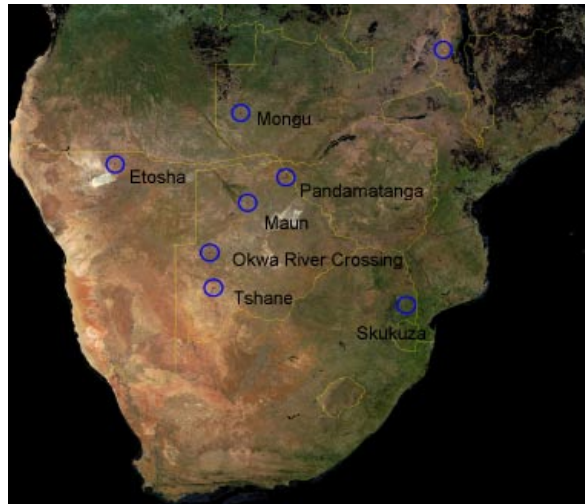


Southern Africa Validation of EOS (SAVE) Final Report

May 2003
Period of Report: 1997 -- 2003

PI: Jeffrey L. Privette, Code 923, NASA's GSFC
Co-I: Robert J. Swap, Univ. of Virginia
Co-PI: Anne Thompson, Code 916, NASA's GSFC



Project Objectives

The Southern Africa Validation of EOS (SAVE) project was designed to *validate multiple land and atmospheric products from EOS satellites over southern Africa*. Our land product approach emphasized monthly field measurements such that we could validate products over full vegetation phenological cycles and through different EOS sensor and algorithm configurations. We also targeted multiple field sites spanning the IGBP Kalahari Transect, a ~1000 km north-south precipitation gradient, so that products could be evaluated over varying vegetation structure. Our atmospheric product approach emphasized comparisons with data collected during an intensive aircraft field campaign in August, 2000. Finally, as one of the projects underpinning SAFARI 2000, we sought to establish an enduring regional capacity for satellite product validation beyond EOS Terra (i.e., into the EOS Aqua and NPP/NPOESS eras). Each of these goals was accomplished. All SAVE data are either available through the ORNL Mercury system or in the SAFARI 2000 Data CDROM series.

Supported Personnel

Partial funding was provided by SAVE to:

- R.J. Swap, K. Caylor, J. Aranibar, C. Hely and S. Alleaume (UVA)
- K. F. Huemmrich, UMBC/JCET
- A. Pinheiro, New Univ. of Lisbon/GSFC (travel only)

Major Results

- SAVE directly validated six EOS products, including
 - Leaf Area Index (MOD15A2; Privette et al., 2002; 2003)
 - Fraction of Photosynthetic Radiation Absorbed by vegetation (FPAR; MOD15A2; Huemmrich et al., 2003)
 - Vegetation Index (NDVI; MOD13; Huemmrich et al., 2003)
 - Surface Albedo and BRDF (MOD43B3; Privette et al., 2003)
 - Land Surface Temperature (MOD14A2; Pinheiro et al., 2002)
 - Tropospheric Ozone (TOMS; Thompson et al., 2002)
- SAVE supported validation efforts of five EOS products, including
 - Fire and burn scars
 - Aerosol Optical Depth (AOT)
 - Water Vapor
 - Net Primary Production
 - Vegetation overstory fractional cover (MODIS Continuous Fields)

Summary of Validation Results

- MODIS LAI product (V001, V003) is accurate to within ~0.5 units of LAI (absolute).

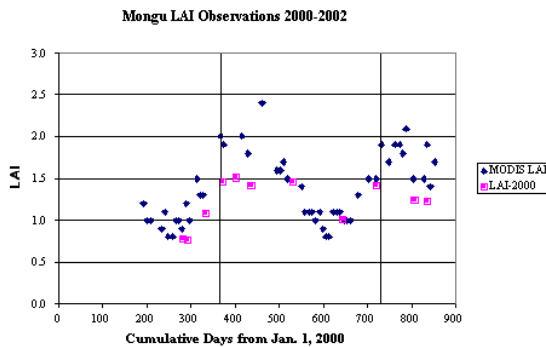


Fig. 1a. Multidate comparisons of MODIS and field-measured LAI values indicates that the MODIS LAI responds correctly to woodland phenological changes.

TRAC and MODIS LAI Profiles at Mongu, Zarr

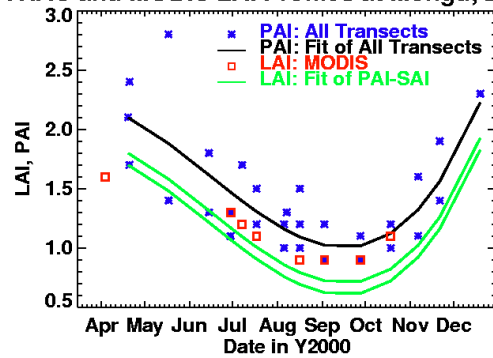


Fig. 1b. Quantitative LAI validation at Mongu found that the MODIS and field-measured LAI values differed by <0.5.

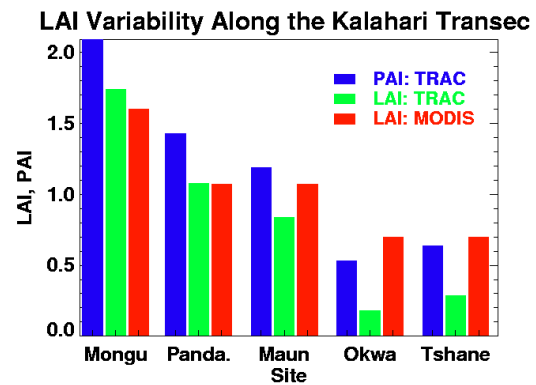
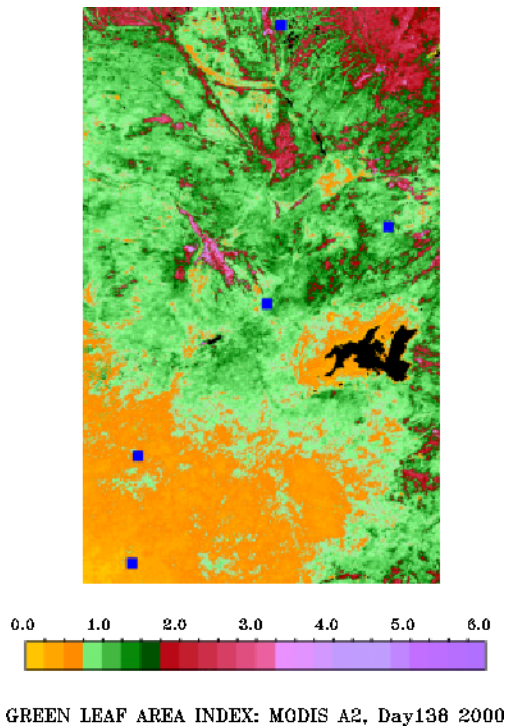


Fig. 2. (Left) The March 2000 Kalahari Transect Campaign characterized five sites in Zambia and Botswana. Measurements revealed that the MODIS LAI product is accurate to <0.5 units over varying vegetation structural conditions (Above: woodland to shrubland).

- The MODIS FPAR product (V003) showed a positive bias and low sensitivity.

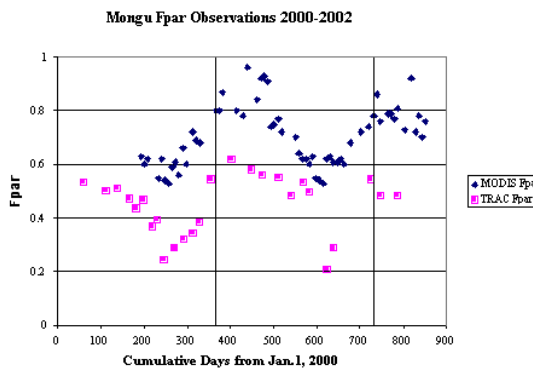


Fig. 3a. FPAR measurements at Mongu commenced in March 2000 and continue to present. The MODIS product varied appropriately with phenological stage.

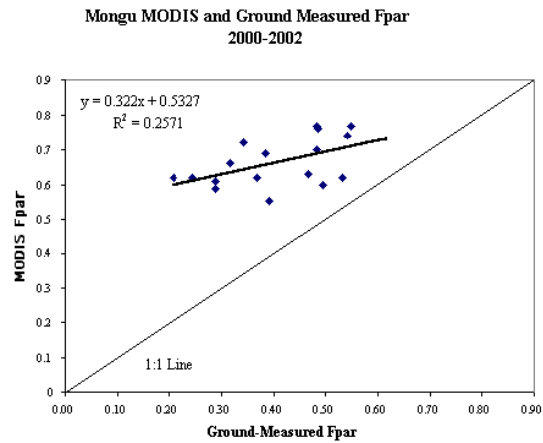


Fig. 3b. Comparisons of MODIS and field-measured FPAR values suggest the MODIS product has a notable bias. Its sensitivity can also be improved

- The MODIS NDVI product (V003) is highly sensitive to LAI and FPAR, and can detect different phenological states.

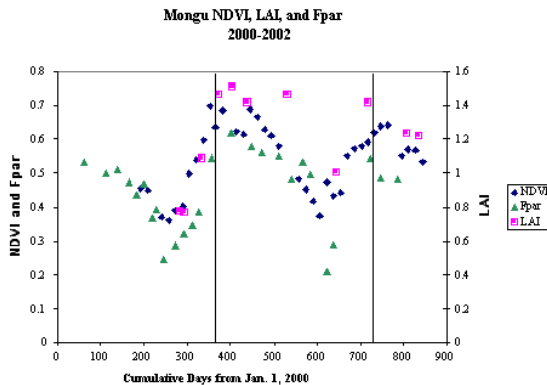


Fig. 4a. The MODIS Vegetation Index (VI) was evaluated for its ability to characterize seasonal changes in LAI and FPAR. Results suggest it tracks LAI and FPAR variability well in woodland systems.

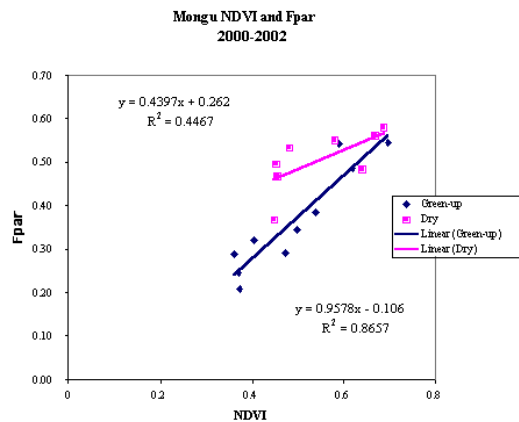


Fig. 4b. The MODIS NDVI was able to discriminate two linear trends in FPAR (measured), corresponding to green-up and senescence periods. These vary with leaf pigment changes.

- The MODIS Albedo product (V003) is accurate to ~ 0.02 (absolute), but can suffer from subpixel cloud contamination.

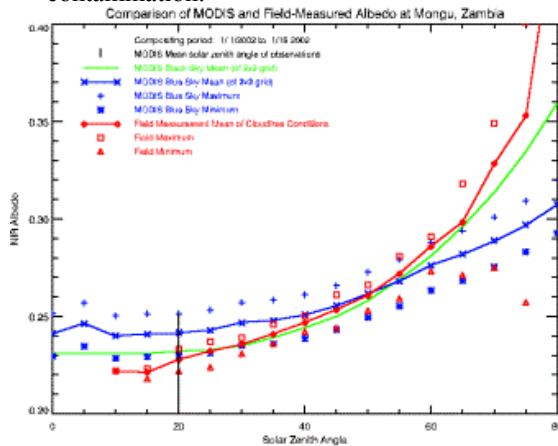


Fig 5a. Wet-season albedo measurements allowed direct validation of the MODIS albedo product. Indirect validation of the MODIS BRDF product was possible by comparing the MODIS albedo estimates at non-observed solar zenith angles with the field-measured albedo through the day.

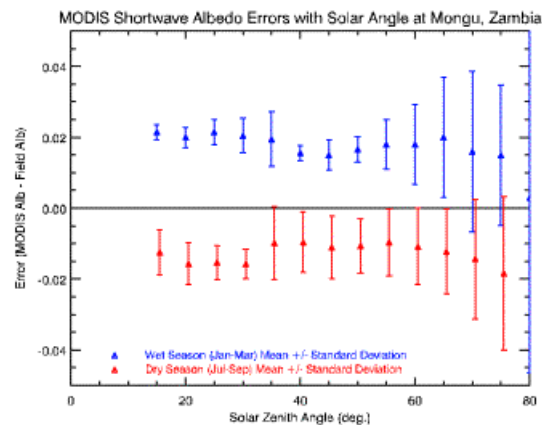
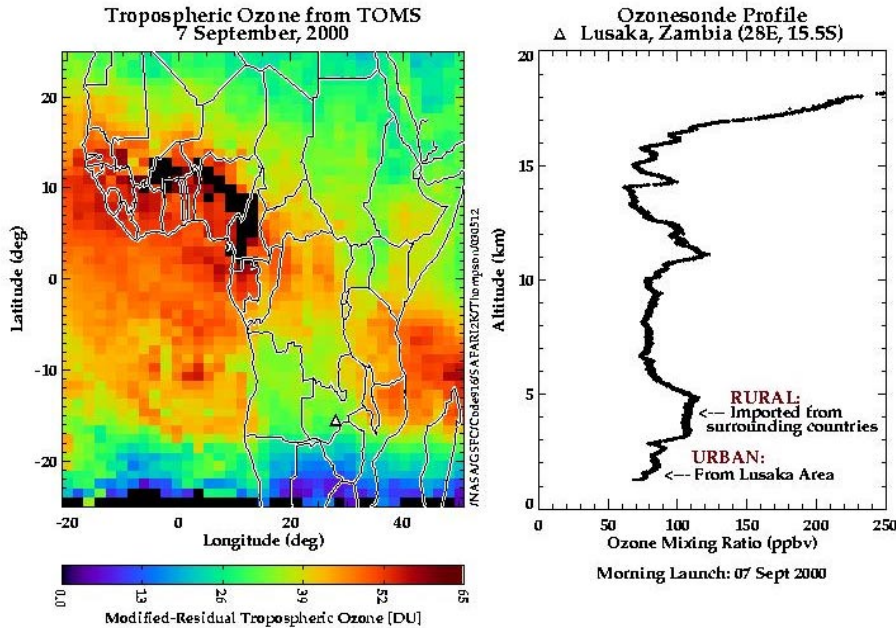


Fig. 5b. Independent comparisons of the wet and dry-season MODIS albedo with field observations over all solar angles suggested seasonal biases, but absolute mean errors were generally < 0.02 . Uncertainty increased at high (non-observed) solar zenith angles.

- Fig. 6. The TOMS tropospheric ozone product accurately captured the very high dry season ozone levels measured with ozonesondes in central Zambia. Subsequent modeling found this peak was caused by a unique convergence of atmospheric flows into this region.



- Land Surface Temperature (LST) results from the EOS split-window algorithm (MOD14 backup) captured the variability and magnitude of field-measured LST values at Skukuza, S. Africa.

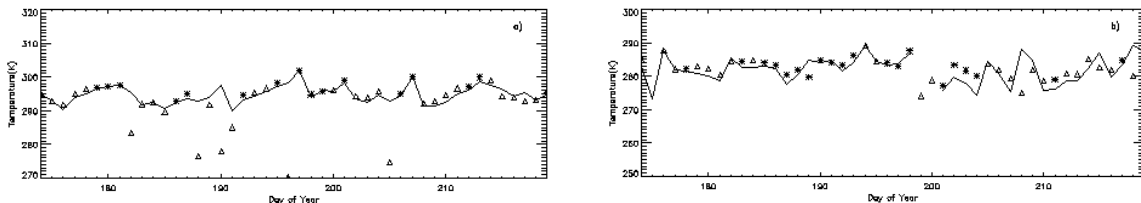


Fig. 7. The EOS split window LST algorithm was applied to NOAA-14 AVHRR data. Comparison of field-derived LST (—) and AVHRR LST (symbols) at the Skukuza site for day (Left) and night (Right) passes.

Other SAVE Accomplishments

- Measured and validated land products at six unique sites in three countries
- Measured LAI, albedo and surface temperature from Year 2000 to present at two sites
- Measured about 20 unique variables for EOS product validation and to parameterize process models
- Participated in four SAFARI Intensive Field Campaigns (leadership roles in each)
- Provided leadership on SAFARI 2000 Steering Committee and on SAFARI Data Group
- Published 16 peer-reviewed articles (incl. *Submitted* and *In press*)
- Published three multiple-disk CDROM volumes (incl. one *in prep.*)
- Provided about 50 presentations and lectures on SAVE/SAFARI 2000 activities and validation results
- Installed two permanent scientific towers (Mongu, Zambia and Skukuza, S. Africa)

Summary of Other Accomplishments

• Towers

SAVE erected two towers in southern Africa in October, 1999. The 33 m Mongu, Zambia tower is currently being used for ongoing albedo (NIR and shortwave), irradiance and thermal infrared measurements. The tower is operated by M. Mukelabai of the Zambian Meteorological Department. An eddy covariance system was installed on the tower in year 2000 by J. Albertson (Duke U.). Albertson is currently seeking funding to reinstall that system for multiyear studies. The 22 m tower in Skukuza, South Africa is currently outfitted with an eddy covariance system as well as albedometers. The eddy covariance system is operated by Hanan (SAVE Co-I) and Scholes (SAVE Co-PI) in cooperation with Kruger National Park Science Staff.



Fig. 7. SAVE erected a 20 m tower in Kruger National Park, S. Africa (Left) and a 30 m tower in Kataba Forest near Mongu, Zambia (Right).

• Data Collection.

Both continuous multiyear measurements (Table 1) and episodic campaign measurements (Table 2) were collected as part of SAVE. The field campaigns and the associated measurements for each are detailed in Appendix 1. The association between field instrument and measured parameter(s) is provided in Table 3. In addition, SAVE coordinated or arranged for the collection of a large and diverse satellite data archive over southern Africa. All data sets collected or procured by SAVE are either in the ORNL DAAC's Mercury Data System or available through the SAFARI CDROM Series.

Year-round measurements

Since 8/99, SAVE has collected LAI, albedo, aerosol, and soil temperature and moisture data at Skukuza, and aerosol, LAI, thermal IR, irradiance and albedo data at Mongu (Table 1). Measurements continue to present.

Table 1. Continuing SAVE-sponsored year-round data collection

| Parameter | Location | Start | Frequency | SAVE Lead |
|----------------------------|----------------|------------|------------|-----------|
| Soil moisture | Skukuza | 8/99 | Continuous | Pinheiro |
| Soil temperature | Skukuza | 8/99 | Continuous | Pinheiro |
| LAI/ %Cover | Skukuza, Mongu | 8/99, 3/00 | Periodic | Privette |
| Surface albedo | Skukuza, Mongu | 8/99, 3/00 | Continuous | Privette |
| Aerosol AOT (AERONET) | Skukuza, Mongu | 7/98 | Continuous | Swap |
| Aerosol source attribution | Skukuza, Mongu | 7/99 | Continuous | Swap |
| Surface temperature | Skukuza, Mongu | 2/00, 9/00 | Continuous | Pinheiro |

Table 2. Episodically-Collected Data: Temporal Measurement Frequency

| | |
|--|--|
| Tracing Radiation and Architecture of Canopy (TRAC) | Mongu/Skukuza: approx. monthly KT and MT campaigns: once/site |
| LiCor Plant Canopy Analyzer (LAI-2000) | “ “ |
| ASD Handheld spectrometer | each IFC |
| Kipp and Zonen NIR and SW albedometers | Mongu/Skukuza: 10 min, year-round |
| Streaker Samplers/PIXE analysis | from Swap |
| CIMEL sunphotometers | archived at AERONET/GSFC |
| Microtops II sunphotometers | ea. 30 min during KT and MT site visits |
| Campbell Sci. soil temperature thermistors (107L) | Mongu/Skukuza: 30 min, year-round |
| Campbell Sci. soil water reflectometers (CS615) | Mongu/Skukuza: 30 min, year-round |
| Everest and Teletemp handheld radiometers (skin temperature) | each IFC |
| GPS photography (Konica LandMaster) | each IFC |
| GPS receiver data (Garmin II+) | each IFC |
| Apogee radiometers (skin temperature) | Mongu/Skukuza: 30 min, year-round |
| PMS pressure chamber (leaf water potential) | Skukuza: approx. monthly |
| Aircraft-based pyranometer (2) | Skukuza: approx. monthly > 9/00 |
| Aircraft-based digital camera (3 band CCD) | Skukuza: approx. monthly > 9/00 |
| LI-1600 Steady-state porometer (Licor) | Skukuza: each IFC |
| Pressure Chamber Instrument (PMS Instr. Company) | Skukuza: each IFC |
| Soil characterization | Mongu/Skukuza: IFC2 |

Table 3. Field Instruments and their Associated Physical Parameters

| | |
|--|--|
| Tracing Radiation and Architecture of Canopy (TRAC) | % cover, clumping index, LAI |
| LiCor Plant Canopy Analyzer (LAI-2000) | effective LAI |
| ASD Handheld spectrometer | endmember spectra |
| Kipp and Zonen NIR and SW albedometers | canopy albedo |
| Streaker Samplers/PIXE analysis | aerosol source attribution |
| CIMEL sunphotometers | aerosol opt. Depth, size distribution |
| Microtops II sunphotometers | aerosol opt. Depth |
| Campbell Sci. soil temperature thermistors (CS107) | soil temperature at 4-5 depths |
| Campbell Sci. soil water reflectometers (CS615) | soil moisture at 4-5 depths |
| Everest and Teletemp handheld radiometers (skin temperature) | endmember or scene brightness temperature |
| GPS photography (Konica LandMaster) | color pictures |
| GPS receiver data (Garmin II+) | geographic coordinates |
| Apogee radiometers (skin temperature) | overstory and understory brightness temps. |
| PMS pressure chamber (leaf water potential) | leaf water potential |
| Aircraft-based pyranometer (2) | landscape albedo |
| Aircraft-based digital camera (3 band CCD) | landscape reflectance |
| LI-1600 Steady-state porometer (Licor) | Leaf stomatal conductance |
| Soil characterization | Soil bulk density, texture, %sand, % silt, %clay |

Satellite data procurement

SAVE personnel, in cooperation with MODIS validation staff, arranged for the procurement of more than 170 Landsat scenes, about 30 IKONOS images, about 20 ASTER scenes, and operational MODIS Land Product and SeaWiFS imagery subsets at 15 SAFARI 2000 Core Sites. The MODIS subsets and ASTER scenes are streamed to special archives in S. Africa and the LP DAAC. The IKONOS and Landsat scenes are stored only through the TRFIC ESIPII site at Mich. State Univ. (PI: Skole). A 3-year AVHRR land product data set created by the GIMMS group was procured and placed on the Volume I SAFARI CDROM.

Appendix I

• SAVE Field Campaigns

| Preliminary arrangements for SAVE activities | |
|---|--|
| Dates | <i>Mongu, Zambia Oct. 31 - Nov. 4, 1997 (After Miombo Workshop, Lusaka)</i> |
| Visiting Participants | Jeff Privette, Bob Swap, and Steve Prince |
| Activities | Discussions on SAVE and Meteorological Department collaboration Met with District Forest Manager (Mr. Moses Nyoni) |
| Site visits (beyond Kataba) | Visited Forest Department in Sesheke and the seven 26m fire towers Visited Kataba Forest with Kataba Forest Manager (Mr. Lombe Christantus) |
| Data Collection | Survey notes |
| <hr/> | |
| Dates | <i>Skukuza, Kruger National Park, S. Africa, Nov. 5-6, 1997</i> |
| Visiting Participants | Jeff Privette |
| Activities | Discussions with B. Scholes on Kruger National Park collaboration; Visited National Parks Office to seek authorization for tower in Kruger |
| Site visits | Visited potential tower site locations with Holger Eckhardt, Harry Biggs |
| Data Collection | Survey notes |
| <hr/> | |
| Vegetation surveys and site selection | |
| Dates | <i>Skukuza, S. Africa July 9-12 and 17-18, 1998 (Before SAFARI 2000 Blydepoort Meeting)</i> |
| Visiting Participants | Jeff Privette |
| Activities/Data Collection | Set up CIMEL sunphotometer Met with Eskom Energy Co. officials to seek SAFARI 2000 support |
| <hr/> | |
| Dates | <i>Changalane and Chobella, Mozambique, July 19-20, 1998 (After SAFARI 2000 Blydepoort Meeting)</i> |
| Visiting Participants | Jeff Privette |
| Activities/Data Collection | Survey potential Test Sites |
| <hr/> | |
| Dates | <i>Mongu, July 22-26, 1998 (After SAFARI 2000 Blydepoort Meeting)</i> |
| Visiting Participants | Jeff Privette, Peter Frost, David Roy, Louis Giglio |
| Site visits (beyond Kataba) | Aerial interpretive survey on chartered small aircraft Sitwi Dambo (dry) to the east of Mongu (~40 km from Kataba) Visited various schools on road to Sesheke with D. Ward to collect hand-held hazemeters (interpretive survey with PF) Aerial interpretive survey on departing flight to Livingston, on to Lusaka |
| Activities/Data Collection | <ul style="list-style-type: none"> • Identified site within Kataba Forest for SAVE tower (NW part of Forest) • Surveyed species, basal prism area, overstory fraction and soil cover composition in the NW, NE and SW quadrants of Kataba |

| SAFARI Intensive Field Campaign 1 | |
|--|---|
| Dates | <i>Skukuza, S. Africa August 5-7 and 14-20, 1999</i> |
| Visiting Participants | Jeff Privette, Ana Pinheiro, Luanne Otter, Niall Hanan, Julietta Aranibar |
| Meetings/Discussions | Cloudquest Company, re. modifying small aircraft to carry MQUALS |
| Site visits (beyond Kataba) | Visited dambo/Agricultural Center measurements |
| Activities/Data Collection | <ul style="list-style-type: none"> • Received/deployed major shipment of SAVE instrumentation from U.S. • Identified 4 specific tower base locations, one soil profile site • Surveyed and flagged Transects A and C (750 m each) • Installed 7 soil TRDs and 5 thermistors in two profiles • Collected handheld thermal IR surface measurements on transects • Conducted soil water infiltration measurement • Measured endmember spectra • Measured leaf water potential of several species • Conducted TRAC measurements over transects • Installed Albedometers on Tsay's SMART platform near airport • GPS photography • Collected soil samples to send to CSIR for composition/isotope analysis |
| SAFARI Intensive Field Campaign 2 | |
| Dates | <i>Mongu, Zambia, August 8-11, 1999</i> |
| Visiting Participants | Jeff Privette, Ana Pinheiro, Gareth Roberts |
| Site visits (beyond Kataba) | Visited dambo/Agricultural Center measurements |
| Activities/Data Collection | <ul style="list-style-type: none"> • Collected GPS data at various points • Defined two 750 m transects (A, C), flagged at each 25 m. Endpoints photographed with GPS camera (JP) • Collected LAI-2000 data (GR) • Collected hemispherical photographs on transects (GR) • Collected TRAC data on transects (JP) • Collected grass spectra at dambo • Collected some endmember spectra w/ PSII and GPS (GR) |
| SAFARI Intensive Field Campaign 2 | |
| Dates | <i>Mongu, Zambia, Feb. 27-Mar. 1, 2000</i> |
| Visiting Participants | Ana Pinheiro, Gareth Roberts, Peter Frost, Jeff Privette (others for KT Campaign) |
| Meetings/Discussions | Courtesy call to provincial government office (MM, JP, J. Albertson) |
| Site visits (beyond Kataba) | None |
| Activities/Data Collection | <ul style="list-style-type: none"> • Defined new 750 m transects A, B and C using 25 m stake flags • Collected spectra of aggregate overstory from tower (each 5 min.; JP) • Hemispherical photographs on transects (GR) • Ceptometer, LAI-2000 on medium and large plots (Scholes, GR, JP) • Commenced long-term TRAC transect operations (JP) • Installed albedometers; commenced long-term monitoring (JP) • Installed soil temperature, moisture and heat flux probes; started long-term monitoring (AP) • Collected leaves for spectra (JP, P. Frost) |

| | |
|--|---|
| A consistent set of measurements were conducted at each of the remaining sites on the Kalahari Transect Campaign. Therefore, we list the sites individually but list the measurements only once. | |
| SAFARI Intensive Field Campaign 2 (Kalahari Transect / Wet Season Campaign) | |
| Dates | <i>Pandamatanga, Botswana, March 3-5, 2000</i> |
| | <i>Maun, Botswana, March 7-9, 2000</i> |
| | <i>Okwa River Crossing, Botswana, March 11-13, 2000</i> |
| | <i>Tshane, Botswana, March 15-18, 2000</i> |
| Visiting Participants | Jeff Privette, Gareth Roberts, BU and UVA teams (others for KT Campaign) |
| Activities/Data Collection | <ul style="list-style-type: none"> • Laid out transects (3 *750 m) • Collected TRAC, LAI 2000 and ceptometer data on transects (with BU) • Took GPS photos along transects • Collected endmember and leaf spectra (with BU) • Collected AOT data with MicrotopsII (MM) |
| Dates | <i>Skukuza, S. Africa, March 22-25, 2000</i> |
| Visiting Participants | Jeff Privette |
| Activities/Data Collection | <ul style="list-style-type: none"> • Collected LAI 2000 data on transects • Took GPS photos at transect ends • Collected endmember and leaf spectra |
| SAFARI Intensive Field Campaign 3 (Aircraft / Dry Season Campaign) | |
| Dates | <i>Skukuza, S. Africa Aug 26-28 and Sept. 8-13, 2000</i> |
| Visiting Participants | Jeff Privette, Ana Pinheiro |
| Meetings/Discussions | Meeting of SAFARI Data Group at Pietersburg aircraft operations |
| Activities/Data Collection | <ul style="list-style-type: none"> • GPS photos along medium grid • LAI-2000 on medium grid • ADC NDVI pictures from tower top and along medium grid • Collected endmembers spectra • Collected handheld TIR data on medium grid (Ana) • Leaf water potential • Leaf stomatal conductance • Soil bulk density, texture, composition |
| Dates | <i>Mongu, Zambia, Aug 29 – Sept. 6, 2000</i> |
| Visiting Participants | Jeff Privette, Ana Pinheiro, Anne Thompson, Jacquie Witte, Gareth Roberts |
| Meetings/Discussions | SAFARI community dinner hosted by M. Mukulabai at Ngulu Motel |
| Activities/Data Collection | <ul style="list-style-type: none"> • Cleaned/serviced albedometers (JP) • Collected canopy spectra from tower each 5 min (JP) • Installed two pyranometers on tower; commenced long-term monitoring • Collected LAI-2000 (head and foot levels) and GPS photographs on transects (JP); Commenced long-term LAI-2000 record (JP) • Collected ground temperature data on transects (AP, JP) • Installed thermal IR sensors; commenced long-term monitoring (AP, JP) • Total sensor configuration at Mongu: 26 fixed sensors, 31 total w/ mobile transect measurement devices • Collected ozonesonde data in Lusaka (AT, JW) |

| SAFARI Intensive Field Campaign 5 | |
|--|---|
| Dates | <i>Mongu, Zambia, Sept. 1-5, 2001 (After SAFARI 2000 Siovanga Meeting)</i> |
| Visiting Participants | Christelle Hely, Sam Alleaume and Jeff Privette (by truck from Lusaka with Muke) |
| Site visits (beyond Kataba) | Local (dry) pan northeast of Kataba Forest |
| Activities/Data Collection | <ul style="list-style-type: none"> • Replaced one albedometer; cleaned/serviced others (JP) • Conducted fire fuel + canopy structure joint work: • Defined 200 m "fire transects" on eastern edge of pan, one in regrowth area on Kataba western edge • Collected TRAC data (MM, JP) • Collected GPS photographs (and regular GPS; JP) • Collected fire fuel load data on fire transects (CH, SA) |
| <hr/> | |
| Dates | <i>Skukuza, S. Africa, Sept. 7-11, 2001</i> |
| Visiting Participants | Jeff Privette |
| Site visits | Historic biomass study sites of KNP Science Services |
| Activities/Data Collection | Serviced albedometers |

• **References Describing SAVE Plans, Methods and Results**

- Alleaume, S., C. Hely, J. LeRoux, S. Korontzi, R.J. Swap, H.H. Shugart and C.O. Justice (2003), Using MODIS to evaluate heterogeneity of biomass burning in southern African savannas: Etosha region study case, *Int. J. Remote Sensing*, in press.
- Annegarn, H., S. Cole, T. Suttles, R. Swap: SAFARI 2000 Dry-Season Airborne Campaign, *Earth Observer*, September/October 2000, Vol. 12 No. 5, pp. 18-23
- Billmark, K.A., P. J. Yanik, R. J. Swap, and S.A. Macko, Stable isotope geochemical characterization of southern African aerosols, submitted to special issue of the *Journal of Arid Environments*.
- Caylor, K. K., P. R. Dowty, H. H. Shugart and S. Ringrose (in press). "Relationship between small-scale structural variability and simulated vegetation productivity across a regional moisture gradient in southern Africa." *Global Change Biology*.
- Caylor, K. K., H. H. Shugart and T. M. Smith (2003). "Tree spacing along the Kalahari Transect." *Journal of Arid Environments* 54(2): 281-296.
- Dowty, Frost, Lesolle, Midgley, Mukelabai, Otter, Privette, Ramontsho, Ringrose, Scholes, Wang (2000), Summary of the SAFARI 2000 wet season field campaign along the Kalahari Transect, *EOS Earth Observer*, 12(3):29-34.
- Hély, C., S. Alleaume, R.J. Swap, C.O. Justice, and H.H. Shugart, SAFARI-2000 characterization of fuels, fire behavior, combustion completeness, and emissions from experimental burns in infertile grass savannas in western Zambia, *J. Arid Environment*, 54(2): 381-394.
- Huemmrich, K.F., J.L. Privette and M. Mukelabai (2003), Ground verification of MODIS land products in Mongu, Zambia, *Int. J. Remote Sensing*, submitted.
- Otter, L.B., R.J. Scholes, P. Dowty, J.L. Privette, K. Caylor, S. Ringrose, M. Mukelabai, P. Frost, O. Totolo, E.M. Veenendaal (2002), The SAFARI 2000 wet season campaigns, *S. African J. Sci.*, 98(3/4):131-137.
- Pinheiro, A.C., C.J. Tucker, D. Entekhabi, J.L. Privette and J.A. Berry (2000), Assessing the relationship between surface temperature and soil moisture in southern Africa, *Remote Sensing and Hydrology 2000*, IAHS Public. 267:296-301.

- Pinheiro, A.C., J.L. Privette, R. Mahoney and C.J. Tucker (2002), Directional effects in AVHRR Land Surface Temperature over Africa, *Proc. Recent Adv. Quantitative Remote Sens.*, [J.A. Sobrino, ed.], Univ. of Valencia Publ., Spain, pp. 971-978.
- Privette, J.L., R.B. Myneni, Y. Knyazikhin, M. Mukelabai, Y. Tian, Y. Wang, G. Roberts and S. Leblanc (2002), Early spatial and temporal validation of MODIS LAI in the Southern Africa Kalahari, *Remote Sens. Environ.*, 83:232-243.
- Privette, J.L., Y. Tian, G. Roberts, R.J. Scholes, Y. Wang, K. Caylor, and M. Mukelabai (2002), Structural characterization and relationships in Kalahari woodlands and savannas, *Global Ch. Biol.*, in press.
- Privette, J.L. (2000), Southern Africa validation of NASA's earth observing system (SAVE EOS), Cape Town 2000, 28th Intern. Symp. Rem. Sensing Environ., CDROM.
- Stein, D.C., R. J. Swap, S. A. Macko, S. J. Piketh, B. Doddridge, and R. Brientjes, Preliminary Results of Dry-Season Trace Gas and Aerosol Measurements Over the Kalahari Region During SAFARI 2000, in press, the Kalahari Transect Special Issue of *Journal of Arid Environments*
- Swap, R.J., H.J. Annegarn, and L. Otter, Southern African Regional Science Initiative (Safari 2000) summary of science plan, *South African Journal of Science*, 98 (3-4): 119-124, 2002
- Swap, R. J, Annegarn HJ, Suttles JT, Haywood J, Helmlinger MC, Hely C, Hobbs PV, Holben BN, Ji J, King MD, Landmann T, Maenhaut W, Otter L, Pak B, Piketh SJ, Platnick S, Privette J, Roy D, Thompson AM, Ward D, Yokelson R, The Southern African Regional Science Initiative (SAFARI 2000): overview of the dry season field campaign, *South African Journal of Science*, 98 (3-4): 125-130, 2002.
- Swap, R. J., H. J. Annegarn, J. T. Suttles, M. D. King, S. Platnick, J. L. Privette, and R. J. Scholes, *Africa burning: a thematic analysis of the Southern African Regional Science Initiative – SAFARI 2000*, in review, SAFARI 2000 Special Issue, *Journal of Geophysical Research*
- Swap, B., J. Privette, M. King, D. Starr, T. Suttles, H. Annegarn, M. Scholes and C.O. Justice (1998), SAFARI 2000: a southern African regional science initiative, *EOS Earth Observer*, 10(6):25-28.
- Swap, B. and J.L. Privette (1999), Overview of the Southern African Regional Science Initiative - SAFARI 2000, *Proc. IEEE IGARSS 1999*, 1:595-597.
- Thompson, A.M, J. C. Witte, M. Tali Freiman, N.A. Phahlane, G.J. R Coetzee, (2002), Lusaka, Zambia, during SAFARI-2000: A collection point for ozone pollution, *Geophys. Res. Lett.*, 29(20) 1976, doi:101029/2002GL015399.
- Tian, Y., C.E. Woodcock, Y. Wang, J.L. Privette, et al. (2002), Multiscale analysis and validation of the MODIS LAI product. I. Uncertainty Assessment, *Remote Sens. Environ.*, 83:414-430.
- Tian, Y., C.E. Woodcock, Y. Wang, J.L. Privette, et al. (2002), Multiscale analysis and validation of the MODIS LAI product over Maun, Botswana. II. Sampling Strategy, *Remote Sens. Environ.*, 83:431-441.
- **Data Publications**
- Privette, J.L., D. Landis, J. Nickeson and J. Morisette, eds. (2001), SAFARI 2000 CD-ROM Series: Vol. 1 (2 discs), NASA's Goddard Space Flight Center, Greenbelt, MD, CD-ROM NP-2001-7-322-GSFC.
- Nickeson, J., D. Landis, J. Privette and J. Morisette., SAFARI 2000 CD ROM Series - Volume 2, NASA Goddard Space Flight Center, NP-2002-7-484-GSFC, 2002.
- Nickeson, J., D. Landis, and J. Privette, SAFARI 2000 CD ROM Series - Volume 3, NASA Goddard Space Flight Center, *in preparation*, 2003.

• **Other EOS References Authored By SAVE Investigators During Study Period**

- Annegarn, H.J., Otter L, Swap RJ, Scholes RJ, Southern Africa's ecosystem in a test-tube - A perspective on the Southern African Regional Science Initiative (SAFARI 2000), *South African Journal of Science*, 98 (3-4): 111-113, 2002
- Aplin, P., J.L. Privette, J.T. Morisette, R.J. Swap, T.P. Dawson, S. Ringrose, G. Roberts and P.N. Francis (2000), The remote sensing component of the southern African regional science initiative SAFARI 2000, Proc. Remote Sens. Soc. 26th Ann. Conf., Sept. 2000 on CDROM
- Aranibar, J.N. L. Otter, S.A. Macko, C.J.W. Feral, P.R. Dowty, H.E. Epstein, H.H. Shugart, and R.J. Swap, Nitrogen cycling along a precipitation gradient in Southern Africa, Accepted Kalahari Transect Special Issue, *Global Change Biology*.
- Billmark, K.A., R.J. Swap, and S.A. Macko, Characterization of sources for southern African aerosols through fatty acid and trajectory analyses, Accepted, SAFARI 2000 Special Issue, *Journal of Geophysical Research*
- Billmark, K.A., R.J. Swap, S. A. Macko, Stable isotope and GC/MS characterization of southern African aerosols, in review *South African Journal of Science*
- Eck, T.F., B.N. Holben, D.E. Ward, M.M. Mukelabai, O. Dubovik¹, A. Smirnov, J.S. Schafer, N.C. Hsu, S.J. Piketh, A. Queface, J. Le Roux, R.J. Swap and I. Slutsker, Variability of biomass burning aerosol optical characteristics in southern Africa during the SAFARI 2000 dry season campaign and a comparison of single scattering albedo estimates from radiometric measurements, Accepted SAFARI 2000 Special Issue, *Journal of Geophysical Research*
- Hély, C., K. Caylor, S. Alleaume, R.J. Swap, and H.H. Shugart, Release of gaseous and particulate carbonaceous compounds from biomass burning during the SAFARI 2000 dry season field campaign, accepted SAFARI 2000 Special Issue, *Journal of Geophysical Research*
- Hély, C., P.R. Dowty, S. Alleaume, K. K Caylor, S. Korontzi, R.J. Swap, H.H. Shugart, and C.O. Justice, Regional fuel load for two climatically contrasting years in southern Africa, Accepted, SAFARI 2000 Special Issue, *Journal of Geophysical Research*
- Huete, A., F. Keita, K. Thome, J. Privette, W. van Leeuwen, C. Justice and J. Morisette (1999), A Light Aircraft Radiometric Package for MODLAND Quick Airborne Looks (MQUALS), *EOS Earth Observer*, 11(1):22-25.
- Justice, C., A. Belward, J. Morisette, P. Lewis, J. Privette, F. Baret (2000), Developments in the validation of satellite products for the study of the land surface, *Int. J. Remote Sens.*, 21(17):3383-3390.
- Justice, C.O., D. Starr, D. Wickland, J.L. Privette and T. Suttles (1998), EOS land validation coordination: an update, *EOS Earth Observer*, 10(3):55-60.
- Morisette, J.T., J.L. Privette, A. Strahler, P. Mayaux and C.O. Justice (2002), An approach for the validation of global land products through the Committee of Earth Observing Satellites, invited chapter for the monograph, "Accuracy Assesment in GIS and Remote Sensing," published by U.S. Environmental Protection Agency, submitted.
- Morisette, J., J.L. Privette and C. Justice (2002), A framework for global land product validation, *Remote Sens. Environ.*, 83:77-96.
- Morisette, J., E. Vermote, D. Roy, J.L. Privette, and A. Huete (2002), Coarse spatial resolution product validation - a regression approach for the comparison of high and coarse resolution data, *Int. J. Remote Sens.*, submitted.
- Morisette, J., J. Privette, C. Justice, D. Olson, J. Dwyer, P. Davis and D. Starr (1999), The EOS land validation core sites: background information and current status, *EOS Earth Observer*, 11(6):21-26.
- Morisette, J., J. Privette, C. Justice and D. Starr (2000), MODIS land validation activities: status and review, *Proc. IEEE, IGARSS 2000*, 4:1699-1701.
- Morisette, J., J. Privette, D. Olson and P. Davis (2000), Spatial statistical analysis of three global land cover maps, *Proc. IEEE IGARSS 2000*, 5:1990-1992.

- Morisette, J., J.L. Privette, K. Guenther, A. Belward, C.O. Justice (2000), The CEOS Land Product Validation (LPV) Subgroup: Summary of May 23-25 Meeting, *EOS Earth Observer*, 12(4):6-7.
- Morisette, J., J. Privette, C. Justice and D. Toll (2001), MODIS Land Team Annual Validation Review Meeting, *EOS Earth Observer*, 13(2):16-17.
- Myneni, R.B., Y. Knyazikhin, J.L. Privette, et al. (2002), Global products of vegetation leaf area and fraction absorbed PAR from year one of MODIS data, *Remote Sens. Environ.*, 83:214-231.
- Pereira, JMC, B Mota, JL Privette, J Silva, A Sa', K. Caylor, W. Ni, and P. Frost (2002), Detectability of understory burns in the wetter miombo woodlands of southern Africa, *Remote Sensing of Environment*, submitted.
- Pinheiro, A.C., J.L. Privette, C.J. Tucker, D. Entekhabi and J.A. Berry (2000), Assessing the relationship between surface temperature and soil moisture in southern Africa, Cape Town 2000, 28th Intern. Symp. Rem. Sensing Environ., CDROM.
- Privette, J.L., J. Morisette, F. Baret, S.T. Gower and R.B. Myneni (2001), Summary of the International Workshop on LAI Product Validation, *EOS Earth Observer*, 13(3):18-22.
- Privette, J.L., G.P. Asner, J. Conel, K.F. Huemmrich, R. Olson, A. Rango, A.F. Rahman, K. Thome and E.A. Walter-Shea (2000), The Prototype Validation Exercise (PROVE) at Jornada: Overview and Lessons Learned, *Remote Sens. Environ.*, 74(1):1-12.
- Privette, J.L., J.T. Morisette, C. Justice and D. Starr (1999), EOS global land validation network, *Proc. IEEE IGARSS 1999*, 5:2587-2589.
- Privette, J.L. and G.P. Asner (1999), The prototype validation exercise (PROVE) for EOS land and atmosphere products, *Proc. IEEE IGARSS 1999*, 1:586-588.
- Privette, J.L., J. Morisette, and C.O. Justice (2003), A global observing system for the validation of space-borne land observations, *Advanc. Space Research*, submitted.
- Privette, J.L., Crystal B. Schaaf, Alan Strahler, Rachel T. Pinker, Michael J. Barnsley and Jeffrey T. Morisette (2002), Summary of the International Workshop on Surface Albedo Product Validation, *EOS Earth Observer*, 14(2):17-18.
- Privette, J.L., R.B. Myneni, J. Morisette and C. Justice (1998), Global validation of EOS LAI and FPAR products, *EOS Earth Observer*, 10(6):33-36.
- Schaaf, C.B., Gao, F., Strahler, A.H., Lucht, W., Li, X., Tsang, T., Strugnell, N.C., Zhang, X., Muller, J-P., Lewis, P., Barnsley, M., Hobson, P., Disney, M., Roberts, G., Dunderdale, M., Doll, C., d'Entremont, R. P., Hu, B., Privette, J.L., and Roy, D. (2002), The at-launch MODIS BRDF and albedo science data product, *Remote Sens. Environ.*, 83:135-148.
- Schaaf, CB, AH. Strahler, F. Gao, W. Lucht, X. Li, X. Zhang, Y. Jin, E. Tsvetsinskaya, J-P Muller, P. Lewis, M. Barnsley, G. Roberts, C. Doll, S. Liang and J. Privette (2001), MODIS Operational Bidirectional Reflectance and Albedo Products, *Proc. IEEE 2001 IGARSS*, 5:2227-2229.
- Swap, R.J.,..., J.L. Privette, et al. (1999), Southern African Regional Science Initiative: SAFARI 2000: Science Plan, Available at <http://safari.geop.virginia.edu>. 35 pp.
- Swap, RJ, Aranibar, Dowty, Gilhooly and Macho (2001), Natural abundance of ¹³C and ¹⁵N in C3 and C4 vegetation of Southern Africa: Patterns and implications, *Global Ch. Biol.*, submitted.
- Swap, B., T. Suttles, ..., J. Privette et al. (1999), Summary of NASA EOS SAFARI 2000 Workshop, *EOS Earth Observer*, 11(3):32-35.
- Swap, B., T. Suttles, ..., J. Privette et al. (2000), Report on SAFARI 2000 outreach activities, intensive field campaign planning meeting, and data management workshop, *EOS Earth Observer*, 12(3):26-28.

Stein, D.C., R.J. Swap, S. Greco, S.J. Piketh, S.A. Macko, B.G. Doddridge, T. Elias, R.T. Bruintjes, Haze layer characterization and associated meteorological controls along the eastern coast region of southern Africa, in review, SAFARI 2000 Special Issue, *Journal of Geophysical Research*

White, M.A., G.P. Asner, R.R. Nemani, J.L. Privette and S.W. Running (2000), Measuring fractional cover and leaf area index in arid ecosystems: digital camera, radiation transmittance and laser altimetry results, *Remote Sens. Environ.*, 74(1):45-57.