Spatial Characteristics of Low Meteorological Visibility over Hongkong and Statistical Retrieval from Satellite Data

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Abstract: Based on twelve observational stations low meteorological visibility (LMV) data during November 2002 to April 2003, the spatial distribution of LMV over Hongkong area (113.8° E-114.4° E, 22.1° N-22.4° N) is studied, using a PCA method. Optical spectrum of NOAA-16 associated with LMV shows that the significant effect factors correlated with LMV in the leading mode are the difference or rate between the visible and near-IR channels and single visible channel. A successful retrieval of LMV is done and a regression equation with a multiple correlation coefficient of 0.67 is obtained.

Keywords: Low meteorological visibility, Spatial distribution, Retrieval, NOAA, Hongkong.

1. Introduction

The low meteorological visibility is a big problem for avigation, navigation, traffic transport and astronomical observation. However, the observation of visibility is difficult over seas so the observational data are very sparse. With the developing of the technique of remote sensing, it is possible to retrieve many atmospheric elements from remote sensing[1, 3]. Although the variation of the horizontal visibility near surface is a weak signal in the satellite images, the LMV over near China seas is mainly affected by the sea-fog/stratus process[2]. Therefore, retrieval of visibility quantitatively from remote sensing is a possible and valuable try[3-4].

2. Data and Methods

The data used in this paper are twelve observational stations (Fig. 1) hourly horizontal meteorological visibility data and the simultaneous NOAA-16 advanced very high resolution radiometer (AVHRR) data over Hongkong area (113.8 E-114.4 E, 22.1 N-22.4 N) during November 2002 to April 2003. Fifty LMV cases are chosen and its comp arison with the optical spectrum characteristics for all channels of the satellites data are performed. The low visibility process is defined by the visibility less than five kilometers.

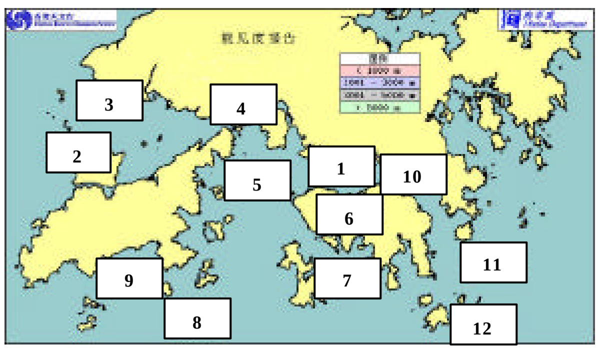

Fig. 1 Geographical distribution of the twelve observational stations over Hongkong area.

Principal component analysis (PCA)[5] was used to analyse the spatial distribution and optical spectrum characteristic of LMV. An optimal subset regression (OSR) method[6-7] was performed to find the linear regression equation between the LMV and NOAA-16 different channels data.

3. Spatial Characteristic of LMV

PCA was performed on a standardized matrix of LMV with two dimensions. One is spatial dimension with twelve stations. The other is sample dimension with 50 LMV cases. The leading mode (Fig. 2a) for the dominant distribution of the meteorological visibility over Hongkong from PCA shows a nearly homogeneous in phase spatial pattern, with a slightly larger amplitude variation in the middle part of the Hongkong area and decreasing gradually in the northwest and southeast directions, accounting for 46.4% variances. The percentage of the variance accounted for by the second mode is 16.9%, with the spatial pattern of a north-south seesaw (Fig. 2b), which might reflect the difference of visibility over land and sea of Hongkong.

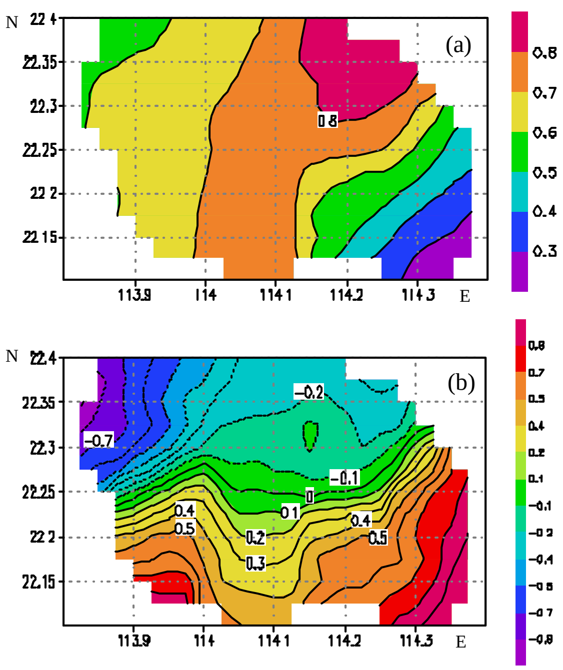

Fig. 2 Correlation distribution of the first (a) and second (b) principal component of LMV from PCA over Hongkong area. The contour interval is 0.1.

4. NOAA-16 Optical Spectrum Property Associated with LMV

In order to find the significant channels in NOAA-16 AVHRR data associated with LMV, PCA was performed upon the five channels (ch1-5) of NOAA-16 and their nine combinations (ch2-ch1, ch3-ch1, ch4-ch3, ch5-ch3, (ch2-ch1)/(ch2+ch1), ch2/ch1, ch4-ch5, ch3-ch2, (ch1+ch3)/(2*ch2)). The cloud was filtered[8] first by satisfying any one of the following conditions: 1) the reflectivity of ch1 or ch2 is greater than 25%; 2) ch2/ch1 is greater than 0.7 and less than 1.1. Thirty-one LMV samples were chosen after cloud filter.

The PCA is based on 14 channals of NOAA-16 data and the reciprocal of corresponding visibility with 31 samples. The result shows that the variance is strongly concentrated in the first mode, accounting for 94.6% fraction of variance. The significant factors associated with LMV in the leading mode are ch3-ch1, ch1, ch2-ch1, ch2/ch1 and (ch2-ch1)/(ch2+ch1), suggesting the difference or rate between the visible and near-IR channels and single visible channel are very sensitive to the variability of LMV. The higher the reflectivity of the visible channel is, the lower the surface meteorological visibility is. Correlation analysis also reveals that the low visibility processes are mostly significantly correlated to the difference between far-IR and near-IR channels (ch5-ch3, ch4-ch3) and the difference between near-IR and visible channel (ch3-ch1), which reflect the difference between air absorbance, cloud top radiation and air dispersion. These results suggest that the low visibility over Hongkong is mainly affected from the sea-fog/stratus process, which indicate good correlations between fog albedo from AVHRR ch1 and fog optical depth and geometrical thickness to spectral extinction and horizontal visibility[3].

5. Retrieval of LMV from NOAA-16 Data

Based on the above PCA results, we can statistically reduce the spectrum dependent variables of visibility into several independent channel combinations. This provided a reasonable basis for quantitative retrieval of visibility from satellite data. Using an optimal subset regression method, we successfully got a regression equation between the reciprocal of visibility and 11 factors of different channels. The regression equation is

$$\begin{aligned}Y &= -0.561 + 0.049X_1 + 0.165X_2 - 0.14X_3 \\ &- 0.088X_4 + 0.154X_5 - 0.203X_6 + 0.218X_7 \\ &- 1.977X_8 - 0.196X_9 + 0.184X_{10} - 0.084X_{11}\end{aligned} \quad (1)$$

in which $X_1 = ch1$, $X_2 = ch2$, $X_3 = ch3$, $X_4 = ch2 - ch1$, $X_5 = ch3 - ch1$, $X_6 = ch4 - ch3$, $X_7 = ch5 - ch3$, $X_8 = \frac{ch2 - ch1}{ch2 + ch1}$, $X_9 = \frac{ch2}{ch1}$, $X_{10} = ch4 - ch5$, $X_{11} = \frac{ch1 + ch3}{2 \cdot ch2}$, and $Y = \frac{1}{Vis}$, Vis denotes the surface meteorological visibility in km.

The regressive precision is relatively high with a multiple correlation coefficient of 0.67. The regressive result is shown in Fig. 3. The red bar denotes the retrieved visibility from eleven NOAA-16 AVHRR channels and their combinations data and the blue one is the observational meteorological visibility. Most of the retrieved visibility agreed well with that of the observations except that four samples exceed 5km, which are not low meteorological visibility according to our definition.

6. Conclusions

The spatial distribution of LMV over Hongkong is studied based on twelve observational stations low meteorological visibility (LMV) data during November 2002 to April 2003, using a PCA method. The first mode is a leading mode, accounting for 46.4% variance. The spatial pattern shows a homogeneous distribution for the LMV over Hongkong area, indicating an in phase variation of LMV.

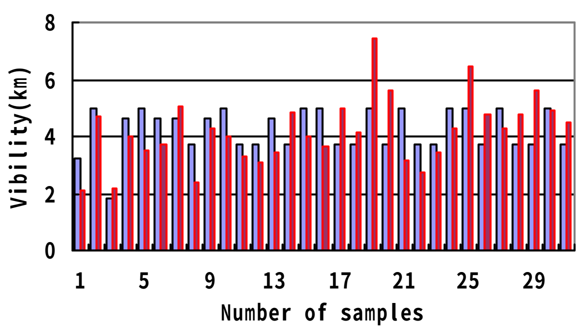

Fig. 3 Comparison of the observational meteorological visibility (blue bar) and the regressive visibility (red bar) from NOAA-16 AVHRR data.

Optical spectrum of NOAA-16 associated with LMV shows that the significant effect factors associated with LMV in the leading mode are the difference or rate between the visible and near-IR channels and single visible channel. This reflects the difference between air absorbance, cloud top radiation and air dispersion, which may suggest that the low visibility over Hongkong is mainly affected from the sea-fog/stratus process.

A successful retrieval of LMV is done and a regression equation with a multiple correlation coefficient of 0.67 is obtained. This result supplies confidence to retrieve visibility from satellite AVHRR data for our first step try. However, the precision is not very high. Whether the regression equation can be widely used, and whether it has a unique formation need further studies.

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