EXNER-EWARTEN, FELIX MARIA VON

(*b.* Vienna, Austria, 23 August 1876; *d.* Vienna, 7 February 1930), *atmospheric physics, meteorology, weather forecasting.*

Exner is counted among the pioneers who introduced theoretical mechanics into meteorology with the aim of calculating future atmospheric states from initial conditions known from measurements. During the first decade of the twentieth century, using an approximated and therefore tractable set of equations, he successfully calculated the four-hourly change of surface pressure over the contiguous United States. His textbook *Dynamische Meteorologie* (Dynamical Meteorology, 1917) was internationally influential for at least two decades. As professor of physics of the Earth and director of the Austrian weather service, he furthermore pioneered laboratory experiments to study the general circulation of the atmosphere and initiated the publication of *World Weather Records*, a series that has continued under the auspices of the *World Meteorological Organization (WMO)*. In the early 2000s, the pressure-dependent factor to convert temperature into potential temperature, the *Exner function*, carries his name.

Felix Maria Exner originated from a Viennese family of renowned scientists and university professors. His grandfather Franz was professor of philosophy in Prague and member of the imperial Academy of Sciences in Vienna, his uncle Adolf taught jurisprudence at the universities of Zurich and Vienna before becoming a state politician, his uncle Karl was professor of mathematics in Innsbruck, his uncle Franz Serafin held a chair of physics in Vienna. His father Sigmund Exner, a celebrated professor of physiology, was raised to hereditary nobility (Ritter von Ewarten) in 1917. His mother, Emilie, née von Winiwarter, also had roots in the liberal bourgeoisie of Vienna. Felix Exner was educated in a liberal thinking family and the *Gymnasium* (classical secondary school). Then he studied mathematics, physics, and chemistry at the University of Vienna, where he graduated after two semesters abroad (Berlin, Göttingen) in 1900 (PhD) and obtained *Habilitation* in 1904.

In 1901, Exner started his professional career as a scientific assistant at the Zentralanstalt für Meteorologie und Erdmagnetismus (since 1904, Zentralanstalt für Meteorologie und Geodynamik; abbreviated ZAMG) in Vienna where he used his broad background as a mathematically oriented physicist to teach himself about atmospheric problems. Eventually he adopted an intermediate position between the vast descriptive climatologies of Julius von Hann (retired director of ZAMG) and the abstract theoretical deductions of Max Margules (an older fellow scientist). Until 1910, Exner laid some foundations for numerical weather prediction by using analytically tractable approximations of the governing equations to calculate the surface pressure change on a regular latitude-longitude grid. During a one-year world tour (1904–1905) he used a visit to Washington, DC, to obtain observational data from the entire North American continent. He used it to achieve a significant, yet little known, milestone for a successful calculation of surface pressure change on a purely physical basis (the single case result given in Figure 1) Notably, it was much more successful and was published fourteen years earlier than the well-known attempt by Lewis Fry Richardson. Technically Exner's final refined approach amounted to computing manually the advective rate of change of a layer of uniform potential temperature; it was based upon incorporating the hydrostatic and geostrophic approximations into the thermodynamic equation. Exner also tried this method for European cases but came to recognize that the

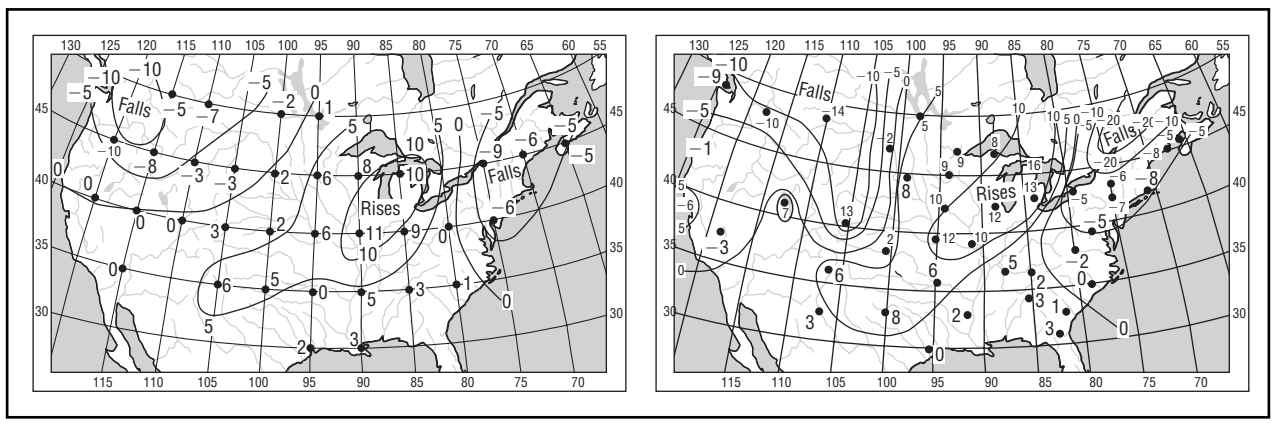

Figure 1. *4 hourly change in surface pressure over the contiguous United States for 3 January 1895 in units of 0.01 inch Hg (approximately 0.33 hPa); left: calculated for a regular 5° x 5° geographical grid; right: observed at a network of 35 stations. Both charts contain manually analyzed isolines and exhibit a sequence of regions where pressure falls and rises.*

disregard of tropopause-level effects often tended to induce substantial errors.

During this period Exner assisted the ZAMG director Josef Pernter with the compilation of a handbook for meteorological optics, which he completed after Pertner's death in 1908. In 1910, Exner embarked on an academic career by moving to the chair for cosmic physics (an old-fashioned term for the combination of meteorology and high altitude physics) at the University of Innsbruck. During the last years of the Habsburg Empire of Austria-Hungary, he condensed his vast knowledge of physical concepts and meteorological observations into the first modern textbook for dynamical meteorology (which appeared in 1917 after a delay of two years due to World War I). Ninety-six short sections were grouped in thirteen chapters dealing inter alia with the general dynamical equations: statics, kinematics, and dynamics of the atmosphere and its general circulation. Rigorous mathematical treatment was mixed with sufficient explanatory text and numerous sketches as well as with observational diagrams.

From 1915, Exner headed the newly established military weather service, and from 1917 until his untimely death, he held the traditionally combined positions of professor for physics of the Earth at the Viennese university and of director of ZAMG, first the imperial and then the republican Austrian weather service. In his academic capacity, he enlarged the fluid dynamics laboratory's novel rotating-tank experiments, forerunners of the famous dishpan experiments of the 1950s (best known in Chicago). He first observed axisymmetric flow at small rotation rates and turbulence in the form of growing and decaying cyclonic and anticyclonic eddies at higher rates (Figure 2). Secondly, Exner inferred that the east-west pressure gradients associated with the large-scale eddies would be an effective brake on the development of strong zonal flow. As director of the weather service, he extended the Viennese analyses of large-scale variations in planetary flow patterns. He constructed one-point correlation (teleconnection) maps based upon Northern Hemisphere station data for the 1897–1906 period, and later for the entire globe for the 1887–1916 period. Thus he documented in a pioneering sense the essence of what was later termed North Atlantic Oscillation (NAO), alongside with the independent, later renowned investigations by Gilbert Walker in India (whom Exner had met on his world tour). At a conference of the International Meteorological Organization, Exner suggested in 1923 the establishment of *World Weather Records* (first realized in 1927 by the Smithsonian Institution in Washington). They contain quality-controlled decadal statistics of daily measurements for climate studies. The corresponding data collection and reduction continued into the twenty-first century.

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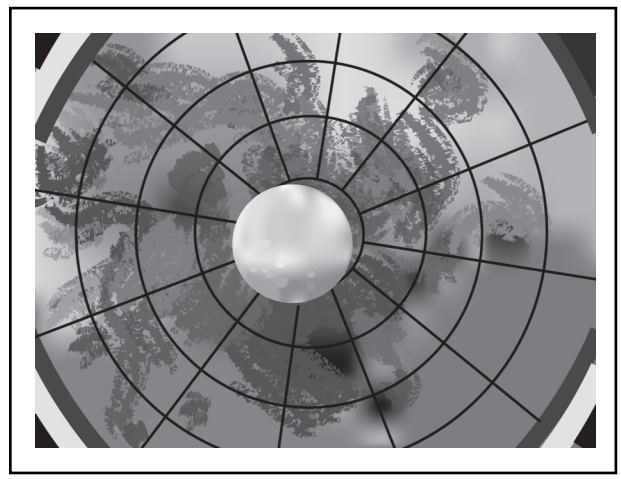

Figure 2. *Image of rotating tank experiment to simulate atmospheric turbulence. The water-filled annulus was heated at the circumference and cooled at the center by a round block of ice. Ink released at the cool center made it possible to mark the temperature contrasts which developed in both zonal and meridional directions.*

Exner's insights and personal opinion regarding the Norwegian cyclone model were documented in the written version of a presentation at a conference convened by Vilhelm Bjerknes in Bergen in summer 1920. It reveals that important ingredients of the textbook standard for the coming decades had also been found by the Viennese school of meteorology. Their conceptualization, however, was less focused and their widespread publication much less energetic. After Hann's death in 1921, Exner took on the onerous task of coediting *Meteorologische Zeitschrift,* one of the leading journals for meteorology of the era from 1870 to 1940, and he continued this work until his own death. Official recognition of Exner's achievements is evident through his full membership in the Austrian Academy of Science (since 1922) and corresponding memberships with the Prussian Academy of Science (Berlin) and the Royal Society (London).

Undoubtedly Felix Maria Exner of Austria belongs to the trio of great pioneers who, in the first third of the twentieth century, turned meteorology into atmospheric physics. Napier Shaw of Great Britain and Vilhelm Bjerknes of Norway stand at his side. Exner was scientifically very productive and took pioneering steps into a number of research avenues that are of continuing relevance. As a geophysical all-rounder beyond meteorology, he observed the time dependence of sandbanks in rivers as well as the movement of sand dunes and proposed simplified equations to describe the observations. Early in his career, he obviously profited from being well connected in scientific circles in one of the political centers of Europe. He was married for twenty-five years to Christiane, née baroness

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Popp von Böhmstetten, and was the father of two daughters and two sons, one of whom, Christoph Exner, became a professor of geology. Exner's personality and position provided ideal links between innovative academic research and routine data collection and analysis. The summit of his career coincided with an era of rapid economic decline and political turmoil in his home country during and after World War I. In combination with his early death, this may explain why Exner's name, quite undeservedly, does not loom very large in early twenty-first century histories of meteorological thought. The barrier between the German text of all of Exner's publications and a potential reception in the English-speaking world of the early 2000s may add to this fact as well as the usage of the renowned, though not widely circulated, transactions of the Viennese academy as his main medium for publications. However, a change in perception emerged in the early 2000s with a special focus on an Austrian school of probabilistic reasoning in science at the beginning of the twentieth century. In this context Felix Maria Exner and other members of the "Exner dynasty of scientists" are being considered as prototypical characters.

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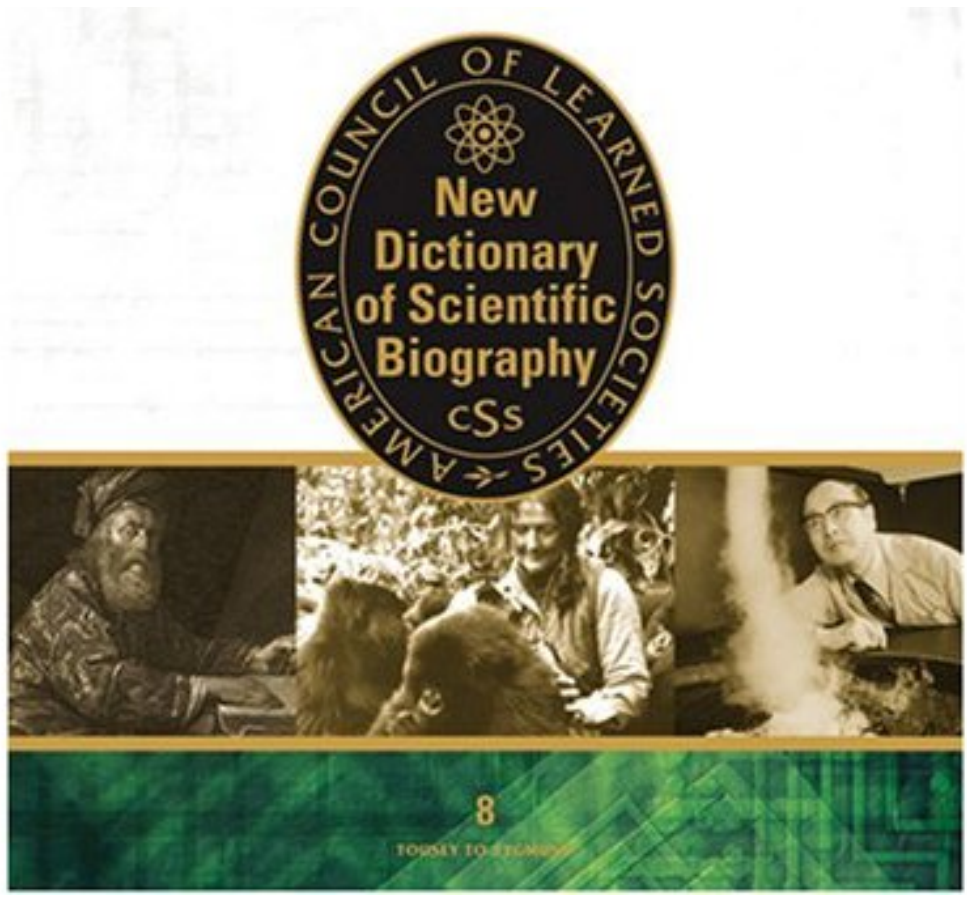

Entry **Exner-Ewarten, Felix Maria** by Hans Volkert

In Norietta KOERTGE (Ed.), New Dictionary of Scientific Biography, Charles Scribner's Sons, ISBN 978-0684313269, 2007, pp. 425-428
