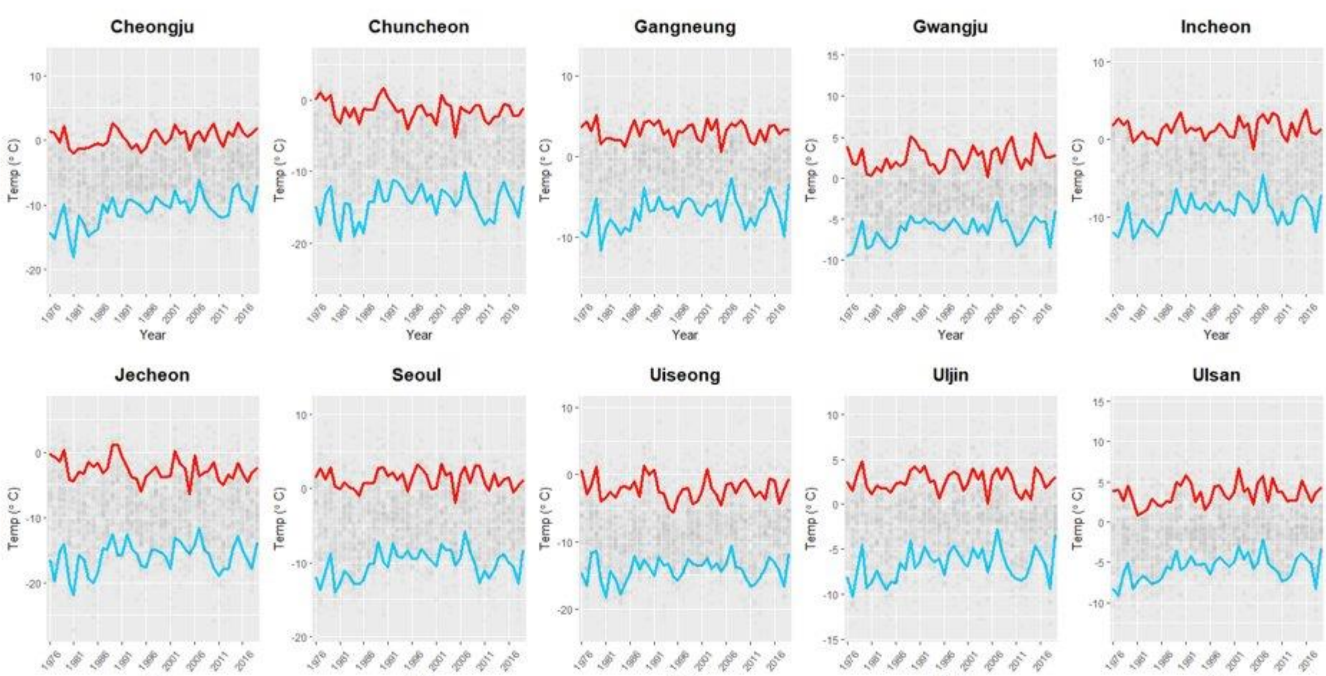

Fig.4: Daily Minimum Temperature in Winter

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Firstly, observe that the variability in the 90th quantile is smaller than the variability in the 10th quantile.

Seoul_quant

	year	ten	ninety
19	2005	-10.33	-1.92
3	1985	-12.90	-0.98

Seoul_quant

	year	ten
1	1980	-14.00
2	1977	-13.61

Seoul_quant

	year	ten	ninety
41	2002	-7.50	3.31
27	1997	-9.40	3.20

Seoul_quant

	year	ten
44	2007	-5.82
43	1989	-7.24

Fig.5: Range of 90th and 10th Quantile #

These screenshots of the sorted quantiles data for Seoul shows this clearly. The 10th quantile data has range of about 8℃, whereas the 90th quantile has range of about 5℃. Same is true for other stations as well.

To clearly see the long-term trends in this data, we perform quantile regression on the annually grouped data for the 10th quantile.

This was actually done for all 22 stations in the study, but **statistically significant slopes were only found in the 10 stations** shown here, which is why we only analyze these 10 stations from now on.

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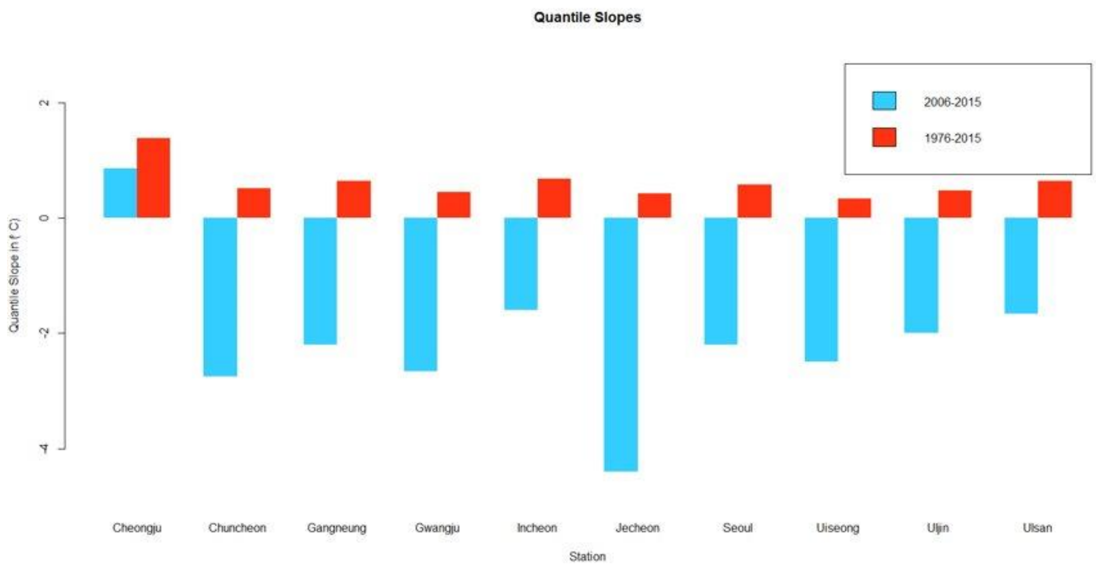

Fig.6: Quantile Slopes for the periods 1976-2015 & 2006-2015

As you can see, all 10 stations show an increasing trend over the period 1976 to 2015, so extreme winters have become less extreme over the 4 decades studied in the original paper. However, except Cheongju here, all others show a very pronounced decreasing trend in the period 2006-2015, which suggests more extreme winters in recent years. We extended this analysis with updated data up until end of 2019, which we'll talk more about later.

Now that we have analyzed the long-term trends in the data, let us look at some of the factors that differentiate the different stations in our study, and see if we can find some sort of pattern there as well.

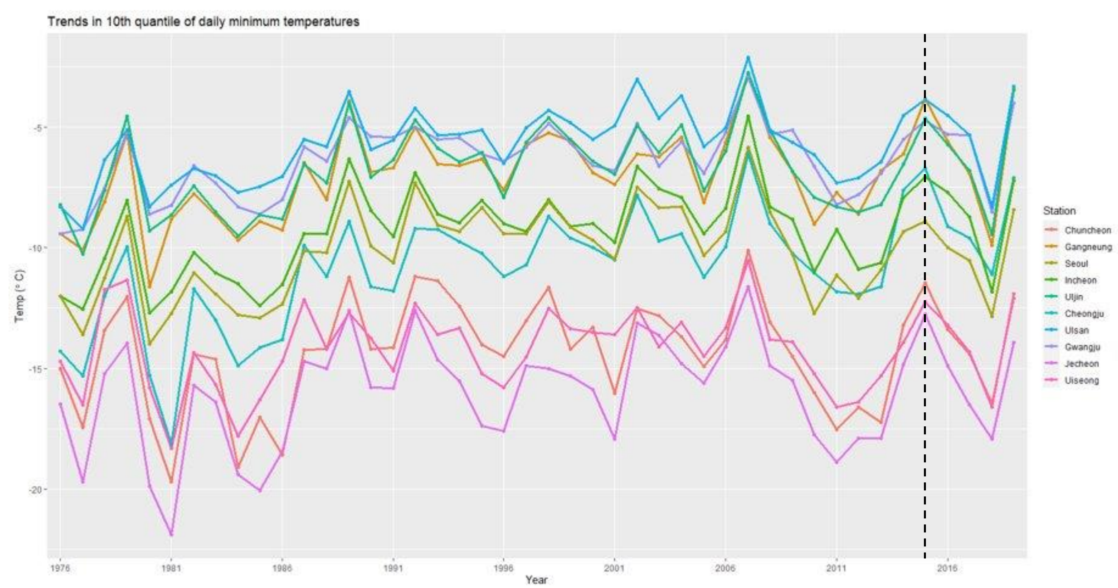

Fig.7: Trends in 10th Quantile in the 10 statistically significant stations

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These are the trends in the different stations, all plotted onto the same graph. It seems that all of them have more or less the same shape, but they are shifted vertically. This is as expected, since various factors like terrain, location, etc would affect the temperatures, but since they are geographically close together, the highs and lows happen in the same years.

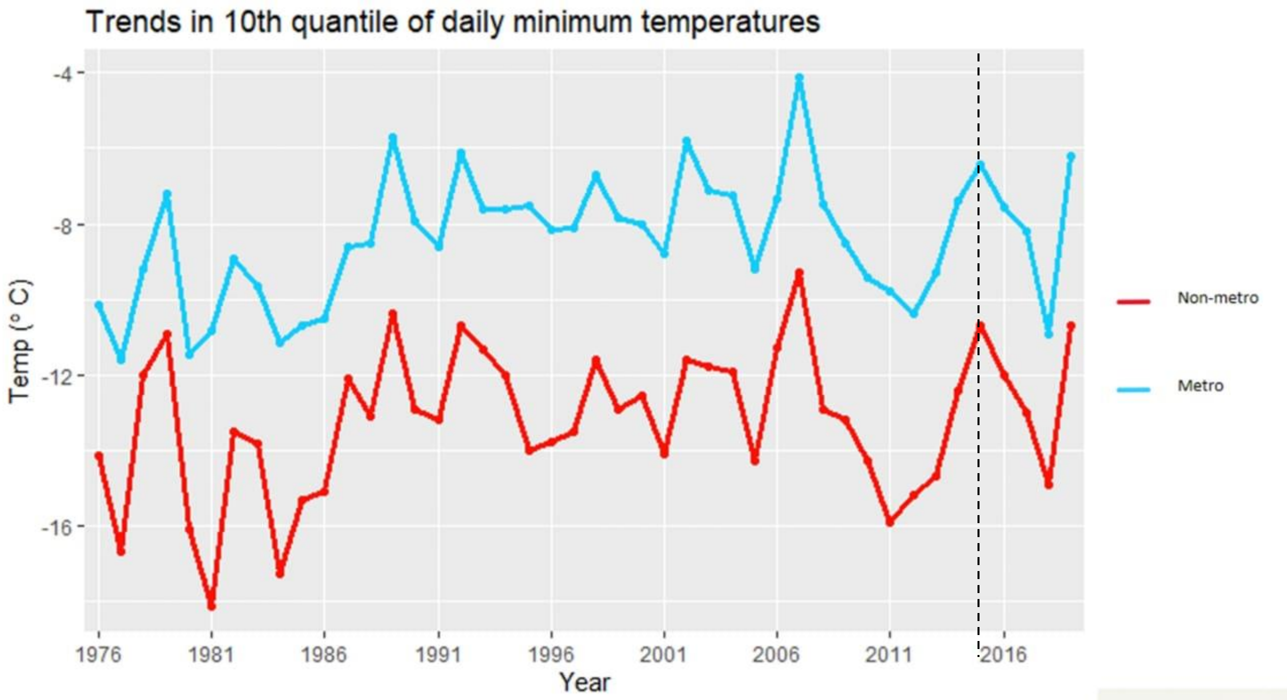

Fig.8: Metro Vs Non-Metro

This graph shows the trends in the quantiles of the metropolitan big cities vis a vis others. As is clear, the metropolitans experience a relatively mild winter, which is an important point to note for the planning of heating and power supplies in Korea.

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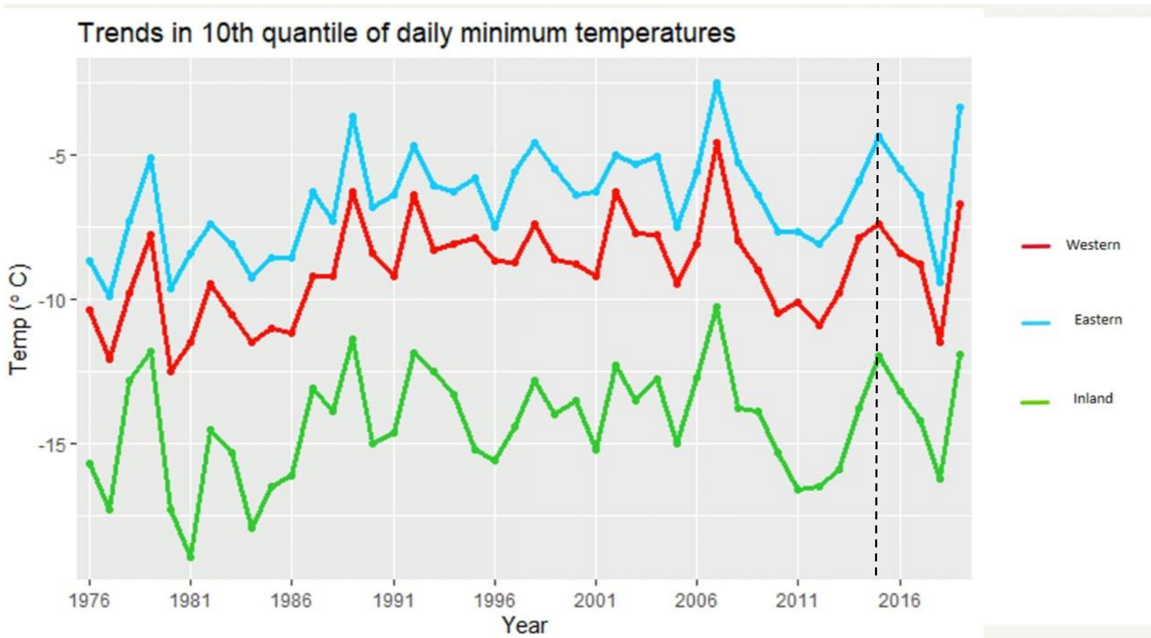

Fig.9: Western Vs Eastern Vs Inland

There's also the comparison by location, where inland locations show most extreme weathers.

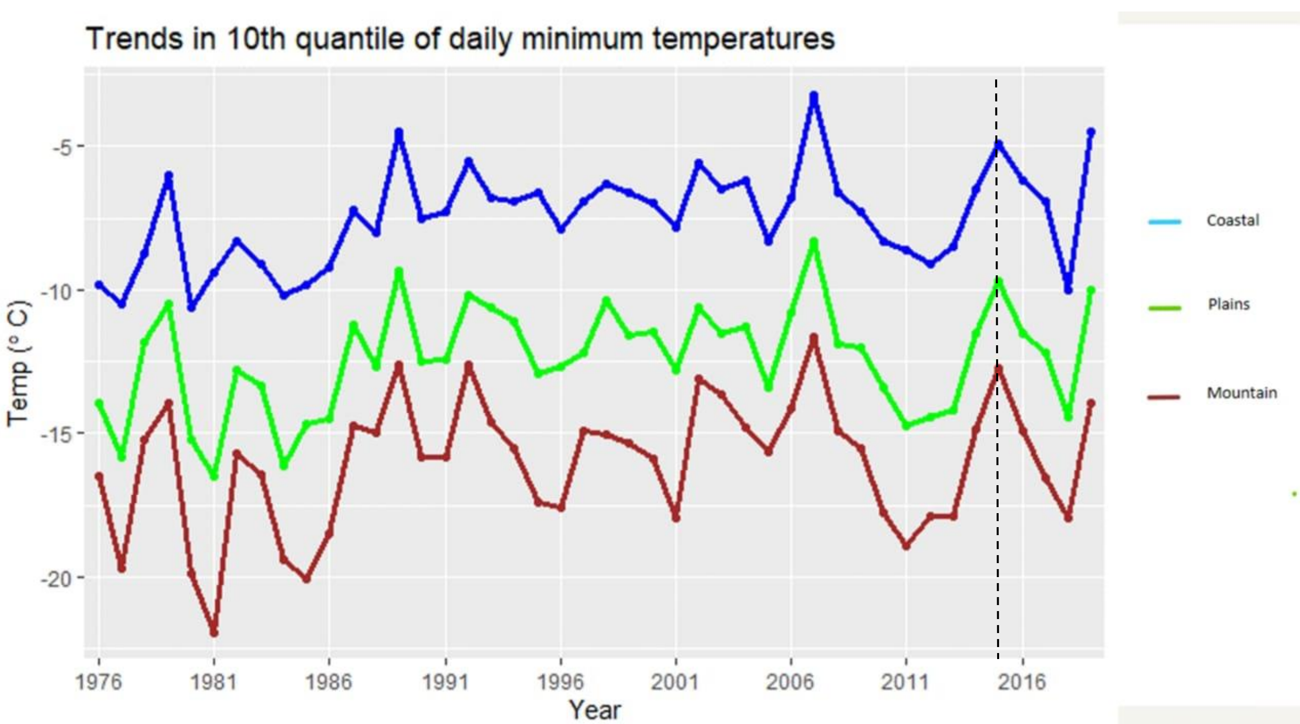

Fig.10: Coastal Vs Plains Vs Mountain #

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This graph was not in the paper, but while studying the previous graphs we realized that it is the mountain region Jecheon that's explaining the extreme winters in non-metro and inland stations. This led us to analyse the differences by terrain, which is a more truthful representation of the factors in our opinion.

Now we move on to the analysis of the other data.

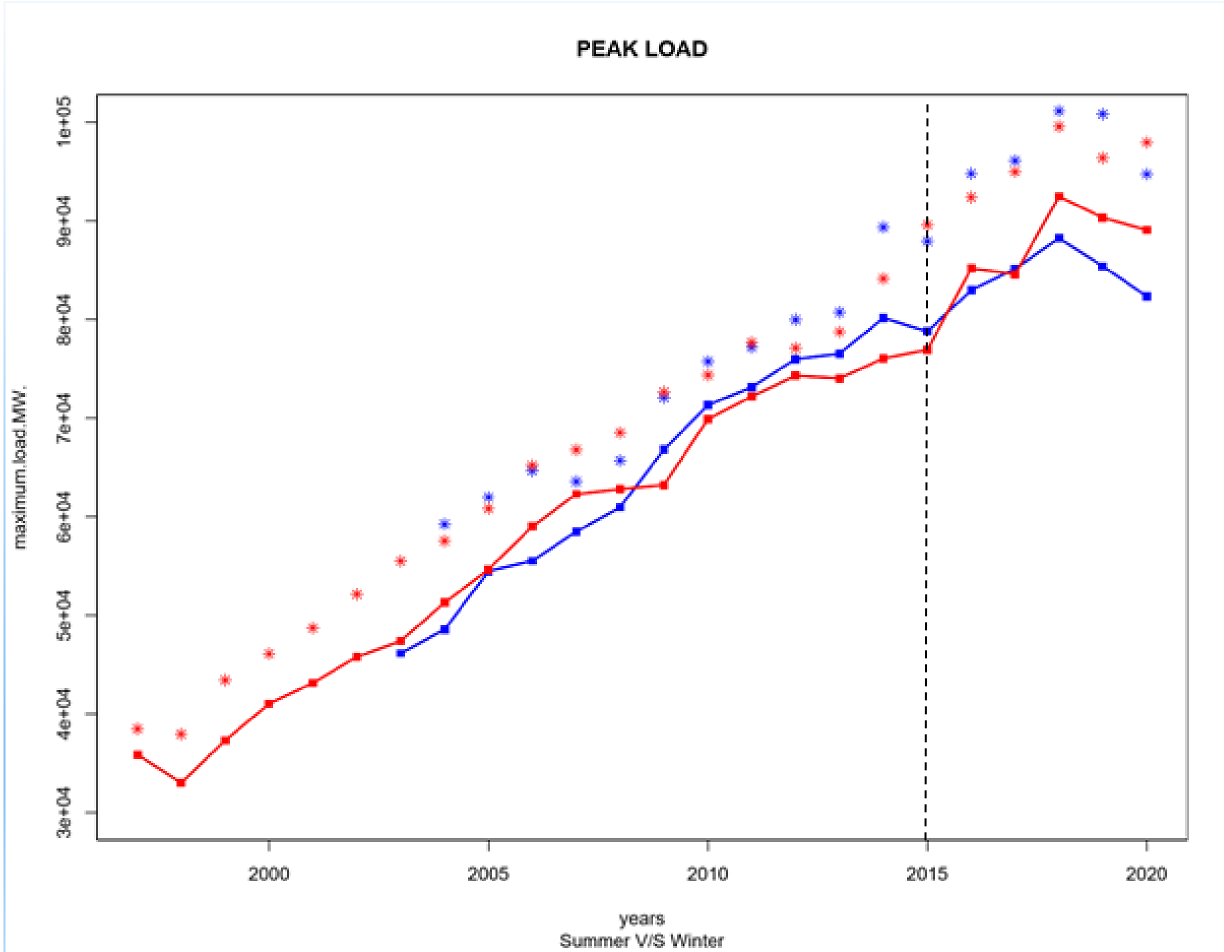

Fig.11: The Annual Peak load graph of South Korea

_- Summer Peak Load; *- Summer Supply Capacity #

_- Winter Peak Load; *- Winter Supply Capacity #

The dashed line denotes the data available in the paper (i.e., the paper contains data till 2015, we have extended observations till 2020)

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From this graph, we can see that peak load in winter has crossed the summer peak load for 7 consecutive years 2009-2015.

But here their definition of winter is not appropriate. They have taken **W(Y)=Jan(y)+Feb(Y)+ Dec(Y)**

So, we change the definition to **W(Y)= Dec(Y-1) +Jan(y)+Feb(Y)** and get

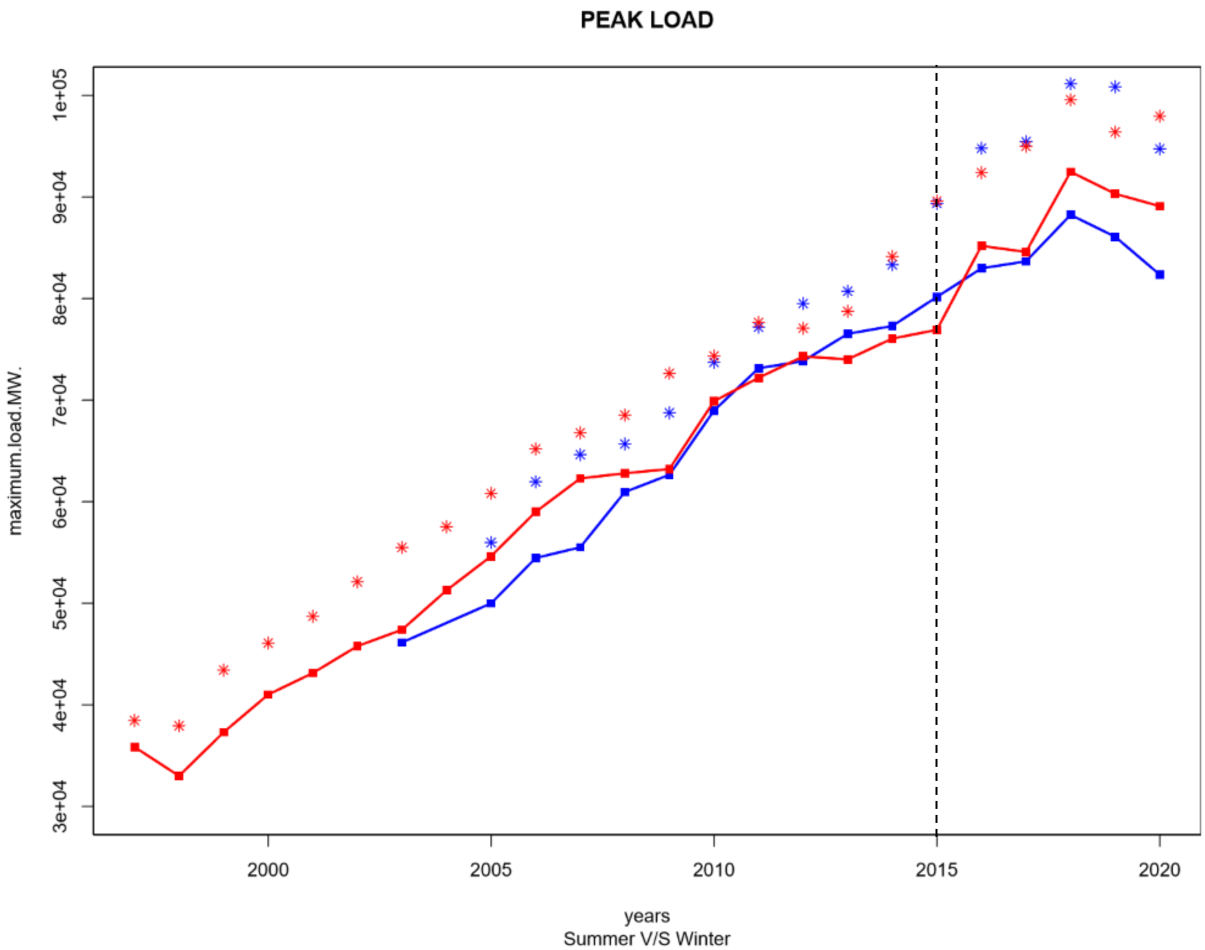

Fig.12: A more efficient graph to study the Peak load #

_- Summer Peak Load; *- Summer Supply Capacity #

_- Winter Peak Load; *- Winter Supply Capacity #

The dashed line differentiates the data available in the paper and the extension (i.e., the paper contains data till 2015, we have extended observations till 2020)

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Here we see that the difference between peak loads of summer and winter has decreased considerably from 2009-2015.

We also see that peak load and supply capacity are close to each other till 2015.

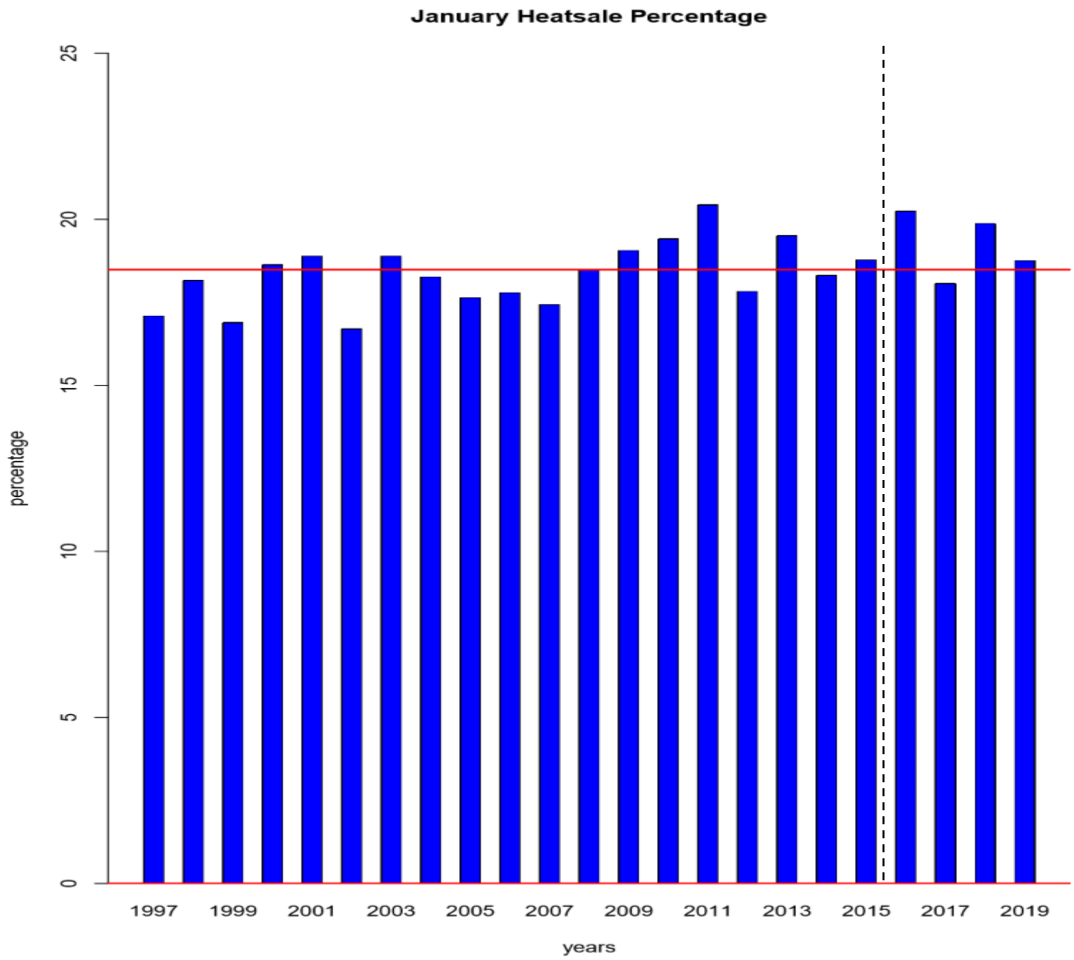

Fig.13: Percentage of heat sale in January of the year

The blue bars represent the % of heat sale in January and the red line shows the average heat sale portion of January.

The years when the heat sales percentage crosses the average are particularly colder than the rest.

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***[3]

Table 1
Quantile slopes (°C/decade) †.

Station	Past four decades (1976–2015)				Last decade (2006–2015)			
	τ = 0.05	τ = 0.1	τ = 0.5	OLS	τ = 0.05	τ = 0.1	τ = 0.5	OLS
Boryeong	3.36***	3.57***	2.24***	2.26***	·	·	−4.56**	·
Cheongju	2.40***	2.13***	·	3.39***	·	6.24*	·	·
Chuncheon	6.13***	5.73***	3.06***	·	−10.35*	·	·	−4.68*
Daegwallyeong	1.47***	1.67***	1.25***	0.70**	7.09*	·	−6.12*	·
Daejeon	2.77***	2.76***	1.45***	1.59***	·	·	−5.29**	·
Gangneung	2.95***	2.63***	0.73***	1.11***	−8.59**	−6.31**	−7.13***	−5.76***
Gumi	4.09***	3.88***	2.44***	2.48***	·	·	·	·
Gwangju	1.80***	1.89***	1.09***	1.41***	−6.10**	−8.68***	−4.02**	−3.96**
Hongcheon	3.88***	4.13***	2.10***	2.13***	·	·	·	·
Icheon	2.66***	2.28***	·	0.66**	·	·	·	·
Incheon	3.03***	2.77***	1.56***	1.59***	·	−6.10*	·	−5.97***
Jecheon	2.05***	1.81***	·	·	−15.64***	−13.19***	·	·
Seosan	·	0.98***	·	·	·	·	·	·
Seoul	2.71***	2.47***	·	1.25***	−9.85**	−6.44*	−10.90***	−8.10***
Sokcho	1.96***	1.43***	·	·	·	·	·	·
Uiseong	1.42***	1.42***	1.00***	0.59**	·	−5.32*	·	−4.19*
Uljin	2.16***	2.04***	·	·	−6.33*	−7.64***	−8.56***	−7.76***
Ulsan	2.66***	2.69***	1.93***	2.07***	·	−4.63**	−4.23**	−3.58**
Wonju	7.12***	6.39***	3.19***	3.51***	−7.26*	·	·	·
Yangpyeong	7.11***	5.81***	2.96***	3.41***	·	·	·	·
Yeongcheon	2.37***	1.66***	1.02***	1.06***	·	·	·	·
Yeongju	4.88***	4.33***	2.38***	2.27***	·	·	·	·

The * symbol denotes that the p-value is $0.05 < p < 0.1$, and the · symbol means the p-value is over 0.1.

Quantile Slope Table (Source: Paper)

Only 10 out of 22 had statistically significant values, and so we studied them only. We are not given the procedure by which they calculated p-value and decide which observation is significant and which isn't.

3. Conclusion

Korea is a country where power consumption is rapidly increasing; therefore, power demand management is very important. However, the recent abnormal cold waves might be causing a change in energy consumption behaviour. But the increase in thermal power plants will increase the release of greenhouse gases which will further worsen the climate change.

So, an efficient, suitable and sustainable energy system should be developed.

[3] There is ambiguity in the process

4.Drawbacks

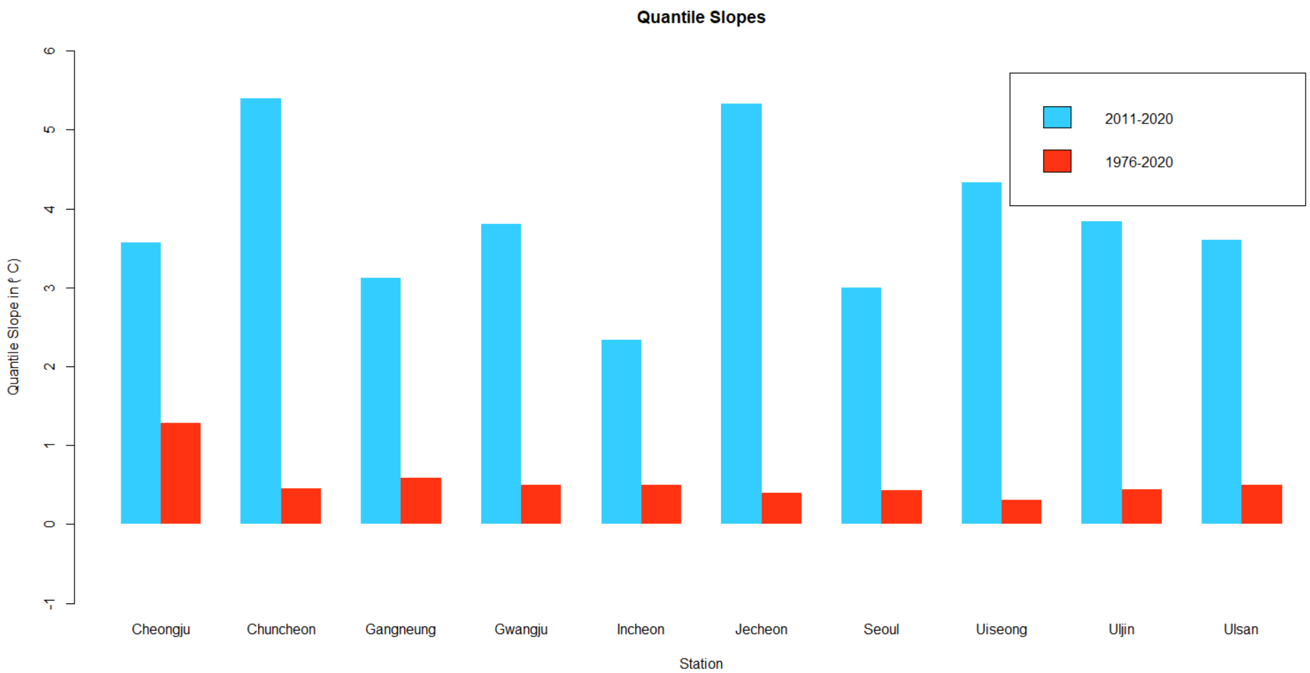

Fig.14: Quantile Slopes for period 1976-2020 and 2011-2020

Their selection of data seems to be biased.

First of all there is no implicit/ natural need to consider a decade as a time period and even if they considered it then why did they take 2006-2015 as the decade when they could have taken atleast 2007-2016 as the paper was published in 2017.

When we calculated quantile slope for 2010-2020 then we see that all the slopes are positive and that too with big amounts. But the reason why we undertook the study in the first place was because we saw a negative trend in 10th quantile. So, the premise of the paper itself is questionable.

Also, when we see Fig.12 we observe that 2015 was the last year when winter peak loads were higher than that of summer. So, it seems that we don't have to consider extreme winter while making power policy.

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5.References

1)Weather and Climate Extremes by Yunsoung Kim and Sanghoon Lee

2)www.wmo.int/pages/prog/wcp/wcdmp/CA_3.php for WMO indices and data.

3)The Korea Meteorological Administration Database. (http://data.kma.go.kr.) for minimum daily temperature and frost day data

4) The Korea District Heating Corporation-Heat sales record

http://www.kdhc.co.kr/noticeList/CM3711.do

5) R.Koenker, Quantile Regression, Cambridge University Press, Cambridge, New York, USA,2005

6) R- code Packages: (i) Tidyverse - Tools to tidy up the datasets

(ii) dplyr - To filter the data

(iii) ggplot2 – To plot

(iv) cowplot - To plot

(v) quantreg - To do Quantile Regression

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