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# Identification of Self-Organized Criticality in Atmospheric Total Ozone Variability

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Long-range spatiotemporal correlations manifested as the self-similar fractal geometry to the spatial pattern concomitant with inverse power law form for the power spectrum of temporal fluctuations is ubiquitous to real world dynamical systems and is recently identified as signature of self-organized criticality [P.Bak, C.Tang and K.Wiesenfeld, Phys, Rev. A38(1988) 364]. Self-organized criticality in atmospheric flows is exhibited as the fractal geometry to the global cloud cover pattern and the inverse power law form for the atmospheric eddy energy spectrum documented by Lovejoy and Schertzer [Bull. Amer. Meteorol.Soc. 67 (1988) 21]. In this paper a recently developed cell dynamical system model for atmospheric flows [A.Mary Selvam, Can. J. Phys. 68 (1990) 831; Int'l J. Climatol. (1991-in press)] is summarized. The model predicts inverse power law form of the statistical normal distribution for atmospheric eddy energy spectrum as a natural consequence of quantum-like mechanics governing atmospheric flows extending up to stratospheric levels and above [P.Mehra,A.M.Selvam and A.S.R.Murty, Adv. Atmos. Sci. 6 (2) (1988) 217]. Model prediction are in agreement with continuous periodogram analysis [A.F.Jenkinson, Met O 13 Branch Memorandum No.57 (1977)] of 30 time series consisting of sets of twenty to hundred daily or up to 14 days non-overlapping averages of total ozone content at 19 globally representative stations. Periodogram estimates of dominant periodicities are given in Table 1 and the corresponding power spectra are plotted in Figure 1 as cumulative percentage contribution to total variance (continuous line) versus the normalised standard deviation t equal to [log $\lambda$/log $T_{50}$)-1] where $\lambda$ is the period in days and $T_{50}$ the period up to which the cumulative percentage contri-bution to total variance is equal to 50. The corresponding statistical normal distri-bution is plotted as crosses in Fig.1. The short horizontal lines indicate the level above which the spectra are the same as the normal distribution as determined by the chi-square test at 95% confidence level.

The important results of the present study are as follows. Atmospheric total ozone variability (in days) exhibits the temporal signature of self-organized criticality, namely inverse power law form for the power spectrum. Further, the long-range temporal correlations implicit to self-organized criticality can be quantified in terms of the universal characteristics of the normal distribution. Therefore, the total pattern of fluctuations of total ozone over a period of time is predictable.

Table 1: Periodogram estimates for total ozone

| Sr. No. | Station (Lat Long) (Degrees) | Time series length | Period From | Period To | Periodicities (days) contributing to maximum normalised variance (H) in the wave band H>=1 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Pechora<br>(65.07N 57.96E) | 50(2) | 1 Mar 88 | 8 Jun 88 | 7.9 | 8.9 | 10.7 | 14.2 | 24.7 | 85.3 |
| 2. | Pechora * | 50(2) | 9 Jun 88 | 16 Sep 88 | 4.0 | 11.0 | 13.9 | 20.2 | 27.1 | 55.9 |
| 3. | Voronez *<br>(51.40N 39.35E) | 20(6) | 25 Aug 88 | 22 Dec 88 | 26.8 | 36.3 | - | - | - | - |
| 4. | Semipalatinsk<br>(50.2N 80.15E) | 25(1) | 1 Apr 88 | 25 Apr 88 | 3.7 | 8.9 | 17.1 | - | - | - |
| 5. | Karaganda<br>(49.0N 74.72E) | 20(2) | 5 Sep 88 | 14 Oct 88 | 4.0 | 12.2 | - | - | - | - |
| 6. | Alma-Ata<br>(43.14N 76.56E) | 20(5) | 31 May 88 | 7 Sep 88 | 18.0 | 25.4 | 37.3 | - | - | - |
| 7. | Cardzou<br>(39.10N 63.30E) | 20(14) | 1 Mar 88 | 6 Dec 88 | 51.3 | 66.2 | 90.7 | - | - | - |
| 8. | Dushanbe<br>(38.35N 68.47E) | 20(8) | 1 Apr 88 | 7 Sep 88 | 28.6 | 53.7 | - | - | - | - |
| 9. | Dushanbe | 20(12) | 1 Apr 88 | 26 Nov 88 | 28.6 | 38.0 | 47.8 | 63.3 | - | - |
| 10. | Dushanbe | 20(9) | 9 Jul 88 | 26 Dec 88 | 24.5 | 29.2 | 53.1 | 82.2 | - | . |
| 11. | Cairo<br>(30.02N 31.15E) | 20(9) | 1 Jan 89 | 1 May 89 | 12.9 | 19.9 | 27.3 | - | - | - |

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|---|---|---|---|---|---|---|---|---|---|
| 12. Cairo | 20(6) | 1 Mar 90 | 28 Jun 90 | 12.4 | 14.4 | 19.5 | 24.9 | 58.1 | - |
| 13. Aswan | 25(3) | 31 May 89 | 13 Sep 89 | 6.0 | 6.8 | 8.6 | 15.1 | 20.8 | 59.3 |
| (24.05N 32.57E) |  |  |  |  |  |  |  |  |  |
| 14. Poona * | 25(2) | 1 Jan 88 | 19 Feb 88 | 4.5 | 5.2 | 8.3 | 42.1 | - | - |
| (18.32N 73.51E) |  |  |  |  |  |  |  |  |  |
| 15. Poona | 20(3) | 31 Dec 88 | 28 Feb 89 | 7.3 | 8.5 | 10.4 | 13.4 | 11.8 | 18.8 |
|  |  |  |  | 26.5 | - | - | - | - | - |
| 16. Bangkok * | 25(4) | 1 Jan 88 | 9 Apr 88 | 8.4 | 9.7 | 11.4 | 13.5 | 23.5 | - |
| (13.44N 100.30E) |  |  |  |  |  |  |  |  |  |
| 17. Bangkok | 20(6) | 24 Apr 88 | 27 Aug 88 | 15.5 | 18.5 | 30.1 | 117.8 | - | - |
| 18. Bangkok * | 20(5) | 6 May 89 | 3 Aug 89 | 10.0 | 12.7 | 14.7 | 53.3 | - | - |
| 19. Reykjavik | 25(1) | 1 Jul 88 | 19 Apr 88 | 3.1 | 3.6 | 5.6 | - | - | - |
| 20. Edmonton | 100(2) | 1 Jan 87 | 19 Jul 87 | 4.0 | 4.8 | 6.7 | 7.3 | 9.7 | 10.5 |
| (53.35N 21.30W) |  |  |  | 13.4 | 17.1 | 30.7 | 40.9 | 91.3 | - |
| 21. Edmonton | 65(3) | 1 Jan 87 | 14 Jul 87 | 6.6 | 9.1 | 9.7 | 13.8 | 20.4 | 30.4 |
|  |  |  |  | 42.4 | - | - | - | - | - |
| 22. Goose | 75(1) | 15 May 87 | 28 Jul 87 | 2.3 | 3.1 | 3.4 | 4.0 | 5.8 | 7.7 |
| (53.19N 60.23W) |  |  |  | 8.8 | 10.2 | 12.4 | 16.1 | 35.4 | - |
| 23. Goose * | 100(2) | 26 Dec 87 | 12 Jul 88 | 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 6.0 |
|  |  |  |  | 7.3 | 10.0 | 11.2 | 13.2 | 14.3 | 15.6 |
|  |  |  |  | 15.6 | 17.6 | 19.8 | 23.2 | 41.5 | 57.6 |
| 24. Goose | 20(6) | 24 Feb 88 | 23 Jun 88 | 39.4 | 64.1 | - | - | - | - |
| 25. Fresno * | 50(1) | 20 Jun 88 | 8 Aug 88 | 2.6 | 3.1 | 3.5 | 4.7 | 6.7 | 7.9 |
| (36.50N 120.50W) |  |  |  | 9.6 | 12.1 | 17.0 | 30.8 | - | - |
| 26. Fresno | 30(5) | 1 Jun 89 | 28 Sep 89 | 20.0 | 24.9 | 31.9 | 43.7 | 69.7 | - |
| 27. Hobart * | 100(1) | 1 Mar 88 | 8 Jun 88 | 2.2 | 2.8 | 2.9 | 3.0 | 3.2 | 3.5 |
| (42.53S 147.21E) |  |  |  | 3.5 | 4.5 | 5.2 | 8.7 | 9.8 | 19.8 |
|  |  |  |  | 40.9 | - | - | - | - | - |
| 28. Perth | 20(2) | 1 Apr 90 | 10 May 90 | 12.3 | - | - | - | - | - |
| (32.00S 115.57E) |  |  |  |  |  |  |  |  |  |
| 29. Brisbane | 40(3) | 1 Jul 88 | 28 Oct 88 | 6.5 | 8.9 | 10.4 | 11.9 | 28.0 | 40.4 |
| (27.30S 153.00E) |  |  |  |  |  |  |  |  |  |
| 30. Nairobi | 20(3) | 31 Mar 89 | 29 May 89 | 8.6 | 11.8 | 19.1 | 32.5 | - | - |
| (01.18S 36.52E) |  |  |  |  |  |  |  |  |  |

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std. dev.: standard deviation of the time series.

* denotes that the data series is not distributed normally.