

Evaluation and prediction of ozone depletion

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Abstract. As is known to all, the ozone hole has brought a series of adverse effects. Therefore, it is of great significance to evaluate and predict ozone depletion in the future for the purpose of healthy development of human society. Firstly, DPSIR model is utilized to establish the evaluation system of ozone depletion. Taking the primary influence factors into account, 16 indicators constituting index layer are selected to represent the ozone depletion situation. Analytic Hierarchy Process is adopted to define the weight of index. Calculation reveals that the ozone hole areas have a tendency of rising first and then descending. Lastly, Extreme Learning Machine model is used for predicting the ozone levels. The result of 50-year forecast shows that ozone level is under the circumstance of safer state and ozone layer will get a great deal of recovery.

1. Introduction

Why is the formation of ozone holes? In 1985, when the ozone hole was discovered all the major physic-chemical mechanisms responsible for its occurrence were unknown and a number of competing theories were put forward to explain the phenomenon. Today, however, the fundamental mechanisms causing the ozone hole are understood and man-made halogen compounds have been identified as the ultimate cause of stratospheric ozone loss. The Antarctic ozone hole is one of the most striking examples of the impact of human activities on the atmosphere.

2. Evaluation of ozone depletion

The evaluation of ozone depletion cannot be performed just by a simple model. As a whole, atmospheric motion system has a complexity among internal variables, external variables and interactions between foregoing two. To be specific, there is a variety of complicated connections in environment and human activities. In addition to natural factors, ozone depletion is affected by human activities to a great degree. Then a general causal framework to describe the interactions between society and environment is needed. Hence, the conceptual model based on the Driver-Pressure-State-Impact-Response framework is taken to describe the process to establish a model for assessment.

2.1. Driver-Pressure-State-Impact-Response

As a general causal framework to describe the interactions between society and environment, the European Environment Agency (EEA) has adopted the Driver-Pressure-State-Impact-Response (DPSIR) scheme [1]. Because of its ability to integrate knowledge across different disciplines and to formalize different decision alternatives, the application of the DPSIR framework has considerable potential for bridging the gap between scientific disciplines as well as linking science to policy and



management. DPSIR is at times criticized for not being able to capture the real world complexity of interactions. Exactly this simplicity however has the advantage of promoting understanding and communication in a policy meaningful way.

In order to place human behaviors and management responses in a wider social-ecological context, we developed a conceptual model based on the DPSIR framework. We applied the framework in a systematic way since it allows for the integration of knowledge across disciplines. Drivers in the framework typically include human activities or environmental changes that put pressure on the environment and change the quantity and quality of resources and the environment that result in impacts that evoke management responses.

2.2. Construction of evaluation index system

Since this study mainly consider the impact of human activities on the ozone ecological security in the target area, the index selection mainly starts from the external driving force, which involves the driving force of economic development and the driving force of social development. In this paper, three related indicators in driving force subsystem were selected, namely, the proportion of the world population, the second and third industries, the global average temperature.

Pressure is caused by human activities, which is the driving force of the form of performance indicators. The main pressures affecting the ecological safety of ozone include air pollutants and meteorological conditions. For these two varieties of pressure manifestations, this paper uses greenhouse gas content, ODS content, atmospheric flow, nitrogen dioxide to represent.

States are physical or chemically measurable features of a region's ozone resources under the combined action of driving forces and pressure. In this article, the ozone whole area, the minimum ozone content and ozone consumption reflect the ozone quality status.

Impact should include both human and ecological aspects. This article select three indicators, respectively, on human health injury, the ground by ultraviolet radiation and ground ozone content.

Response describes a series of positive measures for human response to ozone ecological security changes, including socio-economic response, ecological restoration and pollution control, etc. Using ozone recovery investment, restrictions for the CFC and ODS restrictions stands for the response in this paper.

2.3. Determination of index weight

In this paper, we use the Analytic Hierarchy Process to determine the weight of the indicator layer, while the weight of the criterion layer is obtained from the literature. The results are shown in Table 1.

Table 1. Ozone quality evaluation index system and weight.

target layer	criteria layer:symbol(weight)	indicator level:symbol(weight)
ozone level evaluaton	driving force:B1(0.2297)	world population:C1(0.2297)
		secondary and tertiary industries:C2(0.6483)
		global average temperature:C3(0.1220)
		greenhouse gas content:C4(0.1091)
	pressure:B2(0.6483)	ODS content:C5(0.3509)
		atmospheric flow:C6(0.1891)
		NO ₂ :C7(0.3509)
		ozone hole area:C8(0.5396)
	states:B3(0.1220)	minimum ozone content:C9(0.1634)
		ozone consumption:C10(0.2970)
	impact:B4(0.1091)	human health hazards:C11(0.5)
		ground exposed to radiation:C12(0.25)

response:B5(0.3509)	ground ozone content:C13(0.25) ozone recovery investment:C14(0.5499) restrictions on CFC:C15(0.2098) restrictions on ODS:C16(0.2402)
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2.4. Solution and result

Most of the selected indicators are negative, that is, the larger the index value the more unsafe. Consequently, the ozone quality level classification table is as follows.

Table 2. Ozone quality classification.

level states	estimation scale	ozone level	state description
heavy warning state	V	(0.8,1]	ozone layer appear huge hole and human survival environment has been severely disrupted
middle alarm state	IV	(0.6,0.8]	ozone layer appear large hole, barely meeting human development but difficult to recover
previous warning state	III	(0.4,0.6]	ozone layer of small holes, good living environment, not afford greater interference
safer state	II	(0.2,0.4]	small ozone layer, good living environment, bear particular interference
safe state	I	[0,0.2]	good living environment and resilience

With the help of matlab, we can figure out ozone quality score and the result is as follows.

Table 3. Score of criteria layer.

symbol\year	1995	2000	2005	2010	2015
B1	0.2124	0.3623	0.9314	0.6221	0.5191
B2	0.1975	0.3666	0.8514	0.6272	0.6537
B3	0.1300	0.3348	0.9864	0.7077	0.6291
B4	0.2799	0.3941	0.7964	0.5417	0.5437
B5	0.2518	0.3809	0.8527	0.5752	0.5335

Table 4. Ozone quality score.

year	1995	2000	2005	2010	2015
score	0.3045	0.4057	0.7474	0.5124	0.5527

3. Prediction of ozone depletion

In order to predict the ozone depletion, there are many methods to establish prediction system and measure ozone depletion. Among them, the most frequently used method is time series prediction method. But the prediction results are influenced by the initial values, and the prediction results are influenced by the factors. So. We try to use Extreme Learning Machine (ELM) method.

3.1. Data preprocessing

Meteorological data monitoring is a complicated work, so it is normal that find some mistake in those data[2]. In order to insure the precision of the model, it is necessary to modify these errors. We use the average substitution method to deal with mistakes and the formula is as follows:

$$x = \frac{1}{n} \sum_{i=1}^n x_i$$

For one thing, in order to eliminate the dimensional and uniform data range of variation, processing data convenience for another, describing the state of ozone, volatile, etc, we need to standardize on the data. It also can be significant for the ELM, which will be used in the second model. Min-Max normalization is adopted to dispose the work. The formula is as follows [3]:

$$x_i = \frac{x_i - \min\{x_i\}}{\max\{x_i\} - \min\{x_i\}}$$

3.2. Determination of input layer and output layer

By solving the first question, we find that some factors play a key role in the influence of the ozone state, respectively ozone hole area(A),concentration of greenhouse gases(B),concentrations of ODS(C),human health hazards(D) and comprehensive factor(E).In addition, we choose the relevance matrix to determine the input and output terms of the ELM. We make the t year all kinds of data and the t-1 year data correlation analysis and give the result as follows.

Table 5. Results of incidence matrix.

	A(t)	B(t)	C(t)	D(t)	E(t)
A(t-1)	0.91	0.86	0.69	0.83	0.77
B(t-1)		0.96	0.87	0.90	0.84
C(t-1)			0.95	0.58	0.64
D(t-1)				0.89	0.77
E(t-1)					0.90

Through the analysis of table 5, it can be found that each indicator has a more significant correlation with the previous period of the indicators. Hence the indicators of the previous stage can be used by the Extreme Learning Machine [4] to speculate the next stage of the indicators. Thus, we select the indicators of the t-1 year and t year respectively forecast the indicators of t+1 year.

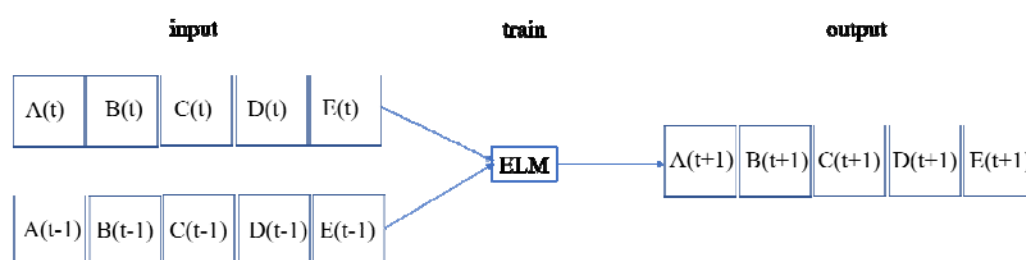


Figure 1. Selection of input layer and output layer.

3.3. Intra-sample prediction

For the sake of verifying the stability of the model, we use the intra-sample prediction for intuitive and effective testing[5].

Monthly data from 1979 to 2012 are selected as training samples and monthly data for 2013 are used as test samples. The values of 8 months in 2013 are predicted by matlab programming. Compared with the test values, the mean square errors are obtained. The values of E and R^2 are 0.278 and 0.851.

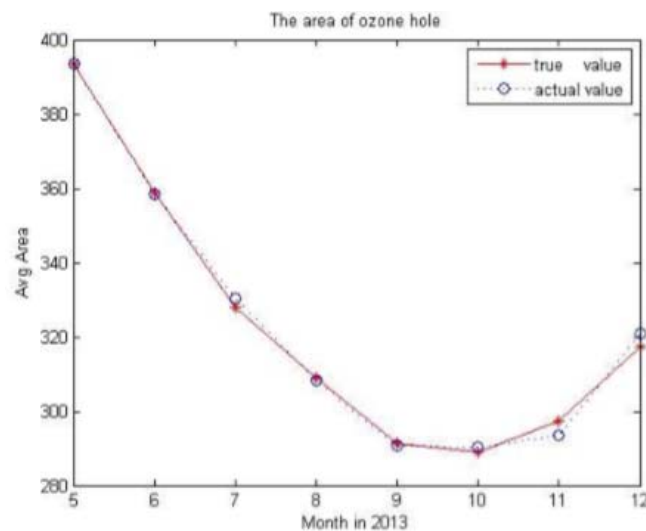


Figure 2. Comparison of real and predicted value.

It can be seen from Fig.2 that the discrepancy between the true value and the predicted value curve is tiny. Also the mean squared error is smaller. Moreover the square correlation coefficient surpasses the qualified line of 0.8, which indicates that the model has good precision and credible result.

3.4. Out-of-sample prediction

Through the intra-sample test, we prove the accuracy of EML model. Nevertheless EML can only do the next stage of accurate prediction. There may be a certain bias for prediction the state of the ozone layer after 50 years. We have been inspired by the cohort thinking in the discipline of data structures and have decided to adopt a step-by-step approach to achieve long-term forecasting, that is, where the prediction is taken as a new input sample after completion of the most recent stage and the first session of input samples will be removed. The specific process is as Fig.3. And we make use of mat lab to solve, the results are shown in Table 6.

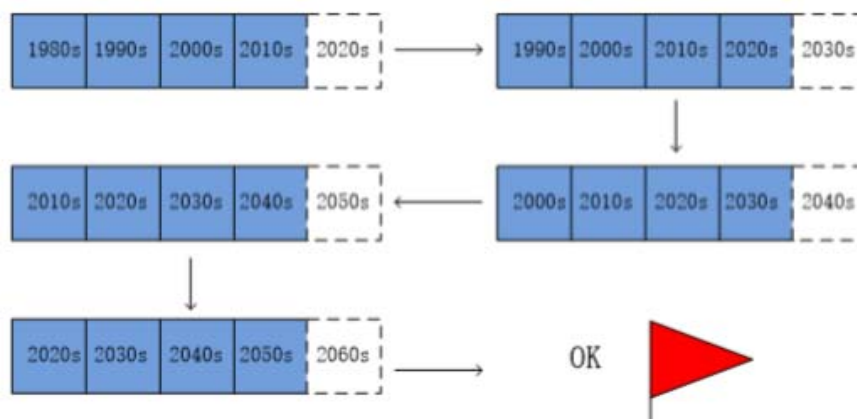


Figure 3. Flow chart of prediction.

Table 6. Prediction results.

index	value
ozone hole area	2.97
ozone mass deficit	5.6
cost of protection of ozone layer accounted for proportion of the total cost	3.7
cost of protection of human health	1437
proportion of industrial output value to total output value	38%
greenhouse gas emissions	520

4. Conclusion

Through the previous evaluation and prediction, we can get the following conclusions.

In the evaluation part, we select five years of data from 1990,1995,2000,2005 and 2010 to evaluate the ozone quality. Quality index were 0.3045, 0.4057, 0.7474, 0.5124, 0.5527. It is clear that the global cavity area is not large in the 21st century and the basic state is in the early warning. After the 21st century, a sharp increase in ozone hole area, with practice, you can determine the industrial is one of the major factors, at the same time, we found that there is a significant lag between 2000 and 2005, which is consistent with the information collected. Data shows that the hollow only exists in the North and South Poles. Due to atmospheric flow, there will be a significant lag.

In the prediction part, we can see that by means of the common efforts of all mankind and the role of nature's self-purification, the area of the ozone hole after 50 years accounts for 1/10 of the ozone whole area now. The proportion of the second industry output value is steady at 38%. Besides volatility is not big. Ozone mass deficit turn into 5.6 compared with 50 years ago so that this index has been improved significantly. Greenhouse gas emissions reduce a third. After ozone quality was improved, we don't need to spend too much cost to put into health. Therefore the cost of health input is from 2000 to 1437. After getting these important indicators, we use the DPSIR model [6] to evaluate the situation of ozone. To bring to the DPSIR model to calculate the indicators, ozone state score is 2.32 and grade is 2.

References

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