Status of the "A 0.05 degree global climate/interdisciplinary long term data set from AVHRR, MODIS and VIIRS" REASoN CAN

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SAIC
and
NASA GSFC – Code 614.5

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, David Roy & Steve Prince.

Collaborator: Chris Justice (UMD).

NASA Study Manager: Dr. Diane Wickland.

Long Term Land 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.

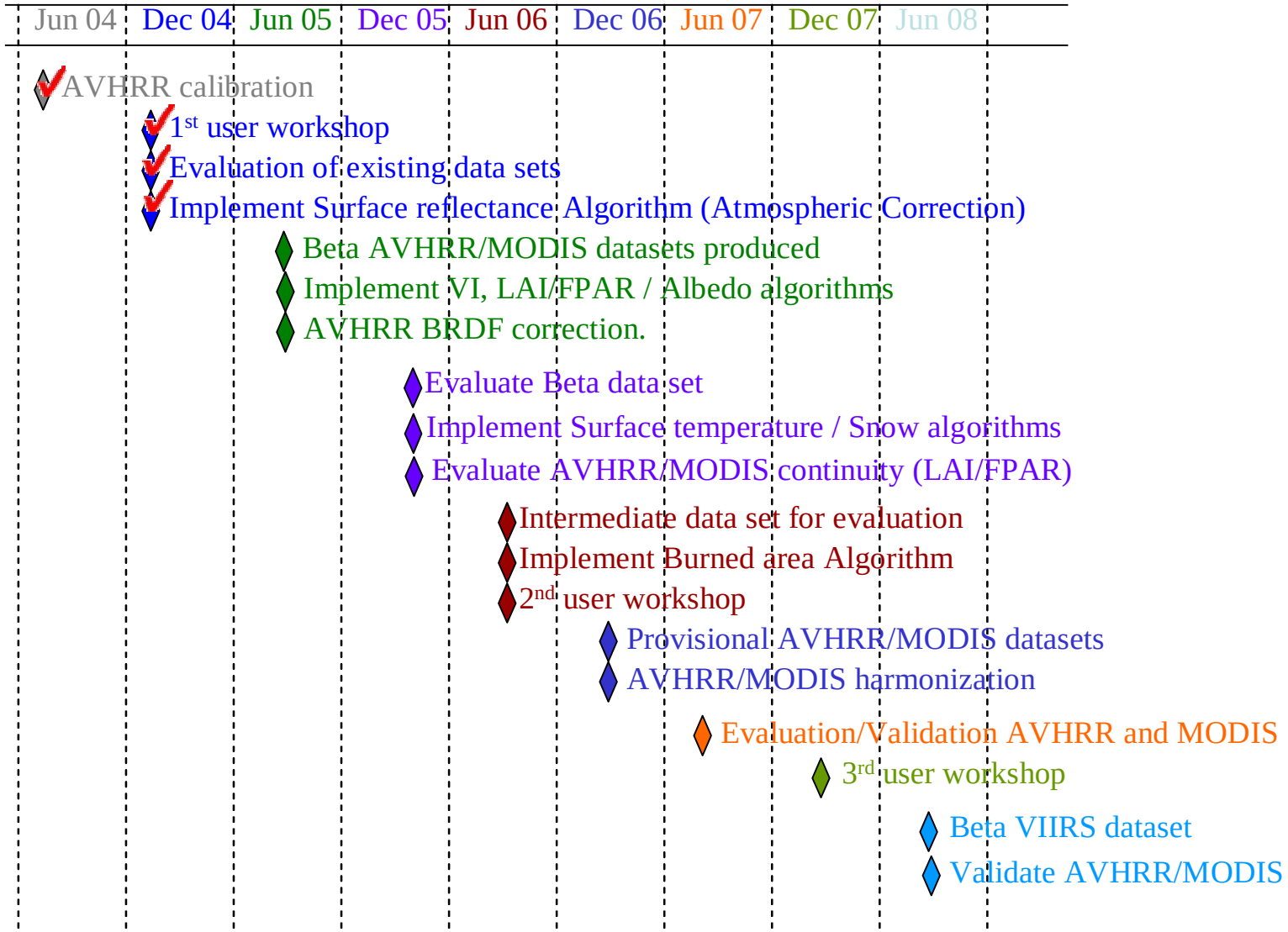
Proposed LTLDR Products

AVHRR, MODIS, VIIRS:

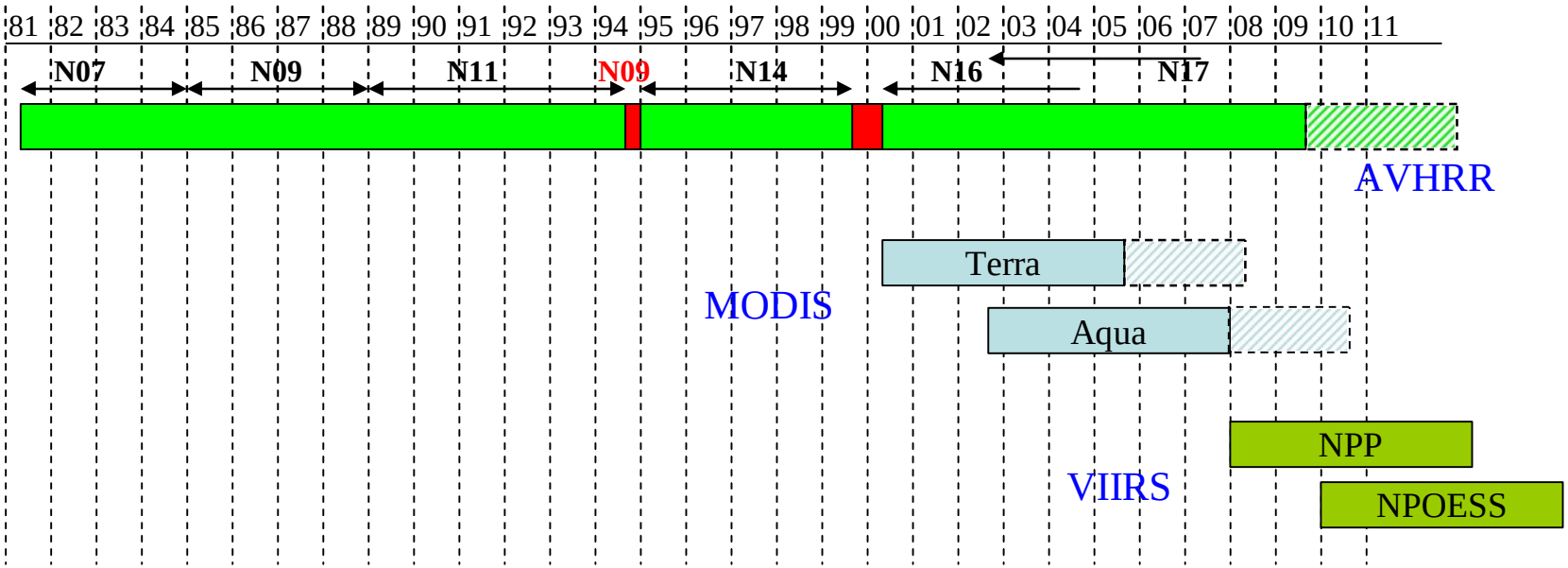
- Surface reflectance
- Vegetation Indices
- Surface temperature and emissivity
- Snow
- LAI/FPAR
- BRDF/Albedo
- Aerosols
- Burned area

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

Project milestones



Data Sources



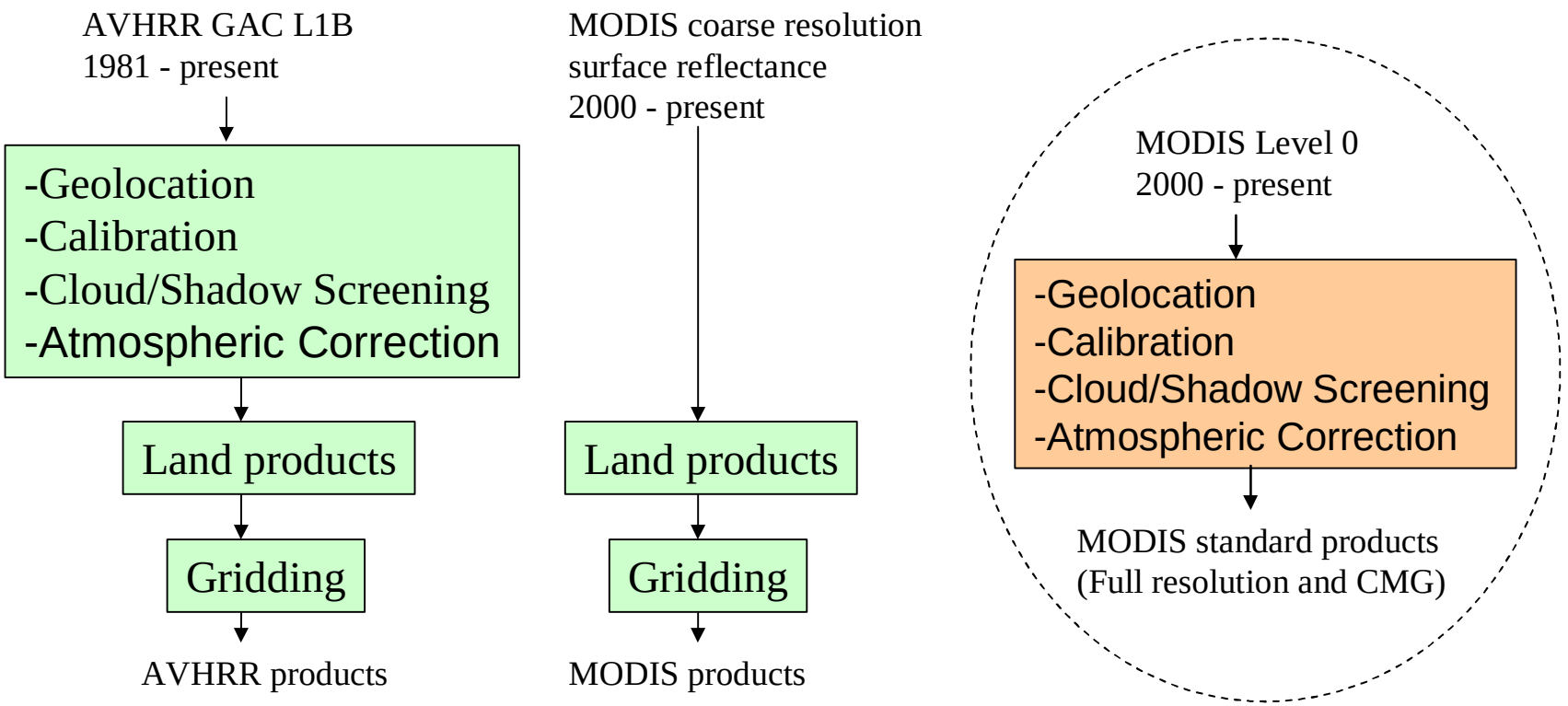
Existing Production Systems

AVHRR:
-Pathfinder AVHRR Land (PAL) data set produced and distributed by GSFC DAAC.
-NOAA (GVI).
-Others: e.g. GIMMS.
Differences in these products due to different processing approaches.
The most widely used is the PAL data set. However, it uses a suboptimal radiometric degradation assumption and includes partial atmospheric correction.

MODIS Terra and Aqua:
-Level 1 produced and distributed by GSFC DAAC.
-Land Level 2 and higher products are generated in MODAPS at GSFC-Code 922 (Ed Masuoka) and distributed from the ECS DAACs.
-Products created in this system are validated to stage 2 and have published accuracies.

NPP/NPOESS:
under development.

AVHRR and MODIS Production Systems



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

Format:
HDF-EOS
Geographic projection 1/20 deg resolution
Daily, multi-day, monthly

AVHRR data set

- AVHRR offers the longest record.
- Lacks onboard calibration.
- Limited set of spectral bands reduces the accuracy of atmospheric parameters retrieval and correction (water vapor and aerosols).
- Broad spectral bands lead to contamination by the atmosphere.
- Orbital drift leads to substantial variation in the solar geometry throughout the mission.

Significant Earth Science findings based on AVHRR

- Examples of major science publications
  - Phenology –lengthening snow-free season in arctic
  - Increased NPP in North America
- Widely-used information
  - NDVI
  - NPP, agricultural yield
  - Phenology
  - Land cover
  - Burned area

Are the AVHRR observations adequate to justify these Earth Science conclusions?

Approaches to the question:

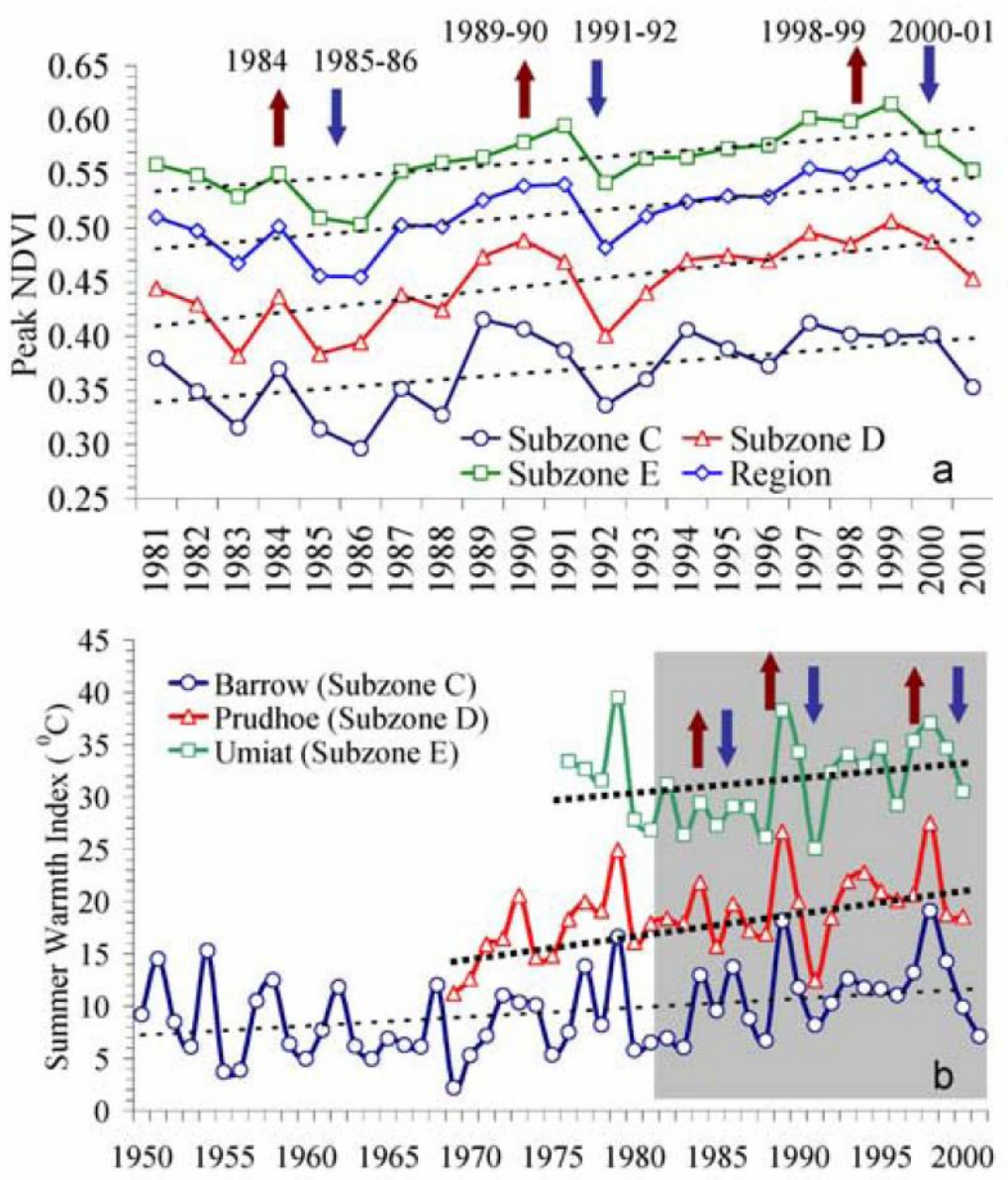
1. What accuracy and precision in the AVHRR data is assumed by users when reporting “significance” of results? Any independent verification?

2. How does the implied data quality compare with the results of best available estimates?

   2.1 Analytical estimates of quality – global, generalized

   2.2 Analytical estimates based on local observations

Example of AVHRR data use



Time series of peak NDVI derived from 8-km resolution AVHRR data from 1981 to 2001 (a) and SWI over the past 22–50 years (b) among bioclimate subzones. Dashed lines are linear regressions. The shaded area highlights the period of SWI covered by NDVI data

Significant ΔNDVI over 21 years =0.056±0.0032 to 0.082±0.028

From: Jia, G.J., Epstein, H.E. and Walker, D.A., 2003. Greening of arctic Alaska, 1981–2001. GEOPHYSICAL RESEARCH LETTERS, VOL. 30, NO. 20, 2067, doi:10.1029/2003GL018268.

Generating Improved AVHRR products

Goal to make the AVHRR data set temporally consistent and consistent with MODIS by using:

- Reliable and consistent calibration across the different NOAA platforms.
- Apply MODIS algorithms to AVHRR where possible, e.g.: the MODIS aerosol retrieval and atmospheric correction approach.
- BRDF correction to address differences in the solar and viewing geometry.
- Coincident AVHRR/MODIS to evaluate and improve AVHRR products and quantify accuracy.

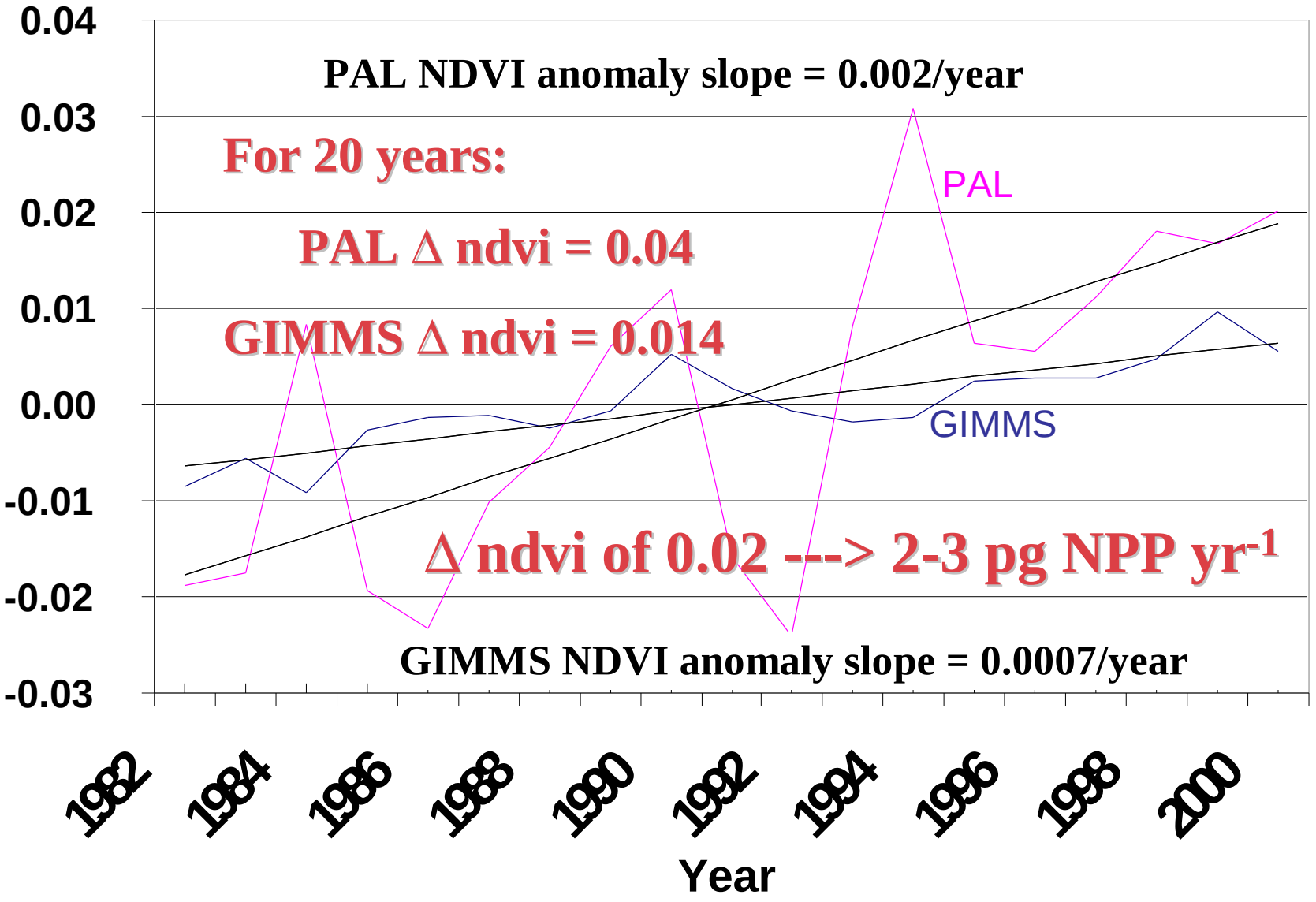
First year activities

- Acquired needed input data (AVHRR L1B, MODIS coarse resolution surface reflectance) and ancillary data (NCEP surface pressure and water vapor, TOMS ozone).
- Evaluated existing data sets and identify areas where improvement is critical.
- Adapted the Vermote/Kaufman AVHRR vicarious calibration approach for AVHRR-3 and used it to calibrate NOAA-07 – NOAA-16.
- Evaluated the vicarious calibration approach using coincident MODIS and NOAA-16 observations over invariant targets.
- Presented planned work and calibration to NOAA (Andy Heidinger's group) and provided group with our derived calibration for NOAA-07 - 16.

First year activities (cont.)

- Used coincident MODIS and AVHRR data to develop a split window water vapor retrieval technique for AVHRR.
- Established a theoretical error budget for AVHRR and MODIS surface reflectance.
- Studied limitations of the surface temperature derived from AVHRR.
- Held a Long Term Data Records session at the fall AGU conference to present the project and solicited feedback.
- Developed a list of potential evaluators for our Beta data set.
- Presented project activities at the ESIPS Federation Meetings and participated in the SEEDS working groups (software reuse, metrics and standards).

Evaluation of existing data sets : PAL vs GIMMS



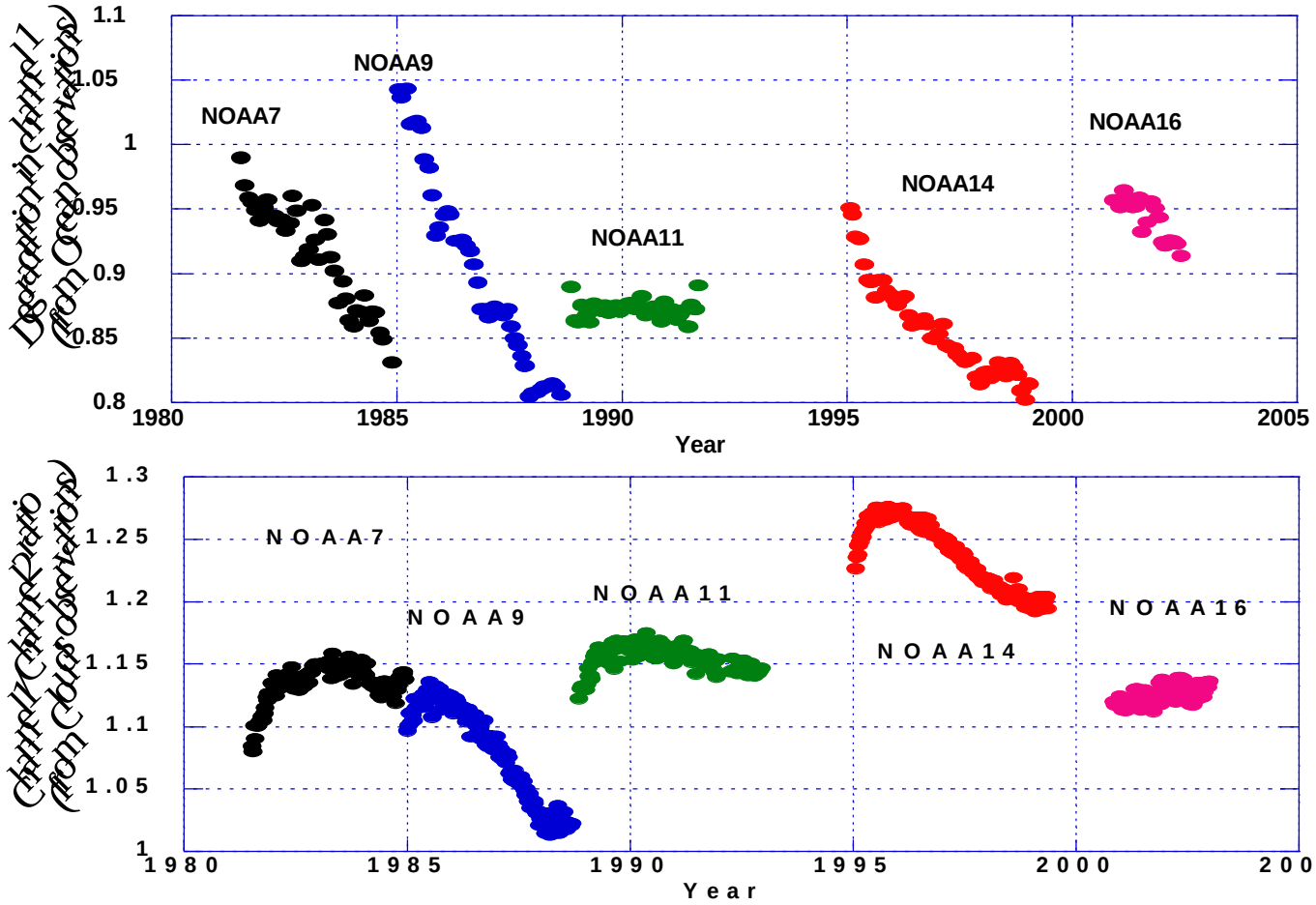
AVHRR Data set improvements

-Radiometric VIS/NIR Calibration

-Atmospheric Correction

Consistent AVHRR calibration across platforms

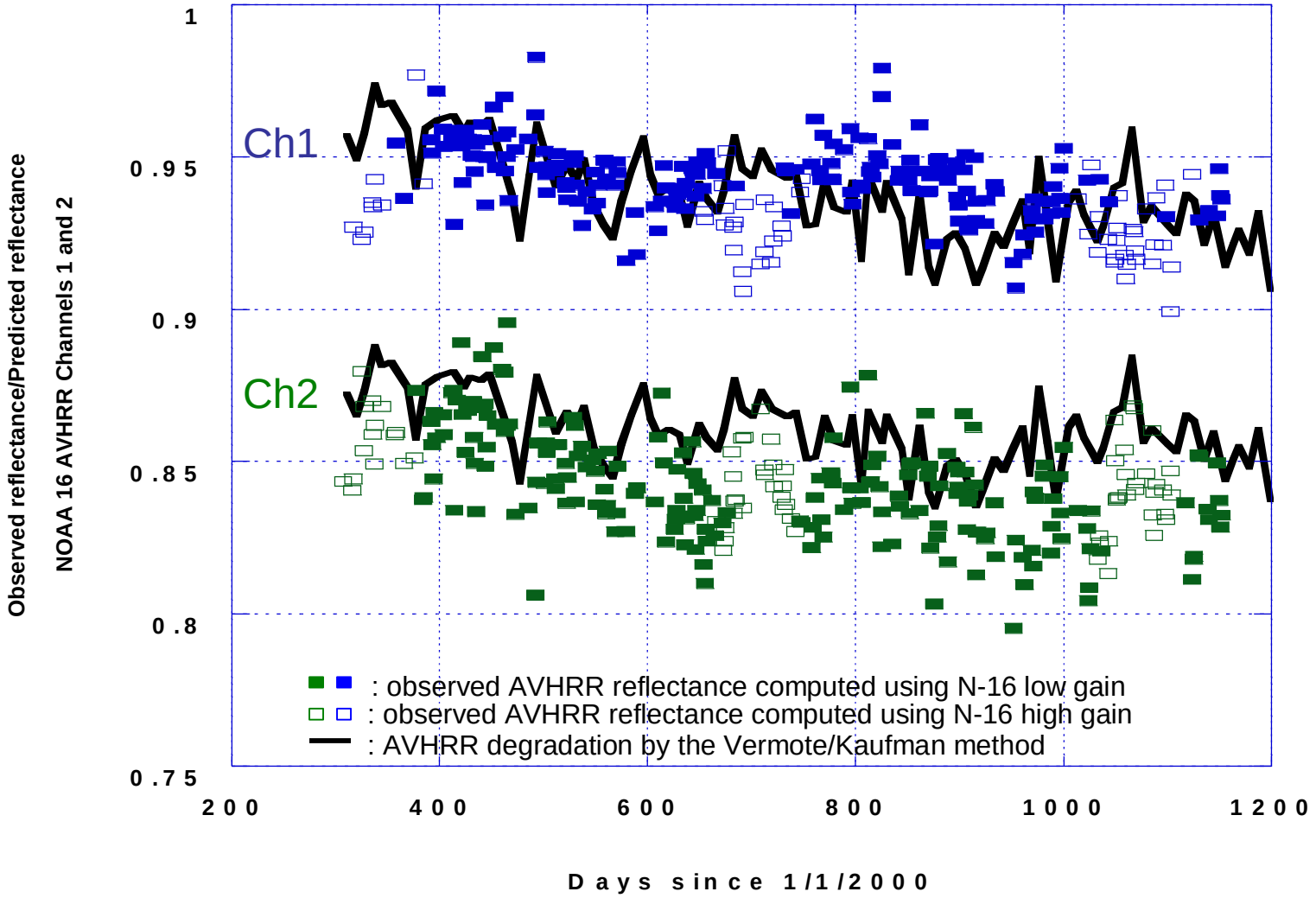
- Use the Vermote/Kaufman calibration approach (1995)



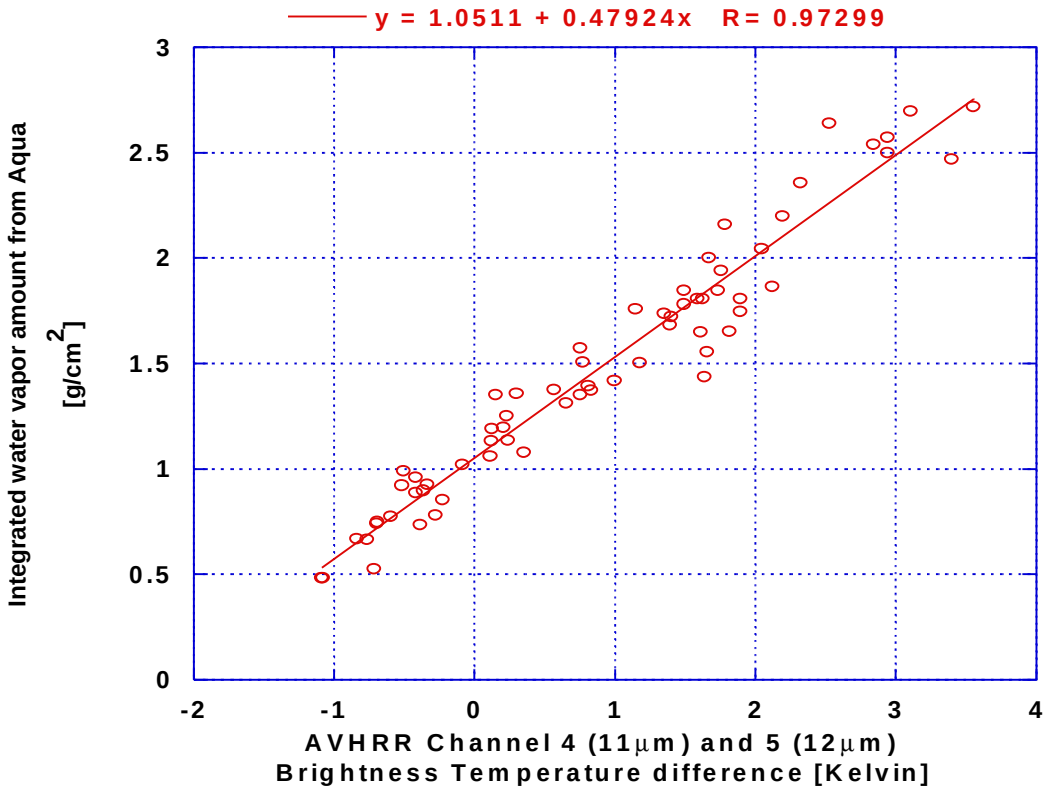
Approach used to validate N16 calibration with MODIS

- Select a stable calibration site.
- Characterize the reflectance spectral variation using MODIS narrow bands.
- Use 2 years of data to characterize the site BRDF using the simple linear kernel model used in the MODIS BRDF product.
  - Rigorous cloud screening is applied to the data.
  - Exclude observations within 15deg of backscattering conditions to avoid the hot spot.
  - Exclude off-nadir observations (viewing zenith angle > 50 deg) where the pixel size variation makes it difficult to select coincident observations.

Evaluating AVHRR calibration using MODIS



Use of MODIS to improve AVHRR atmospheric corrections



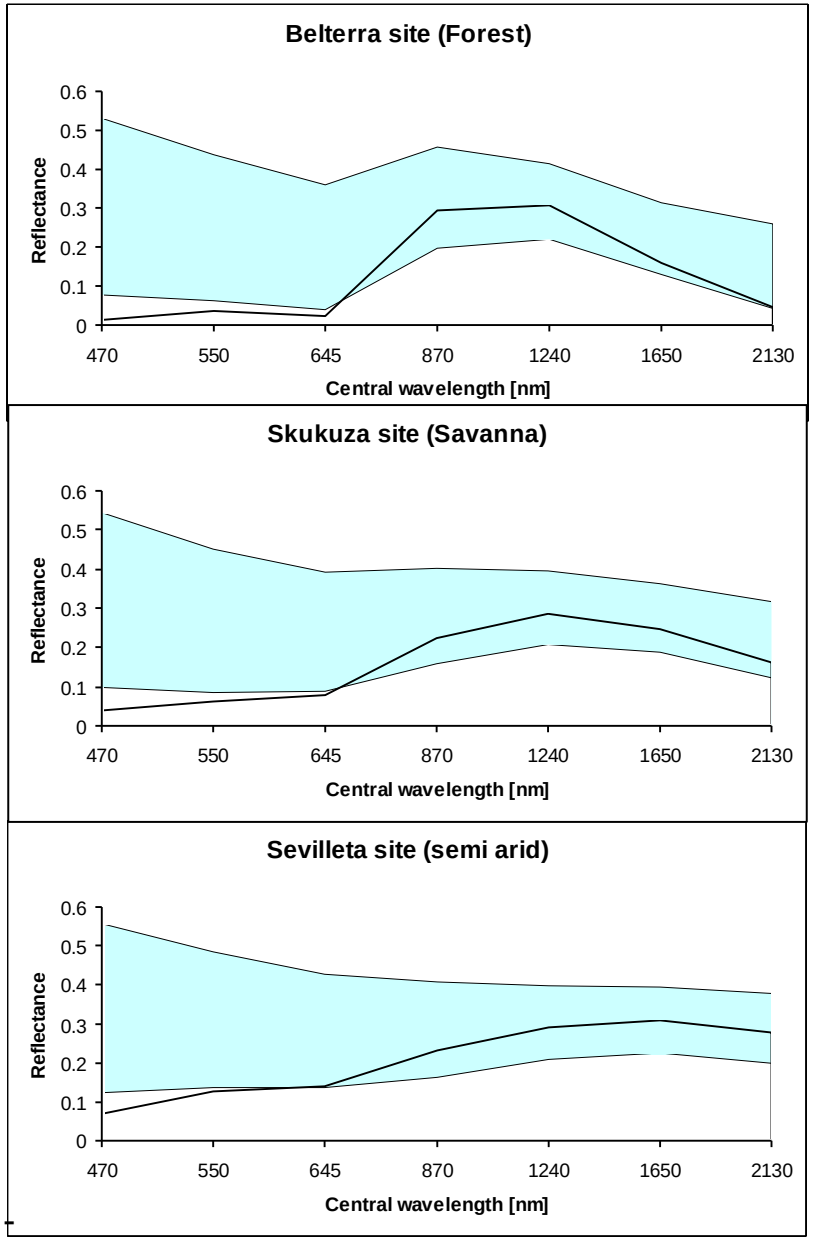
Use coincident MODIS/AVHRR data to develop an approach for water vapor retrieval from AVHRR.

Theoretical Error Budget

Error Budget: MODIS TOA simulations

Parameter	Values
Geometrical conditions	
Aerosol optical depth	0.05 (clear) 0.30 (average) 0.50 (high)
Aerosol model	urban clean,urban polluted, smoke low absorption smoke high absorption
Water vapor content [g/cm2]	1.0, 3.0 and 5.0 uncertainties +/-0.2
Ozone content [cm.atm]	0.25 , 0.3, 0.35 uncertainties +/- 0.02
Pressure [mb]	1013mb, 930mb, 845mb uncertainties +/-10mb

Solar Zenith	View Zenith	Relative Azimuth	Case Name
30	0	0	A
30	30	0	B
30	30	180	C
30	60	0	D
30	60	180	E
60	0	0	F
60	30	0	G
60	30	180	H
60	60	0	I
60	60	180	J



Error Budget: MODIS surface reflectance and NDVI summary

Parameter	Accuracy
Calibration	**2% absolute, 1% band to band**
Pressure	**±10 mbars**
Water vapor	**0.2 g.cm^{-2} (Differential absorption approach)**
Ozone	**±20 Dobson (EP-TOMS)**
SWIR/VIS relation	**± 0.005 reflectance units**
Aerosol type	**Smoke low/high absorption, urban polluted**

	Forest				**Savanna**				**Semi-arid**			
Reflectance/ NDVI	value	Aerosol Optical Depth			value	Aerosol Optical Depth			value	Aerosol Optical Depth		
		clear	avg	hazy		clear	avg	hazy		clear	avg	hazy
3 (470 nm)	0.012	0.0052	0.0051	0.0052	0.04	0.0052	0.0052	0.0053	0.07	0.0051	0.0053	0.0055
4 (550 nm)	0.0375	0.0049	0.0055	0.0064	0.0636	0.0052	0.0058	0.0064	0.1246	0.0051	0.007	0.0085
1 (645 nm)	0.024	0.0052	0.0059	0.0065	0.08	0.0053	0.0062	0.0067	0.14	0.0057	0.0074	0.0085
2 (870 nm)	0.2931	0.004	0.0152	0.0246	0.2226	0.0035	0.0103	0.0164	0.2324	0.0041	0.0095	0.0146
5 (1240 nm)	0.3083	0.0038	0.011	0.0179	0.288	0.0038	0.0097	0.0158	0.2929	0.0045	0.0093	0.0148
6 (1650 nm)	0.1591	0.0029	0.0052	0.0084	0.2483	0.0035	0.0066	0.0104	0.3085	0.0055	0.0081	0.0125
7 (2130 nm)	0.048	0.0041	0.0028	0.0042	0.16	0.004	0.0036	0.0053	0.28	0.0056	0.006	0.0087
NDVI	0.849	0.03	0.034	**0.04**	0.471	0.022	0.028	0.033	0.248	**0.011**	0.015	0.019

Error Budget: AVHRR surface reflectance and NDVI summary

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

	Forest				Savanna				Semi-arid			
Reflectance/ NDVI	value	Aerosol Optical Depth			value	Aerosol Optical Depth			value	Aerosol Optical Depth		
		clear	avg	hazy		clear	avg	hazy		clear	avg	hazy
Ch1 (VIS)	0.0448	0.0056	0.051	0.0803	0.086	0.009	0.0457	0.073	0.143	0.0149	0.039	0.0628
Ch2 (NIR)	0.237	0.020	0.0217	0.0338	0.196	0.0164	0.0225	0.037	0.217	0.0179	0.02	0.0349
Ch3 (MIR)	0.045	0.002	0.0026	0.0031	0.086	0.0042	0.0044	0.0046	0.143	0.0073	0.0074	0.0074
NDVI	0.682	**0.033**	0.195	**0.266**	0.392	0.042	0.124	0.168	0.206	0.046	0.068	0.090
Ch1 (VIS)	0.0448	0.0101	0.01	0.01	0.086	0.0101	0.0101	0.01	0.143	0.0106	0.0104	0.0104
Ch2 (NIR)	0.237	0.0085	0.0133	0.0196	0.196	0.0075	0.0101	0.0141	0.217	0.0081	0.0097	0.0132
Ch3 (MIR)	0.045	0.0014	0.0015	0.0025	0.086	0.0020	0.0022	0.0026	0.143	0.003	0.0033	0.0037
NDVI	0.682	0.056	0.058	**0.064**	0.392	0.043	0.047	0.054	0.206	**0.03**	0.033	0.038

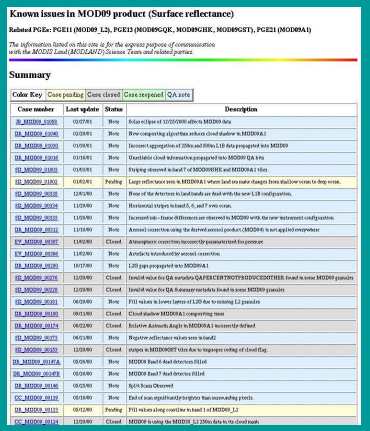
Production and Distribution

- Use a MODAPS-like environment for production.
- Benefit from the MODIS production experience.

-Data products will be kept online and distributed by ftp and through a web page.
-Make intermediate data sets available for evaluators.
-Transition the data sets to the DAAC later in the project when the datasets are validated.

Quality Assessment

Known Issues Tracking



Known issues in MOD09 product (Surface reflectance)

Related PGEs: PGE11 (MOD09_L2), PGE13 (MOD09CQE, MOD09GHK, MOD09GST), PGE21 (MOD09A1)

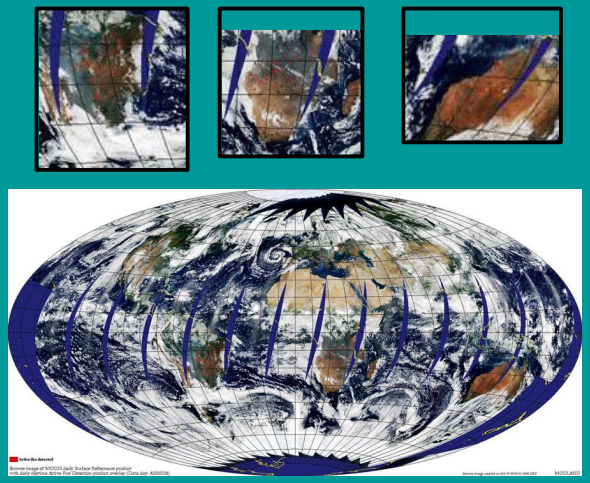
The information listed on this site is for the sole purpose of communication with the MODIS Land (MODLAND) Science Team and related parties.

Summary

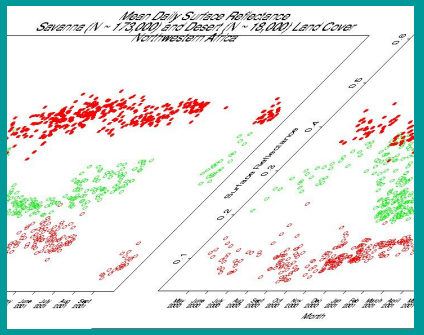
Color Key | Case pending | Case closed | Case reopened | QA note

Case number	Last update	Status	Description
ID_MOD09_01081	02/07/01	Note	Solar eclipse of 11/25/2000 affects MOD09 data
ID_MOD09_01040	02/08/01	Note	New compositing algorithm reduces cloud shadow in MOD09A1
ID_MOD09_01030	01/09/01	Note	Incorrect aggregation of 250m and 500m L1B data propagated into MOD09
ID_MOD09_01018	01/04/01	Note	Unreliable cloud information propagated into MOD09 QA bits
ID_MOD09_01003	01/05/01	Note	Striping observed in band 7 of MOD09GHK and MOD09A1 tiles
ID_MOD09_01002	01/02/01	Pending	Large reflectance seen in MOD09A1 where land sea make changes from shallow ocean to deep ocean.
ID_MOD09_00038	12/01/00	Note	None of the detectors in land bands are dead with the new L1B configuration.
ID_MOD09_00034	11/09/00	Note	Horizontal stripes in band 5, 6, and 7 over ocean.
ID_MOD09_00033	11/08/00	Note	Increased sub - frame differences are observed in MOD09 with the new instrument configuration.
ID_MOD09_00032	11/10/00	Note	Aerosol correction using the derived aerosol product (MOD04) is not applied everywhere
EV_MOD09_00387	11/01/00	Closed	Atmospheric correction incorrectly parameterized for pressure
EV_MOD09_00386	11/01/00	Note	Artefacts reproduced by aerosol correction.
ID_MOD09_00290	10/17/00	Note	L2G gaps propagated into MOD09A1
ID_MOD09_00276	12/03/00	Closed	Invalid value for QA metadata QAPERCENTNOTPRODUCEDOTHER found in some MOD09 granules
ID_MOD09_00228	12/03/00	Closed	Invalid value for QA Summary metadata found in some MOD09 granules
ID_MOD09_00201	06/09/00	Note	Fill values in lower layers of L2G due to missing L2 granules
ID_MOD09_00180	09/11/00	Closed	Cloud shadow MOD09A1 compositing issue
ID_MOD09_00174	08/22/00	Closed	Relative Azimuth Angle in MOD09A1 incorrectly defined
ID_MOD09_00173	06/21/00	Note	Negative reflectance values seen in band2
ID_MOD09_00155	12/03/00	Closed	stripes in MOD09QST tiles due to improper coding of cloud flag.
ID_MOD09_00147A	05/26/00	Note	MOD09 Band 4 dead detectors filled
ID_MOD09_00147B	05/26/00	Note	MOD09 Band 7 dead detectors filled
ID_MOD09_00146	06/15/00	Note	Split Scans Observed
CC_MOD09_00132	05/15/00	Note	End of scan significantly brighter than surrounding pixels.
ID_MOD09_00131	05/12/00	Pending	Fill values along coast line in band 1 of MOD09_L2
CC_MOD09_00124	12/19/00	Closed	MOD09 is using the MODIS_L2.250m data in its cloud mask

Global Browse



Time series analysis



Building on the MODIS Land QA approach

Community Outreach

- Request users input through the project's web site.

-Workshops/Sessions held throughout the project to refine requirements and provide feedback on products.

- Publish team's evaluation of existing and intermediate datasets on the web and request input and comments from users.

-Participation in scientific conferences and peer reviewed publications.

Summary

- The creation of a Long Term Land Surface Data record with documented and comparable accuracy across instruments is feasible.
- The long term trend observed with precursor AVHRR datasets needs to be verified.
- A beta version of the AVHRR data set will become available for evaluation in June 2005.
- The user community involved in the definition and evaluation of the data sets (Pathfinder approach).
- Incremental release of the products (Beta => Provisional => Validated) as they are generated (MODIS approach).