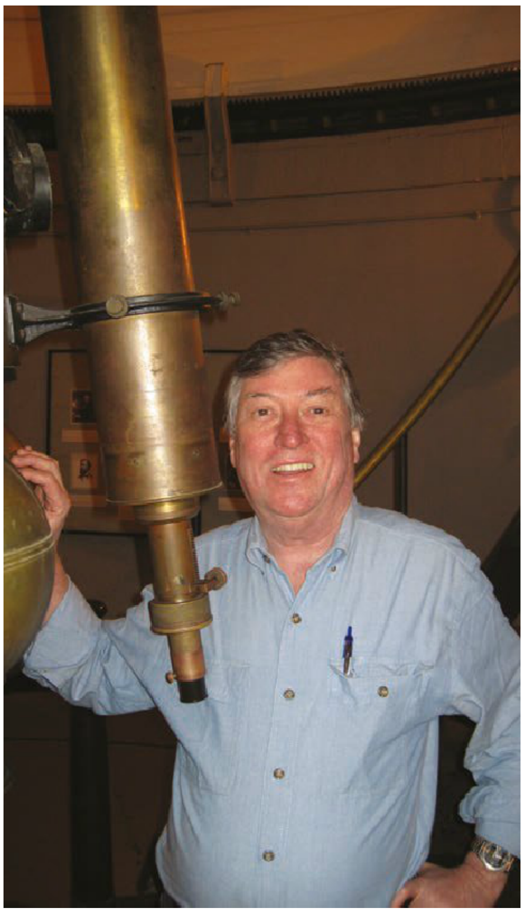
SUNWATCHING:
HUMAN FOOTPRINTS ON EARTH AND SKY

BY KELLY CHANCE



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The Earth is changing, has changed, will continue to change. In the present Anthropocene Age, humans are causing rapid change to the landscape, the environment and likely the climate and weather: It is difficult for seven billion people to walk softly on the Earth as in the Cherokee proverb. We will not destroy the Earth by our actions or by our inaction, but our response to change, anthropogenic and otherwise, will have great consequences for the health and prosperity of life.

Environmental issues and environmental difficulties span the range of the Earth system. Overfishing, versus a mindset that the oceans are too huge for us to have been a major cause of falling stocks, poisoning of the chemical environment, as spotlighted by Rachel Carson in the *Silent Spring,* and groundwater pollution are all examples of anthropogenic change. Atmospheric issues are considered more closely here, as experience at the Smithsonian provides an example of the difficulties of measurements and attribution.

Atmospheric issues include climate variation and change, weather prediction, stratospheric ozone layer destruction by chlorofluorocarbons, and atmospheric pollution. The ozone layer issue has been addressed, we hope fully successfully. Easing pollution-caused acid rain is partially successful but much work remains. Other air pollution issues include ground-level ozone and aerosols that cause lung difficulties, including cancer.

Climate change is a central issue of our time. The human contribution is controversial, and the costs of mitigation and accommodation are enormous. The ability to acknowledge potential consequences and the political and economic will to act are correspondingly difficult.

Atmospheric measurements from the ground, aircraft, balloons and satellites are a vast global effort. The Smithsonian has played an important early and continuing part in atmospheric measurements, beginning with solar and atmospheric absorption measurements made from the backyard of the Smithsonian Castle and continuing to hourly measurements of North American air pollution that will soon be made from geostationary orbit.

Following is an early example of the difficulty of measurement and understanding, although the goal was robust weather prediction rather than human influence on climate change. The measurements began with Smithsonian Secretary Samuel Pierpont Langley, who established the Smithsonian Astrophysical Observatory (SAO) for the purpose in 1890, siting it between the Castle and Independence Avenue. While previously heading the Allegheny Observatory, Langley had invented the bolometer, a heat detector that could be used to make precise spectroscopic measurements in the ultraviolet, visible and infrared parts of the light spectrum. He also invented a method of recording spectra by using the current output of the bolometer to drive the deflection of a galvanometer which would then direct a beam of light to write spectra on a carriage-driven photographic plate. The Moon was also measured: Langley's infrared measurements of the moon were used by Svante August Arrhenius to develop the theory of the atmospheric greenhouse effect in 1896.

Langley set out to determine precisely the influence of the Sun on the Earth, including its sunspot-correlated variation, and the causal relationship of solar input to weather and climate. He wrote in the *Report of the Secretary of the Smithsonian Institution* in June, 1892: "The distinct object of astrophysics is, in

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the case of the Sun, for example, not to mark its exact place in the sky, but to find out how it affects the Earth and the wants of man on it; how its heat is distributed, and how it in fact affects not only the seasons and the farmer's crops, but the whole system of living things on the Earth, for it has lately been proven that in a physical sense it, and almost it alone, literally first creates and then modifies them in almost every possible way."

Langley and his colleagues, including his successor as SAO director and eventually as Smithsonian Secretary, Charles Greeley Abbot, were confident of the role of the Sun as the arbiter of weather and climate. Through solar observations they hoped to predict weather for a week in advance or more and perhaps establish "long-range forecasting of the approaching seasons and of future years." Observing stations were established in California, Chile and southwest Africa, locations selected to minimize the influence of the Earth's atmosphere and its variation on the solar measurements. This proved difficult: Their most quixotic act was to then establish an observatory on Mount Saint Katherine (Zebel Gebir), a spur of Mount Sinai, in 1933, with the assistance of Archimandrate Joakim and the monks of the Monastery of Saint Katherine on Mount Sinai. Transport of equipment and re-supply was by camel train from a port on the Red Sea. Observations were made from 1933 to 1937 until the observatory was closed by economic necessity.

In the end, even the word from Mount Sinai was not adequate. The Sun did not vary as much as was supposed, not enough to have a significant influence on weather, and the absorption and scattering from the Earth's atmosphere were still too variable for definitive solar measurements. A 1936 proposal for high-altitude balloon measurements to predict weather was not considered economically or scientifically valid.

In the end, weather forecasting for seven to 10 days has improved remarkably, through analysis of global atmospheric measurements. Langley and Abbot did not succeed in doing so, as weather is not primarily solar-caused, but they did start us on a path that provided the solution to forecasting and directly supplied tools and techniques for weather, climate and pollution measurement and much else. They contributed to solving the ozone hole mystery, addressing acid rain and understanding smog.

There are object lessons from this pursuit: The Earth–Sun system is complex, assumptions may be unreliable, and measurements and analysis are arduous. We may not, though, conclude that global change and other environmental issues are not worth researching. We have some successes, and we have issues of enormous importance to address. We are not in a position yet precisely to quantify man-made global change, for example, but we are certainly not in a position to deny it in the face of much robust physics. We have indications of the scope and impact of climate change, whatever the cause, and we have much work to do to ameliorate it to the extent possible and to adapt to it. Understanding of the human contribution is underway. It will never be complete but the consequences are now.

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