Trend and interannual variability of surface ozone in Europe during 1990-2010

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Abstract Newly developed data analysis method HHT is applied on the European surface ozone records to investigate the ozone variance at different time scales, especially the interannual scale and the trend. Three GEOS-Chem simulation is conducted to study how much natural and anthropogenic factors contribute to the trend and interannual variance of the surface ozone. The result shows that the observation and simulation have different trend before 2000, and the interannual variance of them have similar spatial structure, but difference is exist at several particular years.

Motivation

Tropospheric Ozone, which produce hydroxyl radical through photolysis and subsequent reactions, is a key species in the tropospheric chemistry. The main source of the tropospheric ozone is the photochemical reactions of nitrogen oxides and volatile organic compounds(VOCs). Considering its negative influence on human health and ecosystem, controlling the surface ozone concentration has always been an important issue in the environment management.

Trend and interannual variability of surface ozone has been widely studied as it helps in the air pollution controlling. One difficulty those research met is how to extract the trend signal from the original observations with large interannual variance.

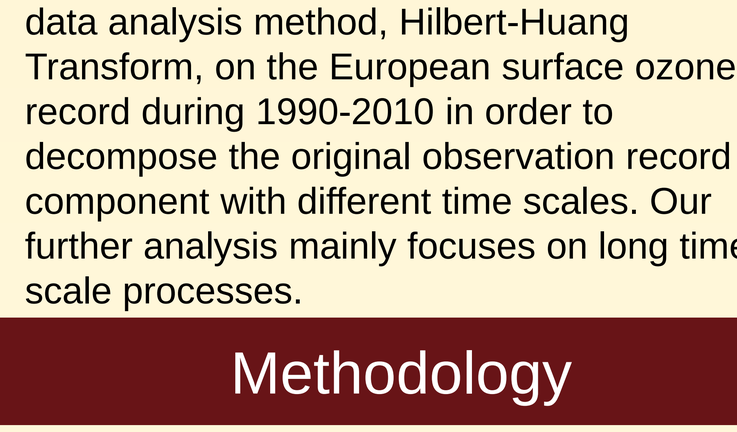
As the concentration of surface ozone can be affected by a variety of factors, which are determined by processes with different time scales, the observation records we get can be treated as a mixture of these processes. In this research, we use a newly developed data analysis method, Hilbert-Huang Transform, on the European surface ozone record during 1990-2010 in order to decompose the original observation record to component with different time scales. Our further analysis mainly focuses on long time scale processes.

Methodology

- **Hilbert-Huang Transform(HHT)**

In order to understand the nonlinear and nonstationary mechanisms of the nature, adaptive analysis method is needed when dealing with such data. That means the definition of the basis in analysis has to be based on and derived from the data.

Empirical Mode Decomposition Algorithm



HHT, a combination of Hilbert spectral analysis(HSA) and empirical mode decomposition(EMD), is such an adaptive analysis method developed by Huang et al.

Methodology

The key part of HHT is EMD with which any complicated data set can be decomposed into a finite number of intrinsic mode functions (IMFs) and one residue trend. The IMFs are ranked automatically from the finest time scale to the largest.

- **Model simulation**

We conduct the simulation of European surface ozone using GEOS-Chem version 9.2 with Caltech chemical scheme on the resolution 2°x2.5° for 21 years from 1990 to 2010. Three simulation is conducted to investigate the natural and anthropogenic contributions to the long time scale variance of surface ozone.

- 1. Simulation with yearly scaled anthropogenic emissions.
- 2. Simulation with constant natural emissions and Meteorological fields in the same year.
- 3. Simulation with constant anthropogenic emissions

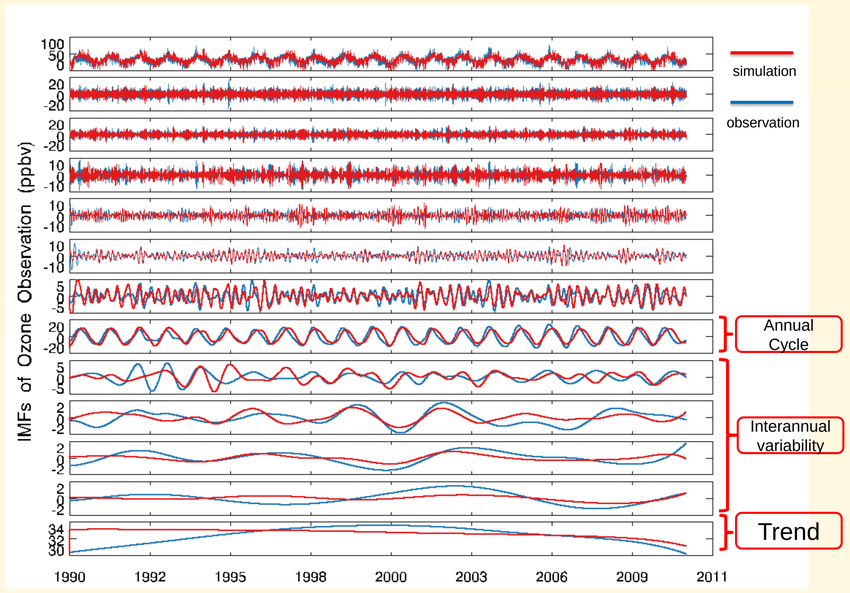
Results

- **Observation data analysis**

The observation records of surface ozone in Europe in this research is from The European Monitoring and Evaluation Program (EMEP). The Chemical Coordinating Centre of this program offers nearly 300 surface sites observation records of chemical compounds including ozone.

Observations of 56 site, which have more than 15 years continuous records, is selected in the analysis. The data is firstly decomposed using EMD method into IMFs with different time scales, and compared with the corresponding result of the simulation. The figure shows one of analysis result which site is located in Austria (47.76°N,16.77°E).

Variance of surface ozone at different time scales based on EMD method



As showed in the figure, the observation trend increased 4 ppbv from 1990 to 2000, and decreased the same level after 2000.

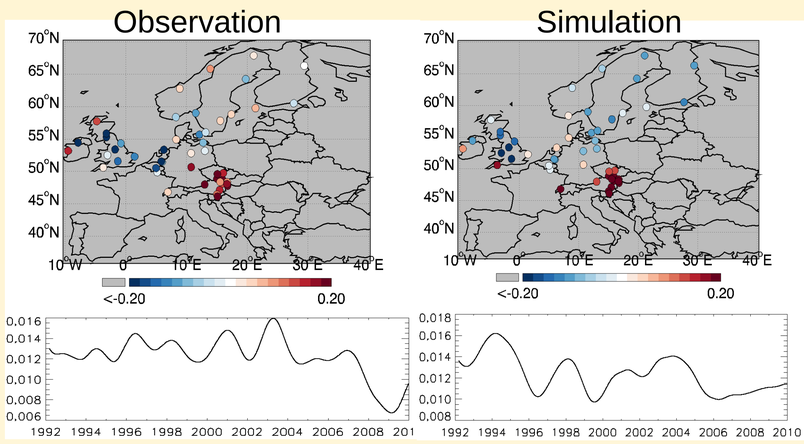
Results

However, the simulation result is continuously decreased since 1990. At the interannual time scale, both observation and simulation generally have similar patterns, but still have difference in some particular years.

- **Spatial structure of Interannual variance**

Analysis above is just ozone's characteristic at one site. In order to fully use all information and investigate the spatial structure of interannual variance, empirical orthogonal function (EOF) analysis is used on the interannual variance of those sites.

Spatial Structure of Interannual Variance



The first mode of EOF results explain 64% and 84% variance of input data respectively. The figure shows that both observation and simulation have similar spatial patterns at the interannual time scale, but their time series are different at several particular years, which may suggest interannual process in the model still have uncertainties.

Conclusion

Based on the newly developed analysis method HHT, Trend of surface ozone shows different characters in observation and simulation. Via EOF analysis the interannual variance of both have similar spatial patterns, but different in the time series, which may suggest uncertainties in interannual process in the model.

Future Directions

Simulation data still need further analysis to investigate the contribution of natural factors and anthropogenic activities.

References

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