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\textsubscript{x} and SO\textsubscript{2} concentrations through past several years

- 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
- 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

<table>
<thead>
<tr>
<th>Domain resolution</th>
<th>27, 9, 3 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical levels</td>
<td>49</td>
</tr>
<tr>
<td>Land surface scheme</td>
<td>Noah</td>
</tr>
<tr>
<td>PBL scheme</td>
<td>YSU</td>
</tr>
<tr>
<td>Initial condition</td>
<td>NNR2 6-h</td>
</tr>
<tr>
<td>Anthropogenic emission</td>
<td>TEDS (fixed)</td>
</tr>
<tr>
<td>Biogenic emission</td>
<td>Megan</td>
</tr>
<tr>
<td>Chemistry</td>
<td>CB05</td>
</tr>
</tbody>
</table>

**Simulation period**
- **Past:** 1979-1986 (8 years Fall season)
- **Current:** 2004-2011 (8 years Fall Season)

- Emission data is fixed
Comparison of surface temperature

(a) Temperature (current)

(b) Temperature (past)

(c) Temperature Anomaly (current)

(d) Temperature Anomaly (past)
Comparison of sea level pressure

(a) Pressure (current)

(b) Pressure (past)

(c) Pressure Anomaly (current)

(d) Pressure Anomaly (past)
Deepened SLP with cyclonic circulation
Increased temperature enhance evaporation
Rainfall increase in Taiwan and surrounding area
Observation data also shows increase of rainfall amounts
3-km WRF simulation result (Difference: current – past)

1400 LST

Air Temp (up)

Skin Temp (down)

PBL height (down)

Rainfall (up)

Soil Moisture (up)

LHF (up)
Observed skin temperature (1979 to 2011)

- Hsinchu
- Taichung
- Hualian
- Yushan
Sea breeze (local wind) becomes weaker particularly over southwestern Taiwan
Due to weakened LSB and PBL height, O\textsubscript{3} precursors such as (NO\textsubscript{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)

Penghu (offshore)

Wuchi (coastal)

Taichung (Urban)

Chiayi (Urban)

Tainan (Urban)

Kaohsiung (Urban)
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

06UTC PBL_Model (2000 - 2016/OCT)

Diagram showing PBL height from NCEP FNL data over the years 2000 to 2016. The graph indicates a trend over time with a red arrow pointing downward, suggesting a decrease in PBL height.
Sounding Data (2000 LST)

PT Oct_AVE(2005–2014) 12UTC

Diagram showing temperature profiles across different years from 2005 to 2014.
Sounding Data (2000 LST)

ΔPT = 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/m$^3$
- 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
- 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.