



a, Eigenvalues of the time-lag covariance matrix from the detrended IPCC global temperature anomaly record over the period 1885–1993. The first two eigenvalues extend appreciably above the so-called noise floor and correspond to eigenvectors (insert) exhibiting an oscillation of 60–70 years. b, Eigenvalues of the time-lag covariance matrix from a detrended time series of equal length to the IPCC record and generated from a red-noise stochastic process (see text). As in a, the first two eigenvalues are appreciably above the others and correspond to eigenvectors (insert) exhibiting an oscillation of 60–70 yr. c, Eigenvalues of the time-lag covariance matrix from a detrended red-noise time series of length twice that of the record used in b (272 values). As before, there are two outstanding eigenvalues corresponding to eigenvectors with periodicities of half the record length (insert).

considered to represent deterministic components, whereas all others are assumed to correspond to random processes. As shown below, however, the situation is not always so simple.

The figure (b) shows the eigenvalues and eigenvectors from a detrended time series generated from a stochastic process $X(t + 1) = \alpha X(t) + \epsilon(t)$ (first-order linear Markov process) and having the same length of 136 values, where $\epsilon(t)$ is white noise and α the lag-1 autocorrelation of the IPCC temperature record. Signals generated in this manner are simple autocorrelated (AR(1)) noise containing no deterministic oscillations.

We observe that b is almost identical to a, indicating that the very low-frequency periodicity of 65–70 years in the IPCC record can arise naturally from the simplest of stochastic processes. The eigenvalues and eigenvector for the same stochastic process but of length 272 (twice the length of the original record) are shown in c. Again we observe two eigenvalues that stand above the rest, and that correspond to eigenvectors with periods commensurate with M. Such spurious periodicities indicate that caution must be used in interpreting eigenvalues associated with low-frequency modes as they may be an artefact of SSA; a proper statistical evaluation must always accompany any evaluation of suspected oscillations in data. Our result suggests that the common practice used in spatial eigenvector analysis of attributing the most significance to the first several eigenvalues is erroneous when applying the SSA.

By decomposing 1,000 detrended AR(1) time series (surrogates) of length 136 and using the same alpha as the original record, we find that the 99%/1% confidence band overlaps the first two eigenvalues obtained from the data. These results do not change if alpha is taken from the detrended IPCC record. Although explaining the largest percentage of

variance in the temperature record, these first two eigenmodes (eigenvalue/eigenvector pairs) are clearly indistinguishable from low-frequency eigenmodes of the simplest autocorrelated noise. We note that our confidence limits, obtained by using the eigenvectors of each surrogate series as basis functions (that is, each surrogate has a different set of basis functions), are very similar to the confidence bands obtained by using a fixed, single set of basis functions from the original record⁵. We speculate that the reason for this similarity is that the eigenvectors from the data are not necessarily a better estimate of the population eigenvectors than are the eigenvectors obtained from the surrogates. Indeed, when a bootstrap procedure is applied to the time series residuals (assuming an AR(1) process), we find large error variances for the eigenvector components suggesting that either method of computing confidence limits is appropriate at least for this record.

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SCHLESINGER AND RAMANKUTTY REPLY — We have used our physical climate/ocean model and four statistical autoregressive models to simulate the response of the climate system to white-noise forcing, for both the globe and the North Atlantic⁶. Each of the five models is run 1,000 times for the 135 years' duration of the observed global mean temperature record and for the 137 years' duration of the observed North Atlantic temperature record. Singular spectrum analysis (SSA) is performed on the 10,000 simulations after each is linearly detrended.

For the global mean temperature, all the statistical models show statistical significance greater than 89.1%, and the physical model shows a statistical significance greater than 33.5%. For the North Atlantic temperature, all the statistical models show statistical significance greater than 91.3%, and the physical model shows a statistical significance greater than 98.6%. Consequently, the hypothesis that the North Atlantic temperature oscillation is due to climatic noise can be rejected at a very high level of statistical confidence. This hypothesis applied to the oscillation in global mean temperatures can be rejected at a lower level of statistical confidence, this as a consequence of the oscillation not existing everywhere over the Earth¹.

Our results and conclusion differ from those of Elsner and Tsonis because we determine the variance of the white-noise forcing for the physical and statistical models, together with the autoregressive coefficients for the latter, from the observed surface temperature record after removal of the temperature changes contributed by increasing greenhouse gases and anthropogenic sulphate aerosols, that is, after detrending. Elsner and Tsonis determine the white-noise variance and autoregressive coefficient for their statistical model from the nondetrended observed temperature record. Thus, they assume that all temperature changes observed since the middle of the nineteenth century are due to natural variability, whereas we assume that only the temperature changes other than those forced by greenhouse gases and anthropogenic sulphate aerosols are due to natural variability. Their assumption means that, unless the anthropogenic forcing of the climate system has been zero year after year, the sensitivity of the

climate system is zero. Although this would mean that there is no global-warming problem, it is not consistent with the varied palaeoclimatic history of the Earth.

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Glutamatergic signals in *Ephedra*

SIR — Plants frequently synthesize toxic non-protein amino acids that disrupt amino-acid transport, metabolism and protein synthesis in leaf- and seed-eating mammals and insects^{1,2}. *Ephedra foeminea* Forssk. (Ephedraceae, Gnetales), the joint-fir, widely distributed in the eastern Mediterranean and the near East³, contains in its fresh stems substantial amounts of the two *cis*-diastereoisomers of the L-glutamate analogue L-2-carboxycyclopropyl glycine, (2*S*, 3*S*, 4*R*)- and (2*S*, 3*R*, 4*S*)-2-(carboxycyclopropyl) glycine (L-CCGIII and L-CCGIV, respectively)⁴. These two compounds, which constitute about 1% of the stem dry weight in this and a related Mediterranean species, *E. altissima* (see table), are rare. L-CCGIII has been reported⁵ in a few North American species of *Aesculus* (the buckeyes). The presence of L-CCGIV in plants has not been reported before. The stem tissue of *E. foeminea* also contains *cis*-3,4-methano-L-proline, a cyclopropane amino acid previously reported only in *Aesculus parviflora*⁶.

Because L-glutamate is central to

amino-acid metabolism and is a neurotransmitter molecule in vertebrates and arthropods, ingestion of L-2-(carboxycyclopropyl)glycines might alter herbivore behaviour. We tested the membrane activity of three L-CCG isomers on two insect tissues *in vitro*. A Na⁺-dependent glutamate transporter in the beetle epidermis⁷ concentrated both *cis*-isomers, whereas L-CCGIII and L-CCGI (the *trans*-2*S*, 3*S*, 4*S*-isomer found in *Blighia sapida*⁸) caused a cockroach hindgut preparation⁹ to contract. In mammalian neurons, L-CCGIII potentiates responsiveness to L-glutamate⁹ and L-CCGIV activates the N-methyl D-aspartate (NMDA) subtype of the L-glutamate receptor¹⁰.

The stems of many *Ephedra* species also contain substantial amounts of a quinoline, 6-hydroxykynurenic acid (6-HKYNA), known to occur in trace amounts in many plants¹¹. In *Ginkgo biloba*, a primitive tree notably free of insect pests, however, it may constitute 0.24% of the leaf dry weight¹². Similar amounts are seen in *Ephedra* (see table). In the mammalian brain, substituted

kynurenic acids are selective antagonists competing with glycine for binding sites on NMDA and non-NMDA glutamate receptors¹³. 6-HKYNA, however, had no activity on the hindgut, whether applied alone or together with glutamate or quisqualate, suggesting that 6-substituted kynurenic acids are not glutamate receptor antagonists in insect visceral muscle. 7-Methoxykynurenic acid, reported to occur in *E. alata*¹⁴, is not a glutamate receptor antagonist in mammalian neurons¹³.

Most Eurasian species of *Ephedra*, such as *E. distachya* and *E. fragilis*, contain the sympathomimetic drugs ephedrine, pseudoephedrine and pharmacologically related amines¹⁵. Ephedrine in the diet is toxic to the pea weevil². The ephedrine alkaloids and the tannins present in the stems of most Eurasian species are absent from *E. foeminea*, *E. altissima* and *E. foliata* (see table). As methanoproline, too, is restricted to tannin- and ephedrine-free species, we propose that cyclopropyl amino acids act as an alternative form of feeding deterrent. A possible reason why some *Ephedra* species are tannin-free may be that tannins block Na⁺-dependent amino-acid transport, compromising the defensive role of ingested cyclopropyl amino acids. The ephedrine alkaloids found in many *Ephedra* species containing tannins are non-polar and do not need special transporter proteins for their absorption. It is remarkable that, despite the more than 100 papers published over the past 100 years or so on the alkaloid content of *Ephedra*, the presence of cyclopropyl amino acids and 6-hydroxykynurenic acid has previously gone undetected.

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CYCLOPROPYL AMINO ACIDS, 6-HYDROXYKYNURENIC ACID AND EPHEDRINE ALKALOIDS, AND PRESENCE OF TANNINS IN THE FRESH STEMS OF SELECTED *EPHEDRA* SPECIES

| Species | L-CCGIII | L-CCGIV | Methano-proline | 6-Hydroxy-kynurenic acid | Ephedrine | Pseudo-ephedrine | Tannins |
|---------------------|----------|---------|-----------------|--------------------------|-----------|------------------|---------|
| <i>E. foeminea</i> | ++++ | +++ | ++ | +++ | — | — | no |
| <i>E. altissima</i> | ++++ | +++ | — | ++ | — | + | no |
| <i>E. foliata</i> | — | — | ++ | +++ | — | + | no |
| <i>E. fragilis</i> | ++ | — | — | ++ | ++++ | — | yes |
| <i>E. distachya</i> | — | — | — | ++ | — | ++++ | yes |

Amounts of amino acids and alkaloids are expressed as per cent dry tissue weight: (—), not detected; (+), < 0.05 %; (++) , 0.05–0.19%; (+++) , 0.2–0.5%; (++++), > 0.5%.