

# Satellite-observed variations and trends in carbon monoxide over Asia and their sensitivities to biomass burning

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## Supplement

**Table S1.** Land cover classification on the basis of the ESA CCI Land Cover

|            | Land Cover<br>in this study | ESA CCI Land Cover   |
|------------|-----------------------------|--|
| Resolution | 1° × 1°                     | 300m   |
| Type       | 1: Forest                   | 40: Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)<br>50: Tree cover, broadleaved, evergreen, closed to open (>15%)<br>60: Tree cover, broadleaved, deciduous, closed to open (>15%)<br>61: Tree cover, broadleaved, deciduous, closed (>40%)<br>62: Tree cover, broadleaved, deciduous, open (15-40%)<br>70: Tree cover, needleleaved, evergreen, closed to open (>15%)<br>71: Tree cover, needleleaved, evergreen, closed (>40%)<br>72: Tree cover, needleleaved, evergreen, open (15-40%)<br>80: Tree cover, needleleaved, deciduous, closed to open (>15%)<br>81: Tree cover, needleleaved, deciduous, closed (>40%)<br>82: Tree cover, needleleaved, deciduous, open (15-40%)<br>90: Tree cover, mixed leaf type (broadleaved and needleleaved)<br>100: Mosaic tree and shrub (>50%) / herbaceous cover (<50%)<br>110: Mosaic herbaceous cover (>50%) / tree and shrub (<50%)<br>160: Tree cover, flooded, fresh or brakish water<br>170: Tree cover, flooded, saline water |
|            | 2: Cropland                 | 10: Cropland, rainfed<br>11: Herbaceous cover<br>12: Tree or shrub cover<br>20: Cropland, irrigated or post-flooding<br>30: Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)   |
|            | 3:Shrubland                 | 120: Shrubland<br>121: Evergreen shrubland<br>122: Deciduous shrubland<br>150: Sparse vegetation (tree, shrub, herbaceous cover)   |

|                 |  |
|-----------------|--|
|                 | (<15%)   |
|                 | 151: Sparse tree (<15%)  |
|                 | 152: Sparse shrub (<15%)   |
|                 | 153: Sparse herbaceous cover (<15%)                                    |
|                 | 180: Shrub or herbaceous cover, flooded,<br>fresh/saline/brakish water |
| 4: Grassland    | 130: Grassland   |
| 5: Urban areas  | 190: Urban areas   |
| 6: Water bodies | 210: Water bodies  |
| 7: Others       | 140: Lichens and mosses  |
|                 | 200: Bare areas  |
|                 | 201: Consolidated bare areas   |
|                 | 202: Unconsolidated bare areas   |
|                 | 220: Permanent snow and ice  |

**Table S2.** The trends of AIRS CO total column in Asia, its sub-regions, and the world<sup>1</sup>.

| Regions              | Annual            | Spring            | Summer            | Autumn            | Winter            |
|----------------------|-------------------|-------------------|-------------------|-------------------|-------------------|
| World                | -0.04±0.02        | <b>-0.05±0.02</b> | <b>-0.05±0.02</b> | -0.04±0.03        | -0.00±0.02        |
| Asia                 | -0.05±0.03        | <b>-0.06±0.03</b> | <b>-0.07±0.02</b> | -0.03±0.08        | -0.06±0.03        |
| Asia (land)          | <b>-0.06±0.02</b> | <b>-0.09±0.02</b> | <b>-0.08±0.03</b> | -0.03±0.03        | -0.04±0.02        |
| Asia (Ocean)         | -0.04±0.04        | -0.02±0.03        | <b>-0.05±0.02</b> | -0.02±0.13        | <b>-0.08±0.03</b> |
| South Siberia        | -0.07±0.05        | <b>-0.15±0.02</b> | -0.08±0.06        | -0.01±0.03        | -0.03±0.10        |
| India                | -0.02±0.02        | 0.01±0.03         | <b>-0.05±0.02</b> | -0.01±0.06        | -0.03±0.03        |
| North China          | <b>-0.11±0.02</b> | <b>-0.13±0.03</b> | <b>-0.12±0.04</b> | <b>-0.07±0.03</b> | <b>-0.10±0.03</b> |
| South China          | <b>-0.10±0.02</b> | <b>-0.08±0.03</b> | <b>-0.13±0.02</b> | <b>-0.12±0.05</b> | -0.06±0.04        |
| Sichuan Basin        | <b>-0.08±0.02</b> | <b>-0.07±0.02</b> | <b>-0.11±0.02</b> | <b>-0.07±0.03</b> | <b>-0.07±0.03</b> |
| Indo-China Peninsula | -0.07±0.03        | 0.02±0.04         | <b>-0.10±0.04</b> | -0.12±0.09        | <b>-0.08±0.04</b> |
| Indonesia            | -0.05±0.11        | -0.02±0.07        | -0.06±0.04        | -0.03±0.36        | -0.10±0.06        |

<sup>1</sup> The values are annual mean and seasonal mean averaged over 2003-2017. Numbers in bold indicate that the correlations are statistically significant at the 95% level ( $p < 0.05$ ). Unit:  $10^{17}$  molecules  $\text{cm}^{-2}$  per year

**Table S3.** Correlation coefficients (r) between AIRS CO total column and the number of MODIS fire counts over different land cover and sub-regions in Asia during 2003-2017<sup>1</sup>

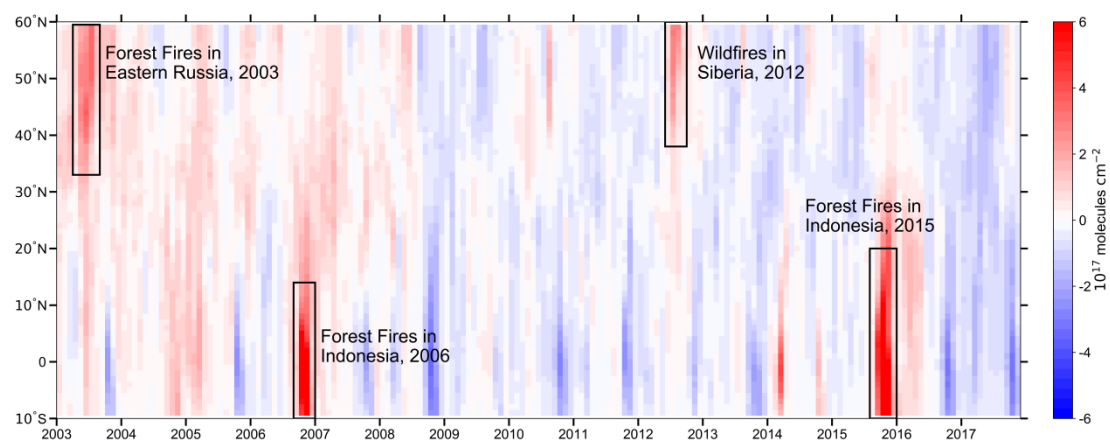
| Regions                     | Land cover | Annual       | Spring       | Summer       | Autumn      | Winter       |
|-----------------------------|------------|--------------|--------------|--------------|-------------|--------------|
| Asia (land)                 | Forest     | <b>0.79</b>  | <b>0.64</b>  | <b>0.75</b>  | <b>0.69</b> | 0.21         |
|                             | Grassland  | <b>0.69</b>  | 0.29         | 0.19         | <b>0.77</b> | <b>-0.60</b> |
|                             | Shrubland  | 0.48         | 0.23         | 0.11         | 0.47        | -0.17        |
|                             | Cropland   | 0.24         | 0.11         | 0.47         | <b>0.76</b> | 0.15         |
| South Siberia               | All        | 0.50         | <b>0.57</b>  | <b>0.71</b>  | -0.09       | -0.09        |
| India                       | All        | -0.44        | 0.23         | <b>0.67</b>  | -0.26       | 0.10         |
| North China                 | All        | -0.32        | <b>-0.71</b> | -0.01        | -0.28       | -0.31        |
| South China                 | All        | 0.24         | 0.10         | -0.37        | 0.34        | -0.04        |
| Sichuan Basin               | All        | <b>-0.54</b> | -0.20        | <b>-0.69</b> | 0.37        | -0.16        |
| Indo-China Peninsula (land) | All        | 0.37         | 0.28         | -0.26        | <b>0.74</b> | <b>0.56</b>  |
| Indonesia                   | All        | <b>0.84</b>  | <b>0.77</b>  | <b>0.75</b>  | <b>0.97</b> | <b>0.56</b>  |

<sup>1</sup> Numbers in bold indicate that the correlations are statistically significant at the 95% level ( $p < 0.05$ ).

**Table S4.** Correlation coefficients (r) between AIRS CO total column and the GFED4 CO emissions from biomass burning over different land covers and sub-regions in Asia during 2003-2017<sup>1</sup>.

| Regions                     | Land cover | Annual       | Spring       | Summer       | Autumn      | Winter       |
|-----------------------------|------------|--------------|--------------|--------------|-------------|--------------|
| Asia (land)                 | Forest     | <b>0.57</b>  | <b>0.60</b>  | <b>0.58</b>  | <b>0.73</b> | 0.34         |
|                             | Grassland  | <b>0.56</b>  | 0.20         | 0.00         | 0.44        | -0.25        |
|                             | Shrubland  | 0.44         | 0.27         | 0.42         | 0.10        | -0.26        |
|                             | Cropland   | 0.10         | -0.05        | 0.03         | <b>0.64</b> | 0.11         |
| South Siberia               | All        | <b>0.52</b>  | <b>0.54</b>  | <b>0.63</b>  | -0.07       | 0.28         |
| India                       | All        | -0.19        | 0.31         | <b>0.61</b>  | 0.18        | 0.10         |
| North China                 | All        | -0.50        | <b>-0.67</b> | -0.31        | -0.26       | -0.49        |
| South China                 | All        | -0.02        | 0.02         | <b>-0.57</b> | 0.29        | 0.05         |
| Sichuan Basin               | All        | <b>-0.79</b> | -0.50        | <b>-0.81</b> | -0.41       | <b>-0.52</b> |
| Indo-China Peninsula (land) | All        | 0.37         | 0.32         | -0.36        | <b>0.58</b> | <b>0.63</b>  |
| Indonesia                   | All        | <b>0.91</b>  | <b>0.77</b>  | <b>0.70</b>  | <b>0.93</b> | <b>0.52</b>  |

<sup>1</sup> Numbers in bold indicate that the correlations are statistically significant at the 95% level ( $p < 0.05$ ).



**Figure S1.** Monthly variations in the anomalies of AIRS CO total column.