SESSION 2: DRY SEASON CAMPAIGN SCIENCE OBJECTIVES AND MEASUREMENTS

CHAIR: BOB SWAP, UVA

2.1 OVERVIEW OF OVERALL S2K AND OBJECTIVES OF THE CORE EXPERIMENT

Dr Bob Swap, UVA

The objective of SAFARI 2000 is to determine and quantify regional aerosol and trace gas emissions, transports and transformations, deposition and impacts. To meet this objective, the core experiment of SAFARI 2000 is designed to create:

- Regional fields of aerosol and trace gas emissions
- Regional fields of aerosol and trace gas transports and transformations
- Regional fields of aerosol and trace gas deposition and impacts

The interaction of these regional fields is illustrated in Figure 13.

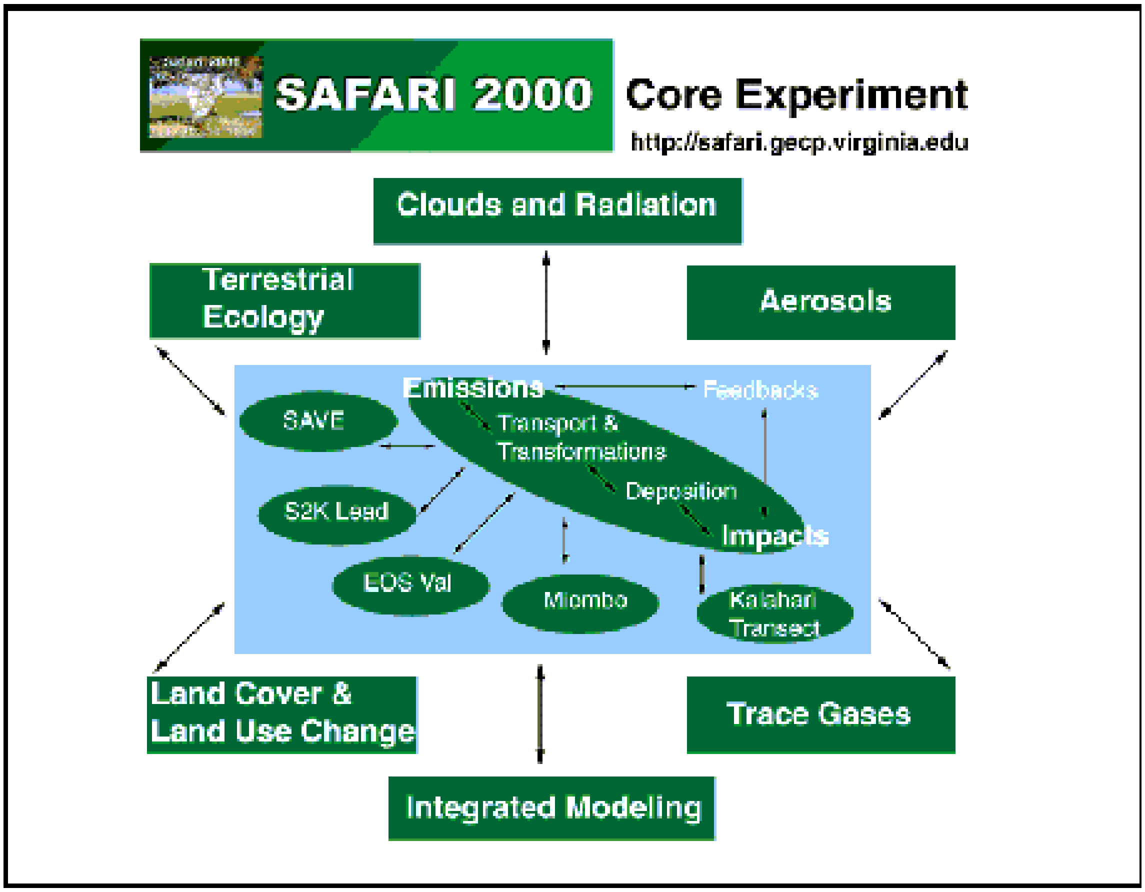

Figure 13. Interaction of regional fields of SAFARI 2000 core experiment.

The main objectives of the core experiment have already been agreed on and no further debate is required in this regard. What is needed is synthesis activities and synthesized data sets across the various regional fields and disciplines indicated in Figure 13. The creation of synthesised data sets is the responsibility of SAFARI 2000 synthesis teams. Funds and working teams are currently needed for the synthesis activities and data set development.

The SAFARI 2000 Synthesis activities will require the use of **SAFARI 2000 Data Bundles.** These bundles comprise hygraded data sets, Golden Days collections, or aggregated data products that have been cleaned and/or compiled. Examples of such data sets include: fire; biogenic emissions; LAI validation, tower data, and Aeronet data sets (etc.). These data bundles will depend on data from individual investigations and data collections associated with SAFARI 2000 science and validation activities and published findings.

The key to the overall success of SAFARI 2000 was given as being the coordination and synergy between SAFARI 2000 intensive flying campaigns, ground-based science and validation activities and remote sensing efforts.

2.2 GROUND-BASED ACTIVITIES

2.2.1 SAFARI 2000 LEAD Project
Dr Luanne Otter, CSIR

A project report has been compiled with details of all the Safari 2000 LEAD Projects. Copies may be obtained from Luanne Otter. A synopsis of the LEAD projects was given as follows:

(1) Anthropogenic emissions - regional modelling of emissions was being undertaken. Obtaining emissions for countries other than South Africa was proving to be difficult. Sulphur, sulphur dioxide, nitrous oxide, methane and VOC emissions data are being collated within an Arc Info Grid format. This data set is nearly complete and will be available shortly.

(2) Domestic bio-fuel combustion - Lackson Marufu was in the process of collecting data in Zimbabwe during the time of this workshop.

(3) Leaf-area dynamics - Bob Scholes was investigating leaf-area dynamics during the February-March 2000 campaign, with more work being scheduled for November 2000. No activities are planned in this regard during August-September 2000.

(4) NO emissions from soils - research being undertaken by Luanne Otter. Temperature and rainfall effects were being modelled over the southern African region. NO emissions and fluxes over different soil types were investigated during the Feb-March 2000 (wet season) campaign. Data has been collated and will be overlaid over climate and vegetation maps. Additional sampling will be conducted during November 2000.

(5) Hydrocarbon emissions - adaptations for hydrocarbon emissions from southern African species were being undertaken. Species compositions are being put together by the National Botanical Institute (NBI) in South Africa. Spatial maps of species composition will be available in about June 2000. The hydrocarbon data collection was done in December 1999.

(6) Aircraft projects - to be discussed by Stuart Piketh

(7) Streaker sampling - undertaken at Skukuza (KNP), Inhaca Island (Mozambique) and Mongu (Zambia). All of these sites are up and running. Sampling at Skukuza will represent one of the most intensive activity during the August-September 2000 campaign. Aircraft activities over Skukuza and Mongu during the August-September 2000 campaign would be most beneficial.

(8) DEBITS - 14 dry deposition sampling sites have been established as part of the DEBITS project. The project is lead by University of Potchefstroom. Data are available from Luanne Otter.

(9) Sulphur and Nitrogen dispersion modelling using the CALPUFF suite - undertaken by the CSIR. It is hoped to set up passive sampling sites within the April to May 2000 period to collect field data for the modelling project. This sampling will be conducted continuously over the next few years.

In conclusion it was emphasized that the main ground-based activities being conducted under the LEAD project during the Aug-Sept 2000 campaign were the continuous measurements at Skukuza and Mongu. Most of the other activities would take place during November and December 2000 to coincide with the rainy season.

2.2.2 SAVE Towers and EOS Validation
Dr Bob Swap, UVA

EOS / SAVE validation towers have been erected at Mongu (Zambia) and at Skukuza in the Kruger National Park (South Africa). An additional tower is planned for Maun. Instruments are located on a platform at the top of the tower. Isolation and meteorological parameters are recorded, in addition to ground based leaf index measurements. Mongu is still lacking equipment.

Detailed information on the SAVE sites are given on the web. During the dry season campaign instruments will be funning continuously at these sites and there is no need to direct specific flights over the sites.

2.2.3 Fire Project Validation

2.2.3.1 MODIS Fire Validation Plan
Dr Bob Swap, UVA presented on behalf of Chris Justice (UVA) and David Roy (University of Maryland, NASA GSFC)

MODIS active fire and burned area product validation activities were described as being complementary. Active fire product validation focuses on quantifying, errors of omission (e.g. small cool fires), and errors of commission (e.g. sunglint, hot reflective surfaces, sub-pixel cloud). Burned area product validation focuses on quantifying errors of omission (e.g. small & fragmented burns, burns with low combustion completeness), errors of commission (e.g. data misregistration, sunglint, hot reflective surfaces, sub-pixel cloud), and error bars on area estimation as a function of size. The emphasis of the study is on pragmatic validation. The study will involve:

- Comparisons of MODIS products with other satellite data;
- Focus on burned areas at sample ‘sites’ over a range of conditions;

- Validation sites defined by Landsat 7 scenes (~185*185km);
- Collect field measurements over ~5 day periods at each site; and
- Use of prescribed burns and airborne data as available.

Initial planning/coordination for fire product validation was undertaken at the Matopos Miombo Network Meeting during 1999. (Matopos is located in the NW corner of Zimbabwe.) Fire validation sites were selected in Botswana, Malawi, Mozambique, South Africa, Zambia, and Zimbabwe (others can be added). Coordination of validation activities with African scientists from the International Miombo Science Network and other EOS scientists is planned. Measures to be taken in this regard will include:

- The development of a field measurement protocol with participants (10-20 July 2000, Vic. Falls to Mongu).
- Implementation of field protocol by collaborators at distributed validation sites, July-October 2000.
- Follow up evaluation meeting planned for early 2001 to assess performance and to design 2001 field program.

MODIS validation sites are outlined in Table 2. At each site activities will include field checking of high resolution burn scar mapping (purposive sampling) and the identification and preliminary description of ambiguous scars. Observations will be undertaken on the ground conditions associated with ambiguous areas.

Landsat 7 data (ASTER and IKONOS data where available) will be used for intermediate comparison at higher spatial resolution and for statistical calibration of burned area estimates. Comparison of high -resolution burn scar maps with MODIS derived burn scar maps will be undertaken.

Table 2 MODIS Fire validation sites

MODIS Fire Validation Sites				
Country *Site Name*	Landsat 7 path/row	Dry season Landsat 7 LTAP schedule	Collaborators	Collaborator type
Botswana *Maun*	174/074	2/1-12/31 every	Budzanani Tacheva (Okavango Research Centre)	Operational user
Malawi *Chimaliro Forest Reserve*	169/69	1/1-12/31 every	Steve Makungwa (Forestry Research Institute of Malawi)	Operational user
Mozambique *Nampula & Mecuburi Forest District*	165/070	1/1-7/31 every 8/1-8/31 once 9/1-12/31 every	Jose Pereira (Instituto Superior de Agronomica, Portugal) Patrick Mushove (FAO)	Academic research Operational user
South Africa *Skukuza* *(*SAVE tower site)*	168/078 168/077	3/1-6/30 every 7/1-8/31 once 9/1-12/31 every 3/1-7/31 every 8/1-8/31 once 9/1-11/30 every	Tobias Landmann (Göttingen University, Germany)	Academic research
Zambia *Mongu* *(*SAVE tower site)*	175/070 175/071	4/1-11/30 every 2/1-7/31 every 8/1-8/31 once 9/1-12/31 every	David Roy, Louis Giglio	MODIS validation
Zimbabwe *Gutu / Save Valley*	169/074	3/1-7/31 every 8/1-8/31 once 9/1-12/31 every	Peter Frost (SAVE) Kudakwashe Mhwandagara (WWF) Cyrus Samimi (Erlangen University, Germany)	EOS land validation Operational user Academic research
Zimbabwe *Matabeleland Central Forest District*	171/073 171/074	1/1 - 12/31 every 3/1-12/31 every	Fidelis Mkosana (Zimbabwian Forestry Commission)	Operational user

The MODIS fire validation plan has *no critical requirements* for prescribed burns or aircraft data but will use whatever data is collected as targets of opportunity. Coordination with Ward and Hao's EOS Fire Validation Project prescribed burns in Mongu Sept 2000 and ER2 MAS (MODIS bands, 50m pixel) overflights were indicated as being highly desirable.

MODIS fire products are to be compared at fire validation test sites with IKONOS; ASTER (onboard EOS-TERRA with MODIS); and Landsat 7 (same orbit as EOS-TERRA, ~30 minute different overpass). MODIS fire products will be compared synoptically over southern Africa with AVHRR (onboard NOAA series) and ATSR-2 (onboard ERS-2). The spatial resolution, spectral bands and numbers of overpasses of southern Africa of ASTER, Landsat 7, AVHRR, ATSR-2 and MODIS Fire is given in Table 3.

Table 3. Spatial resolution, spectral bands and number of overpasses of satellite instruments

	Spatial Resolution	Spectral Bands	No. Overpasses of a southern African Location
ASTER	15m, 30m, 90 m	(14) vis, nir, swir, tir	every 16 days
Landsat 7	15m, 30m, 60m	(8) vis, nir, swir, tir	every 16 days
AVHRR	1.1, 4.0 km	(5) vis, nir, mir, tir	0-2 per day
ATSR-2	1km	(4) vis, mir, tir	once every ~3 days
MODIS Fire	1km	product	daily

Example: Mongu Dry Season 2000 Campaign

Validation performed over Landsat path 175 rows 70 and 71. At Mongu (Landsat path 175) overflight dates include: JUNE 13, JUNE 29, JULY 15 *, JULY 31, AUGUST 16, SEPT 1 **, SEPT 17, OCT 3, and OCT 19. The Mongu site is indicated in Figure 14. The MODIS fire validation field session with collaborators will take place at Mongu during ~12-17 July 12-17. Roy and Giglio are to implement measurement protocol at Mongu during ~2-12 September (activity indicated to be taking place on 10 September 2000).

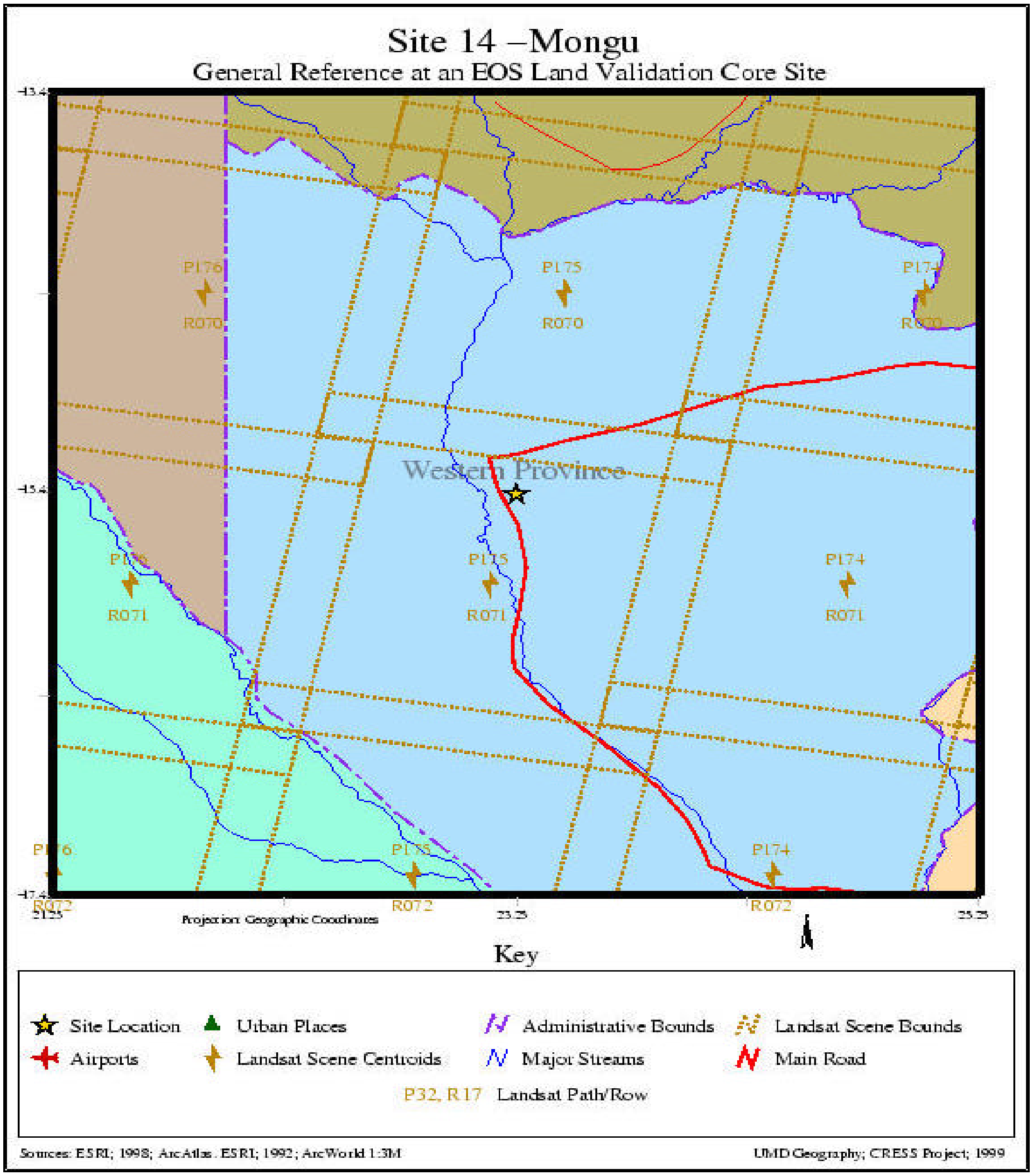

Figure 14. EOS validation site at Mongu, Western Province, Zambia

Collaboration Required

Ideally, the MODIS validation team would like prescribed burns (by Ward and Hao) a day or several days before Sept 1, in the period Sept 2-12, and a day or several days before Sept 17. The team would like ER2 (MAS) flown Sept 2-12 over Mongu along the Mongu N-S road East of the Zambezzi and where any prescribed burns are performed in this period.

2.2.3.2 Biomass Burning and Emissions of Trace Gases and Aerosols: Validation of EOS Biomass Burning Products

Darold Ward, US Forest Service

An outline was given of the Zambia validation study. Immediately following the launch, at least eight areas will be established for large burns. These sites will include Miombo and Dambo sites in the western province of Zambia. Burns will be conducted upwind and downwind of the grid of handheld sun photometers so as to compare with automatic sun photoms.

The ignition time of burns need be planned with the AM overpass in mind (10 AM?). Each burn will comprise an area of about 500 ha. The burns should coincide with airborne sampling of CO/CO_2, b-scat and meteorology.

50 hand-held sun photometers are under construction and are to be distributed to various sites, including Mongu, Lusaka, Ndolo (etc.). These instruments will be of great value to validation efforts. Mr Mukelabai has been operating the photometers for Brent Holben for the past few years. The hand-held sun photometers necessitate good local support. Data is recorded every half hour between 08h00 and 17h00. The data is included in spreadsheets generated by Mr Mukelabai. The data from the hand-held photometers correlated well with the automatic sun photometers.

An increase in aerosol loading in the atmosphere is evident as the dry season (October) progresses. The trend in biomass burning in southern Africa coincides with this trend. Aerosol optical thickness (AOT) was measured. These measurements correlate well with CIMEL aerosol optic depth measurements. A low aerosol index is evident to the south of Mongu with a high aerosol indices occurs to the north of Mongu (TOMS Aerosol Index). AOT thus increases in a northerly direction across the Zambizi River.

Data collected during 1999 is being integrated and will be put of a group homepage. The team is currently still adjusting algorithms. The new sun photometers will comprise automatic downloading capabilities.

Questions and Answers

Q How are sun photometers cross-calibrated.

A They are run side by side with CIMELS twice - once when they are taken out into the field and once when they are brought back.

2.2.4 AERONET

Brent Holben, NASA GSFC

The objectives of the AERONET (Aerosol Robotic Network) sites were given as follows:

- To provide diurnal regional characterization of aerosol optical properties
- EOS validation - through the characterisation of spatial and temporal variations in aerosol optical properties
- Aerosol flux characterization
- AERONET validation (on Peter Hobbs' plane)
- Measurement of direct aerosol forcing at the surface

Particle size distribution measurements in Zambia revealed a wide range of particle size ranges. During the Zambia International Biomass Burning Emission Experiment (ZIBBEE) airborne aerosol loadings were compared with ground-based *in situ* aerosol loadings measured at AERONET sites. A good correlation was obtained between AERONET and airborne measurements indicating that these sites are able to estimate the volume concentration (Figure 15).

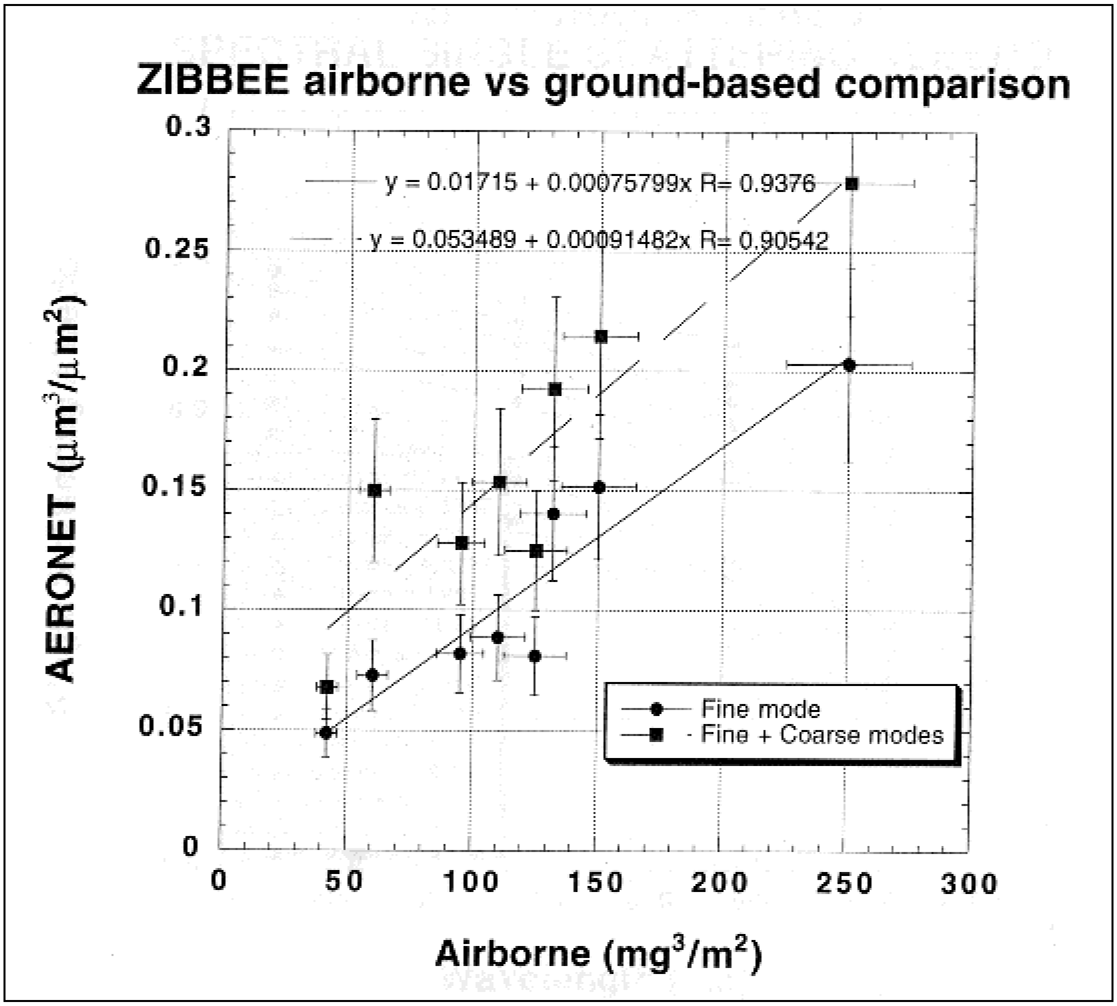

Figure 15. ZIBBEE airborne vs ground-based comparison

AERONET sites (current and proposed) which will be in operation during the August-September 2000 flight campaign include:

- Mongu - in operation
- Etosha - to be established following conclusion of international agreement
- Maun - to be established following conclusion of international agreement
- Inhaca Island - established at the end of May 2000
- Skukuza - in operation
- Bethlehem - in operation

An AERONET site is proposed for Johannesburg but will not operational for Safari 2000. A site is needed in northern Mozambique. This site will be established depending on instrument availability.

During the intensive flight campaign, 5 AERONET sites will be established in Zambia. Instruments to be in operation at each of these sites are as follows:

- Mongu - Cimel, Pyranometer, PAR, MFRSR and Michael Pulse Lidar (MPL)
- Zambezi - Cimel and PAR
- Senanga - Cimel, PAR and Pyranometer
- Kakombe - Cimel, PAR and Pyranometer
- Kafui - Cimel, PAR and Pyranometer

Coordination and Collaboration Required

It is necessary to get the international agreements in place to get the AERONET sites at Maun and Etosha operational. Assistance is required from the Zambia Meteorological Service in terms of ensuring the necessary infrastructure requirements at Mongu. Coordination with Ward's network is required to determine burn times and locations. Finally, coordination is necessary with the airborne platforms is necessary to obtain the necessary profiles and transects.

Questions and Answers

Q Why are so may Cimels being employed in Zambia?
A To characterise the Zambian "box" well in terms of what is going in and coming out. The Cimels quantify concentrations and provide a good representation of aerosol properties and volumes. Darold Ward will be lighting fires in the area (box) during this time.

2.2.5 MISR (Multi-angle Imaging Specto-Radiometer)
Mark Helmlinger, JPL

The science goals of the MISR field operations during the Safari 2000 campaign were given as follows:

- To provide local validation and radiometric assessment of MISR via AirMISR and field data to enable the construction of a long time series of MISR geophysical products for all MISR local mode sites.
- Site selection for aerosol retrievals from field data to be compared with MISR retrievals.
- Site selection for biodirectional reflectance factor (BRF) retrievals from field data to be compared with MISR retrievals.
- Gathering of optical depth, aerosol model, and BRF data at the chosen (representative) sites.

MISR can distinguish between different types of clouds, atmospheric particles and surfaces. Uses of MISR therefore include: the characterisation of the abundance and type of aerosols and investigations into the impact of aerosols on climate; cloud detection and classification by type and altitude; and classification of land cover type. The main MISR geophysical products include:

- Aerosol
  - Optical depth
  - Scattering/absorption model (size distribution, composition, phase) from climatology

- Surface reflectance
  - Hemispherical directional reflectance factor (HDRF)
  - Biodirectional reflectance factor (BRF) in 3 parameter Martonchik, Raman, Pinty, Verstraete model
  - Clear sky surface albedo

- Leaf Area Index derived from BRF

- Clouds
  - Top heights (reflecting level reference altitude)
  - Cloud field albedo
  - Statistics of cloud heights, aerial coverage

The benefits of multiple angle imagery was demonstrated through reference to various images.

MISR Field Validation - Field Instruments, Products and Timing

In order to verify that MISR's instruments are reliable, instruments are taken to the field to measure upward towards the sun and sky form a location as MISR is looking downward, measuring the same location on the earth. Other field instruments measure the intensity of light from the ground itself. Properties of the atmosphere and the surface characteristics made by ground-based instruments are well understood and can be used to verify that MISR is providing consistent results. Field validation instruments include:

- REAGAN Solar Radiometers - which measure optical depth, ozone, aerosol optical depth
- MFRSR - measure surface spectral irradiance
- CIMEL - measure optical depth, sky radiance in almucantar and principal plane
- PARABOLA - sphere scanning radiometer for BRF and HDRF measurement
- ASD field spectrometer - facilitates moderate resolution determination of spectral HDRF.

PARABOLA III - The Portable Apparatus for Rapid Acquisition of Bidirectional Observation of the Land and Atmosphere third generation instrument (PARABOLA III) is owned and operated by JPL. It is a sphere scanning radiometer with a 5° field of view and 72 azimuthal x 37 elevation positions. Data products from the PARABOLA III include surface biodirectional reflectance factor (BRF) with the effects of diffuse illumination having been removed, and hemispherical directional reflectance factor (HDRF) as measured reflectance.

CIMEL - This instrument measures direct sun, aureole and sky radiance. It has a 1° field of view and operates in 8 channels, 10 nm each ranging from 300 to 1 020 nm. Data products include aerosol phase function and single scatter albedo.

REAGAN - This tracking solar radiometer was developed at the University of Arizona. It operates within the following spectral channels: 380, 398, 437, 520, 606, 668, 781, 868, 938, 1028 nm. The instrument retrieves atmospheric optical depths, including aerosol and water vapour components.

MFRSR - The Multi-Filter Rotating Shadow-band Radiometer (MFRSR) is manufactured by Yankee Environmental Systems. It measures total and diffuse downwelling irradiances, operating in the following spectral channels: 413, 500, 616, 670, 865, and 930 nm (plus one broadband channel).

A synopsis of the products to be produced during the field operations was given as follows: (i) instantaneous aerosol and ozone optical depths via Flittner *et al*. Method; (ii) instantaneous aerosol model including single scattering albedo, phase function to provide a complex refractive index and size distribution via the Pilorz method; (ii) BRF from interpretation of PARABOLA III sphere-scanning radiance data; and (iv) spectral HDRF (normal incidence view) from ASD observations.

Timing of field operations - The field operations need to coincide with the coordinated ER-2 and MISR/platform overflights.

Field Data System Needs

Data types are instrument dependent. Data will be downloaded to a laptop to facilitate "quick looks" following which it will be processed at JPL and placed on the MISR website, viz.:

http://www-misr.jpl.nasa.gov/mission/valid.html

The approximate data volume anticipated will be in the order of ~10 Mb per day of full operation. During the post-campaign period, data will be available via the MISR website for approximately 4 weeks after the end of the campaign.

Data format - ASCII with headers and "README" files. Archiving will be undertaken via the MISR web site.

Field Support Needs were given as including:

- Protected instrument deployment site adjacent to simple lab space with 110 vac.

- Inclement weather storage space.
- Access to site before dawn through dusk and reasonably close to lodging.
- All clearances and badging.
- Securing arrangements (guards).
- Communications with other SAFARI 2000 participants.

Field Measurement Strategies may include:

- AirMISR overflight of bright parts of Etosha Pan to give radiance-based calibration of MISR. Assumes AirMISR is radiometrically well-calibrated since Etosha will not be manner by MISR.

- Attempt to find large area (grass?) measurement site that can be used by MISR and AirMISR for BRF recovery (Skukuza or surrounds).

- Perform field measurements of BRF using PARABOLA III at chosen site centered to extent possible on MISR and AirMISR overpasses and flights.

- Characterise surface cover botanically/physically using published descriptions of *in situ* measurements by others, e.g. plant lists, LAI, NDVI.

- Provide coordinated CIMEL measurements from a given site not already covered by AERONET (e.g. Pietersburg) for detection of potential aerosol changes between stations.

The following Issues were identified as requiring consideration:

- What are important field-measurable quantities needed for "ecological" modelling (e.g. C, P, S, N material balances, effects of smoke and pollutants on nutrient sources and/or changes in albedo).

- What geophysical parameters derived from MISR / AirMISR multi-angle measurements contribute to modelling exercises? (BRF, albedo, LAI, faPAR?)

- Does vegetation hotspots (retroreflection opposite sun) contribute useful information to modelling or canopy study efforts?

- AirMISR flight lines are 150 km in length (75 km each about target). Are there problems crossing country boundaries for targets near borders?

AirMISR Overflights

A total of six lines (each full nine angles) will be undertaken over each target to sample BRF in a parsimonius but robust fashion in azimuth, including.: (1) MISR ground track, (2) solar principal plane, and (3) line bisecting (1) and (2) above. Two lines (down and back) will be used for each azimuth to help insure coverage at all nine angles and improve sampling statistics. AirMISR overflights will need to be timed to coincide with MISR/platform overpasses. Target coordinates should be double-checked with pilots before the ER-2 launch. A heading of 190° will be used with an overpass time of around 08h15 UT for the first run. "cam.run" files for AirMISR will be supplied for each target to be flown.

2.2.6 VISTA University Radiation
Stuart Piketh, Climatic Research Group, University of the Witwatersrand

The locations of streaker and sun photometer sites are illustrated in Figure 16. The Mongu, Skukuza and Inhaca Island both has sun photometer and streakers. Bethlehem has a sun photometer in place, with the streaker having been placed at Ben MacDhui. A shadow band is in operation at Sutherland.

An AERONET sun photometer and a streaker is to be installed at Etosha by the time of the intensive flight campaign during August-September 2000. The Max Planck Institute will establish a sun photometer at a west coast site (site to be determined), and a CIMEL sun photometer will be placed at a site in central South Africa (site to be determined) prior to the IFC.

The need for measurements within Northern Mozambique must be addressed. A CIMEL sun photometer and simultaneous streaker is available for establishment there. The challenge is to get someone to run the sun photometer. It was also noted that there was currently no measurements being made in Zimbabwe.

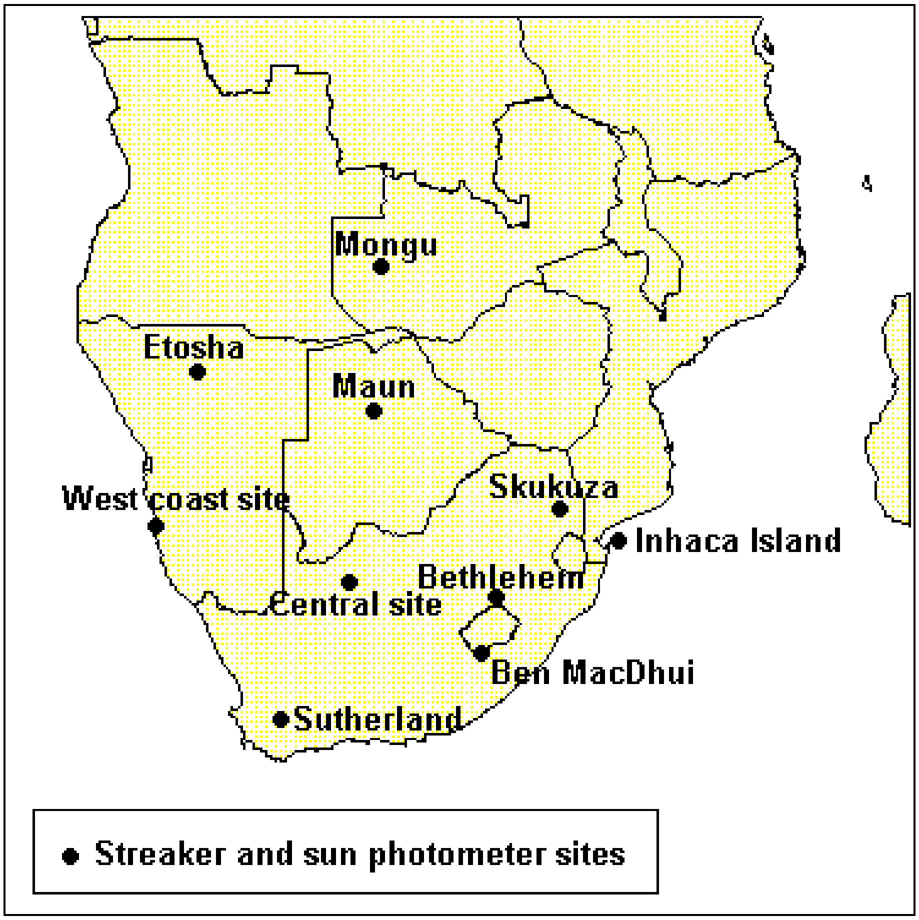

Figure 16. Location of sun photometer and streaker sampling sites

2.2.7 Air Pollution Measurement in Botswana
Frank Eckardt (UB) presented on behalf of M Lenkopane (Dept. of Mines)

Air pollution monitoring was initiated in Botswana due to growing anthropogenic emissions. The Air Pollution Control Division of the Department of Mines, Botswana, request flights to make similar measurements over the ground-based sampling sites to facilitate comparison and contrast with and interpretation of ground-based measurements.

The ground-based sampling points include: Maun (0_3), Francistown (SO_2, NO_x), Tonota (SO_2, O_3), Mmadinare (SO_2, CO), Selebi Phikwe (SO2), Serowe (SO_2, NO_x, CO), Palapye (SO_2), Gabarone (SO_2, O_3, NO_x, CO, HCs), Moshupa (O_3) and Lobatse (NO_x). These points have the highest possibility of impacts from industries. Ghanzi was chosen as a control site.

The longitude and latitude of the ground-based measuring sites and the proposed airborne measurements requested for consideration over each site are listed in Table 4.

Table 4. Ground-based measurements and proposed airborne measurements

Ground-Based Measurement	Location	Proposed Airborne Measurements (height 500 to 600 m above ground)
Selebi Phikwe SO_2, H_2S, NO_x (NO, NO_2), HCs (CH_4, NMHC), CO, O_3, Particulates, NH_3, meteorology (WD, WS, RH, T, Grad)	21°51' lat; 27°50' long	SO_2, NO_x, Particulates, sulphates, Ni & Cu fractions, CO, O_3, chlorides, nitrates, NH3, WD, WS, σ_y,σ_x, σ_z
Gaborone As for Selebi Phikwe	24°31' lat; 25°56' long	SO_2, NO_x, Particulates, CO, O_3
Mahalapye As for Selebi Phikwe	22°59' lat; 26°50' long	SO_2, sulphates, particulates
Sowa As for Selebi Phikwe	20°25' lat; 26°08' long	SO_2, particulates, sulphates, H_2S
Gantsi As for Selebi Phikwe	21°35' lat; 27°39' long	As for Selebi Phikwe

For additional information contact:

mlenkopane@gov.bw

2.2.8 Rangelands Project, Botswana
Frank Eckardt (UB) presented on behalf of Arntzen (UB)

The Rangelands Project involves the investigation of rangeland and livelihood dynamics. The spatial focus of the project includes an area just west of Tshane and can area centred on Ukwi in southwestern Botswana. The aim of the project is to analyse the dynamic relationships between rangeland state and rural livelihoods and to identify, within the southern African context, policy options and interventions that will optimise, sustainably, the welfare of the range communities while maintaining productivity and ecological diversity and integrity. Current activities are focussed on: (i) the analysis of existing information, (ii) the identification of data gaps and priorities for data collection, and (iii) the collation of available data in a systematic framework.

When the project was initiated, the mapping component of the project was started late. The area of interest is covered only by old and medium scale aerial photography. This shortcoming needs to be addressed. To address the situation, satellite imagery could be used if it is available.

Landsat TM 7 with a resolution of 15 m would serve to provide both basemap and thematic data. Higher resolution imagery may be procured to cater for data that is being collected at village level, at Tshane and Ngwatle villages, if funds are available 1 m resolution imagery such as the Ikonos can be used for these villages.

For additional information contact:

Arntzen@mopipi.ub.bw

2.2.9 Aeolian Mineral Deposition and Soil Chemistry
Frank Eckardt, University of Botswana

Soil development is a function of climatic factors, parent material (geology), local conditions(n use, hydrology, etc.) and the EXTERNAL input of mineral aerosols. Salt pans are one of the most significant sources of mineral dust in arid regions. Such salt pans:

- Effect soil and water quality downwind;
- Contribute to salinity in soil and water;
- Influence the nutrient status of soil; and
- Promote the formation of duricrusts (silcrete, calcrete and gypcrete)

The Double Lake in East Texas which is 4 km^2 in area, produces 750 tons of airborne salts each year which can be traced 25 km downwind in soils and groundwater (Wood, 1994).

Southern Africa has some of the largest pans (Etosha in Namibia, Makgadikgadi Pans in Botswana), and has a high density of pans (130 pans per 100 km^2 have been identified in South Africa). Ongoing research is being conducted with the focus on the Sua Pan in Botswana. The objectives of this research is as follows:

- Determination of hydrological pan inputs - origin and evolution of brines (PI Eckardt, UB)
- Soil quality around Sua Pan (PI Wood, USFS)
- Determination of soil mineralogy from remote sensing (PI White, University of Reading, UK) - considering the use of MODIS.

Information still required includes the following:

- Specific source points (pan surface conditions)

- Heading and range of plumes
- Composition and quantity of dust
- Deposition areas
- Frequency of plumes

Imagery, optical depth and *in situ* chemistry could go a long way to providing the necessary data to full some of the information gaps.

2.2.10 SMART (Surface Measurements for Atmospheric Radiative Transfer) Si-Che Say, NASA GSFC

The SMART instrument package includes solar flux radiometers, and ASD flux/radiance spectrometers, a thermal flux radiometer, a Cimel sun photometer, a total/diffuse solar spectroradiometer, a MPL lidar pointing profiler and a SMiR scanning microwave radiometer. Two operators are needed of over a 4 hour period to get SMART operational. It is, however, a self-calibrated instrument.

The Micro Pulse Lidar (MPL) is a ground-based instrument with a maximum altitude range of 60 km. The sensor has the following characteristics: Nd:YLF diode pumper laser with pulse energy of 10 µJ; visible wavelength at 0.532 µm; beam divergence of 1.2 µrad; a field of view of 50 µrad for the transmitter and 100 µrad for the receiver; and a pulse repetition rate of 2500 Hz. The MPL has a vertical resolution of 30 to 300 m, with a one month recording capacity and the ability to self-calibrate against molecular scattering.

The Multi-Filter Rotating Shadow-band Radiometer measures total and diffuse components of solar irradiance. The instrument operates at 6 filter channels at 415, 500, 615, 673, 870 and 940 nm and at 1 broadband ranging from 0.3 - 1.0 µm.

The Cimel sun photometer comprises 2 detectors for direct sun/aureole and sky radiance. This instrument has a 1.2° field of view with 0.05° zenith and azimuth angular accuracy. Other characteristics of the Cimel include: 8 filter channels at 340, 380, 440, 500, 670, 870, 940, and 1020 nm, DCP satellite telemetry and almucantar and principal-plane observation modes. During the Aerosol Recirculation and Rainfall Experiment (ARREX) inaccuracies in Cimel sun photometer measurements became apparent. This was partly due to the thermal dome effect. Corrections for the thermal dome effect were more successful during the night-time where near thermal equilibrium allowed the off-set to be explained. Solar heating and other effects during the daytime made corrections complex.

2.2.11 Atmospheric Emitted Radiance Interferometer (AERI)
Si-Che Say, NASA GSFC presented on behalf of Dr Steven Ackerman (University of Wisconsin-Madison)

AERI has a spectral resolution of better than 1 cm-1 wavenumber from 520-3000 cm-1 (3 - 20 µm). This instrument can be calibrated to within 1% ambient radiance, i.e. better than 1 ambient temperature. AERI is automated and environmentally hardened with a time resolution of 6 - 10 minutes. This time resolution is adjustable.

AERI applications include the following:

- Planetary boundary layer temperature and water vapour retrievals
- Sea surface temperature and emissivity
- Land surface emissivity
- Cloud radiative properties
- Carbon monoxide and ozone retrievals
- Line-by-line model validation

Temperature and water vapour mixing ratio profiles can be retrieved from high resolution AERI spectra up to 3 km. The vertical resolution of the instrument is currently 100 m at the surface, increasing to 250 m at 3 km up. Constraints, however, arise due to cloud base heights. Active ceilometer retrievals can be produced to cloud base.

Models such as GOES/NWP can be used to improve the first guess above the boundary layer (> 3 km) which in turn improve the AERI physical retrieval and the GOES/NWP profile (termed AERIPLUS retrievals). The AERI has been found to effectively detect the erosion of the planetary inversion in various studies.

2.2.12 Southern Hemisphere Additional Ozonesonde (SHADOZ) Project
Dr Bruce Doddridge, University of Maryland, presented on behalf of Dr Anne Thompson (NASA GSFC)

Shadoz was initially initiated by NASA as a two year project to remedy the lack of groundbased balloon sonde data in the tropics and subtropics. Such data is required to validate satellite tropospheric ozone estimates and to provide a data set for process studies and model comparisons. Using TOMS data to retrieve ozone profile data is useful in the investigation of large scale aerosol transport. For Safari 2000 the data set can be used to look at the stratification of the atmosphere and at regional transport.

It was decided to coordinate and/or supply additional sondes and collect weekly data from 10 tropic and subtropic stations during a 1998-2000 sampling period. A central public archive location has been established to facilitate access to the data collected, viz.:

http://code916.gsfc,nasa.gov/Data_services/shadoz

A link to this site has been established on the SAFARI 2000 website. Jacquelyn Witte is the data keeper and webmater of the Shadoz site. Data accessible via the website includes site information, a data disclaimer, a listing of the date on which the data was last updated, and the archived data by month and year. The data status for the 1998-2000 Shadoz period was given as follows by March 2000: Ascension (99 sondes), Fiji (90 sondes), Irene (25 sones), Java (23 sones), Nairobi (94 sondes), Natal (40 sondes), Reunion (55 sondes), Samoa (88 sondes), San Cristobal (77 sondes) and Tahiti (77 sondes). The data base currently needs more end users.

Irene (Pretoria, RSA) represents the Shadoz site in southern Africa. Station and sonde information for the Irene site is given as follows:

- Station location - 25.25°S and 28.22°E
- Elevation - 1524 m
- Ozonesonde type - ECC
- Radiosonde type - Vaisala
- KI Solution - 1% buffered.
- Station chief - Gerrie Coetzee, South African Weather Bureau

The Irene site was started in October 1998. Two sondes are routinely undertaken per month.

SHADOZ Activities during 1999-2000 were given as including:

- First Workshop in Natal, Brazil during November 1999 (seven of the 10 site representatives were present).

- WMO and Payerne visits during November 1999

- Dobson Intercomparisons in March 2000 in South Africa - Irene Ozonesonde demonstration.

- Julich Ozonesonde Intercomparison Experiment (JOSIE) participation during May 2000.

- Relevant meetings during 2000 including: Cape Town International Symposium on Remote Sensing in March 2000, EGS in Nice during April 2000, AGU Special Session in Washington DC in June 2000 entitled "Analysis and Modeling with SHADOZ Data" (http://www.agu.org/meetings), the Quad. Ozone Symposium during July 2000 at Sapporo (http://www.eorc.nasda.go.jp/AtmChem/O3sym), and the COSPAR conference in Warsaw during July 2000 (sss.copernicus.org/COSPAR). A SHADOZ workshop will be held on 29 May 2000 in Washington DC.

Interaction of SHADOZ with SAFARI 20000

A partnership has been developed with SAVE - which includes J Privette (principle investigator), B Doddridge and R Swap. A further partnership have been established with the South African Weather Bureau (SAWB) through liaisons with Gerrie Coetzee.

During the SAVE and SAFARI 2000 campaigns more ozonesondes will be undertaken. One sonde will be taken each week with EOS validation funds being used for this purpose. Three sondes per week were undertaken during the wet season campaign which took place during February-March 2000.

A two week intensive will also be taken at Mongu during mid to late August 2000 with three to four ozone sondes taking place per week.

2.3 AIRBORNE ACTIVITIES

2.3.1 NASA ER-2
Dr Shelton, NASA GSFC

A brief description was given of the ER-2 aircraft. The aircraft is 62 feet in length with a wingspan of 100 feet and a GE F-118 Turbofan (17 K lbs thrust) engine. One pilot is required for the aircraft which has its base at the Dryden Flight Research Center at Edwards, California. Key performance indicators were given as follows:

- Altitude - up to 70 000 feet
- Range of 3000 nautical miles
- Flight duration of 8 hours
- True airspeed of 410 knots (467 mph)
- Payload: 650 lbs in the nose, 650 lbs in Q-bay (Q-bay max 300 lbs with empty nose), and the superpods each take 650 lbs.

Attention was again drawn to the instrument configuration aboard the ER-2 (see Figure 12). It was emphasised that the weight of instruments to be placed on the ER-2 needed to be monitored very carefully.

It was envisaged that the team would set the take off time the day before and have a briefing session of the sequence of events necessary. The first 2 take-offs more time would be given for mission planning, with about 4 hrs required to get ready for the first mission. It is crucial that take-off times be adhered to so that crew rest time is not affected.

Attention was drawn to the RC-10 film camera which will be aboard the ER-2 aircraft making available imagery whilst flights are in progress. Two cameras will be used in case one breaks. The RC-10 film camera comprises two 12" focal length and a 9" by 9' image format. It is a passive optical instrument used for earth imaging. The principle investigator of the PC-10 film cameras is Bruce Coffland, NASA Ames Research Centre (bcoffland@mail.arc.nasa.gov). Further information regarding this instrument is available at the site: http://www.asapdata.arc.nasa.gov/. The imagery will be processed by the South African Airforce. A photo-interpretation office is needed in Pietersburg to support the utility of this instrument. Colour imagery is required for AirMISR. During the data management discussions it will be determined what should be done with the imagery once the teams leave Pietersburg.

Questions and Answers

Q Which hours of the day can flights take place?

A The crews have 12 hour shifts. Taking into account the mission planning time required, a 6 hour mission would imply that already 9 hours of the crew shift has been taken up. The ER-2 can take-off and land after dark.

Various of the collaborating scientists on the ER-2 were invited to give a description of their instruments and research efforts.

2.3.1.1 MODIS Airborne Simulator (MAS)
Dr Steven Platnick, NASA GSFC

MODIS (Moderate-Resolution Imaging Spectro-radiometer) is a satellite sensor on the EOS AM-1 satellite. The objectives of the MAS is as follows:

- Simulation of the majority of atmosphere and land spectral channels of MODIS for algorithm development. (MAS has fifty spectral bands covering 0.55 to 14.2 µm.)

- Obtain measurements of reflected and emitted radiation with a single instrument under a wide variety of earth-atmosphere conditions.

- Validate retrievals of atmospheric and surface properties with nearly simultaneous *in situ* aircraft and surface observations.

- Calibration intercomparisons during MODIS overflights.

MAS has a much higher spatial resolution and a different swath width when compared to MODIS. A comparison of the spatial resolution, spectral bands, platforms and detectors of MAS and MODIS is given in Table 5.

Table 5. Comparison of MAS and MODIS characteristics

	MAS	MODIS
Platform	ER-2 (20 km)	Terra (705 km, 10h45 descending node)
Spectral banks	50	36
Spatial resolution at surface (nadir view)	50 m	250 m (0.65, 0.86 µm) 500 m (0.47, 0.56, 1.24, 1.64, 2.13 µm) 1 km
Swath width	37 km 716 pixels/scan (scan rate of 6.25 Hz)	2330 km 1600 pixels/scan
Detector (filter radiometer)	Single	10 km along track array

MAS is useful for two components of investigation of SAFARI 2000, viz. aerosol retrievals and fire characterisation, and the Namibian stratocumulus study. MAS atmosphere algorithms include the following:

- Cloud mask for distinguishing clear sky from clouds - 48/(25) bit mask

- Aerosol optical properties
  - Optical thickness over the land and ocean
  - Size distribution over the ocean (ration between the assumed tow log-normal modes, mean size of each mode)
  - Land: use reflectance of dense dark vegetation where aerosol is most transparent (2.13 µm) and use to infer reflectance at 0.47 and 0.66 µm.

- Cloud radiative and microphysical properties
  - Cloud top pressure, temperature and effective emissivity
  - Cloud optical thickness, effective radius and thermodynamic phase

- Atmospheric profiles of moisture, temperature, column water vapour amount

MAS Level 1B data is archived in HDF format. The data is processed at NASA Goddard Space Flight Center and Ames Research Centre. Most data is archived at NASA Goddard DAAC, with some being archived at NASA Landgley DAAC. The MAS homepage is:

http://ltpwww.gsfc.nasa.gov/MODIS/MAS/Home.html

Questions and Answers

Q How long does it take to get access to data.
A Level 1 "Quick Look" imagery will be available the day after the flight.

2.3.1.1 AirMISR - Airborne Multi-angle Imaging Spectro-Radiometer
Dr Jeannette van den Bosch, NASA DFRC

AirMISR is essentially an aircraft emulator of a satellite sensor (MISR) to study atmospheric dust and aerosols, and ocean and land surface properties. AirMISR utilizes a single camera in a pivoting mount to view the same scene from different 'look ' angles. Dr Jim Conel (Jet Propulsion Laboratory) is the principal investigator. MISR/AirMISR science objectives were outlined as follows:

- Provide radiometric calibration of MISR to supplement on-board and vicarious calibration exercises conducted elsewhere.

- Provide local validations for: MISR aerosol optical depth and model retrievals, MISR BRF/HDRF retrievals and surface albedo, TOA/Cloud morphology and top and base height and albedo.

- Provide correlated MISR - AirMISR overflights with simultaneous measurements at intensive field measurement sites and AERONET stations.

Based on the above mentioned objectives having been met, it is the intention to provide a stand-alone basis for the construction of a long-term series of MISR geophysical products and cloud retrievals at regionally representative scales.

MISR comprises various view angles (670.5°, 660.0°, 645.6°, 626.1°, 0° (nadir)) and operates within 4 wavelength bands (446 - blue, 558 - green , 672 - red and 866 nm - near infrared). The spatial resolution of MISR is in the order of 1.1 km (BRF) and 17.1 km (aerosol) with a local mode of ~250 m. The local overpass time at southern mid-latitudes of the MISR is around 08h20 hrs UT. Repetition time for coincident local observations is given as 16 days. The ground tack azimuth is in the order of 190°.

AirMISR was fabricated from a spare MISR camera. It is attached to a gimbal system with rotation to facilitate occupation of all MISR view angles. Air MISR will be mounted in the nose cone of ER-2, operating at 20 km above ground level. The attached software generates motion-corrected and registered image data for MISR algorithm interpretation. AirMISRs target overflight strategy will include:

- Ground azimuths: (i) colinear pattern to provide statistical average response for calibration exercises, and (ii) crossing pattern (MISR ground tack, principal plane and bisector) to provide multiple azimuth multiangle data for study of BRF and hotspots, i.e. the so-called "rose" pattern.

- Overpass azimuth pattern and time to coincide with MISR overpasses.

The MISR has 233 paths which are fixed with respect to the Earth's surface. The MISR's swath width is 350 km with block lengths along the track of about 141 km. Paths 168, 169 and 167 are of interest in terms of Skukuza calibration requirements.

Clear sky conditions will be sought for aerosol and BRF retrievals.

Field Measurements and Timing

A field measurement campaign will be in progress at the time of AirMISR deployment. Instruments to be used in the field will include REAGAN solar radiometers (optical depth, ozone, aerosol optical depth measurement), MFRSR (surface spectral irradiance measurement), CIMEL (optical depth, sky radiance measurement in almucantar and principal plane), PARABOLA sphere scanning radiometer (BRF and HDRF measurement) and ASD field spectrometer (moderate resolution determination of spectral HDRF). Field measurements need to coincide with ER-2 and MISR platform overflights.

Four potential sites for field measurements are to be determined. Mark Hemlinger will be in the field during the experiment. In selecting the sites the team wants to be close to other instruments and within the satellite overpasses for the local mode to be optimized. Co-siting with active AERONET stations and sites with meteorological or flux instruments and/or ground measurements of BRF and reflectance would be beneficial.

ER-2 Flight Hours for Selected Sites

It is important to determine the sites which the AirMISR would need to fly over in order to quantify how much time is required for ER-2 flights. An example is given in Table 6 of the elapsed times assuming a full rose BRF pattern flown on each target.

Table 6. Example of ER-2 flight times assuming full rose pattern flights over targets

Site	Elapsed Waypoint Time	No. of Waypoints	Turn Time (6 min /	ER-2 Total Elapsed	Geographic Issues

			turn)	Hours	
Skukuza	2 hrs 29 min	9	54 min	3 hrs 23 min	Mozambique, Swaziland (?)
Mongu	4 hrs 47 min	9	54 min	5 hrs 41 min	Botswana, Zimbabwe, Zambia
Etosha	5 hrs 33 min	9	54 min	6 hrs 17 min	Botswana, Namibia
Makgadigadi	3 hrs 05 min	9	54 min	3 hrs 59 min	Botswana

AirMISR Data

Data types required by AirMISR include navigation data and spectroradiometric images. AirMISR raw data volumes are in the order of 0.25 GB/run for Level 0 data (a run comprises nine angles, four wavelengths.) After processing to Level 1 the data volume will be in the order of 1.25 GB/run. Data formats include native HDF and HDF-EOS.

Data will be available through the Langley DAAC 3 months after the campaign. Level 0 archiving will take place at MISR SCF, with Level 1 data archived at Langley DAAC.

Further reading regarding AirMISR is available at:

http://www.misr.jpl.nasa.gov/armain.html

2.3.1.2 MOPPIT-A

Dr James Drummond, University of Toronto

MOPITT, an instrument for the Measurement of Pollution in the Troposphere, is a satellite sensor on the EOS AM-1 satellite. MOPITT collects CO at 3 levels at all times, with Co and methane columns only being collected during the daytime. Images produced are in the order of 22 km by 22 km per pixel.

MOPITT-Airborne or MOPITT-A is a nadir-staring infrared radiometer, using correlative spectroscopy with on-board gas cells to measure carbon monoxide and methane in the atmosphere. MOPITT-A has a field of view of ~1.8°, yielding a spot size on the ground of ~630 m. The instrument represents an aircraft version of MOPITT. It is based on a space engineering model, and uses the same correlation cells, detections and signal processing as MOPITT. Further information can be obtained from the following website:

http://www.atmosp.physics.uto

MOPITT-A has a ground pixel size of 630 m (along tract) x 2500 m (across tract). Data sampling is undertaken at 0.45 seconds per sample. MOPITT-A operates across 4 channels and has a ground speed of 210 m/s. A sketch map was presented of *possible* flight paths with MOPITT-A aboard is given as Figure 17.

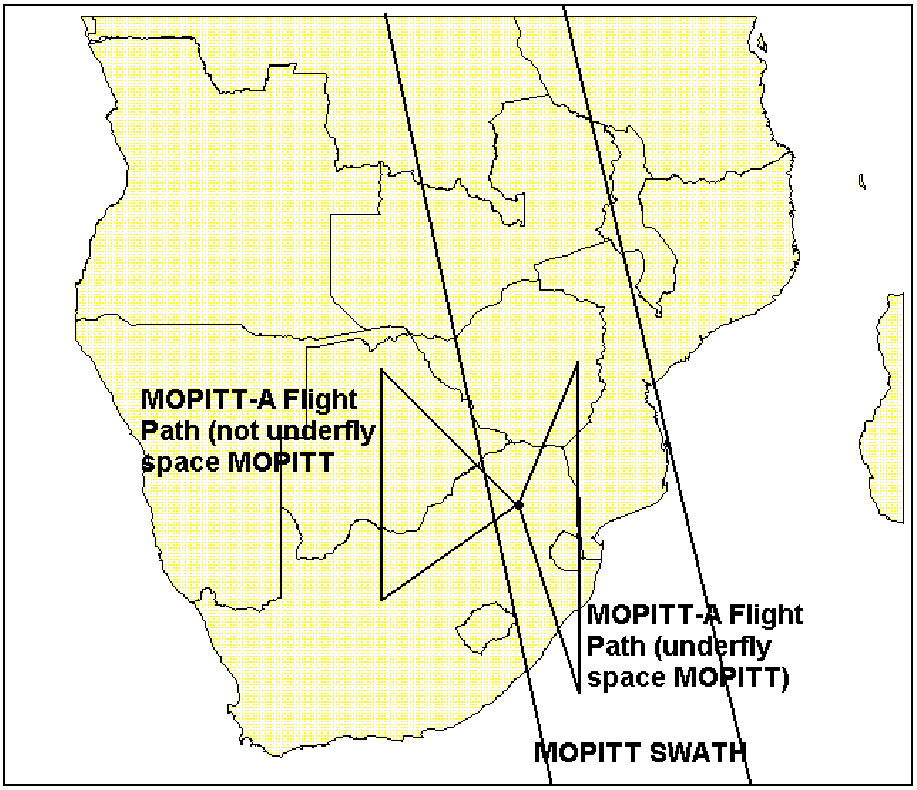

Figure 17. Sketch map of *possible* flight paths for MOPITT-A.

The main objective of the MOPITT-A study were given as follows:

- Validation of MOPITT Level 1 data product;
- Validation of MOPITT Level 2 data product;
- Key SAFARI 2000 objective is the measurement of CO and methane in various environments including pristine conditions, biomass burning areas and areas subject to extensive industrial pollution.

In terms of logistics, 3 persons will be required with a lab space of about 14 by 14 feet (200 m^2) necessary for the instrument.

Description of Data

The MOPITT-A data is not real time data, but rather a true Level 2 product. Data will be collected on hard drives and downloaded in Toronto for storage and processing (etc.). The final data product will be CO and CH_4 column profiles.

Questions and Answers

Q When and where will the MOPITT-A data be made available?

A MOPITT-A data will be available at the same website as MOPITT data. The team will negotiate with the DAAC people for space at the site. Although an attempt could be made to give people Level 1 data, it is not considered to be of much use.

2.3.1.3 Cloud LIDAR System (CLS) SAFARI 2000 Deployment

Dr Tim Suttles, NASA GSFC presented on behalf of PIs James Spinhirne and Matthew McGill (NASA GSFC)

The CLS is a LIDAR (Light Detection and Ranging) instrument which provides the true height of cloud boundaries and the density structure of less dense clouds, by measuring the time interval and intensity of reflected laser pulse. The science capabilities of CLS for SAFARI were given as including:

- Three wavelengths (355, 532, 1064 nm);
- Cloud and aerosol profiling with 30 m vertical and 200 m horizontal resolution at all three wavelengths;
- Determination of cloud optical depth (up to OD3);
- Aerosol, boundary layer, and smoke plume structure;
- Depolarization at 1064 nm to determine cloud phase;
- Direct optical depth determination from Rayleigh attenuation at 355 nm; and
- Photon-counting detection to minimize data calibration needs and data processing time.

Types of data which can be collected using the CLS includes attenuated backscatter profiles and cirrus cloud structure profiles. An example is given in Figure 18 of CLS measurements of attenuated backscatter profiles.

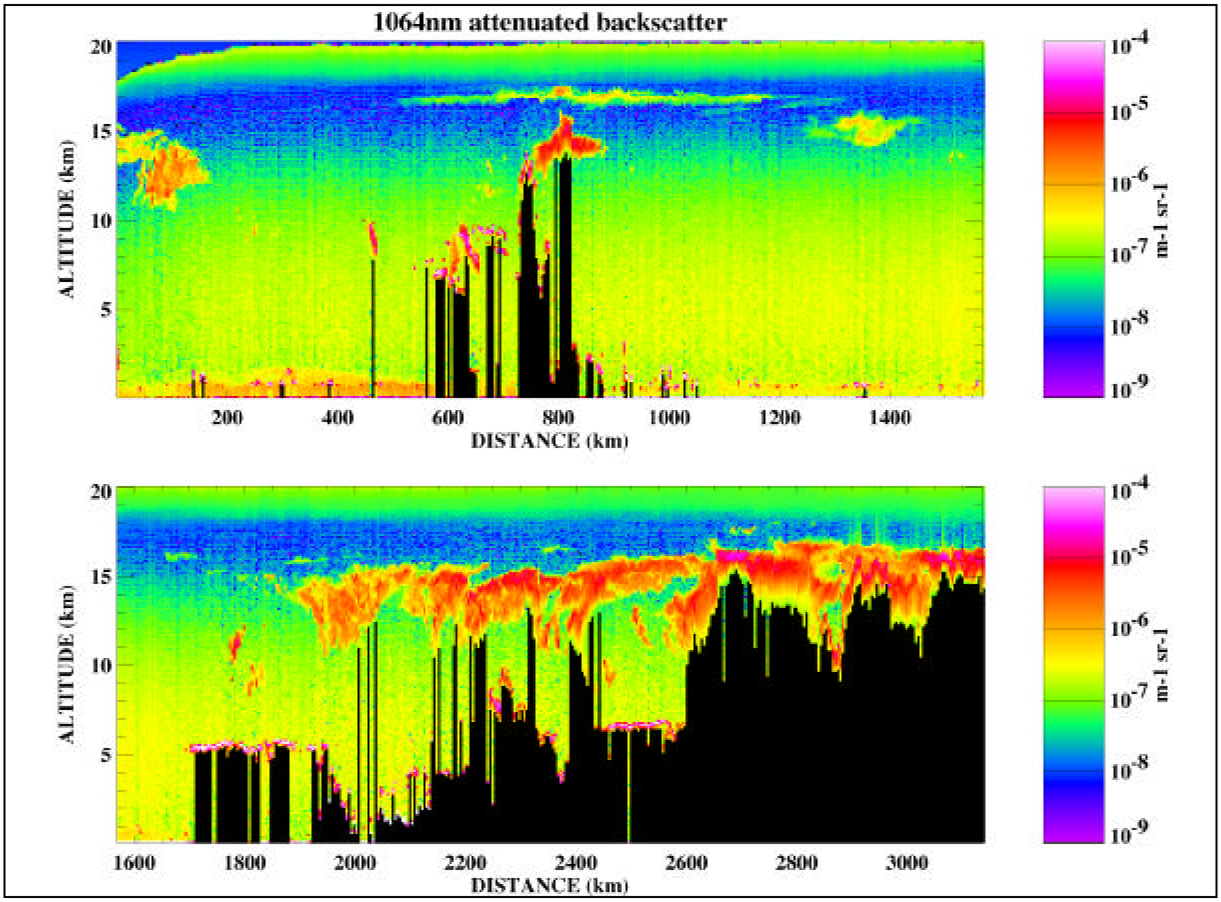

Figure 18 CLS measurements of attenuated backscatter profiles.

CLS Data Products and Data Volume, Storage and Dissemination

Fully analysed and calibrated profiles will be available within 3 to 6 months after the campaign. The storage format has not yet been determined (possibly HDF). Data to be available within 24-hours will include:

- Quick-look pictures of cloud and aerosol backscatter;
- Quick-look pictures of depolarization ration; and
- Text file with 1-second average of optical depth and cloud boundaries.

The 24-hour data (quick-look pictures and text files) will amount to 10-50 Mbytes per day. Processed data will be 270 Mbytes per hour of flight time. The team can store the analysed, quality-confirmed data in HDF format if desired or required.

All data will be archived on computers at Goddard, or can be archived on a NASA DAAC facility if desired. Processed data will be available from the principle investigators on DVD or tape or via the

CLS web site. The primary data contact will be Bill Hart, with Dennis Hlavka being the secondary data contact.

CLS Support Needs

CLS will be staffed by two people at all times. Office space with a desk, chair and phone would be beneficial. An internet connection would also be desirable. Two hotel rooms would be needed for the period August 10 to September 24.

Dry nitrogen is needed for purging the instrument. Some of the support equipment will be shipped on the transport aircraft.

2.3.1.3 S-HIS (Scanning High Resolution Interferometer Sounder)

Dr Tim Suttles, NASA GSFC presented on behalf of PIs James Spinhirne and Matthew McGill (NASA GSFC)

The S-HIS represents a Michelson Interferometer which forms interferograms from upwelling atmospheric and surface radiation in the 3.8 to 19 micron spectral region. The principle investigator of the S-HIS is Hank Revercomb of the University of Wisconsin (hankrevercomb@ssec.wisc.edu). The S-HIS will be placed on the DC-8 and on the ER-2. The instrument provides high-spectral resolution, operating within the 3-4 µm to 20 µm range.

Terra/Aqua related objectives were given as follows:

- Direct comparison of S-HIS radiance measurements to those of MODIS/MAS to validate radiometric calibration of MODIS/MAS in the infrared. This important function provides accuracy information about the MODIS spectroradiometer.
- MODIS Cloud Detection/Properties product validation
- Validation of clear atmospheric temperature and moisture structure retrieved by MODIS through comparison with S-HIS measurements.
- Continue to develop and validate cloud detection, cloud height, and cloud particle characteristics measured by high-spectral resolution measurements in the infrared.
- Improve radiative transfer modeling in the IR.

Specific SAFARI related objectives were given as including:

- The provision of a well-calibrated data set of high spectral and spatial resolution radiation measurements to support the objectives of SAFARI 2000;
- Characterization of the infrared spectral properties of clouds (maritime stratus); and

- Mapping of environmental tropospheric temperature and water vapor distributions in support of SAFARI 2000 objectives.

Cloud retrieval approaches adopted include the development of algorithms that combine MAS and S-HIS to retrieve cloud properties. MAS provides cloud cover within the SHIS footprint, with the SHIS being used to retrieve IR properties. S-HIS capabilities are combined with MODIS and AIRS for application within the aqua field.

Additional information on the S-HIS may be obtained from the University of Wisconsin website: http://www.ssec.wisc.edu/.

2.3.1.4 SSFR (Solar Spectral Flux Radiometer)

Dr Peter Pilewskie, NASA Ames Research Centre

The SSFR project team includes Warren Gore, Maura Rabbette, Larry Pezzolo, John Pommier and Steve Howard (NASA Ames Research Centre, Moffed Field, CA). The SSFR measures spectral solar irradiance at moderate resolution to determine the radiative impacts of clouds, aerosols, and gases and also to infer the physical properties of aerosols and clouds. The package comprises identical instruments looking up and down to determine upwelling and downwelling fluxes. The net solar flux is obtained from the up- and down-welling information.

The SSFR measures in the spectral wavelength range of 300 nm to 1700 nm, facilitating simultaneous zenith and nadir viewing. The instrument has a spectral resolution of 9 nm (300-1000 nm) to 12 nm (1000-1700 nm), and a sampling resolution of 3.25 nm. The sampling integration time is in the order of 100 minutes, and the spectral sampling rate is approximately 1 Hz. The light collector used comprises a spectralon integrating sphere with a conical baffle. Data storage is facilitated by a 225 Mbyte PCMCIA flash memory card.

Plans and objectives for the deployment of SSFR as part of the SAFARI 2000 campaign were expressed as follows:

- Deployment of nadir- and zenith-viewing SSFR on the University of Washington's CV-580 and on NASA's ER-2.
- Deployment of zenith-viewing SSFR by Si-Chee Tsay at a ground site.
- Measurement of solar spectral irradiance with a 0.1% precision and 1-3% accuracy.
- Determine the net solar radiative forcing due to aerosol, water vapour and cloud.
- Quantification of the solar spectral radiative energy budget.
- CERES validation.

- Archiving of data at several levels.

An example was shown of how the SSFC has been implemented in Oklahoma on 10 March.

Support needs were emphasized as including:

- Laboratory space for one 6 ft work bench/table and 100 square feet storage space.
- Office space for 2 tables and 4 chairs.
- A network with 2 10-basedT ports.
- A phone.
- Data support including aircraft navigational data (pitch, roll, heading, latitude and longitude data).

2.3.1.5 LAS (Leonardo-Airborne Simulator)

Dr Si-Chee Tsay, NASA GSFC

Dr Tsay emphasized that no formal funding has yet been obtained for the development and implementation of this instrument. Initially a satellite version of the instrument has been developed and they are currently working towards a ER-2 version of the instrument. The instrument design addresses the issues of angles of measurement which represents one of the most important issues in satellite science.

The multi-dimensional nature of the Leonardo Spectrometer means that it views the same spot from randomly distributed directions. Alternatively the same spot can be viewed at random times during a 24-hour cycle. Leonardo Science was developed in an attempt to gain a better understanding of both the angular and spectral variations of radiative forcing. Angular variation cannot be well measured by a single satellite, and represents by far the biggest uncertainty in instantaneous radiative forcing. A fleet of formation-flying micro-satellites with spectrometers, all pointing at the same Earth target, can measure BRDF in the most natural way. Such spectral information enables understanding of what is being viewed. A sketch of a possible satellite configuration based on the Leonardo Concept is given in Figure 19.

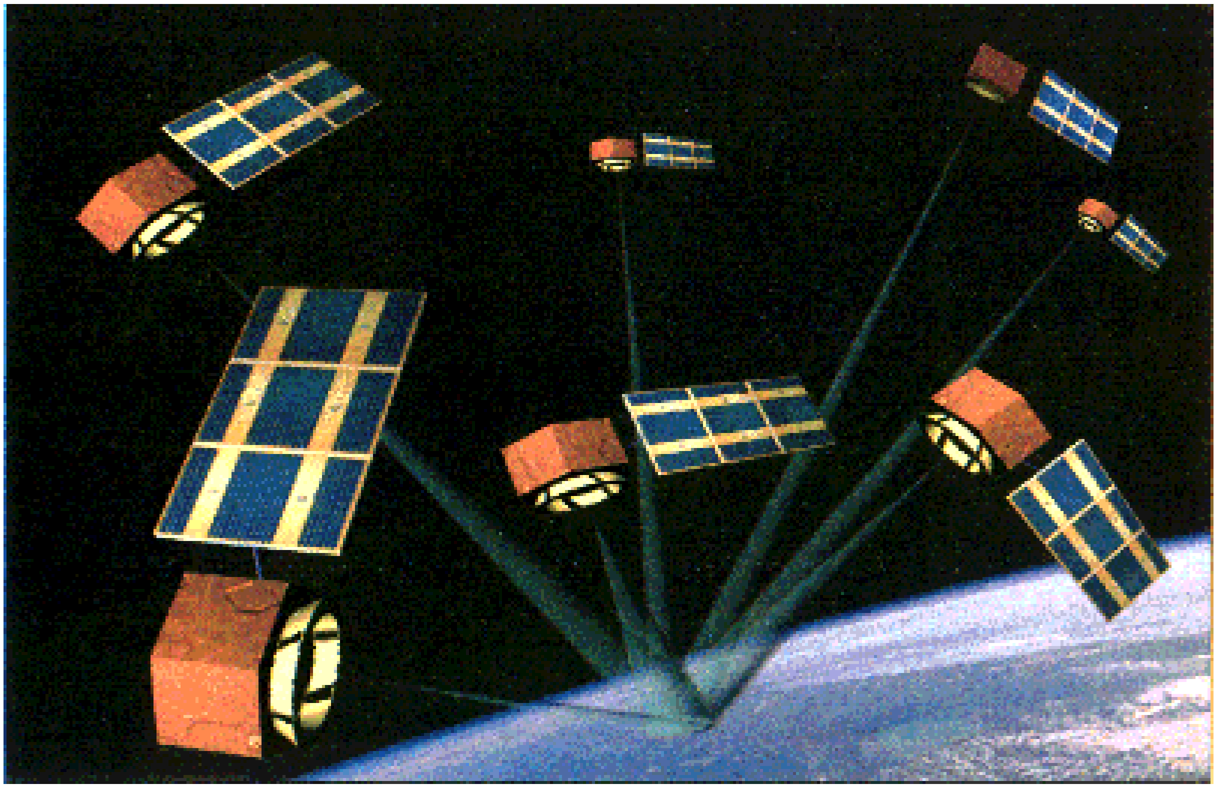

Figure 19. Sketch of satellite configuration facilitating multiple views of the same earth-based target.

The Leonardo Spectrometer measures *instantaneous radiative forcing*, comprising the net radiation energy flux leaving the earth at 30 km altitude. Radiative forcing is the common language through which diverse phenomena such as hurricanes, biomass burning and ozone hoes (etc.) can be compared in terms of their effect on global change.

In developing the instrument one of the most important requirements was that the instrument be inexpensive, inter-changeable and that it use off-the-shelf parts. Small optics and detector modules, with no moving parts were preferred for easy calibration. It was required that the instrument be integrated with a data processing system to facilitate fast data collection and space processing. Further requirements included space programmable instruments, spaceborne calibration technologies and the delivery of usable data directly to a variety of users.

It is proposed that the LAS be included in the rear of one of the ER-2 superpods should funding be obtained and the instrument be completed in time for the intensive flight campaign.

2.3.2 UNIVERSITY OF WASHINGTON Convair-580
Dr Peter Hobbs, University of Washington

The main aim is to improve remote sensing algorithms and resolve discrepancies by *in situ* measurements. Characteristics of the UW's Convair-580 research aircraft are outlined in Table 7. The flight time (6-7 hours) and cruise speed (255 knots) of the aircraft was emphasized to provide an indication of the likely spatial range possible.

Table 7. Characteristics of the UW's CV-580

FAA N Number	N3UW
Call Sign	Husky One
Maximum Research Altitude	32 000 ft
Maximum Range	14000 nautical miles
Maximum Endurance	7 hours
Cruise Speed	255 knots
Research Speed	156 knots
Slow Speed	130 knots
Climb rate at take-off	1400 ft/min
Climb rate at mid-mission	1650 ft/min
Max gross take-off weight	58 000 lbs
Min runway length	5 000 ft
Required runway width	100 ft
Aircraft dimensions	Length of 82 ft, height of 29.5 ft and wing span of 105.5 ft
Fuel	25050 gallons jet fuel
Oil	10 gallons turbine oil
Fuel burn rate	2100 lbs or 300 gallons/hr
Radios	VHF, UHF, HF

Bases for CV-580 Flights

The CV-580 will be based out of Pietersburg for the first 5 weeks. The aircraft is due to move to Walvis Bay for the last few weeks. It was still to be decided whether the aircraft should be based for 1 week further north to address biomass burning issues in Zambia. The aircraft could potentially be established at Kasane in northern Botswana to cover this area. (This was to be decided at the workshop on Thursday.) Lusaka was raised as another alternative to the Kasane site. A possible problem of locating the aircraft at Kasane was that it was uncertain as to whether the plane could be parked off the runway.

Scientific Objectives of CV-580 in SAFARI 2000

(a) The specific objectives to be met in flying out of Pietersburg during the period August 13 - September 9, and in coordinating whenever possible with ER-2 flights, were given as follows:

- Characterisation of physical and chemical properties of aerosols in the horizontal and vertical to distances of about 400 nautical miles from Pietersburg;
- Establish horizontal and vertical trace gas profiles for 400 nautical miles from Pietersburg;
- Characterise emissions (including emission factors when possible for: (i) biomass fires (prescribed and unplanned), (ii) industries, and (iii) other. (*The nature and location of potential industries to be investigated needed still to be established.*)
- Document the evolution of aerosols and gases in the sub-continental gyre. (*The best locations to do so still needed to be determined. Forecasts are needed as to how/when the gyre is set up so as to allow for flight planning. The forecasters and trajectory modelers were asked whether rough Langrangian points in the gyre could be estimated at which sampling could be conducted on successive days.*)
- Vertical profiles over ground-based sun photometers for "closure"-type studies. (*The meeting was asked which sites would be most suited for this purpose.)*

(b) Flights out of Kasone (should this be decided on) would concentrate on the measurement of prescribed fires in Zambia. Information required in this regard included:

  - The location of fires (latitude, longitudes)
  - Timing of fires
  - Number of fires to be set
  - Duration of burns
  - Manner in which coordination could be facilitated

- CAR measurements of surface bi-directional reflection function (BRDF) represented a further objective. (*Recommendations were invited as to where such measurements should be undertaken.*)

- *Other goals? (suggestions invited)*

(c) Flying out of Walvis Bay Bay (September 13 - 22) would involve:

- Coordinated flights with the ER-2 over:
  - The ocean to study marine stratus. (*The exact target area and issue of coordination were to be determined during the course of the meeting.*)

– *Recommendations regarding other locations of coordinated flights were invited.*

- CAR measurements of BRDF over oceans and possible other locations.

- Characterisation of aerosols and gases in outflow "exit" region of gyre (*specific location needs to be determined).*

- *Other goals? (suggestions invited)*

CV-580 Measurements

The main types of measurements to be made aboard the CV-580 during the SAFARI 2000 campaign include the following:

- State parameters - temperature, humidity, winds

- Aerosol - total number concentrations, size distribution (0.01-47 µm), light scattering coefficient, light extinction coefficient, light absorption, aerosol humidification factor, aerosol shape, total mass, ionic species, elemental composition, total organic carbon, total black carbon.

- Gases - hydrocarbons, CO2, CO, SO2, O3, NO/NOx/NOy, reactive and stable gaseous combustion emissions.

- Remote sensing -
  – Surface BDRF and albedo (13 wavelengths from 470-2300 nm)
  – Optical depth, water vapour and ozone columns (14 wavelengths, 350-1550 nm)
  – Solar spectral irradiance or radiance, spectral transmission and reflectance (300-2500 nm)
  – UW hemispherical up and down broadband irradiance
  – Surface radiation temperature
  – Video camera (forward-looking)

Support Needs

In order to maximise the usefulness of the CV-580 flights it is necessary that the following information requirements be met:

- List and locations (latitudes and longitudes) of major anthropogenic sources to be studies, including:

- Power plants (coal)
- Mines (e.g. platinum)
- Smelters (e.g. aluminum)
- Extractive industries
- Domestic burning
- Biomass fires

- List of major natural sources - main ecosystems.

- List of major ground observing sites over which aircraft should fly.

- Best locations for sampling gyre in various stages of its evolution.

CV-580 Schedule

Arrival on August 7 and subsequent installation of instruments arriving separately to be ready for the open house on Saturday August 12. The first flight will take place on August 13, with departure from Pietersburg on Saturday 9 September. The CV-580 will start flying out of Walvis Bay on 12 September, to be completed by 23 September.

Collaborating Scientists

Collaborating scientists (and their instruments or measurements) on CV-580 include:

- Michael King and Steve Platnick (scanning radiometer)
- Philip Russel (sun-tracking photometer)
- Peter Pilewskie (solar spectral flux radiometer)
- Robert Yokelson (Fourier Transform IR Spectrometer)
- Donald Blake (hydrocarbons)
- #Delbert Eatough (organic sampling system)
- #Tica Novakov (black and organic carbon)
- #Peter Buseck (TEM etc. of aerosols)

#Funding is still to be confirmed for these scientists.

Questions and Answers:

Q Are fluxes to be measured?

A No.

Q When and how will data be made available?

A This will differ between the instrument teams. Basic data will be available in real time. The University of Washington will archive the other data within a few months. This data will be available on a server there. (Dr Hobbs will provide the name of a contact person.)

Various of the collaborating scientists on the CV-580 were invited to give a description of their instruments and research efforts.

2.3.2.1 CAR - Cloud Absorption Radiometer
Dr Michael King, NASA GSFC

CAR will be located in the nose of the CV-580, scanning from horizon to horizon. The instrument can be orientated to 4 different configurations depending on the science objective. Most of the work done to date using CAR concentrated on biodirectional reflectance fluxes (BDRF). During the last year it was decided to redesign the instrument. The same engineering team as is working on the Leonardo Simulator (presented by Si-Chee Tsay) is currently working on the redesign of the CAR.

The measurement of BDRF is one of the most interesting applications of CAR. With the plane flying in a circle it is possible to map the entire down radiation and bi-directional reflectance fluxes with the entire upward and downward hemispheres being seen.

2.3.2.2 Airborne Sunphotometry and Integrated Analyses of Smoke and Haze Aerosols, Thin Clouds, Water Vapour and Ozone in SAFARI 2000
Philip Russell, NASA Ames

Co-investigators include Beat Schmid and Jens Redemann (Bay Area Environmental Research Institute), John Livingston (SRI International) and Peter Pilewskie (NASA Ames). SAFARI 2000 represents the first opportunity to fly Russell and Pilewskie's instruments together and to compare data.

Objectives of the investigation were given as including:

- Climate / radiation science - Improve the understanding of smoke, haze, thin cloud, water vapour and ozone effects on the radiation budget and climate of southern Africa and its surroundings.

- Satellite validation: Test and improve the ability of satellite and A/C remote sensors to measure these constituents and their radiative effects, viz. (i) EOS Terra MODIS and MISR, (ii) TOMS, (iii) ER-2 MAS and AirMISR.

- Atmospheric correction: investigation of the effects of aerosols, H_2O, and ozone on remote measurements of surface ecosystems, ocean colour and associated biogeochemcial processes.

Measurements Planned:

Measurements to be made from aboard the UW CV-580 in vertical profiles and on horizontal transects include:

(a) Smoke, haze, and thin cloud optical depth spectra (354 - 1558 nm)
(b) Water vapour column content
(c) Ozone column content

(a) and (b) will be measured continuously, in realtime, whereas (c) will be available 1 day after the flight.

Derived products would include: (i) extinction spectra and gas concentrations (z derivatives of above in A/C profiles), and (ii) aerosol size distributions, surface areas and volumes. These products were found to be useful in previous studies of Saharan Dust in which elevated Saharan dust levels were recorded with no aerosol being recorded between this elevated layer and the polluted marine boundary layer. Many dust properties measurement comparisons are undertaken to determine whether the dust/no-dust difference is statistically stable. The envisaged products will be useful to the Safari 2000 campaign given that distinct aerosol layers, each with their own characteristics, will be studied.

Support Needs

NASA Ames 14-channel airborne tracking sunphotometer (AATS-14) support needs are outlined in Table 7. A maximum of 4 people will be in the field at Pietersburg. At Wavlis Bay, 7 people are needed hence the need for 7 addresses.

Table 8. Support requirements of the AATS-14 sunphotometer team

Office/Lab Space (could be combined)	6 tables (3 ft x 6 ft) 5 chairs 300 sq ft of space
Power	220 V 50 Hz ; 40 A (8800 W) 115 V 50/60 Hz ; 8.7 A (1000 W)
Network	5 10BaseT ports, 7 addresses (1 printer, 4 Macs or PCs)
Gases	Zero Air (preferred) or N2. Consumption approximately 3 - 4 cu. ft/day. Prefer 1 large size (Matheson size 1A, Linde size K, 9" x 55", 225 cu ft) bottle carried in

	aircraft and 1 spare. Smaller bottles OK, but more spares would be required.
Cryogens	None

Clarity Required on Possible Walvis Bay Measurements

It needs to be determined where the measurements need to be made. The measurement needs at Pietersburg are clear but it is uncertain whether or not measurements should be undertaken at Walvis Bay. The main goal of the investigations at Walvis Bay is to determine the characteristics of the marine stratus. However, the presence of such stratus means that the sunphotometer team can not take its measurements.

The characterisation of the nature and extent of the continental outflow from Walvis Bay represents a further possible objective of study at this site. A decision needs to be made as to whether or not the team needs to concentrate on this.

Data Management System Planning Information

Types of data are labeled as Products A, B and C. The characteristics of each of these data types were described as follows:

Product A: NASA Ames 14-channel airborne tracking sunphotometer (AATS-14) data acquired from aboard the CV-580; included are aerosol optical depth at 13 wavelengths, water vapour and ozone columns. One file for each flight. Included in the fields will be the following:

- Time
- Aircraft latitude, longitude, altitude
- Atmospheric pressure
- Detector outputs
- Water vapour column content
- Absolute uncertainty in water vapour column content
- Ozone column content
- Absolute uncertainty in ozone column content
- Aerosol optical depth at 13 wavelengths between 354 and 1558
- Absolute uncertainty in aerosol optical depth at the same 13 wavelengths

Product B: AATS-14 data acquired from aboard the CV-580; included are aerosol extinction at 13 wavelengths and water vapour density profiles. Only during suitable up or down spirals. One file per spiral. Included in file will be the following:

- Time
- Aircraft latitude, longitude, altitude
- Atmospheric pressure
- Water vapour density
- Absolute uncertainty in water vapour density
- Aerosol extinction at 13 wavelengths between 354 and 1558 nm
- Absolute uncertainty of aerosol extinction at the same 13 wavelengths

Product C: Aerosol size distributions. Selected cases.

Data volumes, formats and availability are addressed in Table 9.

Table 9 AATS-14 data formats, volumes and availability

Approximate volume of data expected:	2 MB per flight (depending on duration)
Format to be used:	Column oriented ASCII files, with header information
Approximate time when data would be available after campaign:	Preliminary data in real time, during and after campaign. Archived data set available 1 year after campaign.
Where will data be archived:	NASA Ames Website, SAFARI archive?
Data contact:	Beat Schmid Bay Area Environmental Research Institute NASA Ames Research Center, MS 245-5 Moffett Field, CA 94035-1000 Phone: +1 650 604 5933 Fax: +1 650 604 3625 Email: bschmid@mail.arc.nasa.gov

AATS-14 Investigations and Applications:

(1) Use realtime, quick-look aerosol optical depth (AOD), column H_2O and O_3 in flight direction and planning.

(2) Calibration and validation studies for AOD, column H_2O and O_3 measurements by: (i) EOS Terra MODIS and MISR, (ii) TOMS, and (iii) ER-2 MAS and AirMISR (also with NOAA 14/GOES 8 and AATS-6). In cases of disagreement, causes will be investigated and retrieval algorithms improved.

ATSR, the predecessor of MISR has 2 look angles. The team wants to try the same within for Safari. By determining the nature of aerosol changes the fidelity of the satellite imagery changes can be determine. Experience has shown that when no dust is present in the atmosphere, satellite imagery is biased high, whilst being biased low when dust is present.

(3) Combine the teams' data with *in situ* measurements of aerosol chemical composition, size distribution, hydroscopic growth, and single-scattering albedo. Provide tests of closure and integrated assessments of aerosol and trace gas radiative effects.

(4) Combine out data with those from the Pilewskie SSFR and conduct new analyses of aerosol radiative forcing sensitivity, single scattering albedo, and the solar spectral radiative energy budget.

(5) Investigate effects of aerosols, H_2O and O_3 on remote measurements of surface ecosystems, ocean colour and associated biogeochemical processes.

Comments

In terms of requirements for gas mentioned under support needs, the ER-2 group is organizing with AFROX to meet such needs. The team needs to talk to Betty Symonds in this regard (Tim Suttles).

2.3.2.3 Airborne FTIR

Darold Ward, US Forest Service presented on behalf of Dr Robert Yokelson, University of Montana

The FTIR measures molecules in real time. It can be used to quantify various gases. The airborne FTIR (AFTIR) is 69" long, 11" wide and weighs about 135 pounds. Air is admitted to the glass cell through a sampling port on the aircraft exterior. The *in situ* mixing ratio for the gases present above (~10 ppbv) is measured. This instrument has successfully been installed on the CV-580.

To date, in ground-based open-path FTIR (OP-FTIR) and airborne FTIR (AFTIR) experiments, the team has quantified the a number of the compounds in smoke (Table 10). The large majority of other compounds present in smoke, not included in the table, are apparently less abundant. Compounds indicated by an astrix in the table have been measured by AFTIR. Many of the compounds on this list are common and important, but hard to measure by other techniques. The primary emphasis with be on hydrocarbons during the SAFARI 2000 campaign.

Table 10. Compounds present in smoke related to various formation processes

Dominant Formation Process:			
Flaming	Smoldering	Pyrolysis	Photochemistry

Carbon dioxide* Nitric oxide* Nitrogen dioxide Sulphur dioxide Water*	Carbon monoxide* Methane* Ammonia* Ethane Carbonyl sulphide	Acetic acid* Formic acid* Formaldehyde* Methanol* Ethylene* Acetylene* Phenol Glycolaldehyde Propene Isobutene Terpenes Furan Hydrogen cyanide*	Ozone*

Although SAFARI-92 was highly successful, there is sill no data on the emissions of many important trace gases from Southern African fires. Andi Andreae's 1997 review article on emissions from savanna fires stated that no reliable data on ammonia emissions from savanna fires could be obtained during SAFARI-92. Andreae further stated that "[i]n spite of its obvious atmospheric chemical importance the emission of this compound class from biomass fires has not yet received much scientific attention, mostly due to the difficulties associated with the quantitative determination of the oxygenates".

In an experiment at Camp Lejeune (April 1997), the FTIR was found to be effective in characterizing emissions of ammonia. An understanding of the photochemical reactions and the aging of aerosol emissions as they are transported downwind was found to be crucial. AFTIR results from the Camp Lejeune experiment also demonstrated that the four most common oxygenated organic compounds (CH_3OH, HCHO, HCOOH and CH_3COOH) can exceed methane emissions. It will be important to see if the model developed by the team applies to tropical fires. Most of the biomass burning occurs in the tropics and the oxygenated compounds will strongly effect ozone formation in biomass burning plumes. Ozone is an important pollutant, and is strongly linked with the oxidizing capacity of the atmosphere. Ozone is also an important greenhouse gas, especially in the upper tropical atmosphere. As a result of the improved understanding of oxygenated HC it is therefore also possible to establish the ozone plume as we move downwind, especially 2 to 4 hours after the release of these compounds.

The OP-FTIR system is being used for continuous emissions monitoring in "small fire mode" in the lab. This approach will allow the measurement of the compounds on the fill list (see Table 10) from domestic fuel use. In addition, the OP-FTIR setput works well (with the addition of a teflon chamber) to measure biogenic emissions. On the aircraft (CV-580) the instrument will be used in a flow through mode, i.e. the sample will be captured and spend 1 min or so in the chamber for analysis.

DAY 2

2.3.2.3 AEM - Analytical Electron Microscopy
Peter Buseck, Arizona State University

Many aerosol studies concentrate on bulk samples to determine the chemical nature (XRF, INAA, PIXE, etc.) and structure (XRD) of particles. Such bulk analyses are averaged and have important limitations. The AEM allows for the characterisation of individual aerosol particles. The effect of aerosols on climate, haze, health depend on properties of individual particles, not averaged values. For example:

- elements dispersed as traces amount all particles vs concentrated in a few particles (e.g. As)
- speciation and concentration of elements on particle surfaces or interiors influence radiative properties

The goals of AEM are as follows:

- To show what real particles look like
- To compare mixing states, coatings etc of natural and anthropogenic particles
- To see whether useful new information can be obtained from studying individual particles

Transmission electron microscopy (TEM) provides comprehensive data about individual particles, including:

- Composition, crystallographic structure, which is needed for speciation
- Sizes and shapes of particles
- Extent of aggregation – interval vs external mixing
- Degree of reaction, scavenging, and recycline (e.g. in clouds)":
  - surface coatings
  - mixed composition

Assumptions frequently made about aerosol particles include the assumption that most aerosol particles are simple in shape and consist of only one species. Speciation is therefore often ignored or deemed unimportant. Aerosol coatings are also assumed to be uncommon or it is believed that coatings can not be studied in detail.

Observations have shown that real particles are vastly more complex that theoretical ones. Individual particles show wide ranges in composition, being comprised of multiple species, and having highly complex shapes. In terms of speciation, the composition, structure, size, shape and mixing state can all be determined on the same particle using TEM. Observations have also shown that the occurrence of coatings is widespread and can be studied in detail. Such studies provide information about reactions in the atmosphere with regard to the scavenging of gases, absorption of pollutants, and volcanic emissions. The two most important particles in terms of haze were identified as being soot and sulphate. Soot particles are frequently found to be attached to the sulphate.

It was noted that in the application of AEM a small number of samples are to be looked at. Samples characteristic of certain features (e.g. pollution plumes) need therefore to be obtained for analysis. Samples are collected for analysis in the lab. No real time measurements are done.

Dr Buseck indicated that they were looking for a student to do work on the project, assuming they get funding.

2.3.3 SAWB AEROCOMMANDER ACTIVITIES

Two Aerocommander 690 A's (JRA and JRB) will take part in the campaign: (i) JRB is to be funded by NASA - UVA and will be under the coordination of Bruce Doddridge, and (ii) JRA is funded by the SAWB and its operations during SAFARI 2000 will be coordinated by Stuart Piketh.

2.3.2.1 Aerocommander Activities (ARREX)

Stuart Piketh, University of the Witwatersrand

The key issues to be addressed by the Aerocommander activities include the following:

- Transport in the anticyclonic gyre
- Regional characteristics of the aerosol
- Transport out of the Highveld industrialised region of South Africa
- Characterise emissions from industrial, biomass burning, marine and dust aerosols
- Determine CCN characteristics over the subcontinent
- Characterise the variability in the boundary layer

The investigation of the mass flux of aerosols over the subcontinent represents the main focus. For example, 48 to 58 tonnes of material has been estimated to be transported to the Indian Ocean (estimates vary with *in situ* measurements). The actual value needs to be determined with more certainty.

Instrumentation aboard the planes to facilitate aerosol measurement and characterisation will include PCASP, FSSP, 2DC, airborne streaker, CN TSI. Trace gases to be measured include O3, SO2, CO, NO and NO2 and VOCs. The airborne streaker is designed to look at individual aerosols.

ARREX Activities during SAFARI 2000

The two Aerocommander 690 A's (JRA and JRB) will be based at Pietersburg. The SAWB have hanger facilities in Pietersburg. JRA will be operated by the WITS/SAWB operated and JRB operated by UVA/UMD. These aircraft will operate out of Pietersburg between 12 August and 12 September. JRA will thereafter be transferred north to Kasane or Livington for 2 weeks to fly experiments for Darold Ward and his colleagues. Mark Jury also indicated an interest in operations within the Zambian Box.

Flight paths during ARREX campaigns are illustrated in Figure 20. The circle indicated in the figure represents the area that can be covered in 1 day, the range of the aircraft being 6 hours. This flight path can:

- touch on biomass burning emissions which generally occur north of 28°S;
- characterise CCN on flights to the coast;
- characterise biomass burning over Mozambique;
- investigate industrial aerosols as move of the lowveld and through southern paths; and
- flights over Botswana could be used to characterise aeolian dust.

Careful note must be made of the ground based activities to facilitate as much collaboration and calibration/validation opportunities as possible. Such ground-based activities are indicated in Figure 21.

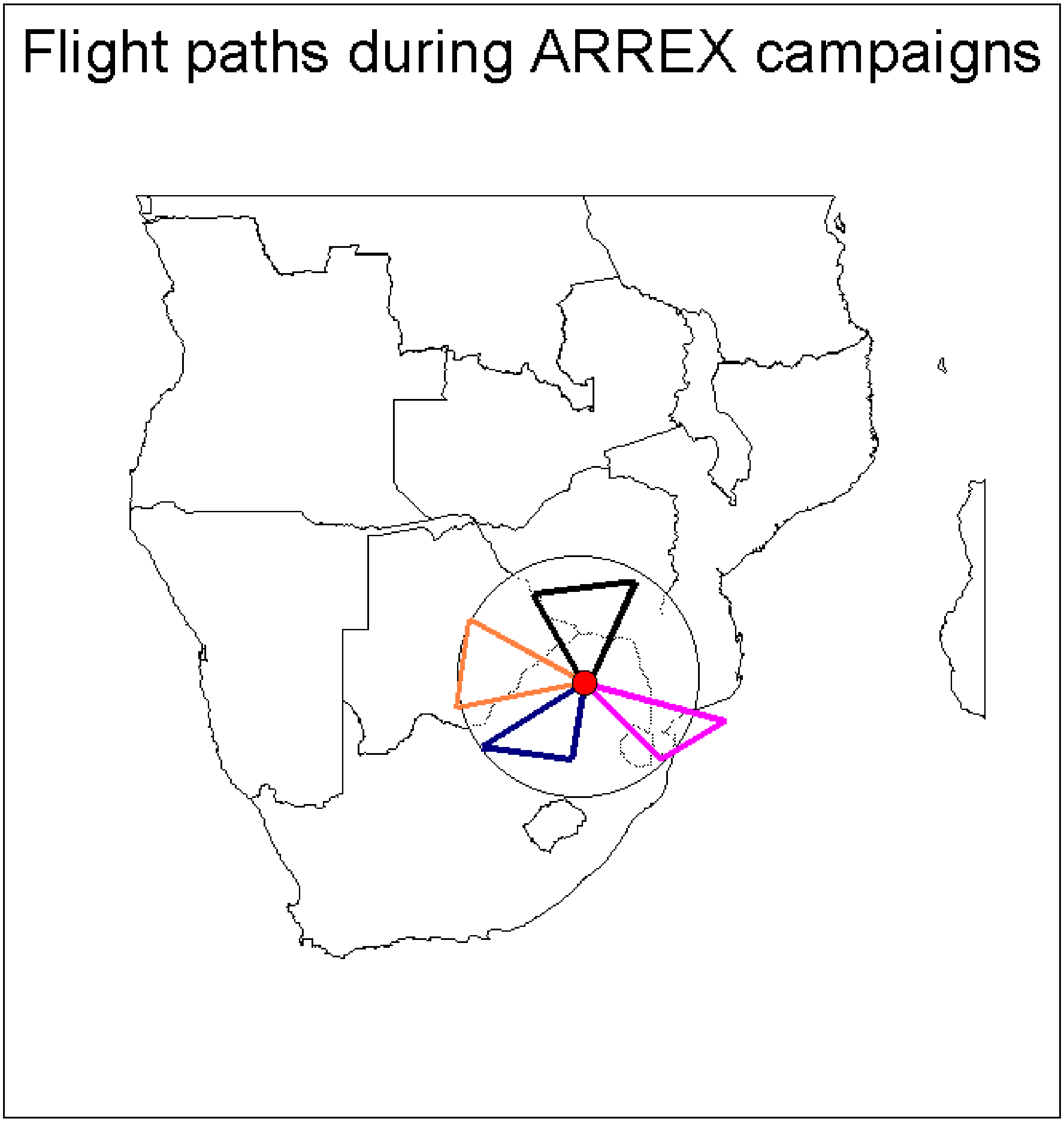

Figure 20. Typical flight paths during ARREX campaigns.

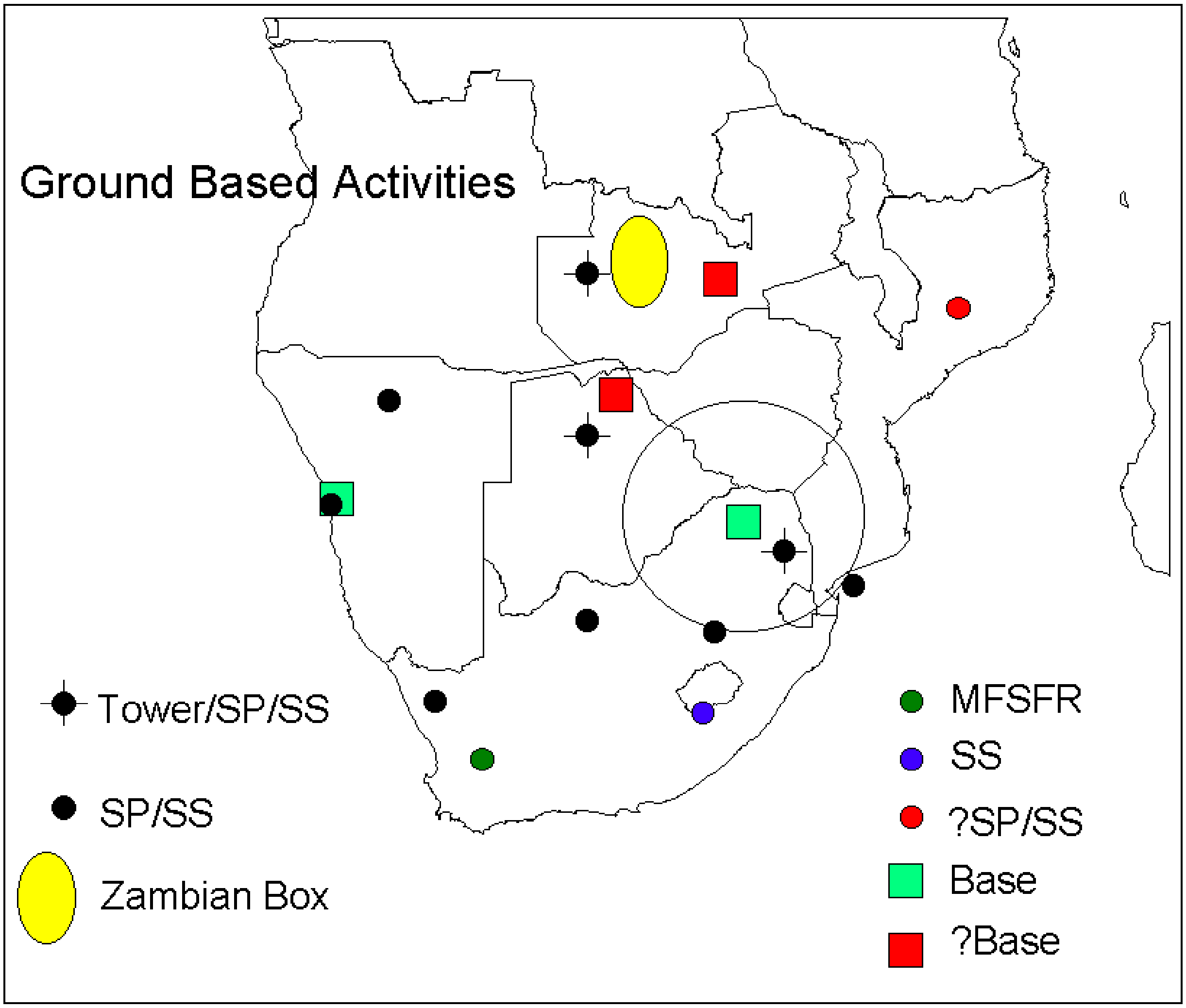

Figure 21. Location of ground-based activities during the Safari 2000 campaign

Potential instrumentation to be included on the Aerocommanders were listed as follows:

- Wyoming CCN counter
- TSI CN counter
- SPP-100 probe
- PCASP and FSSP and 2DC probes

There was also the possibility that a third Aerocommander 500 would be available by way of collaboration between the University of Potchefstroom, Eskom and Wits University. This aircraft would comprise a bubbler system for chemistry and filter samples. There would be place for other instruments aboard this plane.

It is important to gather information on the space required by each of the instruments and of their weights. A matrix will be placed on the web and key principal investigators required to provide information regarding the size and weights of their instruments.

A tethersonde has been made available by Eskom, should anyone have any ideas on where best to use it they should contact Stuart Piketh.

2.3.2.2 JRB Activities
Bruce Doddridge, University of Maryland

Co-investigators for the project include Harold Annegarn, Bob Swap, Deon Terblanche, Stuart Piketh, Dr Dickerson and Anne Thompson. Funding for the SAWB Aerocommander 690 A ZS-JRB from the US NSF is currently pending. The goal of the JRB's activities is to investigate, characterise, quantify, and interpret trace gas and aerosol sources and sinks over southern Africa, in terms of meteorology, atmospheric dynamics, transport and photochemistry.

JRB will only operate during the first month of the August - September 2000 Intensive Flight Campaign, being based at Pietersburg from August 13 to September 13. JRB's measurement suite during the SAFARI 2000 campaign is outlined in Table 11.

Table 11. JRB's Supplemental measurement suite

Parameter	Temporal Resolution	Detection Limit	Instrument
O_3	4 s	1 ppbv	TEI 49 C
NO	10 s	50 pptv	Custom TEI 42 C
CO	1 min	20 ppbv	Modified TEI 48
SO_2	1 min	30 pptv	Modified TEI 43C
CO2/H_20	1-10 s	0.2 ppmv	LI-COR LI-6262
Aerosol absorption	1 min	0.9 Mm-1	Modified Rad. Res PSAP
Aerosol size	5-7 min	-	Modified TSI 3934L
Aerosol scatter	1 min	0.1-0.4 Mm-1	TSI 3563

The measurement of H2O is very important for the Weather Bureau and for ecologists. Most of the equipment which will be aboard the aircraft has been specially modified or customized. The George Washington University is currently in the process of developing a small NO monitoring instrument, which may be included in the JRB's monitoring suite.

Support Needs

Support needs for the campaign were described as being minor, with arrangements being made with the SAWB and Wits University for what was needed.

Bruce Doddridge is, however, currently looking for a post doc student to work on the project.

Data Management

Data can be generated overnight and would include ASCII data and MS Excel spread sheets with embedded plots. These data will be made available to all Safari 2000 principal investigators.

Key Elements:

- Aircraft coordination is deemed critical for the success of the campaign, with "team players" being required.
- Vertical profiles to be collected aimed at: (i) covering air parcels of diverse character, (ii) evaluating surface products (lidars at Mongu and Skukuza) and satellite products (Terra, TOMS, GOME), and (iii) ozone sonde intercomparison (Irene, Mongu sites).
- Constant altitude transects.
- Tower fly-bys are necessary for: (i) intercomparison of measured scalars, and (ii) placing surface data in a regional context.

Hal Maring is to add his instruments to JRB. Many of these instruments are the same as those of Bruce Doddridge, but included in an ultrafine condensation particle counter for aerosol concentration measurement.

2.3.3.2 Vertical Profiles of CO, CH_4 and other Trace Gases as part of the MOPITT Validation Programme (measurements to be taken from JRB aircraft)
Paul Novelli, NOAA/CMDL

Other member of the team include Brad Gore, Doug Guenther, Patricia Lang and Ken Masarie (NOAA.CMDL). The home page of the Carbon Cycle Group is http://www.cndl.noaa.gov/ccg. The following three studies are being undertaken by NOAA/CNDL is support of the validation of MOPITT, viz.:

(1) Long-term monitoring of CO and CH_4 in the low and mid troposphere at 5 sites: Poker Flats, Alaska (65.1 N, 147.5 W), Harvard Forest, MA (42.5 N, 71.2 W), Carr, Colorado (40.1 N, 104.4 W), Molokai, Hawaii (21.4 N, 157.2 W), and Raratonga, Cook Islands (21.2 S, 159.8 W). The Alaska site provides background levels and the Colorado, Hawaii and Cook Islands sites are ocean sites.

(2) Pre-MOVE ad MOVE experiments undertaken in March 1998 and May 2000 at the ARM Cart Site.

(3) SAFARI 2000 dry season (August 2000) and potentially wet season (March 2001) campaigns.

Long-term Monitoring Activities

At the long-term monitoring sites small aircraft (unpressurized turboprops) which can achieve heights of 7 to 9 km are used to sample on a monthly or biweekly basis. Grab samples of air are collected using a portable pump unit and suitcase container holding 20 2.5 litre glass flasks. After the flight, the flask package is returned to Boulder for analysis. CO, CO_2, CH_4, H_2, N_2O and SF_6 are measured. All measurements are internally consistent and calibrated against internationally recognized reference scales.

MOVE (MOPITT Validation Exercise) Activities

The goal of Pre-MOVE activities, undertaken at the ARM – Cart site during March 2-6 1998, was to compare CO correlative measurements obtained by various groups using different methods, including: Grab samples / GC analysis (NOAA/CMDL), MATR (NCAR), FTIR (University of Denver) and grating spectrometer (University of Toronto). Results from this experiment indicate generally good agreements between NOAA and the University of Denver. Problems were identified with MATR retrievals. These results are published in the Earth Observer (vol. 11, no.1, Jan-Feb 1999).

MOVE activities, undertaken at the ARM-Cart site during May 8 – 28 2000 aimed to compare CO correlative measurements obtained by various groups using different methods, and to test correlative data processing and compare data to MOPITT retrievals.

SAFARI 2000 Activities

CMDL participating in the Safari 2000 dry season campaign will be in the order of 3 weeks. Grab samples will be taken during the SAFARI 2000 campaign in a similar manner to what is being done at the long-term sites. This is believed to be long overdue for Africa. With CO, CO_2, CH_4, H_2, N_2O and SF_6 being measured and samples being sent to Boulder for analysis. SF_6 is a good tracer of anthropogenic emissions. The grab sampling system to be placed aboard JRB is automated. Such a system has been working well in Colorado for several years.

Details on the grab sampling to be conducted were given as follows:

- 4 – 5 flask units, with sampling being undertaken the first and third weeks.
- Shipping of samples from Pietersburg to Boulder (~3 days by Fed Ex).
- 20 flasks per unit with samples taken at a height of 10 km and a resolution of 500 m.
- Sample off vertical spirals maintaining altitude every 500 m.

The pump unit dimensions are 16 x 50 x 60 cm, and it weighs 150 kg. The flask unit dimensions are 25 x 50 x 70 cm, with a weight of 120 kg.

In situ measurements will comprise:

- VURF instrument (vacuum UV resonance fluorescence) use.
- Continuous measurement with a 0.1 second response, and a 1-2 second signal average.
- The instrument will be deployed during selected flights during weeks 1 to 3.

The VURF instrument dimensions are 48 x 15 x 53 cm and it weighs 22 kg. Three compressed gas tanks weighing 150 kg will be used. (Connect to the intake line, mount on rack.)

2.3.2.4 Operation of JBA within the Zambia Box
Darold Ward, US Forest Service

During the Zambia International Biomass Burning Emission Experiment (ZIBBEE) a good relationship was developed between the Cimel AOD and the column integrated particulate samples. It is hoped to improve on this with the aerocommander flights to be undertaken as part of the Safari 2000 IFC. The point of the flights are to use the sun photometer measurements at the various sites (Mongu, and probably Kaloma, Lusaka, etc.) and to interpolate between those points in order to produce isoline plots which are representative of the spatial distribution of AOD over the western part of Zambia. This exercise is useful since it allows ratios to be calculated with *in situ* measurements.

2.3.2.5 Recommended Additional Objectives for the Zambia Box
Mark Jury, University of Zululand

It was recommended that account be taken of the local meteorology in establishing the flight paths of the aircraft. It was indicated that some flights to the NW of Angola would be useful to track the airflow leaving the Zambia Box.

Flights within the band 18° to 12°S was suggested, with a north-south flight path being followed. The target of such flights was to observe the easterly flow and try to pick up jets overlooked previously. Strong moisture gradients also exist in this region, and it is hoped that these gradients may be characterised. North-south flight paths should follow Darold Ward's fires within the Zambia Box. This would take approximately 4 hrs of flying time. It is envisaged that 12 flights at 4 hrs flying time would be required. Flights are needed at 5h00 to 9h00 am and some in the afternoon (13h00 to 17h00) in order to characterise diurnal trends. An example of the possible sawtooth flying pattern presented by Mark Jury is indicated in Figure 22.

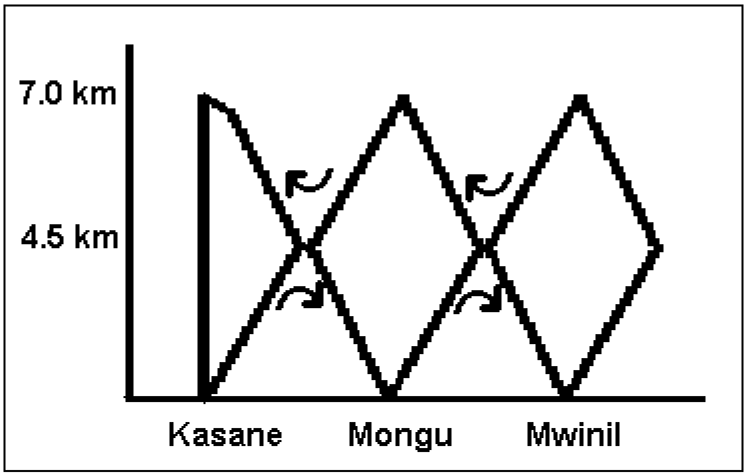

Figure 22. Flight path and pattern proposed for the Zambia Box

(A work plan drafted by Mark Jury subsequent to his presentation is provided in Appendix B. The plan provides more information on the desired location and pattern of flights.)

Comments

Sulphur dioxide should be added as a parameter to be measured over Zambia if it has not been added already. The copper belt to the east of the site is an important source of sulphur dioxide emissions. The transportation of these emissions will be towards Namibia. The flights could therefore serve to confirm the suspected sulphur dioxide transport (Harold Annegarn, Wits University).

2.3.3 UK MET OFFICE C-130 - MEASUREMENTS FOR SAFARI 2000
Dr Peter Francis, UK Meteorological Office

Scientific Objectives

The scientific objectives of the UK Met Office C-130 campaign for SAFARI 2000 were outlined as including (i) investigation of optical properties and direct radiative effects of biomass-burning (and other) aerosols, and (ii) *in situ* measurements of aerosol composition, gas phase chemical composition, and their interaction.

Planned Timetable (as at March 28 2000):

- JET 2000 - August 25 to August 31, based between Sal, Cape Verde Islands and Niamey, Niger.
- SAFARI 2000 - September 3 to September 18, based in Windhoek, Namibia.

- SHADE - September 21 to September 30, based at Sal, Cape Verde Islands.

Instrumentation to be Aboard the C-130:

- Broad-band radiometers (SW and LW)
- Infrared (3-16 µ) interferometer
- Filter radiometer (0.55 µm - 2.26 µm)
- SW spectrometer (0.4 µm - 1.7 µm)
- PMS probes (PCASP, FSSP, 2D-C)
- Counterflow Virtual Impactor (CVI)
- Nephelometer (450, 550 & 700 nm)
- Particle Soot Absorption Photometer (565 nm)
- Filter sampling (MPIC Mainz):
  - Water-soluble ions and total elemental mass (ion chromatography and PIXE analysis)
  - Speciation of carbon components (thermal analysis)
- CCN spectra
- Atmospheric Pressure Chemical Ionization Mass Spectrometer (APCIMS, MPIC Mainz):
  - Sulphur dioxide
  - Oxygenated hydrocarbons, including acetone, acetonitrile, methanol and organic acids
- Water vapour
- Ozone
- Carbon monoxide
- Sulphur dioxide
- NO_x (NO and NO_2)
- Non-methane hydrocarbons (University of Leeds)

Flight Plans

Flight plans were fairly flexible at the time of the workshop. It was envisaged that there would be an even balance between radiation legs (above and below aerosol layers) and *in situ* legs within the aerosol layers. Flying was being planned over the sea off the Namibian coast, and over the land over Namibia and Botswana. Other potential flight paths included:

- Flights over SAFARI ground-based sites.
- *In situ* validation flights for satellite measurements.
- Coordinated flights with other aircraft.

Informational Requirements:

- Information on logistical support for SAFARI 2000, e.g. meteorology, trajectories, burning patterns, evolving flight plans, campaign dates, etc.

- Information on ground-based sites, e.g. proposed instrumentation, possibility of over-flying.

- Information on satellite overpasses.

Data Availability

Data processed after the flight can be made available relatively quickly, e.g. cloud physics and aerosol data, radiation measurement calculations. Some data measurements are taken by outside researchers and the availability of their data will be up to them. It is intended that the data be place on a local ftp site so as to be available to all Safari participants. It could also potentially be place on the Langley DAAC as was done for a previous project.

2.4 BIOMASS BURNING PATTERNS

2.3.1 AVHRR Fire Record
Dr Bob Swap, UVA

A series of satellite images were shown to illustrate the progress of fires occurring over the period May 1 to October 2. Fire counts were indicated, with the whiter the colour on the image the higher the fire count. It was stated that Jim Tucker could get the data to the SAWB so as to obtain a forecast for smoke transport. The giff files comprising the fire count plots would be sent across the web for flight planning purposes.

Discussion

Q It was asked whether the plots reflected morning or afternoon fire counts.
A Most probably afternoon fire counts.

Concerns were raised, on the basis of the fire count presentation, of whether Pietersburg was still too far south a site considering the locations of most of the fires. It was indicated that Pietersburg had been chosen for logistic purposes and that the site did facilitated the investigation of biomass burning in, for example, Mozambique in addition to facilitating the investigation of other issues (e.g. industrial and aeolian dust sources).

SESSION 3: METEOROLOGY
CHAIR: Eugene Poolman, SAWB

3.1 FORECASTING PLANS AND SAMPLE PRODUCTS
Michael de Villiers, SAWB

The SAWB will have a full time forecaster in Pietersburg during the intensive flight campaign. Local and international weather charts will be made available during the campaign. International charts comprising temperature and wind field predictions for 18 to 24 hours in advance will be made available every 6 hours. Domestic sigmets charts are produced every 3 hours and issued 4 hours in advance. All forecasts required for landing purposes will be made available. It was indicated that the UK Met Office should ask Windhoek for weather data. All aviation data and forecast data will be archived and kept available for use later on. More detailed information regarding the aviation and general products available from the SAWB is given in Table 12.

Table 12. General and aviation products available from the SAWB

Aviation Products	**Significant weather charts:** *International* - 6 hourly synoptic times. Issued by WAFC Bracknell. *Domestic / Regional* - 3 hourly synoptic and intermediate synoptic times. Issued by WAFC Bracknell. **Upper winds and temperatures:** *International* - 2 daily based on 0000 and 1200 UTC UKMO model for 24 and 36 hours ahead. Issued by WAFC Bracknell for Flight Levels 100, 180, 240, 300, 350, 390, 450, 530. *Domestic / Regional* - 2 daily. Based on 0000 and 12000 UTC UKMO model up to 36 hours ahead. Issued by SAWB Pretoria for Flight Levels 10, 30, 50, 70, 100, 130, 150, 170, 210, 240, 270, 300, 350, 400, 450.