CityZen

megaCITY - Zoom for the Environment

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Scientist(s) responsible for this deliverable: Yuanhang Zhang

Contribution authors: Xuesong Wang, Wei Lu, Yuanhang Zhang* (yhzhang@pku.edu.cn)

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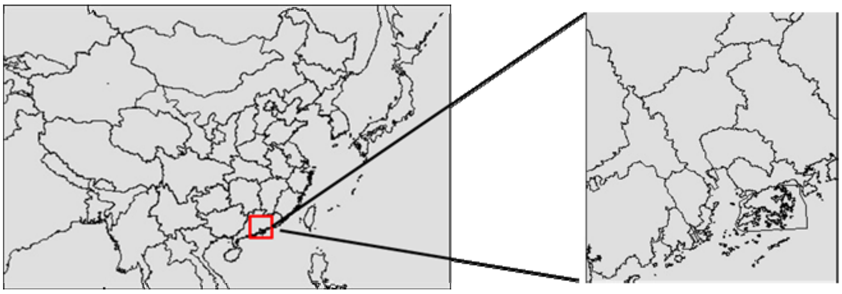
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

As a great city cluster in South China, the PRD affects surrounding areas by exporting pollutants there; on the other hand, imports of pollutants from surrounding areas can affect the air quality in PRD region as well.

To discern import/export fluxes of major pollutants, boundaries are set to encompass PRD region in four directions (Figure 1), based on which the import/export fluxes of SO_2, NO_2, O_3 and PM_{10} are calculated. In addition, the fluxes of emissions and depositions are calculated to investigate the contributions of different atmospheric processes on the budgets of pollutants in PRD.



(a) (b)

Figure 1 (a) the 36 km domain for CMAQ simulation; (b) the PRD region defined in this study

SO_2

To give an overview of the pollutant budget over PRD region, total contributions of individual processes (i.e., emission, chemical reaction, deposition and horizontal import/export processes) were calculated over all the 13 layers (deposition in surface layer only) as shown in Figure 2.

Figure 2 shows that on a yearly basis, emission is the dominant process accounting for SO_2 accumulation, which is ~2.5 times of the import process. Export is the major process accounting for SO_2 loss, which is ~1.5 times of the deposition process. We find significant (seasonal) variations of import/export processes but slight variation of emission and deposition processes. In all year round, we can expect the chemical consumption of SO_2 and we can see budget balance of SO_2 in PRD region. The emission process is 2.75 times of the net transport process.

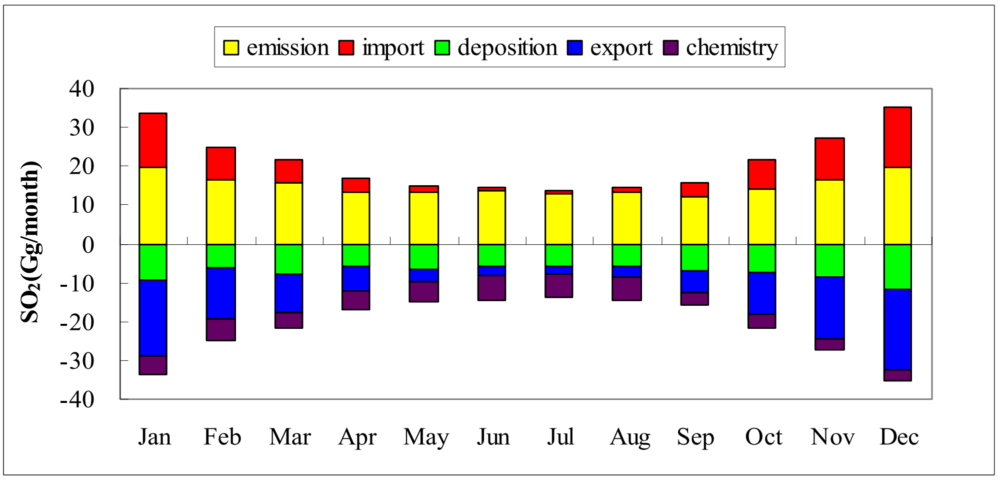


Figure 2 Modeled SO_2 budget in PRD region

Horizontal transport of pollutants is closely associated with their ambient concentrations and horizontal wind fields. Figure 3 depicts the seasonal average surface wind fields in PRD. In winter, it's the strong northeastern wind dominating the entire PRD while in spring, eastern or southeastern winds become important. In summer, the Asian summer monsoon causes invasion of southern wind by introducing clean marine air masses, and in autumn, it is the northeastern wind controlling PRD.

Besides the surface wind field, significant impact were also found for wind fields 1000m/5000m above ground, which represents wind fields in the upper boundary layer and the free troposphere, respectively. At the height of 1000 m above ground level (AGL), the wind fields begin to change from north to east in winter and southern wind dominates the transport in spring. In summer and autumn, the dominant wind at 1000 m AGL is similar to those in surface layer. In free troposphere (~5000 m AGL), westerly winds are dominant in winter, spring and autumn, but southerly winds dominant in summer over PRD. These wind fields are associated with the horizontal transport flux of different pollutants in PRD region.

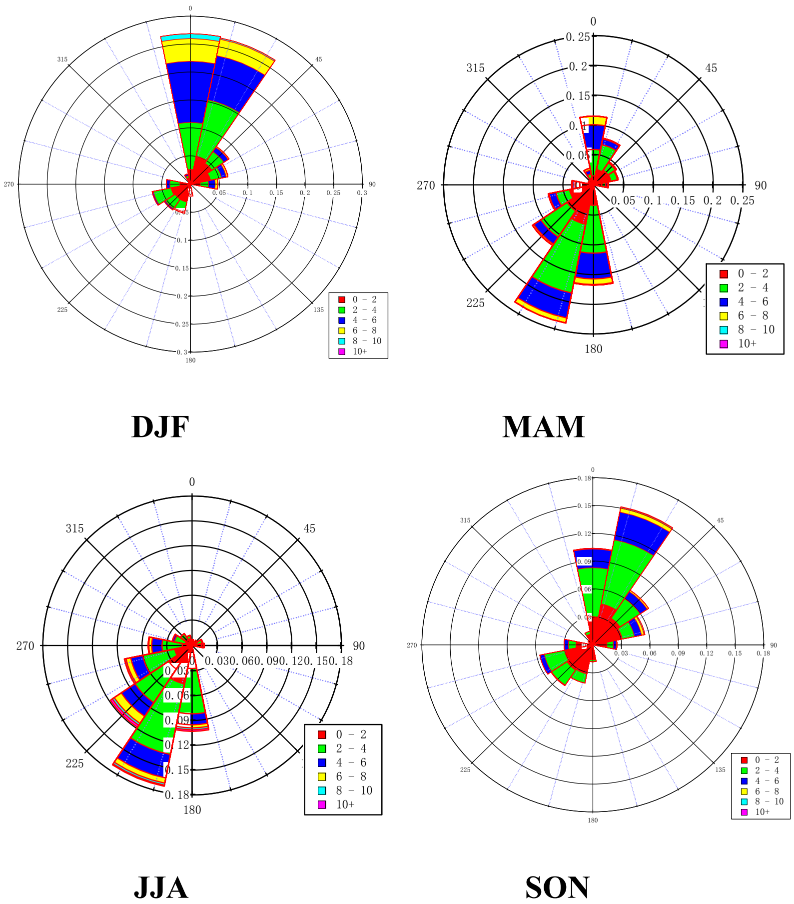


Figure 3 Seasonal average surface wind distribution in PRD

Figure 4 shows the horizontal transport flux densities of SO_2 at different vertical layers in PRD. In the year round, the export flux of SO_2 is greater than the import flux, which could be attributed to the high emission intensity in central PRD region. In winter, PRD is subject to great import flux from the north boundary and the east boundary and great export flux from the south boundary and the west boundary. It is interesting that this mainly happens below the 1000 m. In the free troposphere, strong westerly winds result in west boundary import and east boundary export. In spring, import through north&east boundary and export through north &south boundary are found in lower layers. This season is the beginning of southerly wind, great north import and south export mainly attributes to the month of March, which serves as the transition period for northerly winds and southerly winds. In summer, because of the invasion of Asia monsoon, south import and north export can be found in lower layers, the horizontal transport in free troposphere is weak. In autumn, synoptic northeast winds cause great north and east boundary import as well as south and west boundary export in the boundary layer. Weak transport occurs in the free troposphere. Figure 5 shows the SO_2 flux density of horizontal transport up to 3000m.

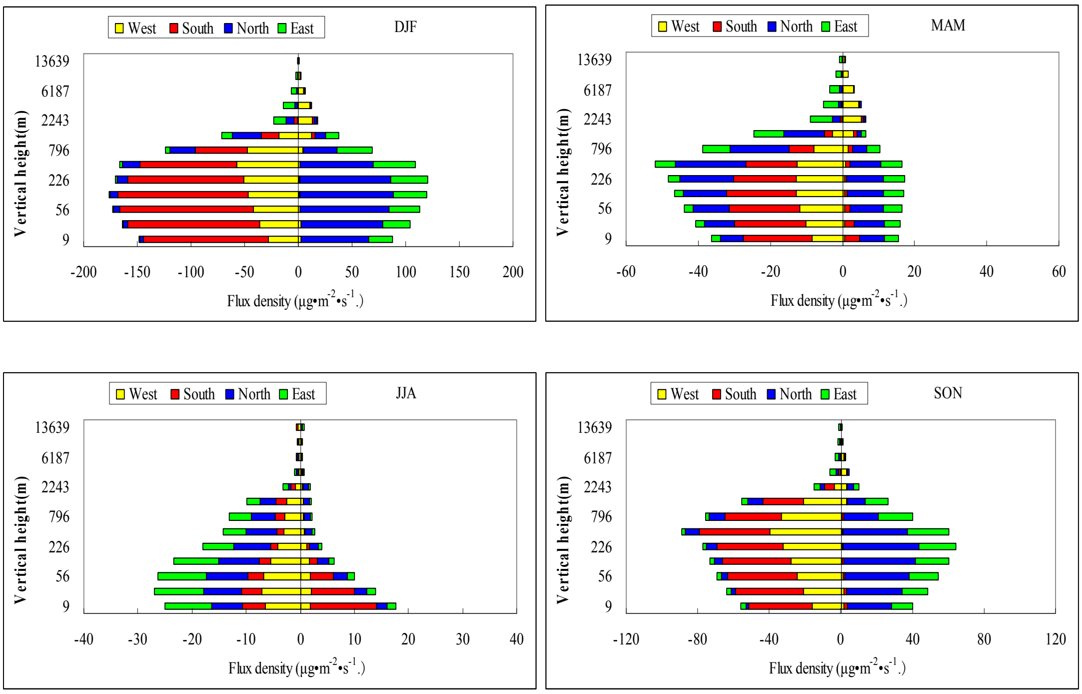


Figure 4 SO_2 horizontal transport flux densities in different vertical layers over PRD

(red: south boundary; yellow: west boundary; blue: north boundary; green: east boundary)

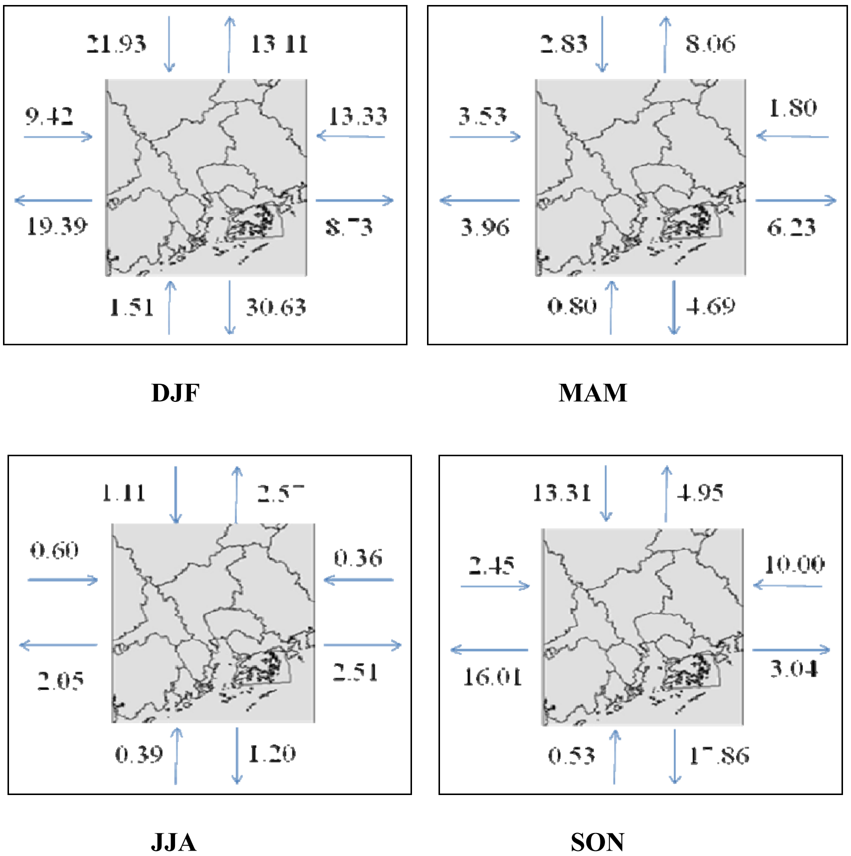


Figure 5 SO_2 flux density of horizontal transport up to 3000m

NO_2

The contributions of the emission, chemistry and horizontal import/export processes over all the 13 layers and the deposition in surface layer for the PRD region are summarized in Figure 6. On a yearly basis, emission is the dominant process for NO_2 accumulation, which is ~2 times of the import process. Export is the major process for NO_2, which is ~5.5 times of the deposition process. We find significant seasonal variations of the import/export processes but slight variation of the emission and deposition processes. We can expect year round NO_2 chemical consumption in PRD region. The emission intensity is 1.76 times of the net transport process.

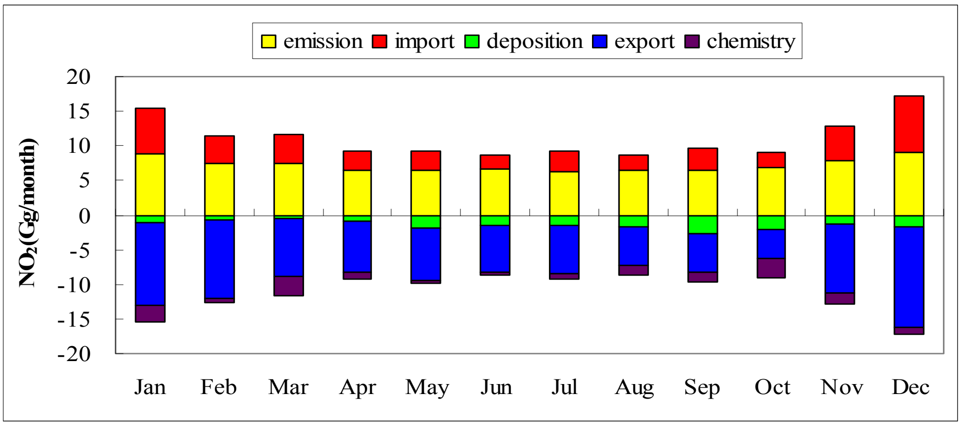


Figure 6 Modeled NO_2 budget in PRD region

Figure 7 represents the season variation of NO_2 horizontal transport flux at different vertical layers in PRD region. The results show similar characteristics of NO_2 horizontal transport regime to those of SO_2. As to the different features, for example, the input from the south boundary is week all year round because of relatively low NO_2 concentration in the marine atmosphere than in the continental.

Figure 8 shows the NO_2 flux density of horizontal transport up to 3000m. We can see significant correlation of flux density to the dominant wind direction. Due to the higher NO_2 concentration in central PRD area, we can see larger export values than import values through all seasons.

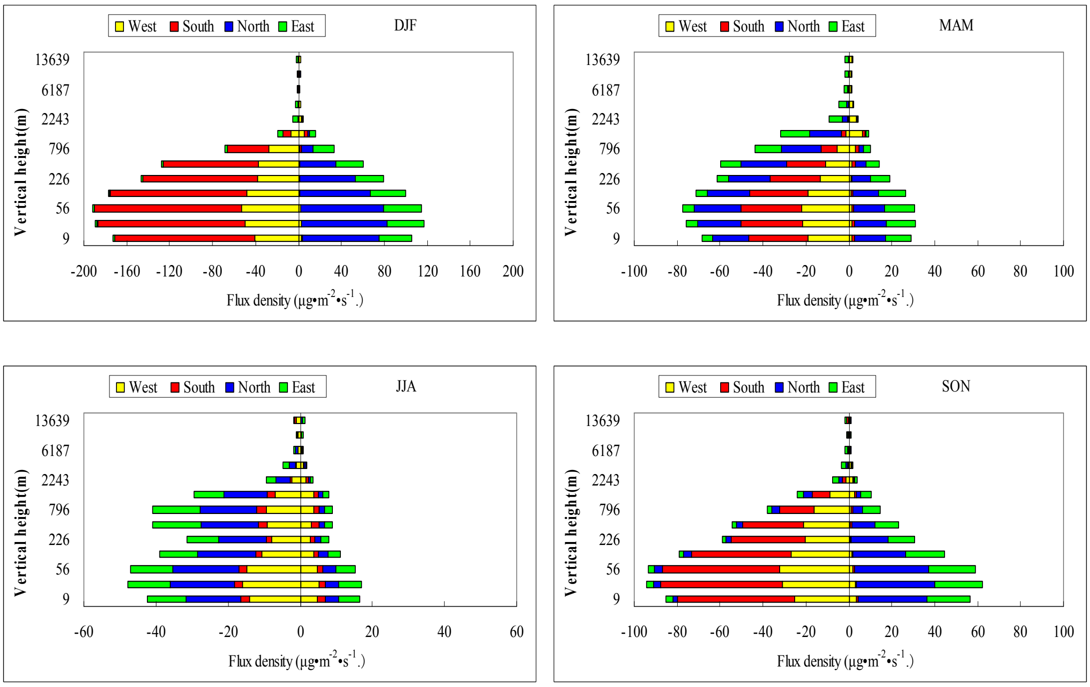


Figure 7 NO_2 horizontal transport flux densities in different vertical layers over PRD

(red: south boundary; yellow: west boundary; blue: north boundary; green: east boundary

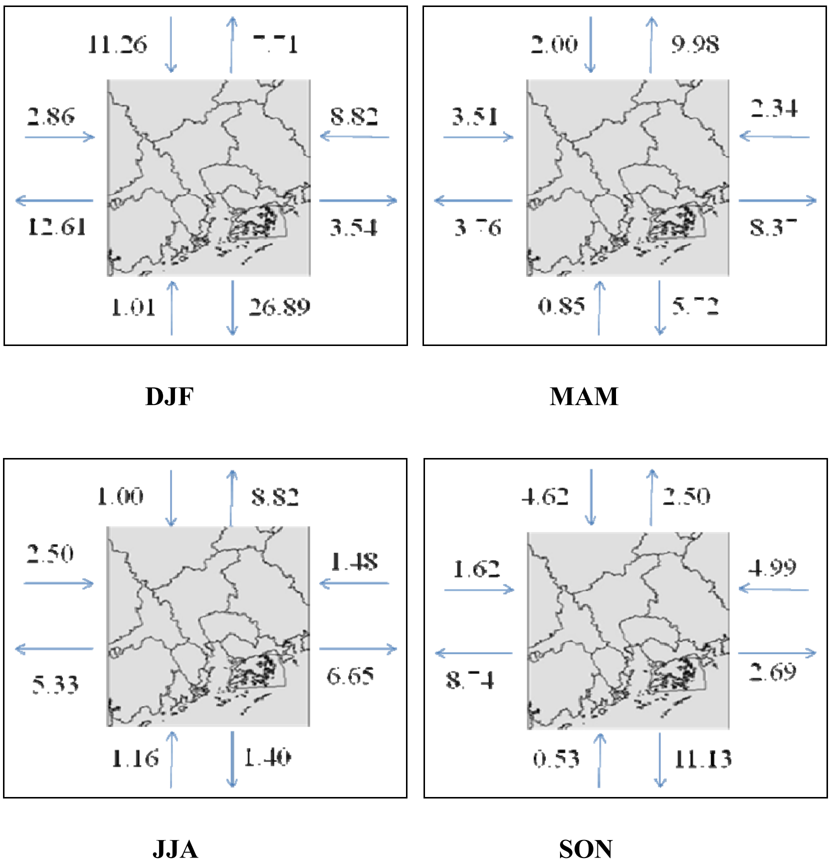


Figure 8 NO_2 flux density of horizontal transport up to 3000m

O_3

The contributions of the emission, chemistry and horizontal import/export processes over all the 13 layers and the deposition in surface layer for the PRD region are summarized in Figure 9. The import and export processes are nearly of the same magnitude as for O_3. Horizontal import serves as a major source process accounting for O_3 accumulation and horizontal export is the major sink process accounting for O_3 loss in this area. The magnitude of deposition process is much smaller than export process. The results present the chemical loss of O_3 in winter and chemical production in other seasons. The chemical process is about 2.8 times of the net transport process.

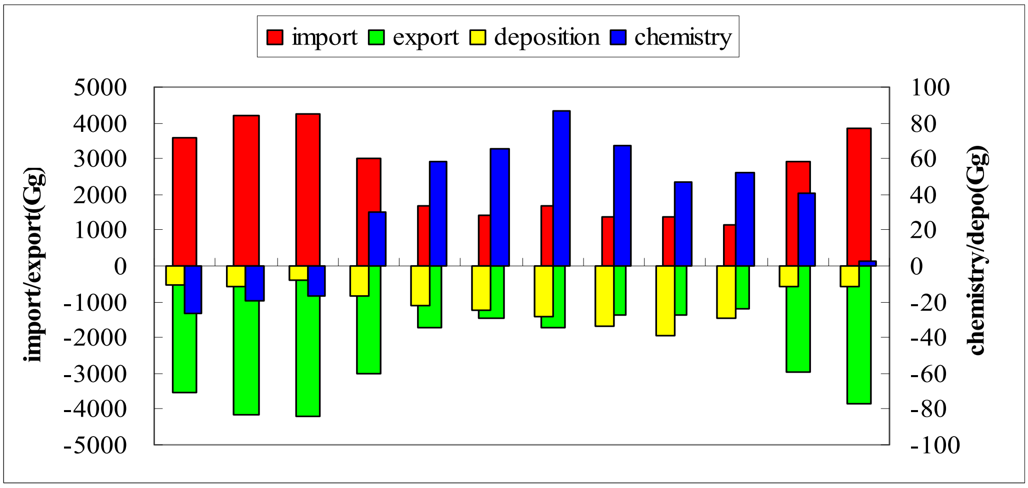


Figure 9 Modeled O_3 budget in PRD region

Figure 10 is the seasonal variation of O_3 horizontal transport flux at different vertical layers in PRD, which shows different horizontal transport pattern from those of NO_2 and SO_2. As a secondary pollutant, significant amount of O_3 is distributed in the free troposphere, where the westerly wind dominates in PRD region except in summer. Strong westerly winds result in significant west import and east export of O_3 at upper layers in PRD.

Figure 11 shows the O_3 flux density of horizontal transport up to 3000m. We can see significant correlation of flux density with the dominant wind direction. Because of higher O_3 concentration in central PRD area, we can see larger export values than import values through all seasons. West boundary import dominates in all year except in autumn due to westerly wind above 1000m.

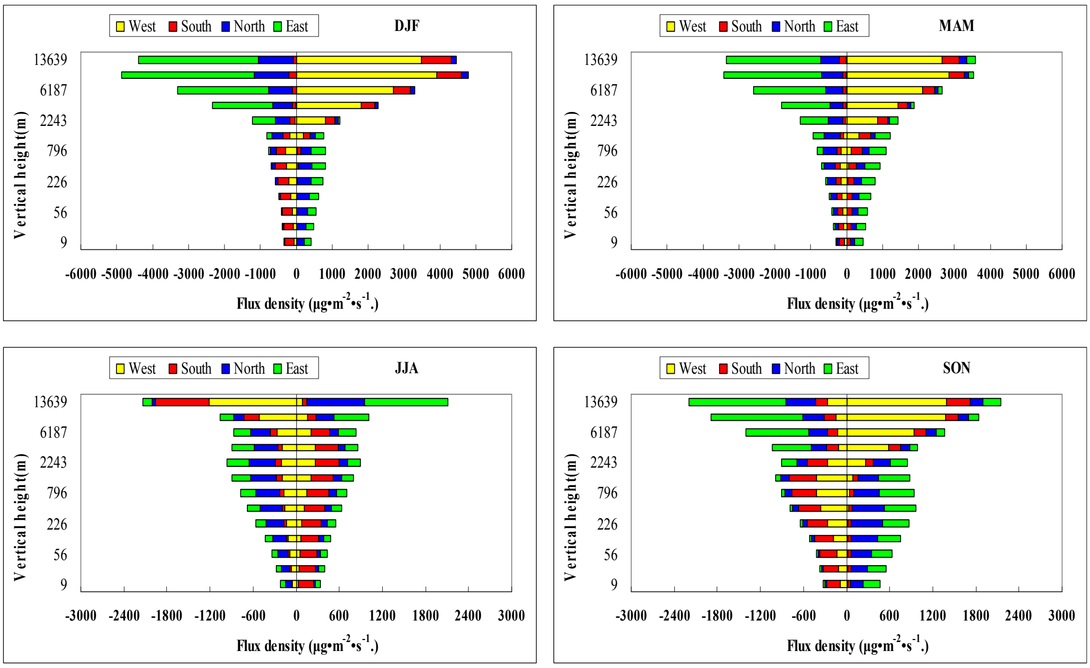


Figure 10 O_3 horizontal transport flux densities in different vertical layers over PRD

(red: south boundary; yellow: west boundary; blue: north boundary; green: east boundary

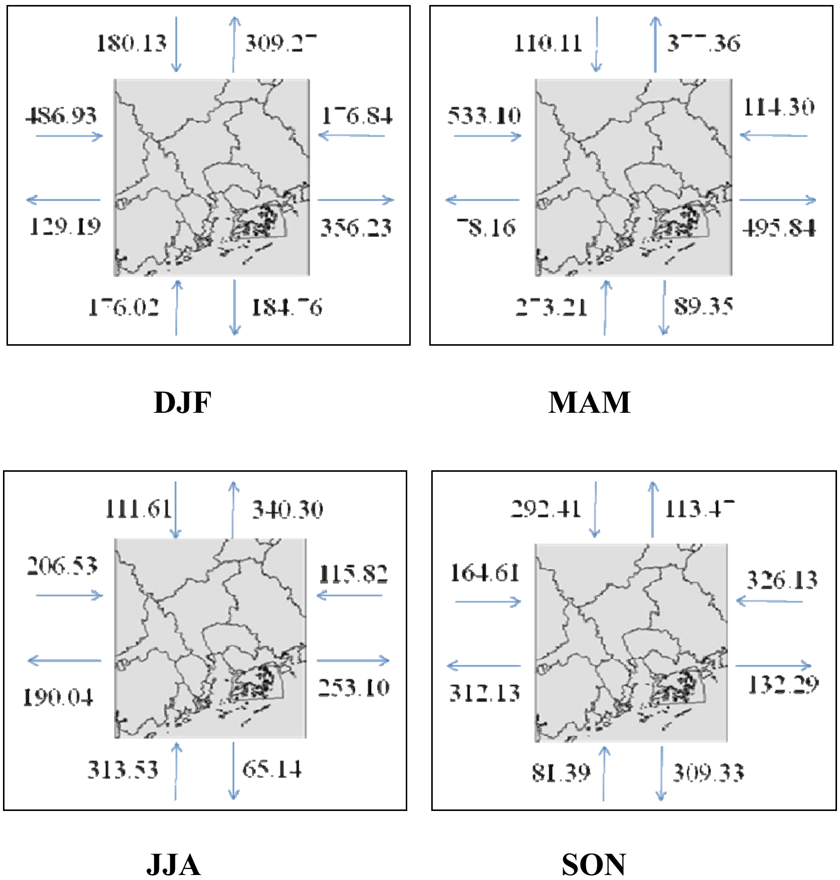


Figure 11 O_3 flux density of horizontal transport up to 3000m

PM_{10}

The emission process, aerosol process, import/export process and deposition process all contribute to the ambient PM_{10} concentration. Figure 12 shows that emission process and import process contribute to ambient PM_{10} accumulation at a similar magnitude. The export process and the deposition process serve as important sinks of $PM_{10.}$ The deposition process is dominant compared to the export process expect in winter when PM_{10} has longer residential time and less deposition. The aerosol production can be expected in all year round.

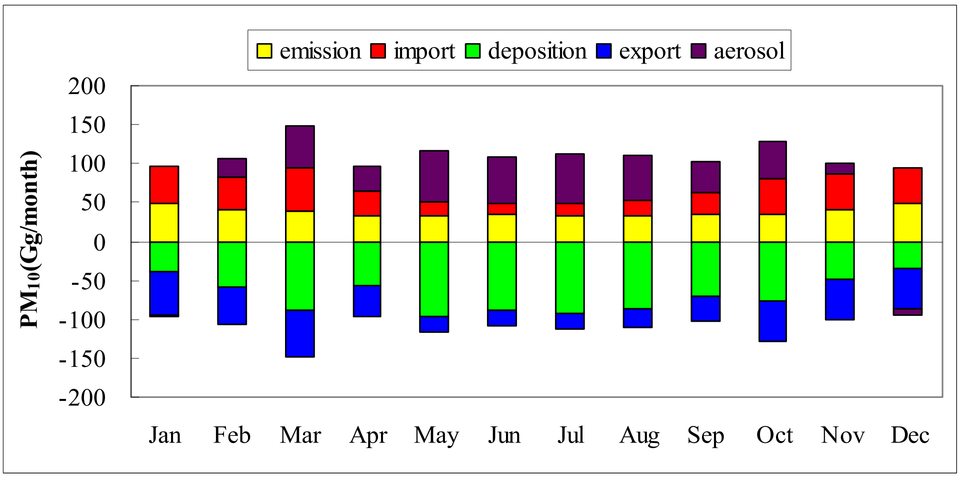


Figure 12 Modeled PM10 budge in PRD region

Figure 13 shows the seasonal variation of PM_{10} horizontal transport at different vertical layers in PRD. PM_{10} has similar horizontal transport pattern as SO_2 and NO_2. The vertical height below 2000m plays a more important role in PM_{10} horizontal transport.

Figure 14 shows the O_3 flux density of horizontal transport up to 3000m. We can see significant correlation of flux density and the dominant wind direction. Because of higher PM_{10} concentration in central PRD area, we can see larger export values than import values through all seasons.

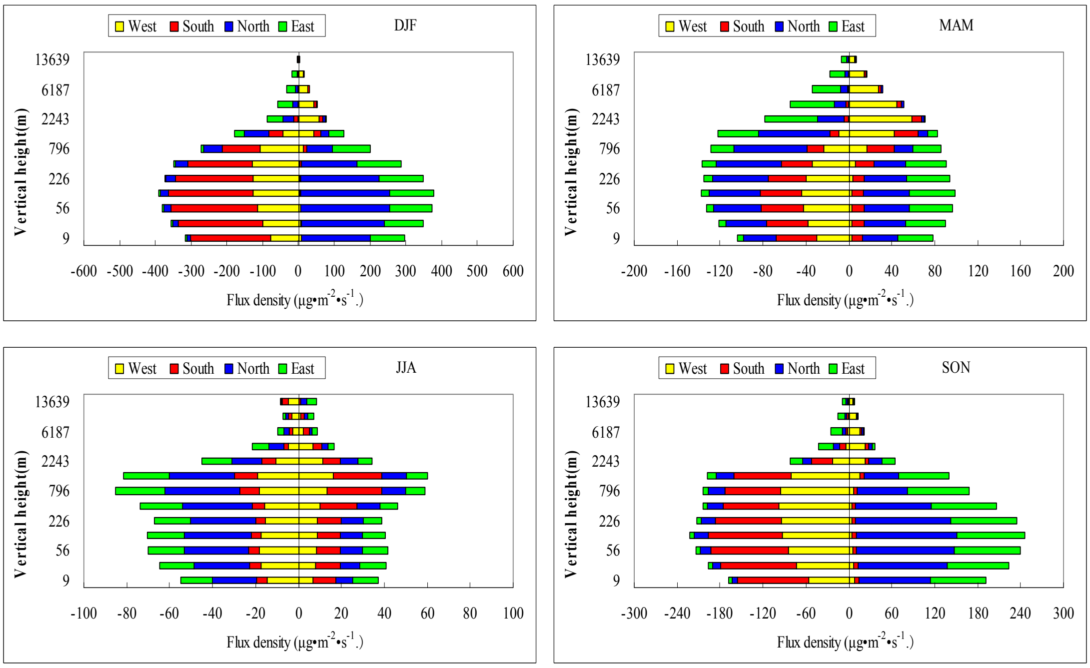


Figure 13 PM_{10} horizontal transport flux densities in different vertical layers over PRD

(red: south boundary; yellow: west boundary; blue: north boundary; green: east boundary

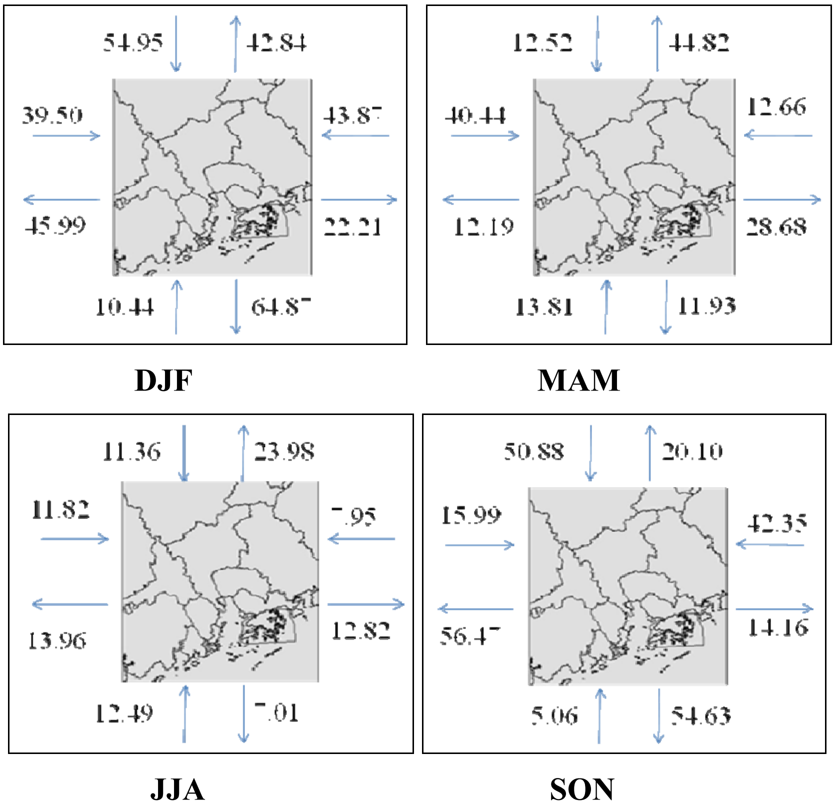


Figure 14 PM_{10} horizontal transport flux densities of different vertical layers in PRD region