

ATER/NASA COLLABORATION ON ATMOSPHERIC CORRECTION OF REMOTELY SENSED DATA

WORKSHOP REPORT

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Background and status of the Project (John Vande Castle)

The LTER/NASA atmospheric correction project is proceeding in its second year. The primary goal is develop an operational method to correct satellite data for artifacts introduced by the presence of aerosols and water vapor in the atmosphere. This is the second workshop for the project, held August 16-18 at the LTER Network Office at the University of Washington. The workshop included discussions of the status and future plans for the project by the LTER and NASA researchers at this meeting.

The goals outlined for the LTER/NASA atmospheric correction project have followed the objectives, which are defined within the original proposal to NASA, with modifications and augmentation from discussions during the initial workshop. The primary goals of this project are to develop an operational method to apply atmospheric corrections to remote sensing data and to make these methods and corrected data available to ecological researchers for verification purposes.

The report of the first workshop has been distributed, and is available online through the main LTER home page (<http://lternet.edu>), through links in online documentation describing LTER/NASA collaborations (<http://lternet.edu/nasa>) as well as the direct link to the ATMCOR project home page (<http://lternet.edu/nasa/atmcor>). In the first year of the project, computer resources were established including accounts for project scientists on the LTER servers, addition of disk storage for correction software and data storage, and system upgrades to speed processing of the corrected data. The atmospheric correction programs were ported to the LTER servers, and 18 full Landsat-TM scenes were placed on-line for use in the project.

The primary LTER server dedicated to this project is known as "time" (time.lternet.washington.edu). All on-line archive data for the project can be accessed in the directory called "/archive" which links to online LTER datasets. In addition direct links for the project of "/d12/atmcor" are used to more easily separate data used in the projects from other remote sensing data in the archive. A more complete description of the data and examples of running the atmospheric correction software are given at the end of this report.

Data, as well as the processing software "demonstrat" from the NASA sunphotometer network (AERONET) has been updated in the last year at NASA/Goddard (GSFC). This includes all the data from the LTER sunphotometer network used in this project, which is now part of the larger AERONET network. All of the new data has been mirrored on the LTER servers, as well as an updated version of the "demonstrat" software. This software is described in the ATMCOR meeting report of 1995. The software is now installed and running on servers at GSFC as well as at the LTER Network Office.

Atmospheric Correction Software (Hassan Ouaidrari)

The atmospheric correction software used in this project is based on part of the "6S" code. Documentation on the specific software correction process can be found on the ATMCOR web page (http://lternet.edu/nasa/atmcor/tm_atc.htm), and a paper of the "6S" user manual and code documentation also exists (Vermote, E. F., Tanre, D., Deuze J. L., Herman, M. and Morcrette, J. J. (1997), Second Simulation of the Satellite Signal in the Solar Spectrum: an overview, accepted to IEEE Trans. Geosci. Remote Sens.

Vermote, E. F., Tanre, D., Deuze, J. L., Herman, M. and Morcrette, J. J., 1996, Second Simulation of the Satellite Signal in the Solar Spectrum: user manual, Version 1.0 University of Maryland, Dept. of Geography / Laboratoire d'Optique Atmospherique.)

The atmospheric correction software relies on data inputs obtained in the header documentation file of Landsat-TM data, converting the TM digital number data to radiances. This is based on water vapor information from climatology or sunphotometers, aerosols, from dark targets in the TM data or sunphotometers, surface reflectances in the TM data, and ozone from climatology or TOMS data. The

latter has relatively small effects and generally low spatial variability.

The software correction can be applied with options of top of atmosphere (file extension .TAR), atmospheric corrections only (.ACP), or atmospheric and adjacency effects corrections (.ACT). The TM data are processed in grids of 16 cells to reduce processing time. Processing for .ACT data takes the longest, .TAR data takes the least. In addition, a "mask" data file is generated which contains an 8 bit quality control flag with the following information:

- atmospheric correction 1=applied, 0=not
- data integrity 0=good 1=bad
- surface land vs. water
- ozone
- aerosols 0=clear 1=average 2=turbid

Based on the current data, a regression of LTER site aerosol optical density (AOD) from the TM data vs. AOD derived from sunphotometer data shows a good correlation. The regressions are best for lower wavelength data (i.e. blue) since these data are most strongly affected by atmospheric effects. For TM band 1 (blue), the correlation is strong with $r^2 = 0.89$ and slope close to one. Points from SEV data do not fit as well due to a lack of good dark targets in the scene. At the VCR LTER (Hog Island) two scenes were evaluated to compare data from "hazy" and "clear" day. Changes in the surface reflectance information in the data of 12 and 28 July 1993 were assumed to change very little. In raw, uncorrected data, a comparison of the histograms from TM band 1 data were quite different, but more similar from in histograms from the corrected data. These result are, however preliminary and point to needs of future work including:

- finish all TM data processing
- modify correction software to include polarization
- modify correction software for choice of aerosol model
- validate atmospheric point spread function correction
- refine dark target selection
- include NOAA-AVHRR data in the test data set

Sun Photometer - (Brent Holben)

Sunphotometers are used in the ATMCOR work for validation of the atmospheric correction. The original sunphotometer network that incorporated the LTER sites has grown substantially. It is now known as AERONET (formerly SPAM) - AErosol RObotic NETwork. It is funded through the Earth Observing System (EOS) for aerosol validation and characterization for the EOS platform. The network has land sites in many continents as well as oceanic sites. These sites can be permanent, seasonal or for short time observations.

The data processing system for the sunphotometer network has been modified for

simplified access. The original "demonstrat" processing program still exists for access to raw data, but an automated Web-network access has also been installed at an address of <http://spamer/gsf/nasa/gov/>. The Web access represents a "second generation" of the demonstrat processing software, with a purpose of simplifying access to the sunphotometer data archive. In this version the data will be filtered through a number of automated processes, so the data can be more easily used by the remote sensing community.

MODLERS Project - (Robert Kennedy)

The "MODLERS" project grew out of specific plans for collaboration between the NASA MODIS land science team (MODLAND) and scientists associated with the LTER program. The MODLERS project was convened after a number of planning meetings including one held by Warren Cohen at the H.J. Andrews Experimental Forest LTER site to finalize plans for the project. The project, in its present form will, among other research, produce products of LAI, IGBP Landcover classes and Net Primary Productivity over a range of scales from 30m to a 10x10km area for 14 LTER sites.

NDVI - John Vande Castle

John Vande Castle presented information on initial evaluation applying atmospheric correction to Landsat TM data and its effect on full-scene NDVI. A comparison of the corrected (ATC) data compared to more conventional top of the atmosphere (TOA) corrections show that, for example data of the Madison (NTL-LTER) data, the ATC data produce NDVI results 25% greater than the TOA adjustments. For less forested/agricultural regions such as the Sevilleta and Jornada LTER sites, ATC data lower full scene NDVI estimates and increase the NDVI variance within the scene.

North Temperate Lakes/Madison LTER site (NTL) - Randy Wynne

Randy presented results from analysis of ATC data for estimating water quality data. Since the ATC processing often reduces the dynamic range of Landsat TM data at the lowest reflectance values, the standard processing of ATC data will need applications of scaling factors so the signal at low reflectances (i.e. clearer water) is not diminished.

Harvard Forest LTER (HFR) - Mary Martin

Mary presented data comparing work at HFR using the PnET Model using input parameters derived from AVIRIS data, with comparisons to species composition, foliar nitrogen, and foliar biomass data. There was a good correlation with ground nitrogen data, and also highly correlated with lignin content.

Bonanza Creek LTER - (BNZ) - Phyllis Adams & Dave Verbyla

David and Phyllis described the vegetation and land cover of the site and the continued operation of the sunphotometer station. They mentioned that compared to past years, the site required more maintenance and cloud cover was more of a problem. Coordination for future sunphotometer data acquisition as well as processing two 1994 Landsat TM datasets in the LTER Network Office archive were also discussed.

McMurdo LTER (MCM) - Gayle Dana

Gayle described the Antarctic LTER dry valley area as a "polar" desert with no visible land vegetation. The deployment of the MCM sunphotometer known as "Mr. Sunny" was again successful, with plans to continue data acquisition through at least 1998. Since the site is not in view of any geostationary satellites for data transmission, the instrument requires daily download of data, which is later sent to GSFC by computer ftp transmission. Primary plans for use of these data is for comparison and correction of AVHRR data.

Sevilleta LTER (SEV) - Greg Shore

Greg covered background on the use of Landsat TM data for vegetation mapping on the LTER site. The mapping project was started in 1992 with interagency partners to produce a multi-temporal analysis of vegetation change. Some problems in comparison of different scenes were noticed, which may be due to data calibration problems. Using atmospherically corrected data might solve this problem, but all data would need to be reprocessed.

Virginia Coast Reserve LTER (VCR) - John Porter

John described the dynamic character of the barrier islands, with dramatic changes from storm events. Landsat TM data has been useful for determining water depth and vegetation changes of the island. A sunphotometer has been installed for short term

use in the past and there are plans for future deployment because of its proximity to Wallops Island.

General use of Hyperspectral data for LTER sites- John Vande Castle

A short overview was presented to introduce the possibility of incorporating atmospheric correction techniques using hyperspectral data, to take advantage of AVIRIS data collected over a number of LTER sites. Collaborations developing between the LTER Network Office and facilities such as the San Diego Super Computer Center and the UNM-Maui High Performance Computing Center could be used in these efforts. Plans to acquire future hyperspectral data including that from the LEWIS HSI sensor could be a part of this effort.

Hyperspectral Tools - Sally Westmoreland

A demo package of hyperspectral tools developed by Photon Research Incorporated, showed potentials for initial use of atmospheric corrections to hyperspectral data. The routines are similar for both broad-band as well as hyperspectral data using radiative transfer code of MOZART with some elements for MODTRAN. The toolbox currently runs on the SGI computer platforms with potential plans to port the code to Sun workstations.

Earth Observing System (EOS) overview- Steve Running

Steve discussed validation-planning efforts for future EOS efforts. An important link for this can be found at the EOS project science web page at http://sps02.gsfc.nasa.gov/sps0_homepage.html. Included in this effort will be global validation efforts for the Global Climate Observing System (GCOS) and Global Terrestrial Observing System (GTOS). Linkages between GTOS and the LTER and International LTER ("http://lternet.edu) programs might be starting points for future collaborative EOS validation efforts.

Action Items:

Final discussion focused around what action items need to be worked on from here. These were developed as a list of action items for a continuation of the ATMCOR efforts:

- Acquire AVHRR data - McMurdo/TDV Dec 1995 data (coordinate with Gayle) use

this for AVHRR work - develop others in future project.

- Develop a separate ATMCOR Home Page to distinguish from the LTER/NASA AERONET Efforts and the LTER/NASA ATMCOR work.
- Incorporate links on the LTER/NASA home page to EOS Validation and Land Panel pages, also links to the POLDER satellite page and other related projects
- John and Eric will work on a JRS Paper as part of MODLERS Project
- Clean up links in MODLERS (J Porter will do) and ATMCOR pages (jvc will do).
- Work with Barb Nolen for working up scenes for JRN - perhaps coordination with SEV data.
- Get Reflectance data for JRN
- Eric will check for TARFOX TM scene for VCR (July 20^{th(?)} (Saturday) of 1996)
- Randy Wynne will provide modeled reflectance data for NTL/MAD
- HFR - Mary Martin will check on reflectance data available at Harvard Forest
- Brent will coordinate with HFR to install a sunphotometer for 1997
- Check into the calibration problem observed at SEV in the FAST Format transition period of 1991-1992 TM data - Greg Shore to coordinate with JVC and Eric.
- Add top of atmosphere corrected data - "TAR" data to archive for comparison with atmospheric corrected data (ATC)
- Make a flowchart showing data correction process - from satellite data onwards - describe the process and add to homepage
- Transfer ancillary database to the LTER/NASA project server (DAO (data assimilation and TOMS data)
- Data access and documentation will be put on the ATMCOR home page
- Work with AERONET to use consistent acronyms for data types
- Hassan will see if EDC can provide the original EOSAT header file for it newer data since the header file is not in standard FAST format.
- Hassan will provide the key information needed in FAST Format Header files - so header files can be created for data set if needed (i.e. SEV Georegistered data)
- Randy and David will coordinate with JVC to work up a solution for atmospheric correction problem over water - perhaps add threshold for band4 > band3
- The group should consider NCEAS project funding - ecological applications
- Update remote sensing activities report for CC meeting presentation - document what has been done by the LTER remote sensing group (including links to NASA researchers). Also, improve link to the LTER data management group.
- Coordinate presentations of ATMCOR data use/results - fill in gap due to lack of LTER ALLSCI meeting - perhaps future NASA meeting
- Links of results to ATMCOR home page.
- Register ATMCOR page with indexing services.
- Put ATMCOR information in LTER Network news.
- Check format and process the HFR 1993 which has concurrent sunphotometer data in the LTER archive, adding to the project

Example of atmospheric correction:

The atmospheric correction of Landsat data is accomplished in a number of steps, with options for different levels of correction. Listed below is an example run for a

Landsat-TM scene.

Step 1 - Generate a parameter file using the Landsat TM header. This is done by running the program "mkparmsfile". The first step in the atmospheric correction process is to generate a parameter file as input to the atmospheric correction program. This parameter file is constructed from information in the Landsat-TM Fast Format header file, or a header file created from scratch with pertinent information included. The command line to create the parameter file includes the program name, the input header file name, the output parameter file name, the location and root name of the input data files, and the path to the ancillary data used in the corrections. The input data for correction should be in standard "FAST FORMAT" with a common base name and extensions of "b1, b2, b3, etc. for the individual TM bands. On the LTER server machines, the following command is used to generate the parameter file:

```
"/homes/hassan/LTER/bin/mkparamsfile 940723.hdr 940723.prm /d12/atmcor/raw/bnz/tm/940723 /homes/hassan/LTER/ancillary"
```

Note that "/homes/hassan" may be something like "/home/nasa/hassan". The parameter file that is generated is a simple text file that can be viewed and edited. For example, to control the location of the output files, a line can be added to the parameter file to do this:

```
DATA PATH OUT = /My-Directory
```

An example listing of a parameter file looks like this:

```
# this params file was generated by mkparamsfile on 10/16/1996
```

```
# using TM header : 940724.hdr
```

```
#
```

```
DATA PATH = /d12/atmcor/raw/and/tm/940724
```

```
ANCILLARY DATA PATH = /homes/hassan/LTER/ancillary
```

```
DATE = 940724
```

```
NUMBER OF LINES = 8510
```

```
NUMBER OF PIXELS = 8975
```

```
PIXEL SIZE = 30.000000
```

```
CAL1 = 0.916214,-2.272727
```

```
CAL2 = 1.438396,-3.414634
```

```
CAL3 = 1.207517,-1.791045
```

```
CAL4 = 0.638823,-1.171875
```

```
CAL5 = 0.049999,-0.170507
```

CAL6 = 0.005656,0.123800
CAL7 = 0.022699,-0.059524
UOZ = -1.000000
UWV = -1.000000
ECMWFSP = -1.000000
ECMWFST = -1.000000
CENTER = 4255,4488,44.617404,-121.410333,34.701828,125.987320,0.389232,130.499542
GP1 = 1063,1121,45.342638,-122.464195,35.749310,125.419945,9.296780,101.860191
GP2 = 1063,3364,45.337039,-121.748598,35.345119,126.317726,4.423517,103.691658
GP3 = 1063,5607,45.326960,-121.033296,34.939770,127.234604,0.535031,261.136658
GP4 = 1063,7850,45.312406,-120.318455,34.536560,128.161392,5.416768,280.274323
GP5 = 3190,1121,44.864006,-122.468653,35.461040,124.899261,8.226439,102.083633
GP6 = 3190,3364,44.858499,-121.759009,35.051151,125.797211,3.346770,104.497940
GP7 = 3190,5607,44.848585,-121.049649,34.643269,126.705109,1.593697,274.979095
GP8 = 3190,7850,44.834271,-120.340738,34.237514,127.623001,6.488310,280.606049
GP9 = 5317,1121,44.385333,-122.473001,35.172771,124.378578,7.156098,102.307076
GP10 = 5317,3364,44.379917,-121.769162,34.760368,125.267319,2.264368,106.063942
GP11 = 5317,5607,44.370166,-121.065600,34.349953,126.166084,2.674932,277.740143
GP12 = 5317,7850,44.356087,-120.362472,33.941647,127.074974,7.560765,280.845673
GP13 = 7444,1121,43.906619,-122.477243,34.887829,123.848381,6.076991,102.601379
GP14 = 7444,3364,43.901292,-121.779067,34.472885,124.727829,1.180555,110.493080
GP15 = 7444,5607,43.891702,-121.081159,34.059929,125.617348,3.761808,278.919189
GP16 = 7444,7850,43.877855,-120.383673,33.645779,126.526947,8.633221,281.085297

Step two:

Once the parameter file is generated, the atmospheric correction program is run. It has options to generate data corrected to the top of the atmosphere, (the output files will have a ".TAR" extension), partial correction, i.e. corrected without adjacency correction (output with ".ACP" extension) or complete correction (".ACT" extension). Processing times vary from an hour to several hours on the current LTER servers (SUN SPARC). The "ACT corrections are the slowest.

The correction program uses the base file name of the input data, the input parameter file name, the correction level (-noatmos for ".TAR", -noadja for ".ACP" and -standard for ".ACT". Again input data for correction should be in standard "FAST FORMAT" with a common base name and extensions of "b1, b2, b3, etc. for the individual TM bands. The output data will consist of the log file that contains calibration coefficients to convert the digital number to reflectance and other information used in processing, the corrected data, a cloud and a quality control mask data file. The thermal channel is not corrected, but coefficients are given in the log file to convert the data to uncorrected degree Kelvin. An example for producing both top of atmosphere and complete correction are:

```
"/homes/hassan/LTER/bin/process_TM-V1 940723 940723.prm -standard 940723.log"
```

```
"/homes/hassan/LTER/bin/process_TM-V1 940723 940723.prm -noatmos  
40723.TAR_log"
```

The correction program reads data in blocks to speed processing. The program does not always write out an incomplete block which might remove 1 or more lines of data. If this is a problem, the incomplete data can be blank filled using a program on the server called "fixsize".

Landsat-TM Data used for validation:

At the time of the workshop, 18 scenes have been assembled for use in the atmospheric correction verification. All of the data were acquired with concurrent sunphotometer data acquisitions. The 18 scenes listed by LTER site acronym and date are as follows:

SEV: 950317, 950418, 950520, 950605, 950707

NTL: 950606, 950622, 950926, 951012.

VCR: 930712, 930728.

AND: 940724, 940809, 940910, 940926.

BNZ: 940723, 940909

HFR: 930705

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