INTERNATIONAL MODIS AND AIRS PROCESSING PACKAGE (IMAPP)

A Direct Broadcast Software Package for the NASA Earth Observing System

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The International MODIS (Moderate Resolution Imaging Spectroradiometer) and AIRS (Atmospheric Infrared Sounder) Processing Package (IMAPP; Huang et al. 2000) is a NASA-funded, freely distributed software package which allows any ground station capable of receiving direct broadcast from *Terra* or *Aqua* to produce calibrated and geolocated radiances and a variety of environmental products. This report describes the features, current applications, origins, and future direction of the IMAPP software, the development of which entered into a NASA-sponsored 3-year continuation phase in April 2003.

The NASA Earth Observing System (EOS) spacecrafts *Terra* and *Aqua* are providing a new generation of sensor observations of planet Earth. The instruments onboard these platforms provide a wealth of information on ocean, land, and atmosphere processes that are of global environmental importance. A critical component of the data distribution system for *Terra* and *Aqua* is the direct broadcast service on the spacecraft. The versions of the IMAPP software released to date have proven to be highly effective tools for the global EOS direct broadcast community, enabling users to receive and process raw data in real-time (i.e., as observations are acquired) and generate environmental products as needed. IMAPP products can provide immediate information to government, educational, commercial, and research sector users in areas such as severe weather monitoring, forest fire detection, fisheries management, weather forecasting, aviation safety, and ice forecasts.

To date, the University of Wisconsin's Space Science and Engineering Center (SSEC) has released IMAPP software for MODIS Level 1 calibrated and geolocated radiances and a selection of MODIS Level 2 geophysical products, including cloud mask, cloud-top properties, cloud phase, atmospheric profiles, and total precipitable water vapor. Working in conjunction with the AIRS Team at the NASA Jet Propulsion Laboratory (JPL), SSEC received the first postlaunch delivery of the AIRS/Advanced Microwave Sounding Unit (AMSU)/Humidity Sounder Brazil (HSB) Level 1 software and released the first version of the AIRS/AMSU/HSB Level 1 IMAPP software on 5 November 2003.

The current IMAPP product algorithms, along with those planned for production during the 3-year continuation phase, are listed in Table 1.

The IMAPP software is available from http://cimss.ssec.wisc.edu/~gumley/IMAPP and has been ported to and tested on a variety of UNIX and PC platforms (see Web site for more details). The software has been well received by a wide variety of users and is currently in use at over 75 ground stations around the world, including those in Germany, Italy, Japan, China, Russia, Korea, Thailand, Australia, United Kingdom, Norway, Singapore, and the United States; it is also supplied as a standard feature by many ground-station manufacturers, including SeaSpace and Integral Systems of the United States, Kongsberg Spacetec of Norway, and Environmental Systems and Services of Australia.

The first version of the IMAPP MODIS Level 1 software (Version 1.0) was released to the international EOS direct-broadcast community under the GNU general public license on May 2000. The on-

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going software development program builds on this release and on previous experience that the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin—Madison has had in creating similar software packages for processing direct-broadcast data from the NOAA operational polar-orbiting satellites. The International TOVS (TIROS-N Operational Vertical Sounder) Processing Package (ITPP) has been distributed to members of the science community since 1985 (Huang and Smith 1986; Smith et al. 1993), and the recently released International ATOVS (Advanced TOVS) Processing Package (IAPP) implements a direct-broadcast processing capability for *NOAA-15* and beyond (Li et al. 2000; Huang et al. 1997). The intention in developing IMAPP for processing direct-broadcast MODIS and AIRS data is to help foster the rapid improvement of retrieval algorithms and other applications of EOS data in a variety of weather, process studies, and climate applications, just as the ITPP and IAPP have done for TOVS and ATOVS data.

Table 1. Summary of current and planned IMAPP MODIS and AIRS product algorithms.

	MODIS	AIRS/AMSU/HSB
Current	Geo-location/navigation Cloud mask Cloud phase Cloud-top property Clear T/Q sounding Total precipitable water	Geo-location/navigation
Planned	Cloud particle size Cloud optical thickness Aerosol optical thickness Surface reflectance Sea surface temperature Snow detection Sea ice detection Scene classification (Clouds and land surface)	Clear/cloudy T/Q sounding Cloud detection Cloud clearing Cloud height/emissivity Surface skin temperature Cloud liquid water AMSU precipitation estimate
	MODIS/AIRS collocation	

As two examples of the wide range of uses of IMAPP to the research and forecast communities, real-time IMAPP products are supporting the NWS as a forecasting tool under the NASA-supported Short-Term Prediction Research and Transition (SPORT) program (www.ghcc.msfc.nasa.gov/sport/sport_observations.html), and Plymouth Marine Laboratory's Remote Sensing Data Analysis Service (RSDAS) in the United Kingdom posts real-time IMAPP MODIS products on their Web site for use in the European CLOUDMAP2 research program (www.npm.ac.uk/rsdas/projects/cloudmap2). Examples of the IMAPP suite of direct-broadcast products produced at CIMSS are shown in Fig. 1.

In the future, IMAPP will evolve to incorporate, adapt, and develop new processing algorithms to meet global users' demands for regional real-time multidisciplinary applications. IMAPP will also continue to incorporate feedback and suggestions provided by users in order to improve its functionality, accuracy, efficiency, and standardization. Most of all, with open-source architecture and rigorous documentation standards, IMAPP can be easily implemented on almost any computing platform. It is anticipated that IMAPP will continue to be an integral part of the real-time downlink and processing systems for the international direct-broadcast community in NASA EOS, and will play a key role in the NASA/NOAA NPOESS Preparatory Project (NPP) and U.S. National Polar-Orbiting Operational Environmental Satellite System

(NPOESS) epoch. It is hoped that in due course the International NPP/NPOESS Processing Package (INPP), as the next generation of IMAPP, can continue to optimize the global utilization of environmental data to improve our ability to monitor and understand the Earth system.

FOR FURTHER READING

Huang, H.-L., and W. L. Smith, 1986: An extension of the simultaneous TOVS retrieval algorithm—The inclusion of cloud parameters. *Tech. Proc. Third Int. TOVS Study Conf.,* Madison, WI, NOAA/Int. Assoc. Meteor. and Atmos. Physics, 118–130.

——, ——, M. S. Whipple, B. Huang, S. J. Nieman, and H. M. Woolf, 1997 : Expected performance evaluation of ATOVS sounding products—A preliminary study of ATPP retrieval algorithm. *Tech. Proc. Ninth Int. TOVS Study Conf.,* Igls, Austria, European Centre for Medium-Range Weather Forecasts, 189–195.

——, L. Gumley, T. Rink, and J. Li, 2000: International MODIS/AIRS processing package—Package information and science objectives. *Tech. Proc. Eleventh Int. TOVS Study Conf.,* Budapest, Hungary, Bureau of Meteor. Research Center, 147–151.

Li, J., W. Wolf, W. P. Menzel, P. van Delst, H.-L. Huang, T. Achtor, W. Zhang, and H. Woolf, 2000: The International ATOVS Processing Package (IAPP): the algorithm and its application in real data processing. *Tech. Proc. Tenth Int. TOVS Study Conf.,* Boulder, CO, World Meteor. Org, 348–359.

Smith, W. L., H. M. Woolf, S. J. Nieman, and T. H. Achtor, 1993: ITPP-5: The use of AVHRR and TIGR in TOVS data processing. *Tech. Proc. Seventh Int. TOVS Study Conf.,* Igls, Austria, European Centre for Medium-Range Weather Forecasts, 443–453.

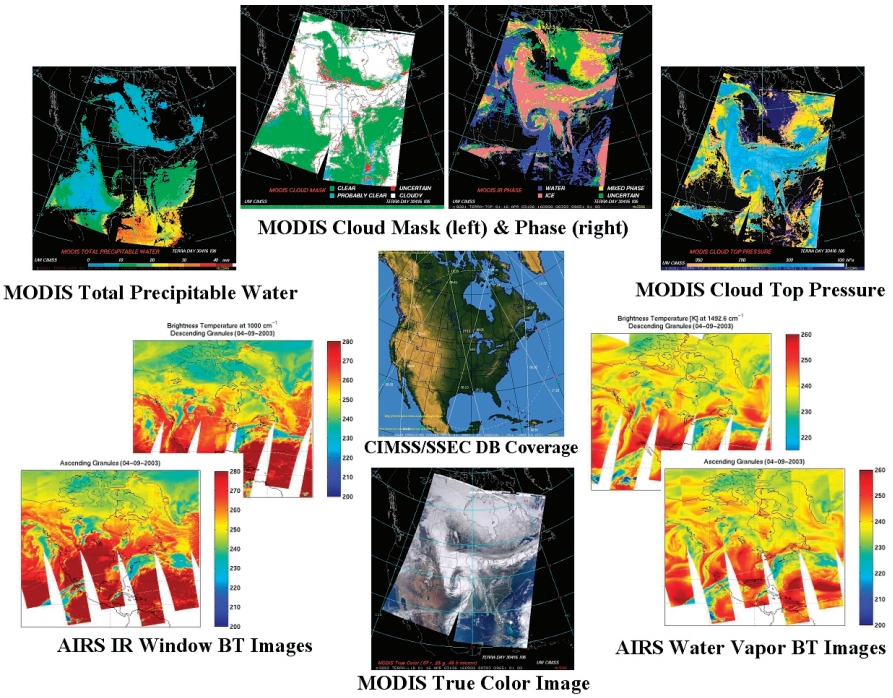

FIG. 1. Examples of real-time IMAPP MODIS and AIRS imagery products generated at CIMSS.