



Typical weather conditions for the severe ozone pollution events in North China

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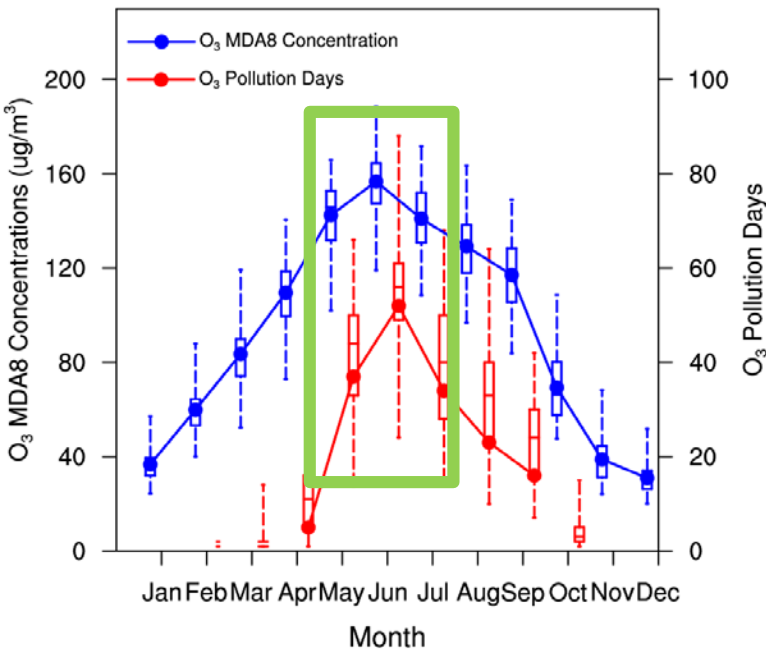
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Severe ozone pollutions in North China



Threshold for ozone polluted days

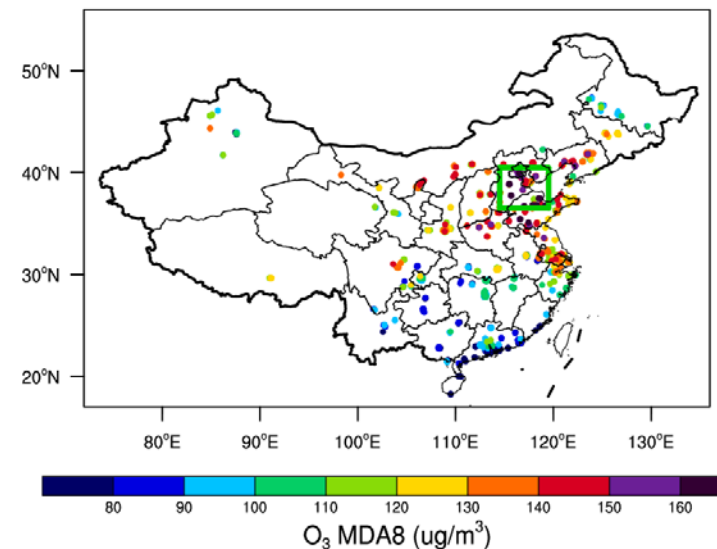
Maximum daily 8-h average ozone concentrations (**MDA8**)

>70 ppbv (~ 140 $\mu\text{g}/\text{m}^3$) by US Environmental Protection Agency

>160 $\mu\text{g}/\text{m}^3$ (~80 ppbv) by Ministry of Ecology and Environment of China

❑ Ozone concentrations are especially high from **May to July**

❑ **Over 1/3 ozone polluted days (123/368)** in May, June and July from 2014-2017



Scientific questions

- What are the highly relevant **meteorological factors** with the **severe ozone pollution events** in North China?
- Are there **existing typical weather conditions** of the severe ozone pollution events in North China? If there exists, **what are the specific mechanisms?**
- What is **the key process** contributing to the severe ozone pollution events?

Data and methods

Data

➤ Observational data

National air quality monitoring network of China

➤ Reanalysis meteorological data

MERRA2 0.5x0.625 in Asia Region

Temporal resolution:

1h for surface variables and
3h for atmospheric variables

➤ Simulated model

GEOS-CHEM, V11-01

MERRA2 nested AS simulation

Time period: May to July for 2014-2017

Resolution: $0.5^\circ \times 0.625^\circ$

Type of simulation: tropchem

Methods

➤ Criteria for ozone pollution events

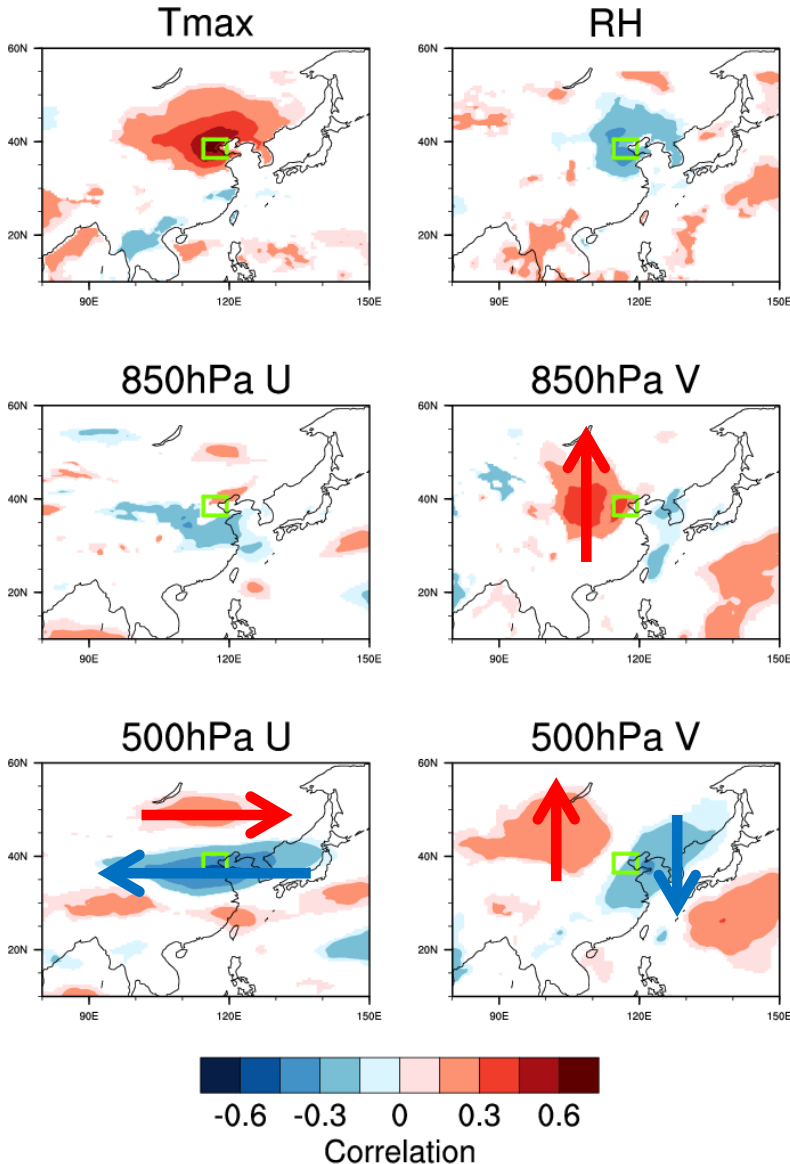
- a) Regional-averaged MDA8 exceeds $160\mu\text{g}/\text{m}^3$
- b) Lasting for over 3 days

➤ Process analysis

- a) Chemical production
- b) Horizontal transports
- c) Vertical transports
- d) Diffusion
- e) Dry deposition

$$PC_i(\%) = \frac{PC_i}{\sum_j abs(PC_j)}$$

Correlations between MDA8 and meteorological factors

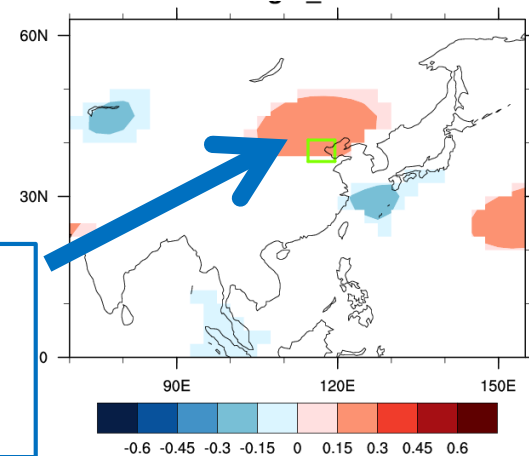


Four factors that are strongly relative to the higher ozone concentrations in North China:

- Higher Tmax
- Lower RH
- 850hPa southward winds anomaly
- 500hPa anti-cyclone circulations anomaly

The **high-pressure systems** are the dominate circulations, leading to **high temperature and low RH**

Positive correlation between MDA8 and height_500

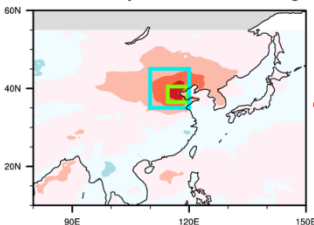


Index_O₃ definition and evaluation to characterize the typical weather conditions

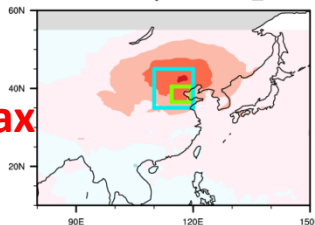
MDA8>160μg/m³

Index_O₃>0

Tmax Anomaly with MDA8>160 ug/m³

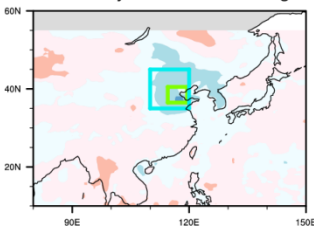


Tmax Anomaly with index_O3>0

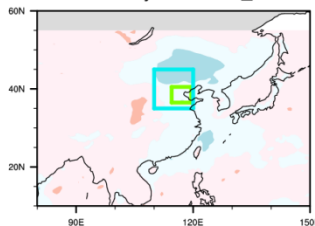


Tmax

RH Anomaly with MDA8>160 ug/m³

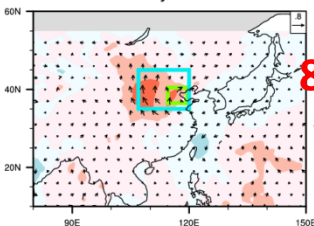


RH Anomaly with index_O3>0

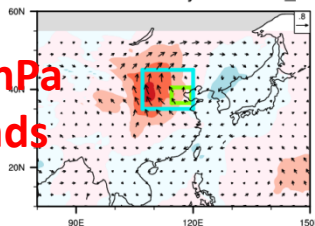


RH

850hPa Wind Anomaly with MDA8>160 ug/m³

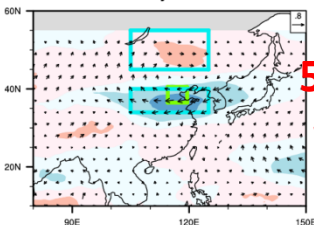


850hPa Wind Anomaly with index_O3>0

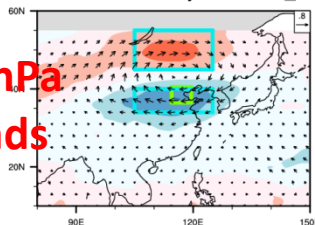


850hPa
winds

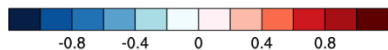
500hPa Wind Anomaly with MDA8>160 ug/m³



500hPa Wind Anomaly with index_O3>0



500hPa
winds



index_Tmax

index_RH

index_V850

index_U500

Series calculated by averaging the normalized values in the highly relative regions

Northern box minus southern box

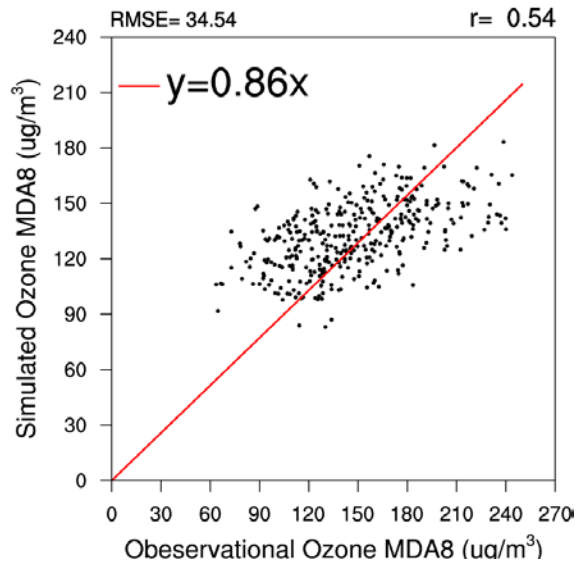
$$\text{index_O}_3 = [[\text{index_Tmax}] - [\text{index_RH}] + [\text{index_V850}] + [\text{index_U500}]]$$

Observed **123 ozone pollution days** and **21 ozone pollution episodes** (90 days)

82.1% (101/123) days and **17 episodes** (69 days) occur with **index_O₃>0**

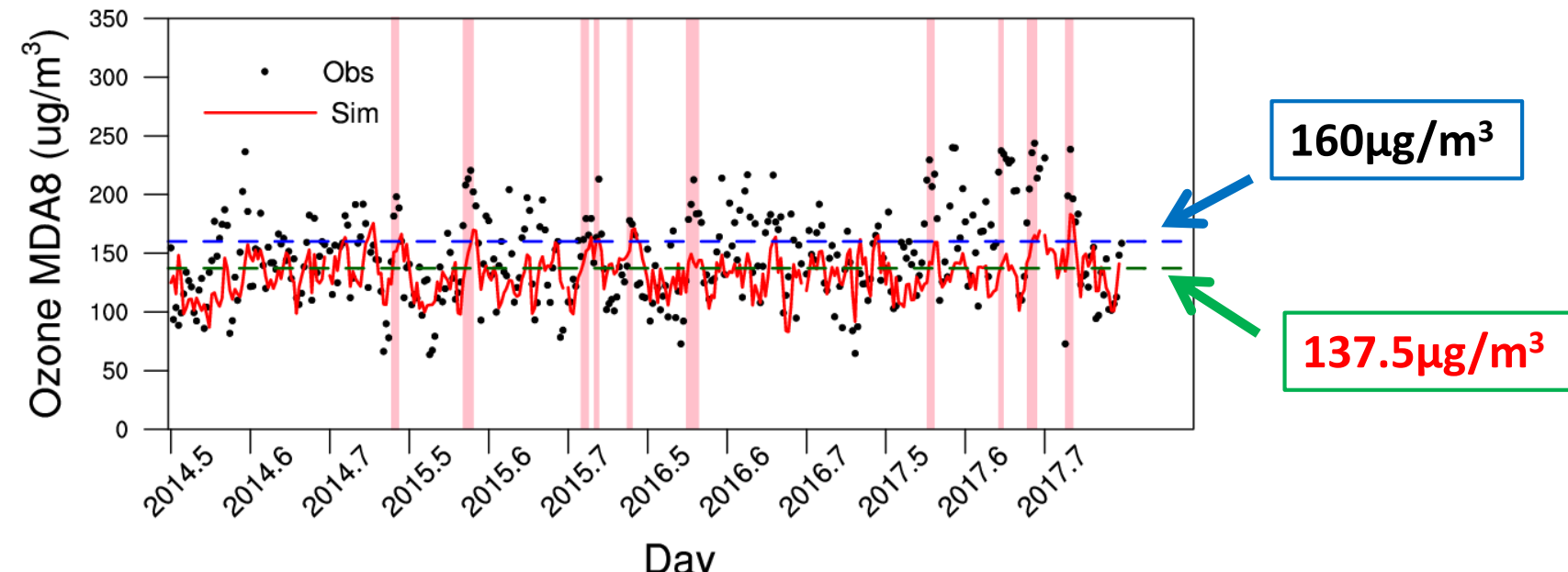
How such weather conditions lead to severe ozone pollutions in North China?

GEOS-CHEM model evaluation



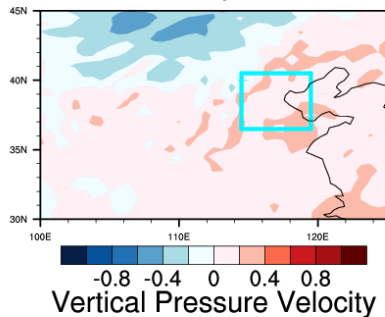
Model underestimate the high ozone concentrations

- **Reducing the threshold** of severe ozone pollution days in the model (MDA8 > **$137.5\mu\text{g}/\text{m}^3$** (160×0.86) according to the linear regression)
- **10 well-simulated episodes with $\text{index_O}_3 > 0$** are selected

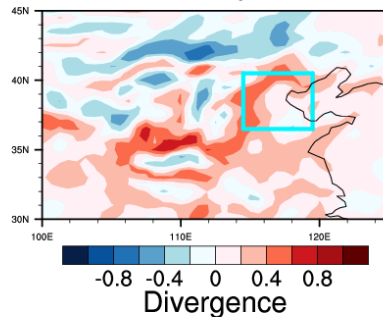


Vertical velocity and divergence evolutions in the process of ozone pollution episodes

w_500 Episodes



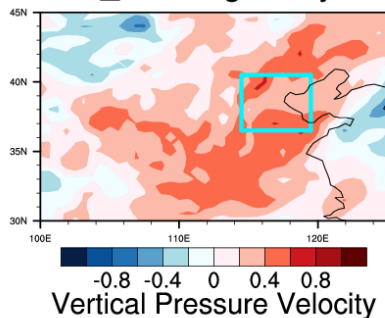
DIV_950 Episodes



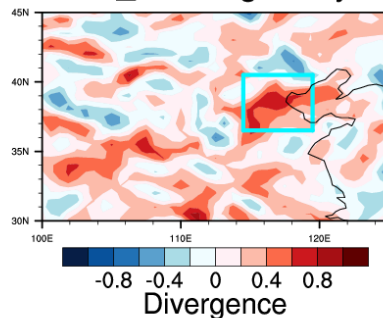
For severe ozone pollution events

- **Downwards air flows**
- **Divergence in lower atmosphere**

w_500 Begin Days



DIV_950 Begin Days

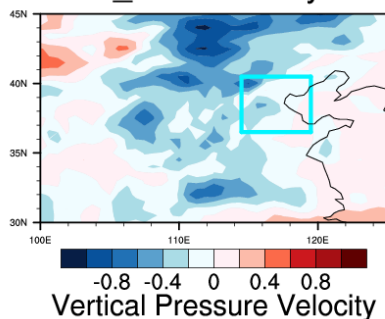


In the first days

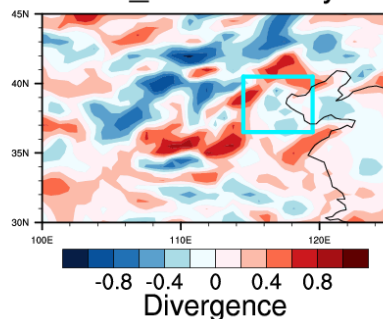
(Before the high-pressure systems)

- Stronger downwards air flows
- Stronger divergence in lower atmosphere

w_500 End Days



DIV_950 End Days



In the final days

(After the high-pressure systems)

- Weak upwards air flows
- Weak convergence in lower atmosphere

Processes anomaly during ozone pollution episodes

Episodes

Begin days

End days

Process contributions (PC) for ozone from surface to 850hPa

$$PC_i(\%) = \frac{PC_i}{\sum_j abs(PC_j)}$$

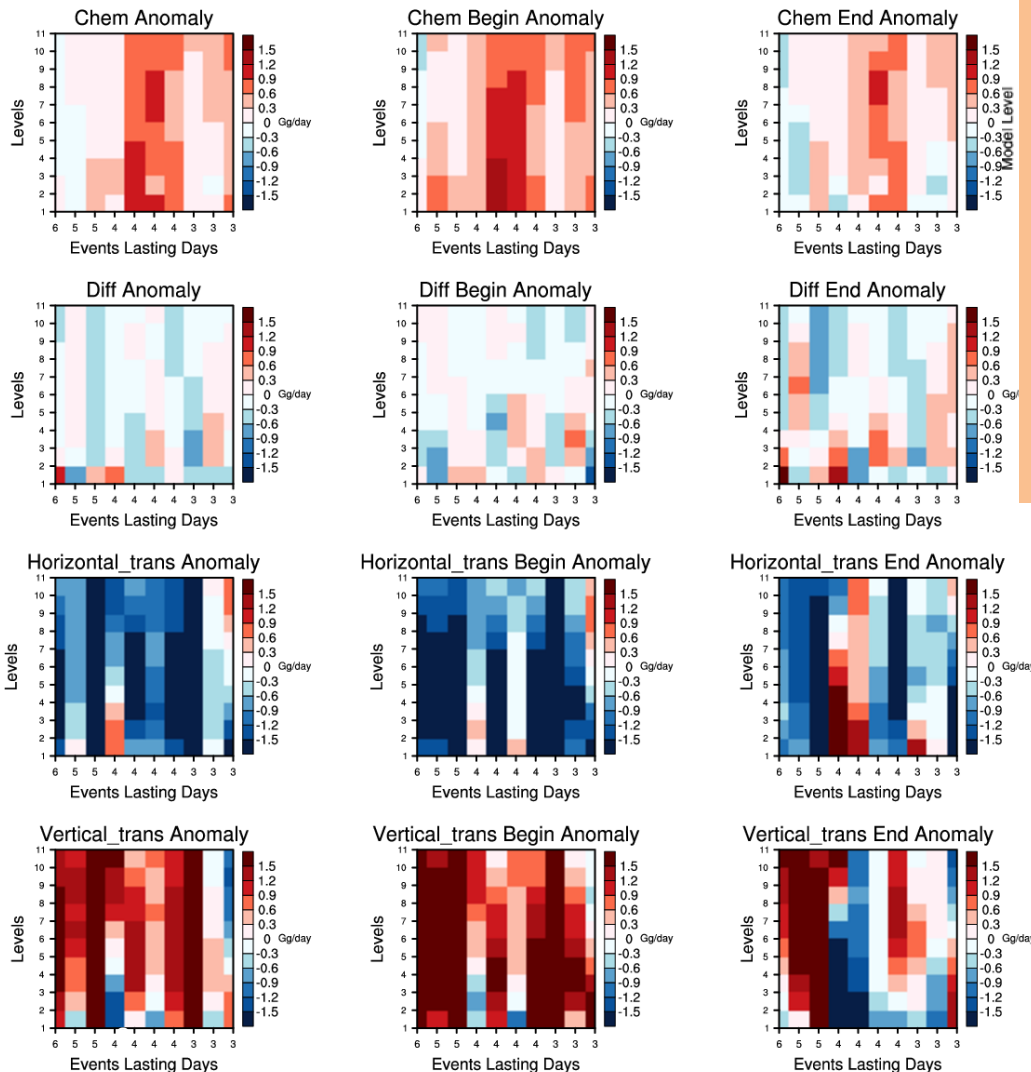
Chemical production: 31.9%

Diffusion: 4.1%

Dry deposition: -18.3%

Horizontal transports: -32.4%

Vertical transports: 13.3%



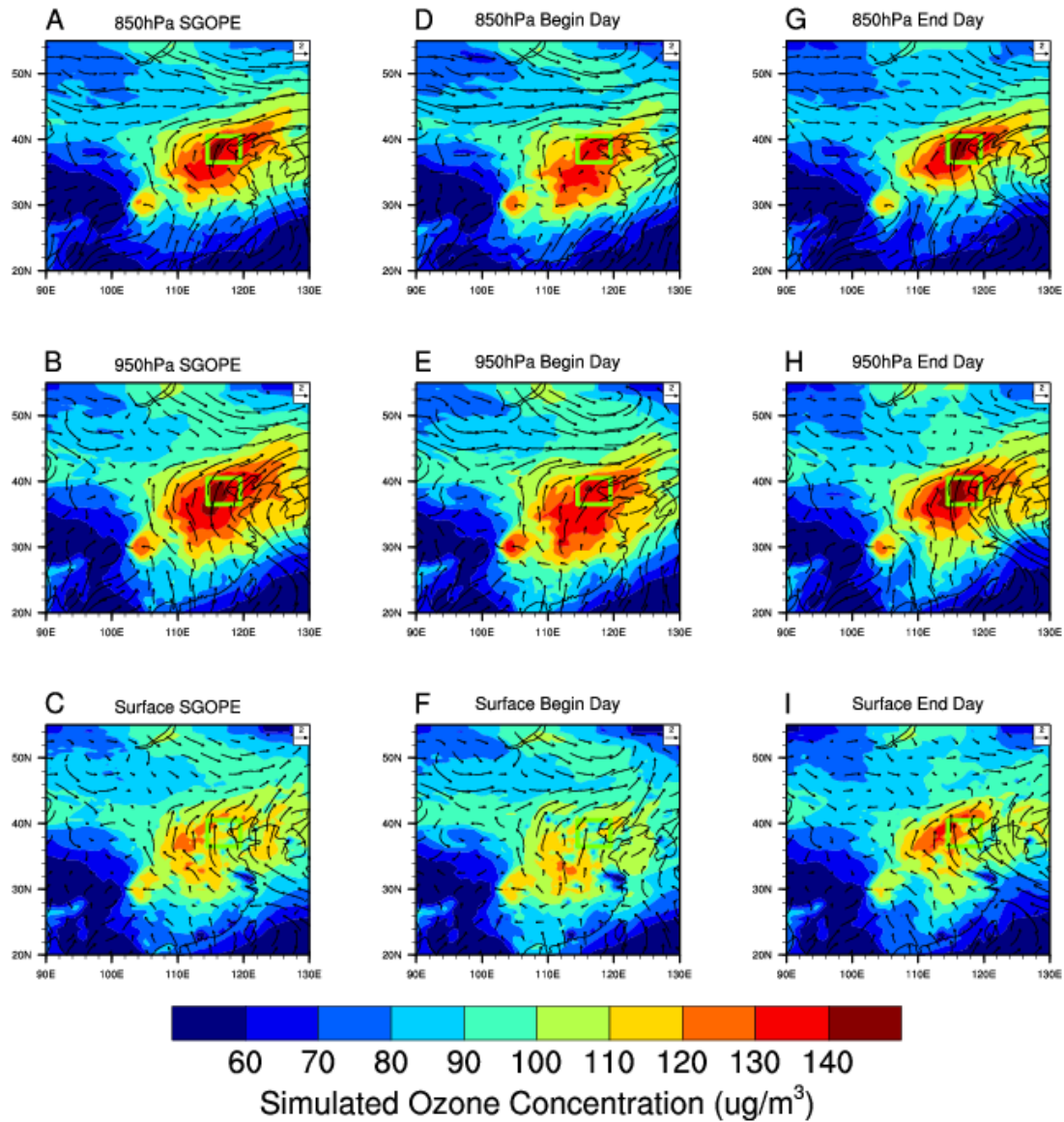
- Chemical production is stronger (hotter and dryer)
- Diffusion change little
- Horizontal transport makes a more negative contribution (Divergence)
- Vertical transport is stronger (Downward air flows)

Summary

- ❑ In this study, we have found the typical weather conditions that occur frequently for the severe ozone pollution episodes in North China, including **higher Tmax, lower RH, southward wind anomaly in 850hPa and anti-cyclone circulation anomaly in 500hPa.**
- ❑ The definition of index_ O_3 can well characterize such typical weather conditions for the severe ozone pollution events.
- ❑ Two main reasons leading to the severe ozone pollution episodes:
 1. Hotter and dryer weather **accelerates the ozone chemical reaction rates**
 2. The high-pressure systems with downwards air flows **make a much stronger ozone transports from upper levels to surface**

Thanks!

Backup slide



Backup slide

For the first days

**Process contributions (PC) for ozone
from surface to 850hPa**

$$PC_i(\%) = \frac{PC_i}{\sum_j abs(PC_j)}$$

Chemical production: 25.8%

Diffusion: 3.0%

Dry deposition: -12.4%

Horizontal transports: -31.5%

Vertical transports: 27.3%

For the final days

**Process contributions (PC) for ozone
from surface to 850hPa**

$$PC_i(\%) = \frac{PC_i}{\sum_j abs(PC_j)}$$

Chemical production: 32.1%

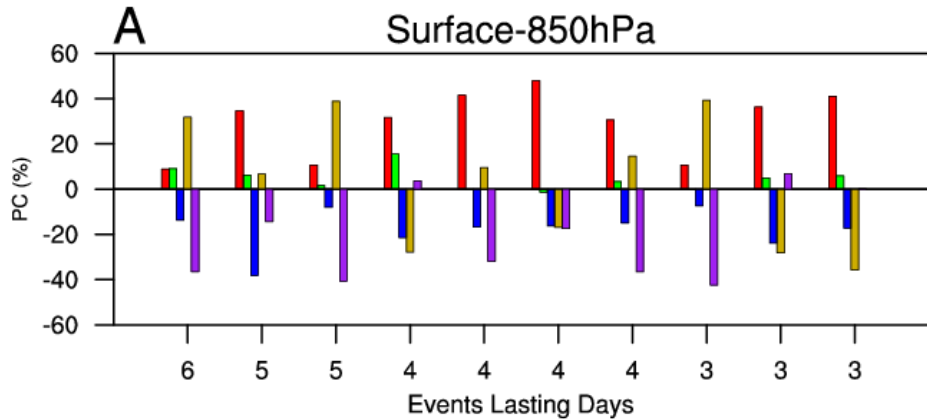
Diffusion: 8.1%

Dry deposition: -22.9%

Horizontal transports: -14.7%

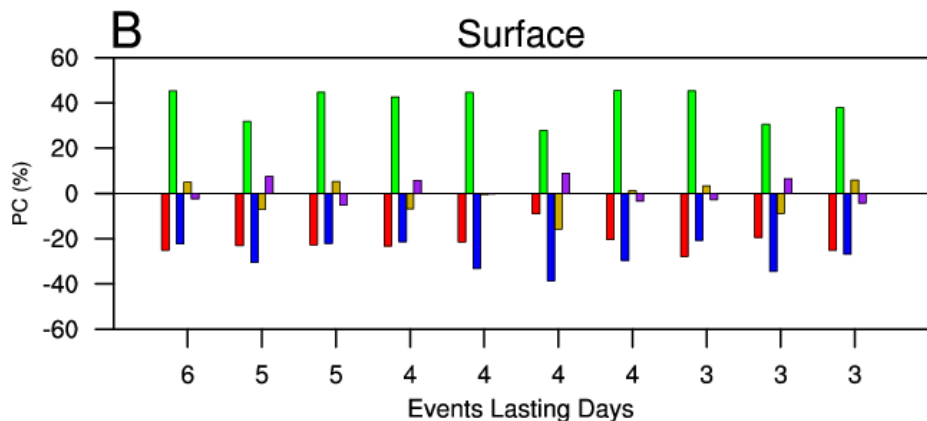
Vertical transports: -22.2%

Key processes contributing to severe ozone pollutions



For ozone from surface to 850hPa levels

- **Chemical production dominates (hotter and dryer)**
- **Horizontal transports** make negative contributions
- Vertical transports vary in different episodes



For ozone in the surface

- **Diffusion dominates**
- **Chemical production** makes negative contributions (**O₃ titration by NO_x**)
- **Horizontal transports** make negative contributions
- Vertical transports still vary

