Capabilities & limitations of space-borne passive remote sensing of dust

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1. INTRODUCTION

Atmospheric dust particles have significant effects on the climate and the environment *[Martin and Fitzwater, 1991, Bopp et al, 2003, Wang et al., 2002, Shinn et al., 2000, Dunion and Velden, 2004, Evan et al., 2008*], and despite notable recent advances in modeling and observation, wind-blown dust radiative effects remain poorly quantified in both magnitude and sign *[IPCC, 2001]*. To address this issue, many scientists are using passive satellite observations to study dust properties and to constrain emission/transport models, because the information provided is both time-resolved and global in coverage. In order to assess the effects of individual dust outbreaks on atmospheric radiation and circulation, relatively high temporal resolution (of the order of hours or days) is required in the observational data. Data should also be available over large geographical areas, as dust clouds may cover hundreds of thousands of square kilometers and will exhibit significant spatial variation in their vertical structure, composition and optical properties, both between and within dust events. Spatial and temporal data continuity is necessary if the large-scale impact of dust loading on climate over periods ranging from hours to months is to be assessed.

Instrument	Full name	Reference	Products used for dust studies
AVHRR	Advanced very high resolution radiometer	*Hulsar et al., 1997* *Evan et al., 2006a*	AOT (ocean), Dust fraction (from new dust detection algorithm, *Evan et al., 2006a, ocean*)

TOMS	Total Ozone Mapping Spectrometer	*Torres et al., 1998*	Aerosol index (AI) (land and ocean)
METEOSTAT	European meteorological Geostationary Satellites	*Molin et al., 1997* Legrand et al., 1994	AOT (ocean) IDDI (Dust index)- land and ocean
GOES	Geostationary Satellites	*Wang et al., 2003* *Dunion and Velden, 2004*	AOT (ocean) Dust index (BT differences IR channels)
MISR	The Multi-angle Imaging	*Diner et al.,* 2001	

	Imaging SpectroRadiometer		AOT and properties (land and ocean)
MODIS	Moderate Resolution Imaging Spectroradiometer	*Remer et al., 2005*	AOT (ocean and some land), fine/course aerosol fraction (ocean)

AIRS	The Atmospheric Infrared Sounder	*DeSouza-Machado et al., 2006*	IR Dust mask (ocean)
AATSR	The Advanced Along-Track Scanning Radiometer	*Grey et al., 2006, Thomas et al, 2007*	AOT (land and ocean)
POLDER	POLarization and	*Herman et al., 2005*	AOT, nonspherical fraction of course

	Directionality of the Earth's Reflectances		(ocean)
OMI	Ozone Monitoring Instrument	*Torres et al., 2007*	AI and UV AOT (land and ocean)
SEVIRI	Spinning Enhanced Visible	*Schepanski et al, 2007*	IR dust mask, AOT (land and ocean)

	Enhanced Visible and InfraRed Imager		and ocean)

Table 1. Satellite instruments (names and abbreviations) used for dust characterization studies.

Recently available satellite data from current-generation sensors and from new retrieval algorithms (Table1) make it possible to improve model dust predictions by providing significant new information about dust property evolution, emission, transport, and deposition through UV, visible, near infrared, and thermal infrared dust signatures.

2. OVERVIEW OF SATELLITE RETRIEVAL CAPABILITIES FOR DUST CHARACTERIZATION STUDIES

Dust characterization studies employ both the long-record aerosol optical thickness (AOT) data available from early satellite sensors (mainly for the long-term global climate studies) and advance capabilities recently available from current-generation satellite sensors, specifically design to study spatially and temporally resolved properties of atmospheric aerosols. Some of new sensors are part of the A-train cancellation, creating the opportunity for data synergy and fusion, and for further improving dust property characterization.

Dust climatology (historical data)

The TOMS absorbing aerosol product provides 30 years of global coverage, and is often used to characterize global atmospheric soil dust sources, understand dust transport patterns, and to validate transport models [*Prospero et al.*, 2002, *Ginoux and Torres*, 2003, *Chiapello et al., 2005*]. The AVHRR long-term record of aerosol detection (available since 1982) was used for Saharan dust characterization over the ocean (*Husar et al., 1997*) and, recently, for analysis of winter dust activity off the coast of West Africa *(Evan et al., 2006b).* Dust studies employing geostationary satellites such as GOES and METEOSTAT (re-calibrated data is available since early 1990s), are using sensor's visible and infrared bands to derive visible AOT and IR dust indices (Brightness Temperature Depression from GOES and IDDI from METEOSTAT). Geostationary satellite dust data was mainly used for dust climate studies, such as long-term monitoring of the Saharan dust load over ocean *(Moulin et al., 1997)*, dust effects on hurricane formation (*Dunion and Velden, 2004*), and dust effect on the rainfall rates in the Sahel region *(Brooks and Legrand, 2000).*

TOMS aerosol estimates, over both land and water, are derived using satellite radiances in the ultraviolet region and are based on a quantity known as the aerosol index

(AI). There are large uncertainties in the TOMS AI product, principally because the instantaneous field of view of the sensor is large (50 by 50 km at nadir), resulting in a high likelihood of sub-pixel cloud contamination. METEOSTAT IDDI, derived from sensor's IR band, also provides dust estimates over both land and water, however IDDI sensitivity to dust size distribution and dust vertical resolution introduces data biases. The main issues of dust studies based on AVHRR and METEOSTAT-derived visible AOTs over the ocean is that they have equated the AOT in predominately dusty regions as being due to dust, ignoring the contributions to the AOT from African smoke and sea salt particles.

Dust AOT and properties from recent-generation satellite sensors.
The advanced capabilities of recent sensors, summarized in Table 2, promise to greatly improve our understanding of the properties of mineral dust, and will be extensively discussed in the presentation.

Instrument	Record length	Features	Capabilities	Issues and Limitations
MISR	8+	Multi-angle visible-NIR, hi spatial resolution	AOT, aerosol properties, and dust fraction over ocean/land,	~Weekly global coverage, narrow spectral range, cloud contamination, need better coarse dust optical model

			no sun-glint problems	
MODIS	8+	Nadir-viewing, multi-spectral visible-IR. Hi-resolution, daily global coverage	AOT and fine/course fractions over the water.	Cloud contamination, glint, limited to dark surfaces/ deep-blue is not fully validated, no particle shape sensitivity
AIRS	5+	Hyper-spectral IR. Global	Dust AOT (course mode) day/ night, over ocean/land, no sunglint problems, refractive	Sensitivity to dust IR spectral properties, initial assumption on dust models can significantly

		spectral IR. Global coverage day and night	indices can distinguish between different dust sources	change retrieved aot
AATSR	12+	Dual-look, hi-spatial resolution	AOT over land/water	Weekly global coverage, cloud contamination
POLDER/ PARASOL	2-3+	Multi-look, polarization, global coverage	AOT, 3 aerosol modes including non-spherical course dust over ocean	Short record, not sensitive to aerosol course mode over land
OMI	4+	UV-visible instrument, aerosol property retrieval capabilities	Aerosol index (AI), absorbing and	Cloud contamination, glint, cannot detect low lying aerosols, sensitivity to layer height, and UV aerosol properties only

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