Ground-based retrievals of optical depth, effective radius, and composition of airborne mineral dust above the Sahel

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ARM Atmospheric Radiation Measurement Program

Background and Objectives

- Many airborne minerals have absorption features in the thermal infrared (8-13 µm)
- These absorption features can be used to determine the “radiatively relevant” mineral composition of atmospheric dust
- Optical depth and effective radius are also important parameters that control the radiative impact of the dust
- Objectives:
  - Retrieve the τ, R_e, and composition of dust using AERI obs to characterize the dust properties over Niamey
  - Correlate these microphysical properties with atmospheric conditions
  - Use retrievals to help evaluate aerosol transport models
  - Investigate the role of dust on the (IR) atmospheric heating rate profile and BL structure

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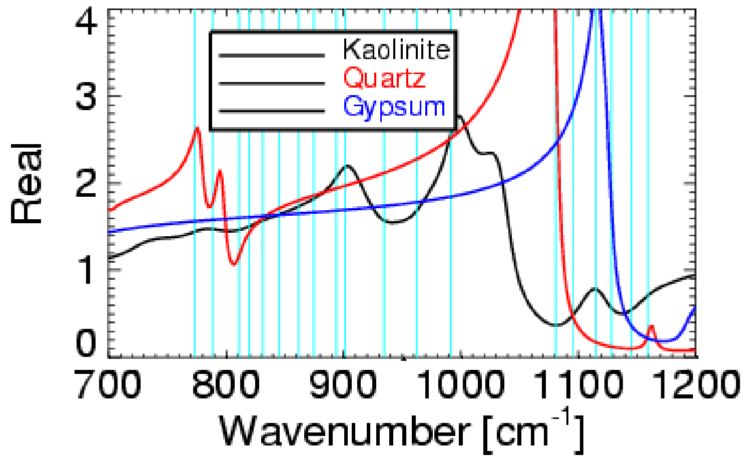
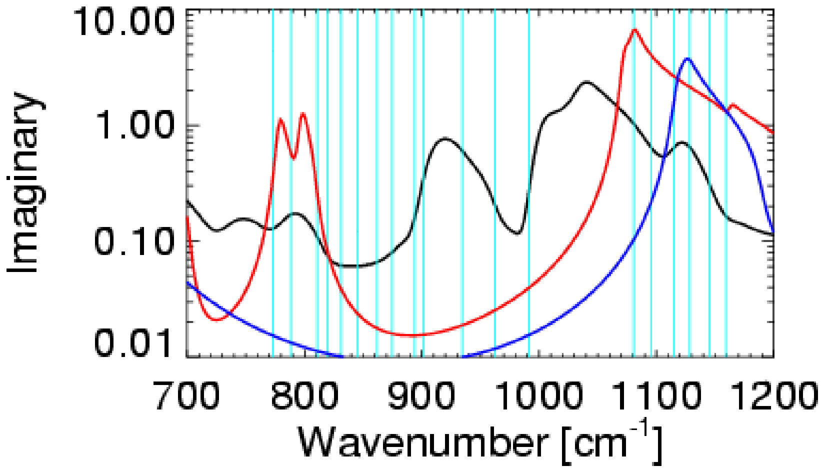
Refractive Indices

- In order to separate contributions from different minerals using AERI obs, each must have a unique absorption band in 8-13 µm band
  - Must avoid bands that are opaque due to H_2O or CO_2, or contaminated by O_3
- Kaolinite, gypsum, and quartz are common minerals in dust over Africa
- Hematite is also commonly found, but does not have an absorption band in the 8-13 µm window





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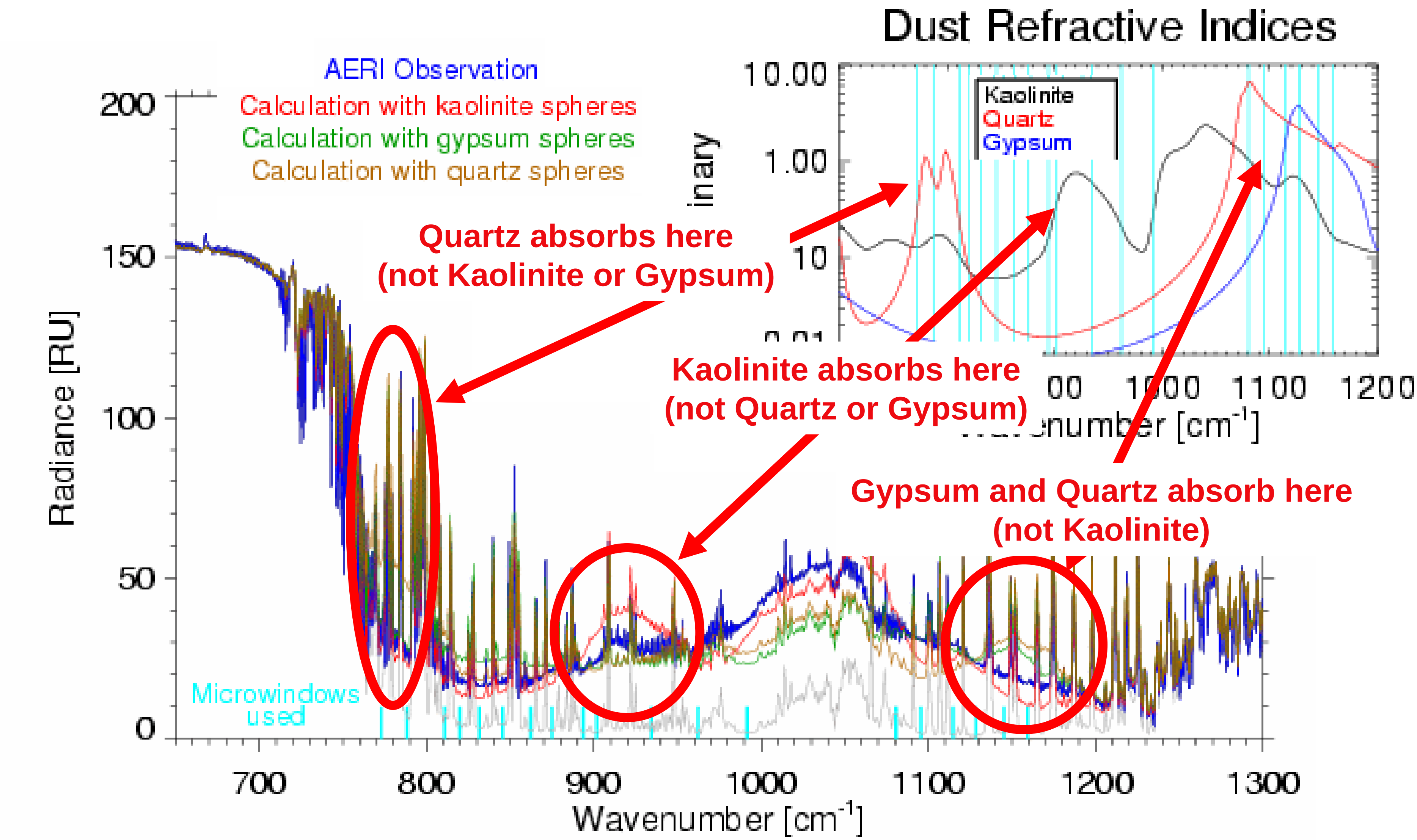
Infrared Spectral Signatures of Different Mineral Types



Approach

- Downwelling IR radiance is sensitive to dust composition, optical depth, and effective radius
  - To detect differences in composition, each mineral must absorb in different spectral regions
  - Able to distinguish between quartz, kaolinite, and gypsum using IR data
- Performed 6 sets of retrievals on manually identified cloud-free periods
  - Quartz-only, kaolinite-only, gypsum-only
  - Quartz+kaolinite, quartz+gypsum, kaolinite+gypsum
- Retrieval with the best statistical fit for each sample was identified
- Results analyzed as function of season and local meteorology

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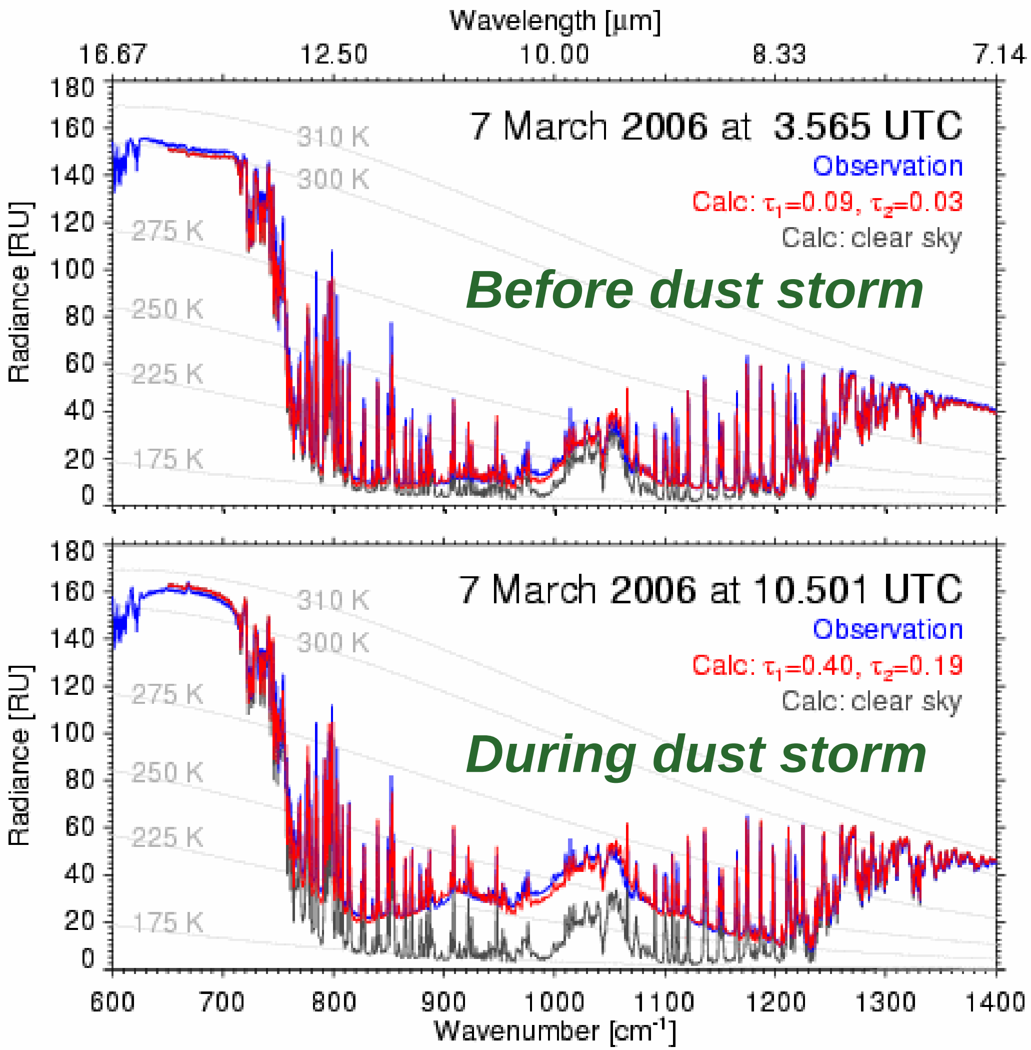
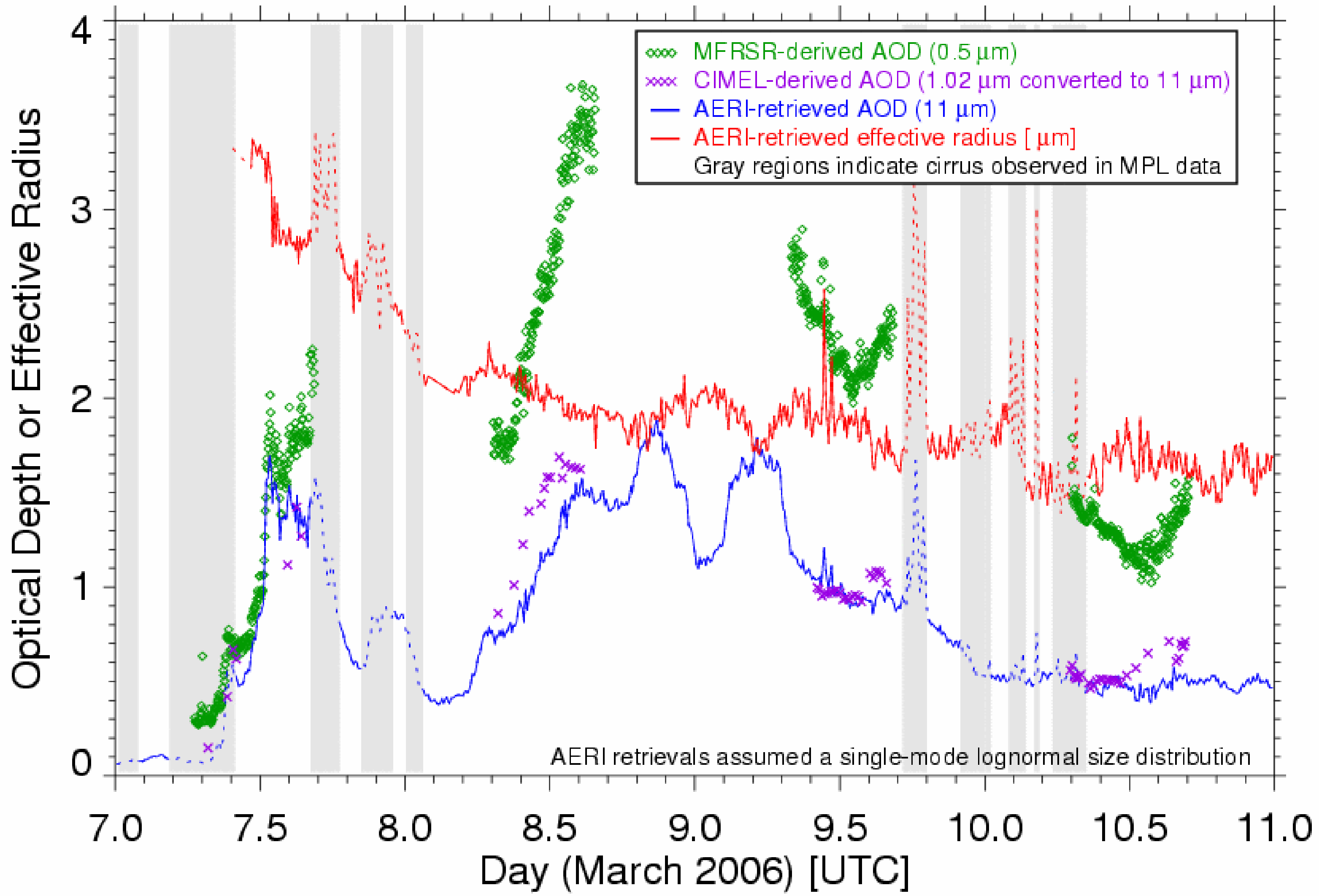
Examples of Spectral Fits

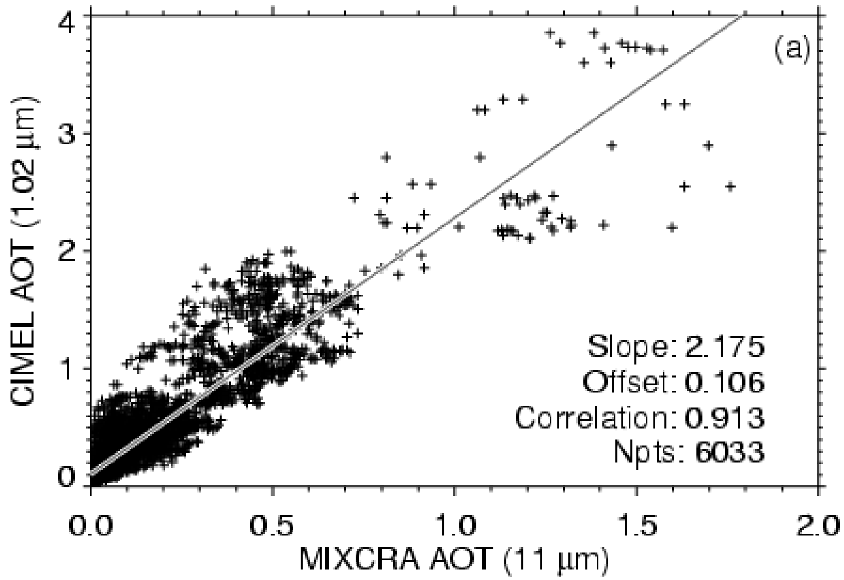


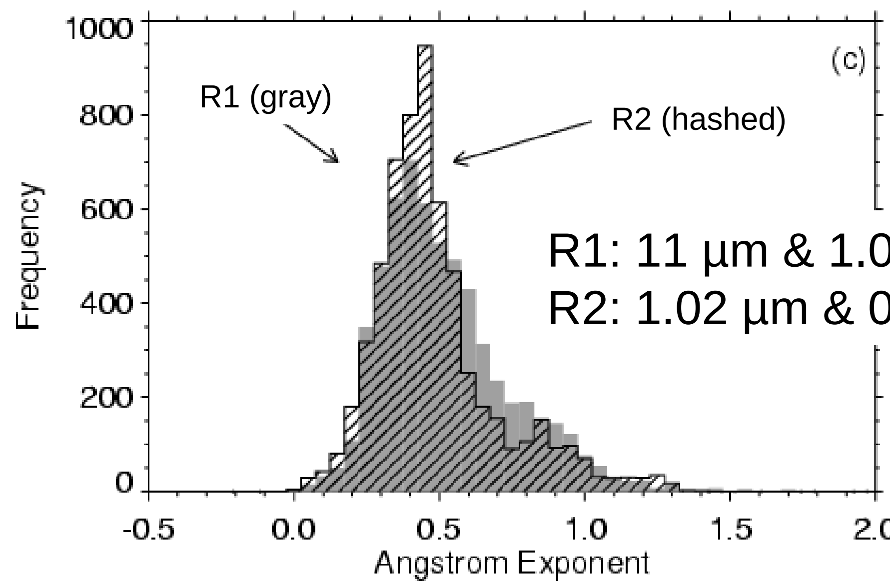
- Dust assumed to be mixture of kaolinite and gypsum in this example
- Use of single mineral results in poorer fit in some spectral regions
- Significant IR forcing at surface due to aerosol

Time-series of Dust Optical Depth and Effective Radius



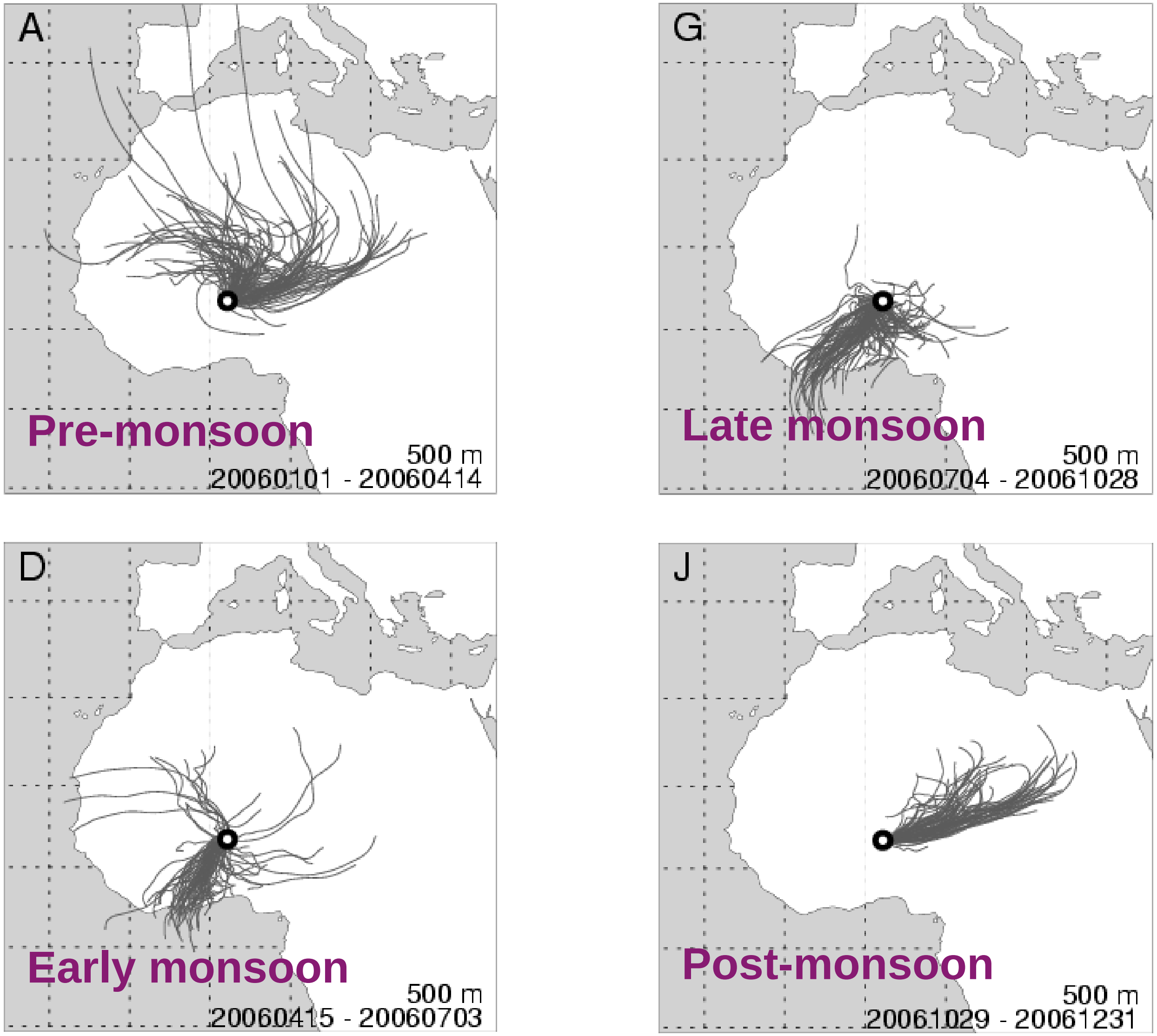
Comparisons with Aeronet





R1: 11 µm & 1.02 µm
R2: 1.02 µm & 0.675 µm

500 m Backtrajectories over Niamey in 2006



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Distribution of Dust Composition

Composition	Pre-Monsoon	Early Monsoon	Late Monsoon	Post-Monsoon	Entire Year
Kaolinite-only	17.8%	29.9%	54.2%	13.7%	20.0%
Gypsum-only	5.9%	4.1%	18.1%	4.0%	5.7%
Quartz-only	0.0%	0.0%	0.0%	0.0%	0.0%
Kaolinite+Gypsum	68.7%	57.6%	19.0%	74.6%	66.6%
Kaolinite+Quartz	7.3%	8.2%	7.3%	7.5%	7.5%
Quartz+Gypsum	0.2%	0.1%	1.5%	0.1%	0.3%
Number of retrievals	5522	1999	1220	8014	16755

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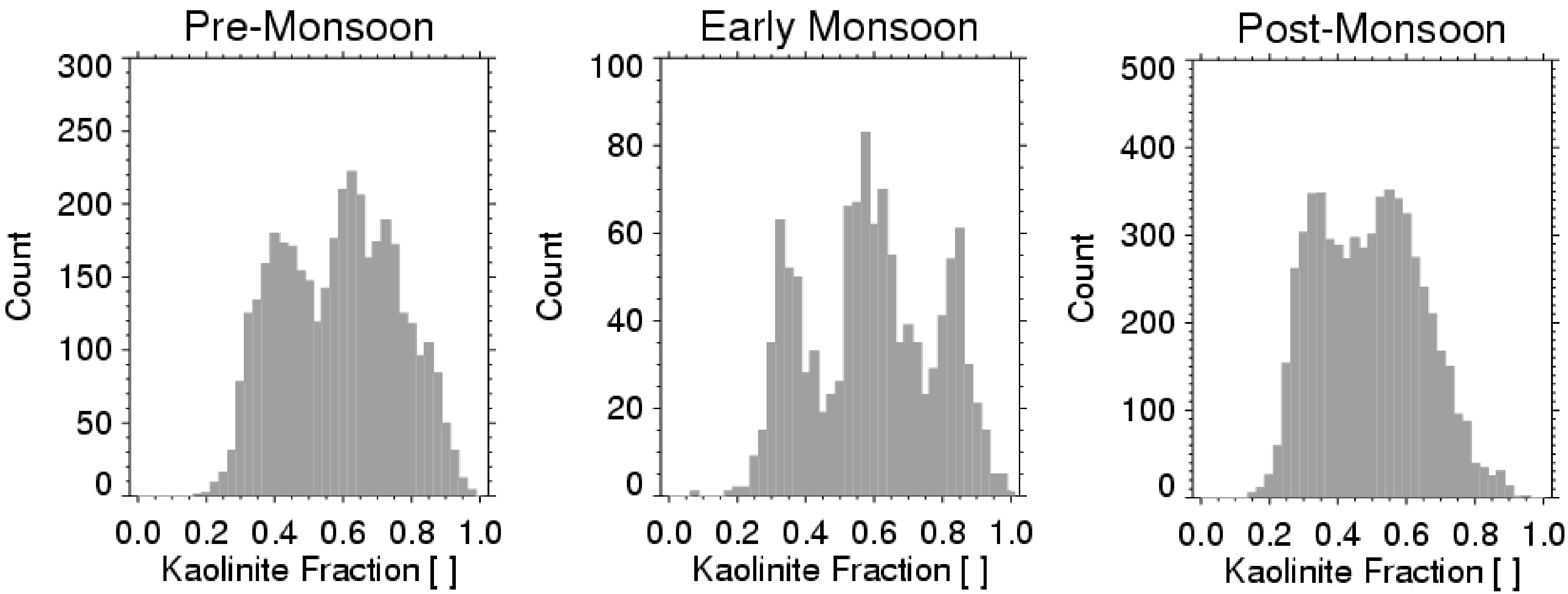
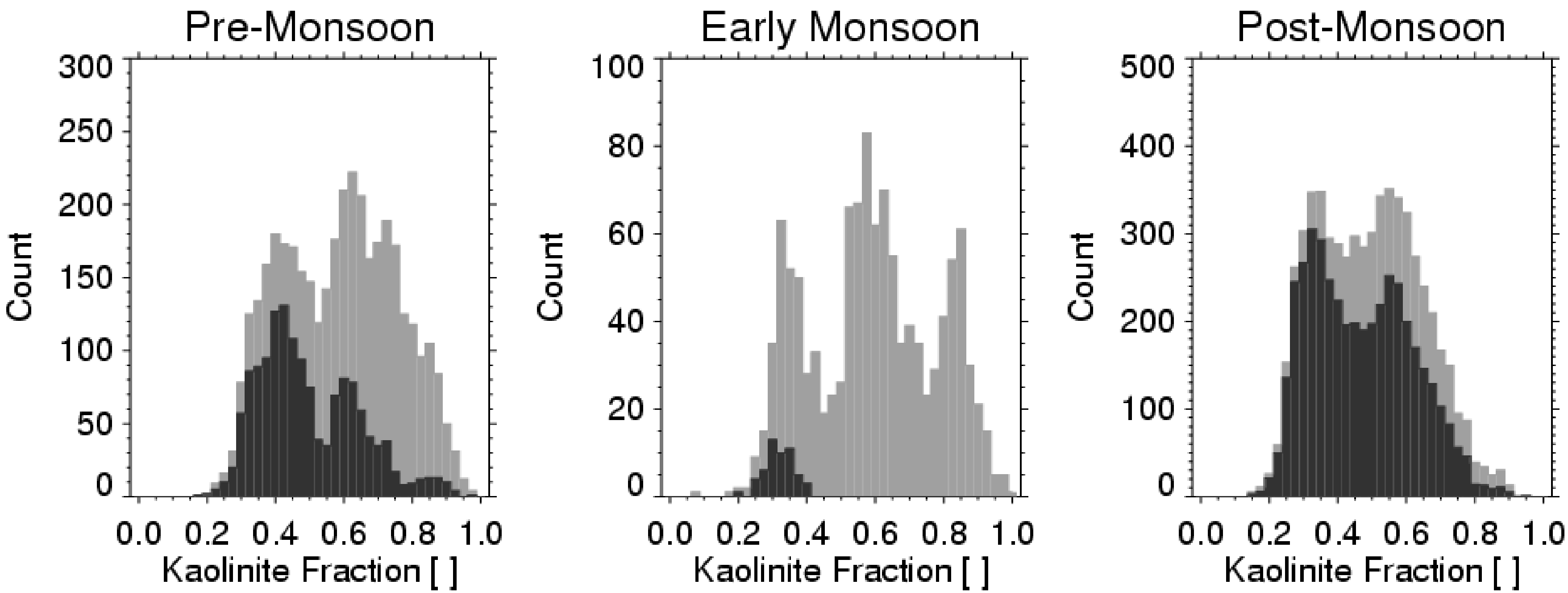
Dependence of Kaolinite Fraction on Season



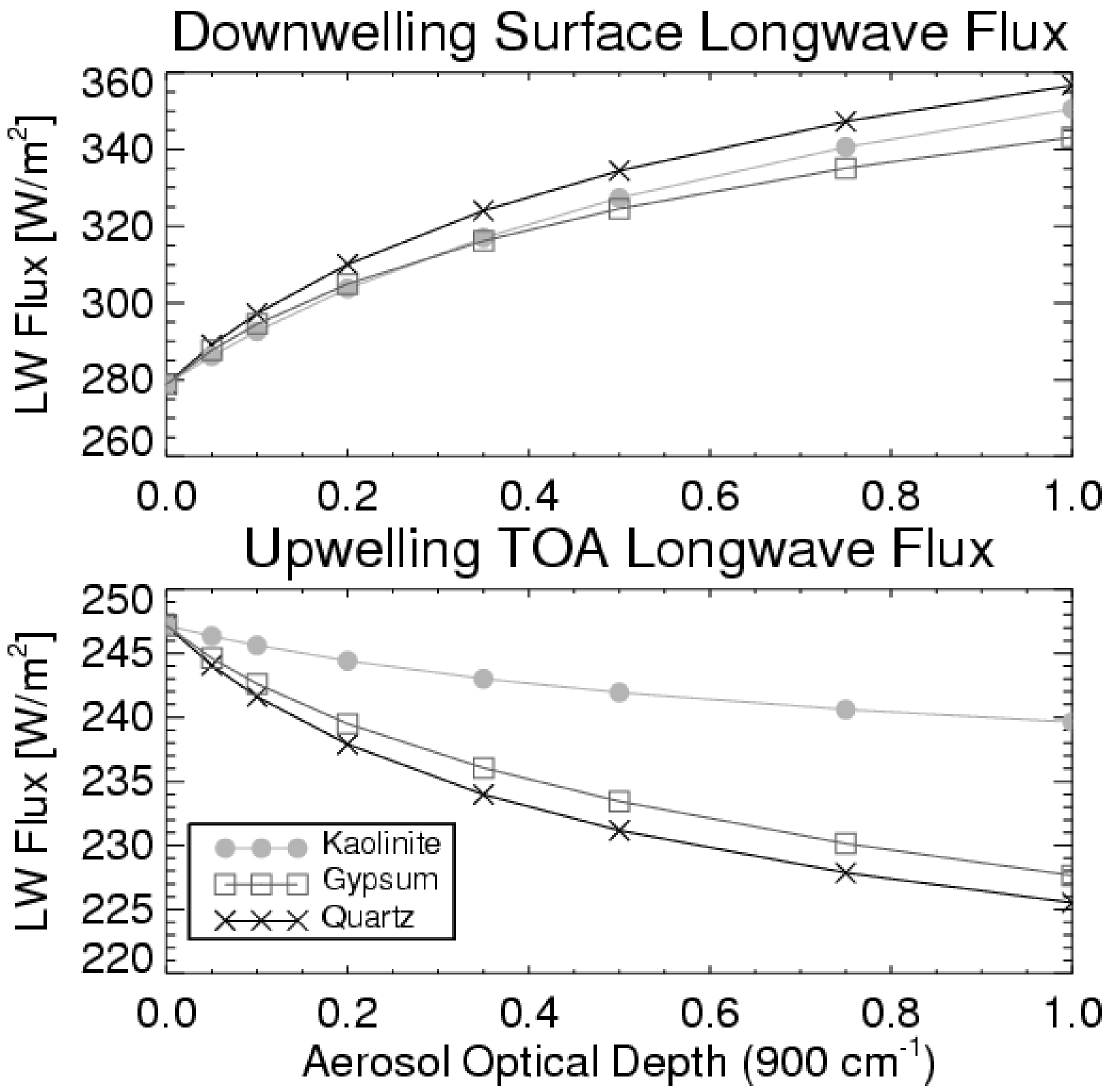
- Using only the kaolinite+gypsum retrievals
- Kaolinite fraction defined as $F_{kao} = \tau_{kao} / \tau_{total}$

Dependence of Kaolinite Fraction on Trajectory Direction



- Gray: distribution of F_{kao}
- Black: subset of F_{kao} where trajectory was from the eastern octave

Impact of Dust Composition on TOA and Surface LW Radiative Flux



Assumed R_e = 1.5 µm

T/q profiles from radiosonde on 15 Mar (1.37 cm PWV)

Summary

- Retrieved infrared optical depth, effective radius, and dust composition from AERI observations at NIM
  - Only used observations from 8-13 μm, and assumed the dust particles to be spherical
  - Dust assumed to be kaolinite, quartz, gypsum, or some combination of any two (external mixtures)
  - Only applied to obs that were identified as cloud free
- Kaolinite is the dominant component of dust for entire year
  - 66% best satisfied by Kaolinite+Gypsum
  - 20% best satisfied by Kaolinite only
  - Quartz was deemed to be relatively insignificant
- Kaolinite fraction exhibits bi-modal distribution, with lower fractions of kaolinite when the wind trajectories are from the eastern octant
- Infrared radiative forcing by the dust can be significant
- Manuscript submitted to JGR

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