1. Novelty:

This paper mainly discusses adverse meteorological conditions relevant to the severe ozone pollution in summer, the natural aspect of the complex ozone pollution problem in China. Daily thresholds of meteorological factors relative to severe summer ozone pollution are determined in five regions by combing ozone concentrations at air quality monitoring stations and meteorological elements at weather stations. It is a new viewpoint on investigating meteorological factors compared with most studies discussing ozone concentration correlations with meteorological foctors.

The adverse meteorological frequency combining daily thresholds of wind speed and radiation shows individual trends and periodic characteristics in each region. This broadens our horizon since such frequency and coresponding periodic characters have been less investigated in previous studies. Furthermore, these adverse meteorological frequencies are correlated with Western Pacific Subtropical High and Southern Oscillation, different from those studies about their roles on ozone concentration. Finally, with cyclo-stationary empirical orthogonal function analysis, we substantiate impacts of global warming, Pacific Decadal Oscillation, El-Nino and La-Nina on the Western Pacific Subtropical High in two typical months.

These results give us more insights on meteorological effects on ozone pollution and would be helpful in its projection when planning air quality improvements.

2. Data and Methods

Ozone concentration of maximum daily 8-h average (MDA8) at air quality monitoring stations in summer (June, July and August), from 2014 to 2018, are acquired from the China National Environmental Monitoring Center. China Meteorological Administration (CMA) provides the daily meteorological station data from 1961 to 2018 which comprise daily solar radiation, daily maximum temperature, wind speed of daily average, relative humidity of daily average and daily precipitation. Every air quality monitoring station is matched with the nearest meteorological station within 20 km in the same topography so as to connect ozone concentration with meteorological factors.

WPSH index is defined as the area with geopotential height at 500 hPa above 5880 gpm in the region of 10°N~60°N, 110°E~180°E, which is accessible to National Climate Centre of CMA. SOI is from National Oceanic and Atmospheric Administration of America (NOAA). Monthly reanalysis data of SST and GPH are from the National Centers for Environmental Prediction (NCEP) with the respective spatial resolution of 2.0°×2.0° and 2.5°×2.5° from 1948 to 2022.

Regression in CSEOF analysis is to decompose all variables with identical PC time series of the target variable. PC time series of the predictor variable--PCP(t), is regressed onto the target PC time series-- $PC^{(i)}(t)$, as formula (1).

$$PC^{(i)}(t) = \sum_{k=1}^{m} \alpha_k^{(i)} \cdot PCP_k(t) + \varepsilon^{(i)}(t), i = 1,2,3 \ldots (1)$$

Where m, $\alpha_k^{(i)}$ and $\varepsilon^{(i)}(t)$ are the number of predictor PC time series used for regression, regression coefficients for i-th mode, and regression error respectively.

Regressed CSEOF loading vectors GPHR(r, t) for SST, are obtained as formula (2). GPHR(r, t) is physically consistent with SST for each mode.

$$GPHR^{(i)}(r,t) = \sum_{k=1}^{m} \alpha_k^{(i)} \cdot GPH_k(r,t),\ r \in R, t \in T \quad (2)$$

Consequently, the entire data can be expressed as formula (3).

$$Data(r,t) = \sum_{i=1}^{n} \{SST_i(r,t), GPHR_i(r,t)\} \cdot PC_i(r,t) \ (3)$$