Observed and simulated changes of PM$_{2.5}$ and O$_3$ under recent China droughts

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GCA1
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Standardized Precipitation Evapotranspiration Index (SPEI) – 1 month Reference period (1950-2010)
Drought: SPEI < -1.3 (10\textsuperscript{th} percentile)
Normal: SPEI (-0.5,0.5)
Future changes of drought (Average aridity, CMIP5–RCP8.5)

Mean: -1.5

Mean: -1.1
Future change

Drought occurrence frequency 1990-2014 Mar. to Oct. (%)

Future changes of drought (Frequency, CMIP5–RCP8.5)
Significant negative correlation

\[ O_3 +3.5 \text{ ppbv} \]

\[ PM_{2.5} +17\% \]

Wang and Xie et al., 2017, ACP
Anthropogenic emission
- 1990-2003: 4.9 ppbv
- 2004-2014: 4.2 ppbv

Meteorological condition
- Enhanced stagnation/heat wave ~40%

Wang and Xie et al., 2017, ACP
Drought

U.S. air quality – causes

**Anthropogenic emission**
- 1990-2003: 4.9 ppbv
- 2004-2014: 4.2 ppbv

**Meteorological condition**
- Enhanced stagnation/heat wave ~40%

**Dry deposition**
- Up to 30% decrease

**BVOCs emission**
- Increase by 7-20%
- Decrease at severe drought

**O₃ change**

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*Wang and Xie et al., 2017, ACP*
Drought occurrence frequency 1990-2014 Mar. – Oct. (%)

Significant negative correlation
$O_3$ +3.5 ppbv
$PM_{2.5}$ +17%
GEOS-Chem model performance

GEOS-Chem simulated PM$_{2.5}$-SPEI slope (MERRA)

\[ y = 0.16 + 0.21, \ r = 0.05 \]

Observed slope

Simulated slope

GEOS-Chem simulated PM$_{2.5}$-SPEI slope (MERRA2)

\[ y = 0.54 + 0.23, \ r = 0.26 \]

Obs. -0.48

Mod. -0.10

Improved PM$_{2.5}$-SPEI correlation due to improved cloud field

Xie et al., in prep
GEOS-Chem model performance

GEOS-Chem simulated $O_3$-SPEI slope (MERRA2, 2000-2014, Mar to Aug)

$y = 0.83 - 0.34$, $r = 0.79$

Obs.   -1.45
Mod.   -1.19

Xie et al., in prep
China $O_3$ change

GEOS-Chem simulated $O_3$-SPEI slope (MERRA2, 2000-2014, Mar to Aug)

- Observed slope: $-1.45$
- Simulated slope: $-1.19$

Mean: $-0.81$

Smaller sensitivity of $O_3$ to drought over China

$y = 0.83 \cdot -0.34$, $r = 0.79$

Obs. -1.45
Mod. -1.19

Xie et al., in prep
China O$_3$ change

GEOS-Chem simulated O$_3$-SPEI slope

- Mean: -1.19

Smaller O$_3$ enhancement

- Mean: -0.81

GEOS-Chem simulated O$_3$ change

- +2.6 ppbv

- +1.4 ppbv

Drought

Xie et al., in prep
China $O_3$ change – causes

High sensitivity: southwest (biogenic emission); Tibetan Plateau (higher PBL)

Xie et al., in prep
Future changes

Slope

Changes in SPEI

Drought

Mean: 0.9

Mean: 3.2

ppb/unit SPEI

ppb

ppb
Conclusions

- Degradation of air quality under drought (Met + ecosystem-atmosphere interaction)
- GEOS-Chem can reproduce O$_3$-SPEI correlation but not PM$_{2.5}$-SPEI
- Less O$_3$ increase under drought over China compared to U.S. under current and future climate
Obs. $O_3$

- NC: +15.5 ppbv
- SC: +5.2 ppbv

GEOS-Chem. $O_3$

- NC: +2.0 ppbv
- SC: +2.8 ppbv

Obs. PM$_{2.5}$

- NC: -1.9 $\mu g\ m^{-3}$
- SC: -3.6 $\mu g\ m^{-3}$

GEOS-Chem. PM$_{2.5}$

- NC: -0.83 $\mu g\ m^{-3}$
- SC: +2.8 $\mu g\ m^{-3}$

Xie et al., in prep