NONLINEAR PREDICTION AND DYNAMICS

NORBERT WIENER
THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

A problem which is both mathematically fascinating and practically important arises in meteorology. We can conceive of the various constants which make up the weather on earth as part of a vast dynamical system which must be extended ultimately to include the rotation of the earth and the change of seasons, the variations in radiation from the sun, as well as those from the surface of the earth into empty space, and perhaps other driving forces. The ideally Newtonian way of building up a scientific meteorology would be to set up equations for the course of all the meteorological variables in time, and these equations would naturally assume the form either of partial differential or integral equations or combinations thereof. In order to make an effective use of such equations, we should have a very complete knowledge of the course of our variables in the past and at least of their values at some instant in the past. This completeness of knowledge, which would lead to the justification of a purely dynamical meteorological prediction, is absurdly far from what has actually been given us. In fact, we only have meteorological data from a few hundred or a few thousand stations all over the surface of the globe, and not all of these data have been collected continuously, but rather at certain stated intervals. Moreover, they are in no significant sense absolutely precise. If the thermometer in the weather bureau station in Boston reads 35° Fahrenheit, it is scarcely conceivable that this reading will characterize the effective temperature over the Boston area, which it is meant to represent by closer than 1°; and it is highly probable that this is too precise an estimate.

Thus the data on which meteorological prediction is to be done represent a very sketchy sampling of the true data which include every local gust of wind and every cool spot or warm spot in every area. Perhaps it may be possible to maintain that these local fluctuations are unimportant in the development of the weather. It is quite conceivable that the general outlines of the weather give us a good, large picture of its course for hours or possibly even for days. However, I am profoundly skeptical of the unimportance of the unobserved part of the weather for longer periods. To assume that these factors which determine the infinitely complicated pattern of the winds and the temperature will not in the long run play their share in determining major features of weather, is to ignore the very real possibility of the self-amplification of small details in the weather map. A tornado is a highly local phenomenon, and apparent trifles of no great extent may determine its exact track. Even a hurricane is probably fairly local where it starts, and phenomena of no great importance there may change its ultimate track by hundreds of miles. Meteorology is a living exemplification of the old proverb: