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Preface to special section on Yoram J. Kaufman Symposium on Aerosols, Clouds, and Climate

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[1] Yoram J. Kaufman's scientific career spanned more than 30 years, beginning as a student at the Technion in Israel and ending tragically on the grounds of the NASA Goddard Space Flight Center (GSFC) in Maryland in May 2006. Dr. Kaufman, or more appropriately simply Yoram, approached his science with a creativity and a contagious joy that inspired researchers world wide and advanced our understanding of satellite remote sensing, aerosols, clouds, and climate processes. Yoram was noted for his publication productivity, the wide range of topics he addressed, the large numbers of collaborators and coauthors, and the high citation rate of his publications. No single introduction can touch on all aspects of Yoram's career, but in this preface to the special section organized in his honor, we would like to mention some of his career highlights and show the progression of Yoram's pioneering ideas evolving into the research of today and the papers that appear in this section.

[2] Yoram's first scientific publications revolved around studies he did with lasers as part of the work toward his Masters degree. Even as a Masters student Yoram made a noted contribution to science on an international stage, as three of these papers [*Kaufman and Oppenheim*, 1974; *Kaufman*, 1976; *Kaufman and Gersten*, 1976] were selected for the SPIE milestone series.

[3] Yoram completed his Masters at the Technion and then pursued a Ph.D. at Tel Aviv University under the direction of Yuri Mekler. His work as a Ph.D. student and as a young post-doc at the NASA Goddard Space Flight Center working with Robert S. Fraser focused on radiative transfer issues and specifically on the "adjacency effect." This is a radiative transfer problem in which targets surrounded by a dark background will appear darker, while targets surrounded by brighter background will appear brighter [*Mekler and Kaufman*, 1980; *Kaufman*, 1982; *Kaufman and Fraser*, 1983; *Mekler et al.*, 1984; *Lyapustin and Kaufman*, 2001]. This work had immediate applications for satellite remote sensing of the Earth's surface. Furthermore, the atmosphere that intervened between intended targets on the Earth's surface and the satellite had to be characterized and "removed" in a process called "atmospheric correction." Finding a method for atmospheric correction led to Yoram's "dark target method" [*Kaufman and Sendra*, 1988]. This paper became the grandfather of subsequent atmospheric correction approaches [*Tanré et al.*, 1992; *Vermote et al.*, 1997; E. Vermote and S. Kotchenova, Atmospheric correction for the monitoring of land surfaces, submitted to *Journal of Geophysical Research*, 2007] and the basis for the MODIS aerosol over land algorithm [*Kaufman et al.*, 1997a]. In a side light to the atmospheric correction work, Yoram contributed to developing simple measures of vegetation productivity (vegetation indices) that would be less sensitive to the atmosphere and thus not require extensive atmospheric correction [*Kaufman and Tanré*, 1992; *Karnieli et al.*, 2001].

[4] In the late 1980s, satellite remote sensing became the focus of Yoram's work. At that time, the satellite sensors of interest were AVHRR, GOES, and LandSat. None of these sensors had onboard calibration devices or dedicated characterization teams. To use these data for quantitative atmospheric applications, Yoram and his colleagues had to perform vicarious calibration techniques, some of which became standard methods [*Fraser and Kaufman*, 1986; *Holben et al.*, 1990; *Kaufman and Holben*, 1993; *Vermote and Kaufman*, 1995]. Calibration and characterization of satellite sensors continues to be an important area of scientific research today (P. Lallart et al., POLDER2/ADEOSII, MISR, and MODIS/Terra reflectance comparisons, submitted to *Journal of Geophysical Research*, 2007).

[5] In parallel to his work with satellites, Yoram also contributed to suborbital observations and field experiments. One of the most notable products of this work is the Aerosol Robotic Network (AERONET) [*Holben et al.*, 1998]. Yoram recognized the value of a global Sun/sky radiometer network from the beginning, advocated for the network, and gave the network its name. He saw the value of the sky measurements and used a manually operated Cimel precursor to test and put into practice the technique of inverting sky radiance measurements to obtain aerosol characteristics [*Kaufman et al.*, 1994; *Nakajima et al.*, 1996]. This precursor work evolved into the multiproduct AERONET data set that provides us with a global characterization of aerosol properties [*Dubovik et al.*, 2002].

[6] AERONET's first deployments were in conjunction with field experiments including the Smoke/Sulfate Clouds And Radiation (SCAR) experiments. These were a series of

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three multiaircraft field experiments taking place in 1993, 1994, and 1995 that characterized aerosol and surface properties in both urban/industrial pollution and biomass burning environments [*Kaufman et al.*, 1998a]. The SCAR experiments built on Yoram's experience with biomass burning in Brazil [*Kaufman et al.*, 1989; *Kaufman et al.*, 1992] at a time when most aerosol studies focused on midlatitude pollution. Yoram played a pivotal role in the organization of these experiments. He used these results and others before and after the SCAR experiments to characterize aerosol physical and optical properties [*Fraser and Kaufman*, 1985; *Kaufman et al.*, 1986; *Kaufman* 1987; *Remer and Kaufman*, 1998; *Yamasoe et al.*, 1998; *Chu et al.*, 1998; *Remer et al.*, 1998; *Martins et al.*, 1998; *Tanré et al.*, 2001; *Derimian et al.*, 2006; *Satheesh et al.*, 2006]. One of his most significant contributions in this area was the incontestable evidence that transported Saharan dust was significantly less absorbing than previous studies reported and conventional wisdom believed [*Kaufman et al.*, 2001]. The characterization of aerosol properties continues and is represented in this special section by four papers attempting to characterize different aspects of aerosol [*Cachorro et al.*, 2008; *McConnell et al.*, 2008; *Stone et al.*, 2008; J. Joseph et al., Determination of most probable height of desert dust aerosol layer from space, submitted to *Journal of Geophysical Research*, 2007].

[7] Even though Yoram made significant contributions to suborbital measurements, we remember him best as a remote sensing scientist. In particular, Yoram, in partnership with the MODIS (Moderate Resolution Imaging Spectroradiometer) team members, developed the aerosol algorithms [*Kaufman et al.*, 1997a; *Tanré et al.*, 1997]. To do so required understanding the information content available for inversion [*Tanré et al.*, 1996] and solving issues of estimating surface reflectance for retrievals over land [*Kaufman et al.*, 1997b]. The fruit of this work continues today in the use of the MODIS aerosol retrievals to describe the global aerosol system (L. A. Remer et al., An emerging global aerosol climatology from the MODIS satellite sensors, submitted to *Journal of Geophysical Research*, 2007). Yoram also contributed to the MODIS water vapor retrieval algorithm [*Kaufman and Gao*, 1992] and to the retrieval of fire radiative energy [*Kaufman et al.*, 1998b; *Ichoku and Kaufman*, 2005; *Ichoku et al.*, 2008]. However, Yoram was not limited to just the MODIS sensor [*Kaufman et al.*, 2002b]. He served as the Terra project scientist, representing all the sensors aboard Terra, and he developed retrieval algorithms for space-based capabilities beyond Terra's scope including the availability of polarization [*Kaufman et al.*, 2002a] and lidar [*Kaufman et al.*, 2003]. In this special section we see the continued struggle to expand and understand techniques for the remote sensing of aerosols, clouds, and other constituents and to overcome the retrieval challenges [*Ackerman et al.*, 2008; *Marshak et al.*, 2008; *Oreopoulos and Platnick*, 2008; A. Davis, Multiple-scattering lidar from both sides of the clouds, signals, noises and retrievals, submitted to *Journal of Geophysical Research*, 2007; I. Laszlo et al., Comparison of single- and multi-channel aerosol optical depths derived from MAPSS data, submitted to *Journal of Geophysical Research*, 2007; S. Platnick and L. Oreopoulos, The radiative susceptibility of cloudy atmospheres to droplet number perturbations: 1. Theoretical analysis and examples from MODIS, submitted to *Journal of Geophysical Research*, 2007; G. Wen et al., Role of molecular Rayleigh scattering in the enhancement of clear sky radiance in the vicinity of cumulus clouds, submitted to *Journal of Geophysical Research*, 2007].

[8] Remote sensing is not an end in itself, but a tool for understanding real geophysical processes. In the last 5 years of his life, Yoram was fond of telling people that he was not a data producer, but a data user. Yoram published the first use of the MODIS aerosol product in a geophysical application when he estimated the mass flux of dust aerosol as it was transported from the coast of Africa to the Americas [*Kaufman et al.*, 2005c]. In this issue, we see the continuation of this application as focus switches from dust to pollution transport [*Rudich et al.*, 2008; *Yu et al.*, 2008]. In another innovative use of the MODIS data, Yoram conceived the idea of inverting MODIS products to find and quantify aerosol source strength [*Dubovik et al.*, 2008]. However, in Yoram's mind the primary application of the MODIS aerosol product was to help in reducing the uncertainties associated with estimating climate forcing and response. To go beyond radiative effect to radiative forcing, Yoram needed to derive the anthropogenic component of the total aerosol optical depth retrieved from MODIS [*Kaufman et al.*, 2005a]. At that point, he could begin to work toward a measurement-based estimate of aerosol radiative forcing [*Yu et al.*, 2006]. Even so, Yoram realized the need for models to complement the observations, and he reached out to a variety of models and modelers to find a common vocabulary and common scientific ground [*Alpert et al.*, 1998; *Chin et al.*, 2004; *Jacobson and Kaufman*, 2006; *Takemura et al.*, 2007; *Menon et al.*, 2008]. In this issue, in addition to the Menon et al. paper that Yoram coauthored, we see the continuation of this theme as two studies combine measurements and models to investigate the effect of aerosols on vegetation and surface processes [*Zhang et al.*, 2008; T. Matsui et al., Aerosol light scattering effect on terrestrial plant productivity and energy fluxes over the eastern United States, submitted to *Journal of Geophysical Research*, 2007].

[9] One of Yoram's most innovative research directions was the study of aerosol-cloud interaction. He approached this problem both theoretically [*Kaufman and Tanré*, 1994], but most importantly by using remote sensing data. Through the use of AVHRR [*Kaufman and Nakajima*, 1993; *Kaufman and Fraser*, 1997], MODIS [*Koren et al.*, 2004, 2005; *Kaufman et al.*, 2005b], and AERONET [*Kaufman and Koren*, 2006], he established observational relationships between aerosol optical depth and cloud properties that suggested significant climate forcing consequences. One of his last papers begins to question our entire paradigm of separating clouds and aerosols into mutually exclusive entities when actually there exists a continuum between them [*Koren et al.*, 2007]. When *Kaufman and Nakajima* [1993] was published there were few studies, besides the ship track studies, of aerosol-cloud interaction using satellite data. Today, the combination of passive and active sensors linked with advances in cloud and mesoscale modeling invites a rich field for exploration. Several studies appearing in this special issue take advantage of these advances [*Berg et al.*, 2008; *Gassó*, 2008].

[10] The above review gives just a taste of Yoram's publication record and his contribution to science. A comprehensive list is beyond the scope of this preface. With such a rich and fruitful scientific career, we have not yet realized the full impact of Yoram's sudden death. Yoram Kaufman continues to coauthor papers (four in this special section alone) as his ideas and contributions mature in the hands of his collaborators.

[11] At the 1 year anniversary of the accident that took Yoram's life, approximately 100 scientists and friends returned to GSFC to honor Yoram's life time achievements in a 3 day symposium of invited presentations of recent science results. The symposium highlighted different areas of science that Yoram had influenced in his lifetime: (1) passive remote sensing of aerosols, clouds, and the Earth's surface; (2) active remote sensing of aerosols and clouds; (3) aerosols, clouds, and climate; (4) field experiments and suborbital observations; and (5) future aerosol and cloud space missions.

[12] The symposium was not a retrospective of Yoram's past career, but a vibrant exchange of latest results and an optimistic look forward. The collection of papers found in the following special section, likewise, reflects the breadth and depth of Yoram's scientific interests, but moves forward toward new scientific results. We hold the memory of Yoram J. Kaufman dear to our hearts and honor him best by continuing his work, pushing the boundaries of our scientific knowledge and pursuing cutting edge research with joy, as he did along his career thanks to the support of all the members of his family, Jean, Nadav, and Daphne.

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