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Long-term variations of meteorological characteristics and air pollution problem in Taiwan

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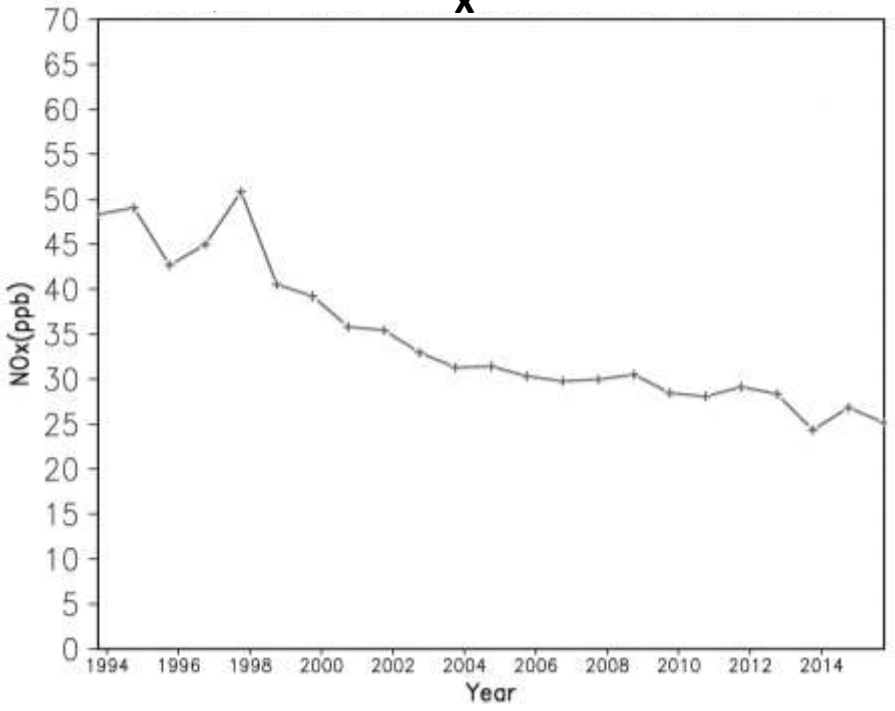
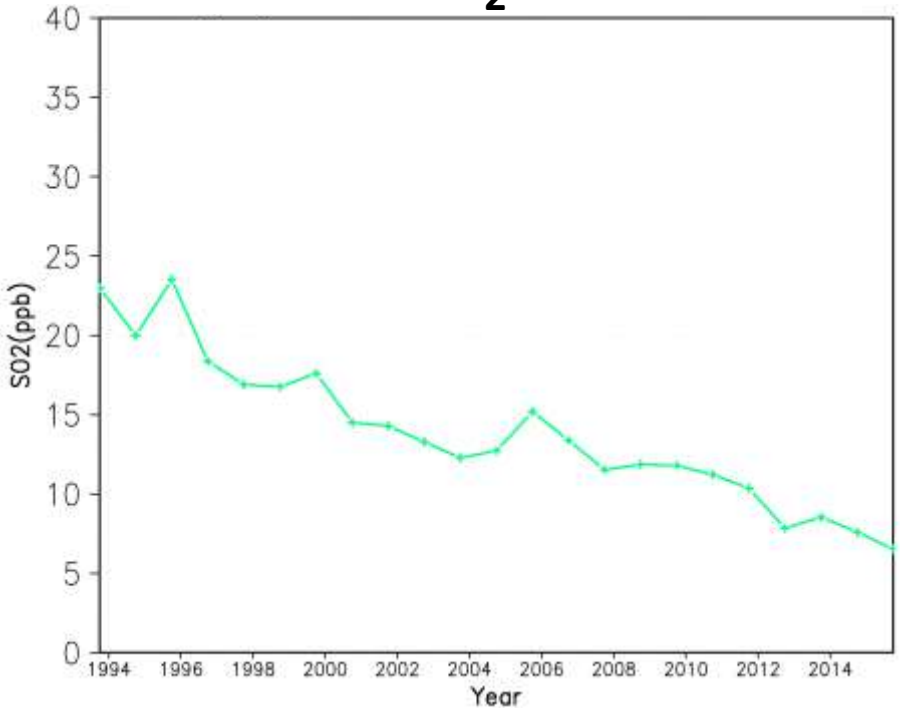
Question to think and answer:

- Emission control strategy successfully reduced primary air pollutants such as NO_x and SO_2 concentrations through past several years

NO_x



SO_2



- But do we feel air quality been improved?

Purpose

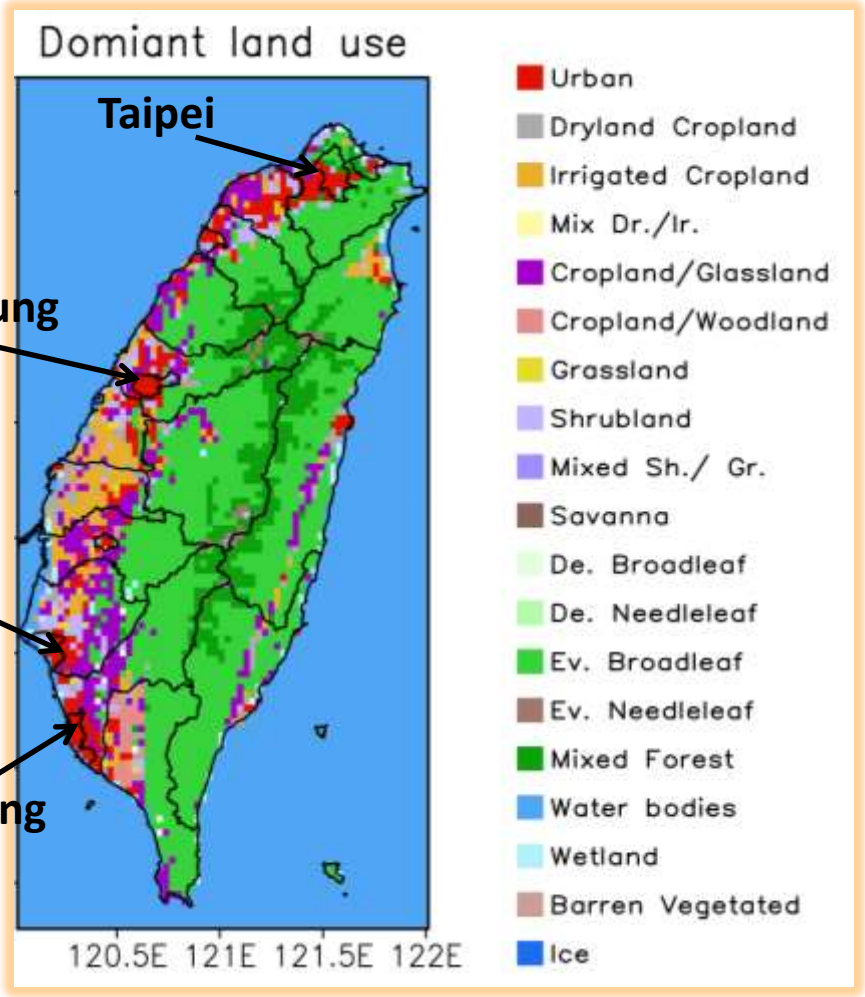
- **Under global warming scenario, how does it affect regional climate and air pollution problem in area of Taiwan?**

--- 33-year NCEP-DOE Reanalysis dataset

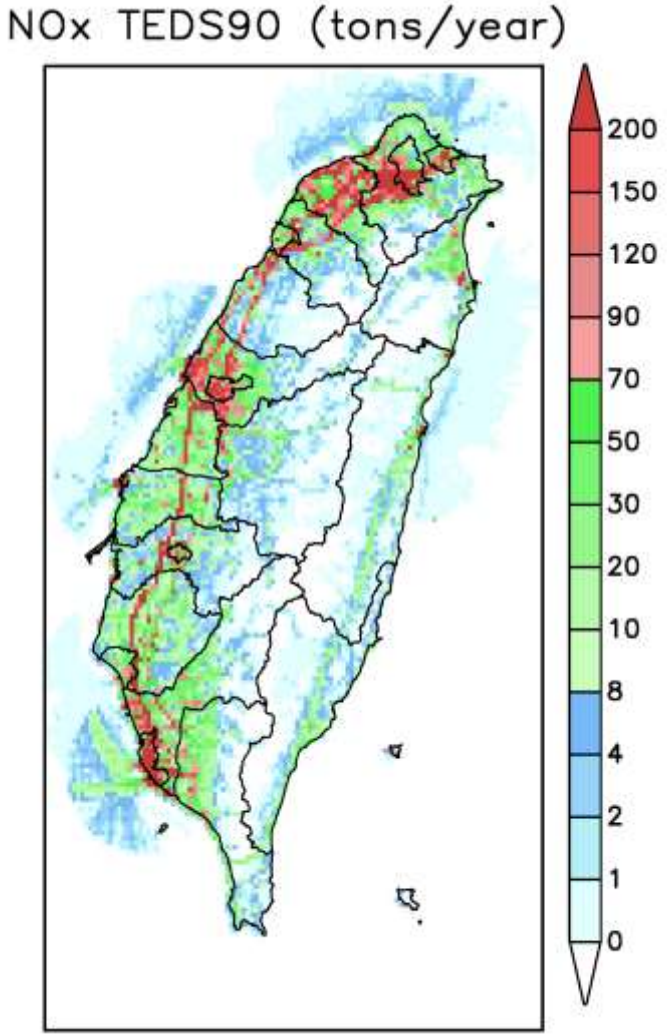
--- WRF and CMAQ simulation

--- Characterization of long-term observational dataset

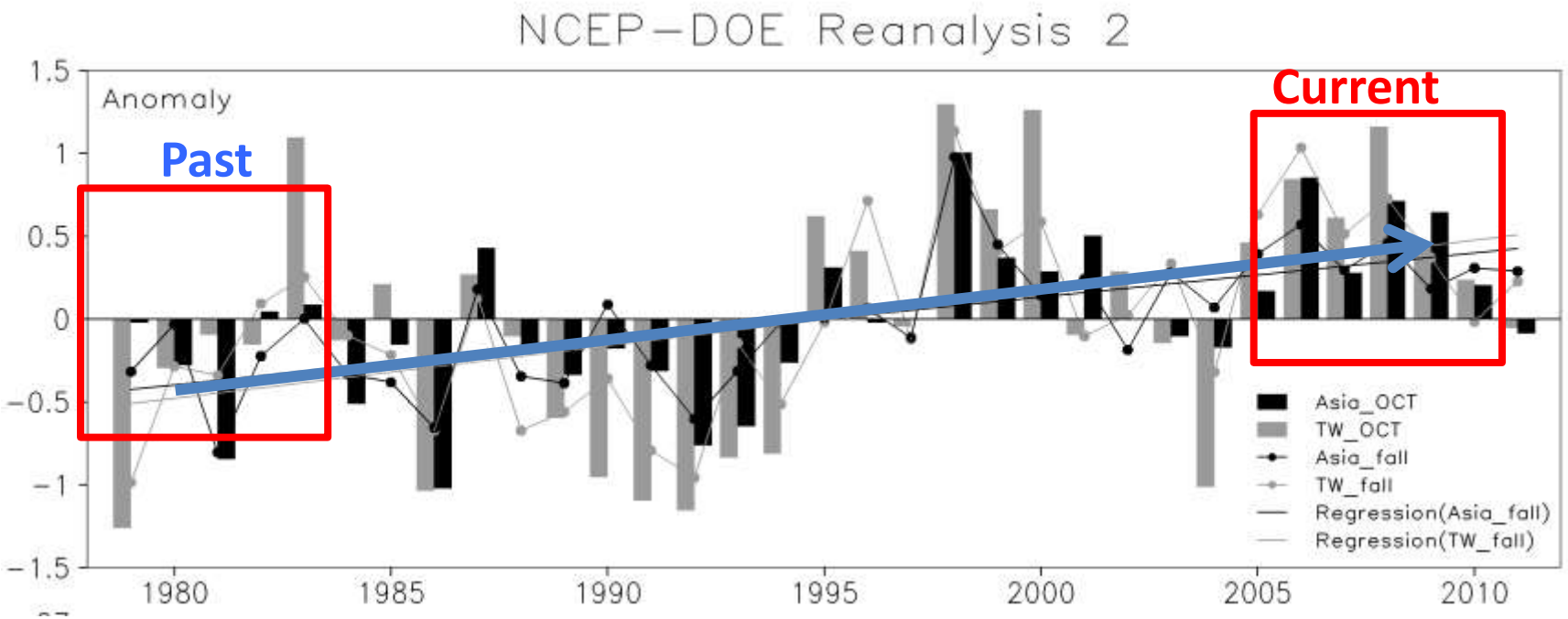
Landuse



Emission



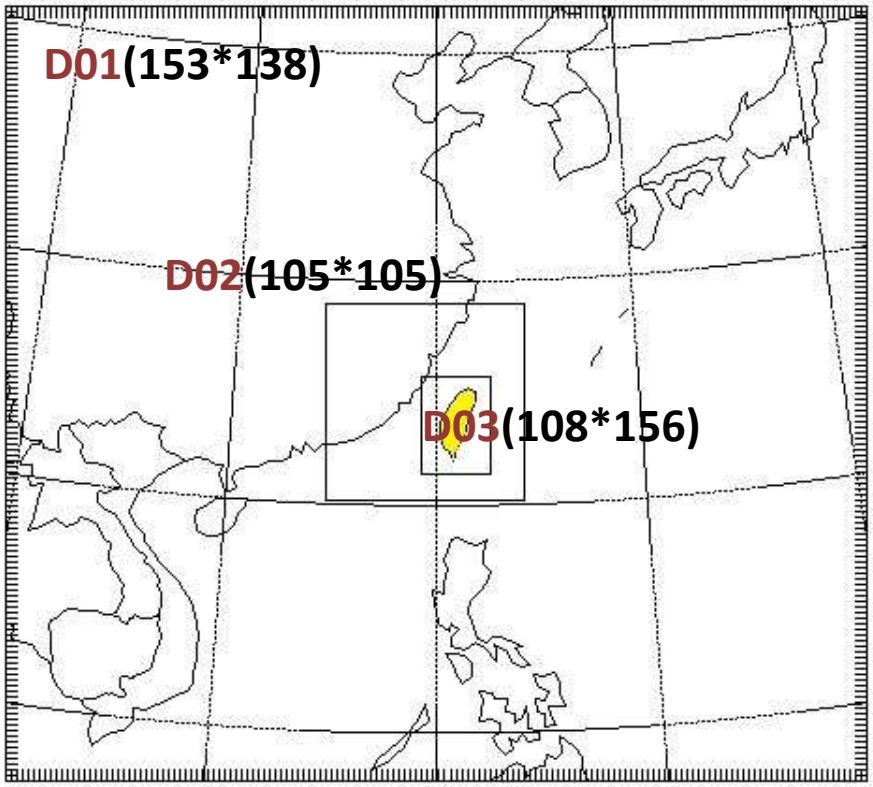
Temperature anomaly from year 1979 – 2011



- Apparent warming tendency

- Select two scenarios: **past** (1979-1986) and **current** (2004-2011)
- Apply WRF and CMAQ modeling to discuss influence of regional climate change on local meteorology and subsequent effect on local air quality in Taiwan

Model Configuration



Domain resolution	27, 9, 3 km
Vertical levels	49
Land surface scheme	Noah
PBL scheme	YSU
Initial condition	**NNR2 6-h**
Anthropogenic emission	TEDS **(fixed)**
Biogenic emission	Megan
Chemistry	**CB05**

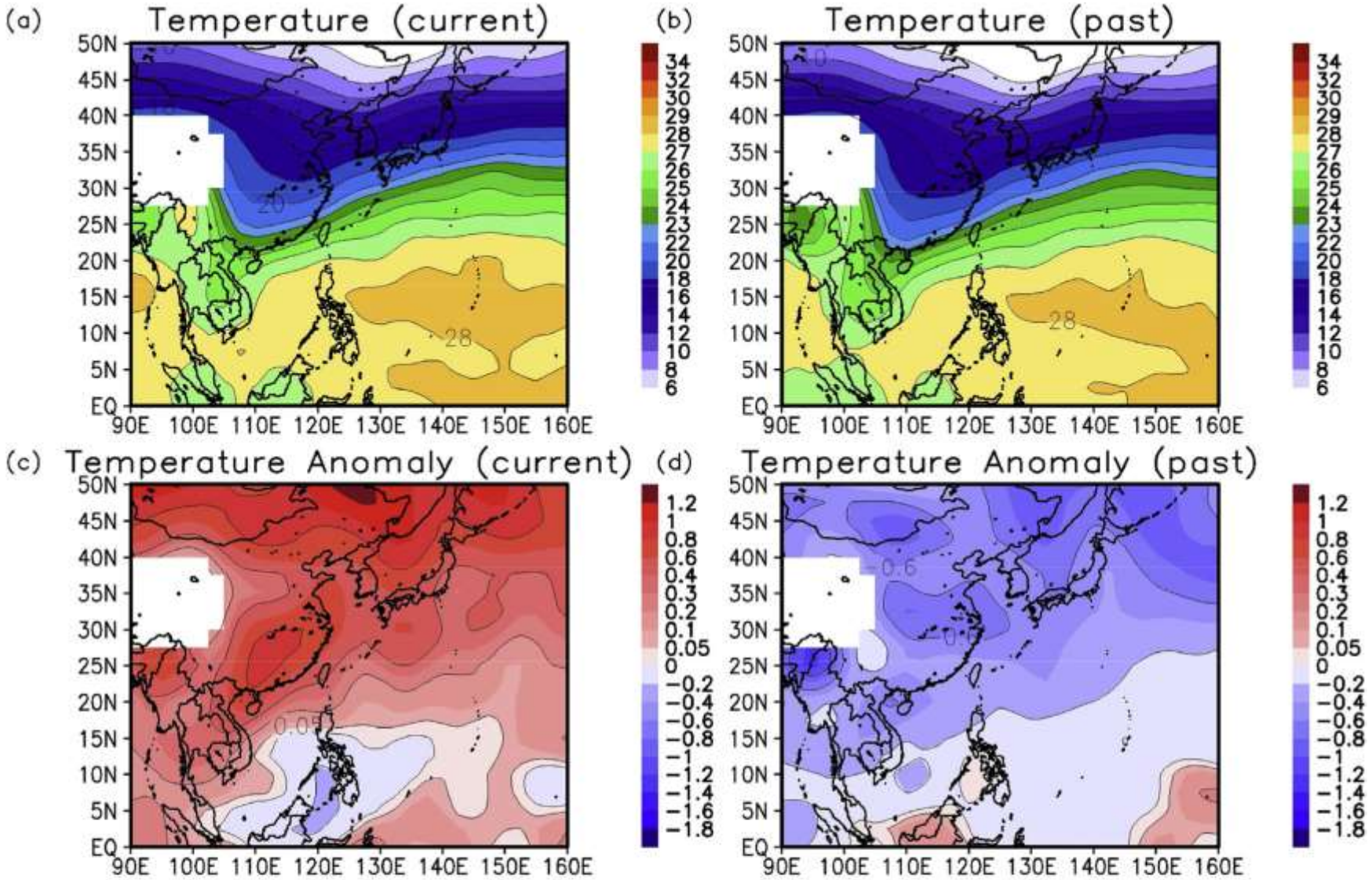
Simulation period

Past: 1979-1986 (**8 years Fall season**)

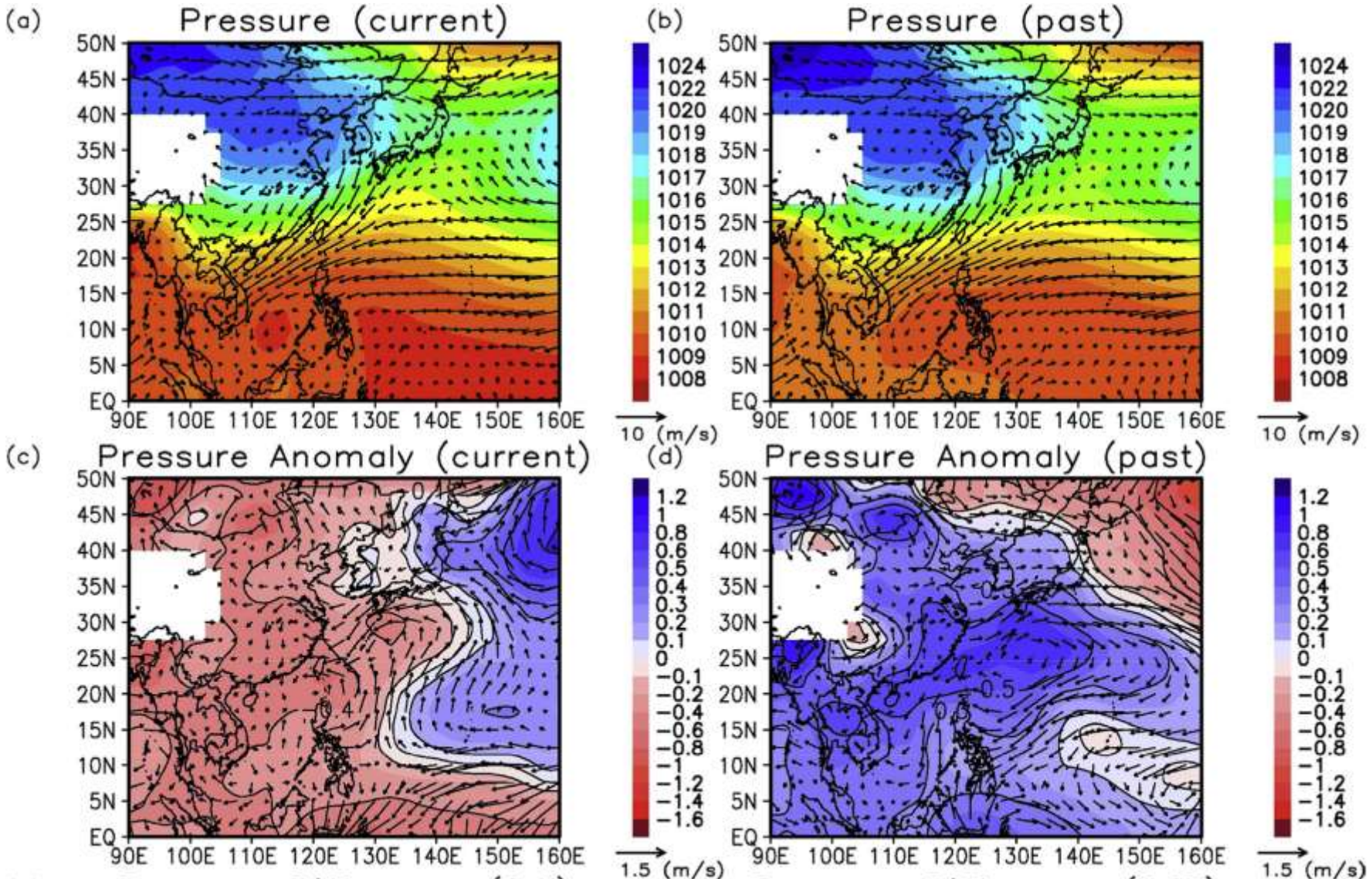
Current: 2004-2011 (**8 years Fall Season**)

- Emission data is fixed

Comparison of surface temperature

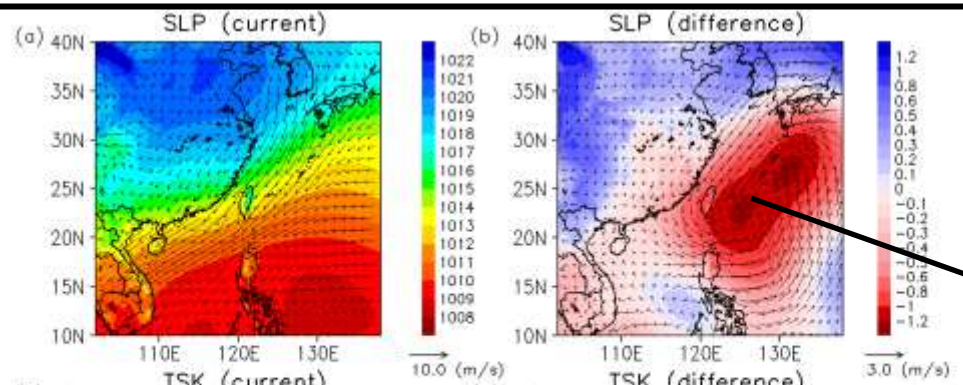


Comparison of sea level pressure



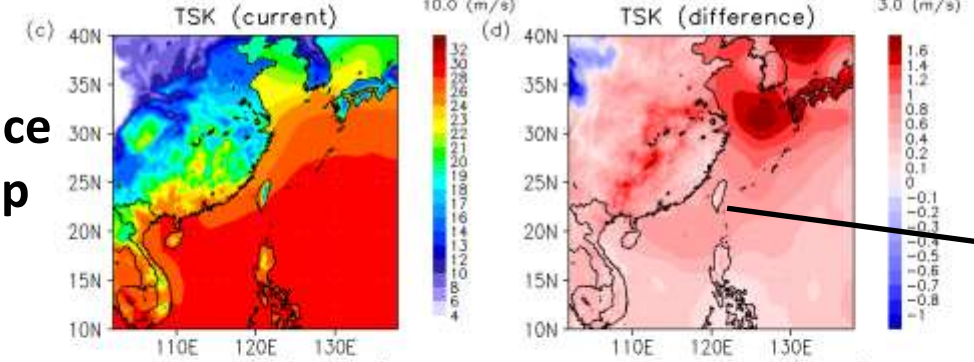
27-km WRF result

SLP



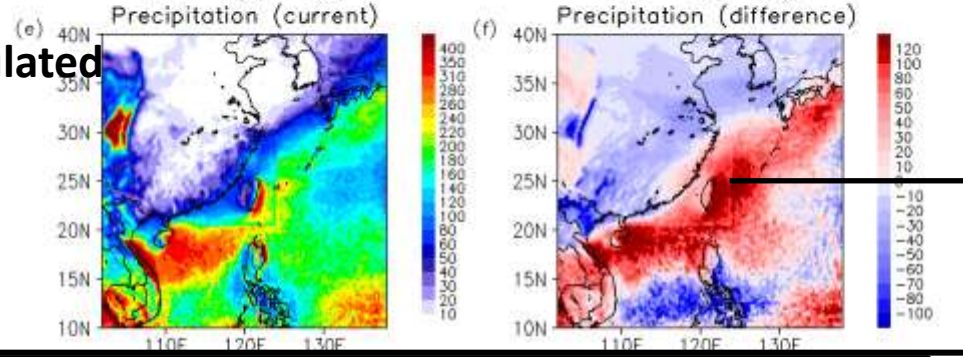
Deepened SLP with cyclonic circulation

Surface Temp



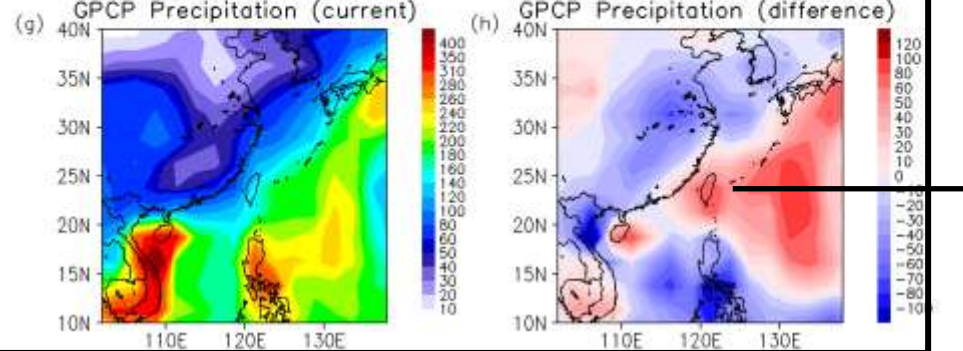
Increased temperature enhance evaporation

Accumulated rainfall



Rainfall increase in Taiwan and surrounding area

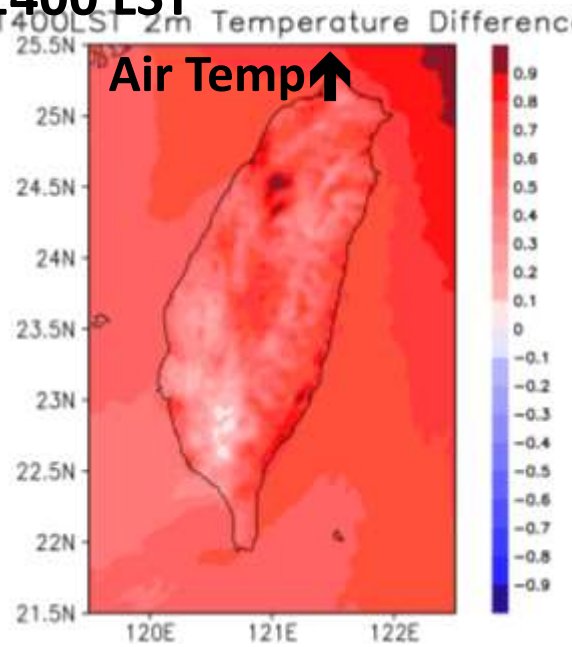
NASA GPCP

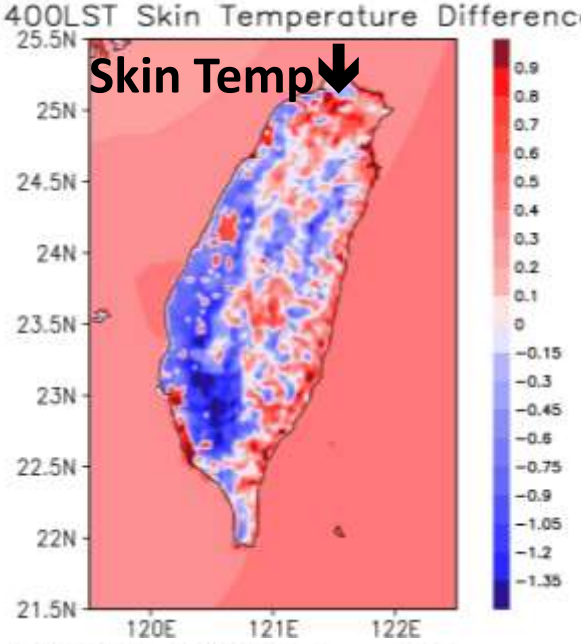


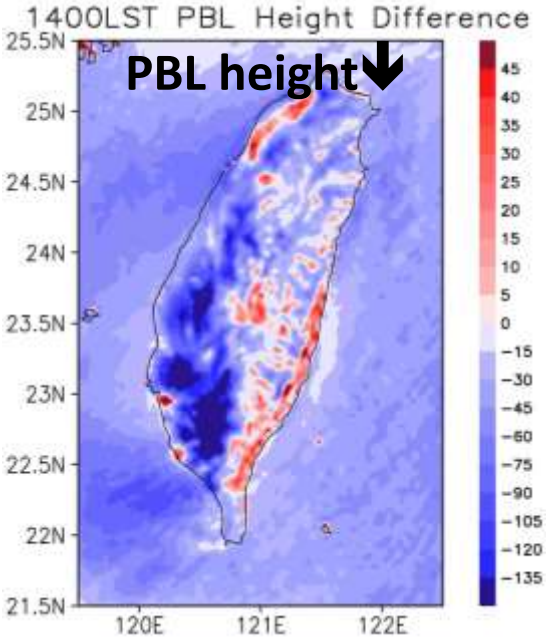
Observation data also shows increase of rainfall amounts

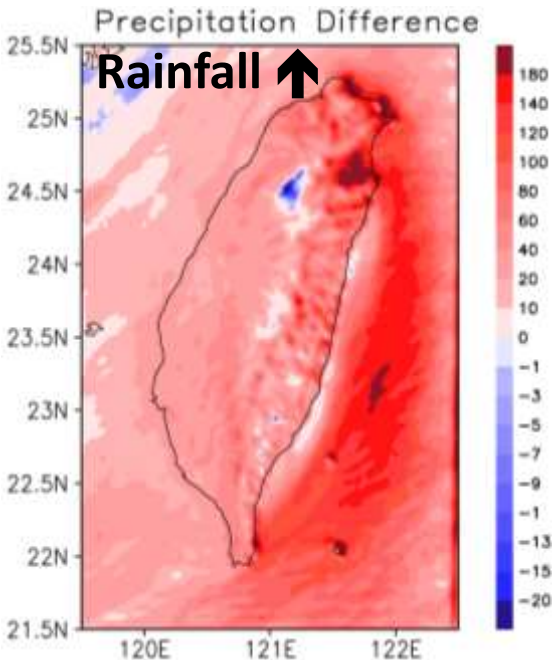
3-km WRF simulation result (Difference: current – past)

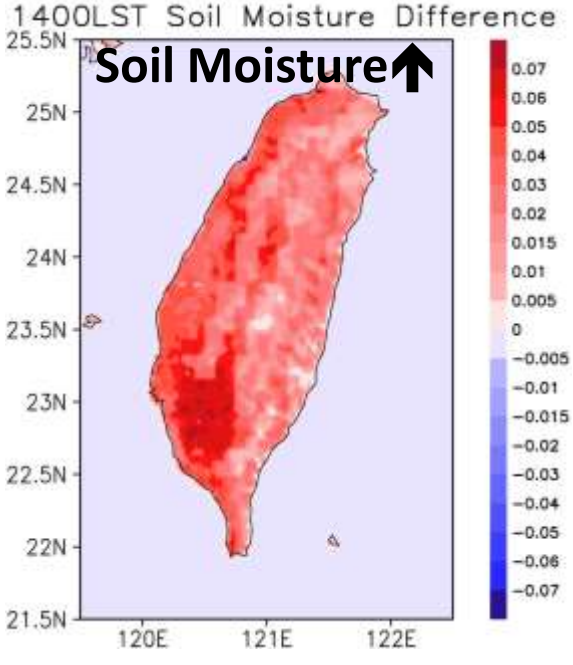
1400 LST

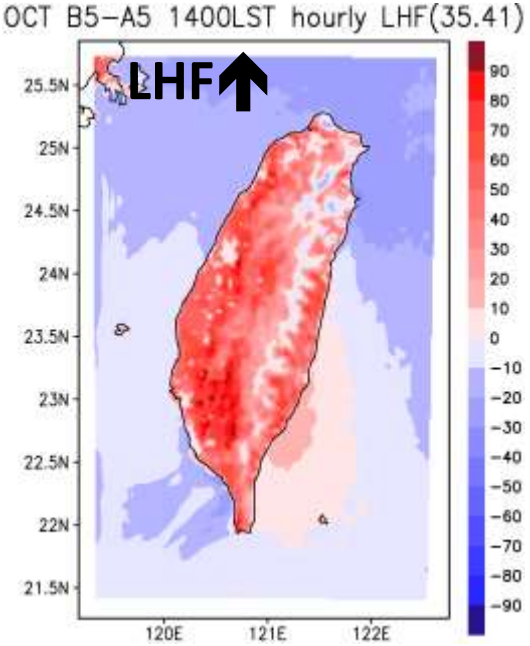




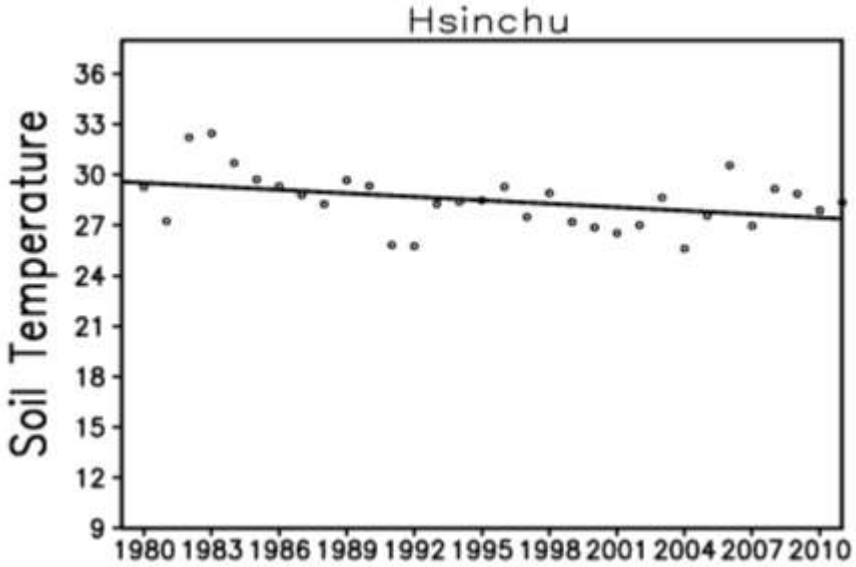


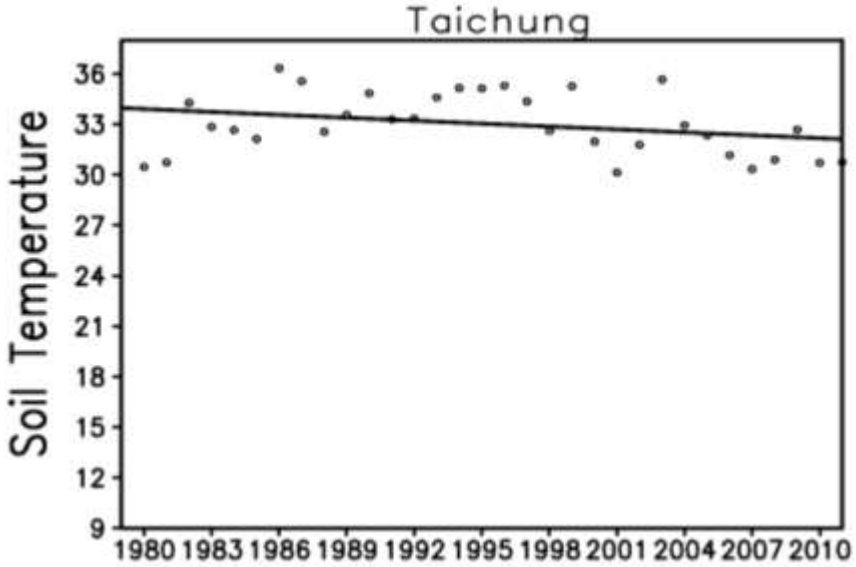


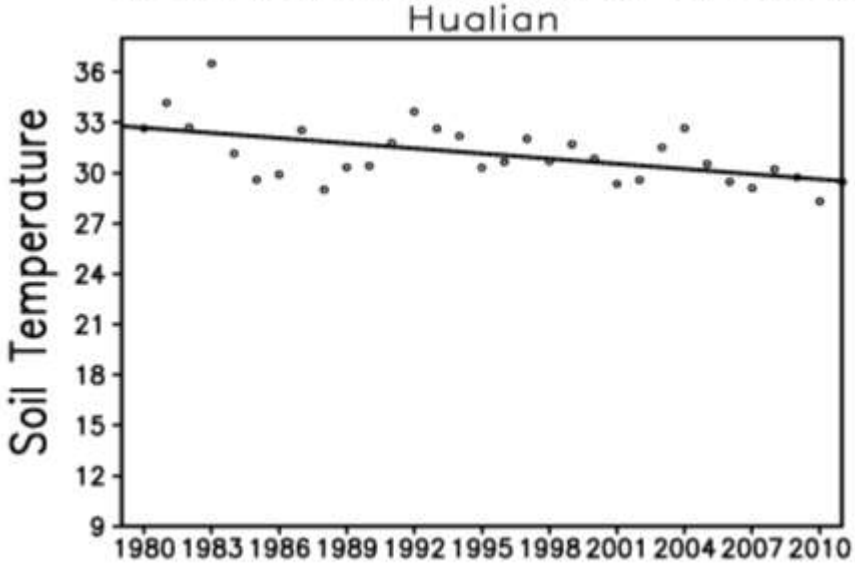


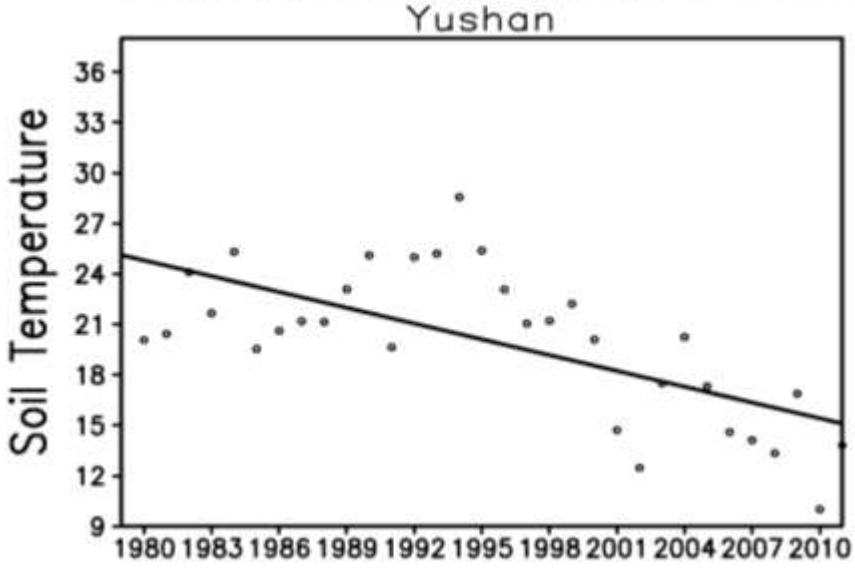


Observed skin temperature (1979 to 2011)



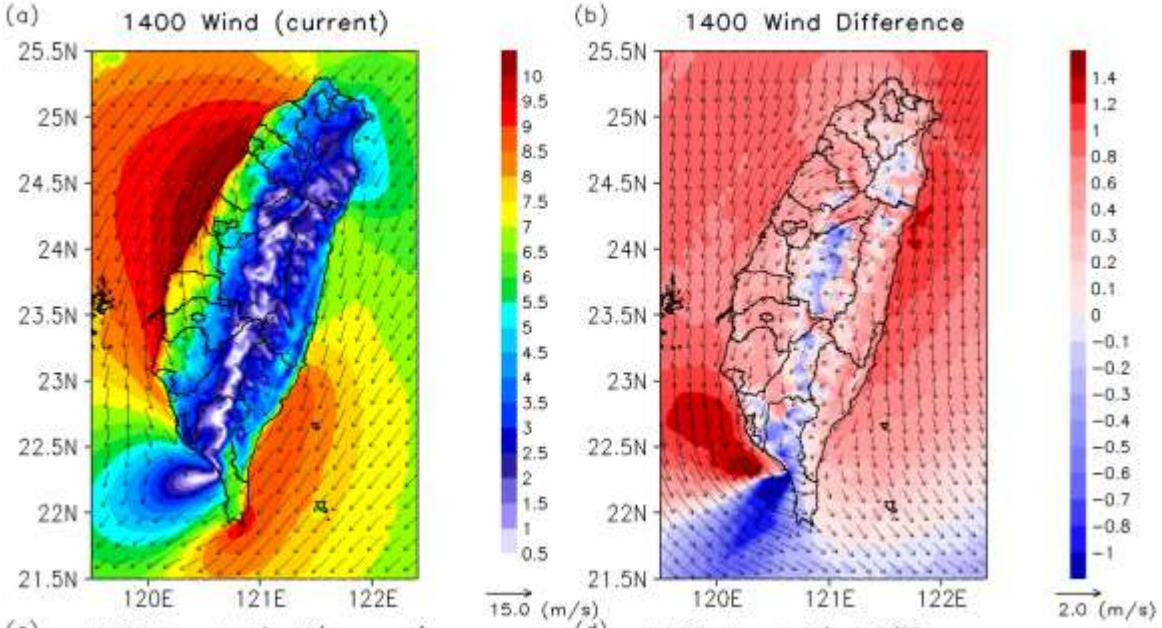




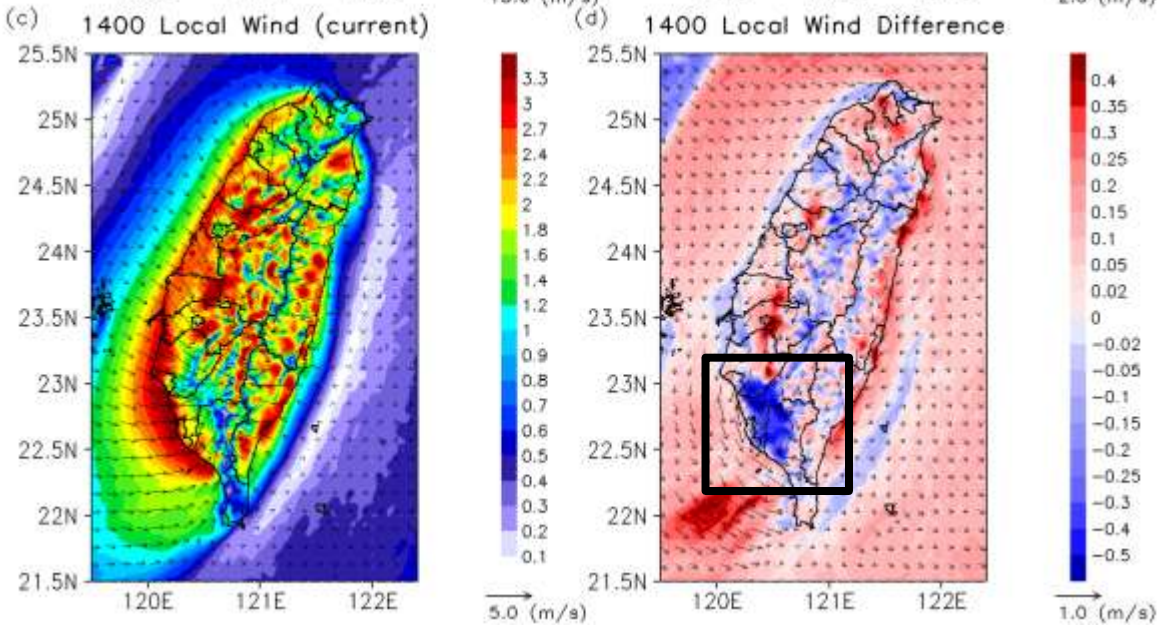


1400 LST Local Circulation

Total Wind



Local Wind



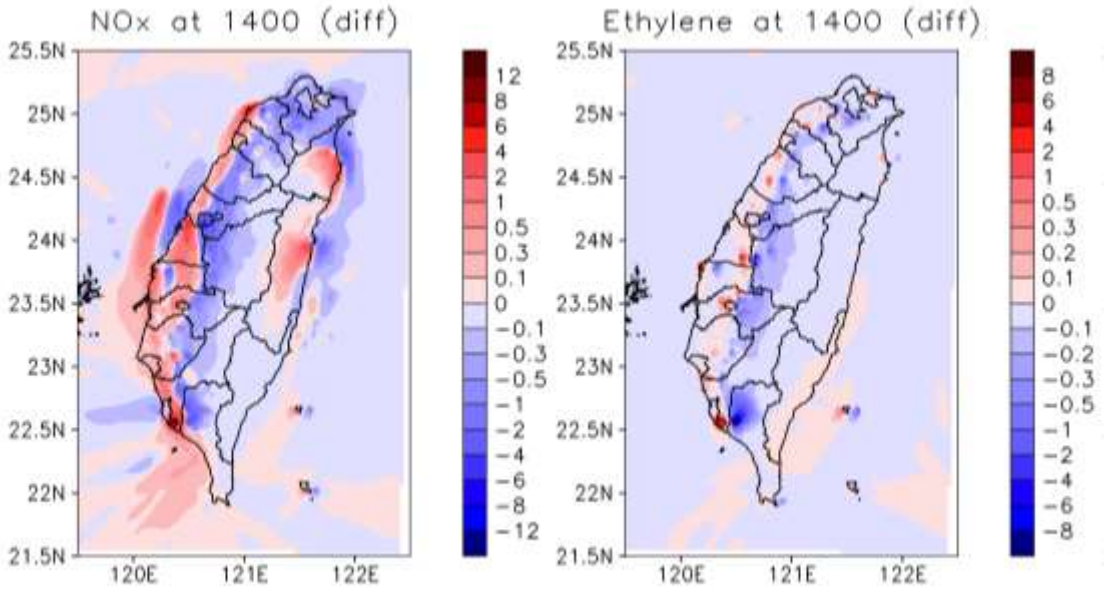
$V_{total}=V_{local}+V_{DailyAve}$

Sea breeze (local wind) becomes weaker particularly over southwestern Taiwan

3-km Air quality simulation (Difference: current - past)

1400 LST

NO_x **ethylene**



- Due to weakened LSB and PBL height, O_3 precursors such as (NO_x and ethylene) is more easily to accumulate in the source region.

Brief summary:

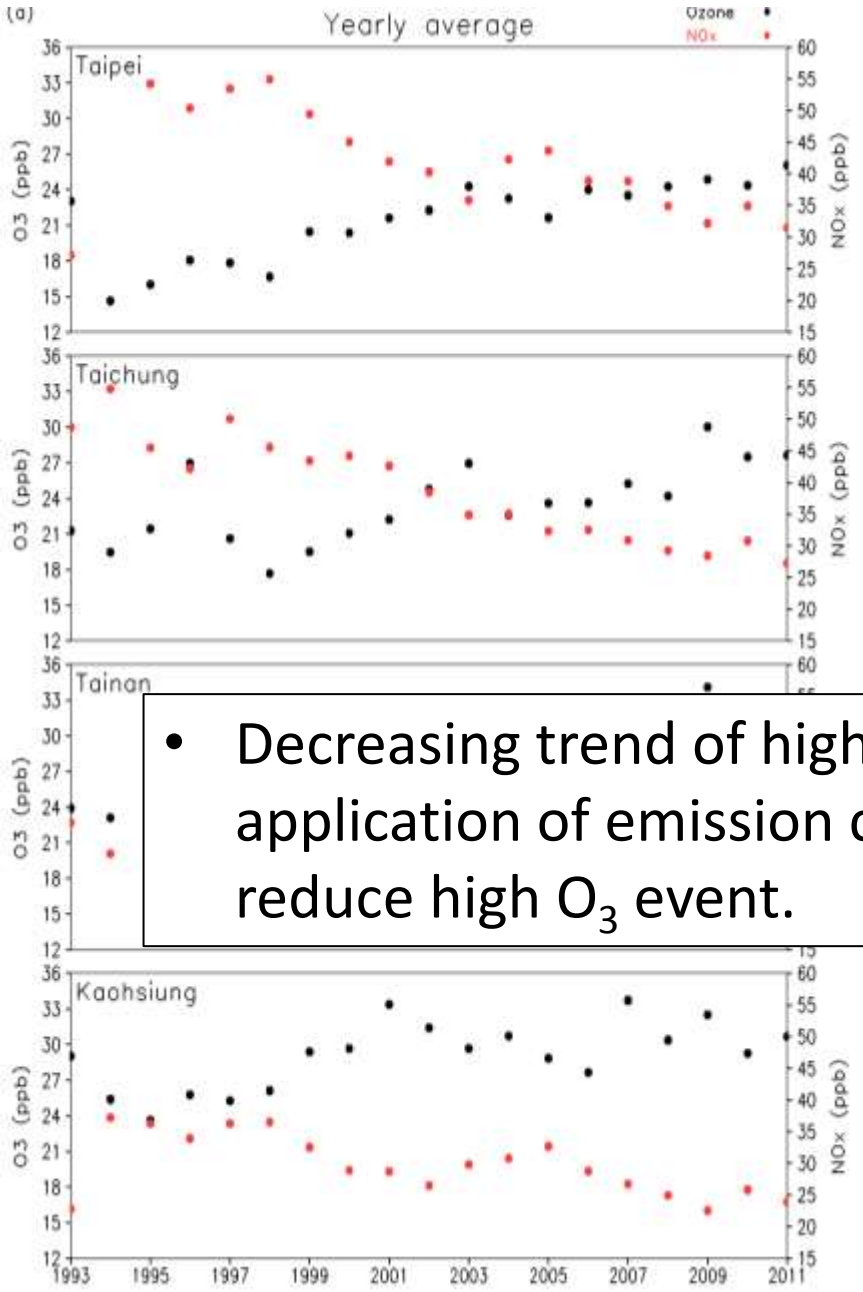
- Analysis of NCEP DOE data indicate **increased air temp and weakened Asian Continental anticyclone**. WRF and CMAQ simulation show **enhanced rainfall**. Through land physical process, the damped soil increase surface LHF that reduced PBL development, and together with weakened LSB flow, that would restrict air pollution dispersion process.

Analysis of long-term observation data

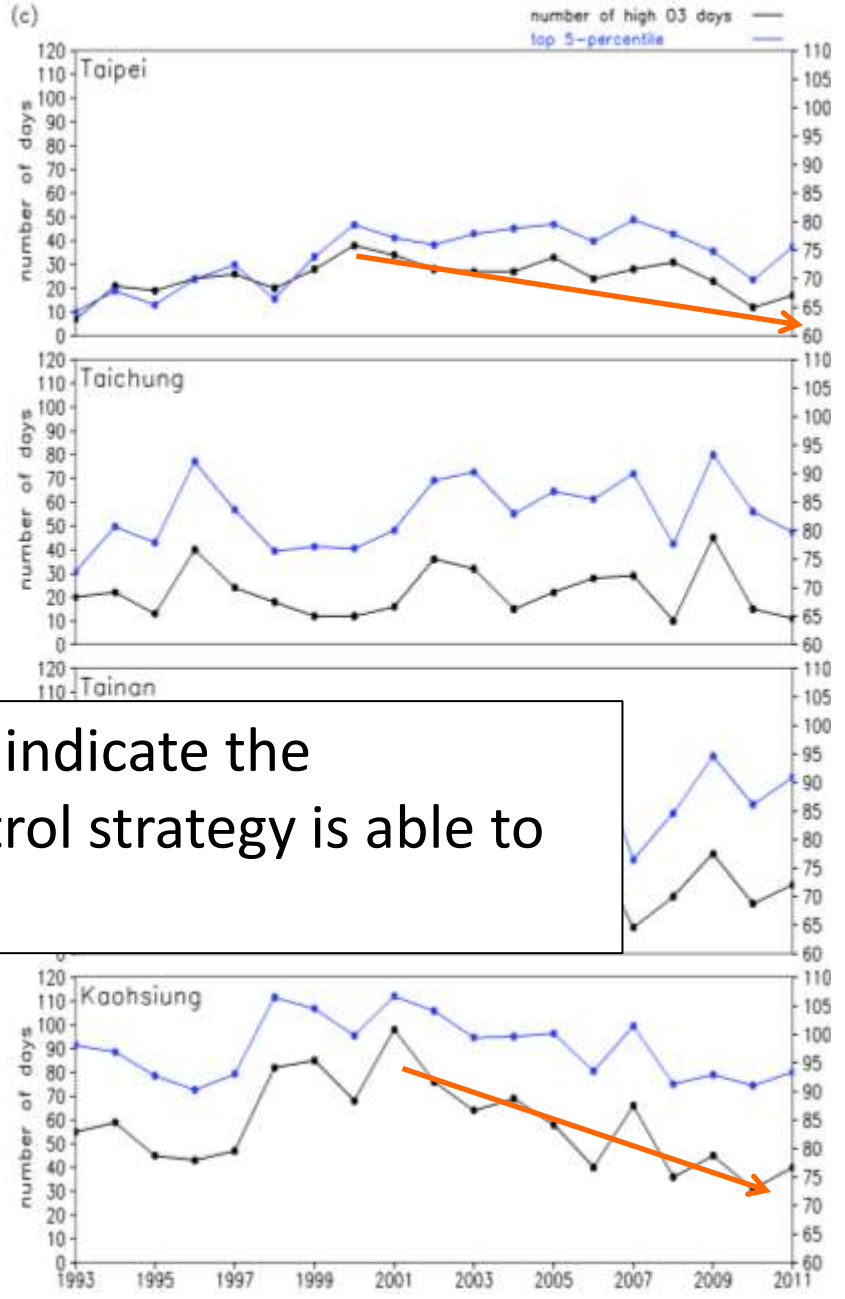
- Wind speed
- PBL height
- $PM_{2.5}$ concentrations

(Only process data in October and November for which the high levels of air pollution occur frequently and is mostly due to Taiwan's emission).

Annual averages of O_3 and NO_x from 1993-2011



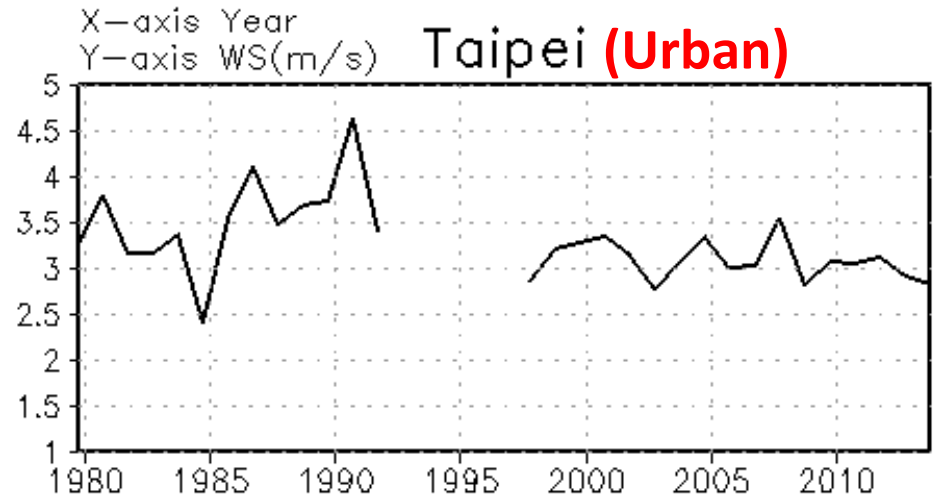
Top 5-percentile O_3 and O_3>100 ppb

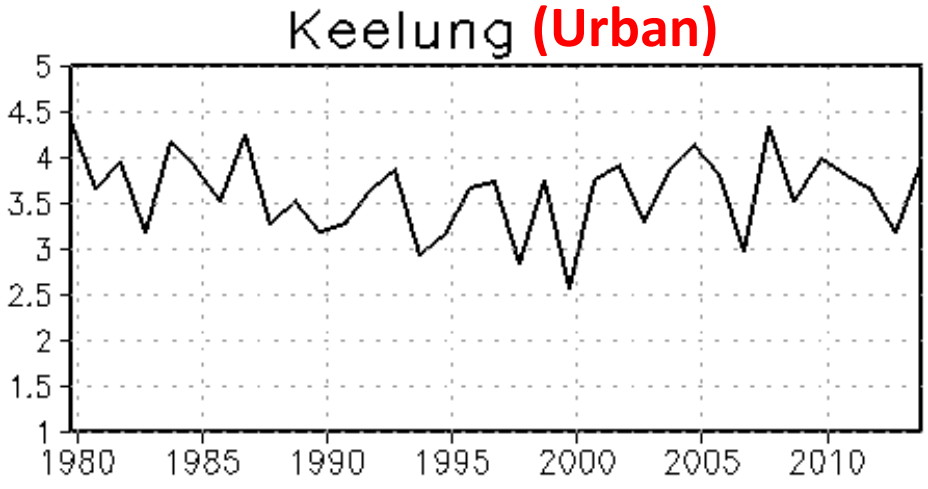


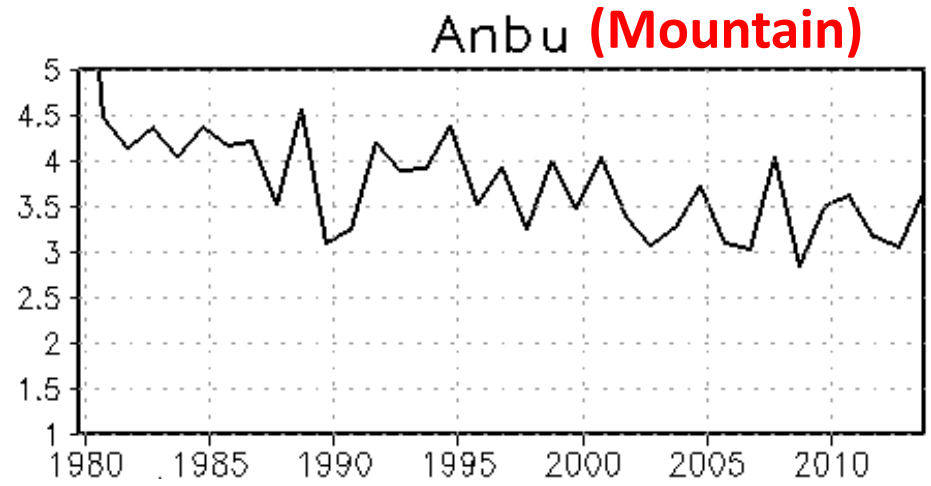
- Decreasing trend of high O_3 indicate the application of emission control strategy is able to reduce high O_3 event.

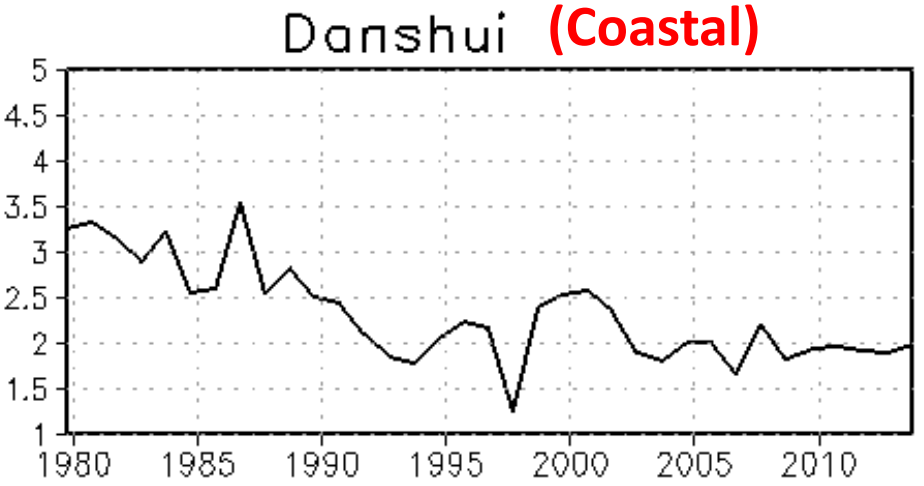
Northern Taiwan --- Wind Speed (1979 – 2015)

- Data processed only in Oct and Nov (high pollution is frequently observed and with less LRT)



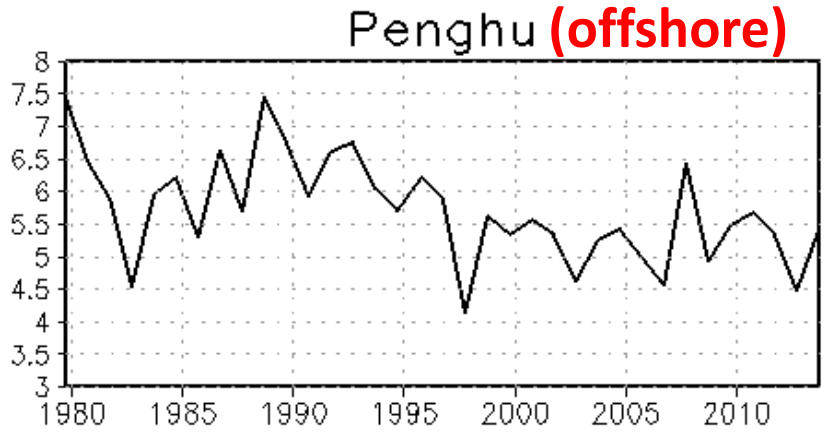


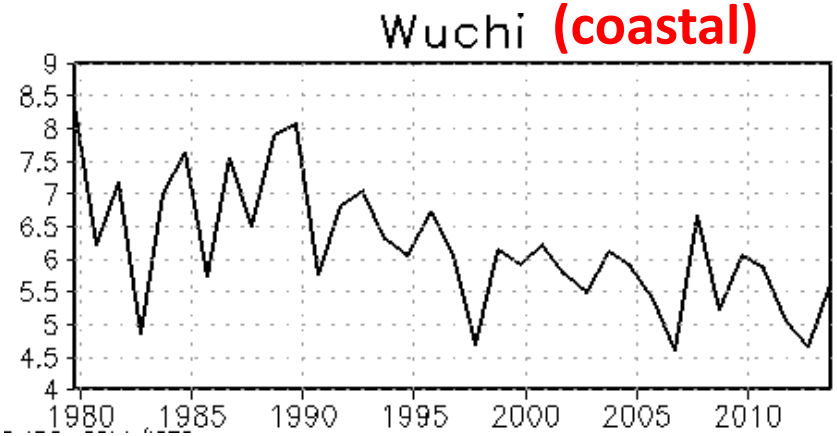


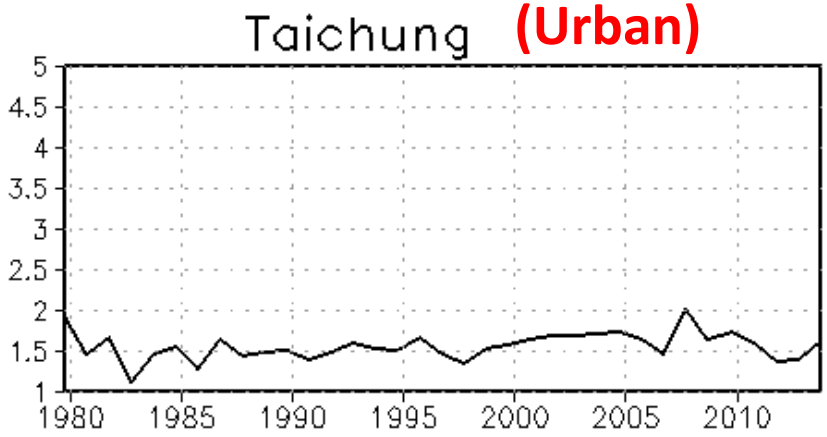


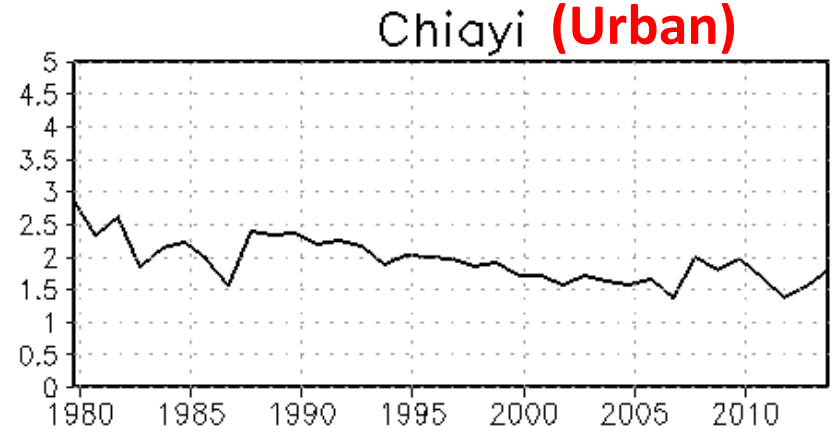
- Stations in northern Taiwan show an apparent decreasing trend of wind speed variation

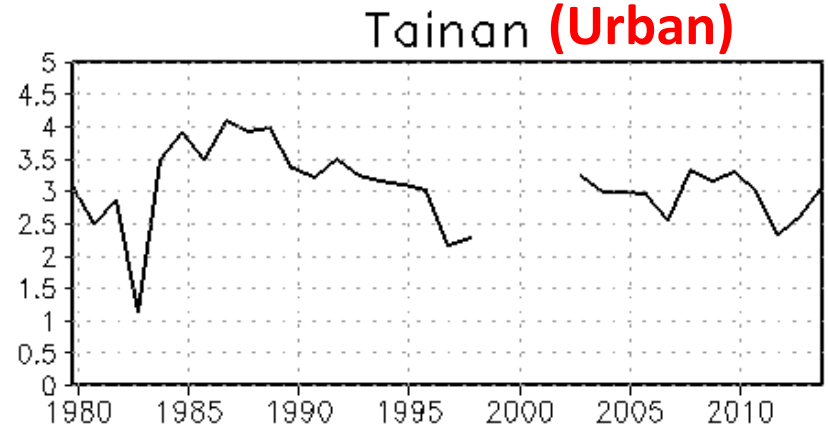
Wind Speed (1979 – 2015)

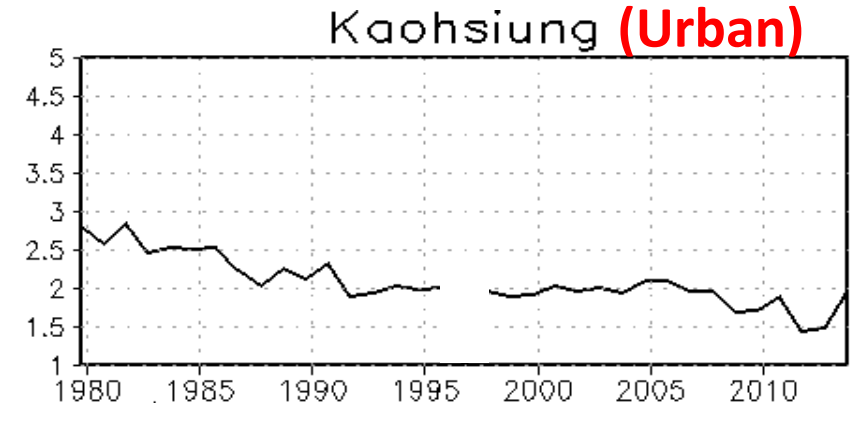












Analysis of PBL height

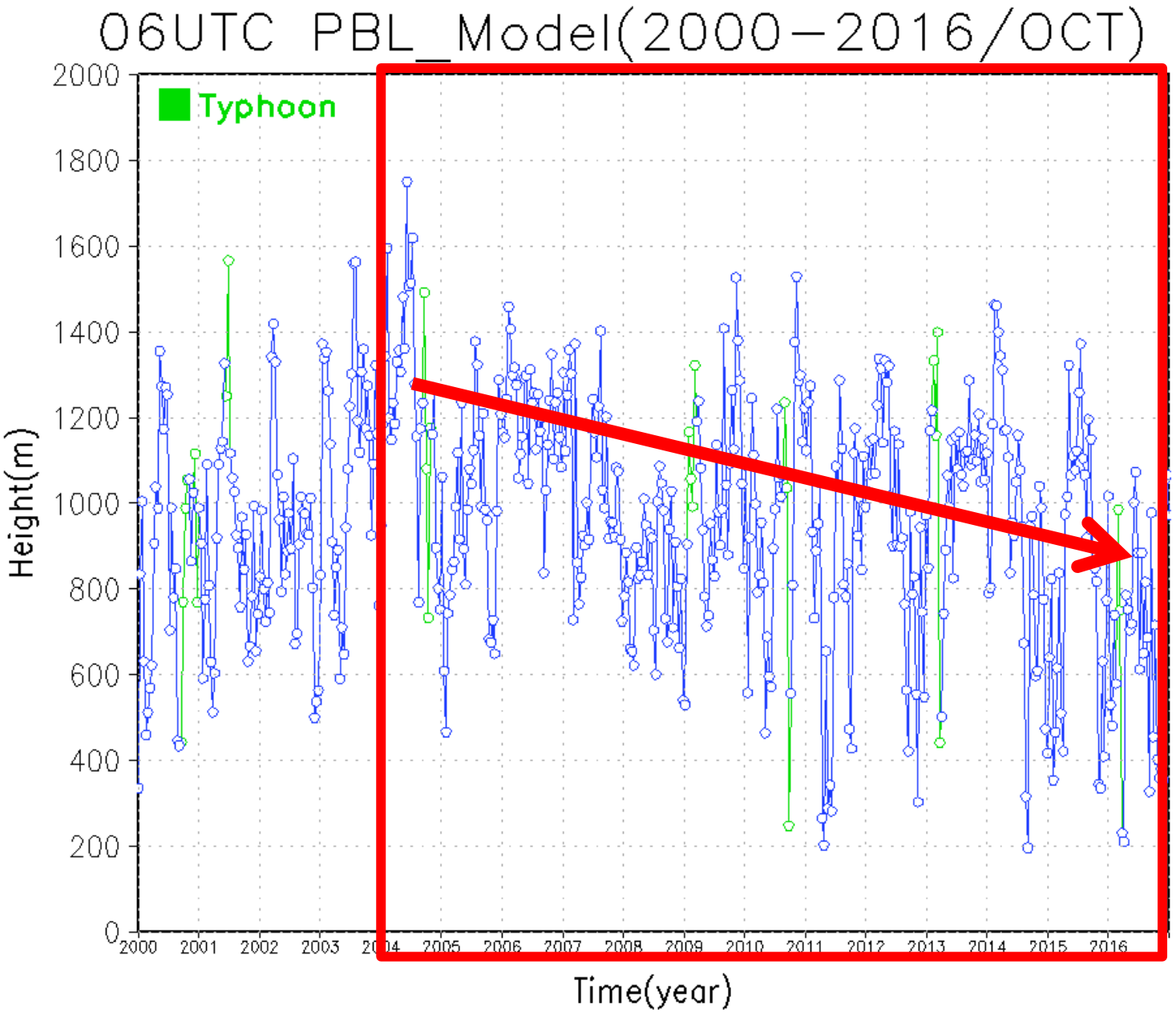
- Datasets:

1. NCEP FNL (final global analysis) datasets (1-degree) (Time: 2000 – 2016)

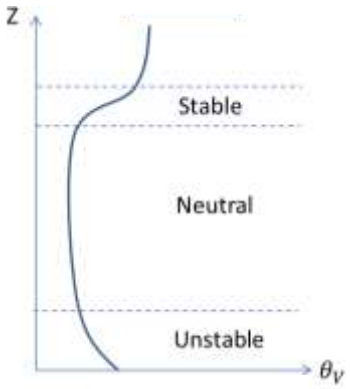
2. Sounding data in northern Taiwan (Time: 2004 – 2014). Data is available at 08 and 20 LST)

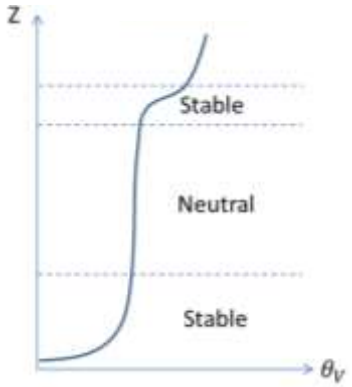
(Only consider data in October and November for which the high level of air pollution is likely to happen).

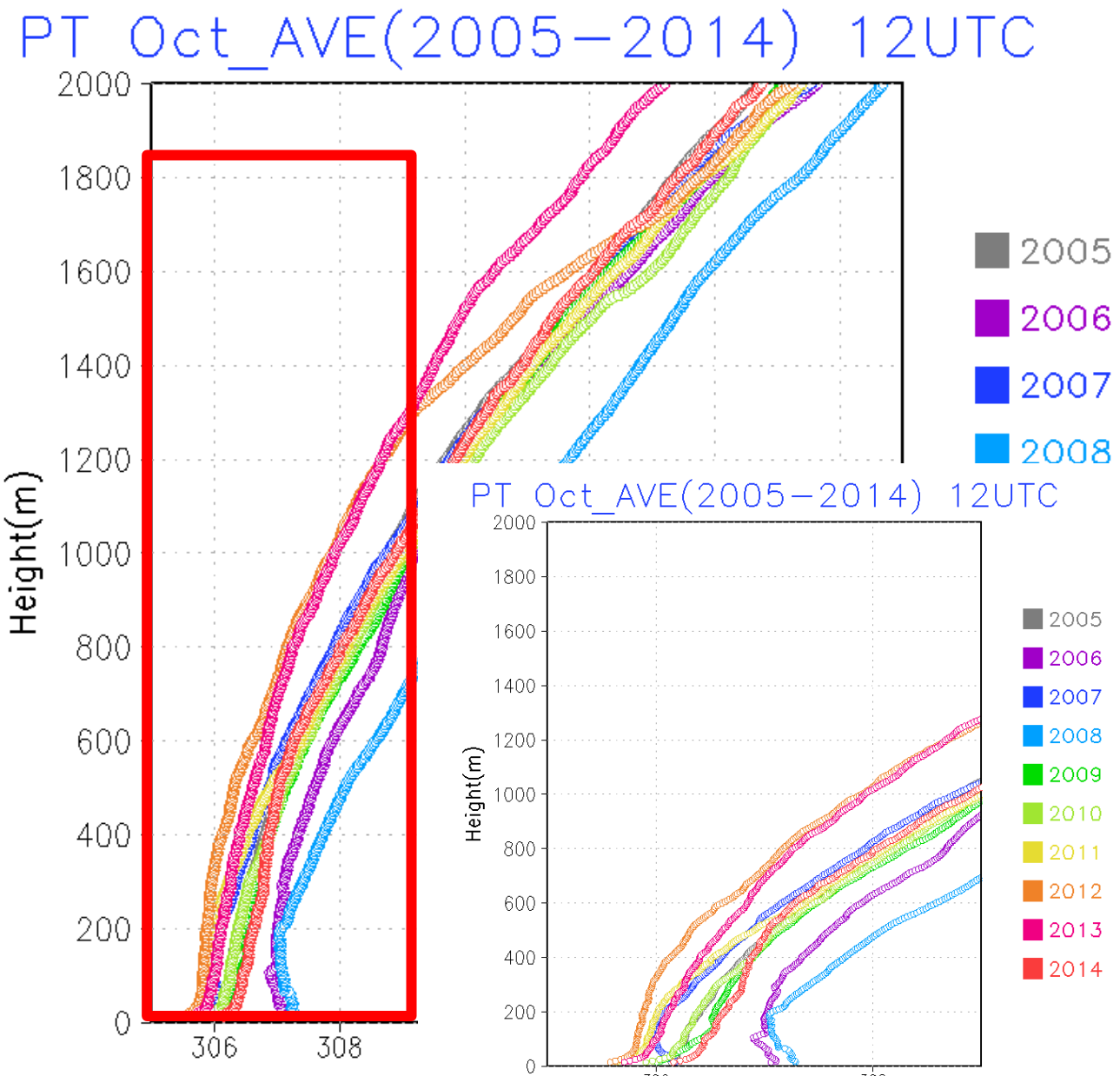
PBL height from NCEP FNL data



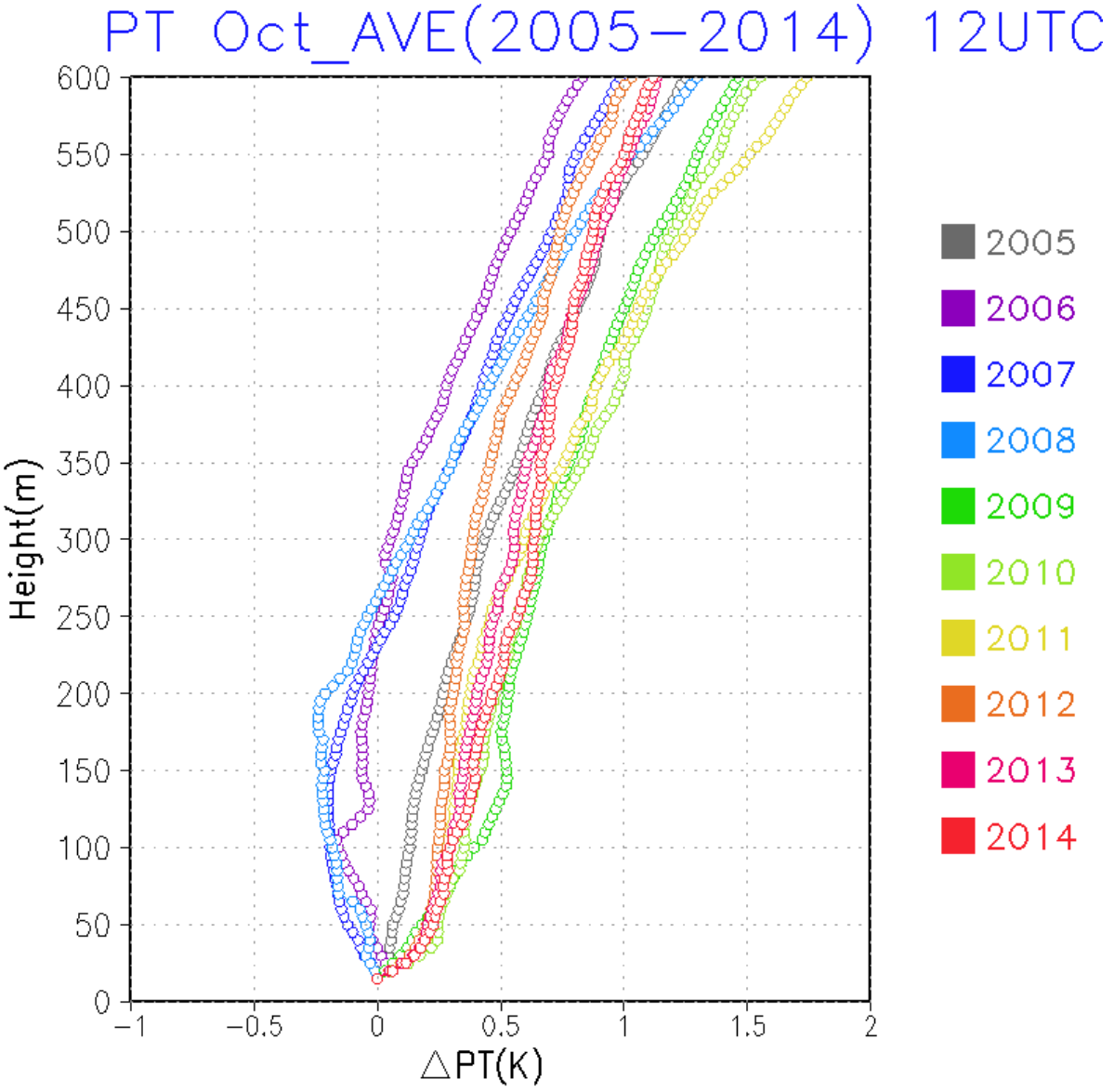
Sounding Data (2000 LST)







Sounding Data (2000 LST)



$\Delta PT = PT_{lev} - PT_{lev1}$

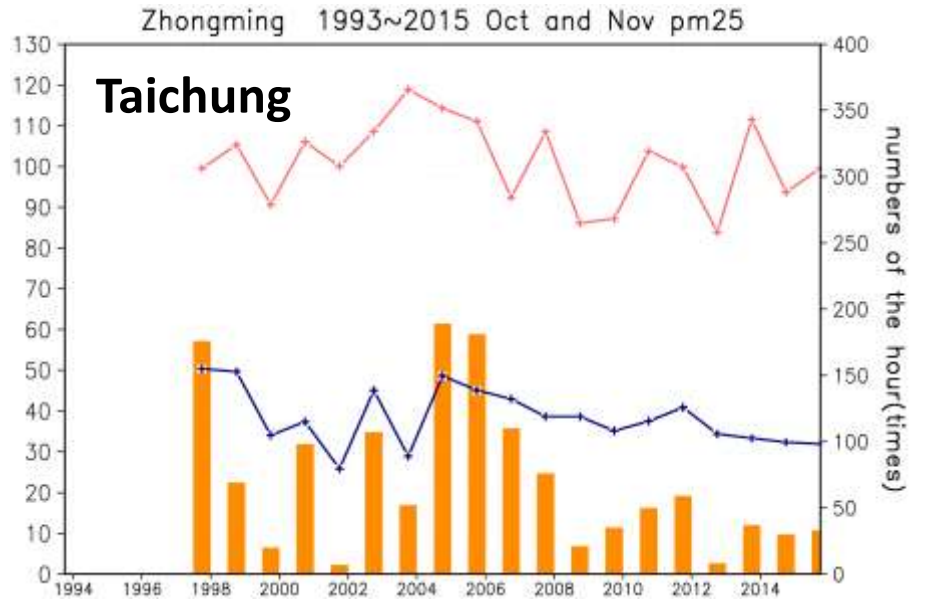
Put the data at lowest point at 0 line.

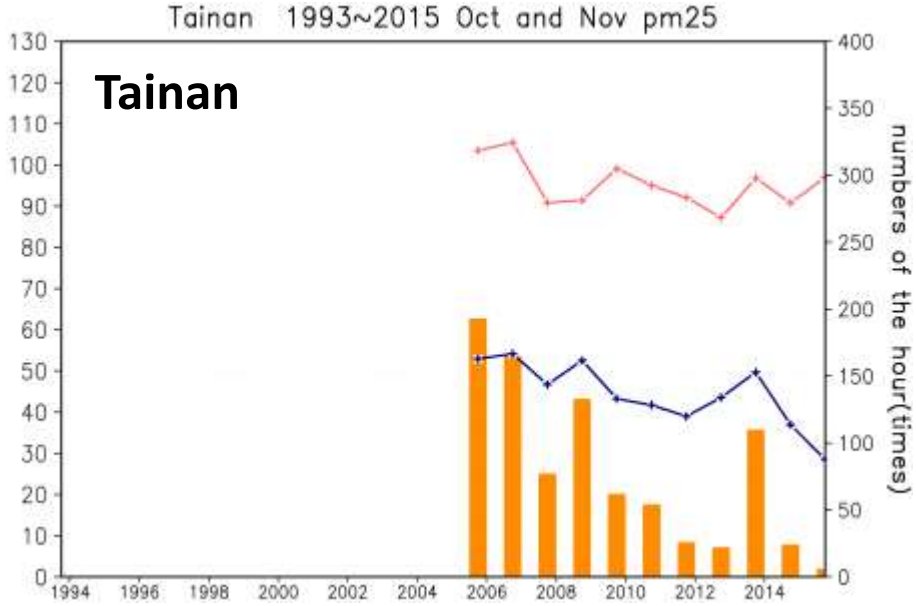
Recent year shows a more **stable** structure.

2005 – 2008 shows a **less stable** structure.

$PM_{2.5}$ (1993 – 2015)

- **Red : $PM_{2.5}$ > 80 ug/m³**
- **Blue: averaged $PM_{2.5}$ concentration**





Summary

- Analysis of NCEP DOE data indicates **increased air temp, weakened Asian Continental anticyclone, enhanced rainfall**.
- WRF and CMAQ simulation show a weakened land-sea breeze flow and PBL height that restrict the air pollution dispersion process.

- Observed surface wind fields shows a decreasing trend through past 35 years
- Analysis of sounding data reveals **enhanced atmospheric stability condition through year 2004 – 2016**.
- Reduced wind speed and enhanced atmospheric stability limit atmospheric dispersions.
- Long-term variations of $PM_{2.5}$ concentrations show decreasing trend that can be due to the effectiveness of emission reduction; yet, high levels of $PM_{2.5}$ does not change much that might be related to change of meteorological conditions such as the reduced wind flow and enhanced atmospheric stability.