**Supplementary Material**

**Investigation of Vertical Wavenumber Spectra during Sudden Stratospheric Warming (SSW) Events over the Indian Region**

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**Table S1-S8** provides the VWN spectral slope values (approx.) of SSW events and their corresponding control days for the years 2003 (Table 1), 2004 (Table 2), 2006 (Table 3), 2008 (Table 4), 2009 (Table 5), 2011 (Table 6), 2013 (Table 7), 2016 (Table 8), respectively. The VWN spectral slope (approximate values) ranges for SSW events: -3.90 to -1.28 (2003), -4.23 to -2.44 (2004), -3.86 to -1.79 (2006), -4.35 to -2.15 (2008), -4.02 to -1.9 (2009), -4.64 to -1.53 (2011), -4.82 to -1.78 (2013), -3.77 to -2.11 (2016). For control days, the VWN spectral slope (approximate values) ranges: -3.16 to -1.81 (2003), -4.68 to -1.83 (2004), -3.72 to -1.96 (2006), -5.64 to -2.38 (2008), -4.85 to -2.08 (2009), -6.74 to -2.03 (2011), -4.84 to -1.53 (2013), -3.60 to -1.53 (2016). It is seen that the VWN slope value is minimum for the year 2013 which matches with the united impact of wavenumber 1 and 2 PWs during 2013 SSW event. The cases where VWN spectral slope values during both SSW events and control days both show lower value are considered to be spurious and are not taken into account for interpretation. Although the spectral slope value during 2011 SSW event is -4.64, it is not considered as the control day spectral slope is -6.74.

**Table S1.** Vertical wavenumber spectral slope (approx.) during 2003 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 6 January 2003 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -2.98 | -3.11 | -3.10 | -2.89 |
| 20-30 | -2.17 | -2.13 | -2.33 | -2.21 |
| 30-40 | -2.36 | -1.28 | -2.21 | -2.61 |
| 40-50 | -2.85 | -3.22 | -3.19 | -3.44 |
| 50-60 | -2.41 | -2.76 | -2.72 | -2.54 |
| 60-70 | -3.90 | -2.57 | -2.24 | -2.91 |
| Control day 4 January 2003 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.04 | -3.04 | -3.16 | -3.03 |
| 20-30 | -2.54 | -2.41 | -2.26 | -2.52 |
| 30-40 | -2.65 | -2.46 | -2.01 | -2.68 |
| 40-50 | -2.99 | -1.81 | -2.71 | -2.40 |
| 50-60 | -2.02 | -2.37 | -2.74 | -2.56 |
| 60-70 | -2.68 | -2.67 | -1.04 | -3.04 |

**Table S2.** Vertical wavenumber spectral slope (approx.) during 2004 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 15 February 2004 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.14 | -3.15 | -2.99 | -2.93 |
| 20-30 | -2.51 | -2.82 | -2.44 | -2.60 |
| 30-40 | -2.62 | -2.35 | -2.49 | -2.62 |
| 40-50 | -2.78 | -2.98 | -3.35 | -4.23 |
| 50-60 | -3.15 | -2.66 | -2.68 | -2.92 |
| 60-70 | -3.02 | -2.53 | -2.56 | -2.98 |
| Control day 28 February 2004 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.04 | -3.06 | -3.03 | -2.93 |
| 20-30 | -2.54 | -2.79 | -2.34 | -2.50 |
| 30-40 | -2.65 | -2.70 | -2.64 | -2.23 |
| 40-50 | -2.99 | -1.83 | -4.68 | -3.66 |
| 50-60 | -2.02 | -3.19 | -2.43 | -2.71 |
| 60-70 | -2.68 | -3.36 | -2.30 | -2.83 |

**Table S3.** Vertical wavenumber spectral slope (approx.) during 2006 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 24 January 2006 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -2.90 | -3.13 | -3.09 | -3.00 |
| 20-30 | -2.31 | -2.42 | -2.05 | -1.79 |
| 30-40 | -2.43 | -2.50 | -2.67 | -2.70 |
| 40-50 | -2.45 | -2.83 | -3.75 | -3.86 |
| 50-60 | -3.26 | -2.81 | -2.32 | -2.69 |
| 60-70 | -3.07 | -2.57 | -1.99 | -2.11 |
| Control day 12 January 2006 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.23 | -3.22 | -3.03 | -2.92 |
| 20-30 | -2.64 | -2.42 | -2.56 | -1.96 |
| 30-40 | -3.05 | -3.10 | -2.79 | -2.51 |
| 40-50 | -2.33 | -3.11 | -2.67 | -3.72 |
| 50-60 | -2.77 | -3.33 | -2.97 | -2.17 |
| 60-70 | -2.59 | -2.65 | -3.06 | -2.53 |

**Table S4.** Vertical wavenumber spectral slope (approx.) during 2008 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 26 February 2008 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.09 | -3.19 | -3.14 | -2.98 |
| 20-30 | -2.54 | -2.48 | -2.42 | -2.16 |
| 30-40 | -2.78 | -2.83 | -2.59 | -2.50 |
| 40-50 | -3.28 | -2.44 | -4.35 | -3.42 |
| 50-60 | -2.83 | -2.65 | -2.70 | -3.05 |
| 60-70 | -2.15 | -2.15 | -3.50 | -2.27 |
| Control day 7 February 2008 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.24 | -3.33 | -3.22 | -2.83 |
| 20-30 | -2.84 | -2.69 | -2.58 | -2.38 |
| 30-40 | -2.97 | -3.05 | -2.73 | -2.72 |
| 40-50 | -3.03 | -3.65 | -5.64 | -4.41 |
| 50-60 | -2.62 | -2.74 | -5.36 | -4.49 |
| 60-70 | -3.46 | -3.35 | -2.77 | -2.79 |

**Table S5.** Vertical wavenumber spectral slope (approx.) during 2009 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 16 February 2009 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.05 | -3.06 | -3.02 | -2.97 |
| 20-30 | -2.42 | -2.60 | -2.69 | -2.43 |
| 30-40 | -2.19 | -2.41 | -2.80 | -2.62 |
| 40-50 | -2.42 | -2.45 | -3.14 | -4.02 |
| 50-60 | -3.27 | -3.12 | -2.85 | -1.90 |
| 60-70 | -2.51 | -2.66 | -3.04 | -2.62 |
| Control day 7 February 2009 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.05 | -3.18 | -3.14 | -3.03 |
| 20-30 | -2.56 | -2.42 | -2.43 | -2.88 |
| 30-40 | -2.81 | -2.24 | -2.32 | -4.28 |
| 40-50 | -3.62 | -3.22 | -4.85 | -3.21 |
| 50-60 | -2.68 | -2.66 | -3.09 | -2.08 |
| 60-70 | -2.44 | -2.13 | -2.96 | -3.71 |

**Table S6.** Vertical wavenumber spectral slope (approx.) during 2011 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 28 December 2011 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.04 | -3.06 | -2.94 | -2.95 |
| 20-30 | -2.19 | -2.14 | -2.24 | -2.67 |
| 30-40 | -2.25 | -2.32 | -2.41 | -1.53 |
| 40-50 | -2.93 | -3.27 | -3.74 | -3.92 |
| 50-60 | -2.55 | -3.06 | -1.82 | -2.90 |
| 60-70 | -4.64 | -1.91 | -2.74 | -2.93 |
| Control day 26 December 2011 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.02 | -3.09 | -3.10 | -3.18 |
| 20-30 | -2.54 | -2.37 | -2.73 | -2.96 |
| 30-40 | -2.03 | -2.12 | -2.32 | -3.20 |
| 40-50 | -2.65 | -3.27 | -3.26 | -4.05 |
| 50-60 | -2.19 | -2.95 | -2.95 | -2.46 |
| 60-70 | -2.37 | -3.50 | -6.74 | -2.27 |

**Table S7.** Vertical wavenumber spectral slope (approx.) during 2013 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 26 January 2013 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.06 | -3.16 | -3.09 | -2.89 |
| 20-30 | -2.56 | -2.75 | -2.31 | -2.50 |
| 30-40 | -2.52 | -2.62 | -2.71 | -2.93 |
| 40-50 | -2.74 | -2.03 | -4.82 | -4.41 |
| 50-60 | -3.34 | -3.49 | -1.78 | -2.38 |
| 60-70 | -2.53 | -2.78 | -1.94 | -1.86 |
| Control day 8 January 2013 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.00 | -3.19 | -3.25 | -3.06 |
| 20-30 | -2.65 | -2.80 | -3.19 | -3.05 |
| 30-40 | -2.31 | -2.47 | -3.53 | -3.28 |
| 40-50 | -2.70 | -2.71 | -4.84 | -3.21 |
| 50-60 | -2.84 | -3.07 | -2.81 | -1.53 |
| 60-70 | -3.03 | -2.53 | -2.80 | -2.32 |

**Table S8.** Vertical wavenumber spectral slope (approx.) during 2016 SSW event and control day

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SSW event day 27 October 2016 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.06 | -3.07 | -3.06 | -3.16 |
| 20-30 | -2.11 | -2.26 | -2.73 | -2.98 |
| 30-40 | -2.58 | -2.74 | -3.07 | -3.27 |
| 40-50 | -3.42 | -3.43 | -2.48 | -3.77 |
| 50-60 | -2.75 | -2.38 | -3.16 | -2.50 |
| 60-70 | -2.97 | -2.79 | -2.59 | -2.53 |
| Control day 1 October 2016 | | | | |
| Altitude Range (km) | Location 1 (5º N, 77º E) | Location 2 (15º N, 77º E) | Location 3 (25º N, 77º E) | Location 4 (35º N, 77º E) |
| 0.1-20 | -3.07 | -3.15 | -3.07 | -3.09 |
| 20-30 | -2.54 | -2.68 | -2.68 | -2.49 |
| 30-40 | -2.78 | -1.75 | -2.29 | -2.37 |
| 40-50 | -2.83 | -3.60 | -2.99 | -2.84 |
| 50-60 | -2.58 | -2.57 | -1.78 | -1.53 |
| 60-70 | -1.96 | -2.73 | -2.58 | -2.33 |

The figures S9- S16 depict the selection of SSW event day and common control day for the years 2003, 2004, 2006, 2008, 2009, 2011, 2013 and 2016 respectively.



Figure S9. An illustration for selection of SSW event day and common control days (well outside the event) for the year 2003.



Figure S10. Same as Figure S9 but for the year 2004.



Figure S11. Same as Figure S9 but for the year 2006.

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Figure S12. Same as Figure S9 but for the year 2008.



Figure S13. Same as Figure S9 but for the year 2009.



Figure S14. Same as Figure S9 but for the year 2011.



Figure S15. Same as Figure S9 but for the year 2013.



Figure S16. Same as Figure S9 but for the year 2016.