SAFARI 2000: Ground Data and MISR Aerosol Optical Depth and BRF/HDRF Validation

Summary Prepared by J. Conel for
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1. Introduction - This summarizes ground activities by the JPL MISR Validation team during and subsequent to the SAFARI 2000 Dry Season campaign of August September, 2000, in Southern Africa. A summary report has been written for AirMISR investigations as part of the present workshop. Ground observations were carried out at two principal sites by the MISR Validation team the Sua Pan, Botswana, and in the Skukuza (RSA) area (see Figure 1).

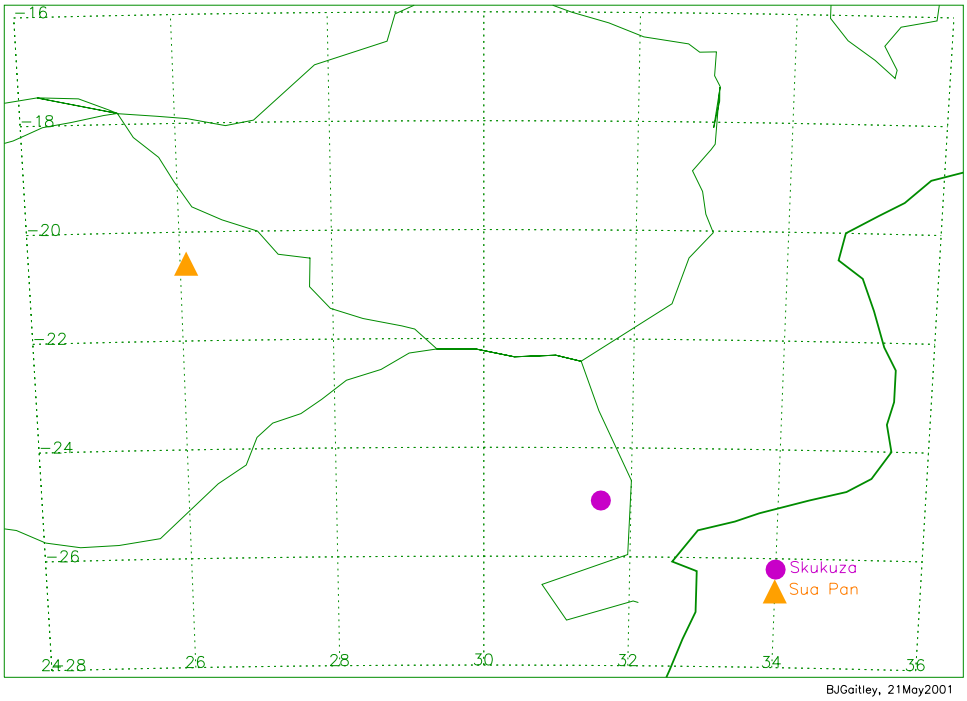


Figure 1. Principal field sites for the ground-based MISR validation effort, identified in legend. lower right hand corner of figure.

2. SAFARI 2000 Science Goals - The principal science goals of the SAFARI 2000 Dry Season Campaign have been summarized well in the SAFARI 2000 Science Plan as follows:
(1) characterize, quantify and understand the processes driving biogenic, pyrogenic and anthropogenic emissions in southern Africa, (2) combine atmospheric transport and chemistry models with ground-based, airborne, and satellite-based observations to validate and extend our understanding of the transport and transformations of these emissions, (3) identify where, when, and how the emissions are deposited, and determine their impacts, and (4) lay the foundation for monitoring

longer term climatic, hydrological and ecosystem consequences of these biogeochemical and physical processes.

3. Characteristics of MISR and aerosol retrieval process - MISR (Multiangle Imaging SpectroRadiometer) was launched into Earth polar orbit aboard the Terra spacecraft December 18, 1999. MISR's scientific objectives include global study of the magnitude and space-time variability of tropospheric aerosols and effects on Earth's radiation budget on regional and hemispheric length scales. (Figure 5 of the present report illustrates the instrument's capabilities for mapping of aerosol optical thickness (AOT) on a subcontinental scale). MISR provides multi-angle, continuous imagery of Earth in reflected sunlight, and uses nine separate CCD-based pushbroom cameras to provide nine discrete view angles of Earth's surface, from nadir to 70.5 deg. relative to local vertical. Imagery is acquired in four spectral bands, e.*g*., 446, 558, 672, and 866 nm. In global observing mode MISR provides 275 m sampling in all bands of the nadir camera and the red band (672 nm) of each of the off-nadir cameras, and 1.1 km for each of the remaining 24 channels. Terra has a 16-day repeat orbit and crosses the equator at approximately 10:45 AM on the decending node.

Spaceborne retrieval of aerosol properties over land requires separation of the surface-leaving radiance and path radiance signals. (see Martonchik, *et al.*, 1998) The operational MISR retrieval algorithm to do this is based upon use of an empirical orthogonal function (EOF) representation of the angular shape of the surface-leaving signal by use of the multi-spectral and multi-angular observed equivalent reflectances at 1.1 km resolution. The EOF representation is at 17.6 by 17.6 km scale. The surface leaving equivalent reflectance is established by calculating a reduced sample equivalent reflectance at each camera view angle by subtracting an average top-of-atmosphere (TOA) reflectance constructed from samples taken over the region. The MISR algorithm establishes candidate aerosol models each containing specified proportions of three component particle types having prescribed chemical and microphysical properties and state of hydration. Path radiances for each aerosol model are calculated assuming a laterally uniform scattering layer. A goodness of fit criterion is applied such that the angular shape of the TOA equivalent reflectance from all samples in the 17.6 x 17.6 km region are similar in a least square sense to the EOF representation of the equivalent reflectance.

4. Principal Goals of the JPL Ground-based Activity - MISR ground validation activities described here were under the leadership of M. C. Helmlinger of JPL. The plan was to provide sufficient surface measurements of the AOT and measurements of surface bidirectional reflectance distribution function (BRDF), and hemispherical directional reflectance function (HDRF) to provide for validation of these geophysical products from MISR, (ii) gather sufficient well-located ground target spectral reflectance measurements with PARABOLA and ASD instruments and AOT and aerosol model constraints with CIMEL contemporaneous with MISR instrument overpasses to provide a basis for vicarious calibration of MISR should need arise to do so. (In addition to periodic on-board MISR calibration, semi-annual vicarious calibration exercises are carried out in the southwestern desert of the United States) (iii)In accord with the established MISR validation plan, employ the southern African array of AERONET instruments to construct correlation diagrams between AERONET and MISR AOT retrievals. (iv) provide ground support for selected overflights of AirMISR, the MISR simulator flying aboard the ER-2, that provides multiangle measurements of ground resolution intermediate between surface (order of meters)

and MISR (275 meters). that may aid in the issue of measurement scaling. (v) seek coordinated overflights involving AirMISR in the ER-2, the Cloud Absorption Radiometer (CAR) in the University of Washington CV-580 providing BRDF surface measurements together with direct sampling measurements of aerosols encountered, and MISR measurements.

With calibration and validation of MISR geophysical products it will be possible to construct time series of MISR geophysical measurements extending throughout the seasons for the lifetime of the Terra mission, thus contributing to Science Goal (4), above.

5. Ancillary Goals- The following are ancillary goals that speak to the issue of transformation of aerosol properties after emission by surface sources and during transport between measurement points on the ground. The plan is to seek AERONET stations that are connected by an airmass trajectory in the gyre and to develop new aerosol models from the *in situ* measurement using the AERONET inversion methods of Dubovik *et al.* (of GSFC), and of Pilorz (of JPL). Particle transformations will be studied by noting changes in size distributions, effective phase functions, extinction coefficients, and chemistry as denoted by complex refractive index; these parameters that can estimated from the inversions. Under proper circumstances it may be possible to image such multiple stations by MISR, thus enabling a comparison between ground and MISR retrievals at multiple sites. This will connect the use of MISR to study of an important aerosol tracking Goal in (2) above Aerosol transformations are the subject of current as well as future research.

6. Ground measurements - We present a few examples of retrievals at field sites occupied by the ground validation team. The matrix of field observations at Sua Pan, Botswana, is shown in Table 1, and at Skukuza Airport and Skukuza Tower, South Africa, in Table 2. Both of these charts are taken from Helmlinger, *et al.* (2000)

Table 1: Data Inventory, Sua Pan

	MISR	PARAB-OLA	ASD	CIMEL	MFRSR	Reagan	Met Station
Aug 18	**Orbit 3553, 08:48 UT**					✔	
Aug 19			✔			✔	✔
Aug 20				✔			✔
Aug 21				✔	✔	✔	✔
Aug 22				✔		✔	✔
Aug 23				✔		✔	✔
Aug 24				✔	✔	✔	
Aug 25			✔	✔	✔	✔	✔
Aug 26				✔	✔	✔	✔

Table 1: Data Inventory, Sua Pan

	MISR	PARAB-OLA	ASD	CIMEL	MFRSR	Reagan	Met Station
Aug 27	Orbit 3684, 08:42 UT	✔	✔	✔	✔	✔	✔
Aug 28				✔	✔	✔	✔
Aug 29				✔	✔	✔	✔
Aug 30		✔	✔	✔	✔	✔	✔
Aug 31				✔	✔	✔	✔
Sep 01		✔		✔	✔	✔	✔
Sep 02				✔	✔	✔	✔
Sep 03	Orbit 3786, 08:48 UT	✔	✔	✔	✔	✔	✔
Sep 04		✔		✔	✔	✔	✔

Table 2: Data Inventory, Skukuza

	MISR	PARAB-OLA	CIMEL	MFRSR	Reagan	Met Station
Sep 14			✔	✔	✔	✔
Sep 15						✔
Sep 16	Orbit 3975, 08:18 UT					✔
Sep 17			✔	✔	✔	
Sep 23	Orbit 4077, 08:24 UT	✔			✔	
Sep 24						✔
Sep 25	Orbit 4106, 08:12 UT		✔		✔	✔
Sep 26		✔				✔
Sep 27			✔			✔
Sep 28		✔	✔	✔	✔	✔
Sep 29			✔			✔
Sep 30		✔	✔	✔	✔	✔
Oct 01		✔				✔

Table 2: Data Inventory, Skukuza

	MISR	PARAB-OLA	CIMEL	MFRSR	Reagan	Met Station
Oct 02	**Orbit 4208, 08:18 UT**		✔	✔	✔	✔

***Aerosol Optical Thickness* (AOT) -** Figures 1 and 2 show the AOT obtained for two days August 27, and September 03, 2001 by three solar radiometers at Sua Pan. The AOT's obtained differ by a factor of about 10 between the days. but the agreement obtained between instruments on each day is reasonably good. These days are cloud free, but hazy. The comparisons with MISR

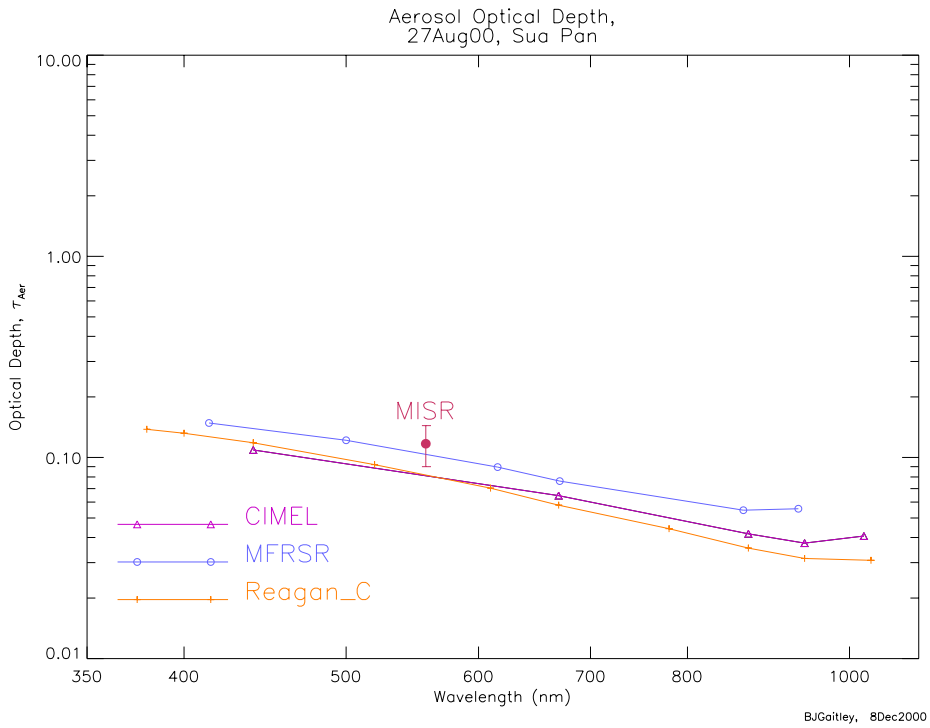


Figure 1. AOTs by various instruments compared with MISR, August 27, 2000, Sua Pan. Note that AOT of this date is a factor of almost 10 lower than that of September 03, shown in Figure 2 (M.C. Helmlinger and B.J. Gaitley for Figures 1, 2 and 3).

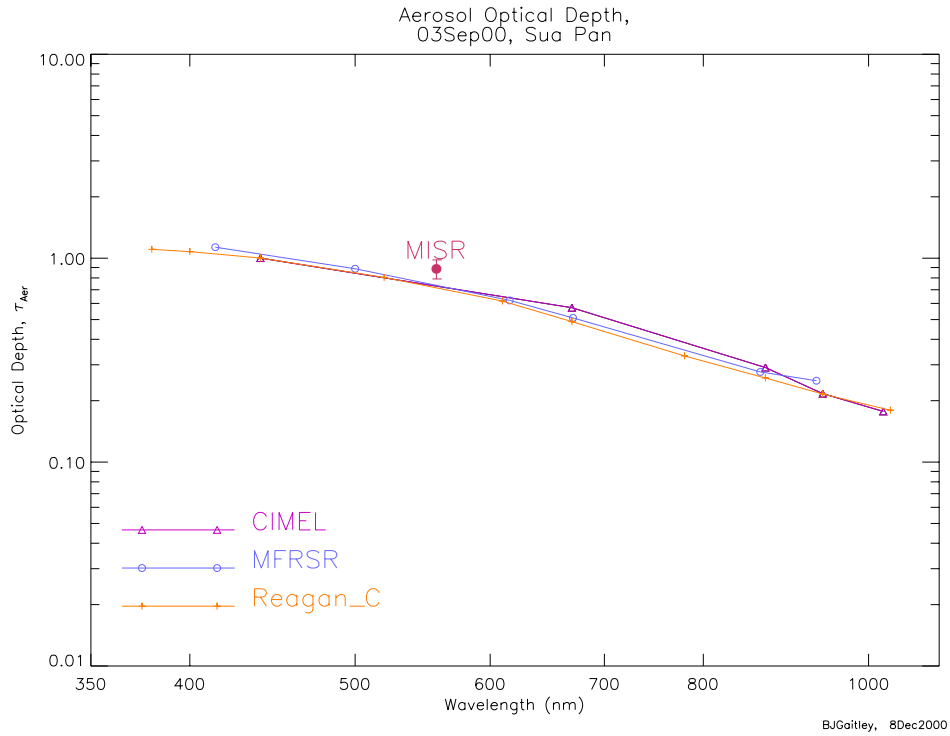


Figure 2. AOTs by various instruments compared with MISR, September 03, 2000, Sua Pan

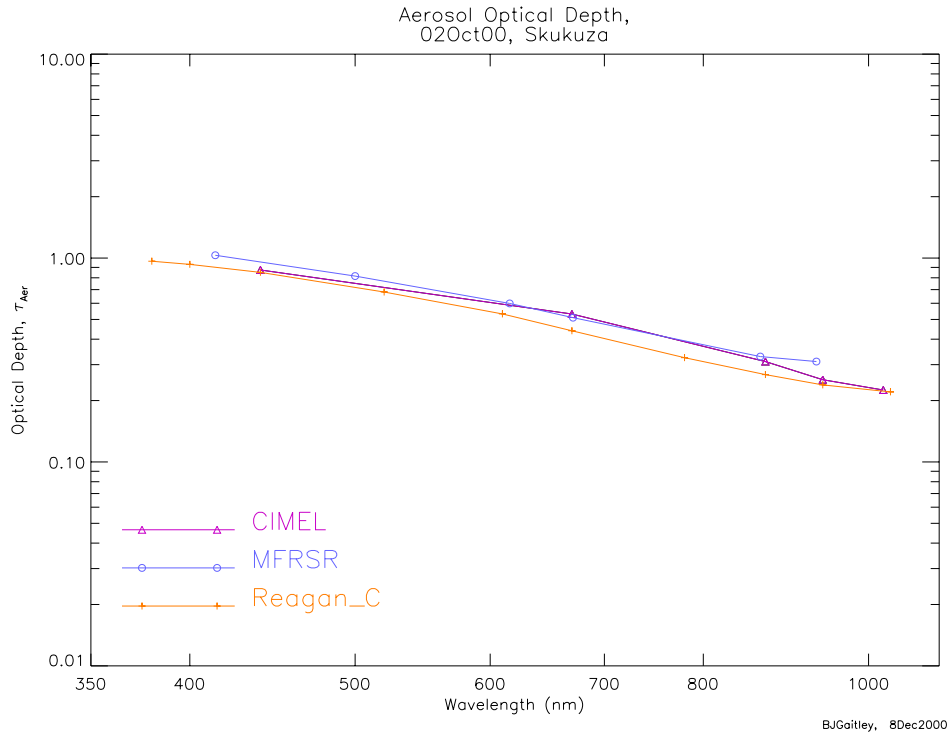


Figure 3. AOT by various instruments at Skukuza Airport, October 2, 2000.

retrievals for 17.6 km square regions about the ground site show MISR AOT (at 558 nm) to be

slightly greater than AOT obtained by the conventional ground methods for both days of comparison. AOT's for Skukuza Airport are shown in Figure 3. The AOT data between solar radiometers show similar close agreement as was also seen at Sua Pan. Unfortunately, no comparison with MISR is available because of bad weather at the Skukuza Airport site on days of platform overpass.

BRDF and HDRF at Sua Pan and Grassland - The JPL PARABOLA (Portable Apparatus for Rapid Acquisition of Bidirectional Observations of the Land and Atmosphere) is a sphere scanning radiometer from which the BRF and HDRF of the surface can be extracted. At Sua Pan the instrument head was mounted on a vertical telescoping stand 3.5 m above the surface. PARABOLA was moved between five different pan and grassland sites between August 27, 2000 and September 03, 2000. (three pan and two grassland) to attempt to compensate for surface inhomogeniety by averaging. As an example, Figure 4 shows a section through the three dimensional reflectance function of the playa surface in the principal plane, illustrating the differences obtained between the surface BRF and HDRF for the extremely hazy conditions of September 03, 2000 and a high solar zenith angle of about 63°. These conditions emphasize differences between the two reflectance representations. Most of the Sua Pan in addition to the grassland PARABOLA data remain to be reduced to BRF and HDRF, but is available in raw format in the JPL SAFARI 2000 archive. Both the so-called hotspot and specular peak in the reflectance are eliminated by the exceptionally strong diffuse incident sky light.

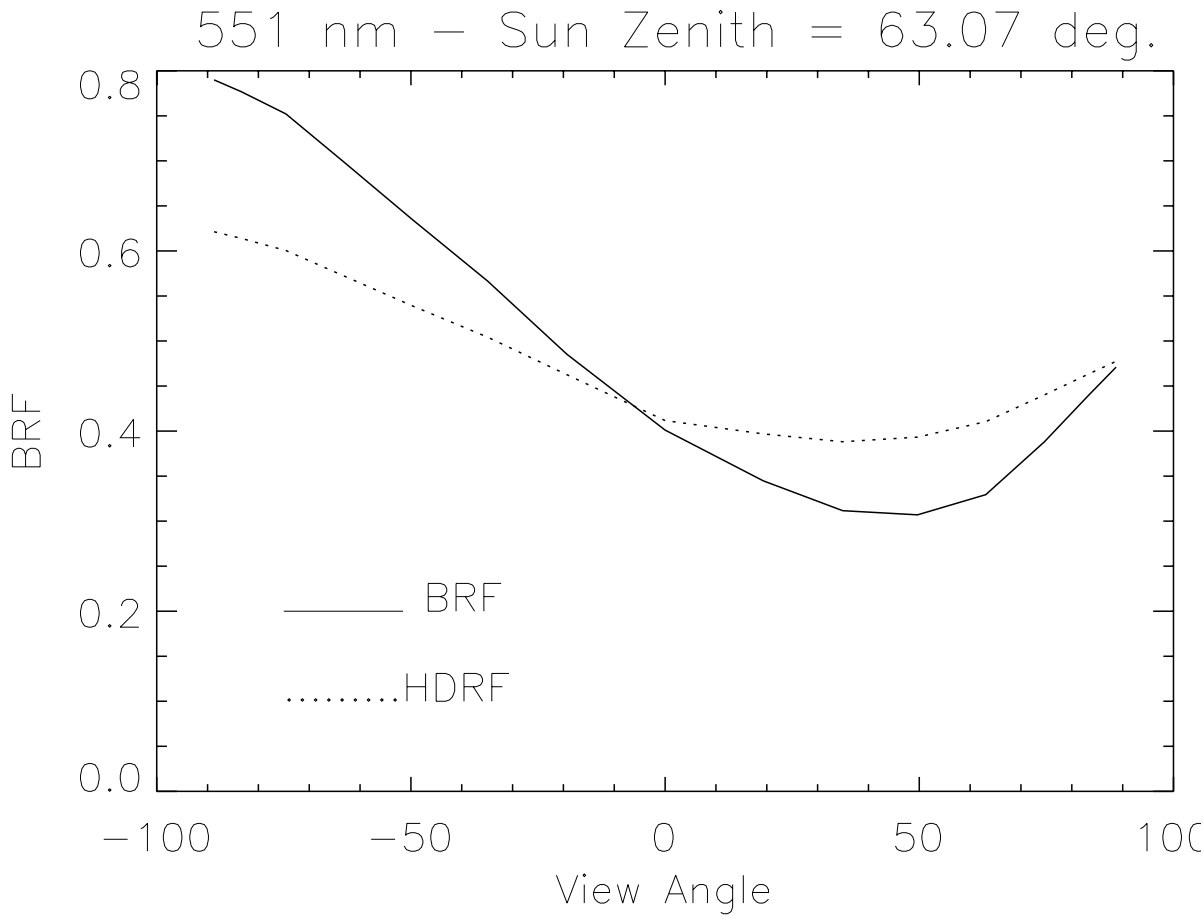


Figure 4. BRF and HDRF of September 03, 2000 at Sua Pan site. Sun is at a (+) view angle of 63.07 deg. Positive view angles represent forward scattering and negative, backscatter. (W.A. Abdou)

BRF and HDRF at Skukuza Tower **-** At Skukuza Tower PARABOLA was mounted atop the telescopic stand which provided an extension of 6 m in addition to the 18 m of the height of the tower (total 23 m). The additional height was used to attempt to gain additional FOV from PARABOLA to help compensate for heterogeneous nature of the canopy cover. No data from Skukuza Tower PARABOLA have yet been reduced because of the extreme complexity of the surface at that site

7. Comparisons of MISR and AERONET AOT's - We used the network of stations of the AERONET (Holben, *et al.*, 1998), which are widely dispersed over southern Africa, Figure 5.

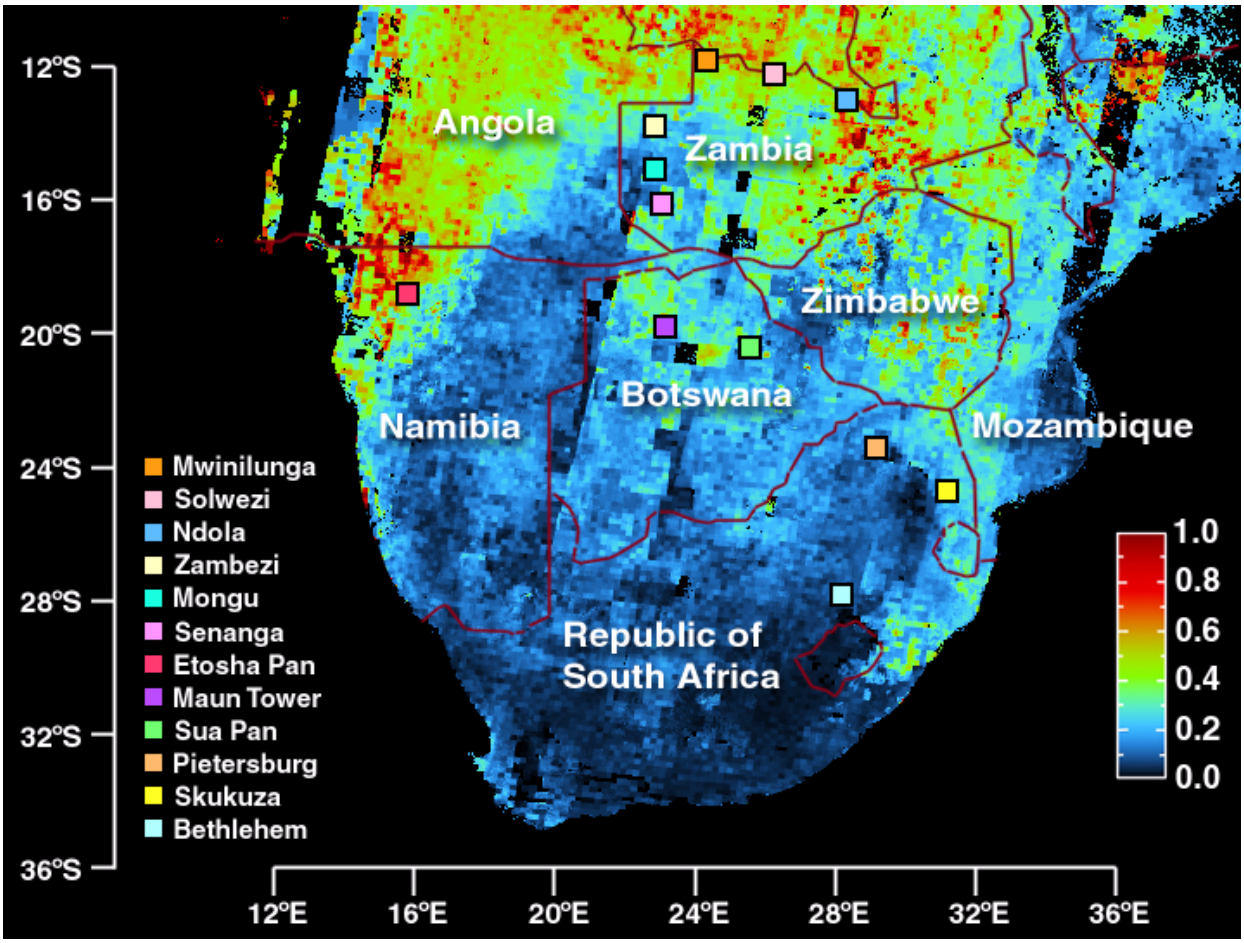


Figure 5. Composite MISR optical depth imagery of southern Africa as background to display locations of AERONET stations compiled for construction of the correlation diagram of Figure 6. The optical depth is illustrated for 558 nm and was compiled from 27orbits of MISR data over southern Africa taken between 14 August and 29 September, 2000, during the dry season campaign. Illustration and caption taken from Diner, *et al*. 2001.

to construct correlation diagrams between AOT retrieved by MISR and AOT retrieved by the AERONET stations. The first version of this diagram utilized level 1.5 data from the AERONET and revealed some bias of MISR retrievals relative to the AERONET such that MISR AOT was always found to be greater than that from the ground-based instruments. The correlation line was found to have a slope of 1.26. This is the kind of difference noted in comparisons from Sua Pan, above. Upon further screening to level 2 (courtesy of Brent Holben), the AERONET-MISR comparisons improved such that the correlation line has a slope of 0.98 (Figure 6).

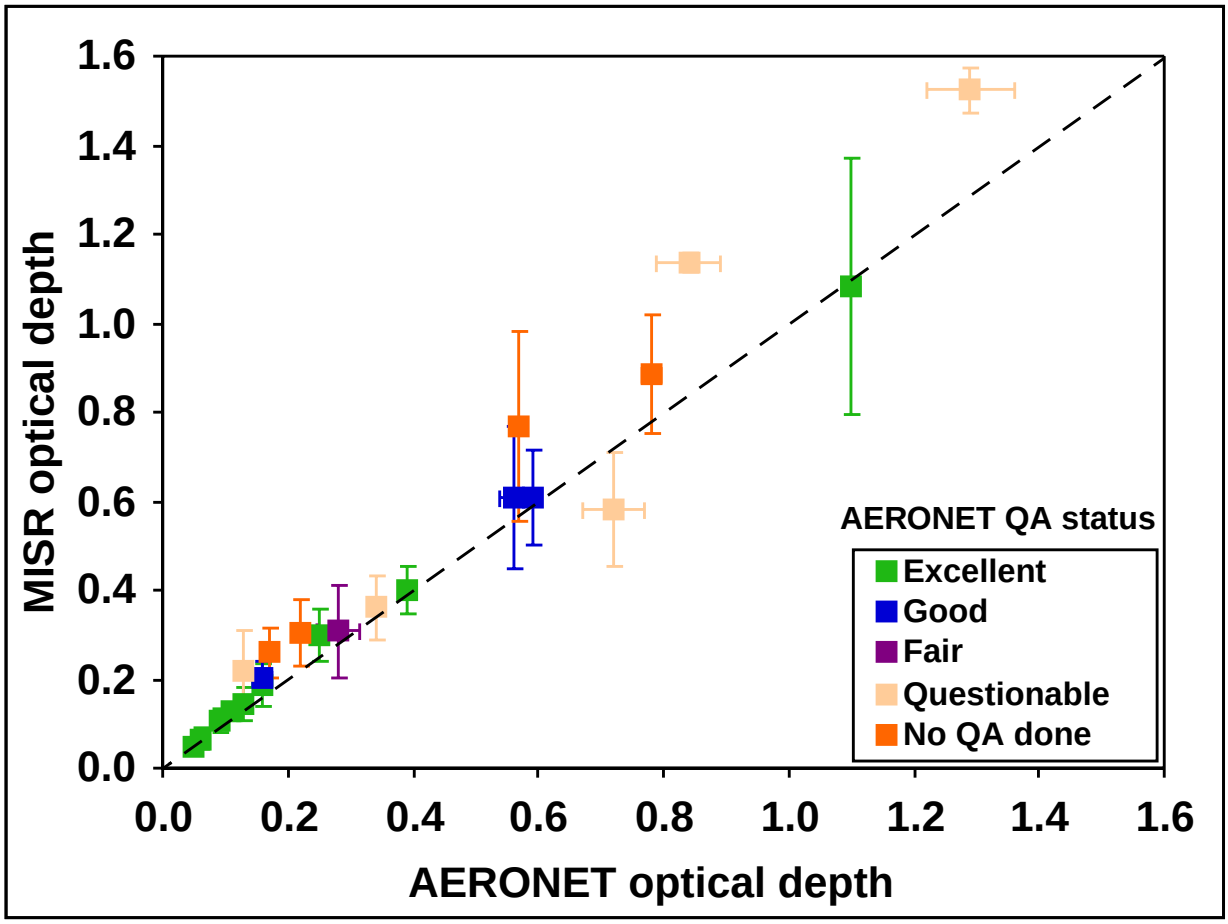
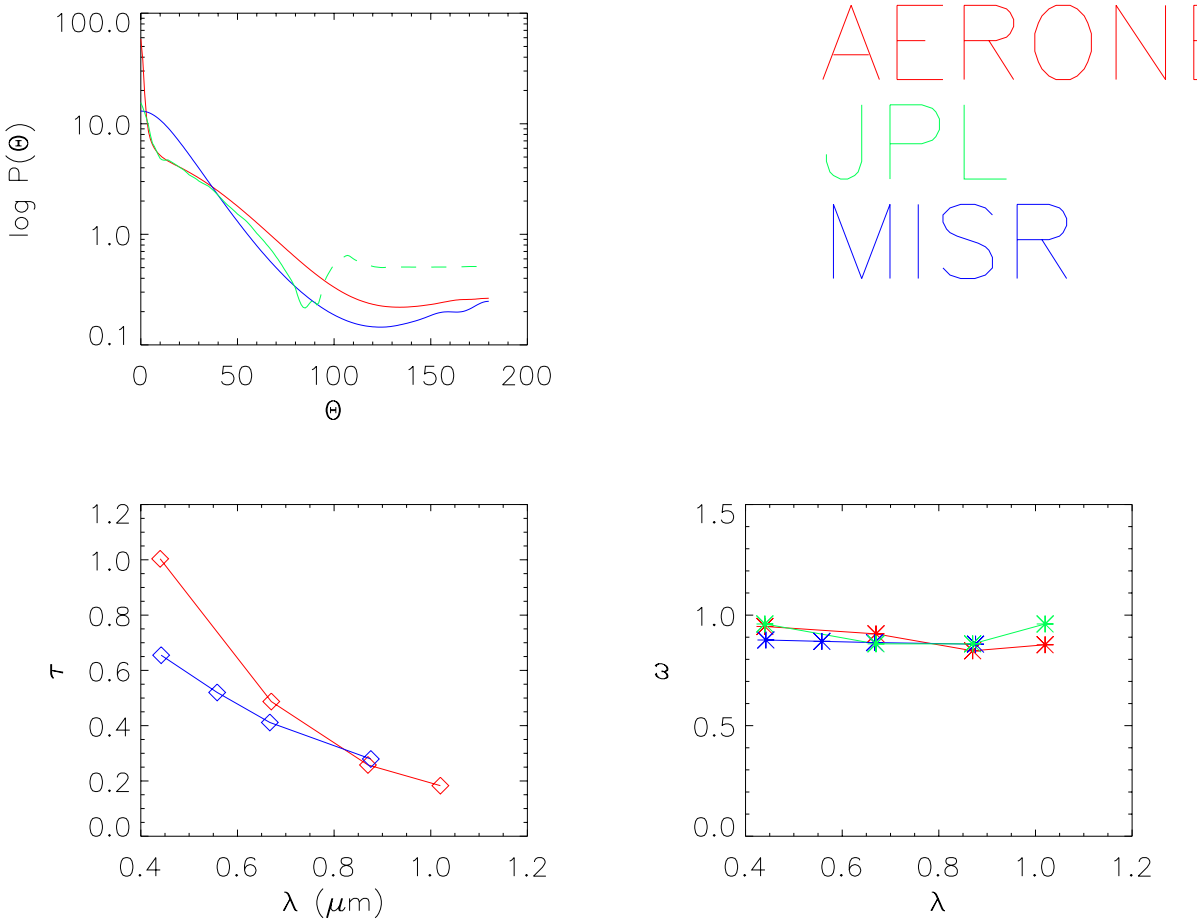


Figure 6. Correlation diagram between MISR optical depth and AERONET optical depth for the AERONET stations depicted in Figure 5. Taken from Diner, *et al*., 2001. QA is Quality Assurance.

These correlations, plus the MISR AOT retrievals over southern Africa depicted in Figure 5, are the subject of Diner, *et al.* (2001).

8. Comparisons of Particle Models via MISR and AERONET Using Dubovik and Pilorz Inversion methods - The AERONET direct solar irradiance measurements, together with the sky radiance measurements in the form of periodic almucantar and principal plane scans, are rich sources for comparison of ground-based aerosol model retrievals and aerosol model retrievals from MISR, beyond those of just AOT. Here we present comparisons for Sua Pan from September 3, 2000, and hint at the possibilities present for conducting experiments on aerosol transformations that may be possible between AERONET stations, particularly with respect to size distribution and complex refractive index (compositional inference) between stations. The potential strategy, given suitable traceable pathways along "streamlines" between stations, has been described under **Ancillary Goals**, above The inversion methods, which differ in important respects are discussed by Dubovik and King (2000), and Pilorz (2001). The results are shown in **Figure 7** .


AERONI
JPL
MISR
log P(Θ)
Θ
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λ (μm)
ω
λ

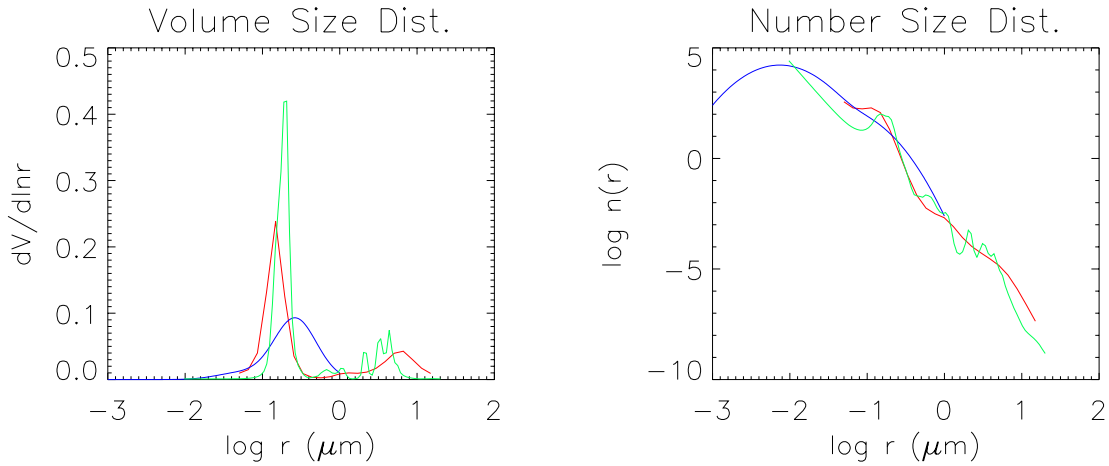

Figure 7. Rsults of comparison of AERONET, MISR and JPL retrievals at Sua Pan, 03 Sep 2000. AERONET (Dubovik and King) , JPL (Pilorz) and MISR are shown in red, green, and blue, respectively. (Figure prepared by S. Pilorz)

9. Status of Data Reduction for Ground Data - Figures 1 and 2 presented checklists of measurements taken as part of ground deployments at Sua Pan, and Skukuza Airport and Tower, respectively. Examples of the data have been presented above Complete data sets of the atmospheric optical instruments, ground spectrometers, and sphere scanning radiometer (PARABOLA) are contained in the SAFARI 2000 data archive at JPL. All of these data have been reduced to provide Level 2 geophysical products according to algorithms standard to the MISR validation activity.

10. Future studies - This summary has dealt with the ground-based validation campaigns carried out as part of the Dry Season field campaign of August-September, 2000. The principal goals of the work have been to provide a basis for validation of geophysical products (especially AOT, BRDF, HDRF) from MISR, and to provide a basis for vicarious radiometric calibration of MISR,

should this latter prove useful in further evaluation of instrument calibration pathways, both on-board and ground-based.

Additional primary goals of the overall experiment included arranging co-flights between AirMISR and the CV-580 to: (i) afford basis for comparison of microphysical models implied by MISR aerosol retrievals, and direct measurement aerosol properties established by in-flight sampling and subsequent analysis. This would include independent direct measurement of aerosol size distributions, aerosol composition (speciated compositional determinations via complex refractive index with particle size), aerosol single scattering phase function, (ii) comparisons of BRF determinations by Cloud Absorption Radiometer (CAR), and BRF determinations by AirMISR. These goals require sifting of the AirMISR flight lines and the CV-580 aerosol and CAR surface BRF retrievals to establish temporal and spatial coincidences present. This has not yet been carried out except in the most cursory manner

The adequacy of the present array of resident (five presently used) MISR aerosol models needs to be checked both by comparisons with CV-580 microphysical property determinations, and by inversions based on AERONET sky radiance measurements (see "Holben, *et al.*, An emerging ground-based aerosol climatology: Aerosol optical depth from AERONET", to be published.), according to Dubovik, et al., and Pilorz. Both the seasonal and geographic dependence of the models needs to be investigated. This should help to reduce scatter and improve correlations between AERONET and MISR retrievals, such as depicted in Figure 6, possibly with emergence of both geographic and seasonal dependences present.

It may be possible to study aerosol transformations between AERONET stations along gyre stream lines connecting them (if such can be found) by utilizing CIMEL-based model retrievals at individual stations. This will require trajectory calculations to trace the flow between suspected candidate stations. The whole issue of how to incorporate MISR-like observations in such a plan needs to be studied. Evaluation of aerosol sources, such as depicted in AirMISR imagery of the Timbuvati fires, should prove useful.

Finally, software development for AirMISR leading to Level 2 aerosol products needs to be developed to aid routine processing of AirMISR Level 1B2 data for AOT.

11. Publications relating to SAFARI 2000 work

(1) Abdou, W.A., J.E. Conel, S.H.Pilorz, C. J.Bruegge, M.C.Helmlinger, B.J. Gaitley, and D.J. Diner, Validation of Multiangle Imaging SpectroRadiometer (MISR) aerosol optical depth retrievals using ground-based solar radiometer observations from the Aerosol Robotic Network (AERONET), Poster presented at the December15-19, 2000, meeting of the American Geophysical Union, San Francisco, CA. (http://www-misr/)
(2) Helmlinger, M.C., C.J.Bruegge, W.A.Abdou, J.E.Conel, D.J.Diner, B.J.Gaitley,W.C.Ledeboer, J.V.Martonchik,S.H.Pilorz, and G.Saghri, MISR aerosol and surface data retrievals in conjunction with the SAFARI 2000 field campaign over southern Africa, Poster presented at the December 15-19, 2000, meeting of the American Geophysical Union, San Francisco, CA. (http://www-misr/)

(3) Diner, D.J., W.A. Abdou, C.J. Bruegge, J.E. Conel, K.A. Crean, B.J. Gaitley, M.C. Helmlinger, R.A. Kahn, J.V. Martonchik, and S.H. Pilorz, and Brent Holben, *Geophysical Research Letters*, accepted for publication, 18 April 2001.
(4) Conel, J., M. Helmlinger, S. Pilorz, W. Abdou, D. Diner, J. Martonchik, R. Kahn, M. Kleeman, A. Eldering, and K. Magliano, Application of multiangle imaging SpectroRadiometer (MISR) to study of regional haze problems in conjunction with California Regional Particulate PM2.5/PM10 Air Quality Study(CRPAQS) and SAFARI 2000 dry season campaign, (Abstract). Submitted to AGU/AWMA Regional Haze Workshop, Bend Oregon, October 2-5, 2001.

12. Other References Cited

Martonchik, J.V., D.J.Diner, R. Kahn, M.M. Verstraete, B. Pinty, H. Gordon, and T. Ackerman, 1998, Techniques for retrieval of aerosol properties over land and ocean using multiangle imagery, *IEEE Trans. Geoscience. Rem. Sens.*, **36**, 1212-1227.

Pilorz, S.H., Inversion of Sky and Solar spectral irradiance observations from CIMEL for aerosol particle scattering models, to be submitted, May 2001.

Dubovik, Oleg, and M.D. King, 2000, A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements, *J. Geophys. Res.*, **105**, 20673-20696.

Holben, B.N., et al., 1998, AERONET -- A federated instrument network and data archive for aerosol characterization, *Remote Sens. Environ*., **66**, 1-16.

13. Acknowledgments - Work described herein supported by MISR Project. Thanks are due to Mark Helmlinger, David Diner, Stu Pilorz, Barbara Gaitley, Carol Bruegge, Wedad Abdou, and Bill Ledeboer for their help in preparation of this work. Additionally, help in the field is gratefully acknowledged by Helmlinger for following individuals: Wolfgang Buermann, Boston University, Dr. Bob Swap, Peter Yanik, Kaycie Billmark, University of Virginia, Prof. Harold Annegarn, Margie Barenbrug, University of the Witwatersrand, Dr. Frank Eckardt, University of Botswana, Blaizer Ntshiamisang, Botswana Ash, Ltd., and Justin, Duan, and Rory Biggs, Kruger National Park, South Africa.

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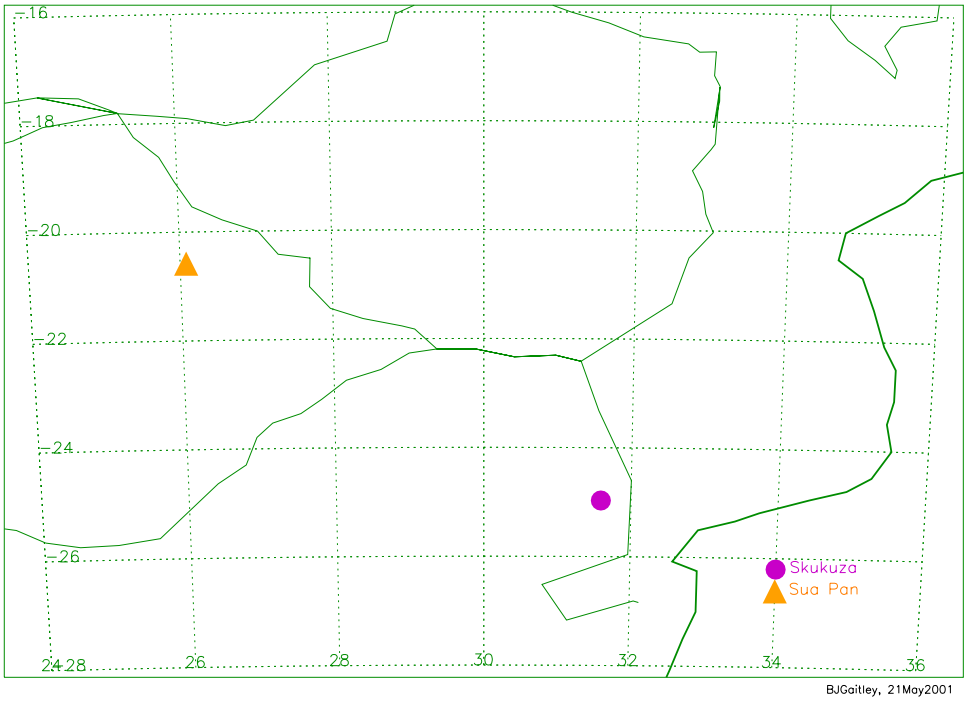

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and MISR (275 meters). that may aid in the issue of measurement scaling. (v) seek coordinated overflights involving AirMISR in the ER-2, the Cloud Absorption Radiometer (CAR) in the University of Washington CV-580 providing BRDF surface measurements together with direct sampling measurements of aerosols encountered, and MISR measurements.

With calibration and validation of MISR geophysical products it will be possible to construct time series of MISR geophysical measurements extending throughout the seasons for the lifetime of the Terra mission, thus contributing to Science Goal (4), above.

5. Ancillary Goals- The following are ancillary goals that speak to the issue of transformation of aerosol properties after emission by surface sources and during transport between measurement points on the ground. The plan is to seek AERONET stations that are connected by an airmass trajectory in the gyre and to develop new aerosol models from the *in situ* measurement using the AERONET inversion methods of Dubovik *et al.* (of GSFC), and of Pilorz (of JPL). Particle transformations will be studied by noting changes in size distributions, effective phase functions, extinction coefficients, and chemistry as denoted by complex refractive index; these parameters that can estimated from the inversions. Under proper circumstances it may be possible to image such multiple stations by MISR, thus enabling a comparison between ground and MISR retrievals at multiple sites. This will connect the use of MISR to study of an important aerosol tracking Goal in (2) above Aerosol transformations are the subject of current as well as future research.

6. Ground measurements - We present a few examples of retrievals at field sites occupied by the ground validation team. The matrix of field observations at Sua Pan, Botswana, is shown in Table 1, and at Skukuza Airport and Skukuza Tower, South Africa, in Table 2. Both of these charts are taken from Helmlinger, *et al.* (2000)

Table 1: Data Inventory, Sua Pan

	MISR	PARAB-OLA	ASD	CIMEL	MFRSR	Reagan	Met Station
Aug 18	**Orbit 3553, 08:48 UT**					✔	
Aug 19			✔			✔	✔
Aug 20				✔			✔
Aug 21				✔	✔	✔	✔
Aug 22				✔		✔	✔
Aug 23				✔		✔	✔
Aug 24				✔	✔	✔	
Aug 25			✔	✔	✔	✔	✔
Aug 26				✔	✔	✔	✔

Table 1: Data Inventory, Sua Pan

	MISR	PARAB-OLA	ASD	CIMEL	MFRSR	Reagan	Met Station
Aug 27	Orbit 3684, 08:42 UT	✔	✔	✔	✔	✔	✔
Aug 28				✔	✔	✔	✔
Aug 29				✔	✔	✔	✔
Aug 30		✔	✔	✔	✔	✔	✔
Aug 31				✔	✔	✔	✔
Sep 01		✔		✔	✔	✔	✔
Sep 02				✔	✔	✔	✔
Sep 03	Orbit 3786, 08:48 UT	✔	✔	✔	✔	✔	✔
Sep 04		✔		✔	✔	✔	✔

Table 2: Data Inventory, Skukuza

	MISR	PARAB-OLA	CIMEL	MFRSR	Reagan	Met Station
Sep 14			✔	✔	✔	✔
Sep 15						✔
Sep 16	Orbit 3975, 08:18 UT					✔
Sep 17			✔	✔	✔	
Sep 23	Orbit 4077, 08:24 UT	✔			✔	
Sep 24						✔
Sep 25	Orbit 4106, 08:12 UT		✔		✔	✔
Sep 26		✔				✔
Sep 27			✔			✔
Sep 28		✔	✔	✔	✔	✔
Sep 29			✔			✔
Sep 30		✔	✔	✔	✔	✔
Oct 01		✔				✔

Table 2: Data Inventory, Skukuza

	MISR	PARAB-OLA	CIMEL	MFRSR	Reagan	Met Station
Oct 02	**Orbit 4208, 08:18 UT**		✔	✔	✔	✔

***Aerosol Optical Thickness* (AOT) -** Figures 1 and 2 show the AOT obtained for two days August 27, and September 03, 2001 by three solar radiometers at Sua Pan. The AOT's obtained differ by a factor of about 10 between the days. but the agreement obtained between instruments on each day is reasonably good. These days are cloud free, but hazy. The comparisons with MISR

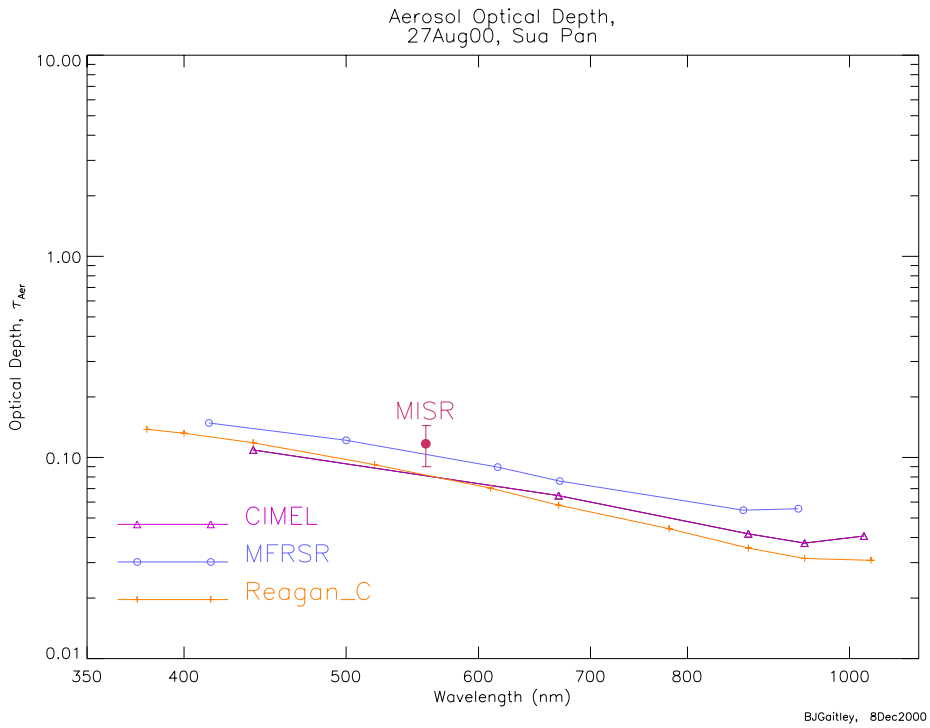


Figure 1. AOTs by various instruments compared with MISR, August 27, 2000, Sua Pan. Note that AOT of this date is a factor of almost 10 lower than that of September 03, shown in Figure 2 (M.C. Helmlinger and B.J. Gaitley for Figures 1, 2 and 3).

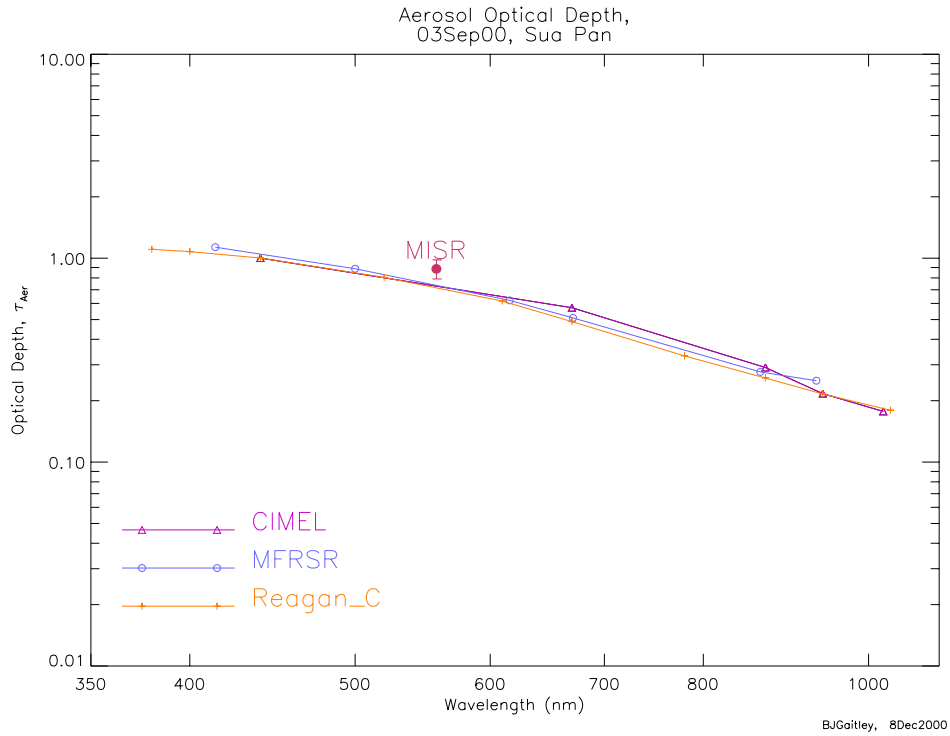


Figure 2. AOTs by various instruments compared with MISR, September 03, 2000, Sua Pan

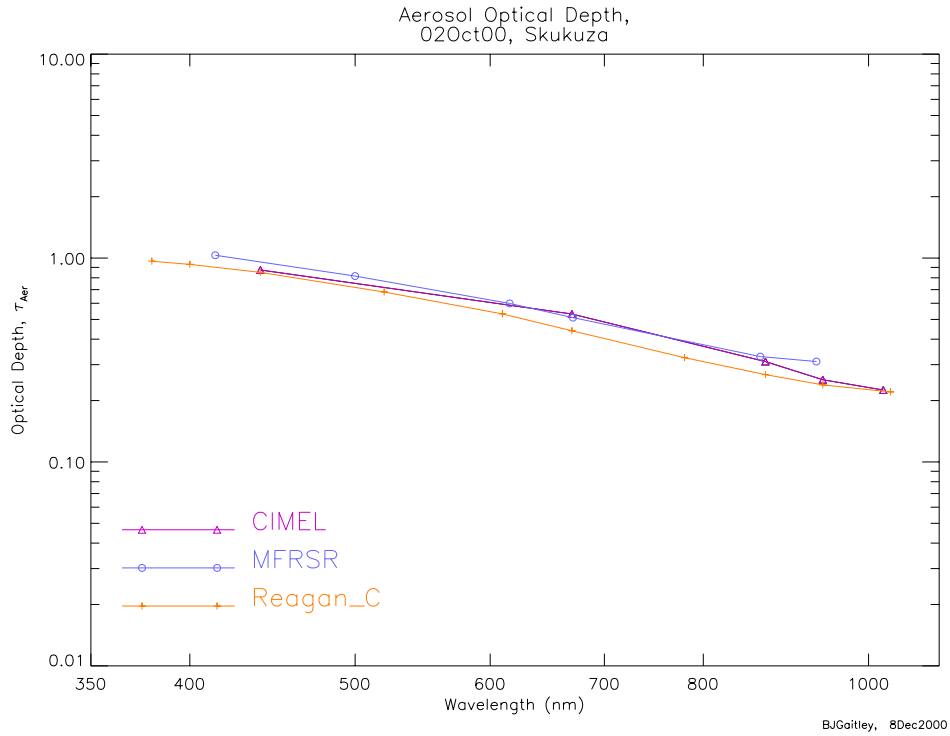


Figure 3. AOT by various instruments at Skukuza Airport, October 2, 2000.

retrievals for 17.6 km square regions about the ground site show MISR AOT (at 558 nm) to be

slightly greater than AOT obtained by the conventional ground methods for both days of comparison. AOT's for Skukuza Airport are shown in Figure 3. The AOT data between solar radiometers show similar close agreement as was also seen at Sua Pan. Unfortunately, no comparison with MISR is available because of bad weather at the Skukuza Airport site on days of platform overpass.

BRDF and HDRF at Sua Pan and Grassland - The JPL PARABOLA (Portable Apparatus for Rapid Acquisition of Bidirectional Observations of the Land and Atmosphere) is a sphere scanning radiometer from which the BRF and HDRF of the surface can be extracted. At Sua Pan the instrument head was mounted on a vertical telescoping stand 3.5 m above the surface. PARABOLA was moved between five different pan and grassland sites between August 27, 2000 and September 03, 2000. (three pan and two grassland) to attempt to compensate for surface inhomogeniety by averaging. As an example, Figure 4 shows a section through the three dimensional reflectance function of the playa surface in the principal plane, illustrating the differences obtained between the surface BRF and HDRF for the extremely hazy conditions of September 03, 2000 and a high solar zenith angle of about 63°. These conditions emphasize differences between the two reflectance representations. Most of the Sua Pan in addition to the grassland PARABOLA data remain to be reduced to BRF and HDRF, but is available in raw format in the JPL SAFARI 2000 archive. Both the so-called hotspot and specular peak in the reflectance are eliminated by the exceptionally strong diffuse incident sky light.

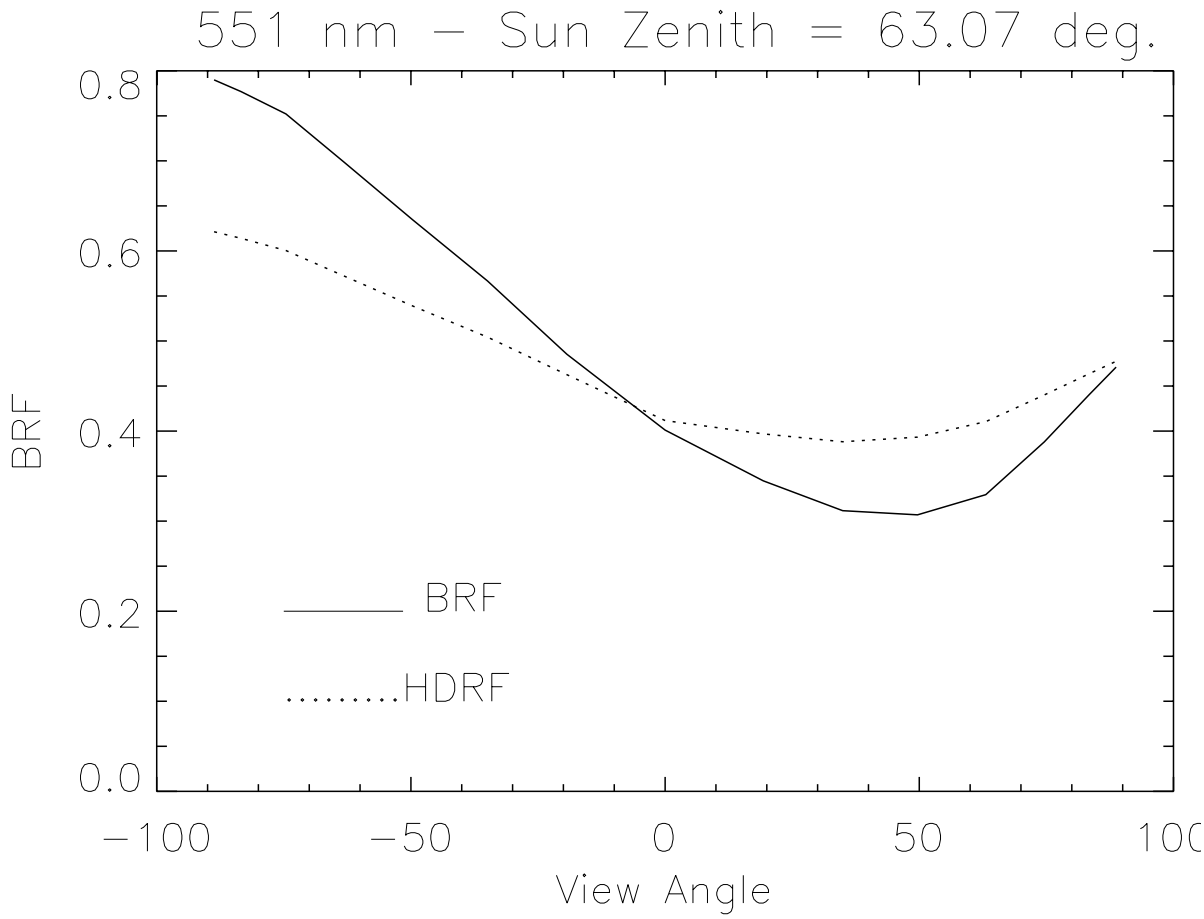


Figure 4. BRF and HDRF of September 03, 2000 at Sua Pan site. Sun is at a (+) view angle of 63.07 deg. Positive view angles represent forward scattering and negative, backscatter. (W.A. Abdou)

BRF and HDRF at Skukuza Tower **-** At Skukuza Tower PARABOLA was mounted atop the telescopic stand which provided an extension of 6 m in addition to the 18 m of the height of the tower (total 23 m). The additional height was used to attempt to gain additional FOV from PARABOLA to help compensate for heterogeneous nature of the canopy cover. No data from Skukuza Tower PARABOLA have yet been reduced because of the extreme complexity of the surface at that site

7. Comparisons of MISR and AERONET AOT's - We used the network of stations of the AERONET (Holben, *et al.*, 1998), which are widely dispersed over southern Africa, Figure 5.

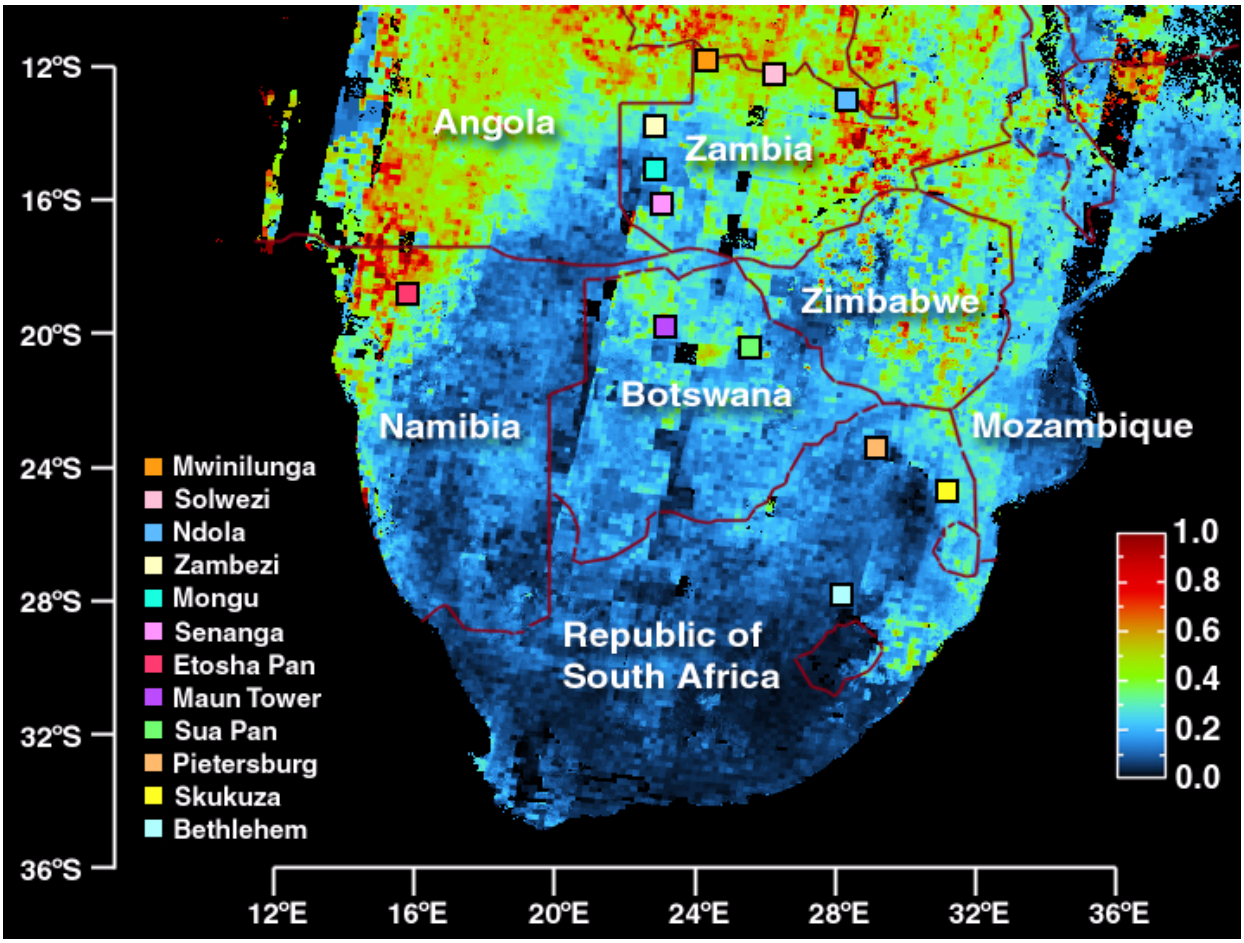


Figure 5. Composite MISR optical depth imagery of southern Africa as background to display locations of AERONET stations compiled for construction of the correlation diagram of Figure 6. The optical depth is illustrated for 558 nm and was compiled from 27orbits of MISR data over southern Africa taken between 14 August and 29 September, 2000, during the dry season campaign. Illustration and caption taken from Diner, *et al*. 2001.

to construct correlation diagrams between AOT retrieved by MISR and AOT retrieved by the AERONET stations. The first version of this diagram utilized level 1.5 data from the AERONET and revealed some bias of MISR retrievals relative to the AERONET such that MISR AOT was always found to be greater than that from the ground-based instruments. The correlation line was found to have a slope of 1.26. This is the kind of difference noted in comparisons from Sua Pan, above. Upon further screening to level 2 (courtesy of Brent Holben), the AERONET-MISR comparisons improved such that the correlation line has a slope of 0.98 (Figure 6).

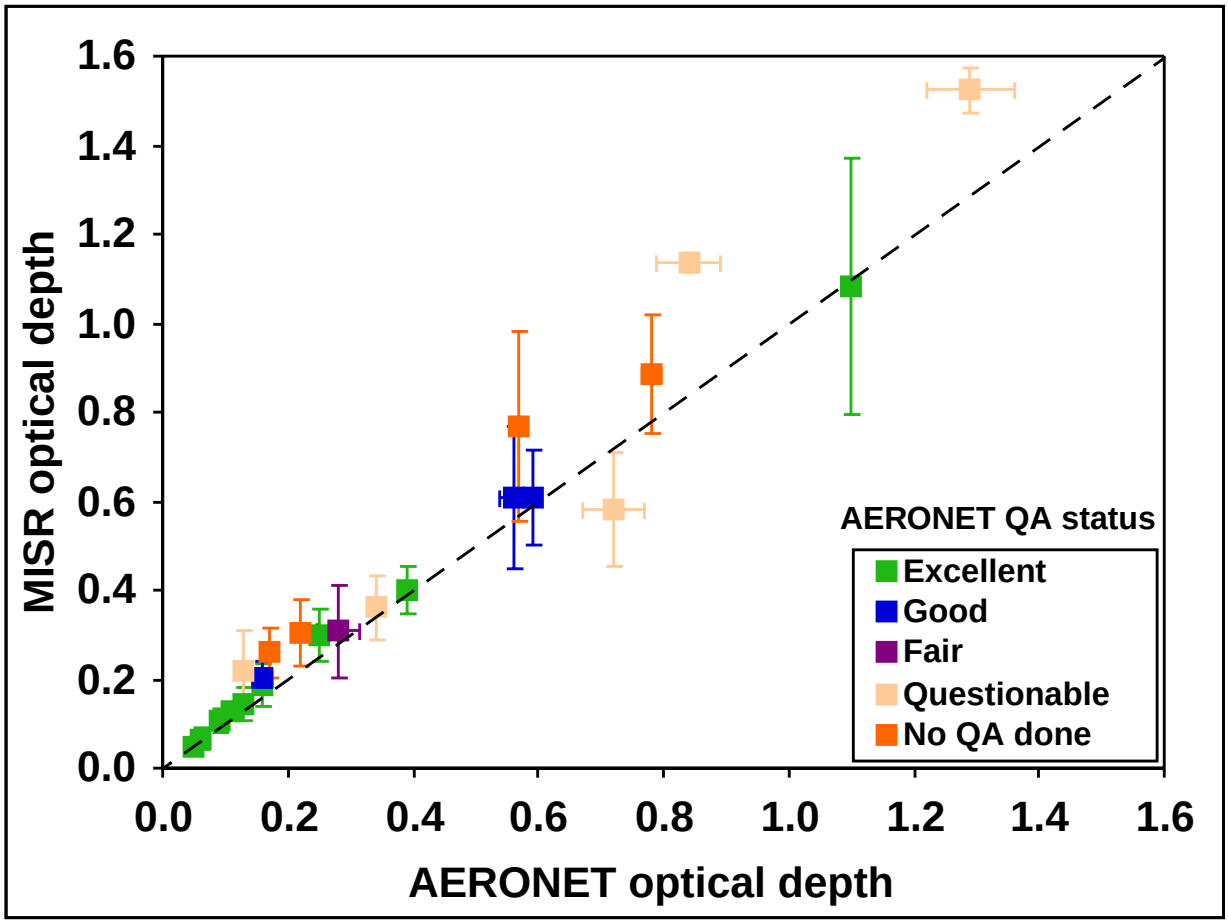
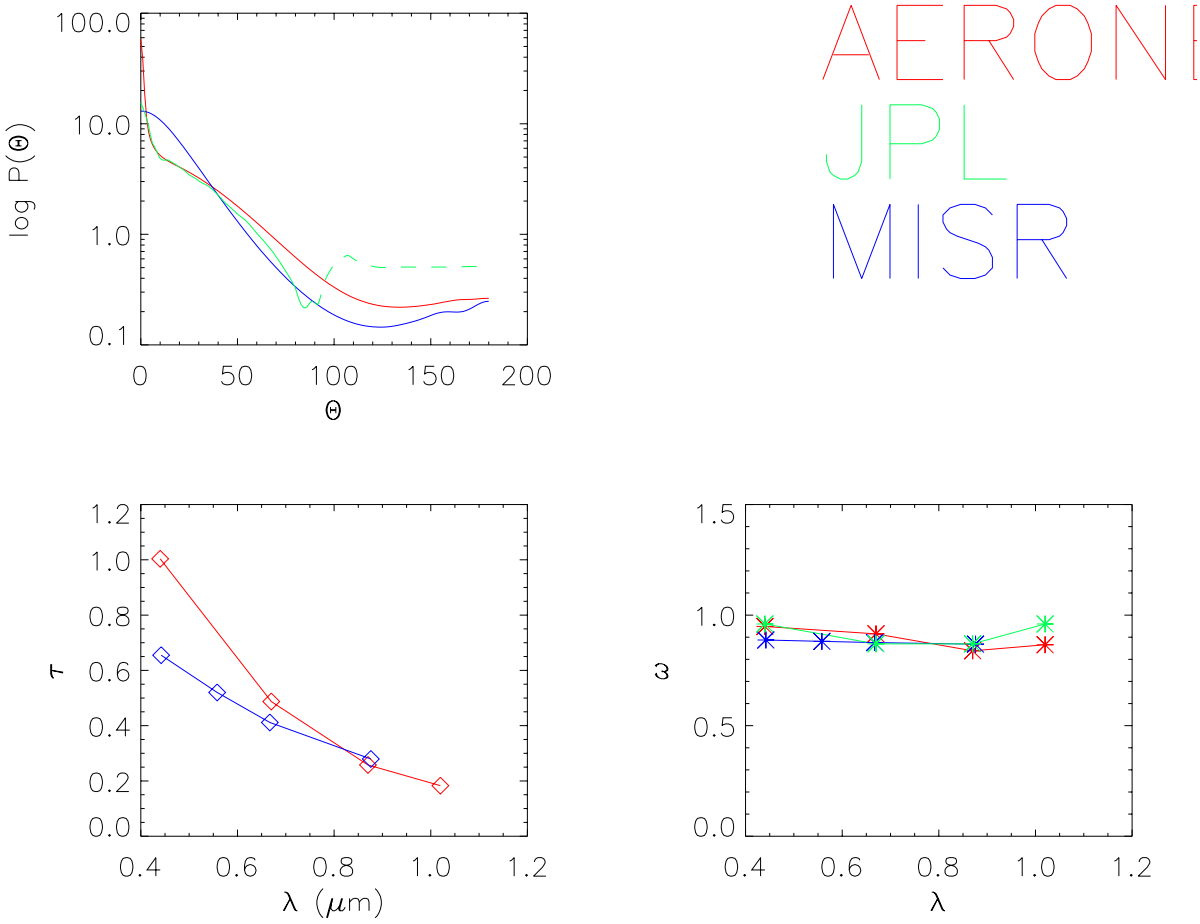


Figure 6. Correlation diagram between MISR optical depth and AERONET optical depth for the AERONET stations depicted in Figure 5. Taken from Diner, *et al*., 2001. QA is Quality Assurance.

These correlations, plus the MISR AOT retrievals over southern Africa depicted in Figure 5, are the subject of Diner, *et al.* (2001).

8. Comparisons of Particle Models via MISR and AERONET Using Dubovik and Pilorz Inversion methods - The AERONET direct solar irradiance measurements, together with the sky radiance measurements in the form of periodic almucantar and principal plane scans, are rich sources for comparison of ground-based aerosol model retrievals and aerosol model retrievals from MISR, beyond those of just AOT. Here we present comparisons for Sua Pan from September 3, 2000, and hint at the possibilities present for conducting experiments on aerosol transformations that may be possible between AERONET stations, particularly with respect to size distribution and complex refractive index (compositional inference) between stations. The potential strategy, given suitable traceable pathways along "streamlines" between stations, has been described under **Ancillary Goals**, above The inversion methods, which differ in important respects are discussed by Dubovik and King (2000), and Pilorz (2001). The results are shown in **Figure 7** .


AERONI
JPL
MISR
log P(Θ)
Θ
τ
λ (μm)
ω
λ

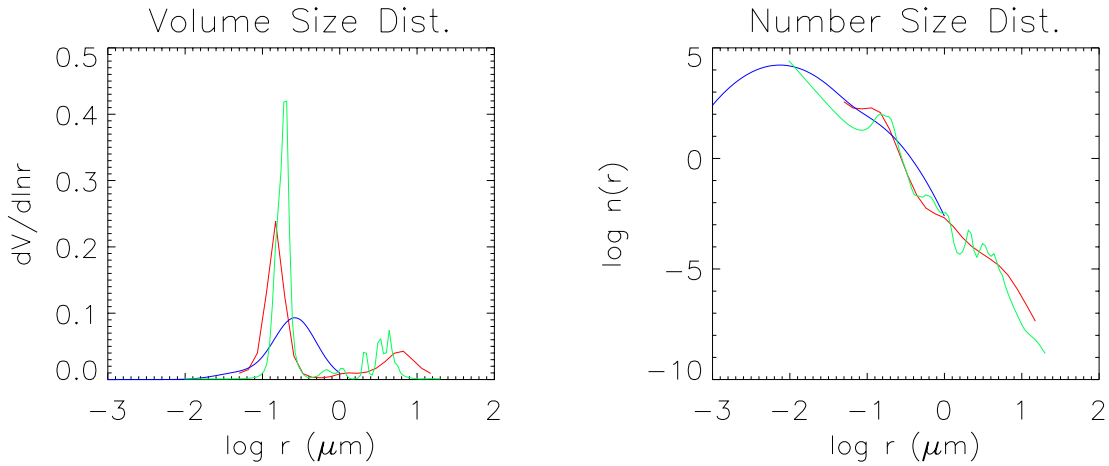


Figure 7. Rsults of comparison of AERONET, MISR and JPL retrievals at Sua Pan, 03 Sep 2000. AERONET (Dubovik and King) , JPL (Pilorz) and MISR are shown in red, green, and blue, respectively. (Figure prepared by S. Pilorz)

9. Status of Data Reduction for Ground Data - Figures 1 and 2 presented checklists of measurements taken as part of ground deployments at Sua Pan, and Skukuza Airport and Tower, respectively. Examples of the data have been presented above Complete data sets of the atmospheric optical instruments, ground spectrometers, and sphere scanning radiometer (PARABOLA) are contained in the SAFARI 2000 data archive at JPL. All of these data have been reduced to provide Level 2 geophysical products according to algorithms standard to the MISR validation activity.

10. Future studies - This summary has dealt with the ground-based validation campaigns carried out as part of the Dry Season field campaign of August-September, 2000. The principal goals of the work have been to provide a basis for validation of geophysical products (especially AOT, BRDF, HDRF) from MISR, and to provide a basis for vicarious radiometric calibration of MISR,

should this latter prove useful in further evaluation of instrument calibration pathways, both on-board and ground-based.

Additional primary goals of the overall experiment included arranging co-flights between AirMISR and the CV-580 to: (i) afford basis for comparison of microphysical models implied by MISR aerosol retrievals, and direct measurement aerosol properties established by in-flight sampling and subsequent analysis. This would include independent direct measurement of aerosol size distributions, aerosol composition (speciated compositional determinations via complex refractive index with particle size), aerosol single scattering phase function, (ii) comparisons of BRF determinations by Cloud Absorption Radiometer (CAR), and BRF determinations by AirMISR. These goals require sifting of the AirMISR flight lines and the CV-580 aerosol and CAR surface BRF retrievals to establish temporal and spatial coincidences present. This has not yet been carried out except in the most cursory manner

The adequacy of the present array of resident (five presently used) MISR aerosol models needs to be checked both by comparisons with CV-580 microphysical property determinations, and by inversions based on AERONET sky radiance measurements (see "Holben, *et al.*, An emerging ground-based aerosol climatology: Aerosol optical depth from AERONET", to be published.), according to Dubovik, et al., and Pilorz. Both the seasonal and geographic dependence of the models needs to be investigated. This should help to reduce scatter and improve correlations between AERONET and MISR retrievals, such as depicted in Figure 6, possibly with emergence of both geographic and seasonal dependences present.

It may be possible to study aerosol transformations between AERONET stations along gyre stream lines connecting them (if such can be found) by utilizing CIMEL-based model retrievals at individual stations. This will require trajectory calculations to trace the flow between suspected candidate stations. The whole issue of how to incorporate MISR-like observations in such a plan needs to be studied. Evaluation of aerosol sources, such as depicted in AirMISR imagery of the Timbuvati fires, should prove useful.

Finally, software development for AirMISR leading to Level 2 aerosol products needs to be developed to aid routine processing of AirMISR Level 1B2 data for AOT.

11. Publications relating to SAFARI 2000 work

(1) Abdou, W.A., J.E. Conel, S.H.Pilorz, C. J.Bruegge, M.C.Helmlinger, B.J. Gaitley, and D.J. Diner, Validation of Multiangle Imaging SpectroRadiometer (MISR) aerosol optical depth retrievals using ground-based solar radiometer observations from the Aerosol Robotic Network (AERONET), Poster presented at the December15-19, 2000, meeting of the American Geophysical Union, San Francisco, CA. (http://www-misr/)
(2) Helmlinger, M.C., C.J.Bruegge, W.A.Abdou, J.E.Conel, D.J.Diner, B.J.Gaitley,W.C.Ledeboer, J.V.Martonchik,S.H.Pilorz, and G.Saghri, MISR aerosol and surface data retrievals in conjunction with the SAFARI 2000 field campaign over southern Africa, Poster presented at the December 15-19, 2000, meeting of the American Geophysical Union, San Francisco, CA. (http://www-misr/)

(3) Diner, D.J., W.A. Abdou, C.J. Bruegge, J.E. Conel, K.A. Crean, B.J. Gaitley, M.C. Helmlinger, R.A. Kahn, J.V. Martonchik, and S.H. Pilorz, and Brent Holben, *Geophysical Research Letters*, accepted for publication, 18 April 2001.
(4) Conel, J., M. Helmlinger, S. Pilorz, W. Abdou, D. Diner, J. Martonchik, R. Kahn, M. Kleeman, A. Eldering, and K. Magliano, Application of multiangle imaging SpectroRadiometer (MISR) to study of regional haze problems in conjunction with California Regional Particulate PM2.5/PM10 Air Quality Study(CRPAQS) and SAFARI 2000 dry season campaign, (Abstract). Submitted to AGU/AWMA Regional Haze Workshop, Bend Oregon, October 2-5, 2001.

12. Other References Cited

Martonchik, J.V., D.J.Diner, R. Kahn, M.M. Verstraete, B. Pinty, H. Gordon, and T. Ackerman, 1998, Techniques for retrieval of aerosol properties over land and ocean using multiangle imagery, *IEEE Trans. Geoscience. Rem. Sens.*, **36**, 1212-1227.

Pilorz, S.H., Inversion of Sky and Solar spectral irradiance observations from CIMEL for aerosol particle scattering models, to be submitted, May 2001.

Dubovik, Oleg, and M.D. King, 2000, A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements, *J. Geophys. Res.*, **105**, 20673-20696.

Holben, B.N., et al., 1998, AERONET -- A federated instrument network and data archive for aerosol characterization, *Remote Sens. Environ*., **66**, 1-16.

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