AEROSOL OPTICAL PROPERTIES

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TexAQS - GoMACCS 2006

LIGHT SCATTERING COEFFICIENT
ABSORPTION COEFFICIENT
RELATIVE HUMIDITY DEPENDENCE
VISUAL RANGE

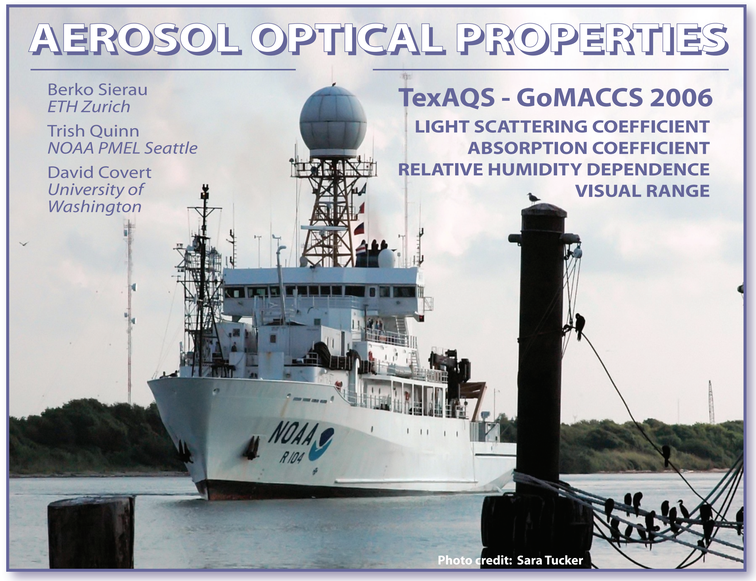


Photo credit: Sara Tucker

DEFINITIONS

AEROSOL OPTICAL PARAMETERS
Particulate light scattering coefficient, σ_{sp}
Particulate light absorption coefficient, σ_{ap}
Particulate light extinction coefficient, $\sigma_{ep} = \sigma_{sp} + \sigma_{ap}$

Atmospheric light extinction coefficient, $\sigma_e = \sigma_{sp} + \sigma_{ap} + \sigma_{s,Rayleigh}$
where $\sigma_{s,Rayleigh}$ is the molecular, Rayleigh, scattering by air

Relative humidity dependence of light scattering, f(RH)

LOCAL VISUAL RANGE
The distance at which a large, dark object viewed against the horizon sky disappears from view due to intervening aerosol (haze) for the average human observer.

$V = 1/\sigma_e * \ln(C/\varepsilon)$
where:
V is the local visual range in km
σ_e is the light extinction coefficient in km^{-1} in the mid-visible wavelength = 550nm
C is the contrast ratio (1 for a black object)
ε is the visual threshold contrast of the observer (generally 0.02)

Thus, for the average viewer V is only a function of σ_e along the viewed path.

Middleton, W.E.K., Vision through the Atmosphere, 1952, pp. 104-122.

MEASUREMENTS

Scattering: integrating nephelometer, TSI model 3563,
three wavelengths (450, 550, 700nm)
sub-10 µm and sub 1 µm size range measured at 60% RH
10 second time resolution, presented as 1 minute averages

Absorption: particulate soot absorption photometer,
PSAP, filter-based,
three wavelengths (467, 550, 660 nm)
sub-10 µm and sub 1 µm size range measured at 20% RH
10 second time resolution, presented as 1 minute averages

Relative humidity dependence of scattering, f(RH):
integrating nephelometers, TSI model 3563,
three wavelengths (450, 550, 700nm)
sub 1 µm size range only
measured at 25% and 85% RH
10 second time resolution, presented as 1 minute averages

Ancillary measurements:
meteorological variables, air mass trajectories,
particulate mass concentration, chemical analysis,
aerosol size distribution

Three time regimes were selected based on the position of the ship, regional scale air mass trajectories and radon level. High Rn levels indicate long trajectories over land; low levels indicate long trajectories over the ocean with minimal land contact or influence.
1. Gulf, southerly - ship was in the Gulf of Mexico, winds were southerly and Rn was low.
2. Land, southerly - ship was on inland waterways, winds were southerly and Rn was low.
3. Land, northerly - ship was near shore or on inland waterways, winds were northerly and Rn was high.

The aerosol optical data were sorted and plotted on this time basis for comparison to aerosol chemistry and aerosol physics presentations.
See sessions C-Aerosol-01, 10, 11.

ACKNOWLEDGMENTS

Thanks to the officers and crew of the NOAA RV Ronald H. Brown who facilitated the cruise logistics, onboard operations and non-standard cruise instructions including 100m accuracy satellite track postioning.

Thanks to NOAA PMEL scientists and logistical support before during and after the cruise.

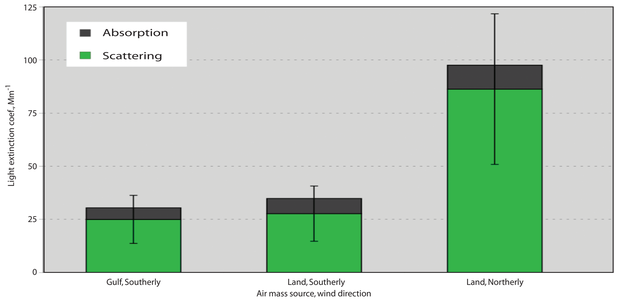
This research was supported by research grants from:
NOAA Climate Programs Office

NSF Division of Atmospheric Chemistry

SUMMARY AND CONCLUSIONS

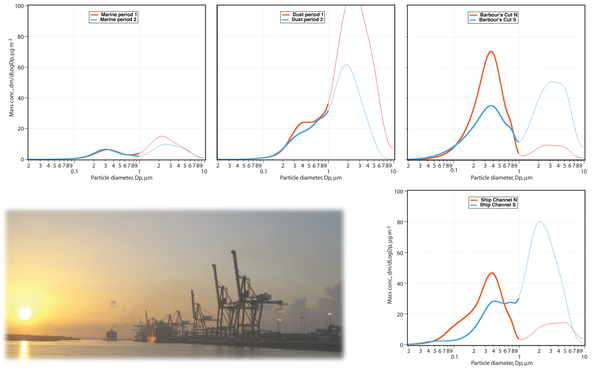
Measurements of aerosol optical properties were made on the NOAA Research Vessel R. H. Brown in coastal waters of the Gulf of Mexico and in inland waterways in the Galveston to Houston industrial region. The results, sorted by ship location and wind direction, showed that aerosol scattering and extinction levels were high during both southerly and northerly wind directions but higher by a factor of two or more under northerly flow from the urban and industrial sources. The submicrometric aerosol associated with southerly flow was highly hygroscopic which reflected its chemical composition of soluble sulfate, nitrate and organic compounds - a highly pollution modified marine aerosol. The aerosol from the urban and industrial sources had a larger organic fraction and was less hygroscopic. The combination of high extinction levels, high hygroscopic growth factors and high ambient humidity leads to significant reduction in visibility throughout the region under all flow regimes.

SUBMICROMETRIC PARTICULATE LIGHT EXTINCTION
Average submicrometric particulate light extinction coefficient at 550nm, 60%RH



Average submicrometric aerosol optical properties, 60% RH, for major source, local flow regimes	Gulf, Southerly	Land, Southerly	Land, Northerly
Light extinction coefficient, Mm^{-1}, 550nm	30.4	34.8	97.6
Standard deviation	11.3	13.0	35.5
Particulate mass conc., µg/m³ gravimetric 60% RH	10.8	11.0	27.1
Mass light extinction efficiency, m²/g @ 60% RH	2.8	3.2	3.6
Visual range, km	91	83	36
Visual range, miles	57	52	22

SUBMICROMETRIC PARTICLE MASS DISTRIBUTIONS



The particle mass-size distributions illustrate the modes that contribute to the aerosol during the location, flow regimes shown above. These average distributions are selected to illustrate the sources rather than match the regional time-space average. (See session C-Aerosol-10)

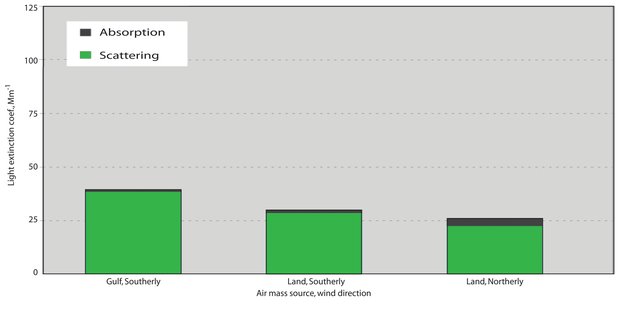
The submicrometric mode modal mass mean diameter was limited to the range 0.3 to 0.4 µm.

Mass concentrations varied by an order of magnitude, from 4 to 40 ug/m³, marine periods cf. Barbour's Cut, northerly winds, respectively.

The fine modes of the marine aerosols during both southerly flow, low radon regimes, were not dominated by seasalt but by sulfate, organic compounds and Saharan dust particles (extending from the dominant coarse mode into the fine range such that the the fine mode is only evident as a shoulder on the coarse mode).

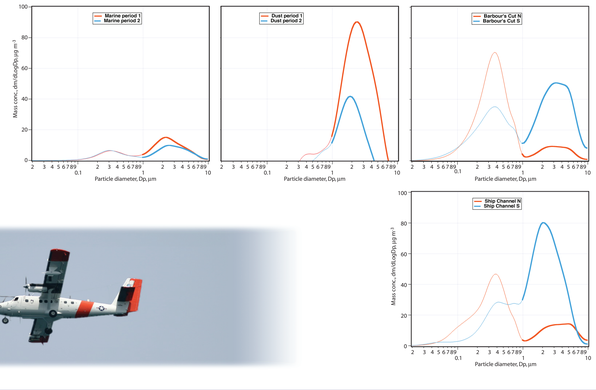
In spite of the variability in the modal parameters of the fine mode there was a close relationship between fine mass concentration and light scattering. The mass extinction efficiencies are given in the tables and are similar to historical values.

SUPERMICROMETRIC PARTICULATE LIGHT EXTINCTION
Average supermicrometric particulate light extinction coefficient at 550nm, 60%RH



Average supermicrometric aerosol optical properties, 60% RH, for major source, local flow regimes	Gulf, Southerly	Land, Southerly	Land, Northerly
Light extinction coefficient, Mm^{-1}, 550nm	39.2	29.9	25.9
Particulate mass conc., µg/m³ reconstructed dry	17.2	16.8	7.4
Particulate mass conc., µg/m³ gravimetric 60% RH	28.0	23.0	16.0
Mass light extinction efficiency, m²/g @ 60% RH	1.4	1.3	1.6
Visual range, km	76	93	102
Visual range, miles	47	58	64

SUPERMICROMETRIC PARTICLE MASS DISTRIBUTIONS



The particle mass-size distributions illustrate the modes that contribute to the coarse aerosol during the location, flow regimes shown above. These average distributions are selected to illustrate the sources rather than matching the regional time-space average.

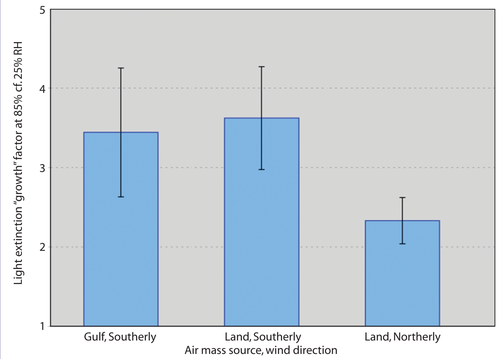
The supermicrometric mode mass mean diameter had a relatively narrow range, 2 to 4 µm.

Mass concentrations varied by an order of magnitude, from 7 to 70 ug/m³.

The coarse modes of the marine and dust aerosols during southerly flow, low radon regimes, were dominated by seasalt and Saharan dust with Dgm of 2.5 µm ±0.5 µm. Modes observed in the industrially influenced inland waterways were slightly larger and dominated by dust and organic compounds. The large coarse mode at Barbour's Cut with southerly wind was likely due to shipping terminal activity. (See session C-Aerosol-01for more chemistry)

The relative constant modal parameters of the coarse mode leads to a tight relationship between coarse mass concentration and light scattering which is not generally the case for coarse aerosols. The mass extinction efficiencies are given in the tables.

DEPENDENCE OF SUBMICROMETRIC EXTINCTION ON RELATIVE HUMIDITY
Average change in light extinction for a change of RH from 25 to 85% at 550nm



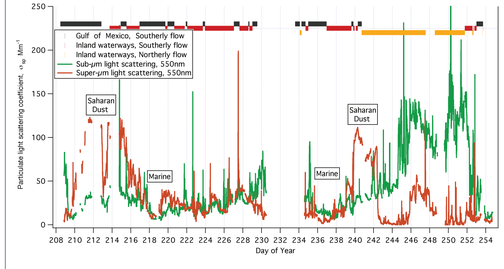
VISUAL RANGE VS AEROSOL SOURCE, SIZE, RH

Local visual range, km	Gulf, Southerly	Land, Southerly	Land, Northerly
Limit due to:			
Air Rayleigh scattering	317	317	317
PM1 @ 60% RH	91	83	36
PM10-1 @ 60% RH	76	93	102
PM10 @ 60% RH	48	51	29
PM10 @ 85% RH	25	23	15

DISCUSSION

Submicrometric light scattering and absorption coefficients during the southerly flow conditions, with a multitude of long-range transport and regional, maritime industrial sources, were similar for both the coastal and inland waterways locations at 30 to 35 Mm^{-1}; during northerly flow conditions with urban and industrial sources upwind, the levels were a factor of three higher. Absorption coefficients were relatively large, 15% of extinction, due the collective combustion sources in the offshore region.

The measured change in submicrometric scattering with relative humidity was highest for the aerosol during southerly flow. The magnitude of the dependence at 85% RH was near the maximum that is possible given the physical and chemical properties of the aerosol. The chemical composition was dominated by water soluble sulfate and organic compounds. During northerly flow the aerosol had a smaller sulfate and nitrate fraction and a larger organic fraction.

Supermicrometric light scattering was highest in the Gulf region during southerly flow at 35 to 40 Mm^{-1}; this period was particularly highly influenced by long-range transport of Saharan dust. Absorption coefficients were relatively large for coarse particles due to the dust fraction in the southerly flow. The source of the absorption in the coarse particles during northerly flow is unclear.

TIME SERIES OF SUB- AND SUPERMICROMETRIC LIGHT SCATTERING OVER THE DURATION OF THE CRUISE