Jet Propulsion Laboratory
California Institute of Technology

MISR Multi-angle Imaging Spectro-Radiometer

SCIENCE DESIGN FILE MEMORANDUM #180

DATE: August 12, 1998
FROM: Carol Bruegge
SUBJECT: Calibration/ validation progress report, 10Aug98.
FILENAME:

Outreach

Web page

• The MISR bibliography report has been updated to include recent publication to the IEEE/ TGARS and JGR special issue. The report can be found at:

http://www-misr.jpl.nasa.gov/mipub.html

• The Calibration/ Validation team home page (restricted to EOS community) has been updated to include:

- this report;
- MISR product accuracy document (requested by Yoram Kaufman);
- SPIE98 vugraphs: AirMISR calibration result.

Peer-reviewed publications

• 1998 Cal/ Val publications are as follows:

Bruegge, C.J., V.G. Duval, N.L. Chrien, R.P. Korechoff, B.J. Gaitley, and E.B. Hochberg (1998). MISR prelaunch instrument calibration and characterization results. IEEE Trans. Geosci. Rem. Sens., Vol. 36, pp. 1186-1198.

D.J. Diner, L.M. Barge, C.J. Bruegge, T.G. Chrien, J.E. Conel, M.L. Eastwood, J.D. Garcia, M.A. Hernandez, C.G. Kurzweil, W.C. Ledeboer, N.D. Pignatano, C.M. Sarture, and B.G. Smith (1998). The Airborne Multi-angle SpectroRadiometer (AirMISR): instrument description and first results. IEEE Trans. Geosci. Rem. Sens., Vol. 36, pp. 1339-1349.

Conference and conference publications

• 1998 Cal/ Val conference talks are as follows:

Bruegge, C.J., J.C. Conel, B.J. Gaitley, N.L. Chrien, W.A. Abdou, S. Pilorz, W.C. Ledeboer, M.C. Helmlinger (1998). AirMISR calibration results. In SPIE 3439, Earth Observing Systems III, San Diego, 19-21 July.

Barnes, P.Y., E.A. Early, B. Johnson, J.J. Butler, C.J. Bruegge, S.F. Biggar, P.R. Spyak, and M. Pavlov (1998). Intercomparison of reflectance measurements. In SPIE 3425, Optical Diagnostic methods for inorganic transmissive materials, San Diego, 19-21 July.

AirMISR

Air-L1B1/ Air-L1B2 product contents

SDFM#178 "AirMISR Level 1B1/ 1B2 data products", 05Aug1998 has been submitted. This documents defines the contents of the Air-L1B1 and Air-1B2 products. These will be written in HDF format, in order to conform to requirements on DAAC data submission. The Air-L1B1 takes the AirMISR DN data and performs data interpolation where missing, corrupt, or saturated data are found. These DN values are then radiance scaled to Système International units. These data will be of interest where the loss of ER-2 navigation data, or other causes, prohibits the production of a registered data set. They will additionally be of interest where traceability to a specific acquisition time or detector element is desired.

The AirMISR Level 1B2 product uses AirMISR Level 1B1 as input. It takes these radiances in line (time sequential) by pixel order as clocked from a given ccd array. These radiances are resampled, or geo-rectified, to a Universal Transverse Mercator (UTM) map projected grid. Thus the radiances as measured in time order are used to create radiances registered to a map grid. It is believed that there will be a greater demand for the Level 1B2 product because of this co-registration and geolocation for the 9 view angles.

The definition of the AirMISR Ancillary Radiometric Product (ARP) is also made in SDFM#178. This product, like the two defined above, has many parallels to its MISR counterpart. The AirMISR ARP supplies the radiometric gain coefficients, signal-to-noise values, and the spectral response function for the AirMISR camera.

Imaging processing

Image JPL(3/20/98) has been processed through Air-L1B2. Images Moffett field (8/25/97) and FIRE III (6/3/97) Runs 2 and 3 are undergoing Air-L1B1 processing. These scenes will be distributed to MISR co-investigators as they are created. After verification is complete, they will be made available to other investigators.

Level 2 .Data products

Matthieu Verstraete arrived July 20th, to begin his 10 week stay at JPL. He will be supporting AirMISR Level 2 product generation. He has currently written an Air-L1B2 access routine. This code will be used by the prototype Level 2 aerosol retrieval code. Matthieu will be a senior next fall, attending the Swiss Federal Institute of Technology, working towards a degree in Physical Engineering.

Science performance assessment

Several AirMISR performance issues were investigated this month. The key ones are described below. It is noted that the AirMISR focal plane is that selected for Engineering Model build for MISR. The signal-to-noise (SNR), stability, and out-of-band response for the camera as a whole is very good. However, the camera has a few pixels (of the 6000 detector elements) which are of poorer quality than typical for these cameras. These pixels are explored in-depth during this study.

- <u>Residual image striping</u> following radiance scaling of the data. In displaying AirMISR radiance-scaled imagery, it has been noted that there is an occasional occurrence of a vertical stripe in the image. This was investigated and found to occur in regions where a ccd pixel element was lower in response than typical for the array. The number of pixels in the AirMISR camera for which the response is 10% or lower than expected is documented in SDFM#80. These pixels are listed here:

Pixel of response loss > 10%. Cells with "-" have <6% response loss.

Pixel	Band	Band 2	Band 3	Band 4
1-8	28±7	18±7	15±5	11±5
9-13	14±3	8±2	7±2	-
62	-	-	-	11
267	-	-	-	11.8
705	-	-	11	14.6
706	-	-	12.2	-
707	-	-	11.9	-
1403	11.3	12	-	-
1404	33.6	12.7	-	-
1405	53.4	-	-	-
1406	62.2	17.8	-	-
1407	57.4	33.4	-	-
1408	50.8	48.1	-	-
1409	47.9	54.4	-	-
1410	45.2	54.5	-	-
1411	41.5	55.7	-	-
1412	30.0	53.5	-	-
1413	16.6	40.5	-	-
1414	-	23.1	-	-
1504	14.3	14.8	12.8	12.9

- Radiometric accuracy in the region of the blue/ green channel degraded pixels. The pixels surrounding Pixel 1411 in the Blue Green channels are occasionally noted to have a residual strip in the radiance-scaled image. We believe this to be due to increased noise in these pixels. The radiance uncertainty for Pixel 1411 has been characterized for both flight and laboratory environments, and as a function of illumination level. Details will be provided in a SDFM and publication (scheduled for 30Sep). The figures generated for this report show that at an illumination level of 0.1 in equivalent reflectance the NEΔρ translates into the following % radiometric error for the worst of the degraded pixels:

Radiometric error for pixel 1411

Band	Radiometric error, %	
	Flight	Laboratory
1/ Blue	0.4	0.38
2/ Green	0.475	0.45
3/ Red	0.3	0.3
4/ NIR	0.3	0.3

It is noted that the radiometric error for the typical pixel in each of the four arrays is around 0.3% at this illumination level. Thus, the Blue and Green bands for this pixels have higher noise than for other pixels in the array. As the performance specification is 6.0% at an illumination of 0.5 in equivalent reflectance, no pixels are known to violate a performance specification, even the pixels in the vicinity of pixel 1411.

The NEΔρ values used to generate the above Table are estimated based on the assumption that we are dominated by photon noise. This approximation was made due to the difficulty in finding a uniform target over which to take a mean and standard deviation. The equation used was:

NEΔρ= ρ/ sqrt([DN-DNo]*electronic_gain

where, electronic_gain = 75. electrons/DN from the light transfer test for AirMISR. Although these approach is not as definitive as using an analysis over a uniform target, it does demonstrate the relative differences in the degraded pixels, as compared to the typical pixel noise. In looking at the flight data over quasi-uniform targets, we have observed the noise in the Degraded Pixel Green band is twice that of other Green-band pixels, or those of the corresponding pixels in the other bands. There was no evidence of the Degraded Blue-band pixels having an increased noise over that observed in the laboratory.

- The characterization of <u>blue channel noise</u>. Imagery has shown there to be noise spikes for a dark scene, blue band. It is shown in an analysis that the spikes are a random noise of value 32 DN. When the downtrack column average is taken, the noise disappears, suggesting it is random temporally as well as spatially.

The occurrence of a +8 DN noise spike on a +10 DN signal (offset subtracted) in the Green channel was also noted. This noise is only observed when there is no illumination on a pixel - it does not exist for even a 40 DN signal. This green channel noise does not disappear with averaging, and is therefore not random.

These two features are too insignificant to cause a radiometric error in the imagery, at any illumination level which would be encountered in flight.

Engineering

A review of the AirMISR instrument was held on July 15, 1998. The purpose of the review was the presentation of the instrument's current status, the identification of instrument performance deficiencies, and the recommendation of approaches leading to corrective actions for these deficiencies. Of primary concern is the frequency of missing navigation or camera line data, and the lack of consistent deployment to all nine view angles. Budget and staffing issues will need to be worked out before rework begins. AirMISR flights have been cancelled for the remainder of this year, in order to allow for this rework.

Vicarious calibration

The vicarious calibration of AirMISR was accomplished using the Moffett field (11/5/97) engineering flight. As it was only an engineering flight, the calibration was performed mainly to get a first look at the flight and laboratory radiometric response of the instrument. The target used for this experiment was between the ER-2 hangers. Although there was a lack of coincident surface measurements and a homogeneous target, the agreement between the laboratory and flight calibrations of AirMISR were quite good (~5%). Optical depth measurements were acquired simultaneous with the flight, surface characterization occurred 2 days afterwards. A publication is in progress.

Other field campaigns

The optical depth and ASD surface analyses have been completed for Mono Lake (SDFM#176), and Rogers Dry Lake (SDFM#169). The first report will be of interest to our colleague Ann Nolin, who conducted snow and ice studies at this time. The second report will help develop an expected conditions data base for this calibration site.

Calibration facility

The integrating sphere and monochromator have been moved out of the Observational Instruments Laboratory (OIL) Building High Bay, and now finds a new home in the LowBay of this same building. As other flight instrument now occupy the HighBay, the move became necessary. The sphere and monochromator have been operated to confirm operability.

Overview of the Field Data Reduction Process (by Stu Pilorz)

An important aspect of the MISR validation effort is to retrieve a model for the atmosphere and surface which, when run with a benchmarked and validated radiative transfer code, produces radiances consistent with observations taken at the ground and/or at altitude. This is done via pathways independent of those used for production of the MISR standard data product.

The primary physical parameters adjusted in the model are the surface albedo and BRDF, and the size distribution and complex index of refraction of tropospheric aerosols. The aerosol particles are assumed spherical at present. Ozone concentration is accounted for, and the algorithms may also later be refined to account for water vapor, as well as stratospheric aerosol and cirrus.

The measurements which are currently used to constrain the model are the directional radiance at the ground (measured with PARABOLA and/or CIMEL), optical depth of the atmosphere (primarily derived from Reagan Solar Radiometer measurements), the ratio of diffuse to direct skylight (primarily from MFRSR), and an estimate of the albedo and/or BRDF (derived from ASD and/or PARABOLA measurements). Directional radiance at altitude may also be used, as taken with AirMISR or with any instrument at altitude which sees a significant angular variation across its swath.

The currently implemented retrieval algorithm separates the recoveries of the surface and atmosphere models. The surface albedo and BRDF are recovered by independent pathways. The aerosol distribution relies primarily upon angular radiance data, but estimates of aerosol optical depth and the ratio of diffuse to direct skylight are supplied by modular routines which are called if such data are available. The iterative procedures insert the surface and aerosol components into a radiative transfer calculation, and adjust the aersosol model based upon the comparison of the predicted radiances with observations.

The surface BRDF is recovered iteratively from measurements of the upwelling and downwelling radiance, which allow accurate estimation of the HDRF, as described in Martonchick (1994). The implemented iteration procedure is currently undergoing sensitivity studies with simulated data sets to assess the dependence of its retrievals at various angles on the number and quality of measurements, and the anisotropy of the simulated BRDF. The alternate pathway for atmospheric model retrievals uses the surface albedo (DHR), which is estimated in the usual way from measurements of the BHR and a standard reflecting target over surfaces which are expected to be nearly Lambertian. The team is also investigating the effect of using the albedo instead of BRDF on the aerosol recovery.

The aerosol size distribution and complex index of refraction are recovered using algorithms which are similar to, but differ in several respects from, the analyses of Nakajima et al. and King and Herman. These physical properties are actually inferred via the optical properties of the air column (scattering phase function, single scattering albedo, and optical depth) which are determined by them. Closure has been obtained, in which the physical properties are successfully recovered with the algorithms using simulated CIMEL, AirMISR, and AVIRIS datasets. Sensitivity studies of the algorithms are being conducted concurrently with refinement of the iterative procedure, and are divided into studying (i) the relationship between the optical properties of the atmospheric column and the radiance distribution (along with quantities related to it), and (ii) the relationship between the optical properties and the physical parameters in the model. The detection of nonspherical particles is the subject of scheduled sensitivity studies.

The radiative transfer code used in the validation algorithms combines a discrete ordinate representation for the atmospheric transmission and reflectance functions, which are assembled via doubling and adding, with the direct integration of single scattered radiance at camera angles and within the solar aureole. Radiances are returned at altitudes within the atmosphere, at TOA, and at the ground. Implicit assumptions in the radiative transfer model include the scale heights for Rayleigh and aerosol scattering. Sensitivity to these assumptions will be investigated systematically.

AirMISR Participation in FIRE ACE (by Roger Marchand)

FIRE, the First ISCCP (International Satellite Cloud Climatology Project) Regional Experiment, is currently conducting an Arctic Cloud Experiment (ACE) to study a variety of arctic cloud systems under spring and summer conditions. The objective of this extensive field campaign is to study how the radiative feedback processes occurring between the clouds and the sea ice surface influence the Arctic energy balance, as well as to provide in situ data for testing satellite, aircraft and surface-based remote sensing techniques.

From mid May through early June of this year, the NASA ER-2 participated in an intensive operations period in coordination with the University of Washington Convair 580, the National Center for Atmospheric Research C-130, and the Canada National Research Council Convair 580. The aircraft observations were made over surface sites provided by SHEBA (Surface Heat Budget of the Arctic Ocean) and ARM (Atmospheric Radiation Measurement) programs.

SHEBA, which is sponsored by the National Science Foundation (NSF) and the Office of Naval Research (ONR), is a research program designed to document and understand the physical processes that couple the atmosphere, ice, and ocean in the Arctic. It is currently conducting a year-long extensive set of measurements directly on, under, and above the sea ice in the Beaufort sea, using the Canadian Coast Guard ice breaker Des Groseilliers as a permanent ice station.

The ARM program is sponsored by the Department of Energy (DOE) to resolve scientific uncertainties about global climate change with a specific focus on improving the performance of general circulation models used for climate research and prediction. ARM is providing a number of key surface-based remote sensing instruments specifically designed for the measurements of clouds and radiation at the SHEBA ice station. ARM is also operating a duplicate set of instruments at Barrow, Alaska, as part of a decade-long program to measure the clouds and radiation in the Arctic Basin. (This and the several other ARM sites form the corner stone of the MISR's long term plan to validate its cloud products.)

Roger Marchand, a member of the MISR science community, was an active participant in the FIRE ACE campaign. He stationed himself along with the AirMISR instrument, at Fairbank Alaska, and directed operations of the instrument. In a real sense this was AirMISRs first major field deployment. During the course of this experiment AirMISR successfully acquired data over a variety of artic cloud conditions. Cloud types observed include both thin and thick, high and low, and multilayered clouds. Data were also acquired over land, ice, and on one occasion a large area of open water. In combination with data from other airborne instruments (i.e., MAS, SSFR, and CLS) and groud-based instruments (lidar, radar, and downwelling radiation), these data will provide a rich resource for the MISR science team members. In particular, these data should prove valuable in testing our albedo and cloud masking algorithms and, in a few instances, to test our stereo-matching algorithms for cloud top height retrieval. At this time two runs acquired on June 3rd have been targeted for intensive study. These images were acquired over the SHEBA ice station under relatively homogeneous arctic stratus cloud conditions.

More information on FIRE ACE and SHEBA can be obtained http://eosweb.larc.nasa.gov/ACEDOCS/, http://www.joss.ucar.edu/sheba/ and http://sheba.apl.washington.edu/.