Satellite Data Support for the ARM Climate Research Facility, 8/01/2009 – 7/31/15

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1. Introduction

The effort sponsored by this agreement, a continuation of analyses begun in the 1990's, was designed to provide cloud properties and top-of-the-atmosphere (TOA) radiative flux products from selected satellites viewing domains surrounding specified locations associated with sites and field programs operated in whole or part by the Department of Energy Atmospheric Radiation Measurement (ARM) and Atmospheric Science Research Programs. These locations include the "permanent" sites and positions occupied by the ARM Mobile Facilities (AMF) or Airborne Facilities (AAF). The datasets are made available to the ARM/ASR and general scientific communities to complement measurements of various parameters made from the instruments on the surface or airborne platforms. Together, the combined measurements provide a more complete characterization of the atmospheric state at large and small scales.

The calibrated and analyzed data from the various satellites are provided on a routine basis through two venues, the Oak Ridge National Laboratory ARM Archive and the NASA Langley Research Center (LaRC) Cloud and Radiation Group Observations web page. IN addition to sending data to the archive, near-real-time (NRT) data are produced for field programs and made available on the LaRC web site to support field mission planning and execution. Such services are provided on request. The data are documented through papers and presentations at relevant scientific meetings. Among the other tasks covered under this agreement are reprocessing of the data when improved calibrations and/or algorithms become available, validation of the results, and collaboration with users to tailor products to their needs.

The work conducted and data analyzed during the six-year period of performance is summarized in this report.

2. Data and Methodology

The satellite data analyzed under this agreement include, but are not necessarily limited to multispectral visible and infrared radiances measured by imagers on the GOES (Geostationary Operational Environmental Satellite) series, Meteosat geostationary satellites, the MTSAT (Multi-functional Transport Satellite) geostationary series, and the Aqua and Terra Sun-synchronous satellites. The data, taken at nominal resolutions from 1 to 4 km, are analyzed with a version of the algorithms described by Minnis et al. (2008a, b; 2011). TOA broadband shortwave albedos and outgoing longwave fluxes were estimated using either of two methods described by Minnis and Smith (1998) or Khaiyer et al. (2010, 2013). In addition to the raw or calibrated spectral reflectances (typically 0.65 μm) and brightness temperatures (generally 3.9,

11, and 12 or 13.3 μm) measured by the particular imager, the analyzed data provided for each pixel include, among others, the location; the viewing and illumination angles; the scene identification (e.g., cloud, clear, snow, etc.); the cloud effective temperature, height, and pressure; the cloud optical depth, phase, and effective particle size; the cloud-top/base height, temperature, and pressure; the cloud liquid or ice water path. More details can be found at http://www.arm.gov/xdc/xds/visst. The latency time for the permanent sites is 1 day, while the lag time for the field campaigns is less than 1 hour.

Data were analyzed for the domains encompassing the Southern Great Plains (SGP) sites, the Tropical Western Pacific (TWP) sites, the North Slope of Alaska (NSA) sites, and the Eastern North Atlantic (ENA) site in the Azores. The field campaigns supported during this period include the AMF Azores (Clouds, Aerosol, and Precipitation in the Marine Boundary Layer), the Small Particles in Cirrus (SPARTICUS) experiment over the central USA, the Storm Peak Lab Cloud Property Validation Experiment (STORMVEX) in Colorado, the CALWATER field campaign in California, the Middle Latitude Airborne Cirrus Properties Experiment (MACPEX) over the central USA, the ACRF MJO Investigation Experiment (AMIE) in the Indian Ocean, the Marine ARM GPCI Investigation of Clouds (MAGIC) over the northeastern Pacific, Observations Modeling of the Green Ocean Amazon (GO-AMAZON) campaign, and the ARM Cloud Aerosol Precipitation Experiment (ACAPEX) in conjunction with CALWATER-II over the northeastern Pacific. Data from previous field campaigns were also reanalyzed. The older campaigns include the Marine Stratus Radiation Aerosol and Drizzle (MASRAD) IOP in California, the Initiation of Convection and the Microphysical Properties of Clouds in Orographic Terrain (COPS) in Germany, AMF China to study aerosol indirect effects in China, and the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) in the southeastern Pacific.

3. Summary of Accomplishments

A new web page (http://www-pm.larc.nasa.gov/ARM) was developed to centralize all of the LaRC cloud products provided in support of the ARM program. The page, represented in Fig.1, provides image links to the active permanent site NRT displays. On the sidebar, it lists links to pages devoted to each of the four permanent sites and to the individual field programs. The information provided at each link varies depending on the age of the campaign and the requested data. All sites contain the satellite imagery and links to the analyzed data for the site or campaign. Ground site pages usually include links to averages of all parameters taken within 10 and 20 km of the site, while airborne campaign pages often include averages of the satellite-retrieved parameters along the flight tracks. Other information of interest is also included.

The data analyzed and provided to the archive and/or made available through the web site are summarized in Table 1 for the permanent sites and in Table 2 for the field campaigns. The status of each dataset is indicated in the following manner. No indicator denotes that the data are in the archive. An asterisk indicates that the data were taken before, but revised during the performance period and submitted to the archive. A dagger denotes that the data are not yet in the archive, but can be obtained from the LaRC website. Direct access to the individual site or campaign datasets is effected through the web site, http://www-pm.larc.nasa.gov/XXXX, where /XXXX is listed in the fourth column of each table. The time when the latest dataset was processed is indicated in the fifth column. NRT means that only the data processed in near real time are available. Data are being archived as quickly as possible. New formats and data sources are being reviewed and

will permit future archival of additional datasets, such as retrievals from MODIS data. In the meantime, data that are not yet in the ARM archive can be accessed from the LaRC web site.

A considerable amount of documentation was produced during the performance period. The publications and presentations are listed in section 5. Eighteen peer-reviewed papers sponsored by this agreement were either published or accepted for publication. They include documentation of the data, comparisons or analyses with ARM surface or airborne datasets, new applications of the satellite data both within and outside of the ARM program, and calibration techniques. Three conference proceeding papers were published and, at least, 79 presentations (posters or PowerPoint talks) were given at national and international scientific meetings or conferences. The topics of the presentations are similar to those of the peer-reviewed papers. This ARM support effort is continuing under a new agreement.

4. References

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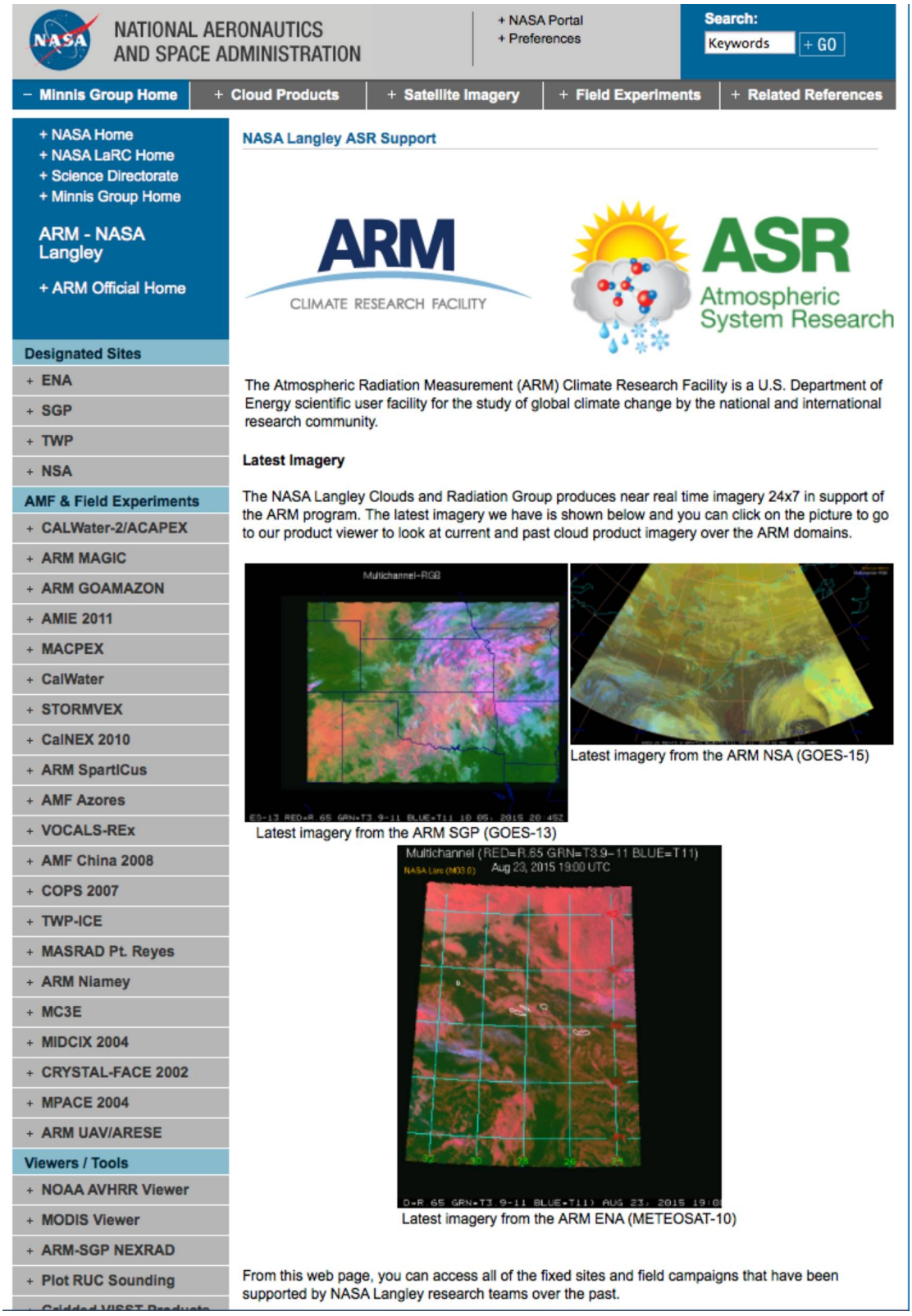

Fig.1. Main web page for accessing NASA LaRC ARM satellite products outside of ARM archive. http://www-pm.larc.nasa.gov/ARM.

Table 1. Analyzed ARM permanent site domain datasets. Website link is http://www-pm.larc.nasa.gov/XXXX.

Domain	Period	Satellites	Link, /XXXX	Process Year
SGP	12/01/11 - 07/31/15	GOES-13	/ARM-SGP	NRT
	09/24/12 – 12/31/12	GOES-15		NRT
	07/01/09 – 11/30/11	GOES-11		NRT
	06/21/06 – 06/30/11			2011
	†01/01/13 – 07/31/15	GOES-15		NRT
	†12/05/11 – 09/23/12	GOES-12		NRT
	†8/31/09 – 12/31/09			
TWP	12/26/11 – 10/31/14	MTSAT-IR/2	/ARM-TWP	NRT
	†11/01/14 – 03/03/15	MTSAT-2		NRT
	†08/12/10 – 12/25/11	MTSAT-1R/2		NRT
	†08/01/09 - 08/11/10	MTSAT-1R		NRT
	*10/01/07 – 12/31/07			2010
	*01/01/08 - 04/30/08			2012
	*05/03/03 – 10/31/05	GOES-9		2011
NSA	†01/01/13 – 07/31/15	GOES-15	/ARM-NSA	NRT
	†@01/13/09 – 12/31/12	GOES-11/15	/RR	NRT
ENA	10/01/14 - 06/30/15	Meteosat-10	/ARM-ENA	NRT
	†07/01/15 - 07/31/15			
	†02/20/14 - 09/30/14			

* revision only, †only at LaRC website, @part of North American product

Table 2. Data from supported field campaigns. Website link is http://www-pm.larc.nasa.gov/XXXX.

Experiment	Period	Satellites	Link, /XXXX	Process Year
*MASRAD	03/14/05 - 09/16/05	GOES-10	/MASRAD	2012
*AMF COPS	04/01/07 – 04/30/08	Meteosat-9	/COPS	2014
*AMF China	04/01/08 – 01/05/09	MTSAT-1R	/AMF-CHINA	2014
*†VOCALS	10/14/08 - 11/13/08	GOES-10	/VOCALS	2010
AMF Azores	03/31/09 - 03/29/11	Meteosat-9	/AMF-AZORES	2015
SPARTICUS	01/14/10 - 06/25/10	GOES-11, †Terra/Aqua	/ARM- SPARTICUS	2011
STORMVEX	11/08/10 - 04/23/11	GOES-11/12	/stormvex	2011
CALWATER	01/31/11 - 03/09/11	GOES-11, †Terra/Aqua	/CALWATER2011	NRT
MACPEX	03/16/11 - 04/26/11	GOES-13	/MACPEX	NRT
AMIE	10/01/11 - 06/20/12	MTSAT-2, FY2E	/amie	NRT
MAGIC	10/01/12 - 09/30/13	GOES-15	/MAGIC	2014
GO-AMAZON	†02/11/14 – 12/06/14 12/07/14 - 09/23/15	GOES-13	/ARM-GOAMAZON	2015
ACAPEX/CALWATER-II	01/21/15 - 04/16/15	GOES-15	/calwater-2	NRT

* revision only, †only at LaRC website

5. Documentation Summary

Peer-reviewed publications (18)

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