中南半島生質燃燒活動氣候變化及區域氣候反饋

黃翔昱[1]　　王聖翔[1]　　黃婉如[2]

國立中央大學大氣科學系[1]　　國立臺灣師範大學地球科學系[2]

摘　要

過去數十年間，中南半島生質燃燒活動對區域空氣品質、大氣能見度和氣候衝擊效應受到廣泛討論。為釐清大氣動力與中南半島生質燃燒活動間的交互作用，本研究選取 2000-2019 年春季 MERRA-2 月平均資料，針對 7-SEAS/BASELInE 實驗研究區域，透過合成分析與主成分分析中南半島生質燃燒活動，找尋其氣候影響因子與氣膠效應。結果顯示，春季期間區域氣候對生質燃燒活動影響可歸類為四項因子：(1)孟加拉灣反氣旋環流、(2)南海反氣旋環流、(3)太平洋副熱帶高壓與(4)中南半島至台灣強西風帶。中南半島至台灣西風帶增強時，更容易造成生質燃燒傳送事件發生。孟加拉灣反氣旋環流增強時，造成穩定大氣並減少降水，增強源區生質燃燒活動。南海反氣旋環流增強時，將利於中南半島至台灣西風帶增強，同時促使南海區域大氣穩定，減少氣膠移除作用，使生質燃燒氣膠傳送至下風處。當太平洋副熱帶高壓增強時，連帶強化中南半島至台灣西風帶，而當太平洋副熱帶高壓向北偏移時，則會造成中南半島至台灣西風帶產生南風分量，改變生質燃燒傳送路徑，使生質燃燒累積於源區。若進一步與大尺度氣候特徵指數(如：ENSO)連結，在聖嬰年(El Niño)孟加拉灣反氣旋環流、南海反氣旋環流及中南半島至台灣西風帶增強，造成生質燃燒活動增強，且更容易傳送至南海及台灣區域。

中南半島生質燃燒期間氣膠輻射效應(ARE)在大氣能量平衡上扮演重要角色，對中南半島北部大氣短波 ARE 會造成 20%的大氣層內淨輻射通量改變，並造成地球環境系統某種程度上熱力與動力調整。此外，3-4 月中南半島生質燃燒與 5 月份夏季季風相關性顯示，中南半島生質燃燒排放與傳送增強時，夏季季風則會同時增強，而生質燃燒氣膠累積於中南半島時，夏季季風則會減弱。然而，氣膠效應對於區域氣候的回饋機制相當複雜，須加入數值模式驗證，可以做為未來生質燃燒氣膠反饋作用的研究方向。

關鍵字：生質燃燒氣膠、氣膠長程傳送、氣膠效應

Transport mechanism and regional climate feedback of Indochina biomass burning aerosols

Hsiang-Yu Huang[1] Sheng-Hsiang Wang[1] Wan-Ru Huang[2]
Department of Atmospheric Sciences, National Central University[1]
Department of Earth Sciences, National Taiwan Normal University[2]

Abstract

Impacts of long-range transported biomass-burning aerosols from Indochina on regional air quality, atmospheric visibility and climate effects have been discussed extensively in the literature over the past few decades. However, the transport mechanism and regional climate feedback of Indochina biomass-burning aerosols is still not fully understood. To clarify the interaction between atmospheric dynamics and biomass-burning aerosols in the Indochina, we present results of the MERRA-2 dataset, satellite and in-situ observation in spring 2000-2019 over the 7-SEAS/BASELInE experiment region. This study finally proposes the main analysis results of the biomass-burning activities in the Indochina, and find four meteorological factors attributed to biomass-burning activities. We identify those factors by using long-term data with composite analysis, principal components analysis and correlation analysis. The four factors include: (1) anticyclone (Monsoon trough) in the Bay of Bengal, (2) relative anticyclone in the South China Sea, (3) Pacific subtropical high, and (4) westerlies from Indochina to Taiwan. The strong westerlies from Indochina to Taiwan positively correlates with the frequency of the postfront LLJ. When the postfront LLJ and biomass-burning transport events occur frequently in the synoptic-scale meteorology, the westerlies from Indochina to Taiwan will also increase in the climate field. The increasing anticyclone over the Bay of Bengal tends to enhance atmospheric stability, reduce precipitation, and turns to strengthen biomass-burning activities in the source region. The increasing relative anticyclone in the South China Sea can enhance westerly from Indochina to Taiwan. At the same time, the relative anticyclone can promote the stability of atmosphere, reduce the deposition efficiency of aerosol, and support the biomass-burning aerosol transport to the downwind region. The strength of the Pacific subtropical high positively correlates with the strength of the westerlies from Indochina to Taiwan. When the Pacific subtropical high northward shift, the circulation generates the southerly wind from Indochina to Taiwan, which changes the biomass-burning transport path and location. We further assess the correlation of attributed factors and different large-scale climate indexes (e.g. ENSO, Indian Ocean Dipole (IOD)). As a result, the biomass-burning activity has a stronger correlation with ENSO, but weak correlation with IOD. In the El Niño year, the increasing anticyclone in the Bay of Bengal and the South China Sea accompanied the stronger westerlies from Indochina to Taiwan, which enhanced the biomass-burning activities and aerosol transport to the South China Sea and Taiwan.

The biomass-burning aerosol effect and its regional climate feedback, as the aerosol frequently located from Indochina to Taiwan at approximately 700 hPa, which can increase the net radiation flux by 20% in the atmosphere as so-called the shortwave aerosol radiation effect (ARE). Furthermore, those ARE can be found that the summer monsoon pattern in May has linkage with biomass-burning activities from March to April. The summer monsoon will be increased when the biomass-burning emissions and transport enhance, and it will be weakened when biomass-burning accumulates in the Indochina. The correlation illustrates that the biomass-burning aerosol feedback may change the precipitation and affect the summer monsoon onset. However, the understanding of the aerosol effect is limited by only using MERRA-2 reanalysis data. To gain a better understanding of the biomass-burning aerosol effect and regional climate feedback mechanism, utilizing a numerical study would greatly benefit in the future.

Keywords: Biomass-burning aerosol, aerosol long-range transport, aerosol radiative effect