German Bight storms analysed

SIR — In the debate concerning climate change due to increasing emissions of radiatively active gases into the atmosphere, many people are concerned about the possibility of an intensification of extratropical storms. Even though the International Panel on Climate Change[1] took a cautious stand in this matter because of lack of evidence, a mixture of indirect evidence and misleading scientific statements has created substantial unease in the public.

Reports have been presented to the North Sea offshore oil industry about extreme waves, higher than ever previously observed. Two workshops "Climate Trends and Future Offshore Design and Operation Criteria" in Reykjavik (29–30 March 1993) and Bergen (30 November–1 December 1992) were held in which the Norwegian Weather Service brought together people from the oil industry, certifying agencies and scientists to discuss whether the wave and storm climate is in fact worsening. No definitive answers emerged — it is not possible to tell whether the extremes had become worse or if reporting systems have improved. The insurance industry has organized meetings with scientists because of the increased number of claims for storm-related damage. Newspapers in northern Europe were full of speculation about the enhanced threat of extratropical storms in the early part of 1993.

To ascertain whether the storminess really had worsened, a systematic analysis was begun at the Seewetteramt Hamburg. Identification of a trend in climatic data requires long and homogeneous time series, but homogeneous daily time series of wind for studying extreme events are rarely available because of changing procedures in observing, reporting or analysing the wind. The geostrophic wind (blowing parallel to isobars and representing the first-order approximation of the real wind) computed from pressure readings from a few stations can be regarded as a proxy for the real wind. From this model, annual frequency distributions of daily wind can be obtained for periods of 100 and more years. Any trend in the wind statistics will be reflected in these geostrophic wind statistics.

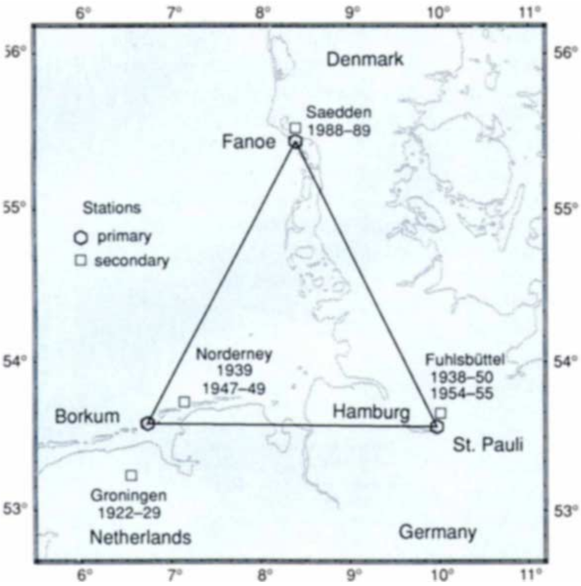

FIG. 1 Location of the meteorological stations from which pressure readings have been used to estimate geostrophic wind speed in the German Bight from 1876 to 1989.

We applied this approach to the German Bight, in the southeast part of the North Sea, where three stations have reported air pressure since 1876 (Fig. 1). The resulting time series of the 1, 10 and 50% percentiles of the annual distributions of geostrophic wind speeds (Fig. 2) stayed remarkably stationary, showing that this storm statistic has not changed in the German Bight in the past 100 years.

An alternative, and potentially more convincing, analysis would be to examine the historical weather maps and count the number of storms with a core pressure below certain thresholds. Such an analysis has been done, revealing a substantial increase in the number of severe storms in the North Atlantic area[2]. The problem with this approach is that it cannot distinguish whether changes are 'real' or whether they result from the ever-increasing quality of the operational analyses arising from more and better observations, more powerful diagnostic tools and other improvements in the monitoring of the state of the troposphere. A more detailed mapping of the pressure distribution, however, automatically yields deeper lows. On the other hand, the long time-series of pressure readings suffers from no substantial inhomogeneities because the measuring instruments (mercury barometers) and reading methods have remained unchanged for more than 100 years.

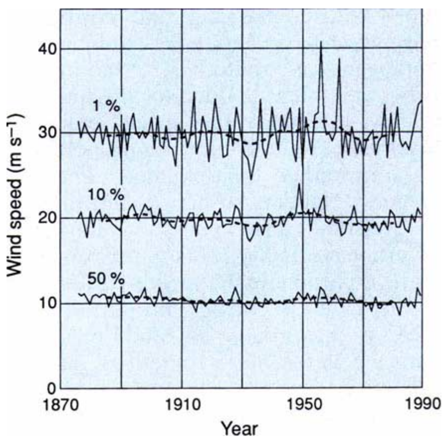

FIG. 2 Time series of the 1, 10 and 50% percentiles derived from annual distributions of daily geostrophic wind speeds in the German Bight. (The p 'percentile' of a distribution X is the number x, such that the probability of observing $X > x$ is p. Thus, the 1% percentile, derived from an annual ensemble of 365 samples, represents the minimum of the 3–4 largest observations.) Solid lines, annual average; broken lines, 30-year low pass.

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Generation time and evolution

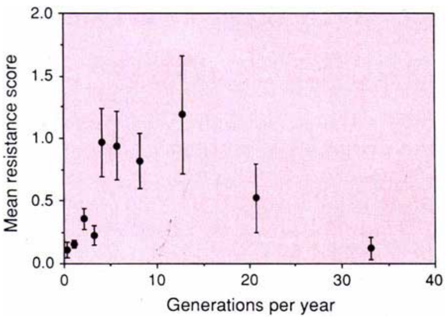
SIR — May in News and Views[1] examined the evolution of resistance to transgenic plants expressing genes for insecticidal proteins derived from the bacterium *Bacillus thuringiensis*. Based on a heuristic model[2], he concluded that the time required for an insect population to become resistant depends directly on the generation time of the insect but only weakly on other parameters (selection strength, initial resistance allele frequency and resistance allele dominance).

The influence of generation time on the rate of resistance evolution hinges on the relationship between generation time and the selection intensity per generation (s). May's analysis assumes that s is constant across species with different generation times. For insects exposed to a relatively constant dose of toxin expressed by a transgenic crop plant, this condition could be satisfied if only one developmental stage of the insect (for example, neonate larvae) is susceptible to the toxin. For insects exposed to conventional insecticides, this condition could be satisfied if the decision to apply insecticides is triggered by the density of the target pest population, and if the realized population growth rate is strongly influenced by generation time.[3,4].

But it is also possible that s will be a function of generation time. Under many field conditions, species with long generation times experience more intense pesticidal selection per generation than species with short generation times. If toxins cause a constant mortality rate per day, then the time for resistance to appear is independent of generation time, and instead, selection intensity becomes a primary determinant of the rate of pest adaptation[4]. Detailed numerical simulations show that generation time can interact with ecological and genetic factors to produce a variety of influences on the rate of resistance evolution[5].

Species with long generation times may in some cases experience such intense selection from insecticides that population densities decline catastrophically and local extinctions occur[6]. In this case, the evolution of resistance in long-lived species may be retarded beyond that expected from population genetics models in which infinite population sizes are assumed[7].

The extensive documentation of resistance evolution in arthropod pests provides an opportunity to test these different theoretical predictions. Our analysis of 586 North American arthropod pests of agriculture revealed no direct relationship between generation time and resistance



Resistance score (mean ± s.e.; defined as the number of insecticide classes to which resistance has been documented in the field) for arthropod pests of agriculture in North America as a function of the number of generations per year completed by the pest. Data were analysed using a polychotomous stepwise logistic regression model; both the linear term (generations per year; $\chi^2 = 4.0$, $P = 0.04$; coefficient = 0.31 ± 0.06) and the quadratic term ([generations per year]^2; $\chi^2 = 20.5$, $P < 0.0001$; coefficient = −0.0098 ± 0.0024) are significant. To facilitate data presentation, 10 intervals of generations per year are defined by the following cutoff points: ≤ 0.5 (n = 27); 1.5 (243); 2.5 (117); 3.5 (83); 4.5 (29); 6.5 (33); 10.5 (22); 15.5 (16); 25.5 (21); and > 25.5 (16). Values of generations per year were obtained from the literature. When estimates for the species in question were unavailable, average values for congeneric species were used (n = 57); for species in the families Aphididae and Tetranychidae, average values for confamilial species were used when congeners were unavailable (n = 20).

evolution[4]. The tendency to evolve resistance to synthetic chemical insecticides as of 1980 was not linearly related to generation time; species with intermediate generation times (between four and ten generations per year) evolved resistance more readily than species with shorter or longer generation times[4], but generation time explained only a very small fraction (5.7 per cent) of the total variation in resistance evolution.

Here we report that an enlarged and updated analysis of resistance evolution in North American arthropod pests confirms the result that resistance evolution does not depend directly upon generation time. The ability of each species (n = 607) to evolve resistance was quantified as the number of insecticide classes to which resistance had been reported up to 1989 (ref. 8). The simplest logistic regression model suggests that the number of generations per year makes no contribution to the ability to evolve resistance (χ^2 = 3.2, P = 0.08). A more complete model that incorporates the influences of pest severity and pest feeding mode (chewing, sucking on phloem and xylem contents, or sucking on cell contents) identifies a significant curvilinear effect for generations per year; species with intermediate numbers of generations per year displayed the greatest ability to evolve resistance (see figure).

The relationship between the generation time of pests and their evolution of resistance to toxins in transgenic plants cannot be fully elucidated until such plants are widely deployed. Selection exerted by toxins produced in transgenic plants may differ from selection exerted by conventional insecticides. Nonetheless, existing evidence from conventional insecticides suggests that the role of generation time may be limited, whereas factors directly linked to the intensity of selection, such as the concentration and temporal and spatial distribution of toxins, are likely to be critical. This result is important because it shifts the focus of attention from a biological trait that one generally cannot control (generation time) to parameters that will be shaped directly by the manner in which insecticidal transgenic plants are deployed.

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Thermodynamics at boundaries

SIR — After showing that entropy is proportional to mass or volume for homogeneous materials, Maddox in News and Views[1] addresses the question of how it is that, in a special case, the black hole, it turns out to be proportional to area rather than volume. The discrepancy appears to him quaint enough to welcome an explanation in which quantum mechanics, plus complex mathematical paraphernalia, are involved. But is the case of entropy proportional to area as uncommon as Maddox apparently believes, or something almost trivially common?

Take the case of the reversible association of two globular protein subunits, a subject that has occupied my attention for the past 10 years (ref. 2 and references cited therein). These associations are entropy driven, as uniformly found since Lauffer *et al.*[3] discovered the first case in 1958. The only contribution to the entropy change on association comes from replacement of the bonds at the boundary between protein and water by bonds of protein with protein. Assuming equal numbers of bonds of a typical energy for each reacting surface, the total entropy change on association is proportional to the number of bonds and therefore to the area of subunit interaction.

From such considerations it is easy to see that the same will be true of all cases of isothermal chemical reaction of polyatomic molecules that involve the bonds of the atoms at the interface and leave others unchanged: energy and entropy changes will be proportional to the interactive area, not to the volume of the reactive entities. Thus thermodynamics at the boundary of a black hole seem in this respect no different, Clausius and Gibbs be blessed, than at any other boundary.

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