A 0.05 degree global climate/interdisciplinary long term data set from AVHRR, MODIS and VIIRS

**PI & Co-I’s:**

- **NASA GSFC:** Ed Masuoka (PI), Nazmi Saleous, Jeff Privette, Jim Tucker & Jorge Pinzon.
- **UMD:** Eric Vermote & Steve Prince.
- South Dakota State University: David Roy

**Collaborator:** Chris Justice (UMD).

**NASA Study Manager:** Dr. Diane Wickland.
Land Long Term Data Record

• Develop and produce a global long term coarse spatial resolution (0.05deg) data record from AVHRR, MODIS and VIIRS for use in global change and climate studies.

• Use a MODIS-like operational production approach including an operational QA team.

• Set up an advisory process.

• Make intermediate versions of the data sets available to the community through a web interface and solicit input from users.

• Hold community workshops for outreach and feedback.

• Prototype the development and production of a climate quality data record.
Proposed LTDR Products

AVHRR, MODIS, [VIIRS]:

- VIS/NIR surface reflectance
- MIR surface reflectance
- Vegetation Indices
- Surface temperature and emissivity
- Snow
- LAI/FPAR
- BRDF/Albedo
- Aerosols
- Burned area

Products and formats will be modified based on feedback from the User Community Workshops.
Project milestones

<table>
<thead>
<tr>
<th>Jun 04</th>
<th>Dec 04</th>
<th>Jun 05</th>
<th>Dec 05</th>
<th>Jun 06</th>
<th>Dec 06</th>
<th>Jun 07</th>
<th>Dec 07</th>
<th>Jun 08</th>
<th>Dec 08</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVHRR calibration</td>
<td>AGU session</td>
<td>Evaluation of existing data sets</td>
<td>Implementation of Surface reflectance Algorithm (Atmos. Correction)</td>
<td>Implementation of VI algorithm</td>
<td>Production of AVHRR Beta dataset</td>
<td>Evaluation of Beta data set</td>
<td>Implementation of Snow algorithm</td>
<td>AVHRR BRDF correction</td>
<td>Implement VI, LAI/FPAR / Albedo algorithms</td>
</tr>
</tbody>
</table>
Data Sources
AVHRR and MODIS Production Systems

AVHRR GAC L1B
1981 - present

-Geolocation
-Calibration
-Cloud/Shadow Screening
-Atmospheric Correction

Land products

Gridding

AVHRR products

Algorithm Prototype

MODIS coarse resolution surface reflectance
2000 - present

Land products

Gridding

MODIS products

Reference Data Set

MODIS Level 0
2000 - present

-Geolocation
-Calibration
-Cloud/Shadow Screening
-Atmospheric Correction

MODIS standard products
(Full resolution and CMG)

List of potential products:
Surface Reflectance, VI,
Surface Temperature and emissivity,
Snow, LAI/FPAR, BRDF/Albedo,
Aerosols, burned area

Format:
HDF
Geographic projection 1/20 deg resolution
Daily, multi-day, monthly
Use of MODIS to improve AVHRR atmospheric corrections

Use coincident MODIS/AVHRR data to develop an approach for water vapor retrieval from AVHRR.
## Error Budget: AVHRR surface reflectance and NDVI summary

<table>
<thead>
<tr>
<th></th>
<th>AVHRR Pathfinder-like processing</th>
<th>With LTDR improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration</td>
<td>10% absolute, 4% band to band</td>
<td>4% absolute, 2% band to band</td>
</tr>
<tr>
<td>Pressure</td>
<td>±10 mbars</td>
<td>±10 mbars</td>
</tr>
<tr>
<td>Water vapor</td>
<td>0.7 g.cm(^{-2}) (NCEP or None)</td>
<td>0.3 g.cm(^{-2}) (split window)</td>
</tr>
<tr>
<td>Ozone</td>
<td>±30 Dobson (LONDON)</td>
<td>±10 Dobson (EP-TOMS)</td>
</tr>
<tr>
<td>Aerosols</td>
<td>No Correction</td>
<td>0.01 error in predicting red refl. from 3.75 µm</td>
</tr>
</tbody>
</table>

### Reflectance / Semi-arid

<table>
<thead>
<tr>
<th>NDVI</th>
<th>Forest</th>
<th>Savanna</th>
<th>Semi-arid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>value</td>
<td>Aerosol Optical Depth</td>
<td>value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>clear avg hazy</td>
<td></td>
</tr>
<tr>
<td>NDVI</td>
<td>0.682</td>
<td>0.033 0.195 0.266</td>
<td>0.043 0.047 0.054</td>
</tr>
<tr>
<td>ρ Ch1 (VIS)</td>
<td>8 6</td>
<td>0.051 0.051</td>
<td>6 1</td>
</tr>
<tr>
<td>ρ Ch2 (NIR)</td>
<td>0.237 0.020</td>
<td>6 4</td>
<td>0.009 0.009</td>
</tr>
<tr>
<td>ρ Ch3 (MIR)</td>
<td>0.045 0.002</td>
<td>5 3</td>
<td>0.009 0.009</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.682</td>
<td>0.056 0.058 0.064</td>
<td>0.043 0.047 0.054</td>
</tr>
</tbody>
</table>
The absolute calibration coefficients derived for NOAA-16 bands 1 and 2, using the Terra MODIS as a reference, were compared to the vicarious coefficients derived using the ocean and clouds method (Vermote and Kaufman, 1995). The coefficients were consistent within less than 1%. A paper for RSE is in press.
Second year activities

• Produce an AVHRR surface reflectance and NDVI beta data set using Pathfinder 2 algorithms (vicarious calibration; Rayleigh, ozone and water vapor correction using ancillary data; aerosol retrieval over dark targets).
• Setup a web/ftp interface for data distribution.
• Identify a set of validation sites for use in the evaluation of the products.
• Evaluation of produced data set and start operational QA activity (global browse, known issues, time series monitoring and trends).
Second year activities (cont.)

• Develop code to process MODIS coarse resolution surface reflectance (MOD09CRS) into a data set with the same spatial and temporal characteristics as the AVHRR data set for use in evaluation and algorithm improvement.

• Start implementing LAI/FPAR, surface temperature and snow algorithms.

• Implement a community feedback mechanism to address users questions and to capture new requirements and concerns.


- Expand error budget analysis to include realistic scenarios (rather than worst case) and to account for temporal compositing.
- Use coincident MODIS and AVHRR data to improve aerosol retrieval and correction in AVHRR.
Production of the Beta Data Set

- Algorithms:
  - Vicarious calibration (Vermote/Kaufman)
  - Cloud screening: CLAVR
  - Partial Atmospheric Correction:
    - Rayleigh (NCEP)
    - Ozone (TOMS)
    - Water Vapor (NCEP)

- Products:
  - Daily NDVI (AVH13C1)
  - Daily surface reflectance (AVH09C1)
  - 16-day composited NDVI (AVH13C3)
  - Monthly NDVI (AVH13CM)

- Format:
  - Linear Lat/Lon projection
  - Spatial resolution: 0.05 Deg
  - HDF-EOS

- Time Period:
  - 1981 – 2000 completed

- Archive and Distribution:
  - Over 1 TB stored online.
  - Distributed by ftp and web

NOAA-11 - 1992193 (7/11/1992) : Ch1, Ch2 and NDVI
Data Set Evaluation

- Quality Assessment based on the MODIS Land approach (Devadiga/LDOPE)
  - Inspection of global browse images
  - Time series analysis

- Statistical analysis using non-linear tools (Pinzon/Tucker)
  - Verify the stability of the calibration
  - Comparison to GIMMS and Pathfinder data sets

- Verify theoretical errors using Aeronet data where available and develop product uncertainty estimates (Vermote/Nagol)

- Provided vicarious calibration coefficients to external users (NOAA/CSIRO)

- Beta users applications
- 50x50 km cutouts centered on aeronet sites
- Surface reflectance and NDVI Time series plots posted on the QA webpage.
- Use aeronet AOT and WV measurement when available to assess errors due to lack of atmospheric correction.

Data Set Evaluation
Evaluation goals (see MODIS poster’s, Vermote, Saleous, Kotchenova)

<table>
<thead>
<tr>
<th>Reflectance/VI</th>
<th>Value</th>
<th>Aerosol Optical Depth</th>
<th>Value</th>
<th>Aerosol Optical Depth</th>
<th>Value</th>
<th>Aerosol Optical Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>clear</td>
<td>avg</td>
<td>hazy</td>
<td>clear</td>
<td>avg</td>
</tr>
<tr>
<td>P3 (470 nm)</td>
<td>0.012</td>
<td>0.0052</td>
<td>0.0051</td>
<td>0.0052</td>
<td>0.0041</td>
<td>0.0052</td>
</tr>
<tr>
<td>P4 (550 nm)</td>
<td>0.0375</td>
<td>0.0049</td>
<td>0.0055</td>
<td>0.0064</td>
<td>0.0636</td>
<td>0.0052</td>
</tr>
<tr>
<td>P1 (645 nm)</td>
<td>0.024</td>
<td>0.0052</td>
<td>0.0059</td>
<td>0.0065</td>
<td>0.08</td>
<td>0.0053</td>
</tr>
<tr>
<td>P2 (870 nm)</td>
<td>0.2931</td>
<td>0.004</td>
<td>0.0152</td>
<td>0.0246</td>
<td>0.2226</td>
<td>0.0035</td>
</tr>
<tr>
<td>P5 (1240 nm)</td>
<td>0.3083</td>
<td>0.0038</td>
<td>0.011</td>
<td>0.0179</td>
<td>0.288</td>
<td>0.0038</td>
</tr>
<tr>
<td>P6 (1650 nm)</td>
<td>0.1591</td>
<td>0.0029</td>
<td>0.0052</td>
<td>0.0084</td>
<td>0.2463</td>
<td>0.0035</td>
</tr>
<tr>
<td>P7 (2130 nm)</td>
<td>0.048</td>
<td>0.0041</td>
<td>0.0028</td>
<td>0.0042</td>
<td>0.16</td>
<td>0.004</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.846</td>
<td>0.03</td>
<td>0.034</td>
<td>0.084</td>
<td>0.471</td>
<td>0.022</td>
</tr>
<tr>
<td>EVI</td>
<td>0.399</td>
<td>0.005</td>
<td>0.008</td>
<td>0.007</td>
<td>0.203</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Abnormally higher values in NOAA-11 over the desert were tracked to the use of incorrect calibration coefficients in production. Problem was also detected by the operational QA (time series) and is being corrected.
Beta Users

In addition to team members, certain users have been identified to use the beta data set in their applications:
- Andy Heidinger / Felix Kogan (NOAA) – Calibration
- Ed King (CSIRO) - Calibration
- Ranga Myneni (BU) - LAI
- Molly Brown (GSFC) - NDVI
- Marc Leroy (CESBIO/MediaFrance) : subset over East Africa : Evaluation of calibration and surface reflectance.
- Ana Pinheiro (GSFC) – Brightness/Surface temperature
- Menglin Jin (UMD) – Brightness/Surface temperature

-Users expressed interest in using the data set in EOS proposals
  - Anderson (BU)
  - Bounoua (GSFC)
LTDR Web Page

http://ltdr.nascom.nasa.gov/ltdr/ltdr.html
Operational Quality Assurance
**Operational QA : Global Browse**

**Land Long Time Data Record**

**Global Browse Images**

LTDs are produced on CMG (Climate Modelling Grid) products at 5km resolution. Global browse images created from these data records are posted in this web site to enable synoptic quality assessment of the data records. This web interface supports interactive selection of browse products and zooming and panning at 5km resolution.

**Browse Availability:**
- NOAA-7: 1981-276
- NOAA-14: 1993-301 — 2000-365

Please direct your questions and comments to Nancy Salomon at nancy.salomon@nasa.gov.

**Please select:**

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Collection</th>
<th>Products</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA-07</td>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>NOAA-09</td>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>NOAA-11</td>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>NOAA-14</td>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>NOAA-16</td>
<td>1</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

**Submit Selection**

**Click Here for the Calendar**

---

**Collection 001**

<table>
<thead>
<tr>
<th>Daily Product</th>
<th>Daily Product</th>
<th>8-day Product</th>
<th>14-day Product</th>
<th>Monthly Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Refrac. (AVHRRC1)</td>
<td>Vegetation Index (AVHRRC1)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Operational QA : Time Series

A time series of summary statistics derived from all the LTDE products at a number of fixed globally distributed locations is maintained and monitored by the LTDE QA personnel in order to enable synoptic quality assessment via the internet. Time series statistics are extracted at all appropriate sites and also from MODIS Land Golden Tile. Product time series are important because they capture algorithm sensitivity to surface (e.g., vegetation phenology), atmospheric (e.g., aerosol loading) and remote sensing (e.g., sensor-related geometry) conditions that change temporally, and because they allow changes in the instrument characteristics and calibration to be examined. Please select the year and an area/site (listed in alphabetical order) or tile and biome combination.

Abnormal behavior of NOAA-11
Due to wrong calibration

Unusable NOAA-14 data
### Operational QA: Known Issues

#### Land Long Time Data Record

**Quality Assessment**

1. TDR QA - Known Product Issues

   QA related issues found as a result of QA performed by the the TDR QA group and Science Teams are posted below. The issues are updated after each reprocessing of the data records with improved algorithm.

   **AVHRR Land Products**
   - Surface Reflectance (AVHRR)
   - Vegetation Index (AVHRI)

   Updated: May 8, 1998

<table>
<thead>
<tr>
<th>Case ID</th>
<th>Date Opened</th>
<th>Date Updated</th>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC AVHRI 0617b</td>
<td>05-02-98</td>
<td>05-18-98</td>
<td>Pending</td>
<td>Discontinuation for image restoration</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>05-02-98</td>
<td>05-10-98</td>
<td>Pending</td>
<td>Cloud may be seen after processing with new algorithm</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-24-98</td>
<td>04-21-98</td>
<td>Note</td>
<td>Some pixels noted as &quot;dark error registration&quot;</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-21-98</td>
<td>03-01-98</td>
<td>Pending</td>
<td>Smoothing in cloud regions, 19, ERF05 grids</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-21-98</td>
<td>03-01-98</td>
<td>Pending</td>
<td>Error and data flagged as Cloud</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-21-98</td>
<td>04-21-98</td>
<td>Note</td>
<td>No flag indicating that a heavy aerosol AVHRI data</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-21-98</td>
<td>04-21-98</td>
<td>Pending</td>
<td>Smoothing in cloud regions, error flags on cloudy</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-21-98</td>
<td>03-10-98</td>
<td>Pending</td>
<td>Areas of discontinuity with surroundings</td>
</tr>
<tr>
<td>CC AVHRI 0617a</td>
<td>04-21-98</td>
<td>03-31-98</td>
<td>Pending</td>
<td>Some ERF01 and ERF02 reflectance values exceed 4.0</td>
</tr>
</tbody>
</table>
SEEDS Activities

- Participated in the Reuse Working Group
- Participated in the Metrics Planning and Reporting Working Group (MPARWG)
Planned activities for the third year

- Complete evaluation of the beta data.
- Outreach activities
  - Vegetation workshop – Aug ’06 Montana
  - Hold a special session at Fall’06 AGU to present results and get feedback.
  - MODIS Land Collection 5 workshop (Jan’07).
- Implement BRDF correction of AVHRR data to remove biases introduced by the orbital drift and changes in the solar and viewing geometries throughout the record.
- Complete implementation of LAI/FPAR and albedo algorithms.
- Compare AVHRR and MODIS data sets to quantify differences and to start addressing continuity issues (starting with higher order products).
Summary

Done:
- Created and started evaluating an AVHRR surface reflectance and NDVI Beta data set.
- Distributed the data set to selected beta users who will evaluate it in the context of their application.
- Posted the Beta data set and the associated QA webpage on the web.
- AVHRR vicarious calibration paper in review/revision.

To be done:
- Complete evaluation and comparison with Pathfinder and GIMMS data sets.
- Hold AGU session on Land Coarse Resolution Long Term Data Record.
- Implement LAI/FPAR and BRDF algorithms.
ESDR pathfinding

- This project provides a pathfinding activity for NASA’s Land ESDRs with respect to inter-instrument calibration, product generation, QA and distribution.

- AVHRR data gaps
  - Two major data gaps exist in the AVHRR PM record.
    - The first one (end of 1994) can be filled using NOAA-09.
    - An option to fill the second one (1999->2000) requires the use of SPOT Vegetation data.

- The current project does not include collection and processing of AVHRR AM data. As with Terra and Aqua MODIS, AM and PM AVHRR data are useful for Thermal products and to improve BRDF retrievals.

- AVHRR on METOP will provide a longer overlap with MODIS.

- Obtaining and processing SPOT and METOP data require collaboration with foreign data producers. This provides an opportunity to test International cooperation in the creation of ESDRs.