3.1.3. ANNUAL CYCLES

The annual cycles of aerosol optical properties for the four baseline and three regional stations are illustrated in Figures 3.1 and 3.2. The data are presented in the form of box and whisker plots that summarize the distribution of values. Each box ranges from the lower to upper quartiles with a central bar at the median value, while the whiskers extend to the 5th and 95th percentiles. The statistics are based on hourly averages of each parameter for each month of the year, also shown are the annual statistics for the entire period of record. A horizontal line is given that intersects the annual median so measurements above and below the median can be easily discerned.

TABLE 3.2. CMDL Baseline Aerosol Monitoring Stations (Status as of December 1999)

Category	Baseline Arctic	Baseline Free Troposphere	Baseline Marine	Baseline Antarctic
Location	Point Barrow	Mauna Loa	American Samoa	South Pole
Designator	BRW	MLO	SMO	SPO
Latitude	71.323ºN	19.539ºN	14.232ºS	89.997ºS
Longitude	156.609ºW	155.578ºW	170.563ºW	102.0ºE
Elevation (m)	8	3397	77	2838
Responsible institute	CMDL	CMDL	CMDL	CMDL
Status	Operational, 1976 Major upgrade, 1997	Operational, 1974	Operational, 1977	Operational, 1974
Sample RH	RH <40%	Uncontrolled	Uncontrolled	Uncontrolled
Sample size fractions	D<1 µm D<10 µm	Uncontrolled	Uncontrolled	Uncontrolled
Optical measurements	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$	$\sigma_{sp}(3\lambda)$, $\sigma_{ap}(1\lambda)$, $\delta(6\lambda)$	none	$\sigma_{sp}(4\lambda)$
Microphysical measurements	CN concentration	CN concentration	CN concentration	CN concentration
Chemical measurements	Major ions, mass	None	None	None

TABLE 3.3. CMDL Regional Aerosol Monitoring Sites (Status as of December 1999)

Category	Perturbed Marine	Perturbed Continental	Perturbed Continental
Location	Sable Island, Nova Scotia, Canada	Bondville, Illinois	Lamont, Oklahoma
Designator	WSA	BND	SGP
Latitude	43.933ºN	40.053ºN	36.605ºN
Longitude	60.007ºW	88.372ºW	97.489ºW
Elevation (m)	5	230	315
Responsible institute	CMDL	CMDL	CMDL
Collaborating institute	AES Canada, NOAA/PMEL	Univ. of Illinois, IL State Water Survey	DOE/ARM
Status	Operational, August 1992	Operational, July 1994	Operational, July 1996
Sample RH	RH <40%	RH <40%	RH <40%
Sample size fractions	D<1 µm, D<10 µm	D<1 µm, D<10 µm	D<1 µm, D<10 µm
Optical measurements	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$	$\sigma_{sp}(3\lambda)$, $\sigma_{bsp}(3\lambda)$, $\sigma_{ap}(1\lambda)$, $\delta(7\lambda)$
Microphysical measurements	CN concentration	CN concentration	CN, n(D) concentration
Chemical measurements	Major ions, mass	Major ions, mass	None

TABLE 3.4. Intensive Aerosol Properties Derived From CMDL Network

Properties	Description
å	The Ångström exponent, defined by the power-law $\sigma_{sp} \propto \lambda^{-å}$, describes the wavelength-dependence of scattered light. In the figures below, *å* is calculated from measurements at 550 and 700 nm wavelength. Situations where the scattering is dominated by submicrometer particles typically have values around 2, while values close to 0 occur when the scattering is dominated by particles larger than a few microns in diameter.
ω_o	The aerosol single-scattering albedo, defined as $\sigma_{sp}/(\sigma_{ap} + \sigma_{sp})$, describes the relative contributions of scattering and absorption to the total light extinction. Purely scattering aerosols (e.g., sulfuric acid) have values of 1, while very strong absorbers (e.g., elemental carbon) have values around 0.3.
g, *b*	Radiative transfer models commonly require one of two integral properties of the angular distribution of scattered light (phase function): the asymmetry factor *g* or the hemispheric backscatter fraction *b*. The asymmetry factor is the cosine-weighted average of the phase function, ranging from a value of -1 for entirely backscattered light to +1 for entirely forward-scattered light. The hemispheric backscatter fraction *b* is defined as σ_{bsp}/σ_{sp}.
α_i	The mass scattering efficiency for species *i*, defined as the slope of the linear regression line relating σ_{sp} and the mass concentration of the chemical species, is used in chemical transport models to evaluate the radiative effects of each chemical species modeled. This parameter has typical units of $m^2\ g^{-1}$.

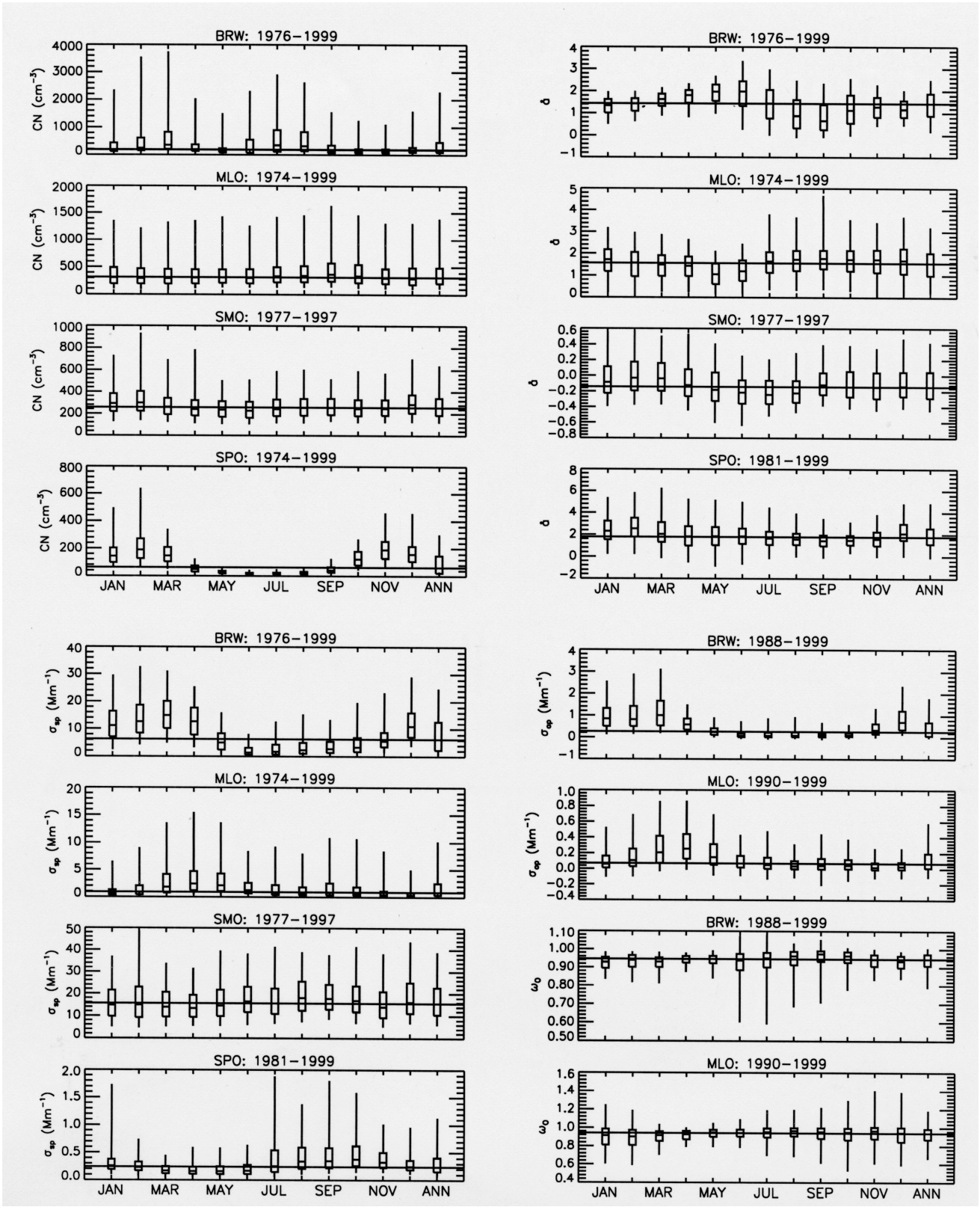

Fig. 3.1. Annual cycles for baseline stations at BRW, MLO, SMO, and SPO showing statistics for condensation nuclei (CN) concentration, total scattering coefficient (σ_{sp}), Ångström exponent (å), absorption coefficient (σ_{ap}) and single-scattering albedo (ω_O). Statistics representing the entire period are given in the last column (ANN), with the horizontal line intersecting the median value.

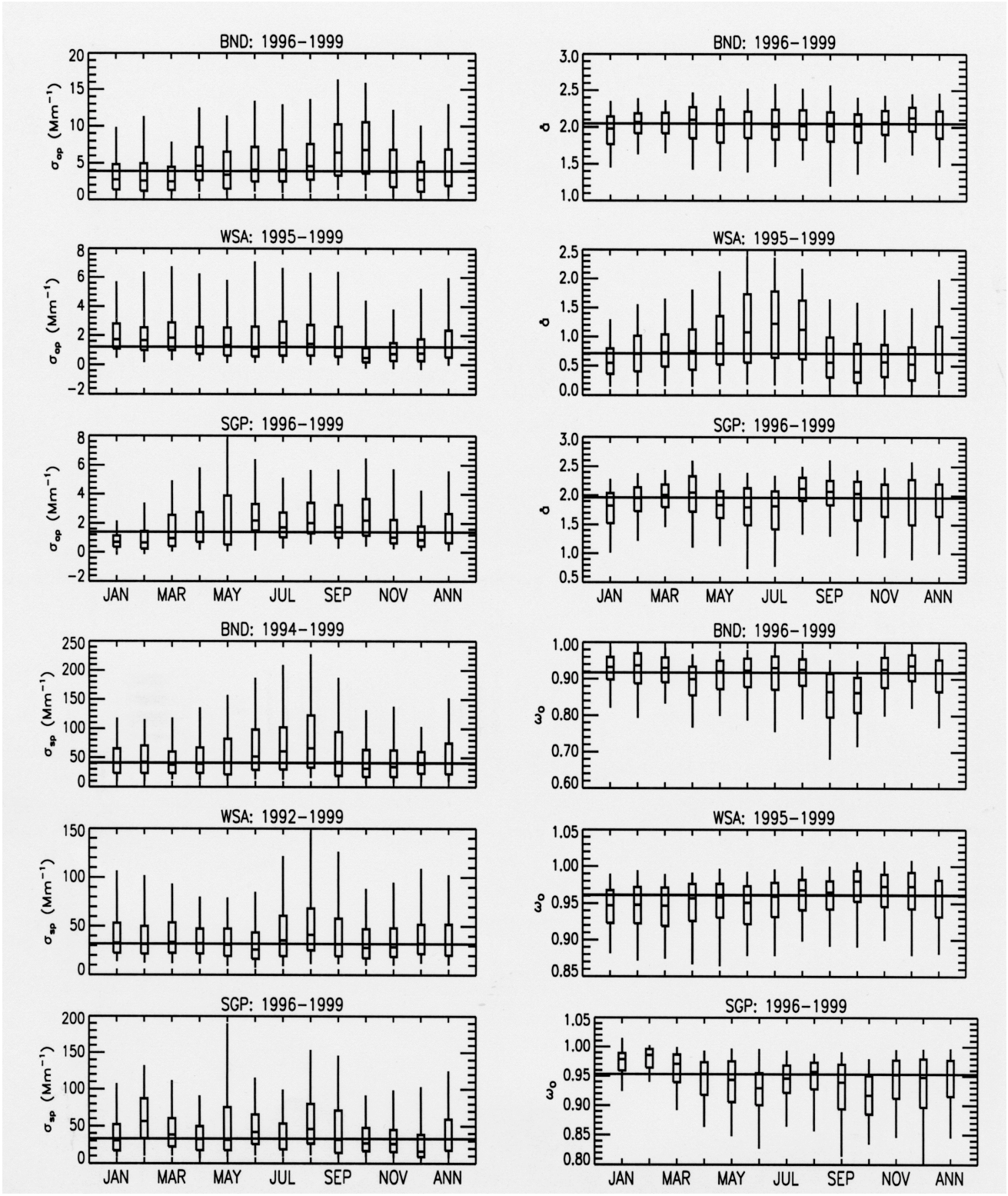

Fig. 3.2. Annual cycles for regional stations at Bondville, Illinois (BND), Sable Island, Nova Scotia (WSA), and Lamont, Oklahoma (SGP) showing statistics of absorption coefficient (σ_{ap}), total scattering coefficient (σ_{sp}), Ångström exponent (å), and single-scattering albedo (ω_o). Statistics representing the entire period are given in the last column (ANN), with the horizontal line intersecting the median value.

In general, changes in long-range transport patterns dominate the annual cycles of the baseline stations. For BRW, the highest values of CN, σ_{sp}, and σ_{ap} are observed during the spring Arctic haze period when anticyclonic activity transports pollution from the lower latitudes of Central Europe and Russia. A more stable polar front characterizes the summertime meteorology. High cloud coverage and precipitation scavenging of accumulation mode (0.1-1.0 μm diameter) aerosols account for the annual minima in σ_{sp} and σ_{ap} from June to September. In contrast, CN values have a secondary maximum in the late summer that is thought to be the result of sulfate aerosol production from gas to particle conversion of DMS oxidation products from local oceanic emissions [*Radke et al*., 1990]. The aerosol single-scattering albedo displays little annual variability, which is indicative of highly scattering sulfate and seasalt aerosol. A September minimum is observed in å when σ_{sp} and accumulation mode aerosols are also low but when primary production of coarse mode seasalt aerosols from open water is high.

For MLO, the highest σ_{sp} and σ_{ap} values occur in the spring-time and result from the long-range transport of pollution and mineral dust from Asia. However, little seasonality is seen in CN concentrations at MLO, indicating that the smallest particles (<0.1 μm diameter), which usually dominate CN concentration, are not enriched during these long-range transport events. Both the aerosol σ_{sp} and Ångström exponent display seasonal cycles at SPO, with a σ_{sp} maximum and an å minimum in winter associated with the transport of coarse mode seasalt from the Antarctic coast to the interior of the continent. The summertime peaks in CN and å are associated with fine mode sulfate aerosol and correlate with a seasonal sulfate peak found in the ice core, presumably from coastal biogenic sources [*Bergin et al*., 1998]. The aerosol extensive properties at SMO display no distinct seasonal variation. Instrument noise at low aerosol concentration is responsible for albedo values at BRW and MLO above 1. These high albedo values are not present in daily averaged data. Furthermore, these high albedo values are removed if you exclude data where σ_{sp} is below 1 Mm^{-1}. Hence, the high albedo values result from an instrument detection limitation problem.

Based on only 4-7 years of measurements, the annual cycles for the regional stations are less certain than those of the baseline stations. The proximity of the regional sites to North American pollution sources is apparent in the results, with a monthly median value of σ_{sp} at the Bondville site (BND) that is nearly two orders of magnitude higher than the σ_{sp} at SPO. BND is situated in a rural agricultural region and displays an autumn high in σ_{ap} and low in ω_o that coincides with the autumn harvest. As evident in the lower σ_{sp} and σ_{ap} values, the Southern Great Plains site (SGP) is more remote than BND. SGP has a similar, but less pronounced, annual cycle with late summer highs in σ_{sp} and σ_{ap} and a corresponding minimum in ω_o. Little seasonal variability is observed in aerosol properties at WSA. Values of å tend to be higher in the summer and likely result from transport of fine mode sulfate aerosol from the continent and lower coarse-mode production of particles with lower summer wind speeds.