atmosphere

Supplementary Materials: Understanding Temporal Patterns and Determinants of Ground-Level Ozone

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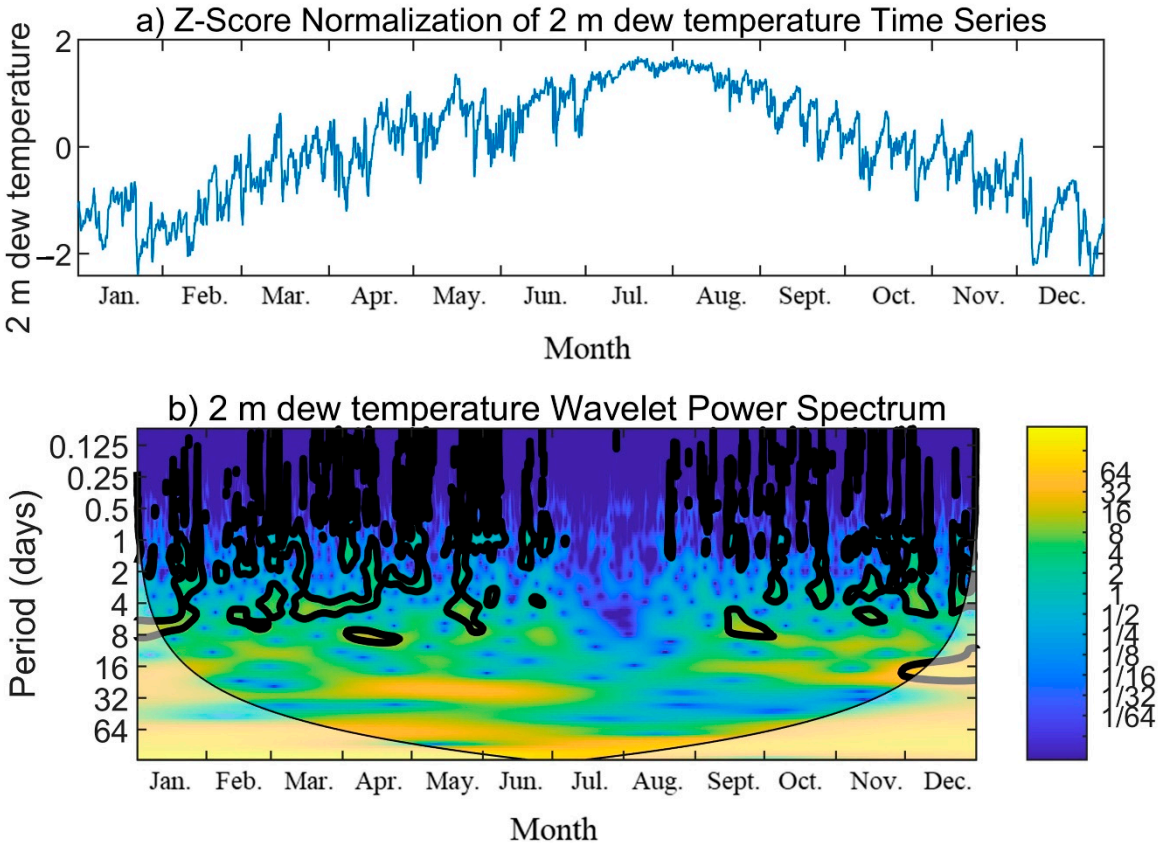

Figure S1. Z-Score normalization time series **(a)** and wavelet power spectrum **(b)** of 2m dew temperature. Line charts represent Z-Score normalization time series for each factor. In the wavelet power spectrum, the left axis is the period, the right axis represents periodic intensity and the bottom axis is time. The thick contour enclosed regions of greater than 95% confidence for a red-noise process and thick curve is cone of influence (COI).

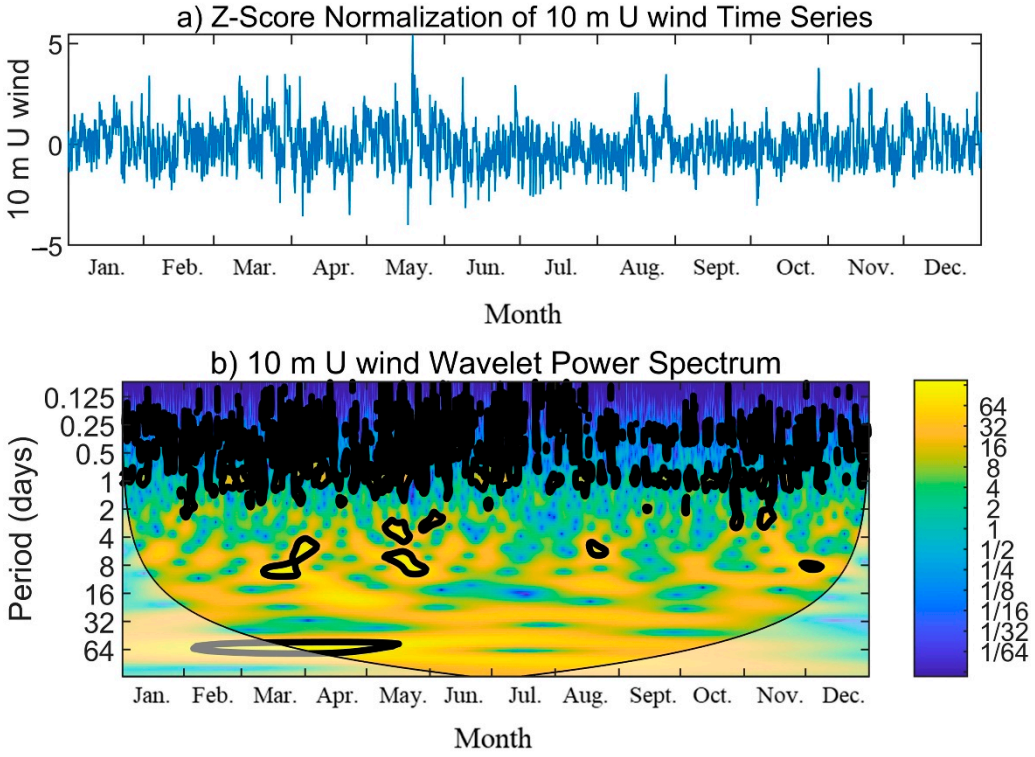

Figure S2. Z-Score normalization time series **(a)** and wavelet power spectrum **(b)** of 10m u-component of wind (10 m U wind). The illustration of figure is the same as Figure S1.

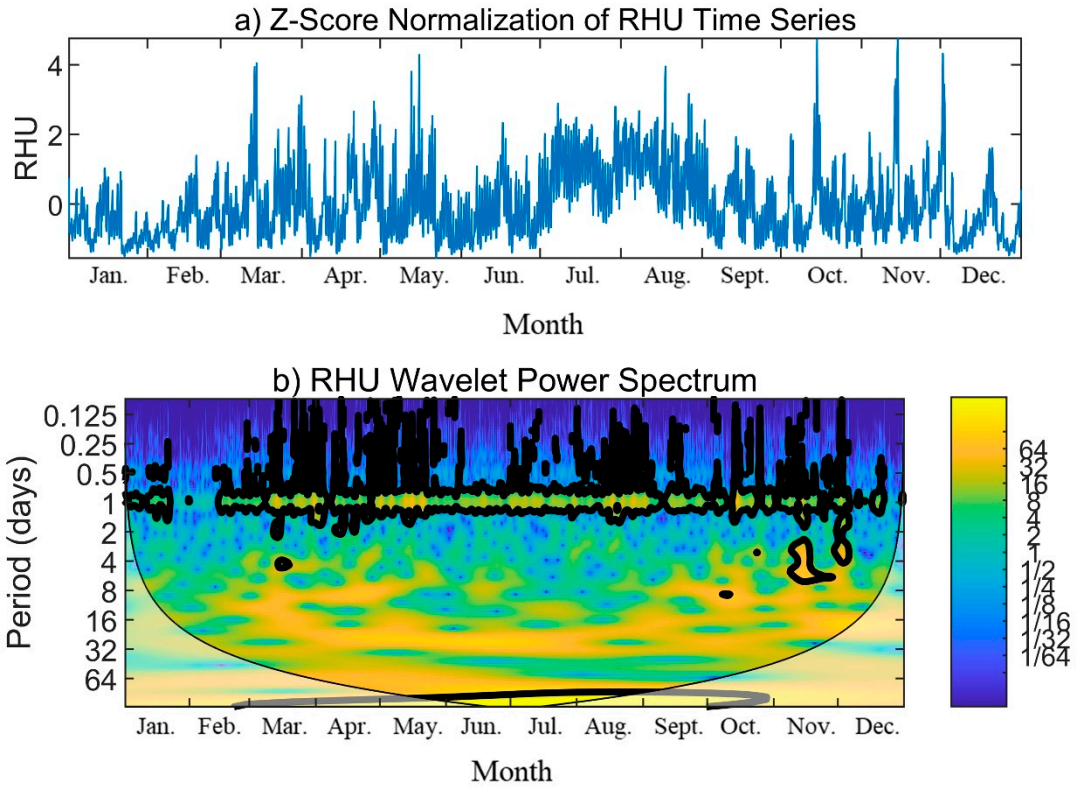

Figure S3. Z-Score normalization time series **(a)** and wavelet power spectrum **(b)** of relative humidity(RHU).The illustration of figure is the same as Figure S1.

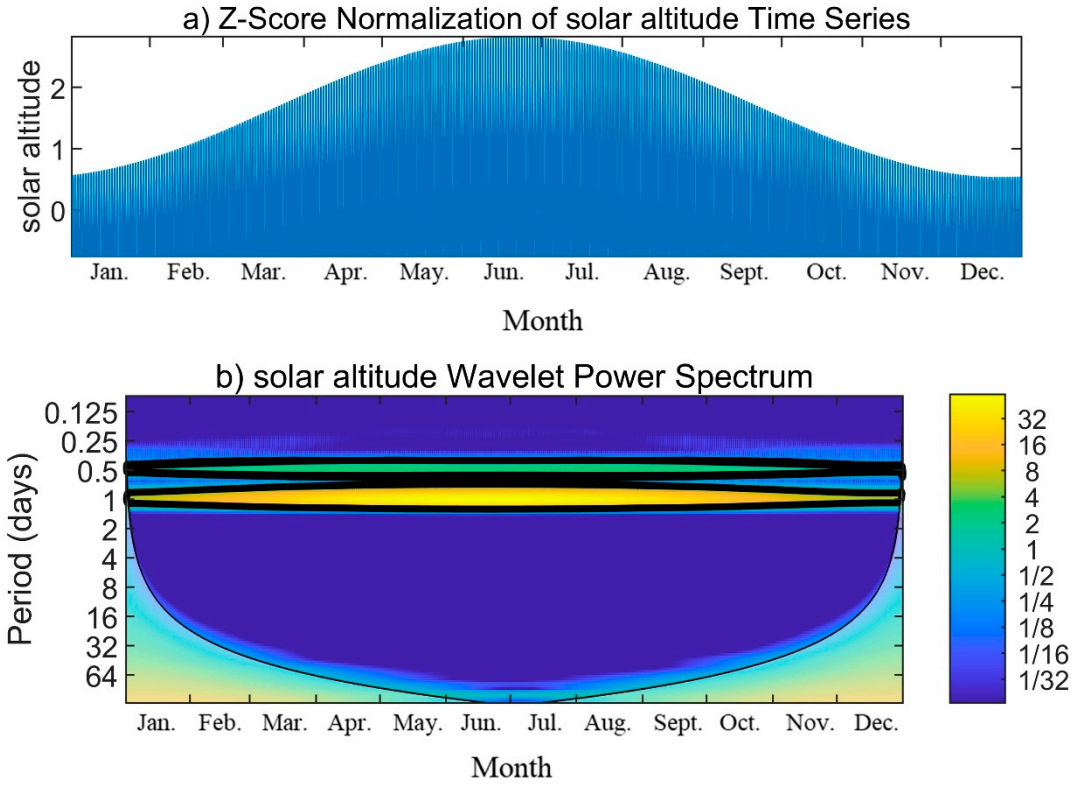

Figure S4. Z-Score normalization time series **(a)** and wavelet power spectrum **(b)** of solar altitude. The illustration of figure is the same as Figure S1.

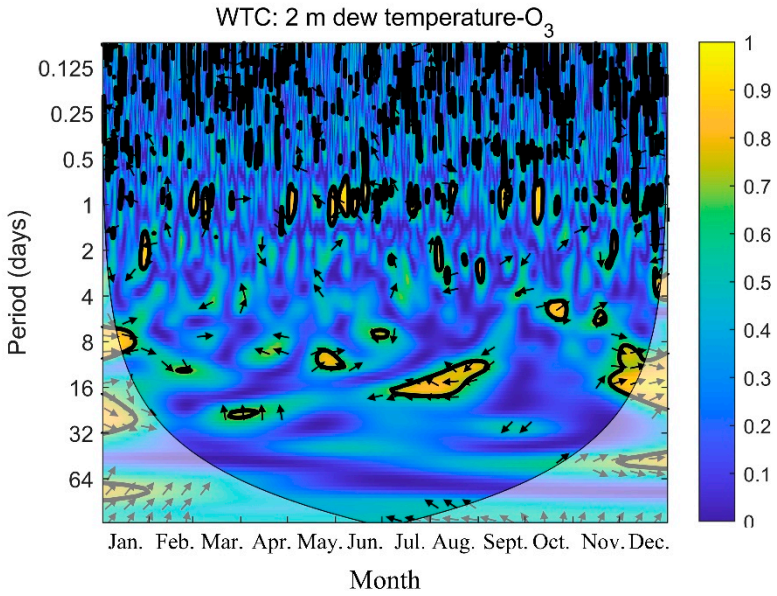

Figure S5. Wavelet coherence spectrum (WTC) of 2m dew temperature and O_3. The left axis is the period, the right axis represents consistency of changing trends, the bottom axis is time. The area surrounded by the thick black solid line indicates the area that passes the 95% red noise confidence test, and the black solid line envelope is the conical influence domain; the relative phase relationship is shown by the arrows (in-phase points to the right, anti-phase points to the left, NO_2 leads O_3 1/4 period when points straight up).

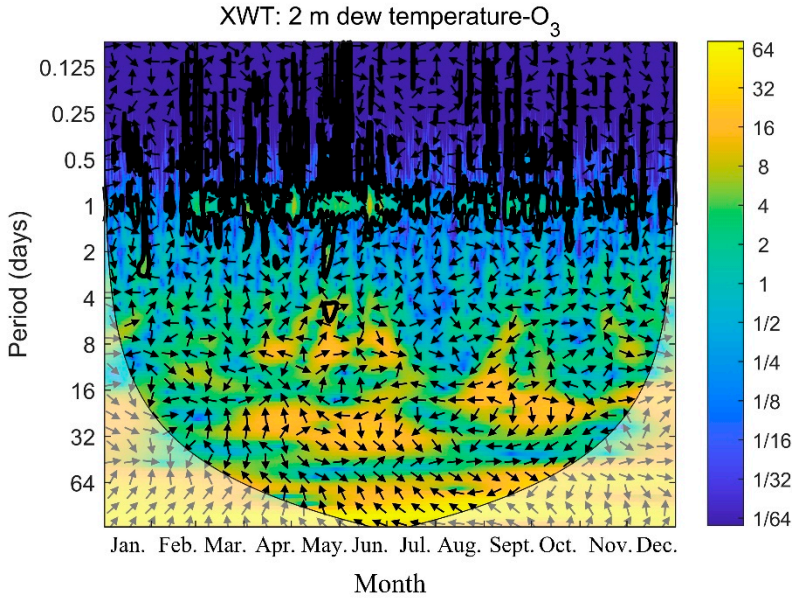

Figure S6. Crossed wavelet spectrum (XWT) of 2m dew temperature and O_3. The left axis is the period, the right axis represents intensity of common period, the bottom axis is time. The area surrounded by the thick black solid line indicates the area that passes the 95% red noise confidence test, and the black solid line envelope is the conical influence domain; the relative phase relationship is shown by the arrows (in-phase points to the right, anti-phase points to the left, NO_2 leads O_3 1/4 period when points straight up).

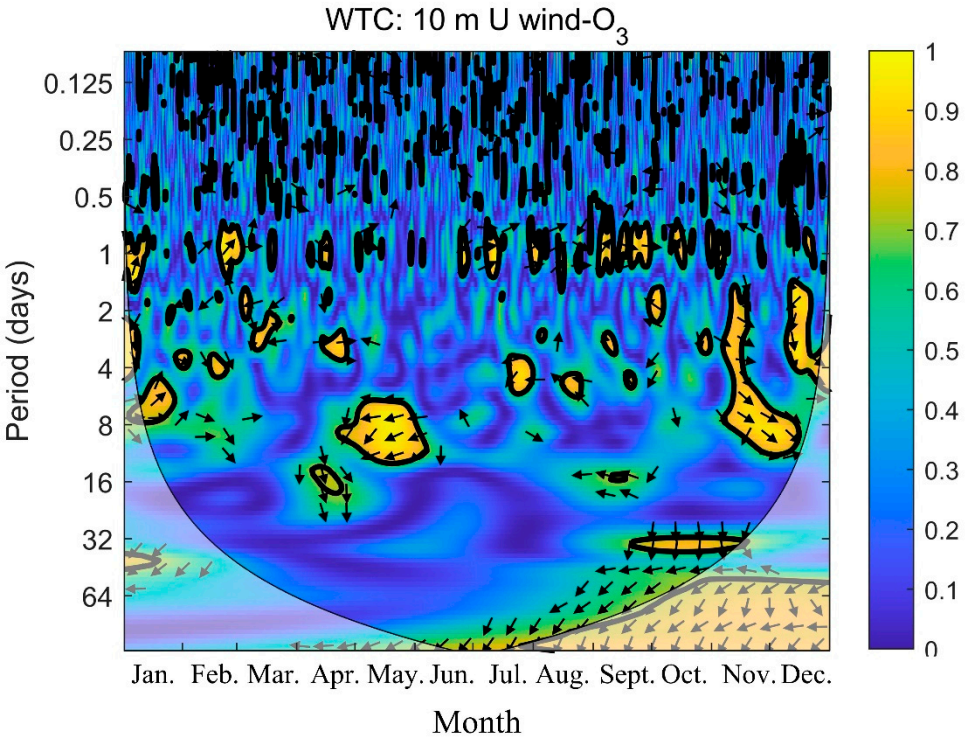

Figure S7. Wavelet coherence spectrum (WTC) of 10m u-component of wind(10m U wind) and O_3. The illustration of figure is the same as Figure S6.

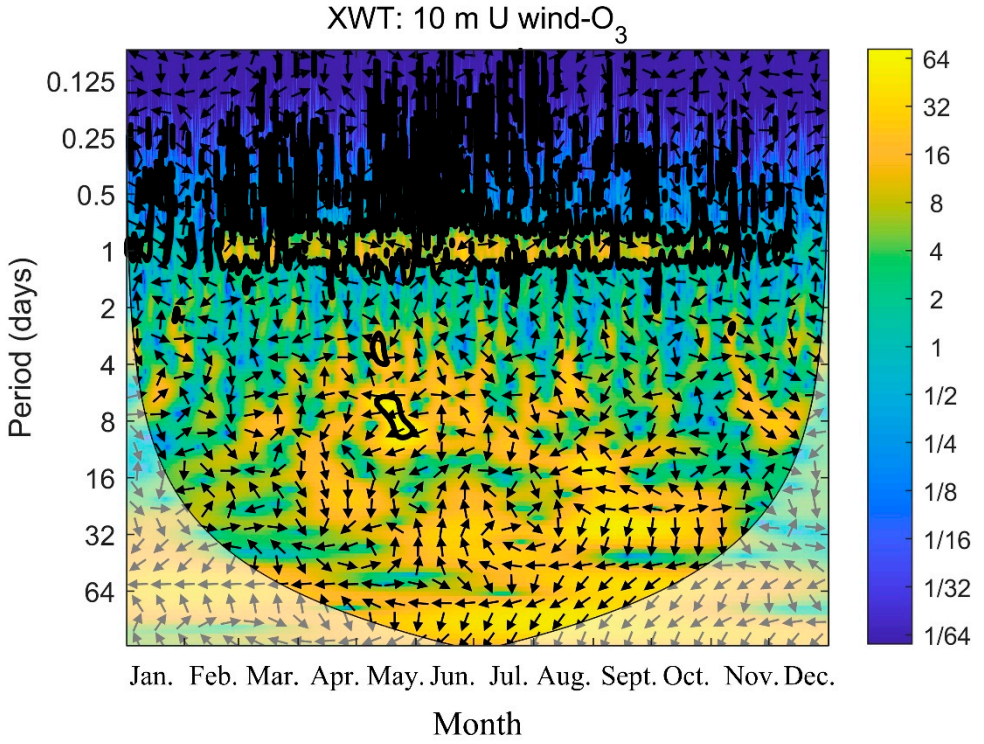

Figure S8. Crossed wavelet spectrum (XWT) of 10m u-component of wind (10m U wind) and O_3. The illustration of figure is the same as Figure S7.

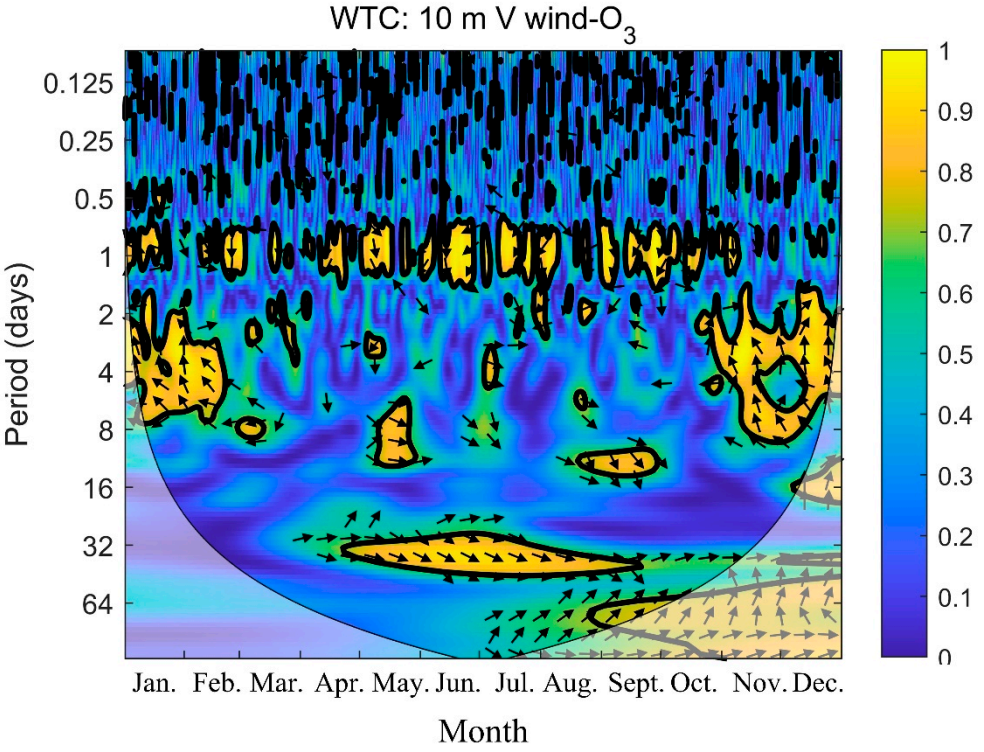

Figure S9. Wavelet coherence spectrum (WTC) of 10m v-component of wind (10m V wind) and O_3. The illustration of figure is the same as Figure S6.

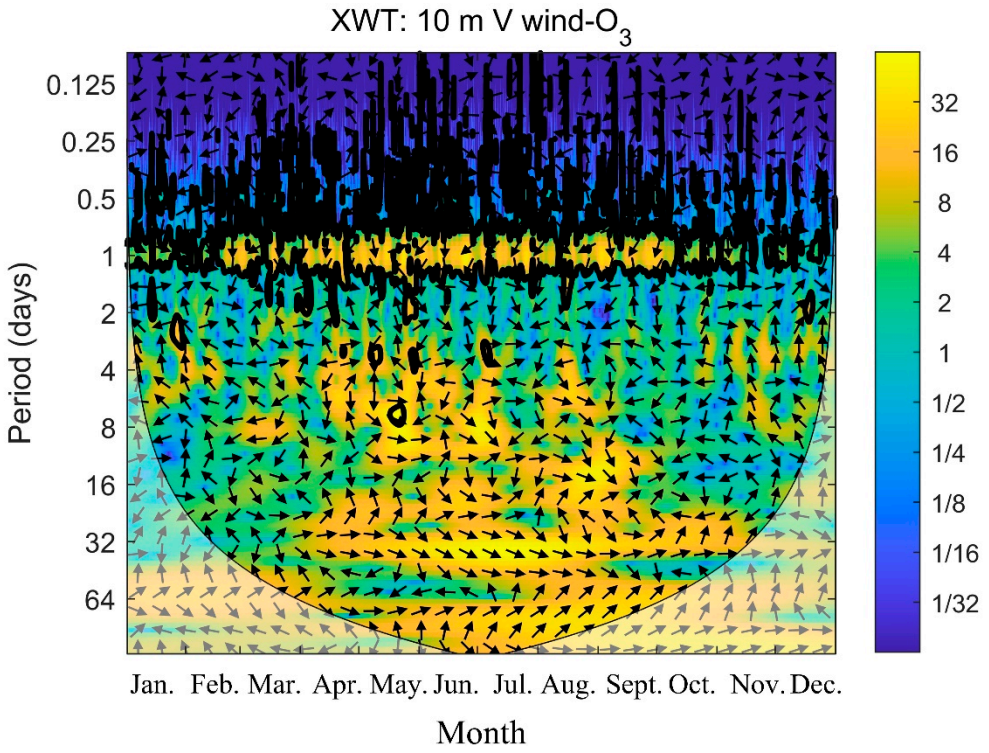

Figure S10. Crossed wavelet spectrum (XWT) of 10m v-component of wind(10m V wind) and O_3. The illustration of figure is the same as Figure S7.

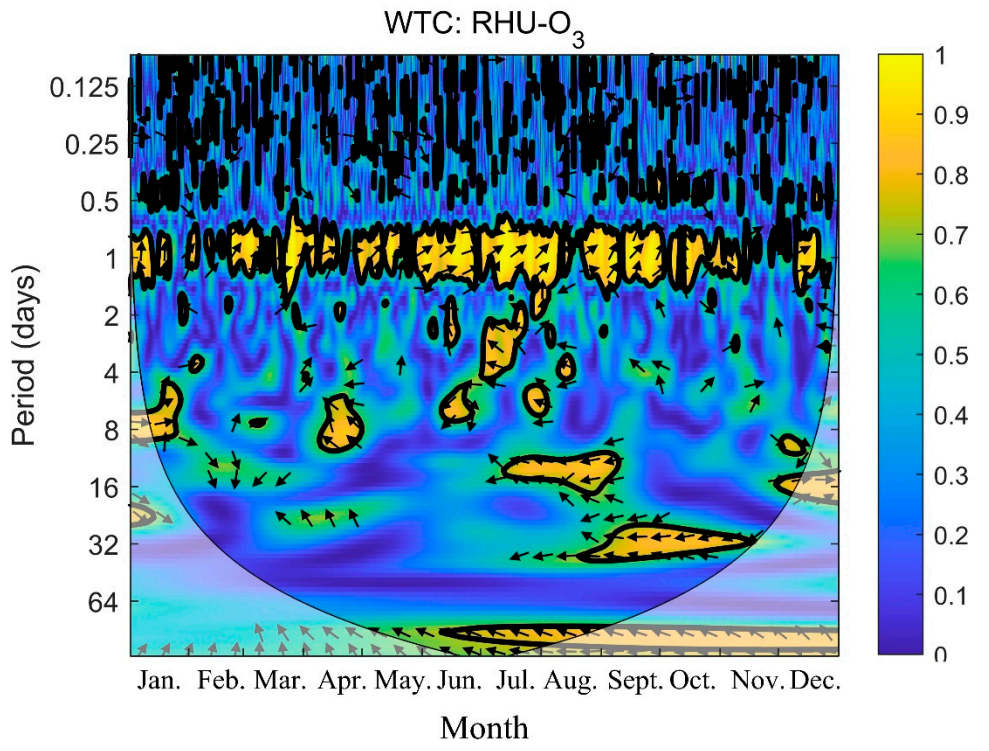

Figure S11. Wavelet coherence spectrum (WTC) of relative humidity (RHU) and ozone(O_3). The illustration of figure is the same as Figure S6.

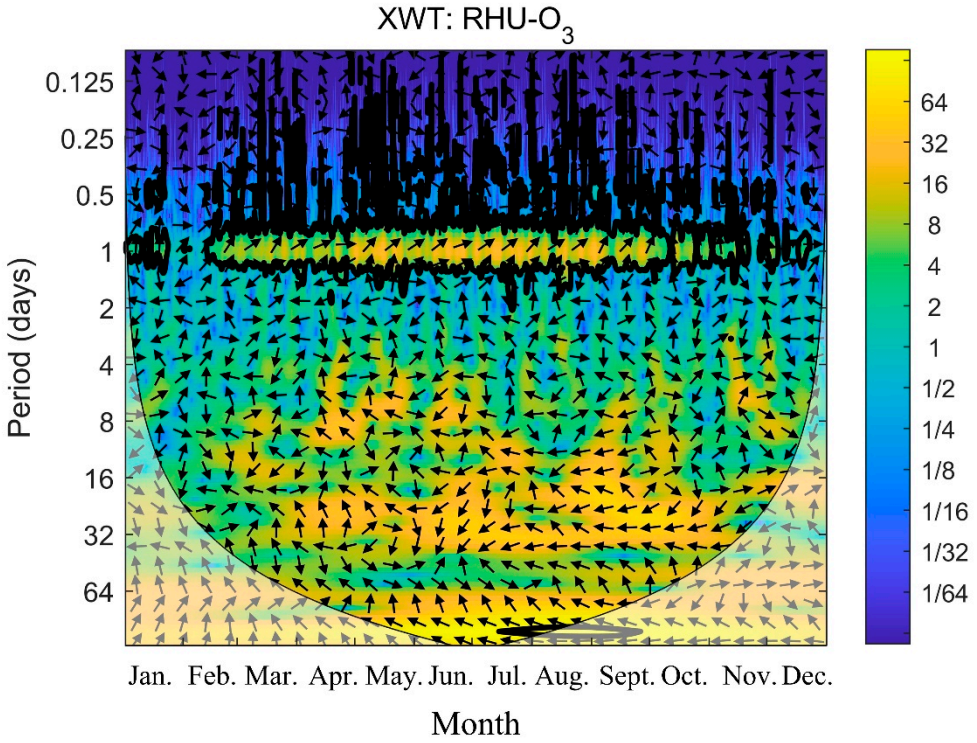

Figure S12. Crossed wavelet spectrum (XWT) of relative humidity (RHU) and ozone(O_3). The illustration of figure is the same as Figure S7.

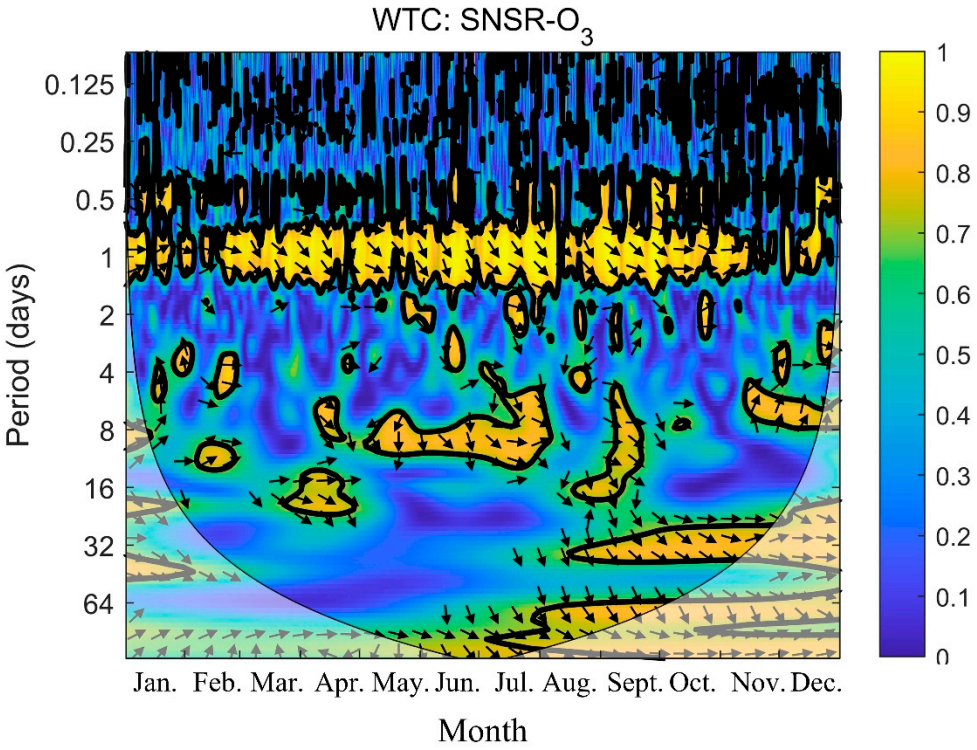

Figure S13. Wavelet coherence spectrum (WTC) of surface net solar radiation(SNSR) and ozone(O_3). The illustration of figure is the same as Figure S6.

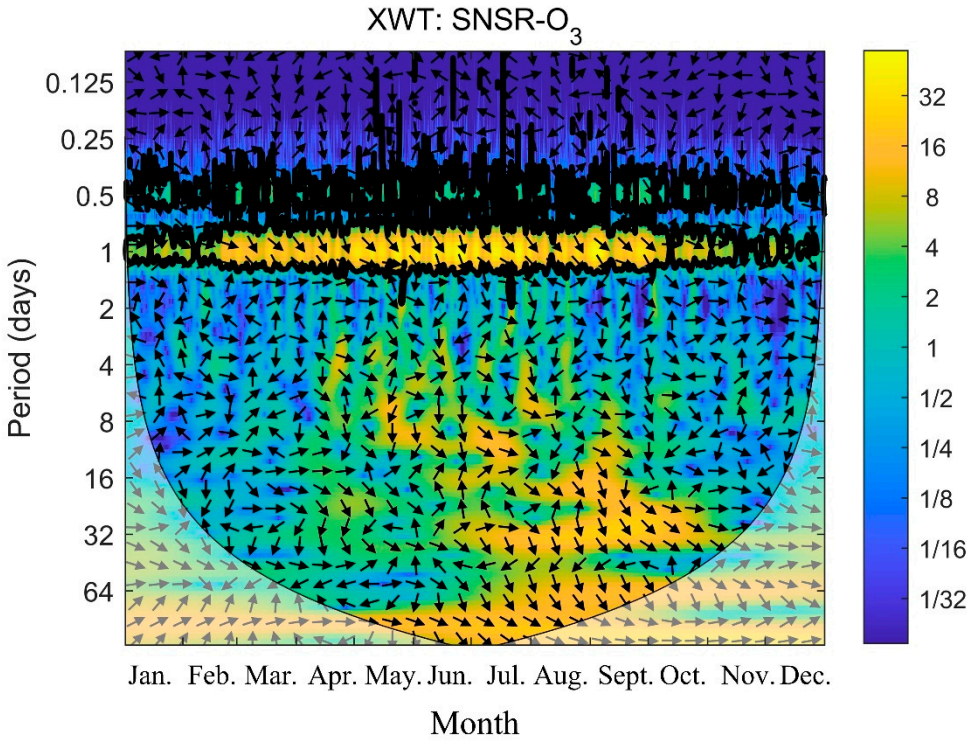

Figure S14. Crossed wavelet spectrum (XWT) of surface net solar radiation(SNSR) and ozone(O_3). The illustration of figure is the same as Figure S7.

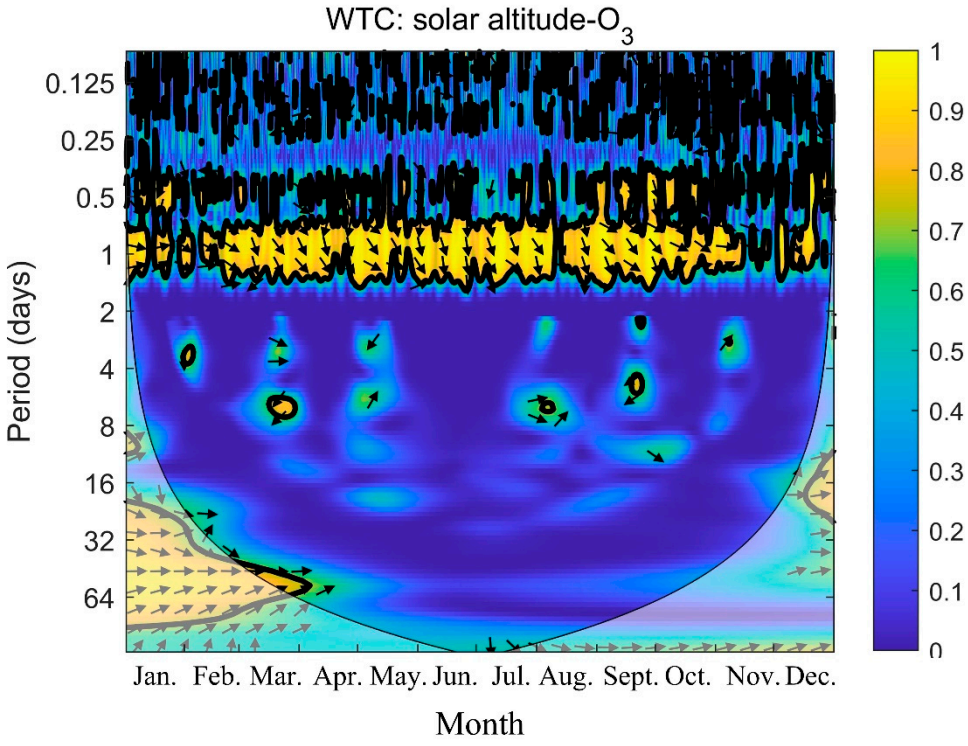

Figure S15. Wavelet coherence spectrum (WTC) of solar altitude and ozone(O_3). The illustration of figure is the same as Figure S6.

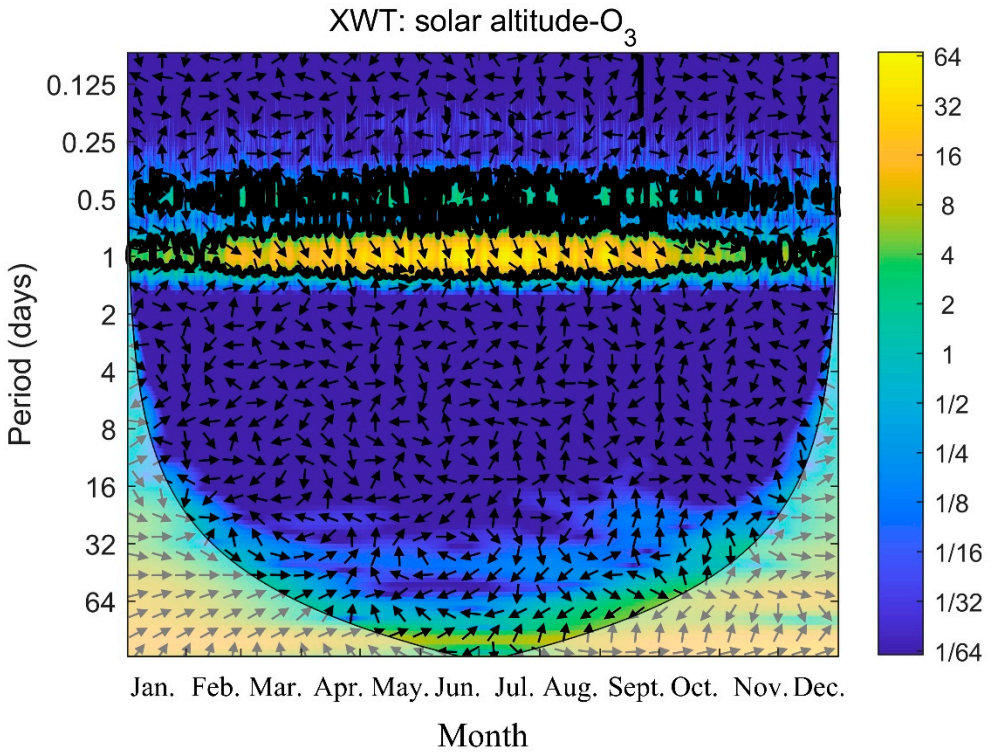

Figure S16. Crossed wavelet spectrum (XWT) of solar altitude and ozone(O_3). The illustration of figure is the same as Figure S7.

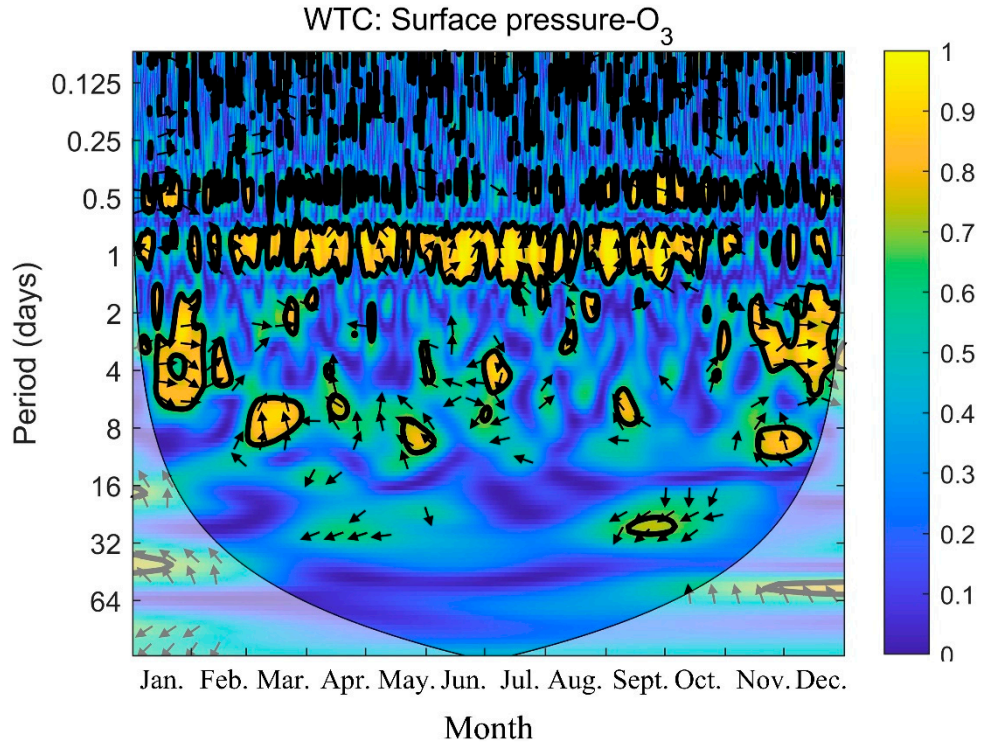

Figure S17. Wavelet coherence spectrum (WTC) of surface pressure and ozone(O_3). The illustration of figure is the same as Figure S6.

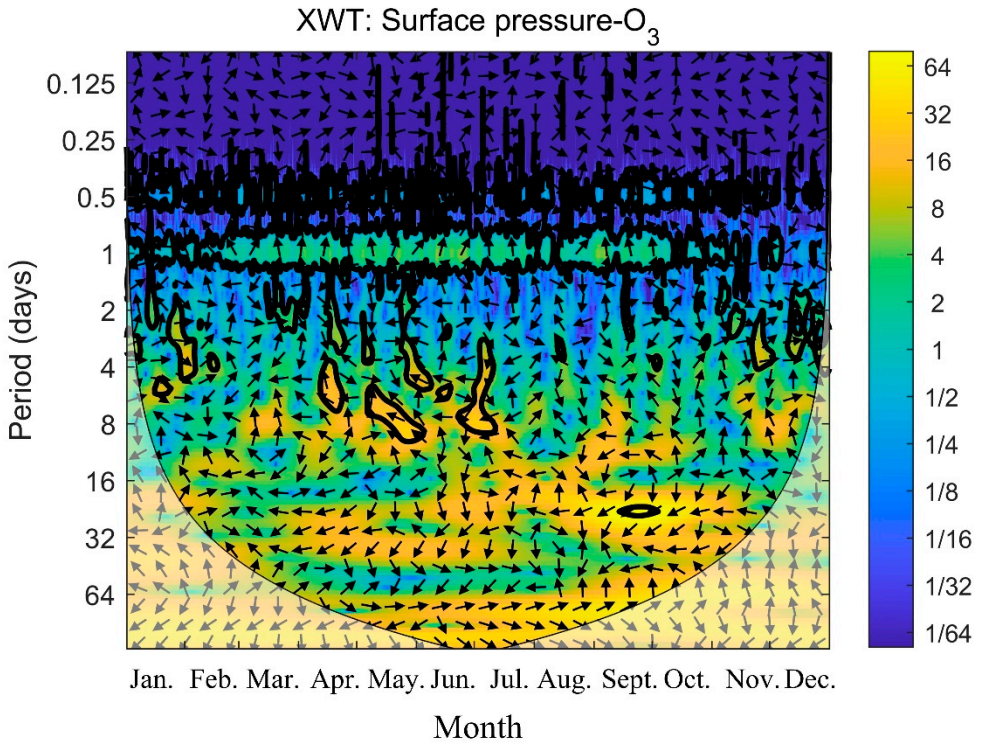

Figure S18. Crossed wavelet spectrum (XWT) of surface pressure and ozone(O_3). The illustration of figure is the same as Figure S7.

Table S1. Parameters from ERA5 land reanalysis data and observation stations.

ID	Name	Description	Units
1	Ozone(O_3)	Observation of ground-level ozone concentrations	$\mu g/m^3$
2	Nitrogen dioxide (NO_2)	Observation of ground-level NO_2 concentrations	$\mu g/m^3$
3	2m temperature	Temperature of air at 2 meters above the surface of land, sea or in-land waters.	K
4	10m u-component of wind	Eastward component of the wind at 10 meters above the surface.	$m \cdot s^{-1}$
5	10m v-component of wind	Northward component of the wind at 10 meters above the surface.	$m \cdot s^{-1}$
6	Surface net solar radiation	Amount of solar radiation reaching the surface of the Earth minus the amount reflected by the Earth's surface.	$J \cdot m^{-2}$
7	Surface pressure	Pressure (force per unit area) of the atmosphere on the surface of land, sea and in-land water.	Pa
8	2m dewpoint temperature	Temperature to which the air, at 2 meters above the surface of the Earth, would have to be cooled for saturation to occur.	K
9	Relative humidity	The percentage of water vapor pressure in the air to the saturated water vapor pressure at the same temperature.	Dimensionless
10	solar altitude	The Angle between the incoming direction of sunlight and the ground plane at a place on the earth	Degree

Note. 1,2 were from Shunyi station (40.1269° N, 116.655° E) in Beijing. 3–8 were from ERA5 land reanalysis data (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era5, accessed on 18 July 2021). 9,10 were calculated by researchers.

Table S2. Number and percentage of missing gaps for air pollutants and meteorological data.

Missing Gaps	Ozone	NO2	All Meteorological Variables
1	98(63.23%)	85(68.00%)	—
2	23(14.84)	18(14.00%)	—
3	10(6.45%)	5(4.00%)	—
4	5(3.23%)	1(0.80%)	—
5	2(1.29%)	2(1.60%)	—
>5	17(10.97%)	14(11.20%)	—

Note. The time series of all meteorological variables did not have missing values.

Table S3. The periods and phase relationship of influencing factors and ozone.

Month		NO_2	2m temperature	10m V-wind component	10m U-wind component	Relative Humidity	2m dewpoint temperature	Surface net solar radiation	Solar altitude	Surface pressure
January	period	0.25-8d	uncertain	2-8d	uncertain	uncertain	uncertain	uncertain	uncertain	2-6d
	phase	anti-phase		1/4 cycle ahead						in-phase
February	period	0.25-8d	uncertain	2-8d	uncertain	uncertain	uncertain	uncertain	uncertain	uncertain
	phase	anti-phase		1/4 cycle ahead						
March	period	0.25-8d	22-26h;6d	uncertain	uncertain	1d	uncertain	22-26h	22-26h	8d
	phase	anti-phase	in-phase			1/8 cycle ahead		in-phase	1/8 cycle behind	1/4 cycle ahead
April	period	0.25-8d	22-26h;6-10d;32-48d	uncertain	uncertain	1d	uncertain	22-26h;16d	22-26h	22-26h
	phase	anti-phase	in-phase			1/8 cycle ahead		in-phase	1/8 cycle behind	1/4 cycle ahead

May	period	uncertain	22-26h;6-10d;32-48d	32d	8d	1d	uncertain	22-26h;8d	22-26h	22-26h
	phase		in-phase	in-phase	anti-phase	1/8 cycle ahead		in-phase	1/8 cycle behind	1/4 cycle ahead
June	period	uncertain	22-26h;6-10d;32-48d	32d	uncertain	1d	uncertain	22-26h;8d	22-26h	22-26h
	phase		in-phase	in-phase		1/8 cycle ahead		in-phase	1/8 cycle behind	1/4 cycle ahead
July	period	uncertain	22-26h;6-10d;32-48d	32d	uncertain	1d	16d	22-26h;8d	22-26h	22-26h
	phase		in-phase	in-phase		1/8 cycle ahead	anti-phase	in-phase	1/8 cycle behind	1/4 cycle ahead
August	period	uncertain	22-26h;32-48d	32d	uncertain	1d	uncertain	22-26h	22-26h	22-26h
	phase		in-phase	in-phase		1/8 cycle ahead		in-phase	1/8 cycle behind	1/4 cycle ahead
September	period	uncertain	22-26h;32-48d	32d	uncertain	1d	uncertain	32d	22-26h	22-26h
	phase		in-phase	in-phase		1/8 cycle ahead		in-phase	1/8 cycle behind	1/4 cycle ahead
October	period	0.25-8d	22-26h;32-48d	uncertain	32d	1d	uncertain	32d	22-26h	uncertain
	phase	anti-phase	in-phase		3/4 cycle ahead	1/8 cycle ahead		in-phase	1/8 cycle behind	
November	period	0.25-8d	uncertain	2-8d	8d	uncertain	uncertain	32d	uncertain	2-4d
	phase	anti-phase		1/4 cycle ahead	7/8 cycle ahead			in-phase		in-phase
December	period	0.25-8d	uncertain	2-8d	uncertain	uncertain	uncertain	8d	uncertain	uncertain
	phase	anti-phase		1/4 cycle ahead				in-phase		