IMAPP - International MODIS and AIRS Processing Package

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CIMSS Space Science and Engineering Center

1. Date, version and main features of IMAPP MODIS releases

Release #	Date	Version	Main Features
1	12 May 2000	MODIS L1 V1.0	1.0 to L1 Geolocation and Calibration
2	1 November 2000	MODIS L1 V1.1	Calibration and look-up-table update to Ver. 2.4. Bug Fixed: Support definitive ephemeris and attitude data Support Solaris86 O.S.
3	13 April 2001	MODIS L1 V1.2	Calibration algorithm and lookup tables update to Ver. 2.5.5 and 2.5.5.1 Geolocation is updated using platform ephemeris and attitude. Terrain correction for geolocation is provided.
4	3 December 2001	MODIS L1 V1.3	Calibration algorithm and lookup tables update to Ver. 3.0.0 and 3.0.0.7 Geolocation algorithm is updated
5	1 May 2002	MODIS L2 V1.1	First science product release for Terra MODIS
6	13 September 2002	MODIS L1 V1.4	First version to support both Terra and Aqua MODIS Aqua MODIS calibration algorithm and lookup tables use version 3.0.1, and 2.1.0.2. Aqua MODIS geolocation requires ephemeris and attitude files IMAPP L1 processing script handles both Terra & Aqua
7	1 October 2002	MODIS L2 V1.2	Second MODIS science product release Atmospheric sounding profile retrieval equivalent to DAAC MODO7 V3.1.0
8	19 February 2003	MODIS L2 V1.3	First MODIS Terra/Aqua compatible cloud mask and cloud top property release Improved cloud mask Band 26 radiation correction Cloud mask updated to DAAC MODIS V4.2.0 Cloud top property and phase updated to DAAC MODO6CT V 4.0.4 First Images of Terra/Aqua provided
9	18 September 2003	MODIS L2 V1.4	Update to Atmospheric sounding profile retrieval equivalent to DAAC MODO7 V6.1.0
10	5 November 2003	AIRS L1 V1.0	First AIRS/AMSU AND HSB geolocation and calibration Functionally identical to GSFC DAAC version. Routine for Red Hat Intel Linux and Sun Solaris (SPARC) only.
11	6 November 2003	MODIS L1 V1.5	Update to L1B software. Updated geolocation software, calibration tables
12	19 November 2003	MODIS Utility	Tutorial on producing MODIS True Color images
13	16 January 2004	MODIS L1 subset	Update for Terra MODIS calibration following spacecraft safe hold
14	3 March 2004	MODIS L2 V1.5	First Aqua/Terra Sea Surface Temperature product release Differs from DAAC version - no ancillary data sets are required
15	6-8 June 2004	IMAPP workshop Nanjing, China	Educate users on Aqua/Terra direct broadcast instruments, remote sensing, IMAPP products and applications
16	5 October 2004	MODIS L2 V1.6	First Aqua/Terra Aerosol product release.
17	23 November 2004	AIRS/AMSU L2 V2.0	First Aqua Level 2 atmospheric profile retrieval. Level 1B and 2 algorithms are equivalent to DAAC Ver. 3.0.8

The evolution of international polar orbiting weather satellite processing packages at CIMSS.

	ITPP	IAPP	IMAPP
Sensor /Data Type	HIRS/2 MSU AVHRR	HIRS/2 AMSU AVHRR	MODIS AIRS AMSU AMSR-E
Example Products	T/Q Sounding Cloud Height SST	T/Q Sounding Cloud Height SST	T/Q Sounding Cloud Mask Cloud Phase Cloud Height SST Others
S/C	TIROS-N to NOAA 14	NOAA 15-17	EOS Terra & Aqua
Operation Period	1983 – Current	1998 – Current	2001 – Current

All IMAPP released software has been ported and tested on the following UNIX/PC platforms:

- **SGI MIPS, IRIX 6.5**
- **Sun Ultra, Sun OS 5.7**
- **IBM RS/6000, AIX 4.3**
- **HP PA-RISC, HP-UX B.10.20**
- **Intel Pentium, Red Hat Linux 7.2 (2.4.7-10) (with gcc/g77 2.96)**
- **Intel Pentium, Solaris8 x86 5.8 (with gcc/g77 2.95.2)**

2. IMAPP Software

SSEC is funded by NASA to develop the International MODIS/AIRS Processing Package (IMAPP). The goals of the IMAPP project include:

i. To release a freely available package for processing MODIS and AIRS/AMSU/HSB data,

ii. To promote and support the worldwide use of EOS data, and to involve the international community in EOS validation efforts.

For this purpose, SSEC has adapted the operational Level-0 to Level-1 MODIS and AIRS geolocation and calibration software developed by NASA. The IMAPP requirements are:

- **IMAPP must be portable to a wide range of UNIX/PC platforms.**
- **The number of required toolkits must be kept to a minimum.**
- **Ancillary data sets must be easily accessible.**
- **Software must be able to process overpasses of any size.**
- **Downlinked spacecraft ephemeris and attitude data may be used for real-time geolocation.**
- **Distributed products must be similar to those produced at the Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC).**
- **The code must be efficient.**

IMAPP User	Purpose
CSIR Satellite Application Centre Hartbeeshoek - South Africa	IMAPP MODIS Level 1B used for generation of surface reflectance, NDVI, BRDF, LST, SST
US Forest Service, Missoula, Montana, USA	IMAPP MODIS Level 1B and eventually aerosol product for fire monitoring
Center for Space and Remote Sensing Research, National Central University, Taiwan, ROC	IMAPP MODIS Level 1 and Level 2 products used for studying the atmospheric temperature, ozonosphere, sea surface temperature, chlorophyl, ocean color, vegetation indices and forest fires
National Institute for Space Research – INPE, Sao Paulo, Brazil.	IMAPP MODIS Level 1B used to serve INPE/CPTEC, IBAMA and other Governmental institutions
Institute of Geography and Resources Research, Chinese Academy of Science	IMAPP MODIS Level 1 and Level 2 products
Kongsberg Satellite Services, Tromso, Norway	IMAPP MODIS Level 1 and Level 2 products distributed with ground stations world wide for a variety of environmental applications
ScanEx Research and Development Center, Moscow, Russia	IMAPP MODIS Level 1, and Level 2 cloud mask and SST used for a wide range of land and sea surface monitoring tasks
Plymouth Marine Laboratory, Plymouth, United Kingdom	IMAPP MODIS Level 1 and Level 2 cloud product, cloud mask, and atmospheric profiles products. Used as a deliverable for the EC funded CLOUDMAP2 project which finished in January 2004.
EROS Data Center, Sioux Falls, South Dakota, USA	IMAPP MODIS Level 1 products are reprojected for users on the AmericaView project, a National and State Partnership to Enable Remote Sensing Education, Training, and Applications
Australian Center for Remote Sensing, Alice Springs, Canberra and Hobart Australia.	IMAPP MODIS Level 1 and, in test right now, Level 2 cloud mask and cloud properties. These products are being utilized in various environmental applications

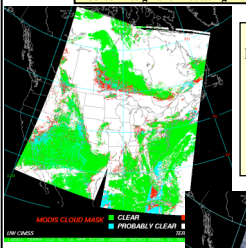
Partial List of Current IMAPP Users

IMAPP may be downloaded at no cost and is licensed under the terms of the GNU General Public License (GPL)

http://cimss.ssec.wisc.edu/~gumley/IMAPP/

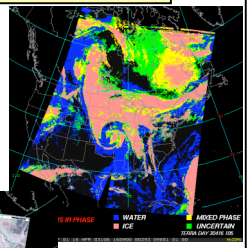
3. MODIS Algorithms/Products Development

- **Continue to update/support MODIS Terra/Aqua L1 & L2 S/W**
- **Continue to explore new products, algorithms and synergistic research**
- **Use MODIS Data, Algorithms and Products to Support NOAA's Geostationary Imager (ABI) Sensor Design and Processing Risk Reduction**

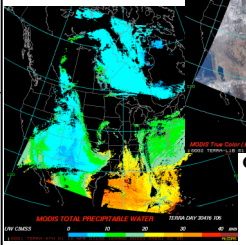


Cloud Mask

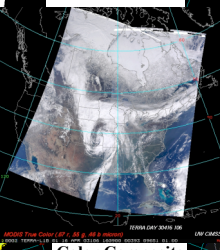
CIMSS/SSEC Direct Broadcast Real-time High-Spatial Resolution MODIS Products 4-16-2003



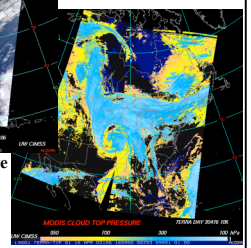
Cloud Phase



Total Precipitable Water

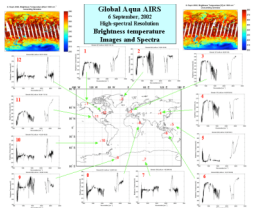


Color Composite



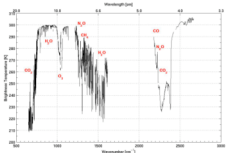
Cloud Top Pressure

4. AIRS Data/Algorithm Evaluation/Development



The Atmospheric Infrared Sounder on AQUA

- IR sounder: 2378 channels
- spectral ranges: 3.7 - 4.61 μm, 6.2 - 8.22 μm , 8.8 - 15.4 μm;
- spectral resolution: λ/dλ ~1200



IMAPP AIRS Single Field of View Clear-Sky Retrieval

- Regression Retrieval of T, q, Ts, TPW, O3, and ε_s under clear conditions
  - Regression Model: X = C Y
  - Least squares regression solution: C = X Y^t $(Y\,Y^t)^{-1}$
  - X... Atmospheric State, C... Coefficients, Y... Measurements
- Preparation of multiple Trainingsets
- Forward Model Calculations using SARTA
- Application of BT/scanang-classification scheme
- Use of MODIS Cloudmask product for AIRS FOVs cloud detection
- Retrieval Validation/Comparison: ECMWF analysis, global RAOBs, MODIS and GOES Retrievals

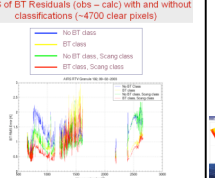
→ SelChans RTV, nch=337
→ PC regression RTV, npc=90

→ TIGR3 & Noaa88 & special desert and polar cases
→ Ecosystem assigned to each point to get realistic surface pressure, surface skin temperature and surface emissivity.

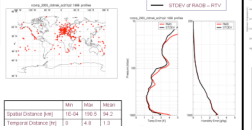
Class	BT@1000 cm^{-1} training	BT@1000 cm^{-1} observations
1	BT ≤ 260	BT ≤ 255
2	260-dBTs270	255-dBTs265
3	260-dBTs280	265-dBTs275
4	270-dBTs290	275-dBTs285
5	280-dBTs300	285-dBTs295
6	290 < BT	295 < BT

IMAPP AIRS RTV

RMS of BT Residuals (obs – calc) with and without classifications (~4700 clear pixels)

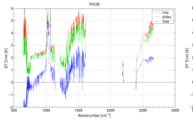


Co-Located RAOB/AIRS Retrieval Statistics: Profiles

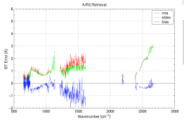


Co-Located RAOB/AIRS Retrieval Statistics: Residuals

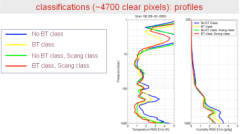
Radiosonde Observations



AIRS Retrieval



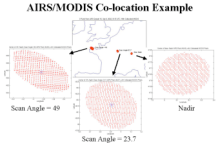
RMS of ECMWF minus Retrieval with and without classifications (~4700 clear pixels): profiles

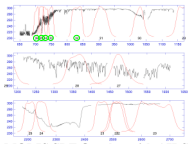


5. MODIS/AIRS Synergistic Cloud Detection/Clearing

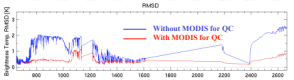
- **Efficient/Accurate MODIS/AIRS Co-location**
- **Develop Synergistic Cloud Detection Algorithm**
- **Develop Synergistic Cloud Clearing Algorithm**
- **Evaluate Noise Filtering Priori to Cloud Clearing**
- **Develop 1 by 2; 1 by 3; 2 by 2 AIRS FOV Cloud Clearing without Microwave Data**
- **Quality Control of AIRS Cloud Cleared Radiances Using 1-km (@ Nadir) MODIS CM/CP/TPW/Tskin**

AIRS/MODIS Co-location Example



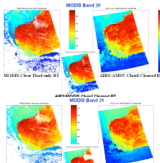


Use of MODIS to Quality Control AIRS/AMSU Cloud Clearing

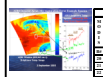


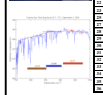
Use of MODIS to Perform High-Spatial Resolution AIRS Cloud Clearing

MODIS SRF Overlay with AIRS Brightness Temperature



AIRS Detector Array Co-Misregistration Error Impact on Observations and cloud-cleared Radiances

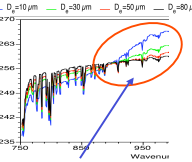




AIRS/AMSU (3 by 3 FOV) Vs. AIRS/MODIS Single-FOV Cloud Clearing Brightness Temperature Images

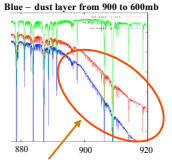
Misregistration Error Between Detector Array M08 and M09					
Hurricane Ivan 14 Sep. 2004		Clear	Partly Cloudy	Overcast	All
%	>NeDT	1.15	12.05	46.25	59.45
	>1 K	0	2.5	26.4	28.90
	>2 K	0	0.7	9.35	10.05
	>3 K	0	0.3	3.5	3.8
	>5 K	0	0.1	0.6	0.7
Degree K	Bias	-0.26	-0.105	-0.03	Mean Atmospheric Variability 4.22 K
	RMSE	0.450	0.780	1.425	

Cirrus Clouds at Different Particle Sizes of CH=10km; COT=1.0; Std Atm.; Ts=288K



Ice Cloud Spectral Slope

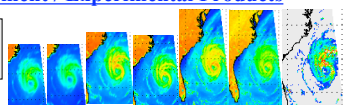
Green – clear sky;
Red – dust layer from 1013 to 701.2 mb;
Blue – dust layer from 900 to 600mb



Dust Spectral Slope

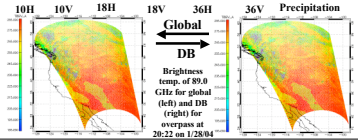
6. Under Development / Experimental Products

Hurricane Isabel AMSR-E Brightness Temperature & Precipitation Estimates



Comparison of DB L1 Tb with Stand L1 Tb

- Jan. 28 to Mar. 4, 2004
- 150 overpasses, except 9 abnormal ones:
- Low freq. Channels (6.9, 10.7, 18.7, 23.8, 36.5 GHz V&H Polarizations): Bias < 0.6 K, RMS < 0.6 K
- High freq. Channels (89.0 GHz V&H polarizations): Bias < 1.0 K, RMS < 1.0 K



Brightness temp. of 89.0 GHz for global (left) and DB (right) for overpass at 20:22 on 1/28/04

7. Summary and Future Work

IMAPP Level 2 Product Summary		
MODIS	AIRS/AMSU/HSB	AMSR-E
Aerosol Optical Depth	Cloud Detection	Soil Moisture
Surface Reflectance	Cloud Properties	Precipitation
Snow Detection	Cloud Height/Emissivity	
Sea Ice Detection	Cloud Liquid Water	
Scene Classification (Clouds and Land Surface)	AMSU Precipitation Estimate	
Cloud Particle Size	Atmospheric Sounding Profile (AIRS science team algorithm)	
Cloud Optical Thickness	Single Clear AIRS FOV Atmospheric Sounding Profile	
Ocean Color		
Suspended Sediment		
Atmospheric Sounding		
Total Perceptible Water		
MODIS/AIRS Collocation		
MODIS/AIRS Cloud Clearing		
MODIS/AIRS Cloud Properties		
MODIS/AIRS Visualization Tool (hydra)		
IMAPP Remote Sensing Workshops		
Real-time Air Quality Monitoring System		
Under Development		
Under Beta Testing		
Processing Algorithm Released		

Summary of current and upcoming IMAPP MODIS, AIRS, and AMSR-E product algorithms

- **Support IMAPP Global Users**
- **Support Regional Near Real-Time Applications**
- **Improve/Expand Algorithms**
- **Release Updated/New S/W**
- **Conduct Algorithm/Product Developments & Evaluation**
- **Conduct Products Validation**
- **Provide Training, Research, & Visiting Scientist Opportunity**
- **Preparation for NPP/NPOESS Direct Broadcast Data Processing**