Table S1. The WRF-CAMx model performance evaluation for temperature, wind speed and $O_3$ concentration

| Variable | MB | NMB | IOA | RMSE | Mean Obs | Mean Mod |
|---|---|---|---|---|---|---|
| 2-m Temp (°C) | 0.33 ($\leq \pm 0.50$) | 0.01 | 0.82($\geq$0.80) | 1.79 | 28.77 | 29.11 |
| 10-m Wspd (m/s) | -0.45($\leq \pm 0.50$) | 0.05 | 0.70($\geq$0.60) | 2.16($\leq \pm 2.0$) | 3.21 | 2.76 |
| $O_3$ (ppb) | 3.09 | 0.13($\leq$ 0.15) | 0.81 | 21.82 | 30.26 | 33.34 |

Temp is temperature. Wspd is wind speed. MB is mean bias. NMB is normalized mean bias. IOA is index of agreement. RMSE is root mean square error. Obs is observation. Mod is model.

Table S2. Contribution of pollutants from different source areas to the $O_3$ concentration over different sub-regions in different cases.

| Sub-region | Case | Source Area | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Local | GBAo | GDo | Neighbor | Other 1 | EC | SWC | NCP | Other 2 | Background |
| GF | Monthly | 17% | 15% | 15% | 16% | 15% | 3% | 1% | 1% | 1% | 17% |
| | Ep1 | 13% | 8% | 22% | 36% | 6% | 3% | 0% | 0% | 0% | 11% |
| | Ep2 | 26% | 33% | 8% | 6% | 18% | 0% | 0% | 0% | 0% | 9% |
| | Ep3 | 14% | 8% | 35% | 23% | 6% | 3% | 0% | 1% | 1% | 8% |
| | Ep4 | 13% | 13% | 17% | 18% | 10% | 8% | 1% | 5% | 3% | 13% |
| HK | Monthly | 5% | 10% | 11% | 17% | 27% | 3% | 1% | 1% | 1% | 23% |
| | Ep1 | 3% | 18% | 18% | 32% | 17% | 1% | 0% | 0% | 0% | 11% |
| | Ep2 | 12% | 8% | 7% | 10% | 47% | 0% | 0% | 0% | 0% | 14% |
| | Ep3 | 4% | 23% | 25% | 22% | 16% | 3% | 0% | 0% | 0% | 7% |
| | Ep4 | 4% | 11% | 11% | 18% | 23% | 9% | 1% | 4% | 3% | 15% |
| SD | Monthly | 17% | 12% | 10% | 15% | 20% | 3% | 1% | 1% | 1% | 19% |
| | Ep1 | 15% | 14% | 14% | 32% | 9% | 2% | 0% | 0% | 0% | 12% |
| | Ep2 | 31% | 16% | 7% | 7% | 27% | 0% | 0% | 0% | 0% | 10% |
| | Ep3 | 14% | 15% | 26% | 22% | 11% | 3% | 0% | 1% | 1% | 7% |
| | Ep4 | 16% | 11% | 11% | 16% | 16% | 9% | 1% | 4% | 3% | 13% |
| ZZJ | Monthly | 10% | 7% | 14% | 16% | 24% | 2% | 1% | 1% | 1% | 23% |
| | Ep1 | 11% | 12% | 27% | 35% | 20% | 0% | 0% | 0% | 0% | 14% |
| | Ep2 | 23% | 7% | 7% | 9% | 39% | 0% | 0% | 0% | 0% | 13% |
| | Ep3 | 9% | 14% | 38% | 24% | 11% | 3% | 0% | 0% | 1% | 11% |
| | Ep4 | 12% | 14% | 19% | 21% | 24% | 8% | 1% | 5% | 3% | 17% |

* Here, *GBAo* represents the area outside the sub-region but within the GBA. *GDo* represents areas outside the GBA but within Guangdong province. *Neighbor* represents the provinces around Guangdong province. *Other 1* represents ocean and other countries. *Other 2* represents other area within the mainland China in the simulation domain.

Table S3. Contribution of pollutants from different emitting periods to the $O_3$ concentration over the GBA and sub-regions in different cases.

| Sub-region | Case | Day-0 | Day-1 | Day-2 | Day-3 | >=Day-4 |
|---|---|---|---|---|---|---|
| GBA | Monthly | 31% | 25% | 17% | 10% | 18% |
|  | Ep1 | 28% | 35% | 21% | 10% | 7% |
|  | Ep2 | 37% | 30% | 10% | 4% | 18% |
|  | Ep3 | 24% | 34% | 19% | 7% | 16% |
|  | Ep4 | 20% | 25% | 19% | 12% | 24% |
| GF | Monthly | 37% | 24% | 15% | 9% | 15% |
|  | Ep1 | 30% | 33% | 19% | 10% | 7% |
|  | Ep2 | 43% | 32% | 9% | 4% | 12% |
|  | Ep3 | 28% | 31% | 19% | 7% | 15% |
|  | Ep4 | 24% | 25% | 18% | 11% | 22% |
| HK | Monthly | 25% | 24% | 19% | 12% | 21% |
|  | Ep1 | 32% | 37% | 18% | 8% | 5% |
|  | Ep2 | 35% | 14% | 10% | 5% | 37% |
|  | Ep3 | 28% | 32% | 17% | 7% | 16% |
|  | Ep4 | 19% | 22% | 19% | 13% | 28% |
| SD | Monthly | 36% | 22% | 15% | 9% | 18% |
|  | Ep1 | 37% | 33% | 19% | 8% | 4% |
|  | Ep2 | 48% | 20% | 8% | 4% | 19% |
|  | Ep3 | 28% | 30% | 17% | 7% | 17% |
|  | Ep4 | 25% | 22% | 18% | 11% | 24% |
| ZZJ | Monthly | 27% | 25% | 19% | 11% | 19% |
|  | Ep1 | 28% | 34% | 21% | 11% | 6% |
|  | Ep2 | 40% | 18% | 9% | 4% | 29% |
|  | Ep3 | 27% | 35% | 18% | 7% | 14% |
|  | Ep4 | 22% | 24% | 18% | 11% | 25% |

Table S4. The setting of the zero-out sensitivity experiment for typhoon case.

| Sensitivity Experiment | Jul-04 | Jul-05 | Jul-06 | Jul-07 | Jul-08 | Jul-09 | Jul-10 |
|---|---|---|---|---|---|---|---|
| Day-0 |  |  |  | × | ✓ | ⊠ | ☑ |
| Day-1 to Day-0 |  |  | × | × ✓ | ✓ ⊠ | ⊠ ☑ | ⊠ ☑ |
| Day-2 to Day-0 |  | × | × ✓ | × ✓ ⊠ | ✓ ⊠ ☑ | ⊠ ☑ | ⊠ ☑ |
| Day-3 to Day-0 | × | × ✓ | × ✓ ⊠ | × ✓ ⊠ ☑ | ✓ ⊠ ☑ | ⊠ ☑ | ⊠ ☑ |

Here, the symbols (×✓⊠☑) represent a series of zero-out sensitivity experiments for the target date (7th,8th,9th, and 10th July, respectively). For each target date, four source time control simulations were conducted, including only control emission on the current day (Day-0), continuous emission control from 1day ago (Day-1 to Day0), continuous emission control from 2days ago (Day-2 to Day0), and continuous emission control from 3days ago (Day-3 to Day0).Three types of source area control were set, including only control emission within the GBA region, control emission within Guangdong province, and control emission from Guangdong and neighboring provinces. All source time control experiments were conducted for each type of source area control. In the zero-out simulations, the emission of $NO_x$ and VOCs of the control time and area were set to 0.

Table S5. The setting of the zero-out sensitivity experiment for sub-tropical high case.

| Sensitivity Experiment | Jul-21 | Jul-22 | Jul-23 | Jul-24 | Jul-25 | Jul-26 |
|---|---|---|---|---|---|---|
| Day-0 | | | | × | ✓ | ⊠ |
| Day-1 to Day-0 | | | × | × ✓ | ✓ ⊠ | ⊠ |
| Day-2 to Day-0 | | × | × ✓ | × ✓ ⊠ | ✓ ⊠ | ⊠ |
| Day-3 to Day-0 | × | × ✓ | × ✓ ⊠ | × ✓ ⊠ | ✓ ⊠ | ⊠ |

Same as Table S4, but the symbols (×✓⊠) represent a series of sensitivity experiments for the target date (24th,25th, and 26th July, respectively).

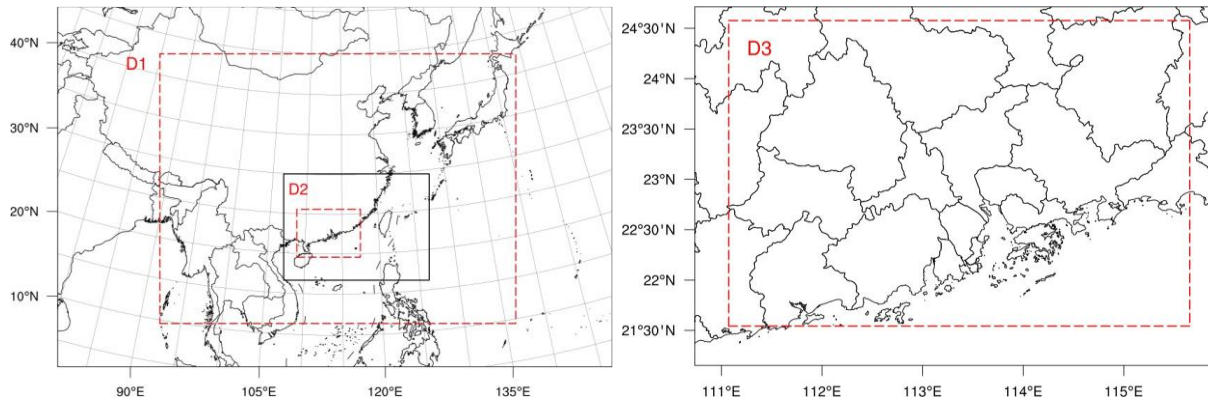



Figure S1. The three nested simulation domain setting of WRF (solid black line)-CAMx (red dash line) models

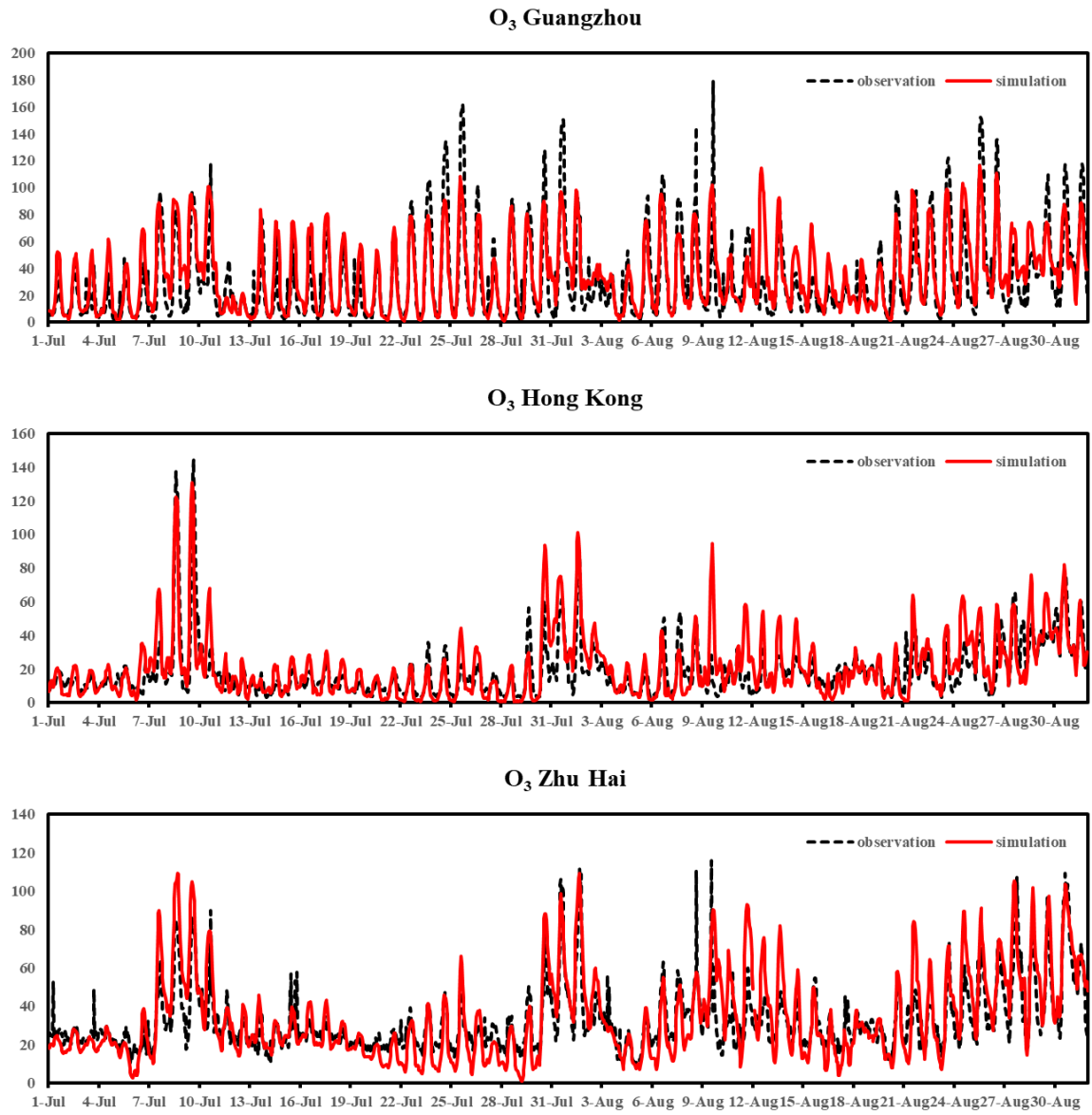



Figure S2. Time series comparison of observed and simulated average O₃ concentration in Guangzhou, Hong Kong, and Zhuhai cities.

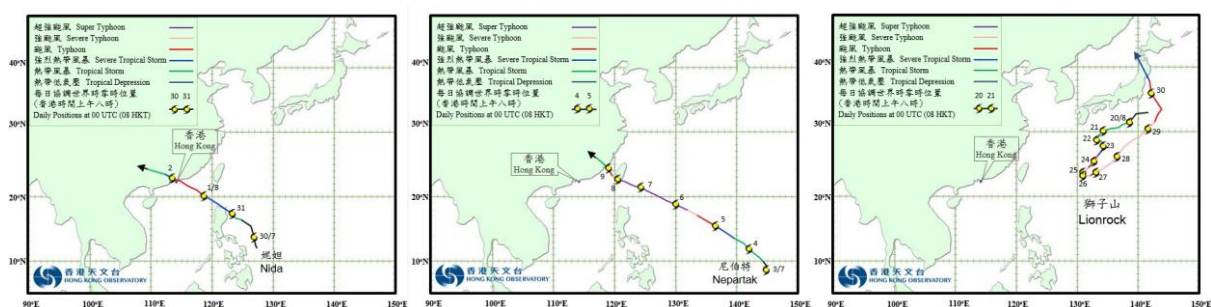



Figure S3. The moving paths of typhoons during the Ep1, Ep3 and Ep4 O$_3$ episodic cases. (The figures were downloaded from the Hong Kong Observatory; https://www.hko.gov.hk/en/publica/pubtc.htm)

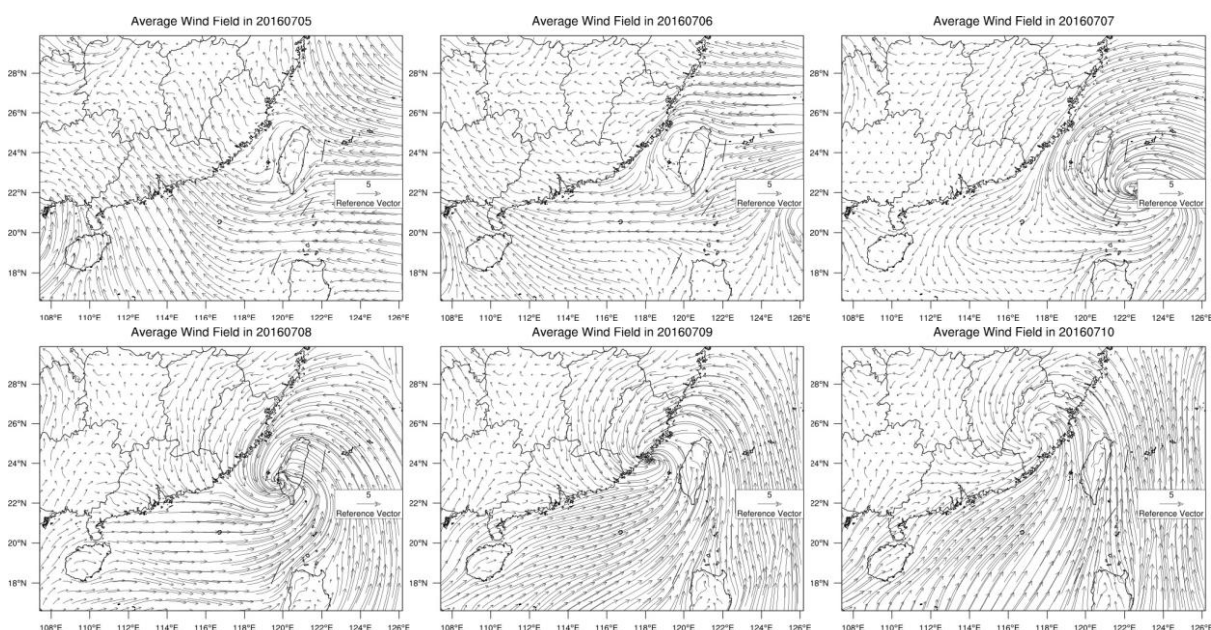



Figure S4. The daily average of 10-m wind field between 5th - 10th July.

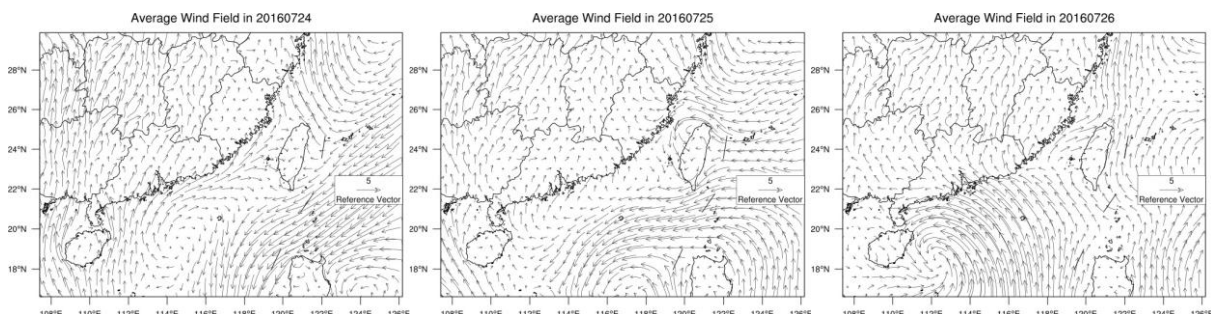



Figure S5. The daily average of 10-m wind field between 24th - 26th July.

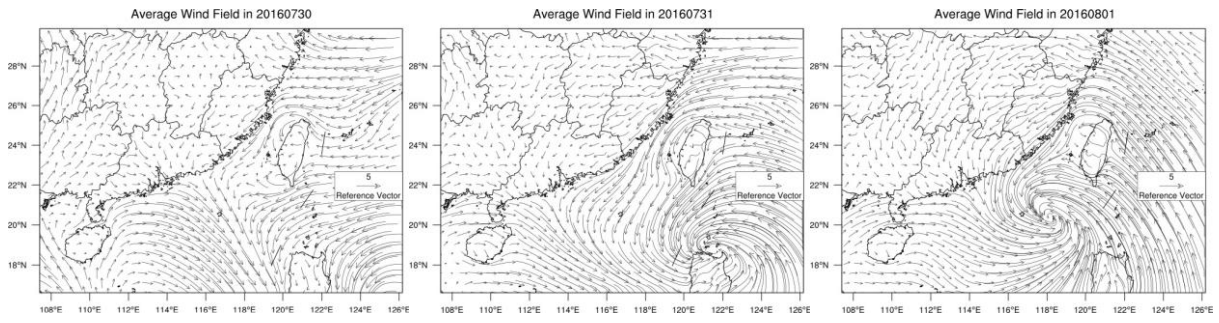



Figure S6. The daily average of 10-m wind field between 30<sup>th</sup> July – 1<sup>st</sup> August.

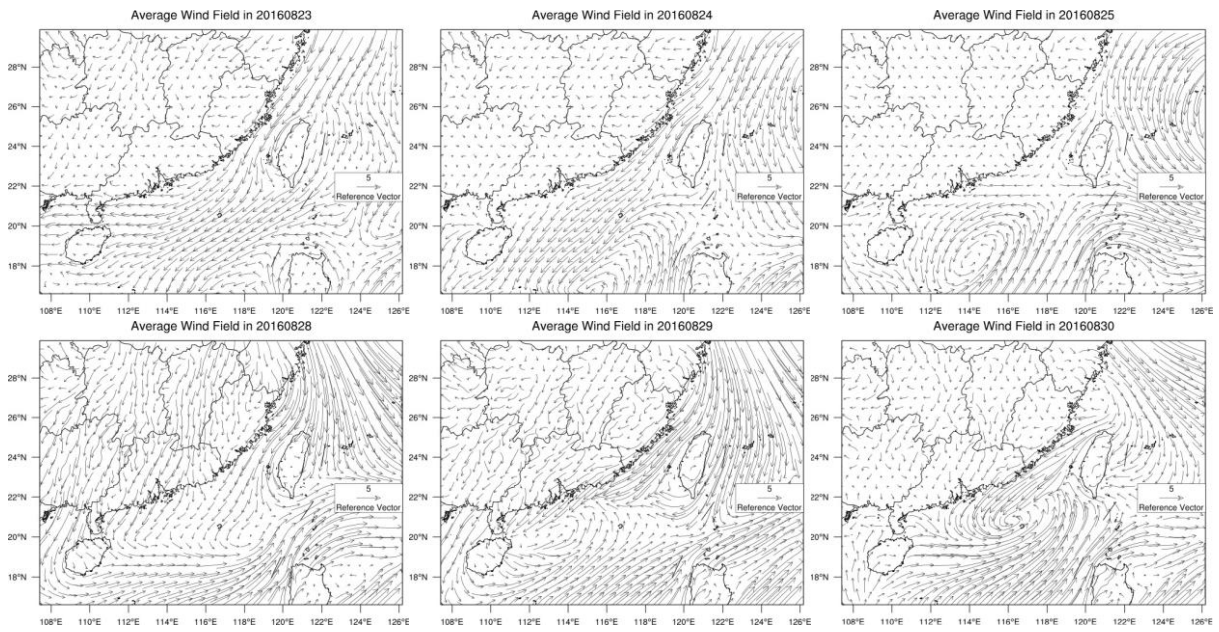
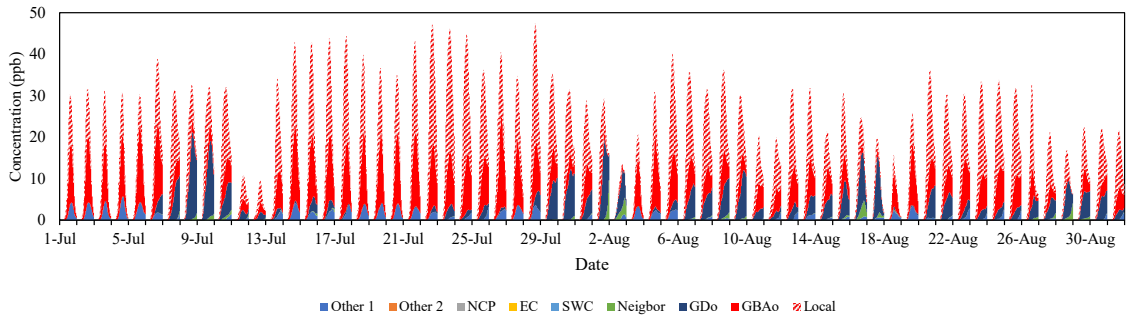
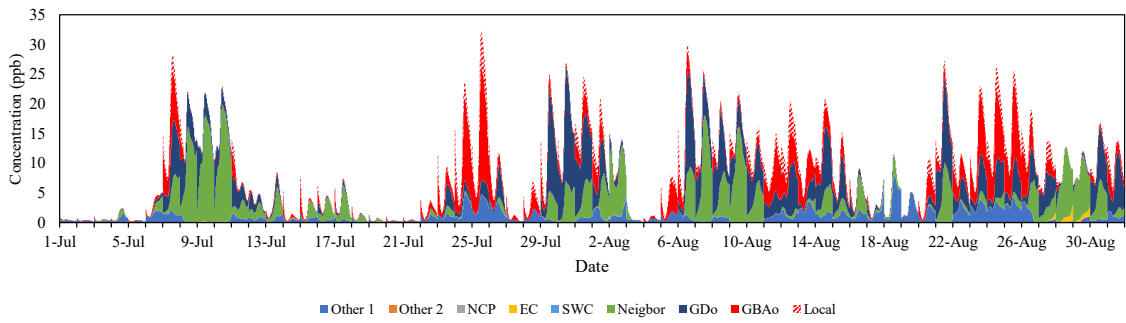
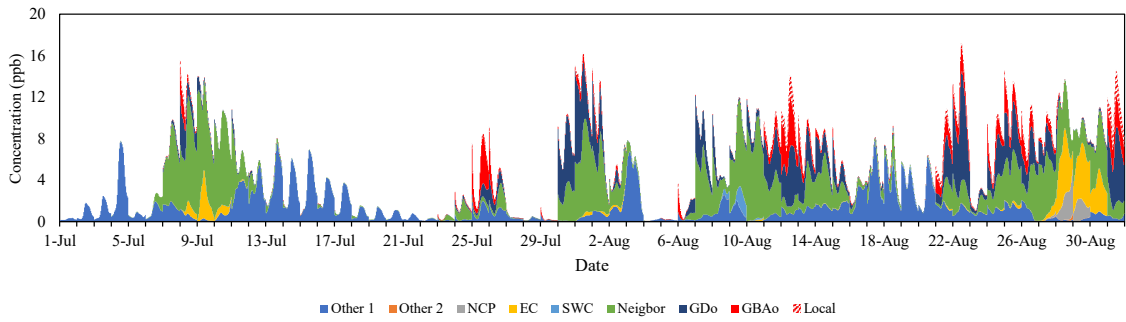
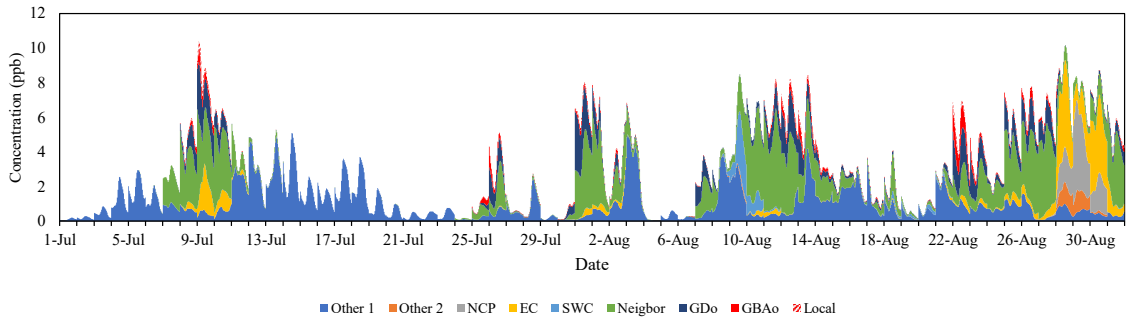
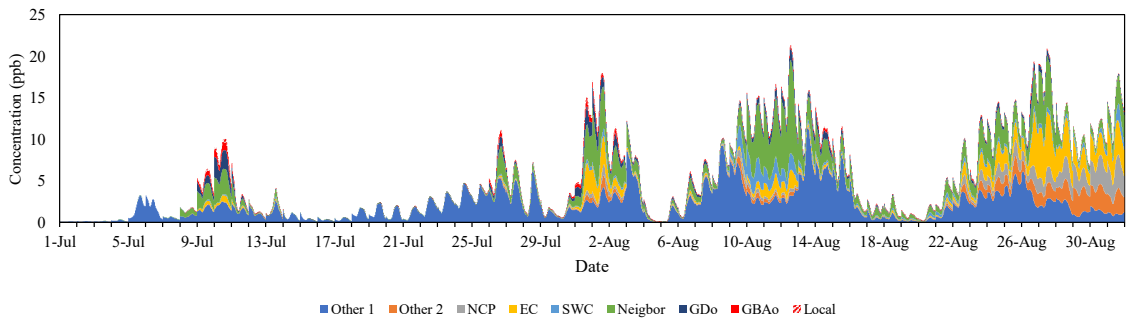
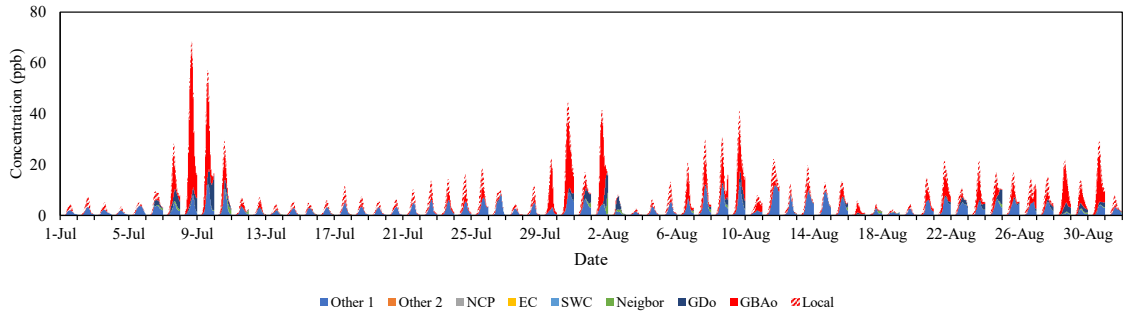
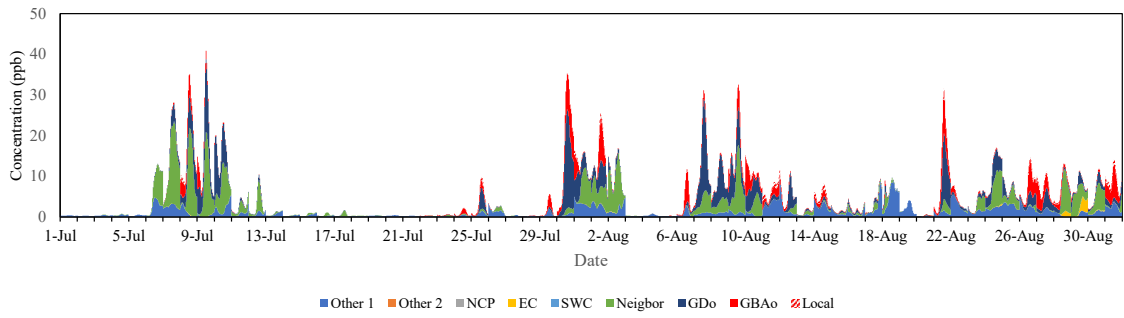
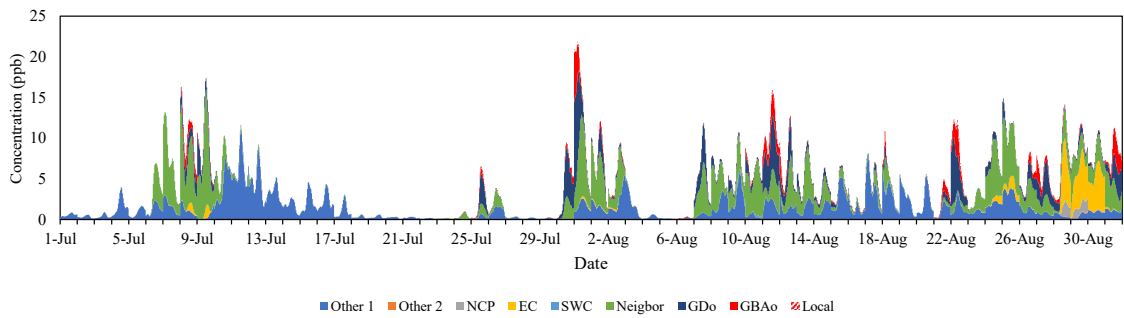
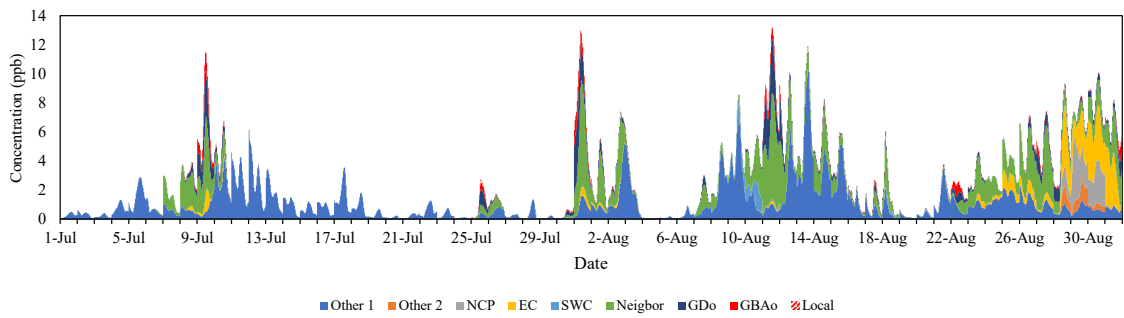



Figure S7. The daily average of 10-m wind field for 23<sup>rd</sup> – 25<sup>th</sup> August and 28<sup>th</sup> – 30<sup>th</sup> August.

Contribution of Day-0 emission to O$_3$ in the GF region

Contribution of Day-1 emission to O$_3$ in the GF region

Contribution of Day-2 emission to O$_3$ in the GF region

Contribution of Day-3 emission to O$_3$ in the GF region

Contribution of Day-4 emission to O$_3$ in the GF region

## Contribution of Day-0 emission to O$_3$ in the HK

## Contribution of Day-1 emission to O$_3$ in the HK

## Contribution of Day-2 emission to O$_3$ in the HK

## Contribution of Day-3 emission to O$_3$ in the HK

## Contribution of Day-4 emission to O3 in the HK

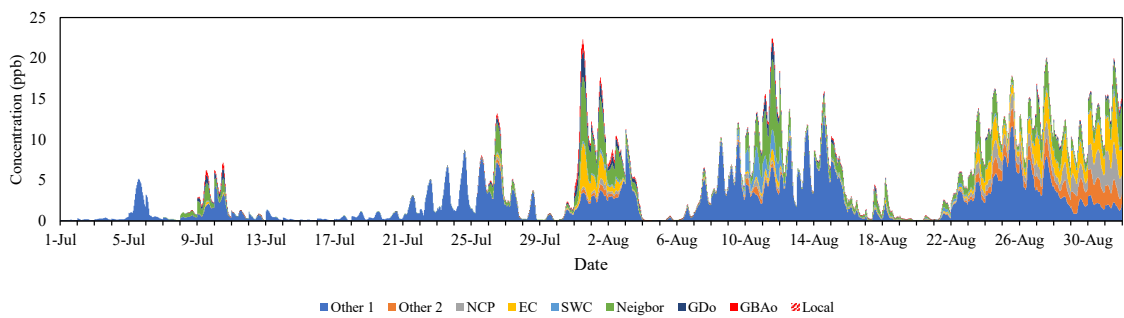



Figure S8. Time series of contributions from different source areas and emitting periods to the $O_3$ concentrations over the GF region and HK city. (*GBAo* represent the area outside the target region but within the GBA. *GDo* represents areas outside the GBA but within Guangdong province. *Neighbor* represents the provinces around Guangdong province. *Other 1* represents ocean and other countries. *Other 2* represents other area within the mainland China in the simulation domain.)

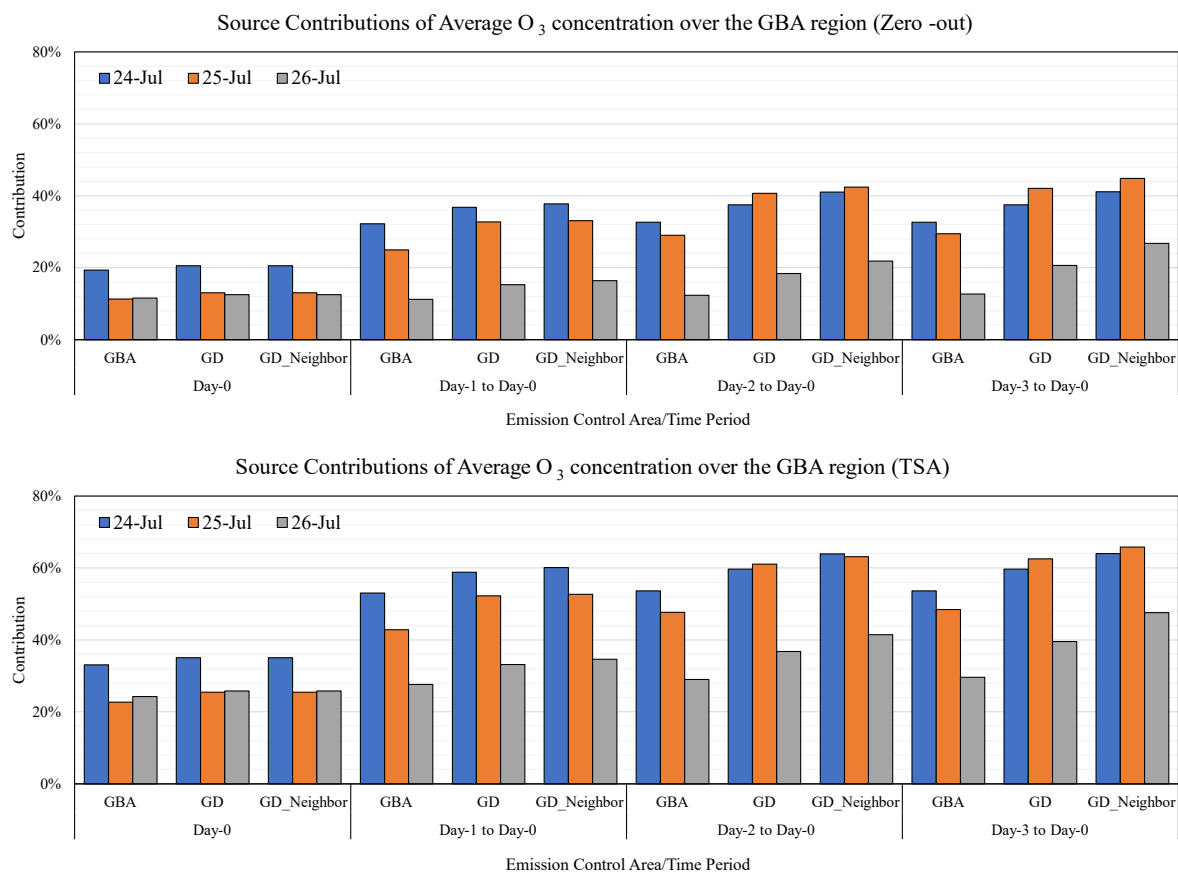



Figure S9. The contribution of different source areas and time periods to the $O_3$ concentration over the GBA in the sub-tropical high case using the zero-out and TSA methods. (Different colors represent different target dates; Upper: Zero-out; Bottom: TSA)

# References

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