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Taking a snapshot of atmospheric aerosols and their optical properties

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The Advanced Navy Aerosol Model provides a quick and simple method to estimate aerosol properties in the maritime atmosphere using standard meteorological parameters.

Aerosols play a fundamental and complex role in climate because they interact with incoming solar radiation. Absorption reinforces the effect of greenhouse gases on global warming; scattering reduces the radiation reaching the Earth's surface and causes cooling. Furthermore, aerosols can act as condensation nuclei and are therefore important in cloud formation. The Intergovernmental Panel on Climate Change considers aerosol effects as one of the larger uncertainties in climate assessment,[1] owing to the heterogeneous spatial and temporal distribution of aerosol particles in the troposphere—the part of Earth's atmosphere closest to the ground—as well as their different origins (natural, anthropogenic).

With 70% of the Earth covered by the oceans, sea-salt aerosols formed by the interaction of air and water represent a major component of the natural aerosol mass. To estimate their concentrations and optical properties (scattering and absorption), the Navy Aerosol Model (NAM), conceived in 1983, was the first model relating standard meteorological parameters to fundamental sea-salt aerosol processes such as production (governed by wind speed) and humidity-induced growth.[2] NAM models the aerosol distribution as a superposition of three lognormal curves—see Figure 1—that are adjusted as functions of the meteorological scenario. For engineering purposes, NAM is available through the widely-used moderate resolution atmospheric transmission code.[3]

Over the years, NAM proved quite successful in modeling the aerosol distribution in remote oceanic regions. However, the model is less successful in coastal areas because of the heterogeneity of the coastal zone, which not only affects the production mechanism of the sea-salt aerosols (changes in wave field, presence of surf zone), but also introduces a variety of additional aerosols in the atmosphere. These particles have been generated over land and are of anthropogenic (industrial, urban) or natural origin. As the sources of the aerosols originating from land are highly localized, their concentration is highly variable in time and space.

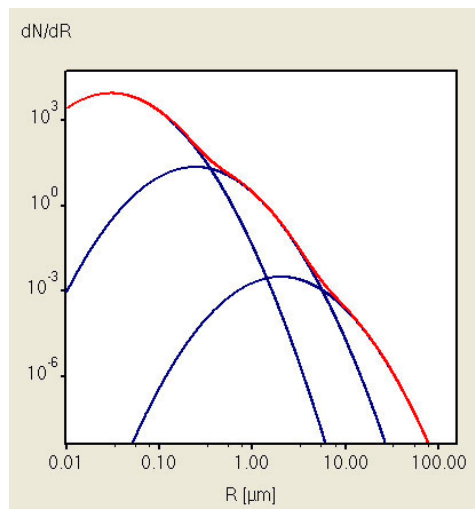

Figure 1. *Lognormal curves of the original Navy Aerosol Model (NAM) (blue) and overall aerosol distribution (red).*

We aimed to remedy the shortcomings of NAM with the Advanced Navy Aerosol Model (ANAM).[4] Part of the ANAM development consisted of a review of the modeling of sea-salt aerosols. We added a fourth lognormal to accommodate the (height-dependent) contribution of very large (∼10μm diameter) sea-salt particles in the atmospheric surface layer. An additional production mode covered the generation of large numbers of sea-salt particles in the surf zone near the beach. We introduced the concept of fetch—distance that an air mass has traveled over water—to accommodate the horizontal dispersion

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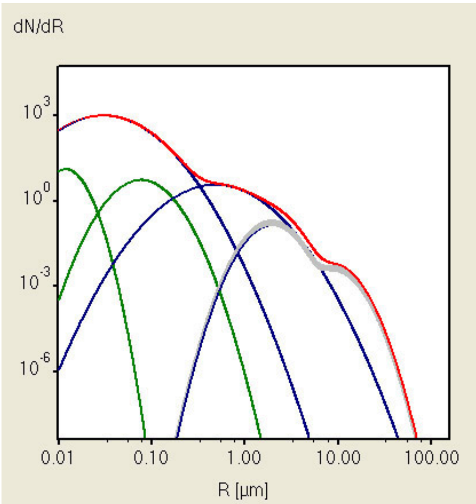

Figure 2. Modes of Advanced Navy Aerosol Model (ANAM). The blue curves represent marine modes, green represents aerosols of land-origin, grey represents surf-generated sea-salt and red represents the overall aerosol distribution.

of aerosols generated over the surf zone and the first few kilometers from shore.

We simultaneously altered ANAM to accommodate aerosols of land origin. Initially, the (A)NAM included the air mass parameter, which can be related to visibility or absolute particle number and governs the relative concentration of sea-salt to dust-like aerosols. The latest version of ANAM replaces the dust-like aerosols with black carbon and water-soluble aerosols (e.g., sulphates), which contribute more significantly to the optical properties. The relative concentrations of the aerosol species are now governed by the Angstrom parameter that describes the variation of aerosol extinction with wavelength. The Angstrom parameter is routinely measured at more than 300 locations world-wide and made available through the community via the Aerosol Robotic Network.[5]

Although the current ANAM includes six modes—see Figure 2—the original NAM philosophy has been retained because the model is still driven by meteorological parameters that can be easily obtained. Several validation efforts have been reported, which demonstrate that ANAM provides an improvement over NAM.[5] For marine conditions (oceanic or coastal with onshore flow), the ANAM predicts aerosol concentrations to within a factor of 2–4, as compared to a factor of 8–10 for NAM. In our opinion, this is probably as good as it gets for regression modeling, i.e., a series of semi-empirical relations between aerosol concentration and meteorological parameters.

Nevertheless, the performance of ANAM in coastal regions with strong influences from nearby land remains limited and discrepancies between model predictions and experimental concentrations can easily reach an order of magnitude. This signals that the local meteorological parameters that are input to ANAM cannot capture the larger-scale processes, such as dispersion of aerosols from their production zone to the measurement site. It is our hope to capture the variability of the coastal zone by the (continued) development of more elaborate models incorporating the full dynamics and thermodynamics of the aerosol lifecycle, as well as the mesoscale meteorological variability.[6,7]

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