Southern Africa Validation of NASA's Earth Observing System (SAVE EOS)

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Abstract — Southern Africa Validation of EOS (SAVE) is 4-year, multidisciplinary effort to validate operational and experimental products from Terra—the flagship satellite of NASA's Earth Observing System (EOS). At test sites from Zambia to South Africa, we are measuring soil, vegetation and atmospheric parameters over a range of ecosystems for comparison with products from Terra, Landsat 7, AVHRR and SeaWiFS. The data are also employed to parameterize and improve vegetation process models. Fixed-point and mobile "transect" sampling are used to collect the ground data. These are extrapolated over larger areas with fine-resolution multispectral imagery. We describe the sites, infrastructure, and measurement strategies developed under SAVE, as well as initial results from our participation in the first Intensive Field Campaign of SAFARI 2000. We also describe SAVE's role in the Kalahari Transect Campaign (February/March 2000) in Zambia and Botswana.

I. INTRODUCTION

Southern Africa Validation of EOS (SAVE) began in 1998 as a funded project under NASA's EOS Validation Program Office. The primary aim of SAVE is to validate operational products of Terra, the largest and most complex environmental satellite platform ever launched. SAVE was designed to augment and leverage off existing scientific capacity in southern Africa (e.g., the Southern Africa Regional Science Initiative, SAFARI 2000; Swap et al., 1999), develop regional familiarization with NASA satellite products and procedures as necessary to support future NASA activities, and support a regional environmental assessment called for by the IGBP and IPCC programs.

II. NASA's TERRA SATELLITE PLATFORM

NASA launched Terra in December 1999, into a polar orbit that coincides with the Landsat 7 orbit. It crosses the equator from north-to-south at about 10:00 a.m. local time, 30 minutes before Landsat's crossing. Aboard Terra are five instruments designed for simultaneous sampling of many earth system variables (Kaufman et al., 1998). The instruments include highly evolved successors to current satellite sensors (e.g., the Moderate-Resolution Imaging Spectroradiometer (MODIS) vs. the existing Advanced Very High Resolution Radiometer (AVHRR)) and new, experimental sensors (e.g., Multi-angle Imaging SpectroRadiometer (MISR)). Together, Terra's sensors will provide an unprecedentedly comprehensive view of the Earth system.

Since about 1990, instrument teams have worked to exploit Terra's potential by developing operational products and algorithms. For example, the products of the MODIS Land Discipline Team (MODLAND; Justice et al., 1998) include ongoing estimates of land spectral reflectance, reflectance anisotropy, albedo, temperature, vegetation index, leaf area index (LAI), and net primary production (NPP) at various spatial and temporal resolutions. These products will be openly available through the Internet after the ~100 day Terra turn-on and checkout period. Such a comprehensive set of operational products is unique to land remote sensing.

Together with NASA's Landsat 7 (launched in April 1999) and SeaWiFS (launched in August 1997) satellites, Terra is well suited for the semi-arid deserts, savannas and woodlands of southern Africa. High spatial resolution sensors such as the Advanced Spaceborne Thermal Emission Reflectance Radiometer (ASTER) on Terra and Enhanced Thematic Mapper (ETM+) on Landsat 7 can detect fine scale landscape heterogeneity, land cover change, and facilitate the scaling of ground measurements over larger areas. Likewise, wide field-of-view sensors like MODIS and SeaWiFS can provide regional monitoring of highly dynamic processes (e.g., fires). Particularly useful will be the ability of MODIS to more accurately detect thin cirrus clouds, fire temperature, aerial extent and thermal energy, and detect surface features through the pervasive smoke layers in the dry season. Aerosol products from MISR should help uncover the primary source regions and transport patterns of the dense aerosol layers prevalent in the dry season. MISR may also help resolve savanna and woodland variability through its bidirectional sampling capabilities. Finally, MOPITT will help resolve large-scale source, sink and transport questions associated with carbon monoxide and methane.

III. CORE TEST SITES AND MEASUREMENTS

Because southern Africa is so expansive, SAVE's strategy is to acquire data over a small set of test sites representative of the major land cover variants. The priority land covers include Kalahari woodland, *acacia/combretum* woodland savanna, dry and wet miombo woodlands, mopane woodland, desert grassland/shrubland, and wetland.

SAVE resources are allocated according to test site capacity, spatial representativeness, and biogeochemical importance. The sites are divided into "continuous" Core Sites hosting instrumentation for year-round measurements, as well as transect campaign sites which will be characterized primarily during Intensive Field Campaigns (IFCs). Table 1 (after references) shows the four IFCs that SAVE will conduct. Each is detailed in the following text.

There are two Core Sites: Skukuza/Kruger National Park, South Africa (*acacia/combretum* woodland savanna) and Mongu, Zambia (Kalahari woodland) (see Fig. 1). These established sites are part of NASA's AERONET (a ground sunphotometer network), Global Land Cover Test Sites (historic Landsat and AVHRR imagery), and EOS Land Validation Core Sites (Privette et al., 1999).

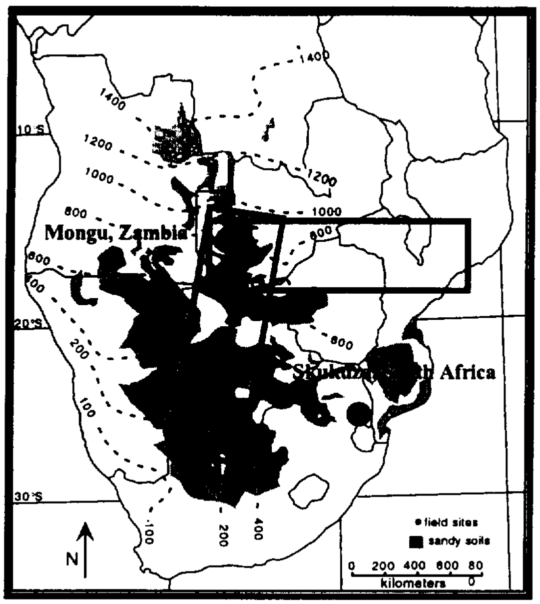

Fig. 1. SAVE Core Test Sites (large dots) and the distribution of Kalahari sandy soils with isohyets of mean annual precipitation (millimeters). The IGBP Kalahari Transect is outlined with a vertical rectangle, and the Miombo woodlands transect is outlined with a horizontal rectangle.

SAVE constructed an above-canopy tower (climb-up) at each in September 1999. A grid of 750 m transects, with flags at 50 m intervals, are marked around each tower (see Fig. 2). Each three- to four weeks, local technicians measure canopy gap fraction and leaf area along these transects. The frequency of these measurements is increased during leaf flushing and leaf fall. In 2000, radiation, energy and CO_2 flux instrumentation will be deployed on the towers. Soil moisture and temperature profiles are currently collected each 30 minutes near the towers.

To extrapolate the ground data, we periodically fly a light aircraft over the Skukuza tower and surrounding area (covering about 20 km x 20 km). The aircraft is equipped with a 3-band (blue, red and NIR) CCD imager, and a shortwave albedometer. A thermal infrared sensor will be added in 2000. ASTER, Landsat 7, IKONOS (a 1 m resolution commercial satellite), and MISR high-resolution data are acquired to allow further extrapolation. Measurements of non-EOS products, including auxiliary parameters needed as fixed inputs to the LAI/FPAR and other Terra algorithms (see Table 2), are measured during the IFCs.

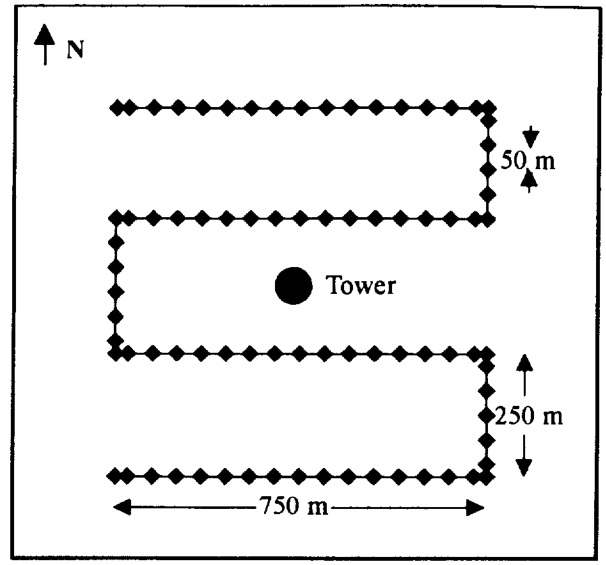

Fig. 2. A bird's eye schematic diagram of the ground transect and their flags (indicated with diamond shapes) around the Mongu and Skukuza sites.

Table 2

AUXIALARY PARAMETERS MEASURED AT TEST SITES FOR USE IN EOS ALGORITHMS

1. Canopy (plot) spectra
2. Leaf optical properties
3. Soil spectra
4. Fractional vegetation cover
5. Canopy allometric data (height, gap size, crown width)
6. Phenological stage
7. Species composition
8. Wet/dry state

IV. TRANSECT FIELD SITES AND CAMPAIGNS

SAVE is conducting less intensive measurements at sites occurring along two significant biogeophysical gradients in the region: the Kalahari and Miombo Woodland Transects. The gradients occur over spatial extents of thousands of kilometers both meridionally, as in the case of the Kalahari sands, and zonally, as is the case of the Miombo woodlands.

To sample these, SAVE will participate in traveling caravans composed of SAFARI 2000 investigators and local students. The first transect campaign (see Fig. 3) will cover the Kalahari sands from north (Mongu, Zambia) to south (Tshane, Botswana; *acacia* shrubland). Because a significant rainfall gradient spans this transect, a marked change in vegetation type and structure occurs. For satellite validation purposes, this allows extensive evaluation of canopy gap and structure over a relatively constant background (i.e., the sands).

The Kalahari Transect caravan (IFC 2) will include ~30 investigators assembling in Mongu. There, investigators will measure the soil, canopy and atmosphere over a 3-day period, then travel south to the next site to repeat the procedure (see

Figure 3) at four Botswanan sites (Kasane, *Biakaea plurijuga* evergreen forest; Maun, *Colophospermum* mopane woodland; Ghanzi/Okwa River Crossing, *Combretum apiculatum* savanna; and Tshane, desert shrubland containing *Acacia* and *Grewia*). SAVE investigators will focus on canopy structure—particularly LAI and fractional overstory cover, radiation absorbed by the canopy (FPAR), soil and canopy spectral reflectance, land cover type, and atmospheric aerosol loading. Energy and CO2 flux data will be collected continuously at Mongu, but only for the 3-day characterization periods at the other sites.

The multi-team caravan approach allows relatively large areas to be intensively measured in a synoptic time frame. The sites include a Core Site such that the episodic data can be evaluated in the context of year-round measurements. Landsat 7 and IKONOS imagery will be acquired to compliment Terra observations of the sites during the campaign. After reasonable data reduction and checkout, all measurements and imagery will be available in the public domain.

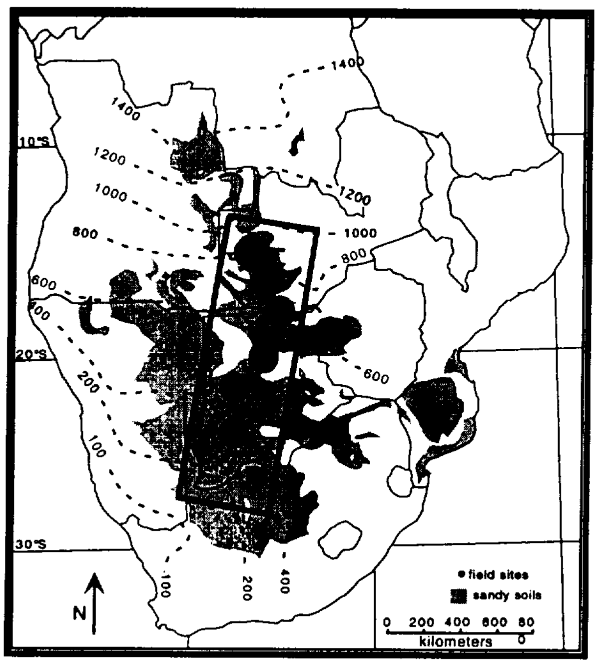

Fig. 3. Field sites to be characterized during the SAFARI 2000 IFC2 (Feb/March '00). From south-to-north, these sites include: Tshane, Ghanzi/Okwa River Crossing, Maun, Kasane, and Mongu. The IGBP Kalahari Transect is outlined with a rectangle.

SAVE investigators will conduct a second transect campaign in the 2000-2001 wet season. The Miombo transect campaign will extend from Mongu, Zambia to Nampula, Mozambique (wet miombo). SAVE will characterize the vegetation structure along this soil gradient, which primarily contains miombo woodlands. The primary sites to be visited include Mongu, Chunga/Kafue National Park, Zambia, Kasungu, Malawi, and Nampula, Mozambique. Miombo sites in Zimbabwe are also planned.

V. ADDITIONAL FIELD CAMPAIGNS

An non-transect field effort, coinciding with the SAFARI 2000 IFC 3, is scheduled for August/September 2000. At least two aircraft featuring extensive aerosol, trace gas and ground observation sensors will be used during this period. In addition, the NASA ER-2 (cruising altitude: 20 km) will fly over test sites with several Terra sensor simulators. Data from these sensors will allow comparison of calibrated radiances against simultaneously-acquired Terra observations. Because IFC 3 coincides with the period of extensive biomass burning, SAVE scientists will focus on using ER-2 data, as well ground sunphotometers data, to validate the MODIS and MISR aerosol products. SAVE will also release ozonesondes from Mongu at this time for validation of tropospheric ozone products. Tropospheric ozone increases as a result transformations in the emissions of biomass burning, and has been strongly correlated with increased aerosols.

SAVE land scientists will focus on fire and burn scar validation during this period. In cooperation with other EOS validation scientists, SAVE will quantify vegetation before and after prescribed burns. Ultimately, these data will be processed to estimate fire fuel load and combustion completeness. However, given the relatively low live biomass and photosynthesis levels in August, a proportionally smaller number of measurements will be conducted.

VI. MODELING ACTIVITIES

Although SAVE's primary purpose is to validate Terra's products, the team is acquiring data required for modeling such that EOS model-based products (e.g., NPP) can be validated and understood. SAVE collaborates primarily with three process modeling studies. The efforts include, 1) an integrated 1-D trace gas and energy flux ecosystem model (PI: Lianhong Gu, Univ. of Virginia), developed for a boreal forest, is being modified to simulate the Mongu woodland site; 2) a phenological/structural dynamics model of NPP is being developed and tested at SAVE sites for fire fuel and NPP simulation (PI: Peter Dowty, UVA), and 3) a coarse-scale SVAT model is being tuned to simulate southern African systems, and its hydrological and radiative energy subsystems will be validated (PI: Ana Pinheiro, GSFC).

These models will be used in a hierarchical strategy to evaluate the MODLAND NPP product. High temporal frequency fluxes at Mongu and Skukuza will be modeled using a maximum amount of in-situ data and relatively few approximations/climatological data sets. These point models will be used to quasi-validate the 3-D coarse spatial scale model which is strongly based on climatological inputs and other approximations. This model will in turn be used to assess the MODLAND NPP product.

In addition, a gap model for savannas is planned and will be related to land cover/use and climate trends (PI Kelly Caylor, UVA). SAVE works with these groups to ensure proper measurements (equipment, temporal and spatial resolutions) are obtained for model inputs, constraints and validation.

VII. CONCLUSIONS

After a two-year procurement and deployment period, SAVE has initiated ground and aircraft data collection to validate operational products from NASA's Terra satellite. Core sites have been augmented with climb-up towers for energy and CO2 flux systems. These sites will collect data continuously year-round, while many other sites will be visited episodically. Particular emphasis is being placed on mobile caravans with which several sites along the Kalahari and Miombo Transects will be characterized in relatively brief periods (~2-3 weeks). The caravans will feature scientists from various disciplines collaborating to characterize soil, canopy and atmospheric conditions under peak biomass conditions. A significant effort is being made to help educate regional students in these activities.

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Table 1

SAVE'S INTENSIVE FIELD CAMPAIGNS (IFC)

Period	*Season*	*Primary Goal*
August-September, 1999	dry	Air and ground characterisation of Mongu and Skukuza field sites; instrument shipping and deployment in region.
February-March, 2000	wet	Characterisation of vegetation structure, optics, and functioning at peak biomass along Kalahari Transect (precipitation gradient).
August-September, 2000	dry	Assess dynamics of dry-season emissions from biomass burning and other sources; Fire fuel load and remote sensing relationships; Major airborne activities.
December, 2000	wet	Characterisation of vegetation structure and optics at peak biomass over Miombo transect (soil gradient).